Movement Test Rig

2011-4

Introduction

During the Movement Test Rig project, all members of the group got the chance to show what they really have learned during our technical studies. Three years of education has provided the basis to start working and not least continue to learn. This project has been a step on the way from education to working life, which has been very instructive.
Since August 2010, a huge amount of hours have been spent researching, designing, programming and of course on discussions within the group. We can now see the end of this project, and what we have come up with is hopefully close to what our client asked for; “a compact and flexible test rig where all you need to do is push to a few buttons”. Luckily, these words were told with a smile at the client’s face. Nevertheless, it represents the ultimate goal both mechanically and electronically, and it was our source of motivation to always reach for the best technical solutions. The rig is even built and programmed with products which none of us never before had heard of, and of which we are grateful that we now have. We are satisfied with the way this test rig project turned out.
We are very grateful for Kongsberg Automotives’ excellent engagement and cooperation. They have made the project exiting, fun and educational.

Summary

In august 2010, Kongsberg Automotive sent a suggestion for a post graduate thesis specifically to a project group which is called Movement Test rig. The task was to design a rig that would test V-stays meant for trucks, and develop a complete production basis, including a price estimate. The rig is designed in SolidWorks and is operated through a control system made in LabVIEW. Due to the given frame of the project, there is neither time nor the resources to produce a full-scale prototype.

A number of documents are made during the project process. The vision document (visjonsdokument) consists of project members and their backgrounds, KA as the client and presents the project task. Feasibility study report includes the project member's positions and responsibilities. Requirements specification presents the 65 requirements that were made. Test specification explains how the requirements will be verified. Project plan tells when the requirement is planned to be implemented. Document of concept represent the different concepts. The design concept was chosen by KA and the controller hardware was decided.

The technical part is divided into mechanical and electrical. The mechanical part consists of a 3D model with cylinder in transversal, longitudinal and vertical direction. The model has linear systems as vertical and horizontal rail systems, which include guide rails with corresponding carriages. The 3D model includes a horizontal bracket with a corresponding rail system. There is a vertical part with a corresponding rail system. There is designed a frame that is compact in size and satisfied the requirement off stiffness. The design and material selection do not exceed 1/3 yield strength of the material. The rig is design to satisfied agronomical working height and vertical cylinder is therefore adjusted to satisfy this need. All parts and sub assemblies have been analyzed and tested using Finite Element Analysis in Solid Works simulation, and by handmade calculations. 2D drawings are developed for future development of the physical test rig.

The control system in LabVIEW acts as the interface between the user and the rig. The interface was designed to be as user friendly as possible. The program is able to perform functional, durability and time-based measurement. It feeds the parameters to the Portable Test Controller and gets measurement values in return. These values are written to an external file which can be read and analyzed. The control system was tested with hardware at KA lab. Substituted equipments like load cells, potentiometer and springs with different stiffness constants were used to get observable signals. The result were analyzed and compared with log data from a real V-stay. DIAdem is used as an analyzing software tool. Simulated data from LabVIEW is used to calculate stiffness and shows numerical and graphical presentations in a template report. A script is made to automate stiffness calculations and report. A user manual is established showing how graphical user interface in LabVIEW and DIAdem are used.

The electrical part also includes electrical drawings that show connections from the computer through the controller to the cylinders.

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HØGSKOLEN
i Buskerud

Department of Technology
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Title of document: Requirement specification rev. 1.3
Course (code/name) SFHO3200 Hovedoppgave med prosjektstyring
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Date: 13.12.2010
We confirm that the submitted assignment is entirely our work.   Elisabeth Espås Jenssen, Jørgen Heum Larsen, Andreas Fossnær Wold, Edward Palm Sandaker og Stina Andersen

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1. The main objective of the requirements

The main objective of the requirements is to provide the "Voice of the Customer" and the purpose of this specification is to limit the scope of the main project. This is a formal document between the client and the developer about what the system should do. It lists aims for the system, and a sketch of the solution.

2. Abbreviations

KA	- Kongsberg Automotive

3. Designations

kN	- Kilo Newton
mm	- Millimeter
kN/mm	- Kilo Newton per millimeter
bar	- Pressure in bar
N/°	- Newton per degree
MPa	- Mega Pascal
Hz	- Hertz

4. Introduction

One of the products Kongsberg Automotive develops is a V-stay for trucks. This V-stay represents the connection between the rear axle and the frame of the truck. Each V-stay leg is attached to the frame of the truck, while the centre point is attached to the rear axle. To dampen vibrations between the drive axle and the frame, there are rubber bushings in both V-stay legs. The bushings in the V-stay have a built-in resilience that changes over time due to the external factors they are exposed to. The bushings affects ride comfort to a great extent, and selection of appropriate elasticity versus life, is a comprehensive process. Since this is a critical component in terms of road safety it is very important that these bushings and the V-stay are both tested regularly and thoroughly, before being mounted in a truck.

5. The client

Kongsberg Automotive (KA) is a Norwegian company with headquarters in Kongsberg and is a global provider of engineering, design, and manufacturer for seat comfort, driver and motion control systems, fluid assemblies, and industrial driver interface products. The product line includes systems for seat comfort, clutch actuation, cable actuation, gear shifters, transmission control systems, stabilizing rods, couplings, electronic engine controls, specialty hoses, tubes and fittings. They target the automotive, commercial vehicle and industrial markets.

KA has almost 50 facilities in 20 countries. With revenues of MEUR 623 (2009) and about 10.000 employees, KA provides system solutions to vehicle makers around the world.

6. Project background

The solution Kongsberg Automotive has today takes up a lot of time in the existing rigs that are initially intended for other tests. The current solution requires that the operator must set up temporary sensors and electronics, as well as moving the test object manually repeatedly through the test. This makes the tests both time consuming and costly to perform, in addition to that it is difficult to manually maneuver the V-stay in the existing rigs. This is due to both the size and weight of the V-stay, where each of the legs measures 70 cm and the V-stay weighing up to 20 kg.

During testing of the V-stay it will run the test continuously until fracture occurs. This can take up to 6 months, and in turn means that a rig is unavailable for testing in this period.

The client also wants to have a test rig which stores data so that results can be looked up for comparison, rather than the current solution where you manually have to go through test results when comparing results. It is also the principal's desire to obtain numerical values and curves that can be used in test reports.

The life of a bushing is estimated to five years. Since performing a life test that exposes V-stay for 10 years of wear over a few months, the problem is that heat occurs in the bushings. This causes the bushings to become soft and falling apart.

KA has a desire to develop a more compact and flexible test rig. The rig will be able to measure stiffness, displacements and perform single axis fatigue tests. The test rig should be able to test over time to fracture occurs.

7. Requirements

To provide an appropriate overview of the requirements, they are divided into categories by their properties. The requirement has its source from KA and Buskerud University College. The requirements are categorized as followed:

- Functional requirements
- Documentation requirements
- Property requirements
- Restrictions
- Interface requirements
- Other requirement

To provide a clearer presentation of the importance of each requirement they are divided into 3 categories. The categories are as followed:

- Category A: essential requirements
- Category B: desirable requirements
- Category C: "nice to have" requirements

The following chapters are summaries of every requirement. The requirements can be read in its entirety in the appendix from 1-6. Every requirement has an unique identification named after requirement properties. Every identifications of the derivative requirement is based on the main requirement. Correspondent test identification is also set for each measurable requirement. The matrix at the end of this chapter shows a complete overview of all requirements in a shorter version than in the requirement tables.

7.1. Functional requirements

These requirements specify the actual functions that the test rig will perform, and also describe what the system must do.

The main functional requirement is to construct a test rig for testing of V-stays, and this is also categorized as a category A-requirement.

The rig must be able to produce dynamic force with nonstop movement, static force and a maximum load frequency to simulate the use of the V-stay in a truck. To be able to measure the stiffness in V-stays, the rig must measure stiffness in transversal, longitudinal and vertical directions. One of the rigs most important requirements is that it must perform both durability tests and functional tests. The stresses produced in the rig must not exceed 1/3 of yield strength of materials. Since the client not only produces V-stays in one size, the rig must be able to have attachment points that must be changeable. This means that the rig must cope with V-stays that are ±10 % in size.

To make a dynamic rig it is necessary to develop a control system and perform simulations of this. A 3D model of the rig is also required, manufacturing drawings and electrical drawings of the system.

7.2.Documentation requirements

These are requirements that specify collecting and preparation of information materials, evidence and documents the project must produce.

The project must produce 2D drawings according to standards. A web site must be available and updated at all time. This is to keep the client and the supervisor updated with the progress of the project. All documentation must be in English and be provided in an open format.

7.3.Property requirements

These are requirements that specify requirements in relation to space, security, ease of use and easily maintained. By constructing a test rig with great forces applied, it is important to maintain the safety of the operators. KA requires protection plates and emergency stop functions. Several operators will work with the rig and it is therefore important that the rig is user friendly. External space for other equipment as a crane and a cooling system is also required.

7.4.Restrictions

Requirements that specify restrictions on equipment, operating systems, software, components, communication standards and generally puts restrictions on what components that can be used.

Restrictions requirement has several A-requirements. It is required from client to use specific working tools as Solid Works, LabView and data processing tools. The V-stay must be placed horizontally and the applied force on the bottom centre of the V-stay must be perpendicular. Every component used on the rig must be CE-approved.

7.5.Interface requirements

These are requirements that specify if the test rig is tied to a new or other existing system.

To analyze the test result the control system must save log data and be shown in Labview operator window. This operator window also displays various parameters during operation.

7.6.Other requirements

These are requirements that specify economic aspects, designations and administrative requirements from Buskerud University College.

Due to the given frame of the project, there is neither time nor the resources to produce a full-scale prototype. Therefore the project must obtain a price estimate on a complete test rig ready for production.

Buskerud University College requires that there must be held weekly meetings with an internal supervisor and also monthly meetings with the client. The client has also set standards in various designations to be used in all documentation.

7.7.Requirement matrix

ID	Requirement	Electro	Mechanical	Functional	Documentation	Property	Restrictions	Interface	Other	Not started	Ongoing	Finished
RF 1	Construct a test rig for testing of v-stays	X	X	X								
RF 2	Dynamic force supply		X	X								
RF 2.1	Nonstop movement (100% duty cycle)	X		X								
RF 3	3D-drawings must be made		X	X								
RF 4	Force supply must produce static loads up to 200 kN	X		X								
RF 5	Force supply must produce dynamic loads up to 160 kN.	X		X								
RF 6	The rig must measure transversal stiffness, Cy: (10)-50 kN/mm from 0 to 200 kN	X		X								
RF 7	The rig must measure longitudinal stiffness Cx: (10)-50 kN/mm from 0 to 200 kN	X		X								
RF 8	The rig must measure vertical stiffness, Cz 0-300 N/° from 0 to 20°	X		X								
RF 9	The rig must be able to perform durability tests	X		X								
RF 10	The rig must be able to perform functional tests	X		X								
RF 11	Make electrical drawings	X		X								
RF 12	Maximum stress must not exceed 1/3 of yield strength of the materials		X	X								

RF 13	A functional simulator of the rig must be provided	X		X								
RF 14	Attachment points for V-stay must be changeable.		X	X								
RF 14.1	The test rig must have different brackets for different V-stays		X	X								
RF 14.2	The test rig must cope with V-stays that are ±10% in size		X	X								
RF 15	Sensors must have minimum 10 times higher resolution than values measured	X		X								
RF 16	The control system must be self–diagnosing	X		X								
RF 17	Must go 60 million strokes	X		X								
RF 18	It must be decomposed forces (stiffness) in several directions.		X	X								
RF 19	Force supply must be able to produce a maximum load frequency of 20 Hz	X		X								
RD 1	Make 2D-drawings according to standards		X		X							
RD 2	A website must be made	X	X		X							
RD 2.1	Produce a website with information about the project	X	X		X							
RD 2.2	Produce continuous updates concerning the progress within the project	X	X		X							
RD 2.3	All sensitive information must be protected by a password	X	X		X							
RD 3	The test rig must have a user manual	X	X		X							
RD 4	All documentations must be in English	X	X		X							
RD 5	All documents must be saved in PDF or MS Office format	X	X		X							
RP 1	The test rig must be covered with protection plates		X			X						
RP 1.1	Protection plates must be detachable		X			X						
RP 2	The rig must contain emergency stop devices	X	X			X						
RP 2.1	Emergency stop device/push button must be placed inside the test rig		X			X						
RP 2.2	Emergency stop device/push button must be placed outside the test rig		X			X						

RP 2.3	Emergency stop device should be implemented in the software	X				X						
RP 3	The rig must contain a safety relay	X				X						
RP 4	The frame must be stiff enough to withstand the forces applied		X			X						
RP 5	The rig must have room available for a bushing cooling system		X			X						
RP 6	The control system must have a user-friendly interface	X				X						
RP 7	The control system must be able to show visual presentation of the data	X				X						
RP 8	The rig must be designed so that the V-stay can be accessed by crane		X			X						
RP 9	An alarm must be switched on when spring travel reaches a given value measured in percent	X				X						
RR 1	Use LabVIEW as a virtual instrument	X					X					
RR 3	Use Solid Works as a design tool		X				X					
RR 4	Force must be 90 degrees on the bottom center of the V-stay		X				X					
RR 5	The V-stay must be placed horizontally in the rig		X				X					
RR 6	Every component used in the rig must be CE-approved	X	X				X					
RR 7	Fine pitch threads screws must be used		X				X					
RR 8	One total supplier for all equipment	X	X				X					
RI 1	The control system must save test log-data	X						X				
RI 2	Operator window in LabVIEW must have setup window with stroke counter	X						X				
RI 3	Operator window in LabVIEW must have setup window with frequency	X						X				
RI 4	Operator window in LabVIEW must show stiffness measurements	X						X				
RI 5	Operator window in LabVIEW must show operating time	X						X				
RI 6	The control system must search for data from former tests	X						X				

RI 7	LabVIEW must be controlled with a keyboard and mouse	X						X				
RO 1	There must be a price estimate on a complete rig	X	X						X			
RO 2	There must be held weekly meetings with a supervisor from HiBu	X	X						X			
RO 3	There must be monthly meetings with the employer	X	X						X			
RO 4	The designation for stress must be MPa		X						X			
RO 5	The designation for stiffness must be kN/mm		X						X			
RO 6	The designation for vertical stiffness must be N/°		X						X			
RO 7	The designation for pressure must be Bar		X						X			
RO 8	One must consider the price against functionality	X	X						X			

Appendix 1: Functional requirements

ID-requirement	Functional requirements		ID-test
RF 1	**Requirement:**	Construct a test rig for testing of v-stays	TF 1
	Comment:		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** A
RF 2	**Requirement:**	Dynamic force supply	TF 2
RF 2.1		Nonstop movement (100% duty cycle)	TF 2.1
	Comment:		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** A
RF 3	**Requirement:**	3D-drawings must be made	TF 3
	Comment:		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** A
RF 4	**Requirement:**	Force supply must produce static loads up to 200 kN	TF 4
	Comment:	This is the maximum load the V-stay must withstand. Transversal load: 200 kN, Longitudinal load: 100 kN	
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** A
RF 5	**Requirement:**	Force supply must produce dynamic loads up to 160 kN.	TF 5
	Comment:	This is the maximum load the V-stay must withstand. Maximum vertical load: ± 5 kN, maximum transversal load: ±160 kN and average transversal load: ±90 kN	
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** A
RF 6	**Requirement:**	The rig must measure transversal stiffness, Cy: (10)-50 kN/mm from 0 to 200 kN	TF 6

		Comment:			
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 7		**Requirement:**	The rig must measure longitudinal stiffness Cx: (10)-50 kN/mm from 0 to 200 kN	TF 7	
		Comment:			
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 8		**Requirement:**	The rig must measure vertical stiffness, Cz 0-300 N/° from 0 to 20°	TF 8	
		Comment:			
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 9		**Requirement:**	The rig must be able to perform durability tests	TF 9	
		Comment:			
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 10		**Requirement:**	The rig must be able to perform functional tests	TF 10	
		Comment:	This means single measurements on the V-stay		
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 11		**Requirement:**	Make electrical drawings	TF 11	
		Comment:			
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 12		**Requirement:**	Maximum stress must not exceed 1/3 of yield strength of the materials	TF 12	
		Comment:			
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 13		**Requirement:**	A functional simulator of the rig must be provided	TF 13	

	Comment:			
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 14	**Requirement:**	Attachment points for V-stay must be changeable.	TF 14	
RF 14.1		The test rig must have different brackets for different V-stays	TF 14.1	
RF 14.2		The test rig must cope with V-stays that are ±10% in size	TF 14.2	
	Comment:			
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 15	**Requirement:**	Sensors must have minimum 10 times higher resolution than values measured	TF 15	
	Comment:			
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 16	**Requirement:**	The control system must be self–diagnosing	TF 16	
	Comment:	The rig will alarm if the system detects any abnormal values within the operation parameters		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RF 17	**Requirement:**	Dynamic force supply must go 60 million strokes	TF 17	
	Comment:			
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	B
RF 18	**Requirement:**	It must be decomposed forces (stiffness) in several directions.	TF 18	
	Comment:			
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	C
RF 19	**Requirement:**	Force supply must be able to produce a maximum load frequency of 20 Hz	TF 19	

	Comment:	Maximum load frequency: 20Hz and average load frequency: 10Hz	
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** C

Appendix 2: Documentation requirements

ID-requirement	Documentation requirements		ID-test
RD 1	**Requirement:**	Make 2D-drawings according to standards	TD 1
	Comment:	The 2D-drawing shall be used as a production base	
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** A
RD 2	**Requirement:**	A website must be made	
RD 2.1		Produce a website with information about the project	
RD 2.2		Produce continuous updates concerning the progress within the project	
RD 2.3		All sensitive information must be protected by a password	
	Comment:		
Date: 05.11.2010	**From:**	HiBu & Kongsberg Automotive	**Priority:** A
RD 3	**Requirement:**	The test rig must have a user manual	
	Comment:		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** B
RD 4	**Requirement:**	All documentations must be in English	
	Comment:		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** B
RD 5	**Requirement:**	All documents must be saved in PDF or MS Office format	
	Comment:		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** C

Appendix 3: Property requirements

ID-requirement	Property requirements	ID-test
RP 1	**Requirement:** The test rig must be covered with protection plates	TP 1
RP 1.1	Protection plates must be detachable	TP 1.1
	Comment: For protection against splash and leakage	
Date: 05.11.2010	**From:** Kongsberg Automotive	**Priority:** A
RP 2	**Requirement:** The rig must contain emergency stop devices	TP 2
RP 2.1	Emergency stop device/push button must be placed inside the test rig	TP 2.1
RP 2.2	Emergency stop device/push button must be placed outside the test rig	TP 2.2
RP 2.3	Emergency stop device must be implemented in the software	TP 2.3
	Comment: The emergency stop must stop the system	
Date: 05.11.2010	**From:** Kongsberg Automotive	**Priority:** A
RP 3	**Requirement:** The rig must contain a safety relay	TP 3
	Comment: A safety relay must be available in case of software shutdown	
Date: 05.11.2010	**From:** Kongsberg Automotive	**Priority:** A
RP 4	**Requirement:** The frame must be stiff enough to withstand the forces applied	TP 4
	Comment:	
Date: 05.11.2010	**From:** Kongsberg Automotive	**Priority:** A
RP 5	**Requirement:** The rig must have room available for a bushing cooling system	TP 5
	Comment:	

Date: 05.11.2010	**From:** Kongsberg Automotive		**Priority:** A
RP 6	**Requirement:**	The control system must have a user-friendly interface	TP 6
	Comment:		
Date: 05.11.2010	**From:** Kongsberg Automotive		**Priority:** B
RP 7	**Requirement:**	The control system must be able to show visual presentation of the data	TP 7
	Comment:		
Date: 05.11.2010	**From:** Kongsberg Automotive		**Priority:** B
RP 8	**Requirement:**	The rig must be designed so that the V-stay can be accessed by crane	TP 8
	Comment:		
Date: 05.11.2010	**From:** Kongsberg Automotive		**Priority:** B
RP 9	**Requirement:**	An alam must be switched on when spring travel reaches a given value measured in percent	TP 9
	Comment:	Spring travel means movement in rubber bushings	
Date: 05.11.2010	**From:** Kongsberg Automotive		**Priority:** B

Appendix 4: Restrictions requirements

ID-requirement		Restrictions requirements		ID-test	
RR 1		**Requirement:**	Use LabView as a virtual instrument		
		Comment:	LabView, National Instruments, must be used as the operating software tool		
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RR 3		**Requirement:**	Use SolidWorks as a design tool		
		Comment:	SolidWorks, Dassault Systèmes		
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RR 4		**Requirement:**	Force must be 90 degrees on the bottom center of the V-stay	TR 1	
		Comment:	In three dimensions		
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RR 5		**Requirement:**	The V-stay must be placed horizontally in the rig	TR 2	
		Comment:	In order not to affect the measurement results		
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RR 6		**Requirement:**	Every component used in the rig must be CE-approved	TR 3	
		Comment:			
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RR 7		**Requirement:**	Fine pitch threads screws must be used		
		Comment:			
Date:	05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	B

RR 8	**Requirement:**	One total supplier for all equipment		
	Comment:	For all mechanical and electrical equipment		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	C

Appendix 5: Interface requirements

ID-requirement	Interface requirements		ID-test	
RI 1	**Requirement:**	The control system must save test log-data	TI 1	
	Comment:			
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	A
RI 2	**Requirement:**	Operator window in Labview must have setup window with stroke counter	TI 2	
	Comment:	Labview, National Instruments		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	B
RI 3	**Requirement:**	Operator window in Labview must have setup window with frequency	TI 3	
	Comment:	Labview, National Instruments		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	B
RI 4	**Requirement:**	Operator window in Labview must show stiffness measurements	TI 4	
	Comment:	Labview, National Instruments		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	B
RI 5	**Requirement:**	Operator window in Labview must show operating time	TI 5	
	Comment:	Labview, National Instruments		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	B
RI 6	**Requirement:**	The control system must search for data from former tests	TI 6	
	Comment:			
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	C

RI 7	**Requirement:**	Labview must be controlled with a keyboard and mouse	
	Comment:	Labview, National Instruments	
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** C

Appendix 5: Other requirements

ID-requirement	Other requirements		
RO 1	**Requirement:**	There must be a price estimate on a complete rig	
	Comment:		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** A
RO 2	**Requirement:**	There must be held weekly meetings with a supervisor from HiBu	
	Comment:		
Date: 05.11.2010	**From:**	HIBU	**Priority:** A
RO 3	**Requirement:**	There must be monthly meetings with the client	
	Comment:		
Date: 05.11.2010	**From:**	HIBU and Kongsberg Automotive	**Priority:** A
RO 4	**Requirement:**	The designation for stress must be MPa	
	Comment:		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** B
RO 5	**Requirement:**	The designation for stiffness must be kN/mm	
	Comment:		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** B
RO 6	**Requirement:**	The designation for vertical stiffness must be N/°	
	Comment:	Newton per degree	
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:** B
RO 7	**Requirement:**	The designation for pressure must be Bar	

	Comment:			
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	B
RO 8	**Requirement:** **Comment:**	One must consider the price against functionality		
Date: 05.11.2010	**From:**	Kongsberg Automotive	**Priority:**	B

Department of Technology
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Table of contents

1. The main objective of the test specification

The test specification is a document that describes how to test a system and its components. Its mission is to give a clear picture of which requirements that are to be tested, how to perform these tests, who is responsible for a given test and the result of this test.

2. Abbreviations

KA	– Kongsberg Automotive
FAT	– Factory Acceptance Test
SAT	– Site Acceptance Test

3. Introduction

Since there are not enough resources, nor time available to produce a prototype or physical model of the test rig, the testing will consist in the form of simulations of various kinds.

The testing will differ between the mechanical and electrical properties of the rig.
The physical stresses produced in the rig will be simulated and tested with a 3D model.
Testing of the electrical properties will consist of system simulations and will ensure that the control system is functioning properly. The electrical drawings and 2D drawings according to standards will work as a production base for the test rig. It is therefore essential that these schematics are thoroughly checked and prepared, so that any potential errors can be detected before a rig is build.

The client also requires a functional simulator of the rig. This simulator is to give a correct perspective of how a V-stay will perform in an actual test rig. This simulator is to be considered as a validation test (FAT/SAT) of the control system.

4. Description of tests

Testing in this project means to check if the system meets the given requirements by performing experiments in a controlled way.

4.1.Mechanical testing

When designing the rig the project have to ensure that the mechanical construction can withstand the physical stresses inflicted and ensure that the materials used does not suffer from plastic deformation. To test this we use a 3D-model of the rig and test its abilities by using FEM-analysis. A physical load or stress is then simulated on the 3D-model to uncover any weak areas of the design. This will be a time-consuming process that will result in a complete design of the framework of the rig.

4.2.Electronic testing

Included in this type of testing are the physical circuits of the rig. As a basis for this hardware are the schematics for the electric circuits. It is of great importance that these schematics are as correct as possible to prevent any following errors in the finished product. It is therefore of great importance that the schematics are tested in a thorough and appropriate way.

The control system consists of a regulating system which controls the force manipulating elements in the rig. These will either be run in continuous cycle or as a single acting function test. This is in other words a very critical part of the test rig and it is important that the control system is properly and thoroughly tested. The hardware to this control system will be delivered by an external supplier, while the project is to develop the software and user interface. This is to be tested by various simulations and by performing physical tests on existing test rig. This is to be done by simulating the operation process of the rig, and then verify the behavior of the control system. The project is also to develop an analysis tool for the results that occurs by operating the rig. These results are to be presented visually. The physical tests consist of implementing the various modules in to the existing rig and verify the behaviour of both the control system and analysis tool.

KA will assist in performing these simulations by providing relevant data and parameters. It is also important that the different parts are compatible with each other.

4.3.FAT/SAT

A final acceptance test usually consists of a SAT (Site Acceptance Test) where the finished product is given a final test by the supplier, or in this case the project. And also a FAT (Factory Acceptance Test) where the finished product is tested when delivered to the customer. The last and final simulator will work as a SAT for this project. Since there is no physical product to be delivered to the client, a FAT will be performed in the form of running the final simulations together with the client for a final approval.

4.4.Static and dynamic testing

To solve some of the challenges we will use static and dynamic testing. Static testing is based on checking the product up against available documentation and given specifications. Dynamic testing is based on simulations and physical tests.

4.5.White-box and black-box testing

In matter of testing the control system, we will make use of both White-box testing and Black-box testing.

White-box testing is based on knowledge of the inner structure and behavior of the program which will be tested.
Black-box testing is based on that we consider the program as black box where only the interface towards the surroundings is known.

5. Test plan

The test plan consists of a general description of the test strategies and test methods that will be used in the project. It provides a description of how the test specifications will be prepared, how the tests should be performed, and procedures if and when an error occur. Test specification table and template for a test planning schedule are appendixes to this document.

5.1.Traceability

All tests are named with a review of test identification that corresponds to the requirement identification. Traceability is verification that all requirements are tested and that the project can easily follow the planned progress of the project.
Appendix 1-5 shows a table of all types of tests to be performed during the project. There are several requirements that will be tested by the same test method. When all measurable requirements from the test specification table are fully tested the system can be considered to be near complete.

5.1.1. Functions to be tested

- Force supply, dynamic and static
- 3D drawings
- Stiffness measurement
- Maximum load frequency
- Continuously running control system
- Control system
- Electrical drawings
- Maximum stress
- Simulator
- Attachment points
- Resolution of sensors
- 2D drawings
- Room for equipment in 3D model
- Emergency devices
- Save log data
- Frame stiffness
- Ease of use
- Visual presentation
- Attachment point of the V-stay
- Functions in operator window in LabView
- Searching function

5.1.2. Test planning

The developer should not be the tester. Best practice is Independent Verification & Validation (IV&V). This means that an independent entity evaluates the work generated by the team or a team member that is designing or developing a given assignment. The test case should be recorded for reuse. A test is successful when it detects an error.

Date and estimated time for test must be decided, and also the purpose of the test. Errors and failures must be documented. Appendix 6 is a template for a test planning schedule.

6. Test strategy

According to the project model, this project is to develop one function at a time. It is therefore most appropriate to test the functional requirements first and then assemble these continuously together into a whole system.

An appropriate test strategy is bottom-up testing combined with incremental testing. Bottom-up testing tests the smallest units in the system and later assemble these together. An incremental test strategy use bottom-up or top-down method, and starts with the most important functions first. Top-down testing starts to test the total system, and break it down into smaller functions. This is not an appropriate method for this project.
The most important functions in this project are A-priority functional requirements. The selected test strategy is based on the incremental testing with bottom-up strategy.

6.1. Verification and validation

During test progress it is important to consider verification and validation, to ensure that every single part of the system is verified and that the product is according to the specified requirements.

Verification is the assurance that the products of a particular phase in the development process are consistent with the requirements of that phase and the preceding phase. Verification is focused more on the activities of a particular phase of the development process. In simple terms, verification makes sure that the product is being built right.

Validation is the assurance that the final product satisfies the system requirements.
The purpose of validation is to ensure that the system has implemented all requirements, so that each function can be traced back to a particular customer requirement. In other words, validation makes sure that the right product is being built.

Appendix 1: Test specification table - functional requirements

ID-test	Test of functional requirements		ID-requirements
TF 1	**Test:**	Simulator test	RF 1
TF 2	**Test:**	Observe and measure using simulation and measurement instrument	RF 2
TF 2.1	**Test:**	Simulate, observe and verify results	RF 2.1
TF 3	**Test:**	Dimensions and tolerances are within specified limits	RF 3
TF 4 TF 5	**Test:**	Simulate, observe and verify results + requirements for the supplier	RF 4 RF 5
TF 6 TF 7 TF 8	**Test:**	Simulate, observe and verify results + comparison with data from KA (estimates in the control system)	RF 6 RF 7 RF 8
TF 9	**Test:**	Simulate, observe and verify results + the control system are running continuously	RF 9
TF 10	**Test:**	Compare with previous results from the same type of test (single measurements). Run a functional test and see if the result is as expected	RF 10
TF 11	**Test:**	Observe and test the logical outcome of drawings	RF 11
TF 12	**Test:**	FEM-analysis	RF 12
TF 13	**Test:**	Run simulation with force applied and compare results with v-stay references	RF 13
TF 14 TF 14.1 TF 14.2	**Test:**	Check 3D-drawings and manufacturing drawings (2D)	RF 14 RF 14.1 RF 14.2

TF 15	**Test:**	Requirements for the supplier, compare with log data from KA. Identify the target area on beforehand.	RF 15
TF 16	**Test:**	Manipulating input / measurements in the code. Determine if the system stops.	RF 16
TF 17 TF 19	**Test:**	Requirements for the supplier	RF 17 RF 19
TF 18	**Test:**	Measure decomposed forces in the v-stay and compare with formerly data. Advance estimates of the output from the system	RF 18

Appendix 2: Test specification table - documentation requirements

ID-test	Test of documentation requirements	ID-requirements
TD 1	**Test:** Control the specified standards for 2D-drawings	RD 1

Appendix 3: Test specification table - property requirements

ID-test	Test of property requirements		ID-requirement
TP 1	**Test:**	Control check on the allocated space in the 3D model	RP 1
TP 1.1	**Test:**	Control check that fasteners have been made for the protection plates	RP 1.1
TP 2 TP 2.1 TP 2.2 TP 2.3	**Test:**	Manipulating input / measurements in the code. Control if the system stops, include emergency stop in electrical forms	RP 2 RP 2.1 RP 2.2 RP 2.3
TP 3	**Test:**	Check if safety relay is implemented in electrical drawings	RP 3
TP 4	**Test:**	FEM-analysis	RP 4
TP 5	**Test:**	Draw a cooling system in the 3D model. Make sure it is taken into account that there is room for it	RP 5
TP 6	**Test:**	Get others to test whether it is easy to learn and easy to operate	RP 6
TP 7	**Test:**	Simulate, observe and verify results	RP 7
TP 8	**Test:**	Check the 3D-drawing	RP 8
TP 9	**Test:**	Manipulating input / measurements in the code. Check if the system stops	RP 9

Appendix 4: Test specification table - restrictions

ID-test	Test of restrictions requirements		ID-requirement
TR 1 TR 2	**Test:**	Control check in the simulation and FEM analysis	RR 4 RR 5
TR 3	**Test:**	Requirements for the supplier	RR 6

Appendix 5: Test specification table - interface requirements

ID-test	Test of interface requirements		ID-requirement
TI 1	**Test:**	Check the storage function of the control system	RI 1
TI 2	**Test:**	Run a test and see if it counts	RI 2
TI 3	**Test:**	Simulate a test and observe the frequency	RI 3
TI 4	**Test:**	Simulate a test and observe if the stiffness correspond	RI 4
TI 5	**Test:**	Simulate a test and observe the time with a timer	RI 5
TI 6	**Test:**	Check in the Diadem whether it is possible to obtain data	RI 6

Appendix 6: Test planner

Test specification for function	
Test ID	
Requirement ID	
Responsible	
Date	
Estimated time for test	
The purpose of the test	
Comments/deviations	

Performed

The test was run by	
Date	
Comments	

Event progress.			
#No.	Maneuvers to be done	Results to be achieved	Check
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

☐ Verified

☐ Not verified

Signature

HØGSKOLEN
i Buskerud

Department of Technology
Kongsberg

Title of document: Project plan rev. 1.4
Course (code/name) SFHO3200 Hovedoppgave med prosjektstyring
Group members: Elisabeth Espås Jenssen Jørgen Heum Larsen Andreas Fossnær Wold Edward Palm Sandaker Stina Andersen
Internal supervisor: Gunnar Flak
Date: 17.12.2010
We confirm that the submitted assignment is entirely our work.   Elisabeth Espås Jenssen, Jørgen Heum Larsen, Andreas Fossnær Wold, Edward Palm Sandaker og Stina Andersen

Table of contents

1. The main objectives of project plan

The project plan covers all aspects surrounding the implementation of the project. The project plan must also specify when the activities are going to be implemented and also who will carry out activities in addition to who is responsible for the implementation of these.

2. Abbreviations

KA - Kongsberg Automotive
FEM - Finite Element Method

3. Introduction – Why design and develop “Movement Test Rig”

One of the products Kongsberg Automotive develops is a V-stay for trucks. This V-stay represents the connection between the rear axle and the truck's frame. This V-stay must be thoroughly tested in a test rig. The solution Kongsberg Automotive has today takes up a lot of time in the existing rigs that are initially intended for other tests. The current solution requires that the operator must set up temporary sensors and electronics, as well as moving the test object manually repeatedly through the test. This makes the tests both time consuming and costly to perform, in addition to that it is difficult to manually manoeuvre the V-stay in the existing rigs. This is because both the size and weight of the V-stay, where each of the legs measures 70 cm and the V-stay weighing up to 20 kg. The rig is also to store and process data in a more convenient way than today’s configuration.

To dampen vibrations between the drive axle and the frame, there are rubber bushings in both V-stay legs. The bushings in the V-stay have a built-in resilience that changes over time due to the external factors they are exposed to. The bushings affects ride comfort to a great extent, and selection of appropriate elasticity versus life, is a comprehensive process. Since this is a crucial component in terms of road safety it is very important that these bushings are both tested regularly and thoroughly, before being mounted in a truck.

4. The main objective of the project

KA has a desire to develop a more compact and flexible test rig. The rig must be able to measure stiffness, displacements and perform single axis fatigue tests. The test rig should be able to test over time to fracture occurs. The goal is to design a test rig including the measurement of applied forces on the V-stay in selected degrees of freedom in addition to stress and lifetime of rubber bushings.

During the project progress we will hold internal and external meetings, and complete three presentations.

5. Delimitation

Since there are not enough resources, nor time available to produce a prototype or physical model of the test rig, the testing will consist in the form of simulations of various kinds.

The project, together with the client has developed a great number of requirements and this gives the project clear and specific boundaries.

6. Risk analysis

In a project like this, there are multiple factors that constitute a risk for the progress in the project. It is important to map out these factors, so that the adverse effects can be reduced or avoided in the best possible way.

6.1.Loss of data

This could be a total crash in one of the computers, or that the external server used for data storage goes down. This can be avoided by taking back-up at a regular basis, and that more than one group member keeps a copy of the work done.

6.2.Short-term illness

This is something that is almost bound to happen during the project. It can be compensated by spreading the workload to the other members over a short period of time, or postpone an activity if possible.

6.3.Long-term illness

If this becomes a reality, the remaining work must be distributed to the other members of the group. It should be discussed whether the size of the project should be reduced in terms of reduced functionality or quality. This is also the solution if the project suffers from a permanent loss of a group member.

6.4.Long term absence of external sensor

There should be established a dialogue with the client for appointment of an alternative sensor.

6.5.Conflict within group

Conflicts within the group could result in a major reduction in the progress of the project. One should first try to resolve the issue in a diplomatic way. If an agreement is not possible, the problem should be discussed with the internal supervisor.

6.6.Disagreement between the group and internal supervisor

Problems like this should be solved as fast as possible in a diplomatic way.
If an agreement is beyond reach, the problem is to be brought along to the internal sensor.

6.7.The client decides to shut down the project

If this should occur, the group will request to continue the project with the remaining available resources. Thus, this is bound to affect the final result in a negative manner.

7. Description of main tasks

The project is divided into main tasks and this represents the borders of the project.

- Project control
- Requirements
- Documentation
- Design and development
- Tests
- Price estimate

7.1.Activities and responsibility

The main tasks are divided into activities that are included in the project. Most of the activities are self-explanatory. Some of the activities will be explained in this chapter. All activities and milestones will be presented in the progress plan.

Date	Milestones
04.02.2011	Choice of concept
03.03.2011	Control system ready for programming
10.03.2011	Controller software ready for physical test
29.04.2011	Finalize 3D model
04.05.2011	Final test
09.05.2011	Finalize system
13.05.2011	Finalize report

Table 1: Milestones

Overall activity number	Overall activity	Subordinate activity number	Subordinate Activity	Description
1.0	Project control	1.1	Internal meetings	
		1.2	External meetings	
		1.3	Proofreading	
		1.4	Presentations	
		1.4.1	Presentation 1	
		1.4.2	Presentation 2	
		1.4.3	Presentation 3	
		1.5	Administration	
		1.6	Web-update	
		1.7	After analysis	
		1.8	Project Model	
2.0	Requirements	2.1	Requirements Specification	
3.0	Documentation	3.1	Document Templates	
		3.2	Vision Document	
		3.3	Feasibility study report	
		3.4	User manual	
		3.5	Project plan	
		3.6	Project Report	
		3.7	Project Poster	
		3.8	Meeting minutes	Every week
		3.9	Follow-up documents	Every week
		3.10	Meeting request	Every week
4.0	Design and development	4.1	Brainstorming	
		4.2	Research	
		4.3	Function-means tree	
		4.4	3D-model	
		4.4.1	Framework	Framework of the whole rig.
		4.4.2	Brackets for equipment	For attachments of V-stay ,cylinders, equipments etc.
		4.4.3	Insert dummies	Implement equipment, e.g. cylinders etc.
		4.5	2D-drawings	According to standards

		4.7	Risk analysis	Risks during the development
		4.8	Simulator	Create a simulator for testing the system
		4.9	Choice of sensors and components	
		4.10	Electrical drawings	Connecting the electrical system
		4.11	Control system	Control and regulate the force supply, and emergency stop.
		4.11.1	Controller software	Code to control system
		4.11.3	Choice of controller hardware	Controls the force manipulating elements
		4.11.4	Choice of software	Software tool
		4.13	Sketches of test rig	Handmade drawings
		4.14	Calculations and dimensioning	
		4.15	Choice of force supply	
		4.16	Choice of materials	
		4.17	Choice of fastenings	
		4.18	Implementation	Implement the whole system
		4.19	Choice of data processing tool	Program to process log data
		4.20	Choice of concept	All components, materials and equipment will be selected
5.0	Testing	5.1	Test specification	
		5.2	Make data processing functionality	Use data processing tool to verify the results from control system
		5.3	FEM analysis	Analysis of stress vs materials and fasteners
		5.4	Check 3D-model	In connection with testing

		5.5	Functional test of control system	
		5.6	Test report	
		5.7	Final test	Final test for whole system
6.0	Price Estimate	6.1	Framework	From 3D model
		6.2	Sensors and electrical components	
		6.3	Control system	Hardware
		6.4	Software	Licence on operator systems and SolidWorks
		6.5	Total budget	

Table 2: Activities

8. Progress plan

8.1.Time and resource schedule

All the activities are assembled in a time and resource schedule. The time duration and date of each activity, and the resources used on each activity are specified. Dependent activities are also linked. The progress plan is based on the incremental project model. Incremental method is based on the requirement specification and provides the opportunities to build the system as separate components, one at a time. Initially, it is important to work with development of the highest priority requirement, in order to realize and then test. Next step is to design and implement new requirements and tests. This process is repeated until the project is completed.

Appendix 1 shows progress plan.

8.2.Cost budget

Material	
Printing of poster	350 NOK
Printing of documents	120 NOK
Binding of reports	140 NOK
CDs to record all documentation	100 NOK
Sum	620 NOK
Hours	
Expected work hours in total	3000 hours (600 hours x 5)

9. Project members and their roles

Stina Andersen – Project leader

- Control the work toward the objective of the project
- Report to internal supervisor
- Keep the project within the limits of the project
- Inform internal supervisor about present or prospective delays

Jørgen Heum Larsen – Design and test responsible, mechanical

- Manage work with design
- Coordinate design documentation
- Responsible for mechanical tests
- Responsible for preparations before each test

Elisabeth Espås Jenssen –Development, electronics, and economic responsible

- Manage work with development
- Coordinate development documentation
- Manage work concerning economic calculations and price estimations
- Coordinate economic documentation

Edward Sandaker Palm – User interface and web-responsible

- Responsible for dialogue with the client concerning user interface questions
- Coordinate user interface and user manual
- Update the web site

Andreas Fossnær Wold – Documentation and test responsible, electro

- Responsible for electronic tests
- Responsible for preparation before each test
- Responsible for all documentation are written and maintained
- Make sure that minutes are done and distributed
- Coordinate and distributes of documents and reports
- Make sure that documents are signed after approval
- Make sure that there are templates for different types of documents
- Make sure that all documents has an overall impression

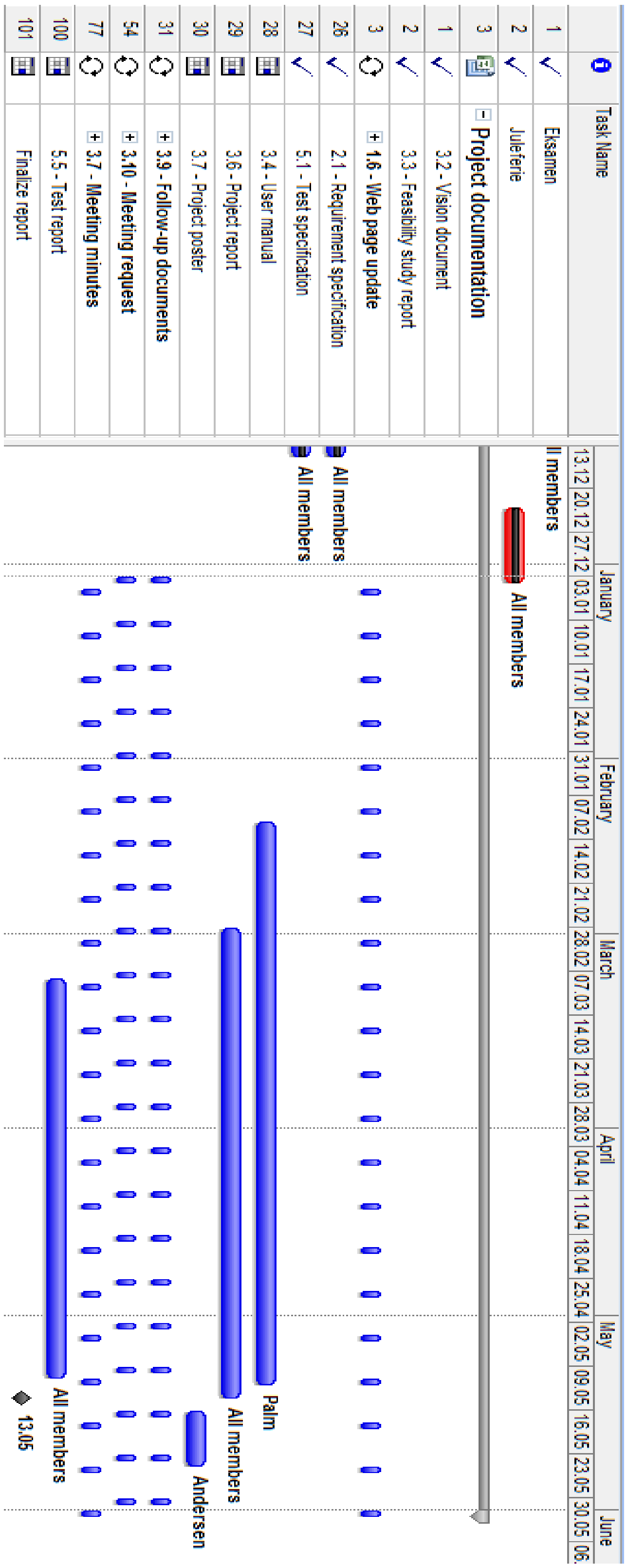
10. Document overview

The assignment is based on the document “Forstudiet 1.11”. The main tasks and activities in time and resources schedule are based on the requirements. All requirements are listed in requirement specification report. The tests in the progress plan are based on the test specification.

Reference to documents

- Forstudiet 1.11 (10.11.2010)
- Requirement specification 1.3 (13.12.2010)
- Test specification rev 1.3 (14.12.2010)

Appendix1: Progress plan – Project documentation



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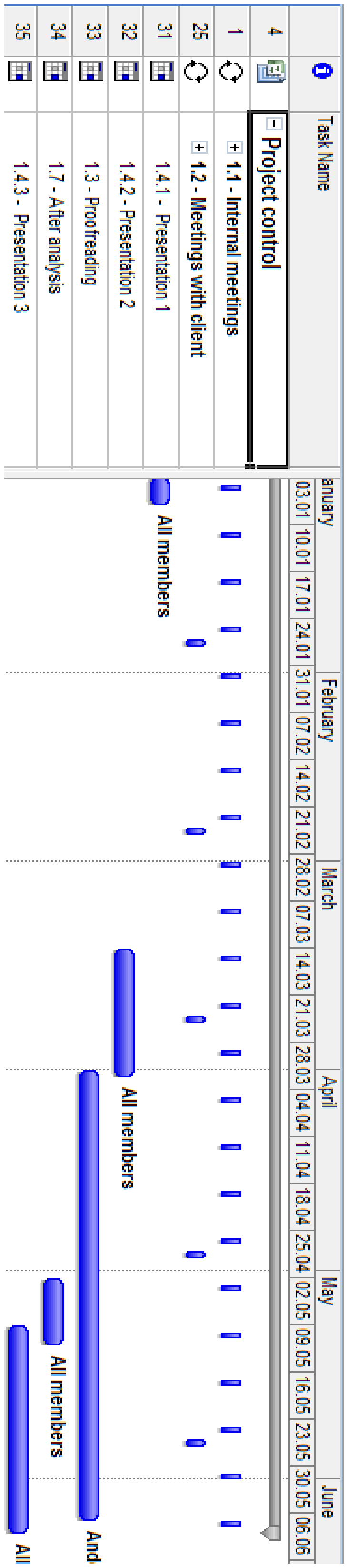
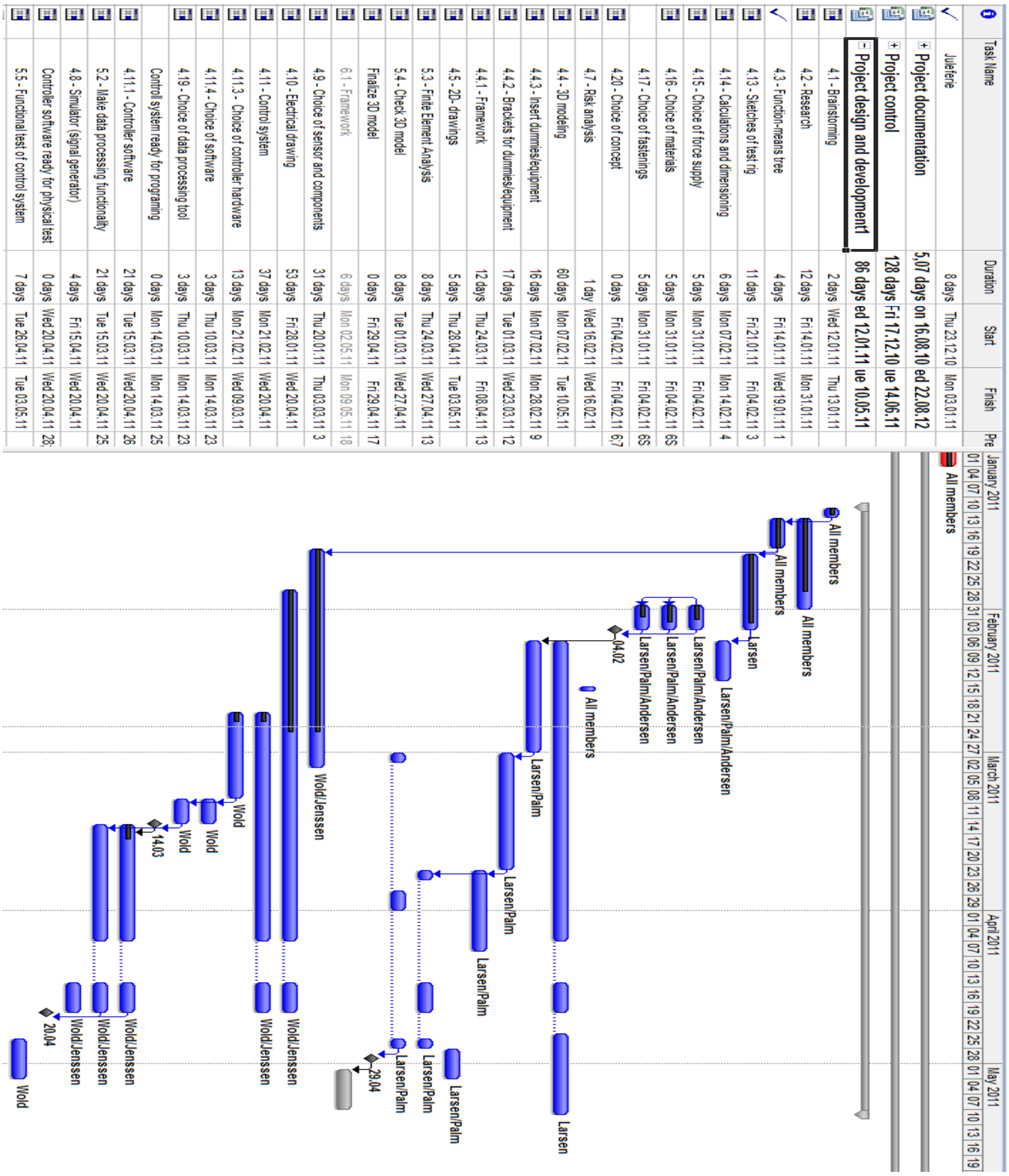
Appendix2: Progress plan – Project control

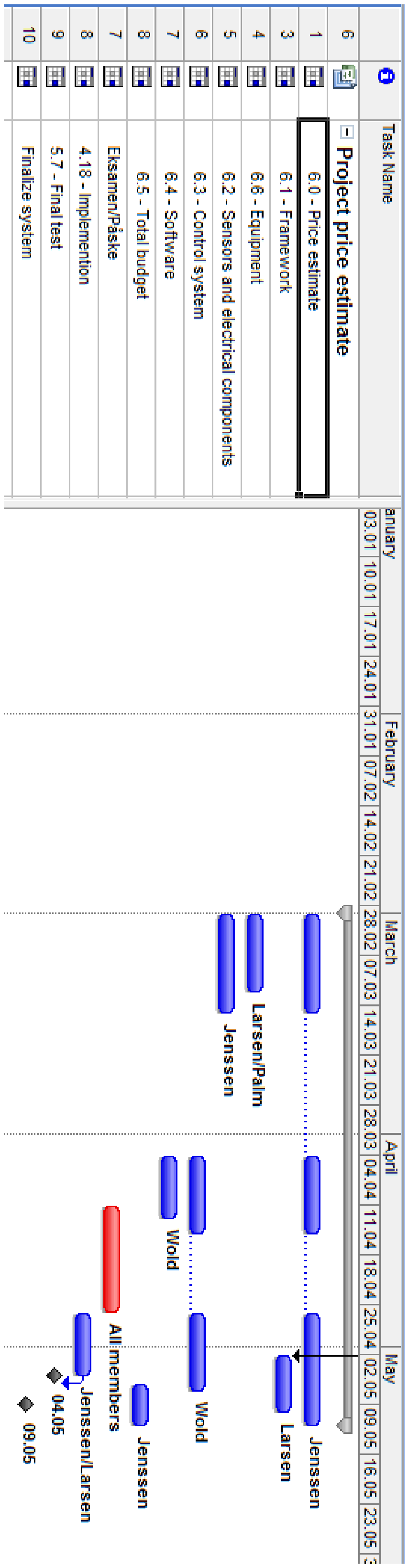


Appendix 3: Progress plan – Project design and development



Task Name	Duration	Start	Finish	Pre
Juleferie	8 days	Thu 23.12.10	Mon 03.01.11	
Project documentation	5,07 days	on 16.08.10	ed 22.08.12	
Project control	128 days	Fri 17.12.10	ue 14.06.11	
Project design and development1	86 days	ed 12.01.11	ue 10.05.11	
4.1 - Brainstorming	2 days	Wed 12.01.11	Thu 13.01.11	
4.2 - Research	12 days	Fri 14.01.11	Mon 31.01.11	
4.3 - Function-means tree	4 days	Fri 14.01.11	Wed 19.01.11	1
4.13 - Sketches of test rig	11 days	Fri 21.01.11	Fri 04.02.11	3
4.14 - Calculations and dimensioning	6 days	Mon 07.02.11	Mon 14.02.11	4
4.15 - Choice of force supply	5 days	Mon 31.01.11	Fri 04.02.11	
4.16 - Choice of materials	5 days	Mon 31.01.11	Fri 04.02.11	6S
4.17 - Choice of fastenings	5 days	Mon 31.01.11	Fri 04.02.11	6S
4.20 - Choice of concept	0 days	Fri 04.02.11	Fri 04.02.11	6;7
4.7 - Risk analysis	1 day	Wed 16.02.11	Wed 16.02.11	
4.4 - 3D modeling	60 days	Mon 07.02.11	Tue 10.05.11	
4.4.3 - Insert dummies/equipment	16 days	Mon 07.02.11	Mon 28.02.11	9
4.4.2 - Brackets for dummies/equipment	17 days	Tue 01.03.11	Wed 23.03.11	12
4.4.1 - Framework	12 days	Thu 24.03.11	Fri 08.04.11	13
4.5 - 2D- drawings	5 days	Thu 28.04.11	Tue 03.05.11	
5.3 - Finite Element Analysis	8 days	Thu 24.03.11	Wed 27.04.11	13
5.4 - Check 3D model	8 days	Tue 01.03.11	Wed 27.04.11	
Finalize 3D model	0 days	Fri 29.04.11	Fri 29.04.11	17
6.1 - Framework	6 days	Mon 02.05.11	Mon 09.05.11	18
4.9 - Choice of sensor and components	31 days	Thu 20.01.11	Thu 03.03.11	3
4.10 - Electrical drawing	53 days	Fri 28.01.11	Wed 20.04.11	
4.11 - Control system	37 days	Mon 21.02.11	Wed 20.04.11	
4.11.3 - Choice of controller hardware	13 days	Mon 21.02.11	Wed 09.03.11	
4.11.4 - Choice of software	3 days	Thu 10.03.11	Mon 14.03.11	23
4.19 - Choice of data processing tool	3 days	Thu 10.03.11	Mon 14.03.11	23
Controll system ready for programing	0 days	Mon 14.03.11	Mon 14.03.11	25
4.11.1 - Controller software	21 days	Tue 15.03.11	Wed 20.04.11	26
5.2 - Make data processing functionality	21 days	Tue 15.03.11	Wed 20.04.11	25
4.8 - Simulator (signal generator)	4 days	Fri 15.04.11	Wed 20.04.11	
Controller software ready for physical test	0 days	Wed 20.04.11	Wed 20.04.11	28;
5.5 - Functional test of control system	7 days	Tue 26.04.11	Tue 03.05.11	

Appendix 4: Progress plan – Project price estimate



Appendix 5: Revised project plan for electro, 23th of February

Milestone ‘Choice of concept’ 17th of February gave a new direction for the project plan for the electrical part of the project. Previous edition of the schedule was not possible to follow up. It is prepared a new schedule that match with real activities and their sequences. There was added some activities and removed any that was obsolete. The new schedule is placed in appendix 3. The first edition of schedule was made before the group started working. It is therefore not surprising that is has produced a revised edition. This is a part of the learning process. Further text in this appendix contains the foundation of the changes that has been done.

The revised edition of activities is listed in chronological order as in the schedule.

Choice of sensors and components

In previous edition the group was supposed to select controller and other components at the same time as concept of mechanical part. It was rather difficult to select a controller before the concept was known. This activity is a choice of electrical concept. It contains research of controllers and other components that satisfies the mechanical requirements. This choice has to be done after choice of concept for the mechanical part.

Electrical drawing

At starting point this activity began early. The group member found it difficult to start with this activity, because of limited information about the concept of rig. An overall sketch is made. This overall sketch will be developed during the work with control system.

Choice of controller hardware

This is a new activity that replaces ‘Controller hardware’ (4.11.2) that was scheduled to do as last activity in the control system. The group found it inappropriate to find hardware after software was developed. The research about controller is done in activity 4.9 and will be chosen as a small activity in this activity. The controller hardware has to be done after the mechanical choice of concept, because it is necessary to know numbers of cylinders. It provides the basis to know inputs and outputs of the controller hardware. There are several suppliers that provide controllers, and one that satisfies the concept requirement has to be chosen.

Choice of software

This is a new activity. The project has required to user LabVIEW as a programming tool. Not every control system is compatible with LabVIEW. The choice of controller hardware (4.11.3) determines which software tool that is most appropriate. That is the basis on the new activity. Restriction requirement RR1 must be reconsidered.

Choice of data processing tool

The project group thought that they were supposed to use program Diadem for National Instrument, which was compatible with the equipment KA use today. Now it turns out that there must be selected a data processing toll that is compatible with the control hardware that becomes selected.

Milestone: Controller software ready for programming

This is a new milestone. The controller hardware, software tool and data processing tool are chosen in cooperate with KA.

Control software

The first edition said that the activity started immediately after milestone choice of concept. The situation today says that programming has to start after milestone ‘controller software ready for programming.’
Operator system is removed from the activity list. It was made before the group had any knowledge about LabVIEW or other programmer software tool. This activity is now a part of control software.

Make data processing functionality

This activity goes parallel with control software.

Simulator

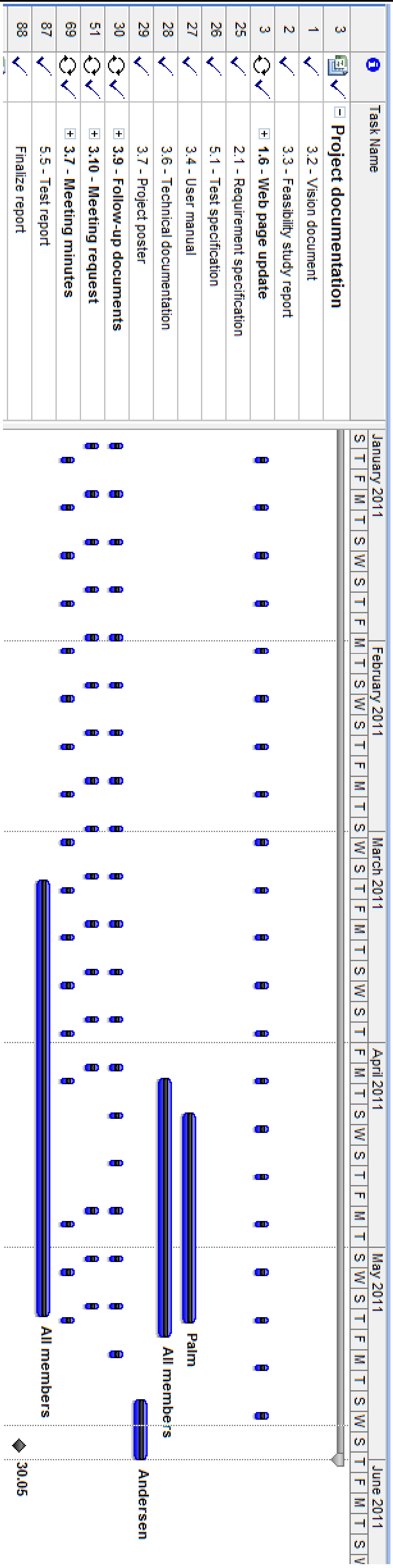
The simulator is scheduled to do in parallel with control software. The project group is unsure if this activity is necessary. It might be a part of control software.

Milestone: Controller software ready for physical test

This milestone has been delayed to 20th of April, and are placed when control software are done. This is before examination period.

Functional test of control system

This test involves testing of control software on existing equipments at KA. Thus the chosen software has to be compatible with the controllers at KA.


Task Name
3 Project documentation
1 3.2 - Vision document
2 3.3 - Feasibility study report
3 1.6 - Web page update
25 2.1 - Requirement specification
26 5.1 - Test specification
27 3.4 - User manual
28 3.6 - Technical documentation
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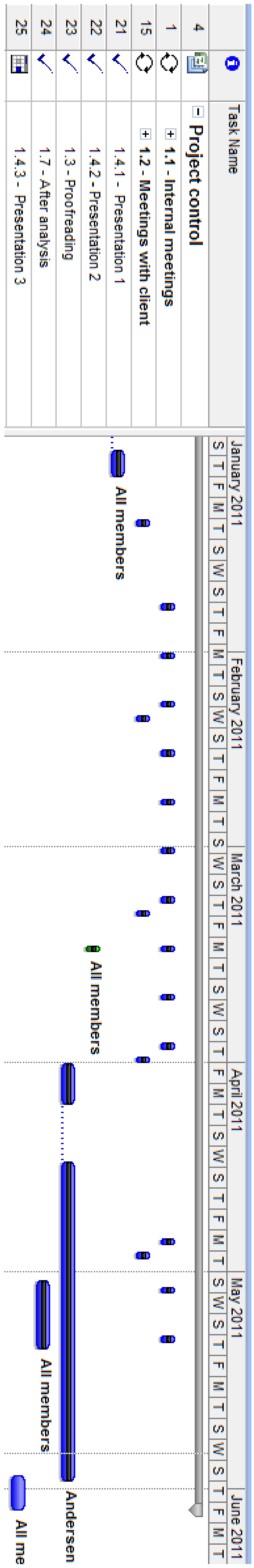
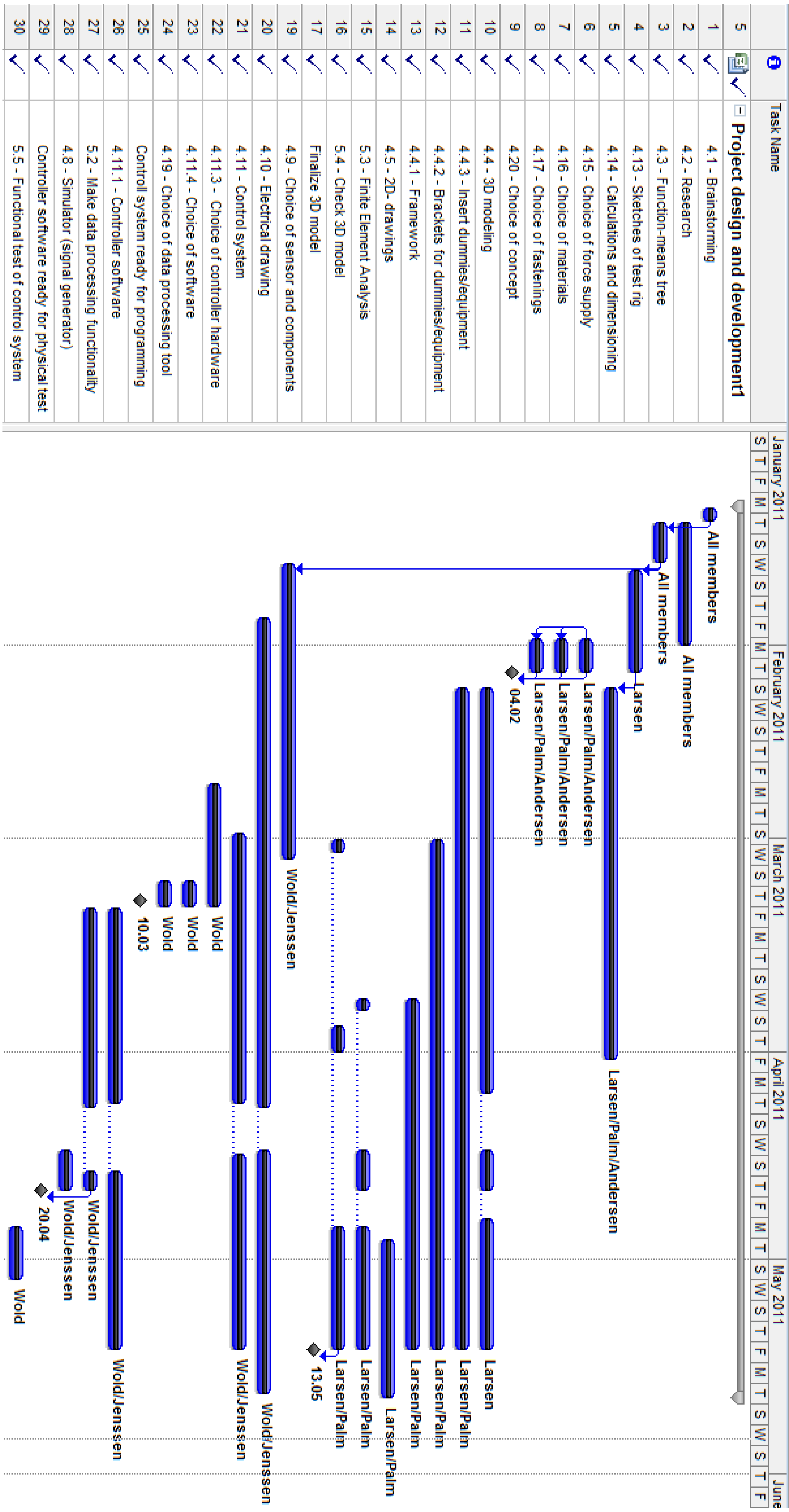
88 Finalize report
January 2011
February 2011
March 2011
April 2011
May 2011
June 2011
Palm
All members
Andersen
All members
30.05



HØGSKOLEN i Buskerud

KONGSBERG AUTOMOTIVE


Task Name
5 Project design and development1
1 4.1 - Brainstorming
2 4.2 - Research
3 4.3 - Function-means tree
4 4.13 - Sketches of test rig
5 4.14 - Calculations and dimensioning
6 4.15 - Choice of force supply
7 4.16 - Choice of materials
8 4.17 - Choice of fastenings
9 4.20 - Choice of concept
10 4.4 - 3D modeling
11 4.4.3 - Insert dummies/equipment
12 4.4.2 - Brackets for dummies/equipment
13 4.4.1 - Framework
14 4.5 - 2D- drawings
15 5.3 - Finite Element Analysis
16 5.4 - Check 3D model
17 Finalize 3D model
19 4.9 - Choice of sensor and components
20 4.10 - Electrical drawing
21 4.11 - Control system
22 4.11.3 - Choice of controller hardware
23 4.11.4 - Choice of software
24 4.19 - Choice of data processing tool
25 Controll system ready for programming
26 4.11.1 - Controller software
27 5.2 - Make data processing functionality
28 4.8 - Simulator (signal generator)
29 Controller software ready for physical test
30 5.5 - Functional test of control system
January 2011
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Larsen
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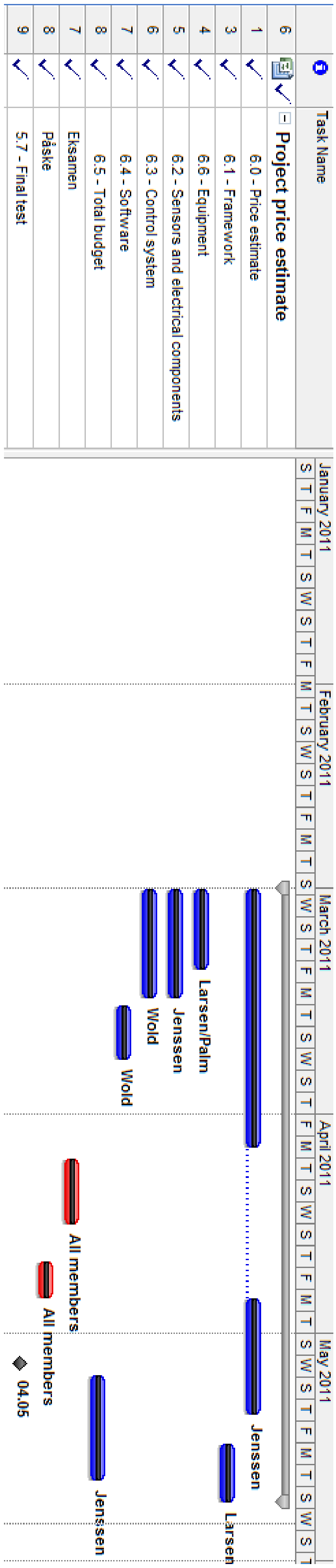
Task Name
Project price estimate
6.0 - Price estimate
6.1 - Framework
6.6 - Equipment
6.2 - Sensors and electrical components
6.3 - Control system
6.4 - Software
6.5 - Total budget
Eksamen
Påske
5.7 - Final test
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March 2011
April 2011
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Wold
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Jenssen
Larsen
Jenssen

HØGSKOLEN
i Buskerud

Department of Technology
Kongsberg

Title of document: Document of Concept rev. 1.18
Course (code/name) SFHO3200 Hovedoppgave med prosjektstyring
Group members: Elisabeth Espås Jenssen Jørgen Heum Larsen Andreas Fossnær Wold Edward Palm Sandaker Stina Andersen
Internal supervisor: Gunnar Flak
Date: 16.02.2011
We confirm that the submitted assignment is entirely our work.   Elisabeth Espås Jenssen, Jørgen Heum Larsen, Andreas Fossnær Wold, Edward Palm Sandaker og Stina Andersen

Table of contents

1. The main objective of the document of concept

The main objective of the document of concept is to present design concepts, electrical components and their potential suppliers. This is a formal document between the client and the developer about the concept to be selected.

2. Abbreviations

KA	- Kongsberg Automotive
cRio	-compactRio
NI	-National Instrument

3. Introduction

Document of concept is divided into two main chapters, mechanical and electrical parts. The mechanical part presents sketches and suppliers for cylinders with mounting brackets and linear movement products. The concept contains of three concepts and three previous ideas. The previous ideas are already been shown to KA, but the client wanted further development of these. With inspiration from previous design there have been developed three new concepts.
The electrical part contains of alternative suppliers for the controls system. There has been considered the solution of today with possible improvements.
Matrixes and flowcharts are used to view a summary.

4. The mechanical part

The mechanical part of the project is mainly the design of the frame and choice of materials, force supply and brackets. In addition to this there must be calculations to identify stress concentrations and bend out to find the right dimensions on the frame and brackets. The calculations are to be done in the next step of the project and after the choice of concept.

4.1. Force supply

Hydraulics is chosen to be the main type of force supply. Kongsberg Automotive has a hydraulic power pack with a capacity of 210 bar already installed, thus making hydraulics a cost effective solution. Requirements like big forces and high frequencies made it difficult for linear electric motors, electric actuators and pneumatics to reach up.

Several suppliers of hydraulics and such were contacted, mostly with e-mails stating the needs and requirements of the projects hydraulic cylinders. Most of the suppliers gave a quick and approximate price offer, exactly what the group needed. Then, provided all the cylinders offered could put up with the requirements, a matrix was made to compare the prices from the different suppliers:

Functionality	Bosch Rexroth	Hänchen	PMC Servi	MTS	Vishay
Price	?	Low	Very low	High	Middle
maintenance					
100% duty cycle	Yes	Yes	Probably not	Yes	Yes
Distance measuring	Yes	Yes	Yes	No, but available	
Spherical bearings	Yes	Yes	No	Yes	
Frequency	OK	OK	20 Hz	OK	OK
Price longitudinal	29000	135 656	20 646	138 000	150 000
Price transversal	29000	150 815	23 298	240 000	200 000
Price vertical	29000	73 725	20 324	114 000	75 000
Total cylinder price	**87000**	**360 196**	**64 268**	**492 000**	**425 000**
Load cells total*	135000	135000	12000	135000	135000
Servo valve**	150000	150000	?	150000	150000
Total system price:	372000	645 196	76 268	777 000	710 000

*: Estimated only, based on separate load cell prices from Vishay.
**: Estimated only, based on separate servo valve prices from Vishay.
Bosch Rexroth's prices are very inaccurate estimates.

As one can see, PMC Servi definitely has the cheapest cylinders. Unfortunately, after looking thoroughly through the data sheets for these cylinders, it became obvious that they were not designed to run with a 100% duty cycle, and especially not in the running environments it would meet. This is absolutely crucial, since tests can last several months. Bosch Rexroth on the other hand, had cheap cylinders for sale, and MTR’s contact person believed that they would be able to run with a 100% duty cycle as well. If only they could give MTR an offer on more than one cylinder, the cylinders would have been taken into a more serious consideration. The prices from Bosch Rexroth shown in the Matrix are very inaccurate, as per today, only the price on one (the longitudinal) cylinder is given.
Hänchen on the other hand, came up with a very detailed price offer, which included everything MTR’s application was going to need. At first, they seemed to have the most

expensive cylinders, but after adding necessities like servo valves and load cells to all other offers, they even turned out to be the cheapest of all the remaining suppliers.
Until MTR get a complete price offer from Bosch Rexroth, Hänchen is considered to be the most complete and price efficient supplier to stick with. Their offer even includes servo valves from Moog, whose products will be seen more of throughout the rig.

The cylinders that are offered from Hänchen (Ratio-Test series 320, and 300 for the vertical cylinder) are made especially for testing environments. The frequency at which they can operate depends only on the performance of its servo valve (except the vertical cylinder, having a restriction of 25Hz, which is plenty), as long as speeds do not exceed 4 m/s. They are also designed to withstand high side forces, which may allow MTR to mount the longitudinal cylinder with rigid mountings (though the price offer given includes spherical bearings in all three cylinders). There is no doubt these cylinders will serve its purpose.

4.2. Guide rail and carriages suppliers

Bosch Rexroth:

Bosch Rexroth provides linear mechanisms in most sizes and shapes, and is therefore a potential supplier for all the main mechanism challenges. The project group has been in contact with Rexroth regarding their products for linear movement and our challenges, and they seem very positive. Even the alignment of the dovetail slides seemed to be feasible. A few examples of their relevant products:
Dovetail slides:

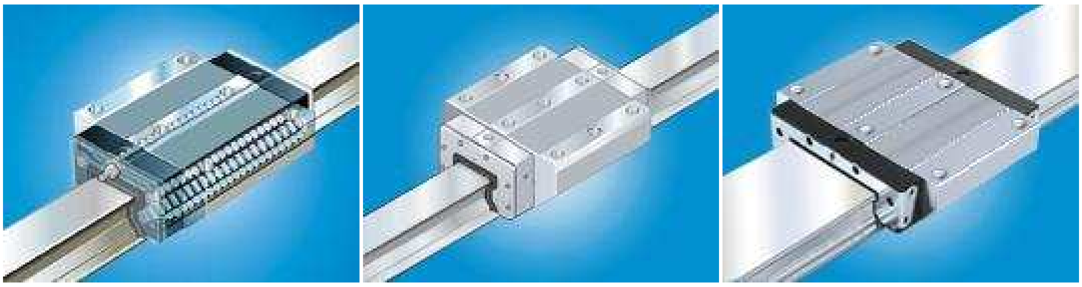


Figure 1: Left: Standard roller rail. Centre: Heavy duty. Right: Wide ball roller rail

PBC Linear

PBC provides linear movement products similar to the ones the group first had in mind. Though they quickly turned out to be way too small for our vertical movement (up to 2 inches in rod diameter, and 1.5 inches in square cross section), they work fine as an idea for future development, or as compensation for the small rotational movement during transversal testing. The group has not been in contact with this supplier. Examples of their products:

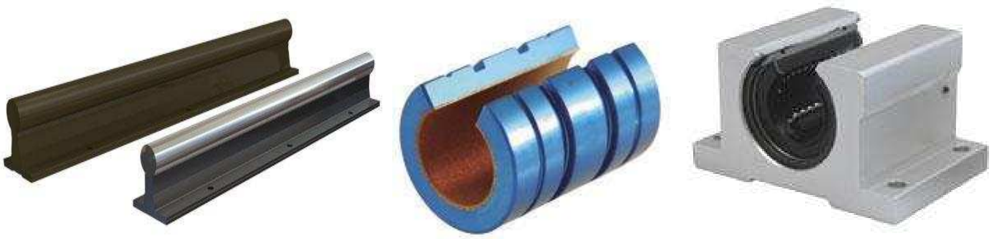


Figure 2: Circular shafts/rods with sliding bearings

Another option from PBC linear:

Figure 3: SB Series

ABTech Inc

ABTech is another supplier that offers some linear movement products. These come in much bigger sizes than the products from the previous mentioned supplier. Unfortunately, they cannot withstand as high forces as you would expect them to. Again probably just a good idea for future development or research. One example:

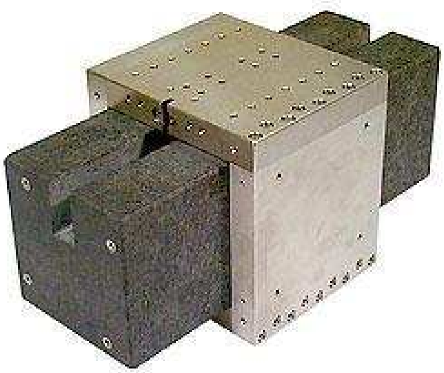


Figure 4: Manual linear air bearings

Schneeberger /Elmeko AS

Schneeberger seems to have a lot of products similar to the ones Rexroth have. Sold in Norway by Elmeko AS. The project group has been in contact with Schneeberger/Elmeko, and with good service and a pleasant dialog, they stand as one solid alternative for our linear movement products. A selection of their dovetail slides are shown below:

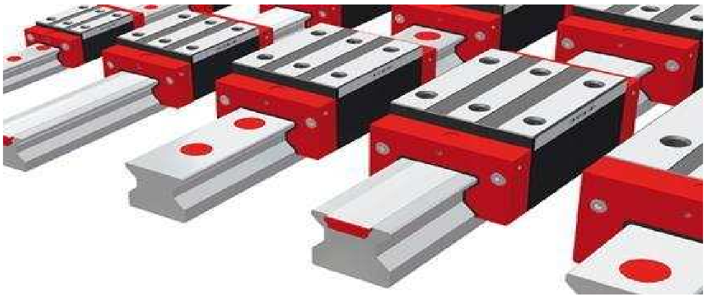


Figure 5: Monorail MR

4.3.Concept 1: Three cylinders

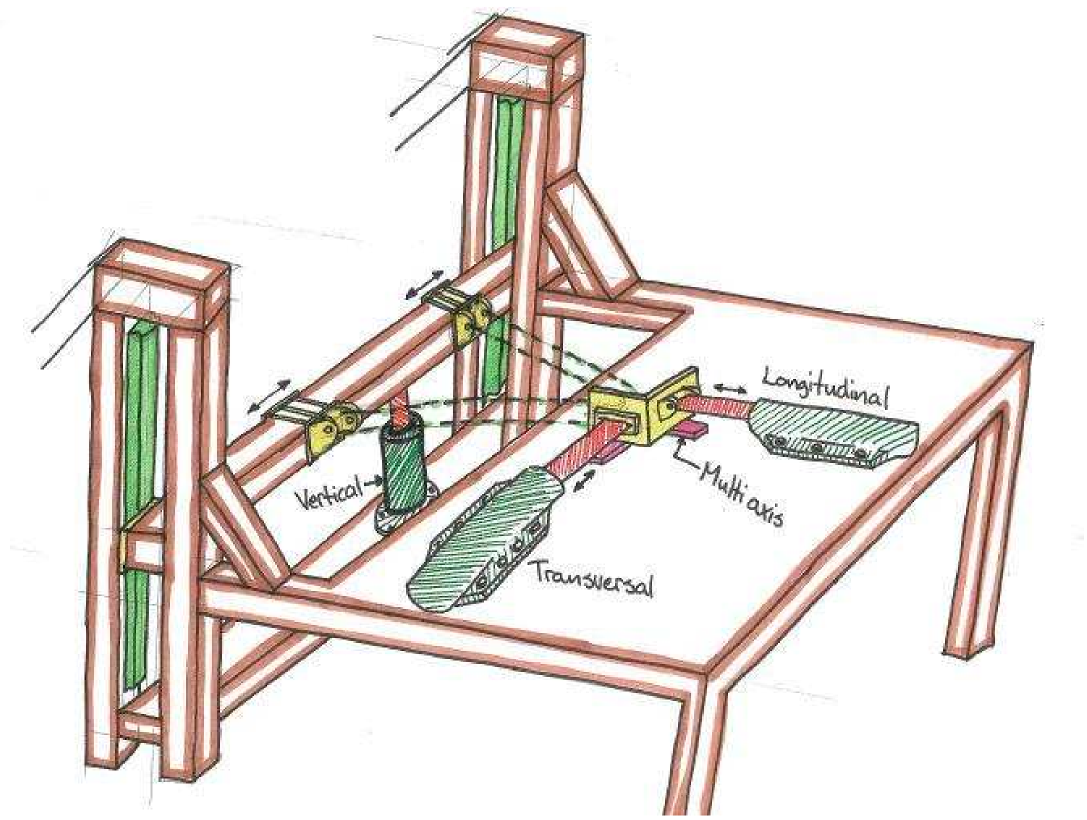


Figure 6

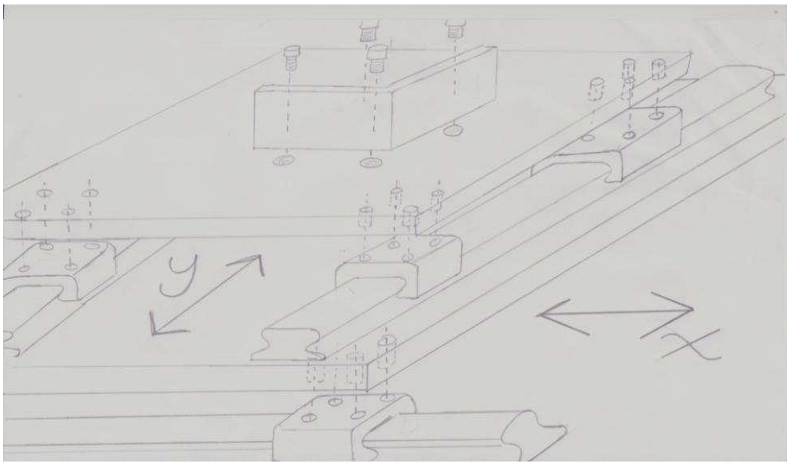
This is the concept that will get the main focus from the group for further development. Longitudinal and transversal testing will be done by pushing on the bottom part of the V-stay, which is lying on an XY table and thus able to slide everywhere in the horizontal plane. The cylinder pushing in the longitudinal direction can and will be mounted without the ability to rotate around any axis, as there will be no forces acting sideways during longitudinal testing, nor will the V-stay move up or down. This will also eliminate some free play issues. The cylinder pushing in the transversal direction would also preferably be mounted in the same way as the longitudinal cylinder. However, this cylinder or its mounting points will have to compensate for a small rotational movement of the V-stay.

Vertical testing will be done by pushing on the beam that is mounted to the V-stays legs. As for the cylinder, this will require a more powerful/bigger one than other concepts would, because of the weight of the beam. Two cylinders, each providing half the forces required will be considered as well, as this can result in a more stable lift of the beam. This, however, could lead to other problems; one cylinder could stop, jam, or there could simply be a small delay due to control system or hydraulic issues. A brief discussion on the subject made everyone think one cylinder might be the best option.

4.3.1. Solutions

The mechanism for the beam mounted to the V-stays legs will have to be very rigid, with little to no free play, and very little friction. To begin with, square bearings that “surrounded” the vertical beams were considered. The group also had something similar in mind, which were rods with surrounding cylindrical bearings sliding up and down on them. Both solutions mentioned would work in a way that the vertical beams/rods were standing by themselves, in other words be a part of the rigs main construction. Positive factors here would be a mechanism almost guaranteed to handle an equal amount of forces in all directions, and possibly a reduction in movable parts and brackets. As for the negative factors, none of the products found were available in sizes anywhere near what would be required for the rig to be stiff enough. The most feasible solution seems to be a robust kind of dovetail slide mounted to traditional construction beams, as they seem to have very little friction and free play, and at the same time can put up with a great amount of forces. Since both longitudinal and transversal forces will be in positive and negative directions, a “double slide” solution (as pictured above) is an alternative, although the more robust slides available seems to handle up to 1000kN statically, dynamically, and if not all, then most directions. In other words, it might be a both time -and money saving option to skip the double slides and just stick with one slide on each side. Torques acting on the slides will have to be considered, and the slides in mind seem to satisfy all torques from what data sheets can tell. There are also brakes/clamping mechanisms to be bought for the different dovetail slides, a big necessity when the horizontal beam has to stand still in one position. The biggest challenge seems to be whether or not these types of slides can be mounted perfectly aligned with each other, but the group has spoken to the two suppliers that are most likely to provide us with these mechanisms, and they seem very positive regarding the way they will be mounted.

The mechanism that allows the bottom of the V-stay to slide freely in the horizontal plane, could also be made using dovetail slides or similar. Obviously, the slides will have to be a lot smaller than the ones used for the vertical moving beam. This is mainly to physically fit the rig, which will be designed as compact as possible, and because of friction issues. One possible solution for this mechanism is shown below. Rod and cylindrical bearing type of slides could be considered as well. Another option is to simply mount the bottom of the V-stay to a plate which is able to roll in all directions on a set of wheels (like a shopping cart). The sketch below shows the option first mentioned:



To compensate for the small rotational movement of the V-stay during transversal testing, spherical bearings in both ends of the pushing cylinder is an option. The positive thing would be a functional and inexpensive mechanism, which guarantees no side forces or bending moments on the cylinder. The negative side is that this will provide two unwanted sources of free play. Again, a dovetail slide or similar could be used. This will also result in two sources of free play, but enables the cylinder to be mounted solid to the rig. Figure 3 shows two alternatives for compensation for rotational movement during transversal testing

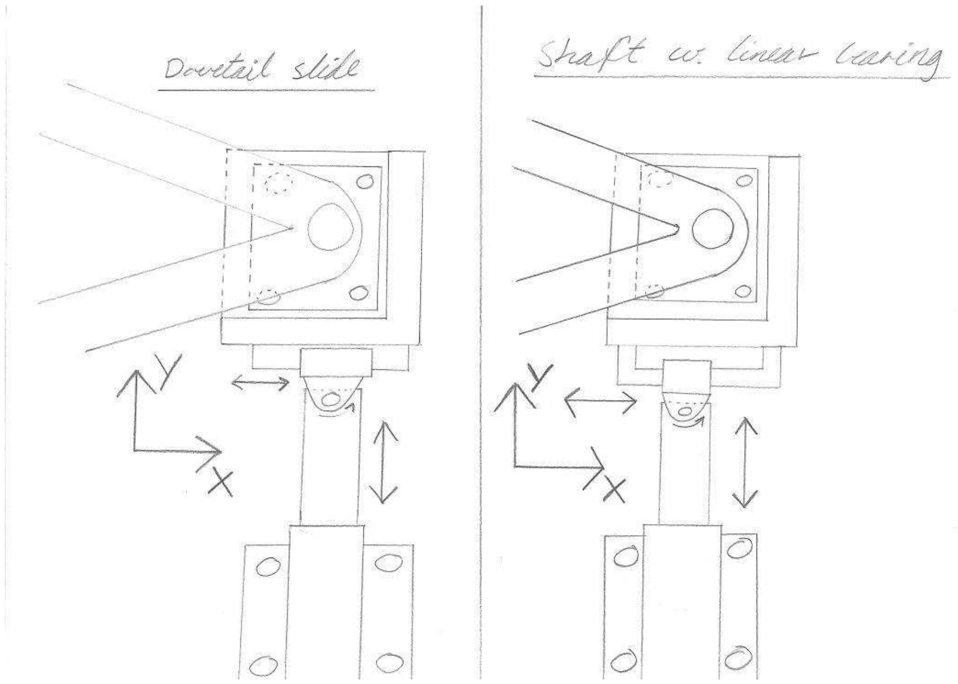


Figure 7: Alternatives for compensation for rotational movement

4.4.Concept 2: Two cylinders

The idea is to use two cylinders, one cylinder for vertical force, and one cylinder for transversal and longitudinal force by rotation around the centre of the main bracket. Force in transversal and longitudinal direction is directed at the bottom of the V-stay. The cylinder must be capable of movement in the V-stay link when there is force applied in the transversal direction, dovetail connector, or spherical bearing at both ends. The V-stay must be able to move, the bottom bracket (main bracket) is attached to a multi-axis rail system that ensures that the V-stay has the opportunity for movement in X- and Y-direction (rotating platform). (See figure 2)
Here we have two alternatives for the rotation:

4.4.1. Concept 2a: Rotating bearings implemented in the bracket.

Rotating bearings implemented in the bracket. The bracket rotates 90 degrees about its center. The operator disconnects the V-stay legs, and the cylinder at the V-stay bottom, then the operator rotates the V-stay and fasten cylinder and V-stay legs (Figures 9 and 10)

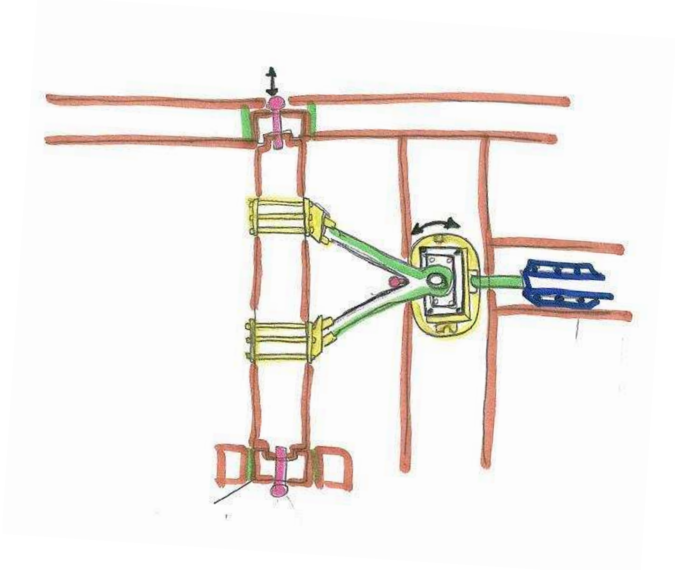


Figure 8

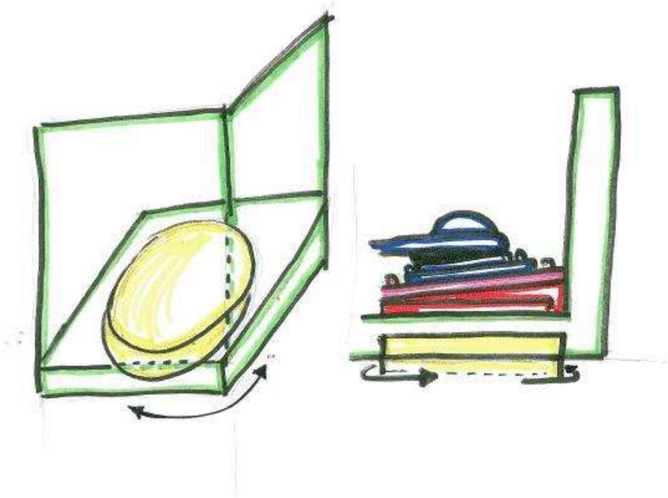


Figure 9

By using this method you don't need to use a multi-axis rail system, since the bracket can be rotated using the same track at the longitudinal and transverse direction (Figure 11).

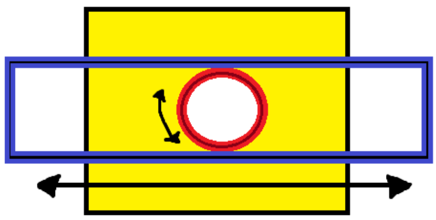


Figure 10

By using this method of rotation of the V-stay causes a challenge with respect to the locking of the rotation. In addition, the operator has to loosen and tighten all fixings when rotating the V-stay.

4.4.2. Concept 2b: A rotating platform

The platform will rotate, where the main bracket is mounted. This is the same concept as mentioned earlier (Figure 12) .

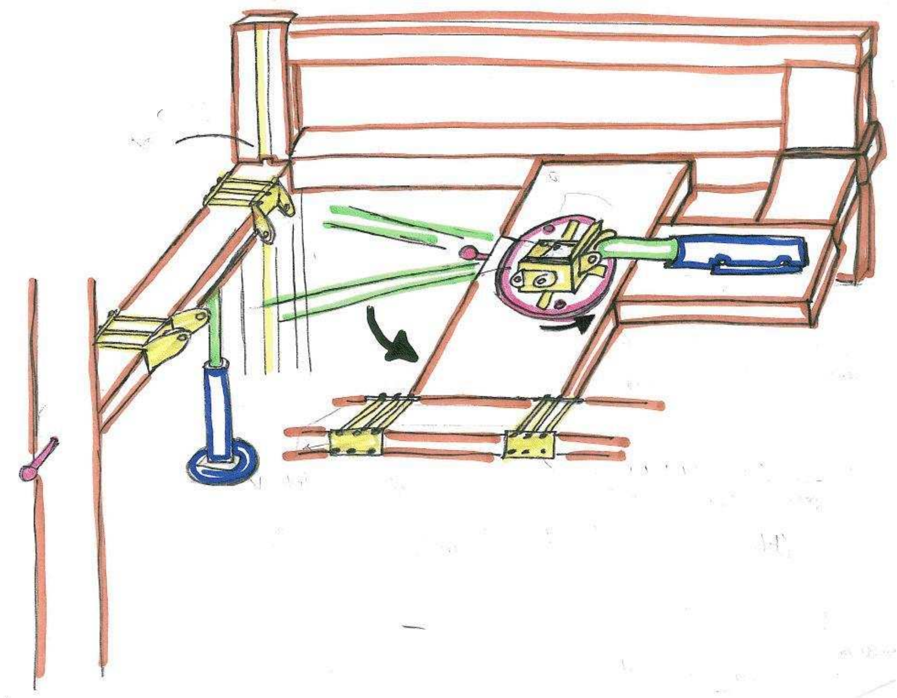


Figure 11

By loosen the cylinder link at the V-stay bottom and fixings by the V-stay legs, and then rotate about the centre of the V-stay bracket. By rotating the platform, one rotates the main bracket and the rail system, these results in that one must have a multi-axis system.

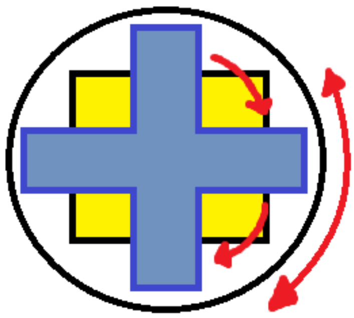


Figure 12

The positive with this alternative is that one has the opportunity to lock the platform either by pins or bolts. Cons here is manual labour, one have to loosen the fixings and lock the platform.

Vertical force will be applied to the V-stay legs. The beam where the V-stay is attached will have force applied in the vertical direction. By using linear constraints on both sides, it moves straight. The beam must be locked when the V-stay is placed horizontally in the rig. The locking mechanism must be robust in order to achieve the desired stiffness, locking can be done with hydraulic locking, bolts / pins. The vertical cylinder is placed at ground level. Brackets at the bar legs can be replaced depending on the V-stay length, the brackets can be moved sideways depending on the V-stay width. Alternative suppliers and product for this mechanism are mentions in the description in concept 1.

An angled bracket is placed in the bottom bracket (main bracket), the angled bracket ensures that the V-stay is horizontal. On the angled bracket is a removable bracket that should be easy to replace in connection with change of the V-stay (Figure 14).

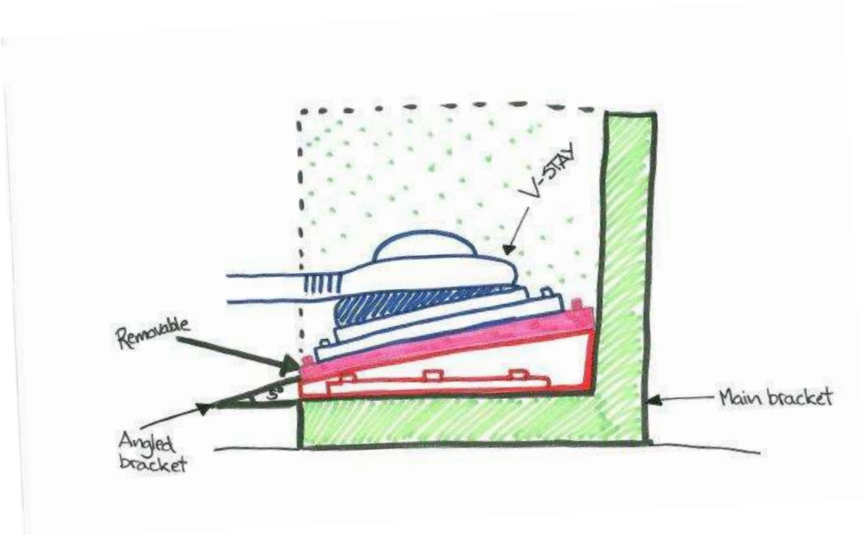


Figure 13

The V-stay is placed high up due to the stroke of the vertical cylinder and convenient working position.

Linear guides for the vertical cylinder must be completely fixed and rigid when the transverse and longitudinal force application is performed, the lock function; hydraulic lock, etc.

4.5.Previous idea 1: Three cylinders and manual work

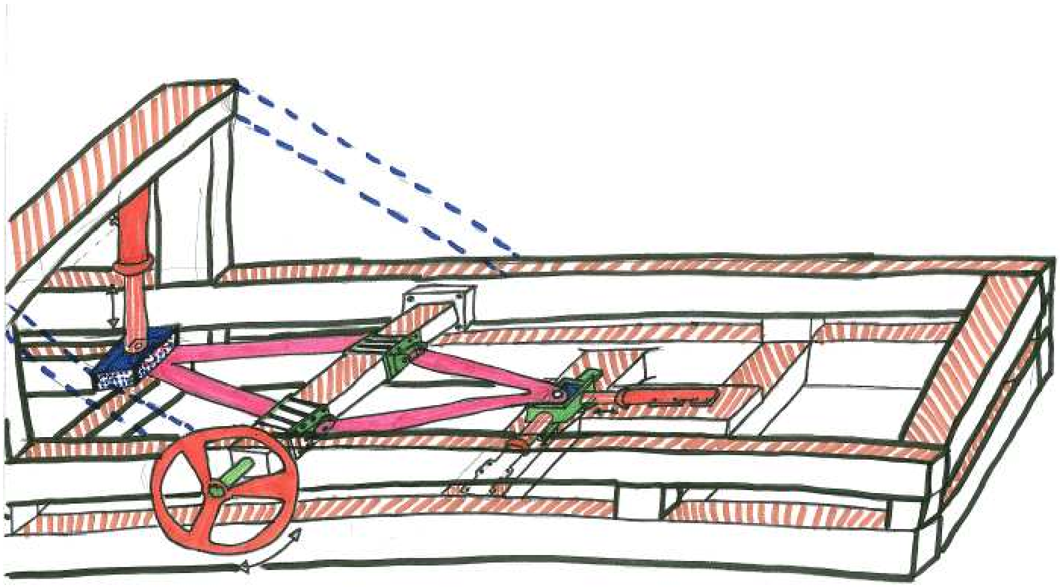


Figure 14

The V-stay is attached (the bottom of the V-stay) to a bracket which is mounted on top of two crossing rails. The rails have got "fences" that slides up and down depending on which direction the force is applied. On top of this bracket is another bracket that is exchangeable, making it possible to easily switch between various V-stays with different attachment points. The V-stay is here subjected to forces in transversal and longitudinal direction.

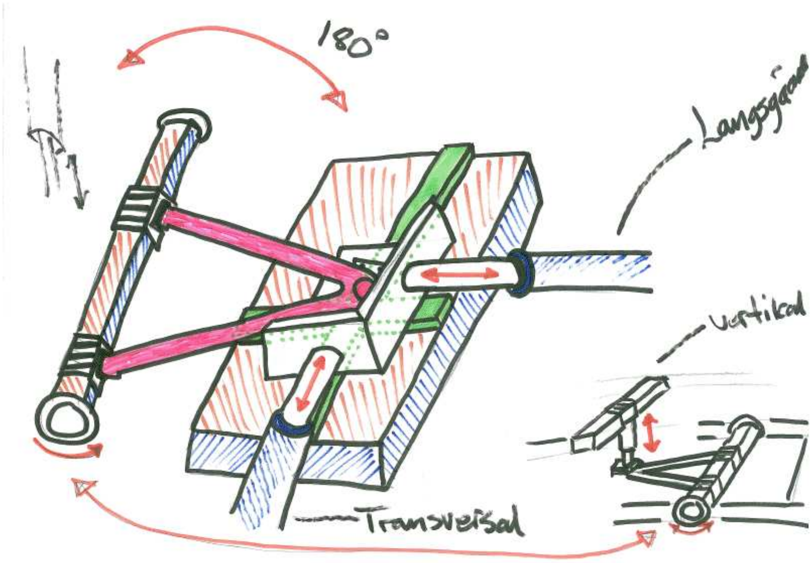


Figure 15

When the V-stay is going to be tested by applying force vertically, the bottom of the V-stay is detached, and by using a rotating beam one is able to rotate the V-stay 180 degrees (manually or by using an electro motor). The bottom of the V-stay will be rotated 180 degrees and ending up having the bottom of the bracket up against the vertical cylinder. An operator will then be able to attach the V-stay to the vertical cylinder and start testing.

The attachment points of the V-stay legs needs to be movable, by making this possible and easy to do we have thought of using fastenings with a set screw which makes it easy to loosen and move. When it comes to making the test rig able to cope with V-stays with various lengths we have thought of using fastenings with brackets that vary in length. Other fastenings will be flanges with screws.

Pros

- Smart linear movement mechanism

Cons

- Manual work
- Time-consuming

4.6.Previous idea 2: Three cylinders

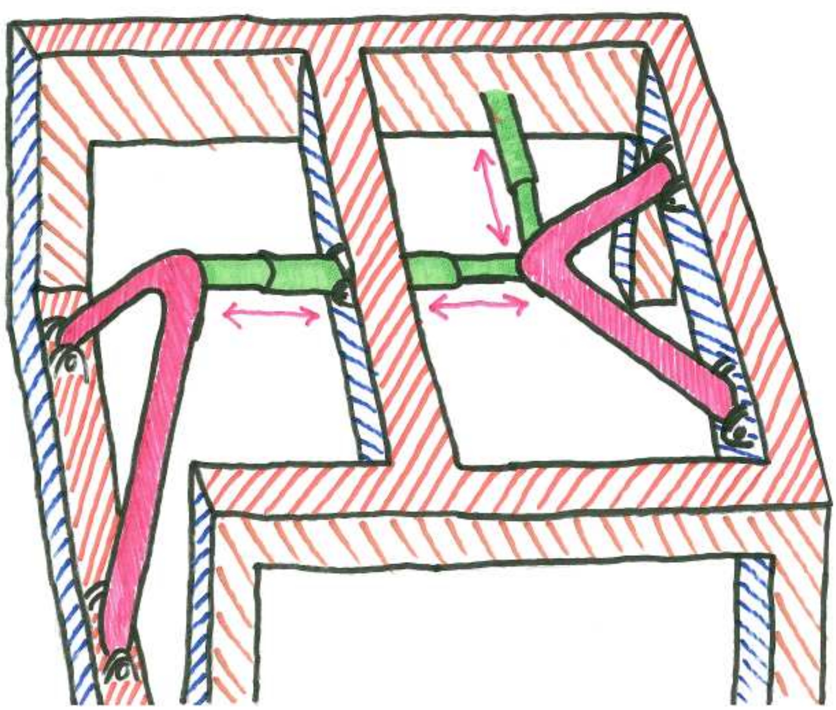


Figure 16

The main idea behind this sketch is to mount the V-stay in separate mountings for the vertical tests. The origin of this idea was a brainstorming session where we had some troubles finding out how to be able to both mount and test the V-stay, if all cylinders were to be mounted with the V-stay in one position. A solution for brackets to be used is in development, and it is going to be far less complex than if the V-stay were to be mounted in one place and one position.

Pros

- Less mounting brackets
- Seemed like a feasible solution at the time

Cons

- No space-saving
- Time-consuming
- Manually work
- Not compact enough

4.7.Previous idea 3

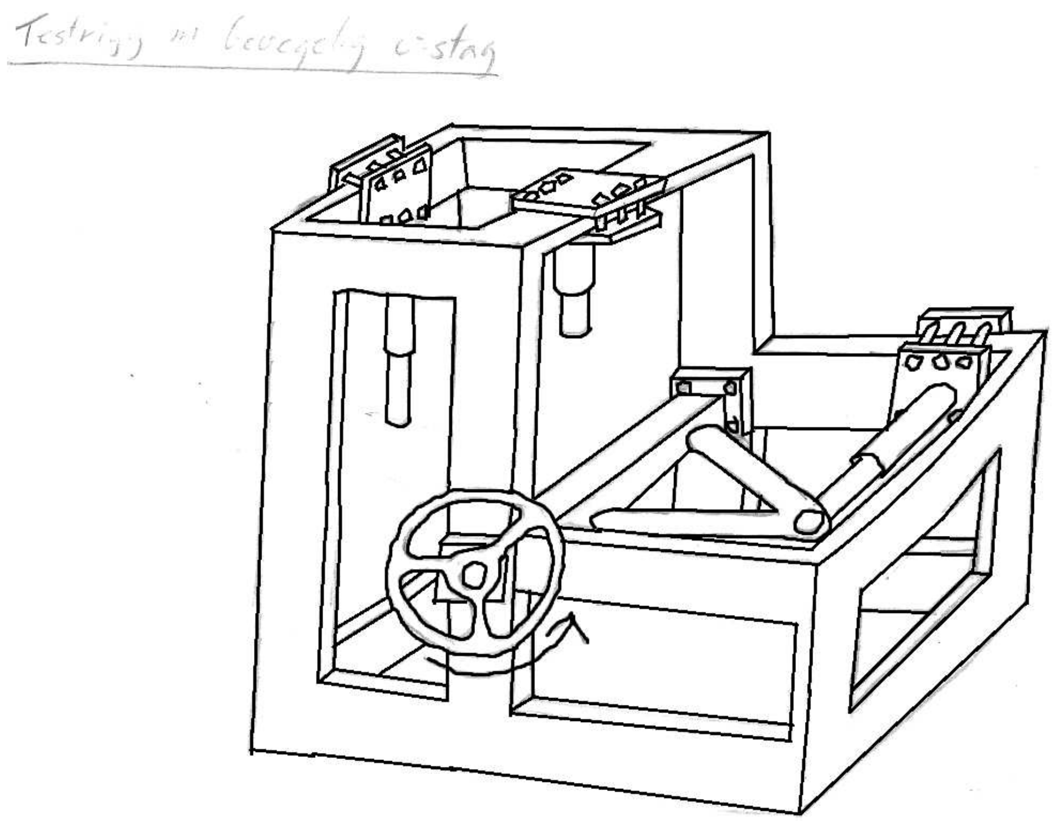


Figure 17

The idea behind this sketch is to eliminate problems that might occur if all cylinders were set to push on the V-stay with the V-stay in one position. The legs of the V-stay are mounted in a very robust beam, which will turn around its own longitudinal axis with the help of a steering wheel, an electric motor or whichever option seems more feasible. There has not been put much work into what brackets and mountings to use, as it will be discussed in another document, though there will be room for adjustment for V-stays with varying lengths and widths.

Comment: To get full use of the beams moment of inertia, several of the beams in the sketch will have to be twisted 90 degrees.

Pros

- Seemed like a feasible solution at the time

Cons

- Manual work
- Not compact

4.8.Criteria that forms the basis of the concept matrix

Rigmor, which is the old rig that is still in use today, is determined as the default design. Every concept and ideas must have criteria that assessed against this default design.

Dynamic/static force 200 kN (transversal)

The rig must be able to produce dynamic and static force of 200 kN in transversal direction.

Dynamic/static force 100 kN (longitudinal)

The rig must be able to produce dynamic and static force of 100 kN in longitudinal direction.

Dynamic/static force 5 kN (vertical)

The rig must be able to produce dynamic and static force of 5 kN in vertical direction.

Changeable attachment points

The attachment points of the rig must be changeable. The test rig must cope with V-stays that are ±10% in size.

Stiff enough

The test rig must be stiff enough; this means that maximum stress must not exceed 1/3 of yield strength of the materials used in the rig. And also that different brackets and mechanisms of the various concepts must withstand the stress produced in the rig.

Number of cylinders

The different concepts have either 2 cylinders or 3 cylinders. Criteria of assessment are the cost saved by using fewer cylinders.

V-stay horizontal in rig

The V-stay must be horizontal in the rig. This means that the bracket at the bottom of the v-rod must have a 5° angle.

Compact rig

The assessment of whether the rig is compact is determined here. This is based on the size and shape of the rig.

Flexible and easy to use

This criterion is rated according to the flexibility and ease of use. This includes also application of the rig and also assessed against the amount of manual work the operator must do.

Low cost

Here the approximate cost of the rig is evaluated in relation to other various solutions.

	Rigmor	Concept 1	Concept 2 A	Concept 2 B	Previous idea 1	Previous idea 2	Previous idea 3
Dynamic/static force 200 kN, transversal	Default Design	S	S	S	s	s	s
Dynamic/static force 100 kN, longitudinal		S	S	S	s	s	s
Dynamic/static force 5 kN, vertical		+++	+++	+++	++	++	++
Changeable attachment points		++	++	++	++	++	++
Stiff enough		S	--	-	S	S	S
Number of cylinders		+	++	++	+	+	+
V-stay horizontal in rig		+	+	+	+	-	-
Compact rig		+++	++	++	+	+	+
Flexible		+++	++	++	-	+	-
Low cost		-	--	-	-	+	-
Freeplay		+	---	--	--	-	--
Manual work		++	-	--	-	+	--
Functional tests		+	+	+	+	+	+
Totals +	0	17	13	13	8	9	7
Totals -	0	1	8	6	2	2	7

5. Electrical part

To control and retrieve data from the test rig the test rig need a control system. The project has looked at different suppliers of such systems. There are respectively

- Vishay Nobel
- MOOG
- MTS Systems
- National Instruments

As mentioned earlier the group has in collaboration with KA chosen concept 1 as the most relevant solution. With this decided the electrical part of the group can go on and choose a specific and tailored solution that fit the rig.

Factors that must be taken into account include price, complexity, compatibility with LabVIEW and an easy-to-use user-interface.

In the flowchart below is general overview over the control system which will be needed to operate the test rig. The various suppliers offer control systems which performs this task.

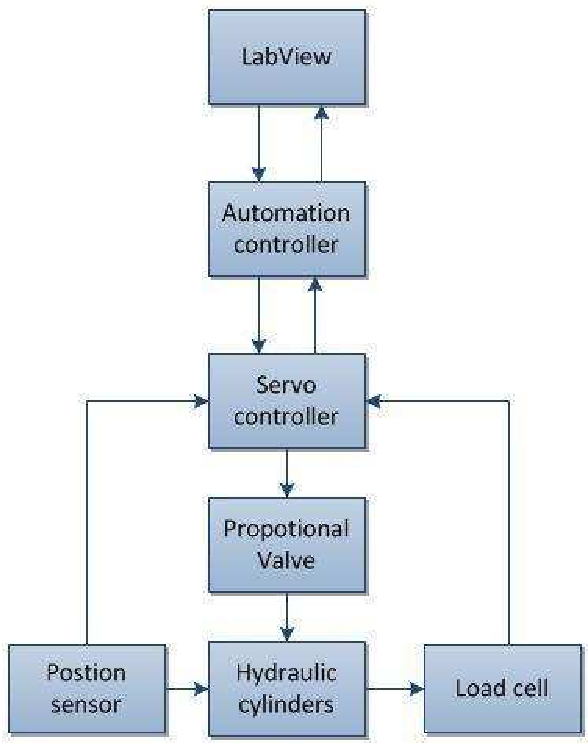


Figure 18: General overview

5.1.Control system with or without an internal processor?

One of the first choices that have to be made is whether or not the control system is to have an internal processor or to be run directly from an external PC. The difference between these two is that a control system without an internal processor, the test procedure, parameters and values are controlled from an external computer. If the control system contains an internal processor, the test procedure will be run from this and the test will not be dependent on the PC’s capabilities. Since the rig is to be used in durability test the most ideal choice is to have a control system with an internal processor. This is because the durability test can go on for months at a time. If the rig was to be controlled by a control system without an internal processor and the external computer crashed two months into a durability test, this would mean a great loss for Kongsberg Automotive in form of both time and money. This is a problem that will be reduced by using a control system with an internal processor. In addition to this, there will be a major flow of communication between the external computer and the control system, which again results in limitations in manner of how fast the system can operate.

The solutions the project has looked at, and that is mentioned below, is all stand-alone solutions that have regards to this issue.

5.2.Suppliers and Control Systems

The supplier's offers control systems with various specifications and price. In the end of this chapter we will present a matrix which presents the different component properties and suppliers against each other. We will start with a brief presentation of the various control systems.

Vishay- MicroPos4

MicroPOS is a regulator which is able to control up to two separate servo channels (hydraulic cylinders). MicroPOS are delivered by Vishay Nobel. This is the control system Kongsberg Automotive use today. MicroPos 4 is a stand-alone solution which means that it have an integrated processor. This control system will be more thoroughly explained in a section below.

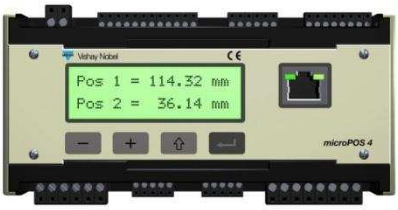


Figure 19: MicroPos4

National Instruments-CompactRIO

CompactRio is a programmable automation controller(PAC) from National Instruments. cRio is a unit that translates data between LabVIEW and MicroPOS. Besides this the cRIO also contains the measurement parameters and values for the test.
The CompactRIO is also a part of the solution Kongsberg Automotive uses today.

Figure 20: National Instrument CompactRIO

Moog – Portable test controller

Figure 21: Standalone Portable test controller

MOOG is a company which has specialized in developing test systems for the automotive industry. The current testing system that the project has considered is named Portable test controller. This is a four-channelled stand-alone controller. It has integrated oscilloscope display and data storage capability on a local hard disk.
It is also fully compatible with LabVIEW without the need of additional software. This is an advantage when it comes to compatibility with the existing solutions at Kongsberg Automotive. Another advantage with the MOOG-solution is that it comes with a variety of hardware options which makes it easy to tailor to specific needs.
Moog are located in Ski, Norway. Maintenance on Moog products are done through PMC.

MOOG have on a previous occasion given Kongsberg Automotive a proposed solutions for a control system. This offer was tailored to Kongsberg Automotive, and the project has largely taken account of this offer.

MTS – Flex Test SE and Flex Test 40

Figure 22: stand alone Flex test SE

MTS is a company which delivers technical solutions, hardware and software, to research, engineering and manufacturers world-wide. This includes versatile and precise solutions for test platforms.
The controller from MTS are named Flex test. This is a standalone controller with integrated oscilloscope. At the start of the evaluation process the project considered a single channel controller, called Flex Test SE. This was based on a proposed solution given to Kongsberg Automotive at a previous occasion. After contacting MTS again the project was introduced to a four-channel controller, called Flex Test 40. This controller was more suitable for the rig and was taken into consideration.
Flex Test 40 is stand-alone solution that are developed with material testing in mind. This controller is also compatible with LabVIEW through with additional software. MTS has also developed its own Software for controlling and setting up tests and data acquisition.
Specific data about flex Test 40 is to find in the comparison matrix further below.

5.3.Solution of today

Today KA primarily uses equipment from Vishay Nobel and National Instruments (NI). This means that KA is familiar with these systems and in addition also gained good contact with the suppliers.
To get a better understanding of this, it would be appropriate to give a brief explanation of the different parts in the system used today.

At the top of the flowchart below there is a box named LabVIEW. LabVIEW is graphical programming software that enables you to design your own control, test and measurement systems. With LabVIEW you design both the flowchart of the system and a control panel for running the tests. LabVIEW presents the data graphically. One advantage with LabVIEW is that it is compatible with a wide range of hardware devices. LabVIEW is a product of National Instruments (NI).

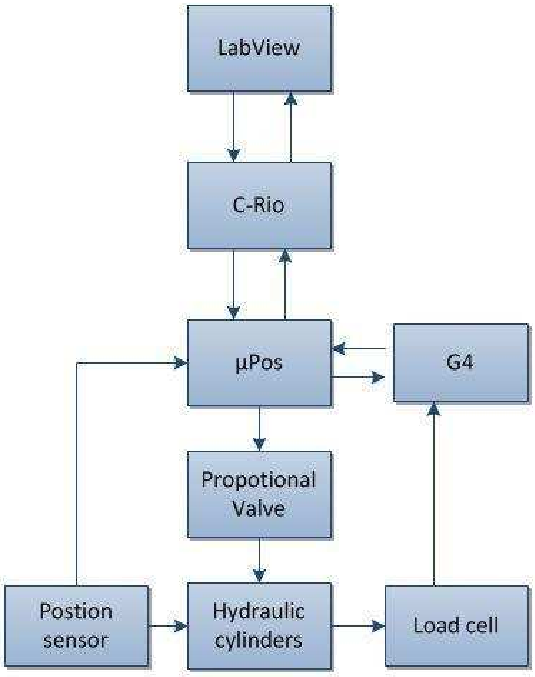


Figure 23: Flowchart with the solution of today

The box under LabVIEW is CompactRio. cRIO is also a product from National instruments. This is a programmable automation controller. cRIO communicates with LabVIEW and contains values and parameters for the test performed.

Below cRio is a box named MicroPOS. The MicroPOS gives a control signal to the proportional valve which again controls the cylinder. To obtain an accurate regulation value, MicroPOS receives measurement values from the G4 unit and the position sensors

The box to the left of MicroPOS is G4. G4 is amplifies and displays the signal from the load cell.

5.4.Number of cylinders in the vertical direction

A question that has to be taken into consideration is whether or not there should be used one or two cylinders in the vertical direction.
It is important that the beam which the V-stay legs are attached to remains perfectly straight at all times. This is to give each side of the v-stay an equal strain. This is necessary to obtain valid test data and resultant forces.

To obtain this, there are some alternatives. One is to use two cylinders to distribute weight and forces. Another solution is to use one cylinder and make sure that the horizontal beam on top is dimensioned in such a way that it does not bend by its own weight or forces applied.
The most desirable option is to use a one-cylinder solution. This is because of the challenge that comes with regulating two cylinders which has to go completely in parallel and simultaneously.
This will require great accuracy of the system as well as further adjustments of the control system.

5.5.Various Vishay-solutions without G4 unit

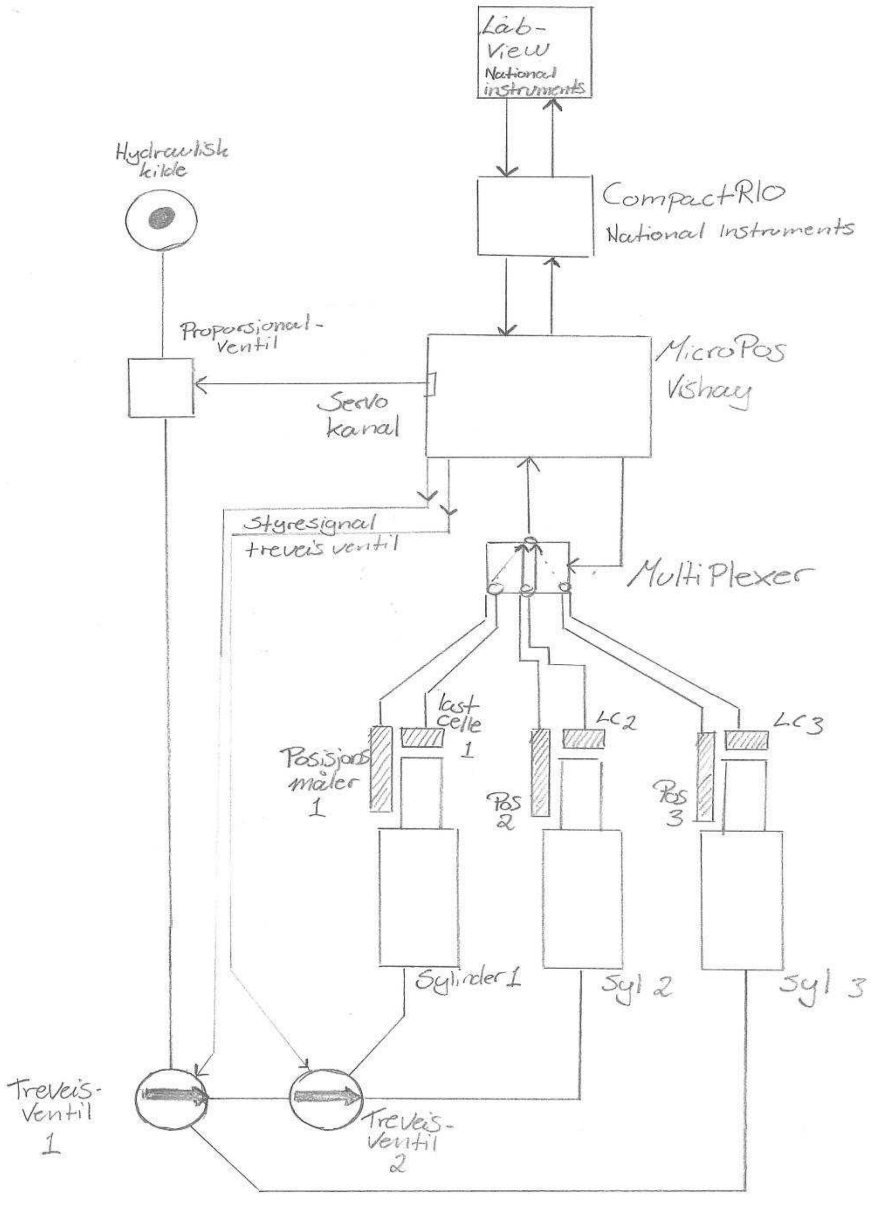
With the current solution, the information from the load cell has to go through the G4 unit. This creates a delay in the information flow which again affects the total speed of the system.

A possible solution to this is to remove the G4 and instead feed the signal directly to the MicroPOS. This will give a quicker processing of information and increase the total speed of the system.
This however requires some updates of the MicroPOS. After feedback from Vishay, this is fully possible.
Since Kongsberg Automotive already have a Vishay control system in existing rigs, the project have looked at various solutions that includes the Vishay control system. We will describe these solutions as follows.

To save costs the group has evaluated a solution where only one microPOS-unit is used. This is possible because the rig is meant to only use one cylinder at a time.

In this solution (See figure below) three-way valves is used to direct the hydraulic flow and a multiplexer is used to direct the signals from the sensors to the microPOS-unit. This raises some challenges in form of possibilities of electrical noise on the measurement signals, which is a very serious issue regarding the accuracy of the measurement signal and the credibility of the test in general.

Another but more expensive solution is to use three updated microPOS-units. One for each cylinder. This will make eliminates the complexity with hydraulic hoses, valve control and directing electric signals with the trade-off of cost effectiveness.



Lab-View National instruments
CompactRIO National Instruments
Hydraulisk kilde
Proporsjonal-ventil
MicroPos Vishay
Servo kanal
Styresignal treveis ventil
MultiPlexer
last celle 1
LC2
LC3
Posisjons måler 1
Pos 2
Pos 3
Sylinder 1
Syl 2
Syl 3
Treveis-Ventil 1
Treveis-Ventil 2

5.6.Price estimate

This price estimate shows overview of price and systems from different suppliers.

	Price pr piece NOK	no#	Total price NOK
Vishay with 3 micorpos with 10Hz			
Upgrade microPos to 10Hz*	180 000	1	180000
Micropos	37 000	2	74000
CompactRIO	50 000	1	50000
SUM			**304000**
Vishay with 3 micorpos			
Micropos	37 000	2	74000
CompactRIO	50 000	1	50000
SUM			**124000**
MTS with LabVIEW			
Test Flex 40**	363 000	1	363000
CompactRIO	50 000	1	50000
Additional program	xx	1	xx
SUM			**413000**
MTS with Test Suit			
Test Flex 40	363 000	1	363000
Test Suit	0	0	0
SUM			**363000**
MOOG			
Portabel test controller	160 000	1	160 000
CompactRIO	50 000	1	50000
SUM			**210 000**

*Upgraded to 10 Hz or more (1 micropos)
*Exchange rate EURO (09.03.2011): 7,74.

5.7.Matrix

These control systems all have their pros and cons. To make it easier to compare these, we have set up a matrix. This consider price against functionality.

	Vishay	MTS	MOOG
Frequency	10Hz	0,001-600 Hz	0,01-500Hz
Controller update freq	200Hz	4KHz	2,5KHz
LabVIEW compatible	Yes	Buy programming library	Yes
Price pr controller	37 000 NOK	363 000 NOK	160 000 NOK
Total system price	304 000 NOK	413000 NOK	160 000 NOK
# Digital Input	5	2	4
# Digital Outout	5	?	4
# Analog Input	-	Yes(Option)	1
# Analog Output	2	Yes(Option)	3
# Servo Kanaler	2	4	4
Inkl CPU	Yes	Yes	Yes
Feedback controll	Force, position	position, force, acceleration	Force, position

5.8.User friendly interface

As mentioned earlier, an important factor to Kongsberg Automotive is that the control system must have a user friendly interface. This is because parameters and values are to be changed at a regular basis. If these settings are hidden well within the menus of the control system it will be both time consuming and frustrating for the operator to perform tests. One way to solve this is to choose a control system that is compatible with LabVIEW. Another solution is to choose a control system with an easy-to-use software and provide sufficient training on this software. Both Vishay and Moog are compatible with LabVIEW. MTS is compatible with LabVIEW if additional software is provided. MTS has developed their own software which they claim is very easy to use.

5.9.Choice of Analysis tool

After meeting with Kongsberg Automotive with the conclusion of recommending the solution from MOOG, the project decided to choose DIAdem as the analytical tool. The moog solution, which is compatible with LabVIEW, is also a product from National Instrument. To keep the number of suppliers down, LabVIEW was chosen in favour of

Glyphworks.

We are to integrate this software which are to analyse and store the data from the various tests performed (This is currently not in the flowchart). This software is also intended to make the data and results easy to find and to compare with earlier tests.

5.10. Force supply

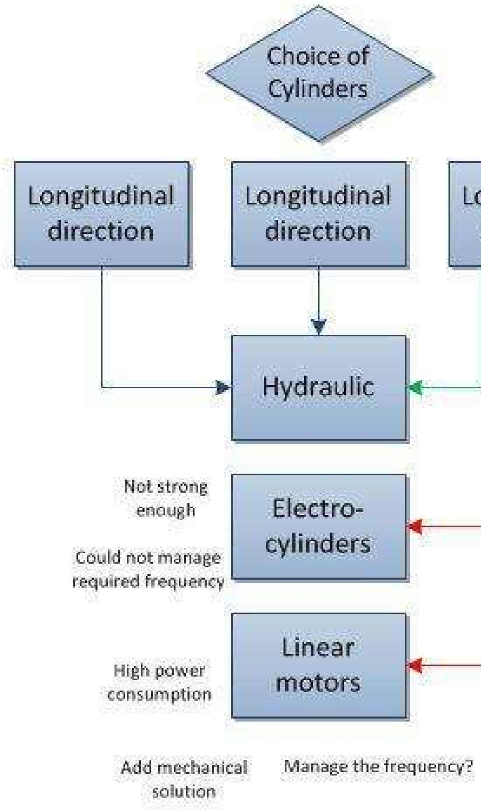


Figure 24: Choice of cylinders

When it comes to applying force in longitudinal and transversal direction, the forces which are to be applied where so great that hydraulic is the only practical solution.

In the vertical direction, there are much smaller forces applied. This gave the project the opportunity to consider other power sources. Alternatives as linear motors and electrical cylinders were considered. In relation to the hydraulic, these solutions gave the project a few extra challenges. Since the rig was to hold a static load for 72 consecutive hours, this would mean that an electric motor would have significant power consumption. This means that the project has to come up with additional mechanical solutions which lock the V-stay in place without use of an electric engine.
In addition there were concerns about these linear engines and if they could manage the frequencies wanted.

Another concern was the price in relations to a hydraulic solution. The electric cylinder is a component which was discovered rather late in the research process. This was a principle which certainly could be relevant for the rig. Unfortunately the project didn't find any electric cylinders that where strong enough or could manage the operating frequencies required.
Since the rig was already to be equipped with two-three cylinders, the project came to an agreement that the simplest and most time-efficient would be to use hydraulic cylinders in all directions where forces were to be applied.

5.11. Sensors to bushings

The bushings need to be measured for temperature. We have considered the option of using infrared radiation. This value will be included in the control system. Later in the project, during price estimate, it will be more details regarding this sensor. There is desirable that the product is compatible with LabVIEW.
The group has been in contact with two suppliers for IR cameras.

FLIR

Flir delivers infrared and temperature measurement. FLIR A300 / A310 og FLIR A315 / A61 are cameras that is connected to the computer during the test and is compatible with LabVIEW. Measurement values will be shown in LabVIEW, and can therefore be used to control the system. Price on this product is not ready. As of today it is waiting for feedback from sales person in FLIR.

Infrared Cameras Inc.

Infrared Camera Inc delivers infrared temperature measurements. This product includes an analysis tool. The request is sent to supplier to determine whether the product is compatible with LabVIEW and functionality that satisfies the projects requirements. As of today it is expected feedback from supplier.

6. Conclusion/Recommendation

Based on research and contact with the various suppliers the group landed on the decision to recommend MOOG as the supplier of the control system. This is based on the fact that it is a simple construction. It also comes out as the cheapest solution. It comes with optional hardware which makes it adaptable to specific configuration. It is also compatible with LabVIEW.

A Vishay solution with one micropos unit will present some technical challenges.
A Vishay solution with a micropos unit for each cylinder will affect the price in a negative manner.

MTS turned out to be a bit expensive. Another disadvantage was the need of additional software to become compatible with LabVIEW.

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Course (code/name) SFHO3200 Hovedoppgave med prosjektstyring
Group members: Elisabeth Espås Jenssen Jørgen Heum Larsen Andreas Fossnær Wold Edward Palm Sandaker Stina Andersen
Internal supervisor: Gunnar Flak
Date: 03.05.2011
We confirm that the submitted assignment is entirely our work.   Elisabeth Espås Jenssen, Jørgen Heum Larsen, Andreas Fossnær Wold, Edward Palm Sandaker og Stina Andersen

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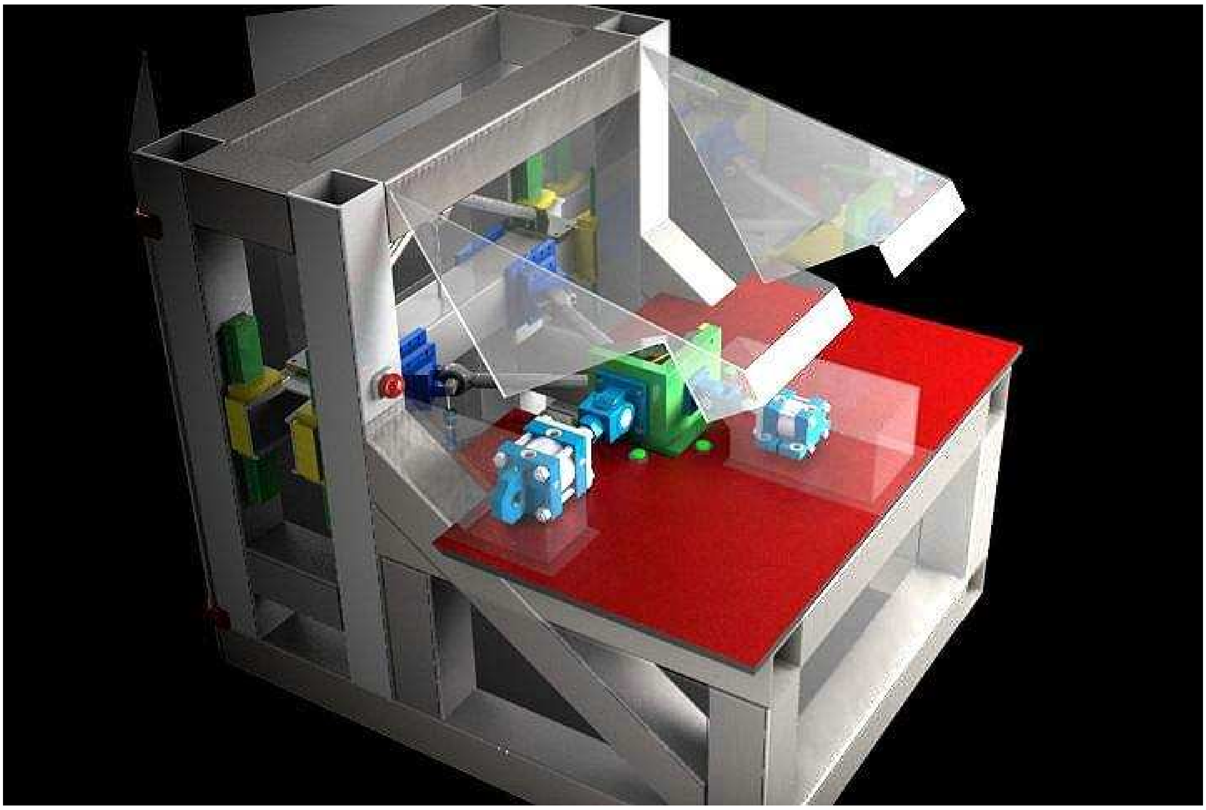


Figure 1: Movement Test Rig

1. The main objective of technical document

The main objective of the technical document is to provide a detailed overview of the projects technical solutions. The document will provide a broad introduction to the functions of the Movement Test Rig, both mechanical solutions including 3D models, and electrical solutions with electrical drawings and control system. The document also includes the equipment, components and materials used with a price estimate. One can also refer to "Document of Concept rev. 1.18" for a more brief description of equipment and components.

2. Abbreviations

KA	- Kongsberg Automotive
SW	- SolidWorks
FEA	- Finite Element Analysis
MTR	- Movement Test Rig

3. Designations

kN	- Kilo Newton
mm	- Milimeter
kN/mm	- Kilo Newton per milimeter
MPa	- Mega Pascal
GPa	- Giga Pascal
N/°	- Newton per degree
bar	- Pressure in bar
Hz	- Hertz
TDM	- Technical Data Management
IO	- Input/Output
SAH	- Test Auxiliary Hardware
SCU	- Smart test Controller Unit
NI	- National Instrument
VDC	- Voltage Direct Current
VAT	- Value added tax

4. Mechanical

Complete collection of 2D drawings of complete test rig with individual parts can be found in appendix 1.

4.1.Frame

4.1.1. Design Development

The frame is mainly made of square beams with dimensions 200 x 200 mm of thickness 10 mm. In addition to four beams with dimensions of 100 x 60 with thickness of 5 mm that form two angles are used to support the table with cylinders in longitudinal and transversal direction. This allows multiple attachment points and better rigidity in the rig. In addition to standard beams there are two supporting plates of thickness 10 mm on both sides. The main purpose of the frame is to make the whole system as stiff as possible, thus making the displacement as small as possible, so the measured values get as correct as possible.

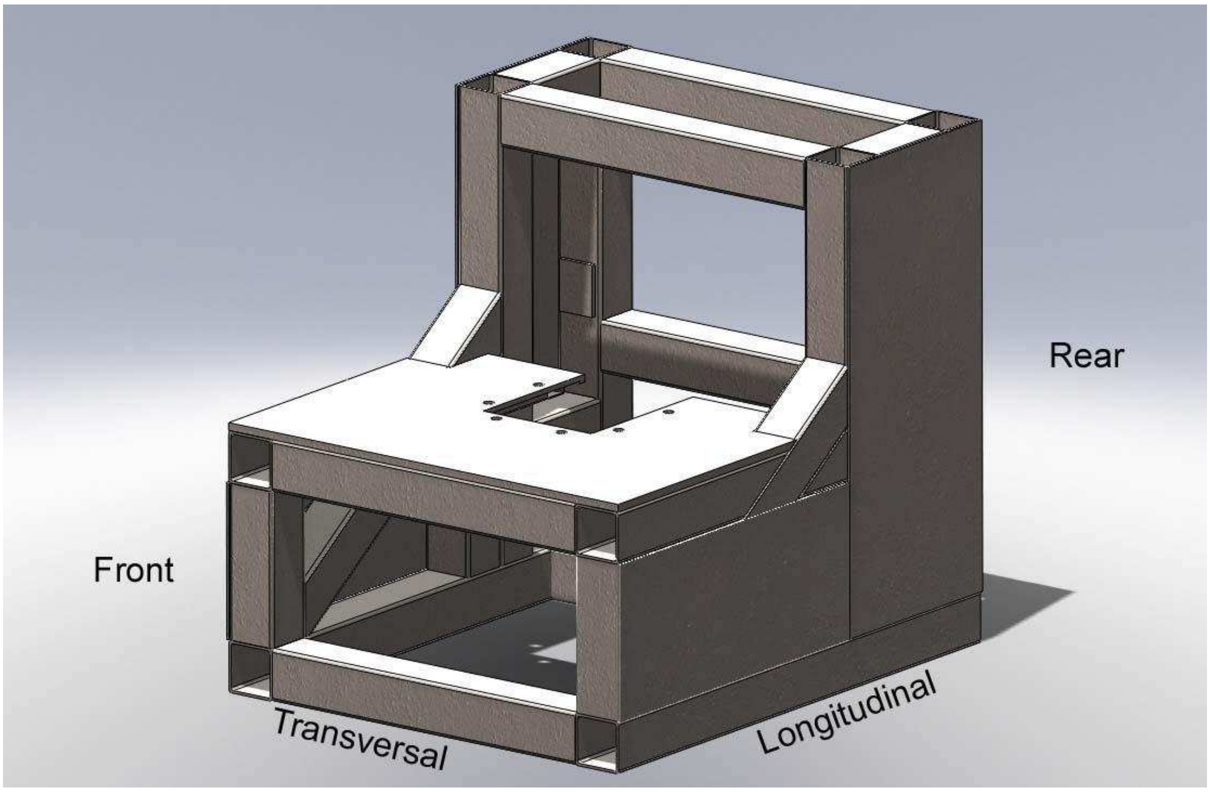


Figure 2: The finale design

The figure shows the final design of the test rig. The outer dimensions of the rig are (width x length x height) 1820 x 2182, 2 x 2000 mm.

Before the final design the project came up with two earlier editions. The first edition is very similar to the sketches in "Document of concept rev. 1.18". Because it turned out that this design was not stiff enough it had to be further developed. This resulted in the second edition. The second edition has some differences compared to the final design. After showing the 3D model of the second edition to client, the client wanted to make the rig shorter than the second edition. On this basis the final design came to life. To clarify where the biggest design differences are, and due to client requirements, the first edition of the rig will be explained in detail without any comparison, while the second edition and the final design will be compared to each other.

4.1.2. First edition

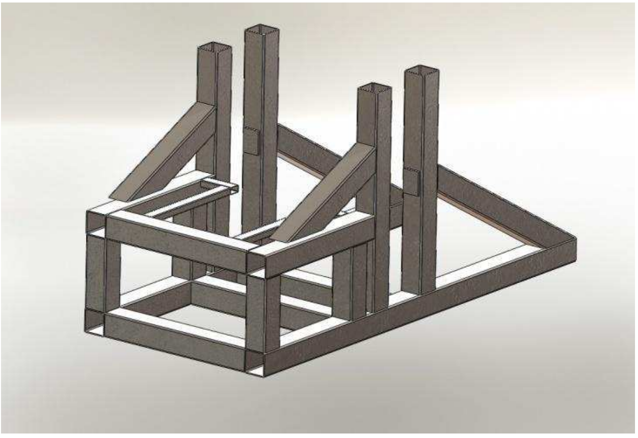


Figure 3: First edition

When developing the concept of the rig, the sketch of the frame was not as complex as the final results. The first draft of the frame was quite similar to the one shown in the figure.

On the basis of requirement from the client the rig will be freestanding. The rig is built up by two main beams in longitudinal direction. To gain more stability and stiffness there are three beams in transversal direction to stabilize and give the rig larger area towards the surface.

To give the operator of the rig the best working height there are four beams on top of the longitudinal beams. These beams are welded to the longitudinal beams, and form an 1800 x 1300 mm rectangle. On top of these beams is a u-shaped beam assembly welded onto the legs. These three beams, including the two angles, give the platform mounting basis. The platform consists of horizontal bracket, longitudinal cylinder and transversal cylinder (see chapter 4.2.1 Horizontal bracket).

The front and rear cross support beams is distributing the forces produced by the longitudinal and transversal hydraulic cylinders, and also gives the rig rigidity.

The four vertical beams are there for mounting of the rail system used in the vertical testing.

Finite Element Analysis of first edition

There are some important issues in the FE Analysis. The project has chosen to use fixed geometry in the analysis. This means that the rig is mounted to the floor. This is not totally correct compared to the real use of the rig. The rig is supposed to be freestanding and not mounted to the floor. Therefore the numbers can differ from the reality. The difference is acceptable for both the project and client.

The force in analyses is put directly on the vertical beams in the analysis of the second edition. When force is put directly on these beams it is in worst case in the rig. In the analysis of the final design the rail system also have been taken in consideration. Since the project has no useable models of the rail system from the supplier there have been made some models similar to the system.

From analysis of the first draft of the rig, it turned out that it had to be rectified. This is with many considerations to displacement of the rig. As mentioned earlier, this rig is first of all a stiffness measuring rig, so the displacement of the rig had to be reduced. Since the platform on top of the rigs frame adds rigidity to the whole construction, it is included in the analysis.

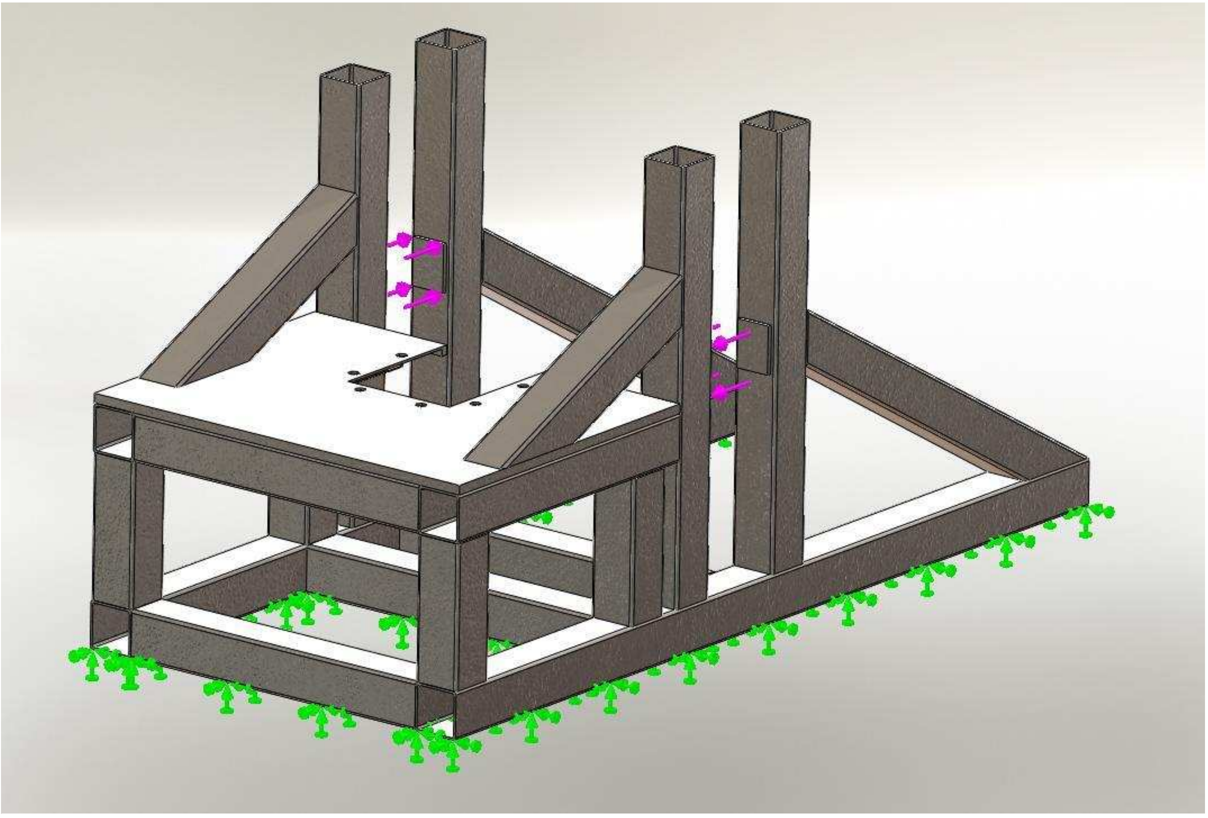


Figure 4: First edition with force and fixtures

To limit the number of test in SolidWorks Simulation it is chosen to test the transversal force, which means that force is applied as shown by pink arrows the figure. The transversal force is 200 kN and will at the same time give the most displacement and stress concentration in the beams. The green arrows are rigid fixtures.

Stress

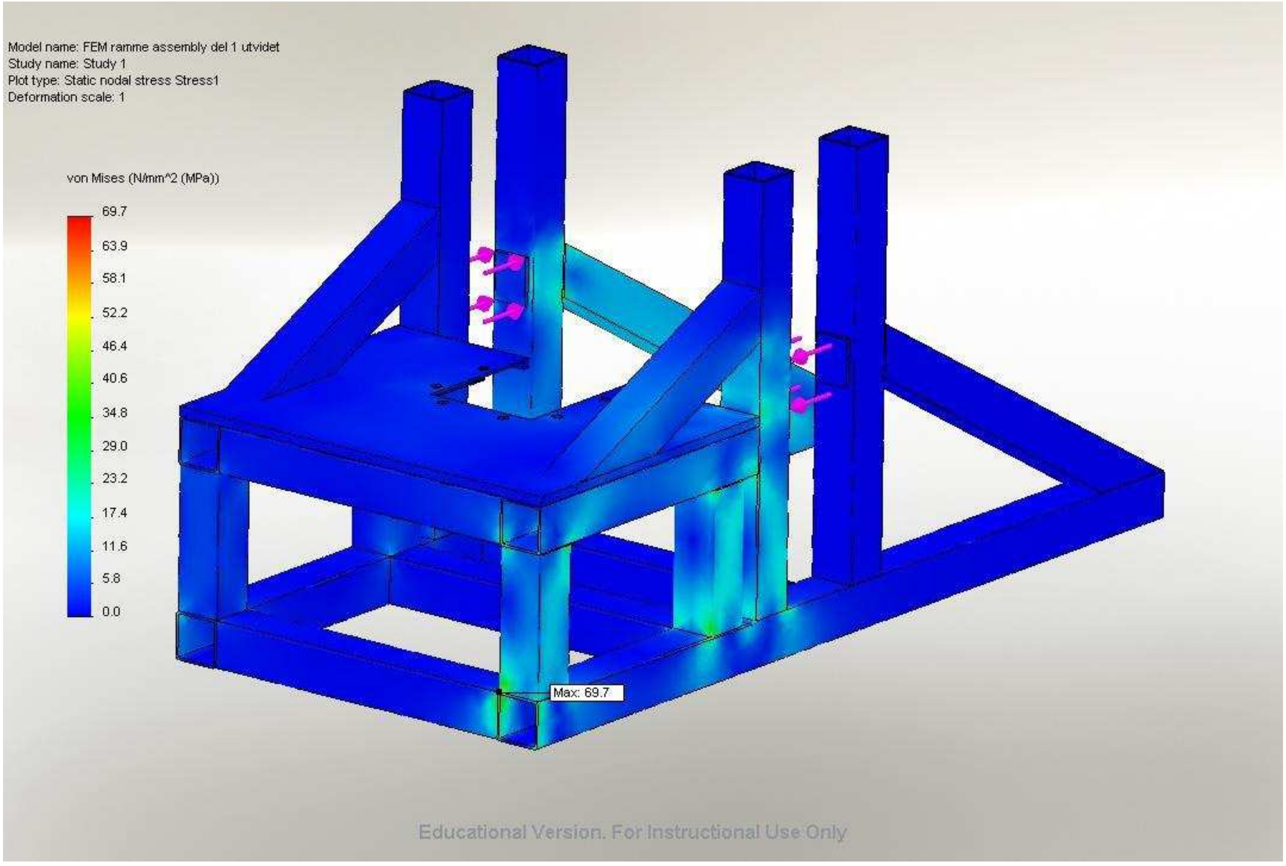


Figure 5: Stress in first edition

The stress analysis shows that stress in the rig is maximum 69, 70 MPa. This satisfies the requirement (ref. PF 1, Requirement specification rev. 1.3). It is also important to analyze how much displacement there is in the rig. The maximum stress concentration is located in the platforms front leg. To decrease this stress the frame needs more stability and more rigidity.

Displacement

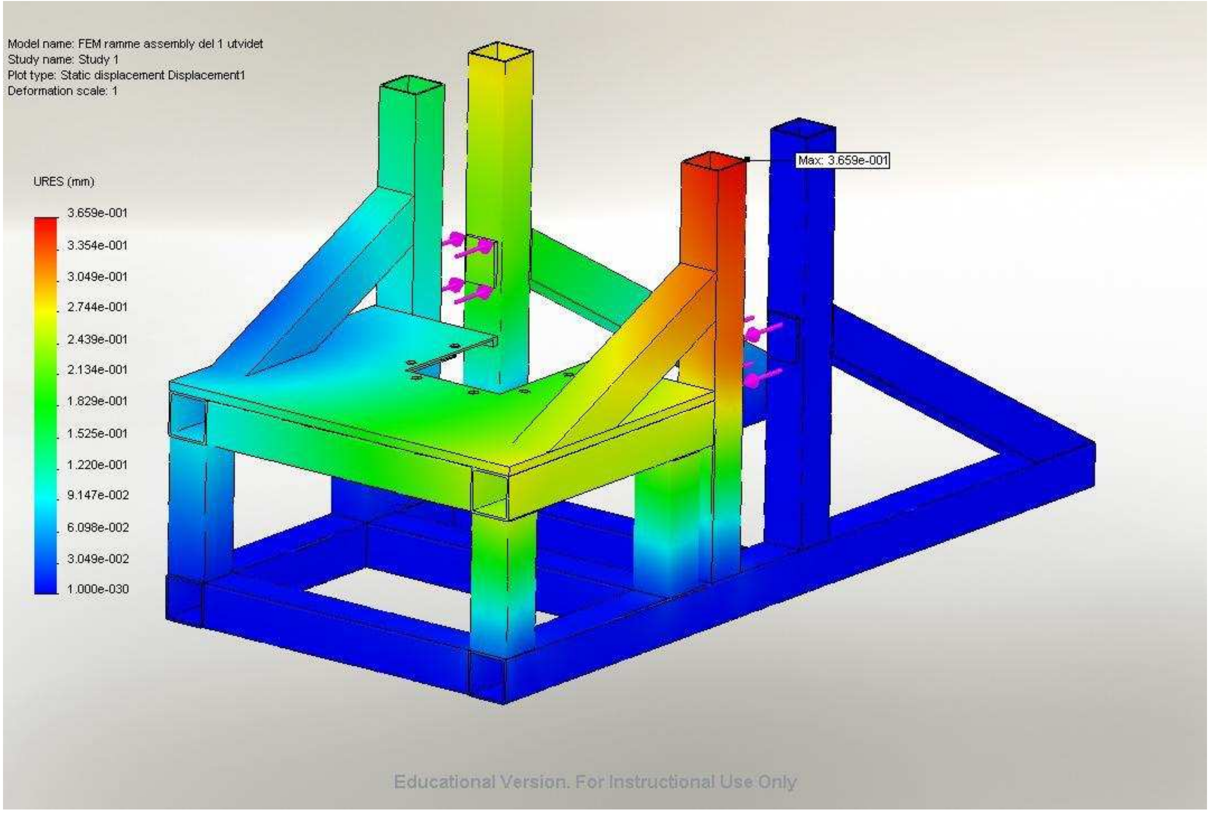


Figure 6: Displacement in first edition

Displacement analysis shows that displacement in the rig is maximum 0, 3659 mm. Even though the maximum displacement occurs in the top of the front vertical beam, it seems that there is almost as much displacement where the force is applied. Although there are no specific requirements on how small the displacement in the frame should be. The project aims to limit the maximum displacement of the frame to less than 0, 1 mm which is “stiff enough to withstand the force applied” (ref. RP 4, Requirement specification rev. 1.3).

4.1.3. Final Design

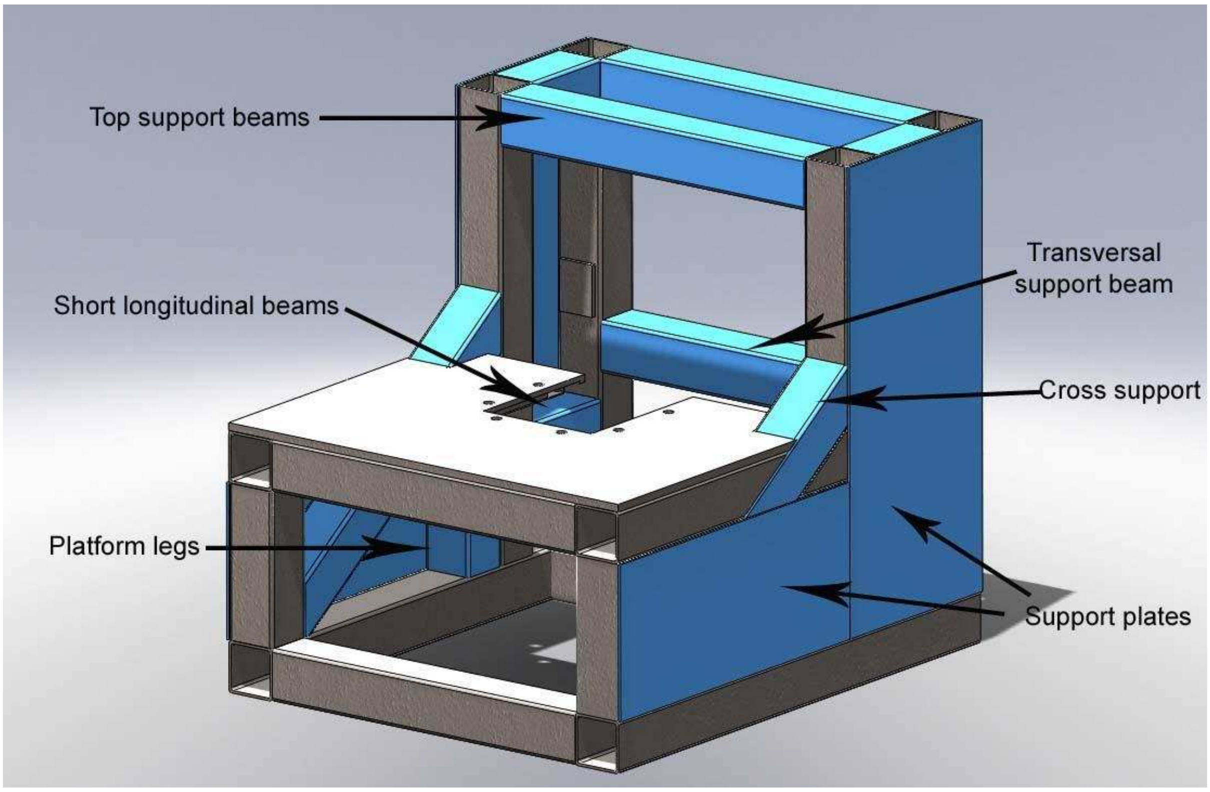


Figure 7: Final design with changes marked in blue

From the first edition of the rig to final result there has been made some changes to the rig. Most of the changes are done to make the rig more rigid. The changes made to the first edition of the rig resulted in a second edition.

Both final design and second edition has their pros and cons. The second edition has its pros in stiffness, but cons in length. The final design has its pros in compact and flexible, but cons in stiffness. This will be proven in the Finite Element Analysis.

Top support beams

The first step in the development of the rig after the analysis of first edition was to decrease the displacement in top of the vertical beams. The top support beams consists of four beams with 200 x 200 x 10 mm, length of 1400 mm and 399,50 mm, two of each beam. The purpose of these beams is to give the rig more rigidity and less displacement in top of the vertical beams. These beams are also limiting the twisting of the vertical beams.

Short Longitudinal beams

Two 399,5 mm long beams are welded between the front and rear vertical beams. These short beams decrease the stress and bending in the vertical beams. They also prevent twisting in the vertical beams.

Transversal support beam

The transversal support beam is 1400 mm long beam welded between the rear vertical beams. This beam is preventing twisting and deformation of the rear vertical beams. The beam also distributes the stress from the rear vertical beams and prevents displacement. Mounting height shall not interfere with the rear part of the brackets to the V-stay legs.

Support plates

Two support plates with dimensions of 1800 x 799,5 x 10 mm are welded along the plate edges. The plates support the vertical beams by providing rigidity to the rig. They distribute stress from the vertical beams. The support plates prevent the vertical beams from twisting when loaded and also decrease the displacement in the vertical beams.

Two smaller support plates with dimensions 1382,69 x 600 x 10 mm are welded along the edge of plate between the legs in front, longitudinal support beam, the rear platform legs and bottom beam.

Legs

The rear platform legs were moved up to the front vertical beams. These legs are necessary because they carry much weight of both the platform and equipment.

Cross supports

By implementing all the changes mentioned, there was no need for the rear cross support beams which supported the rear vertical beams so these where removed. These were moved to the front of the rig and replaced the front support beams. These cross beams goes through and split the longitudinal platform beam.

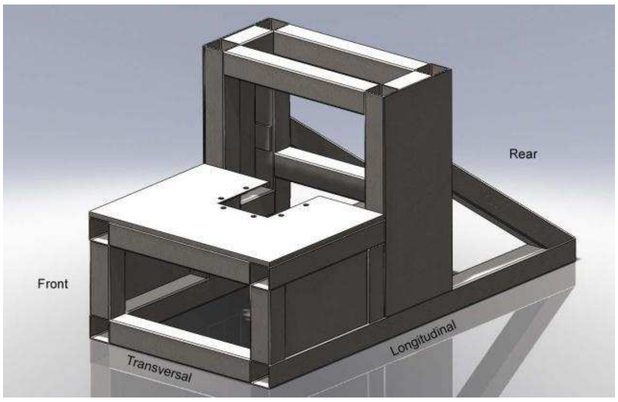


Figure 8: Second edition

Finite Element Analysis final design

Transversal 200 kN

The analysis shows the transversal testing of the V-stay with a force of 200 kN (ref. RF 4, Requirement specification ref. 1.3).

Stress

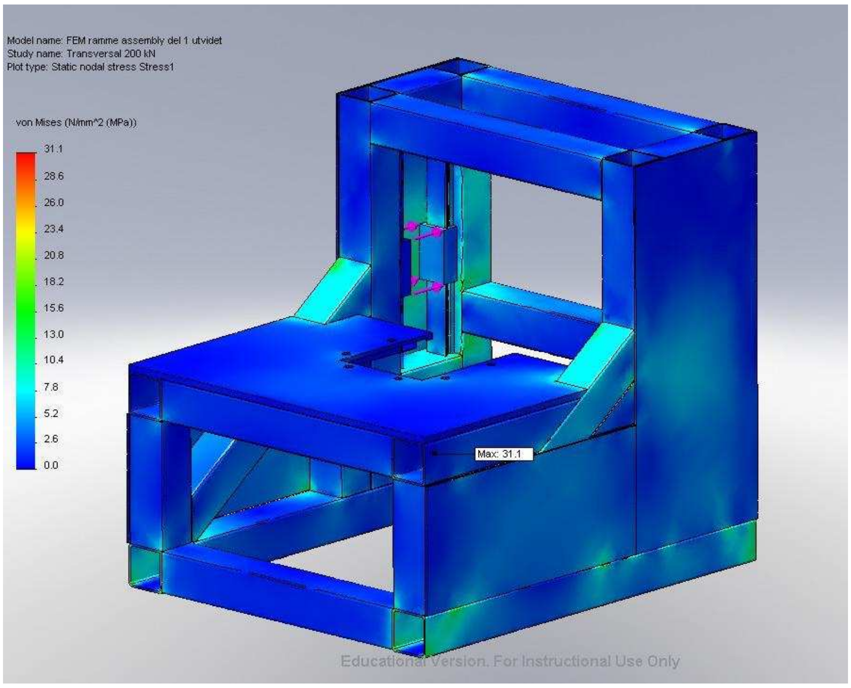


Figure 9: Stress in front view, transversal 200 kN

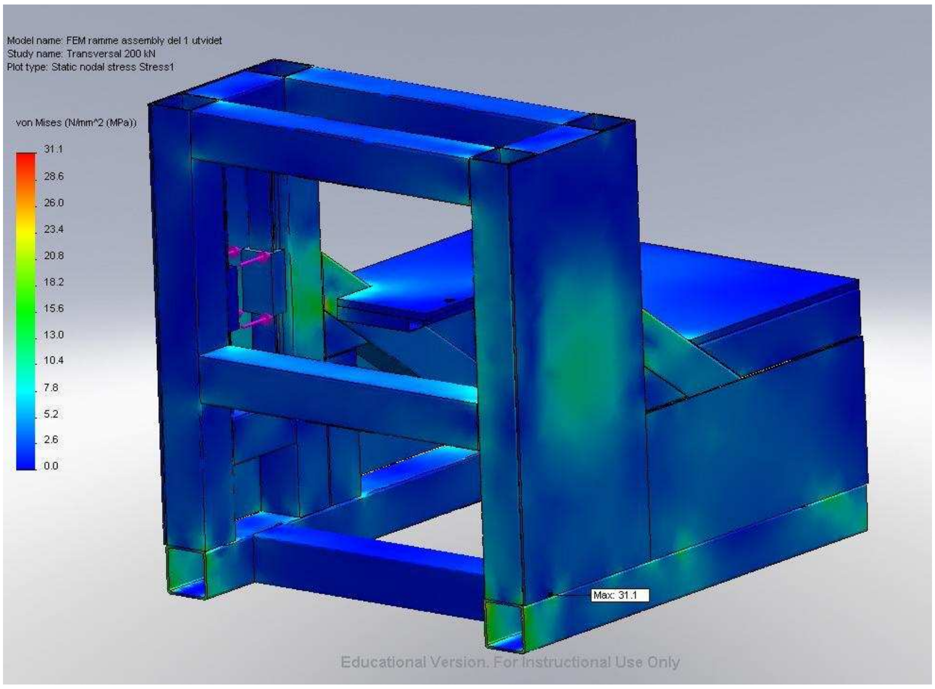


Figure 10: Stress in rear view, transversal 200 kN

Both figures show the force applied to the vertical beams when testing the V-stay transversal with a force of 200 kN. In the analysis of the first edition of the rig there was stress of 69,7 MPa. Now the maximum stress has been reduced to 31,1 MPa, which is still quite low compared to the yield strength of the materials used. The figures show how the stress is uniformly distributed in the structure. The analysis shows no large stress concentration. The stress is very small and creates no risk of fracture in materials.

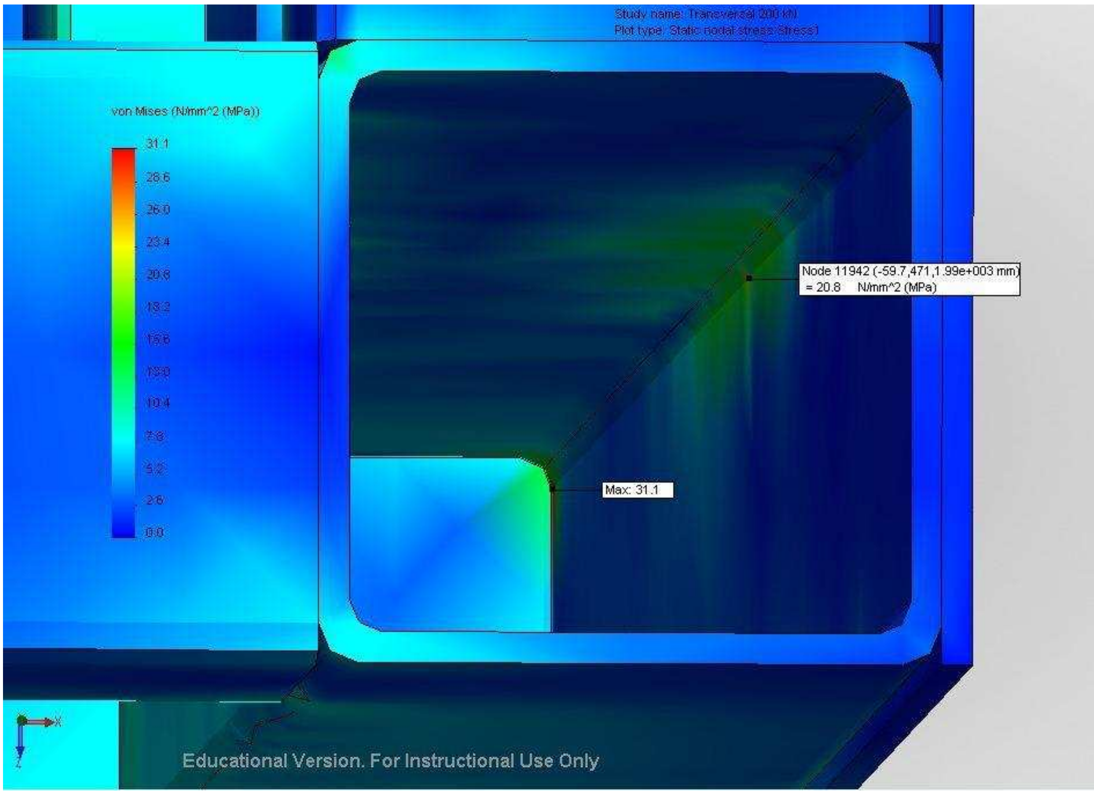


Figure 11: Stress located inside rear vertical beam.

The maximum stress is located inside the bottom of the rear vertical beam, as shown in the figure. This stress concentration may be a source of error. This stress may occur in the analysis because of the beam edges and end. In reality the beams are being welded which will smooth the ends of the beams. The more realistic stress is further up inside the beam as shown in the same figure. Here the stress is 20,8 MPa.

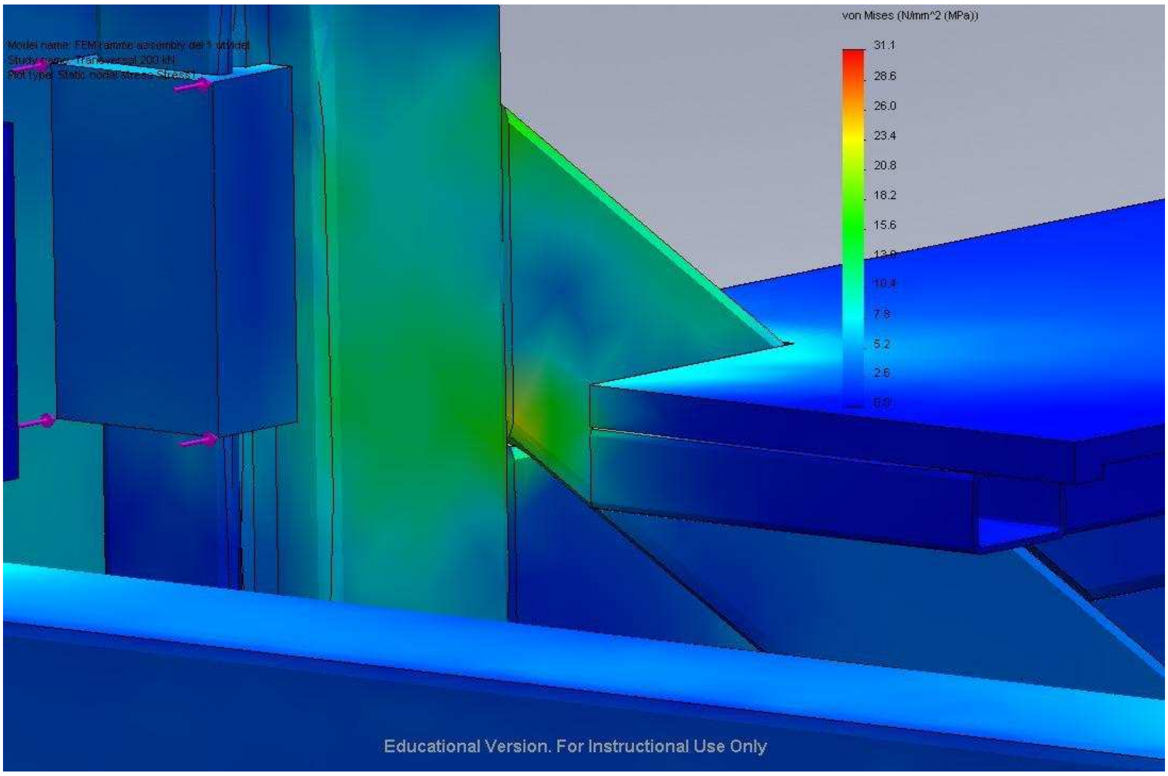


Figure 12: Stress; close up front vertical bam

Stress will occur between the front vertical beam and the cross support. Here the stress is 22,7 MPa.

Second edition: Compared to the second edition the maximum stress is almost same as finale design, 29, 1 MPa. This means that the difference in maximum stress between final design and second edition is insignificant compared to the yield strength of material used. See figures of second edition below.

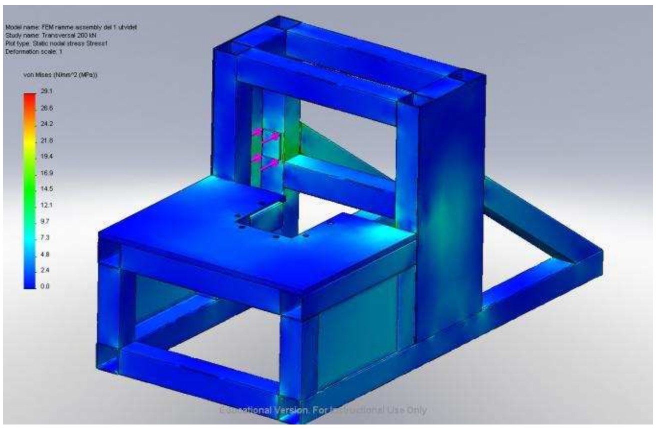


Figure 13: Second edition; stress, 200 kN transversal, front view

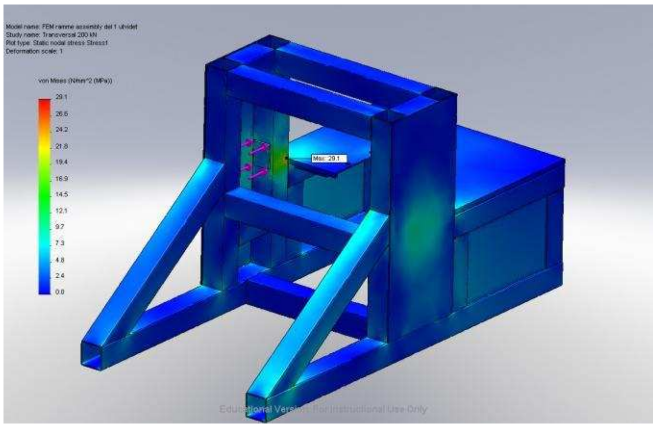


Figure 14: Second edition; stress, 200 kN transversal, rear view

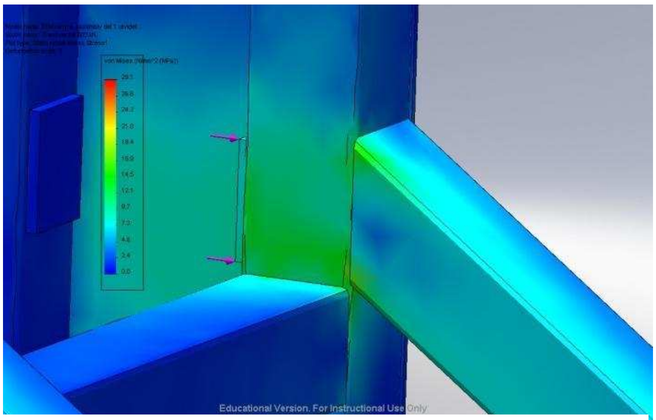


Figure 15: Second edition; stress, 200 kN transversal, close up rear view

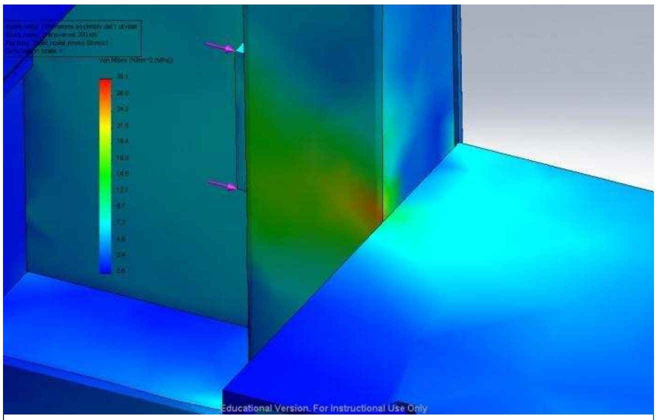


Figure 16: Second edition; stress, 200 kN transversal, close up front view

Figure 15 shows stress in rear vertical beam and how the stress is distributed to the cross support beam. Figure 16 shows front vertical beam and also how the stress is distributed to the platform. The platform gives the structure more rigidity but also more stress in this area, stress is 25 MPa. Since the stress is low compared to the yield strength there is no danger that fracture occurs.

Displacement

The next step in the process is to compare the displacement in the first edition to the final design of the rig. First edition had a maximum displacement of 0,3659 mm in top of the front vertical beam. The final design have a maximum displacement of 0,1532 mm in rear vertical beam and 0,094 mm in front vertical beam. Since the final design has less support rear than front, the displacement is not uniform on both sides. This can be a disadvantage.

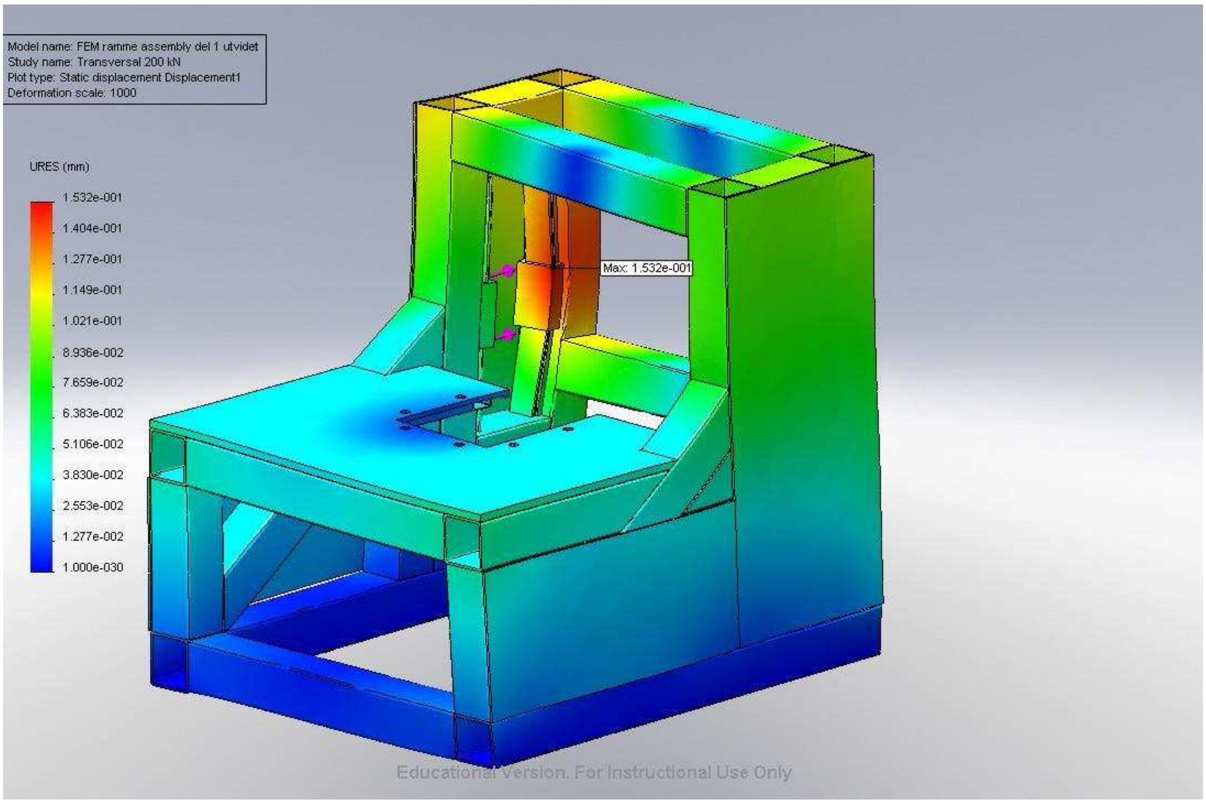


Figure 17: Displacement, 200 kN transversal, front view

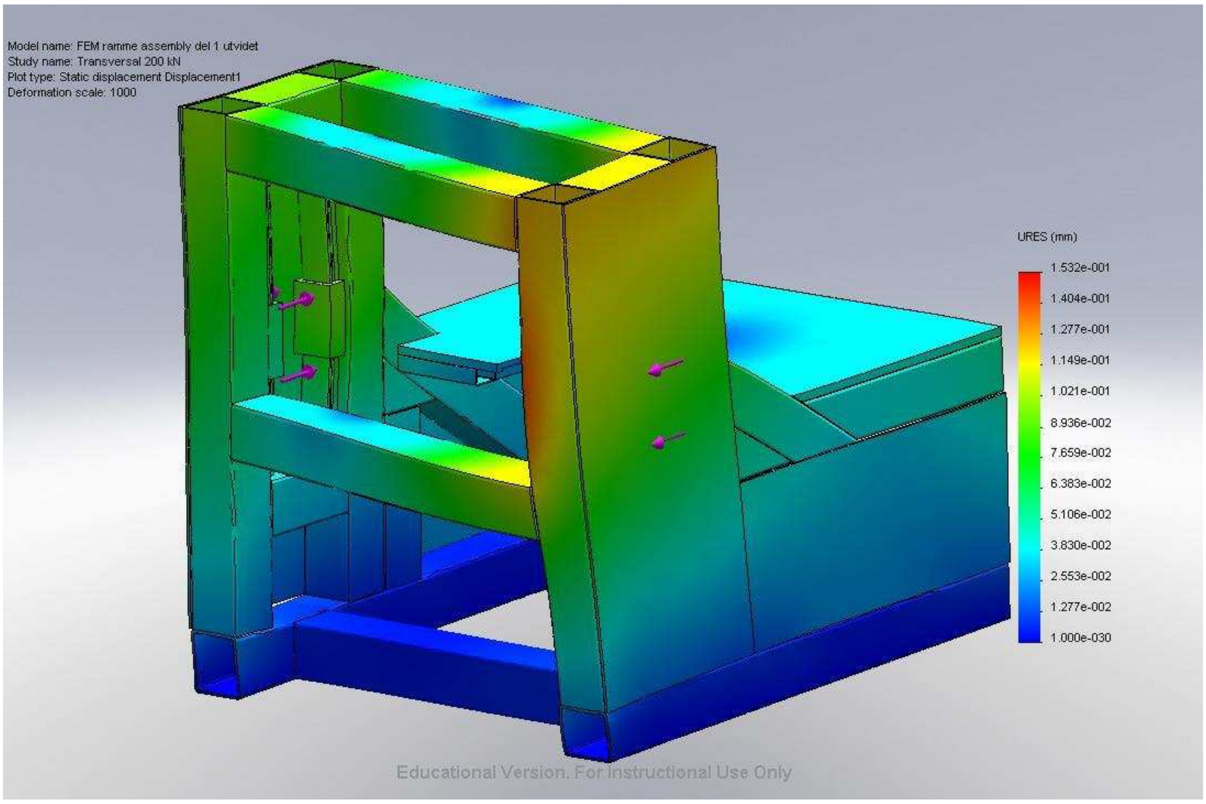


Figure 18: Displacement, 200 kN transversal, rear view

Referring to the figures 18 and 19; most of the displacement is located in the rear vertical beam which is logic because of less support support in the back of the rear vertical beams. Some of the displacement is also located in the upper part of the support plate and vertical beams.

Second edition: When comparing the final design to the second edition there are some differences.

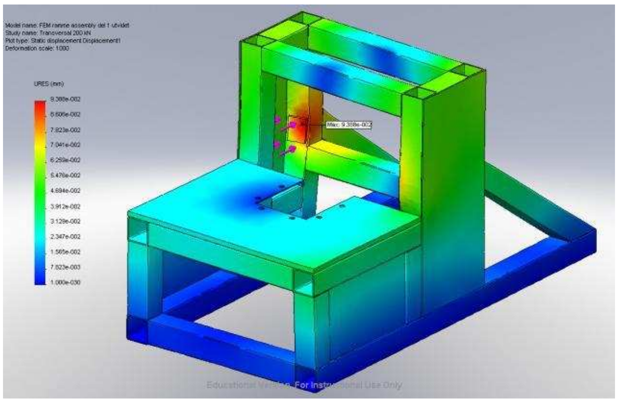


Figure 19: Second edition; displacement, 200 kN transversal, front view

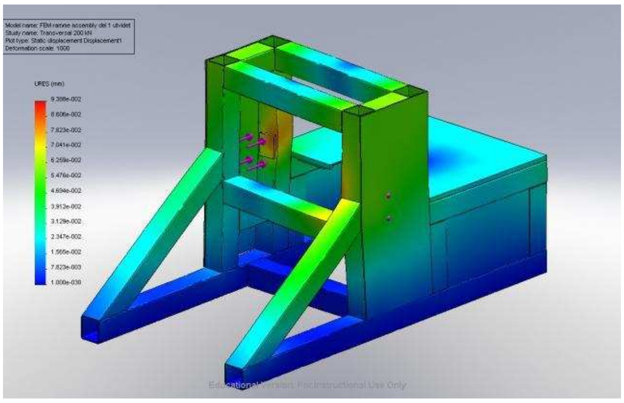


Figure 20: Second edition; displacement, 200 kN transversal rear view

The maximum displacement of 0,09388 mm is located in the rear vertical beam, seen in figure 19 The displacement is more uniform in second edition than in final design. Figure 20 shows the maximum displacement of 0,0807 mm in front vertical beam.

To sum up; the final design is a more compact and flexible rig than the second edition. On the other hand the second edition has more length and needs more space, but it is also a rig with more stiffness. The rig is also more uniform and will get more accurate measuring values.

Both finale design and second edition is better solutions than the first edition.

Longitudinal 100 kN

When testing the V-stay in longitudinal direction the load is one half of the load in transversal direction, but in longitudinal testing the force will act in the same direction unlike to the transverse testing. In theory the longitudinal testing shall not exceed the stress or the displacement produced in the transversal testing. An analysis of the longitudinal testing is done to prove this theory.

Stress

When testing the final design in longitudinal direction by pulling the V-stay, the maximum stress is 18,1 MPa.

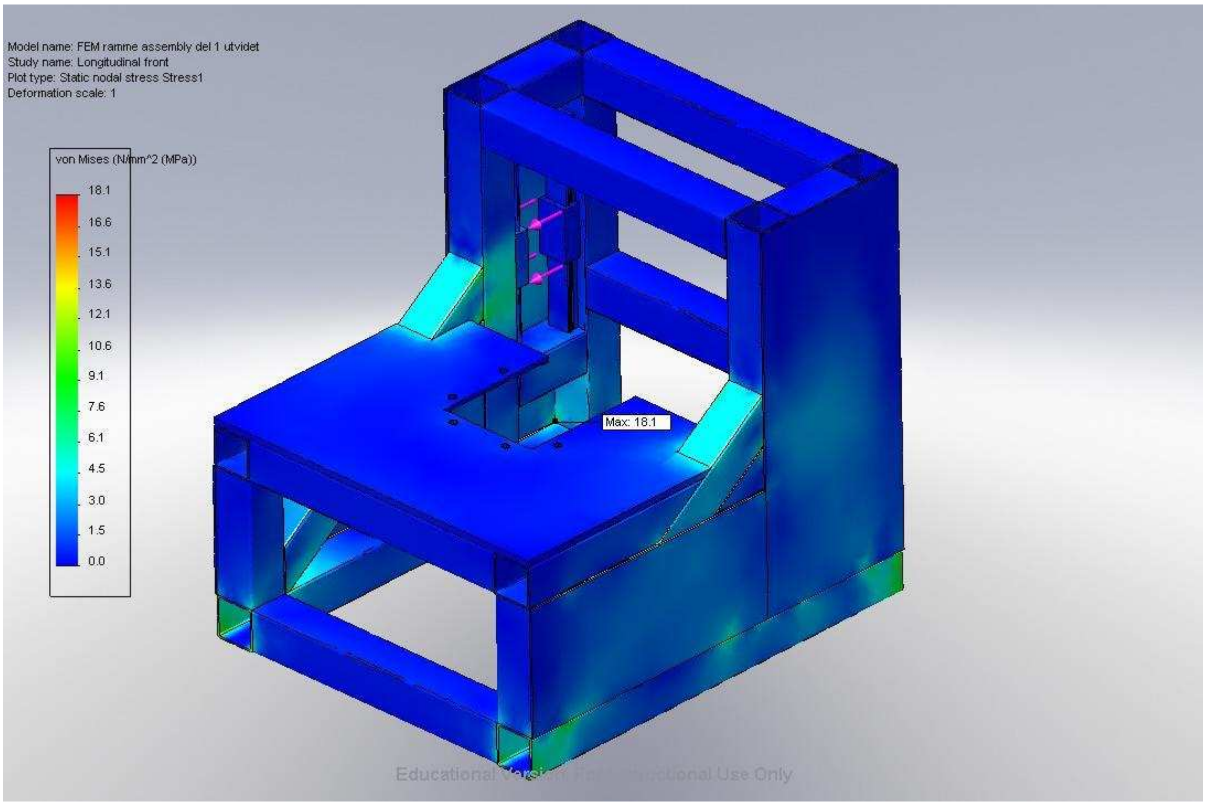


Figure 21: Stress in front view, pulling 100 kN longitudinal

Maximum stress occurs in the bottom of the rear vertical beam, which may be a source of error because of the sharp edge of the bottom of the beam. In reality this edge will be welded and sharp edges will not be so prominent.The stress is even lower than transversal testing, thus no danger of fracture. The more realistic stress is located in the front vertical beam and the cross support. In this area the maximum stress is 10 MPa.

Second edition: The maximum stress is 16,40 MPa and is concentrated in the front vertical beams.

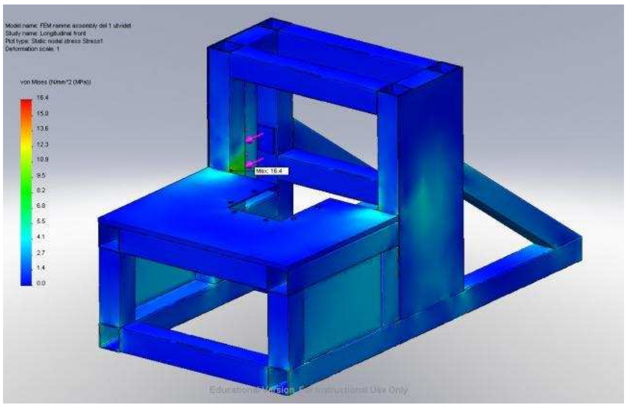


Figure 22: Second edition; stress front veiw, pulling 100 kN longitudinal

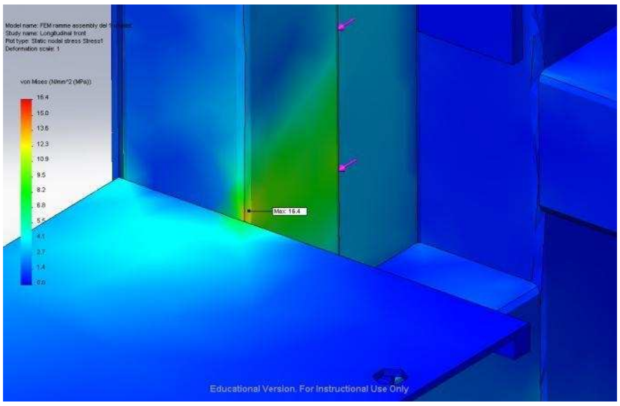


Figure 23: Second edition; stress close up front vertical beam

The figures also show how the stress is distributed in the framework, without any other stress concentrations in the system. Figure 24 shows stress up close, it turns out to be the connection between the platform and front vertical beam that the stress occurs.

When testing the final design in longitudinal direction by pushing the V-stay, the maximum stress is 17,9 MPa.

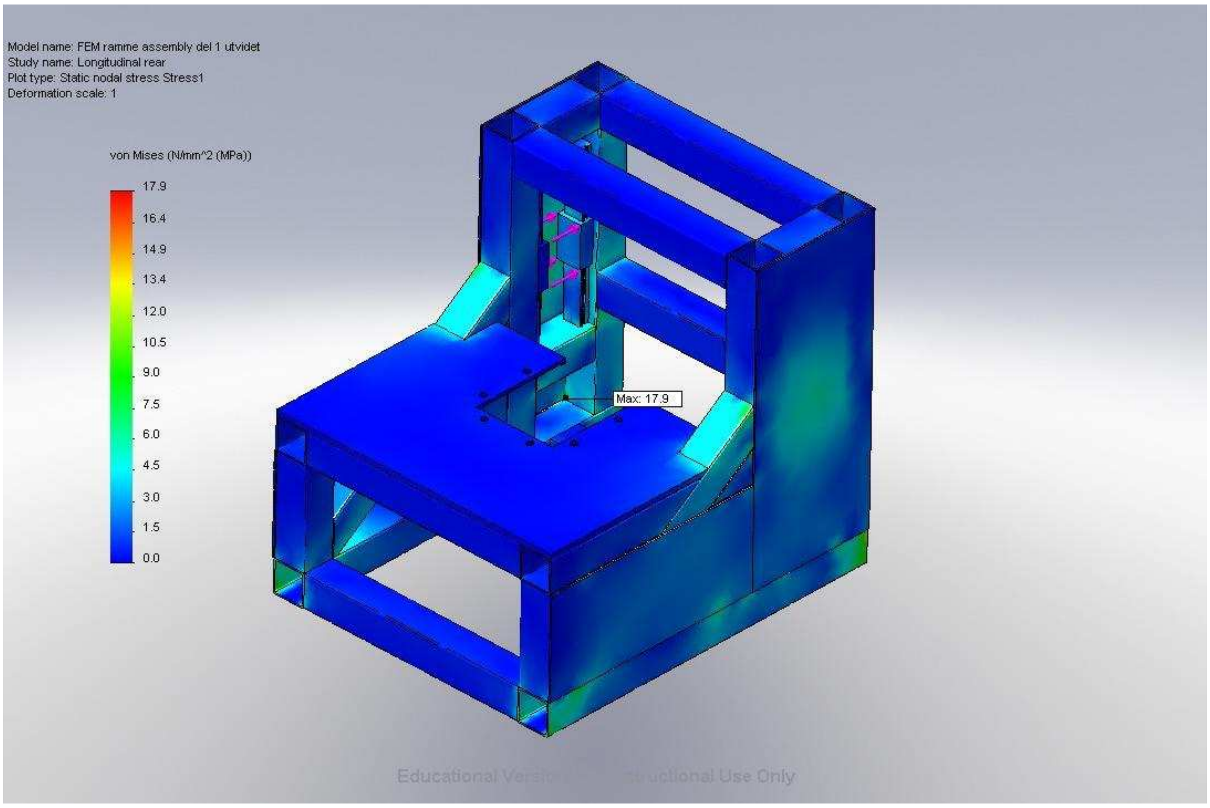


Figure 24: Stress in front view, pushing 100 kN longitudinal

Stress is concentrated in the bottom of the rear vertical beams, which may be a source of error because of the sharp edge of the bottom of the beam. The stress is even lower than transversal testing, thus no danger of fracture. The more realistic stress is located in the front vertical beam and the cross support. In this area the maximum stress is 10 MPa.

Second edition: The maximum stress is 13,3 MPa and is concentrated in the rear vertical beams.

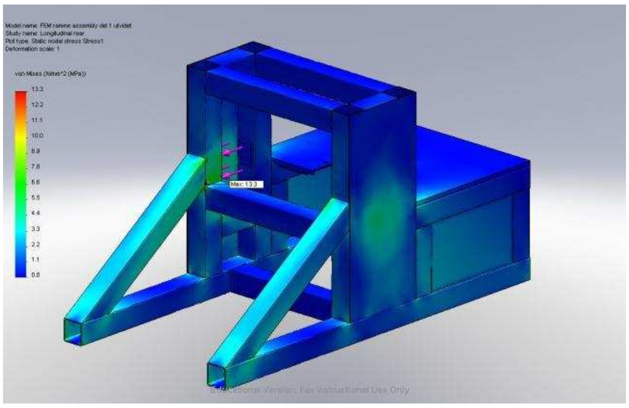


Figure 25: Second edition; stress rear view, pushing 100 kN longitudinal

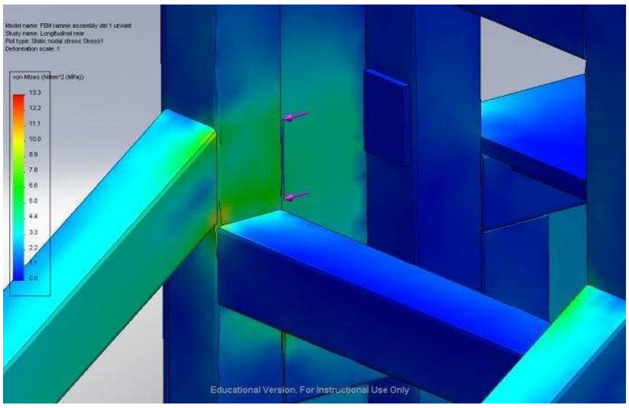


Figure 26: Second edition; stress close up rear vertical beam, pushing 100 kN longitudinal

The figures also shows how the stress is distributed in the framework. The stress is distributed along the cross support beams, with some small stress concentrations along the edge of the beam.

Displacement

Although the stress is no problem in the rig, it is important to analyse the displacement. When testing the final design in longitudinal direction by pulling the V-stay the maximum displacement is 0,06338 mm. The largest displacement is located in the top support beams.

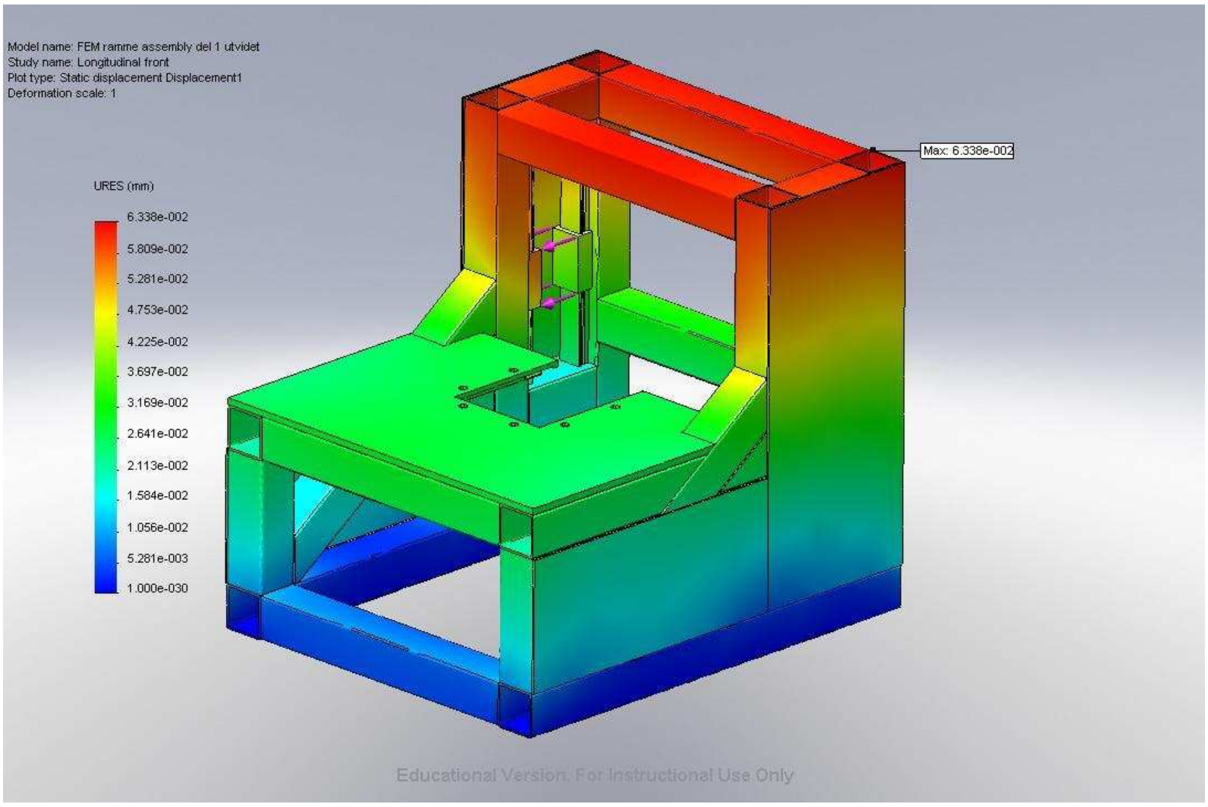


Figure 27: Displacement in front view, pulling 100 kN longitudinal

Second edition: Comparing to second edition the maximum displacement is 0,04578 mm and is located in the front vertical beams. Some of the displacement is also located to the top of the rig, marked with yellow colour in the two figures. The maximum displacement is lower that the projects goal of displacement.

This is a good example that the second edition has a higher stiffness than the final design. The second edition have most of the displacement where the force is applied and get a lot of stiffness and support by the rear cross beams. While the final design get the maximum displacement in the top support beams.

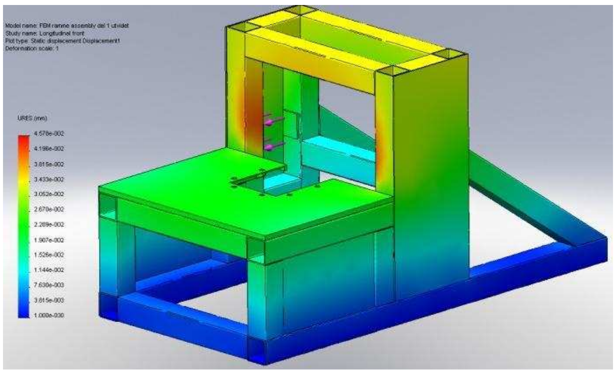


Figure 28: Second edition; displacement front view, pulling 100 kN longitudinal

When testing the final design in longitudinal direction by pushing the V-stay the maximum displacement is 0,08359 mm. The displacement is located in the rear beam in the top support beams and also along the rear vertical beams.

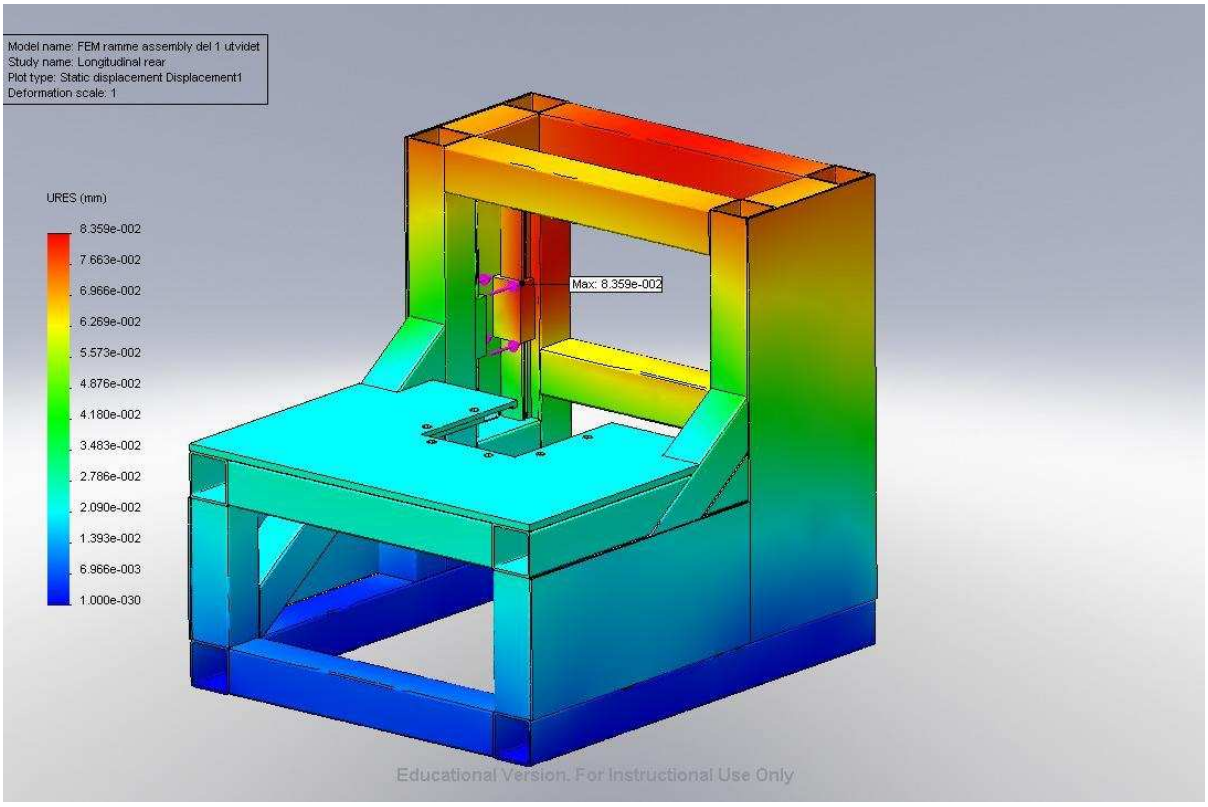


Figure 29: Displacement in front view, pushing 100 kN longitudinal

Second edition: Comparing to second edition the maximum displacement is 0,04908 mm and is located in the rear vertical beams. Some of the displacement is also located on top of the rig along with the cross support beams and the rear transversal support beam.

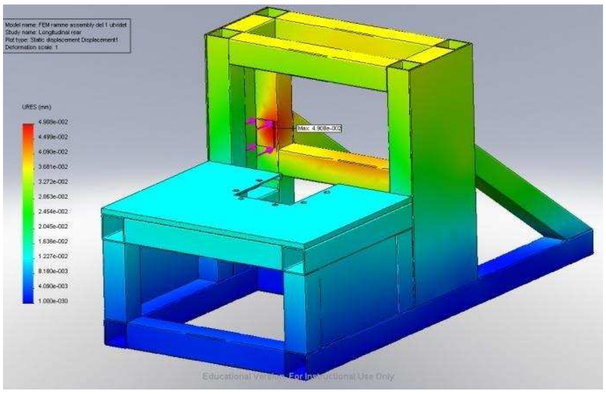


Figure 30: Second edition; displacement front view, pushing 100 kN longitudinal

This is also an example that the second edition has a higher stiffness than the final design. In the second edition the displacement is more local and is affecting a smaller area than in the final design. The final design has displacement in larger areas.

4.2.Horizontal testing

4.2.1. Horizontal bracket

This document will deal with the construction of the horizontal part of the test rig; how it is designed, and how the different parts are connected.

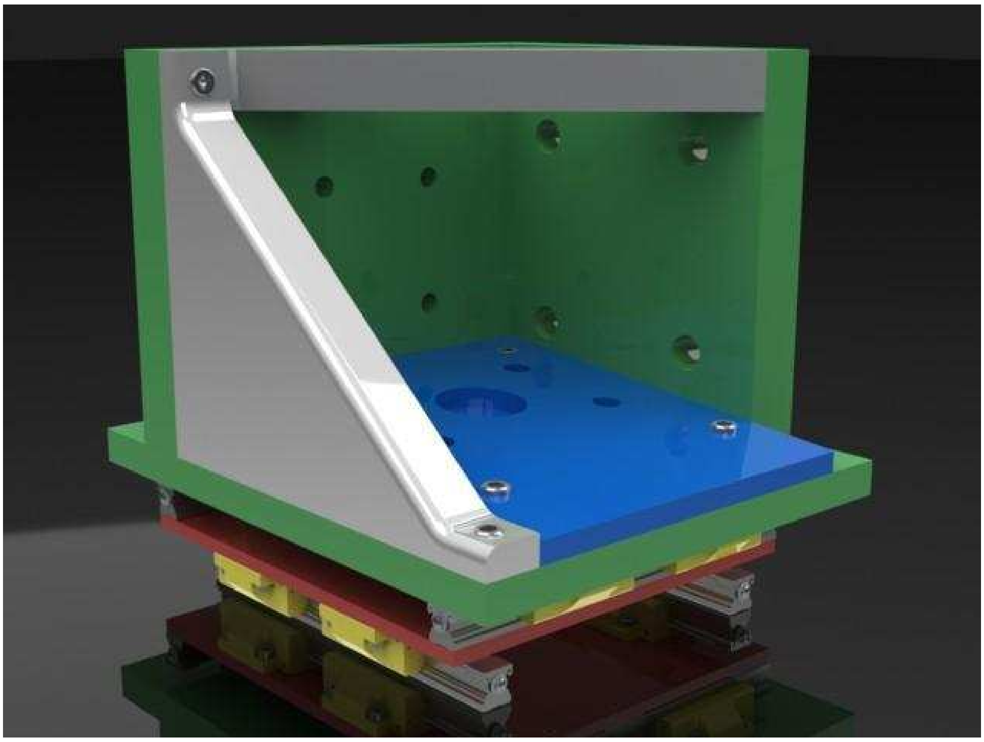


Figure 31: Horizontal bracket

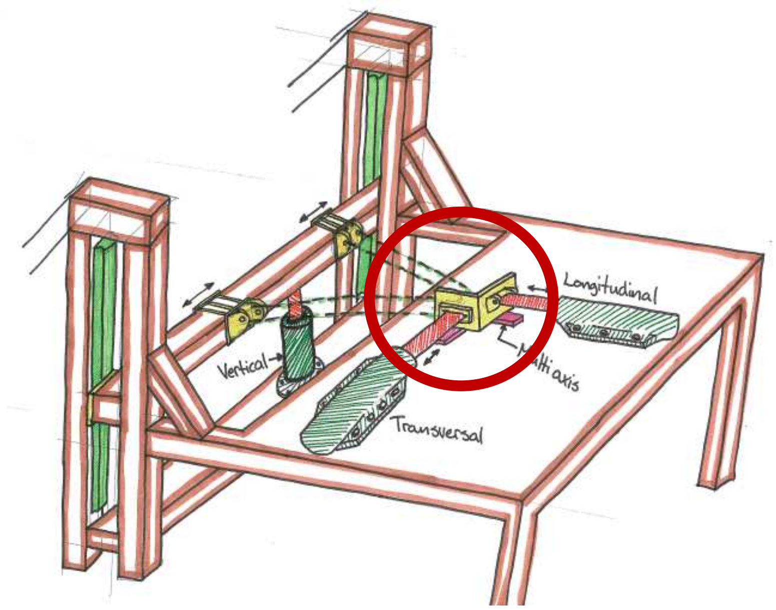


Figure 32: From concept sketch, the circle marks the horizontal bracket

The whole horizontal bracket system is built up from different sub assemblies and several parts:

The horizontal bracket assembly, which contains;

- Main bracket
- Angled changeable bracket
- Stabilizing beams/bars

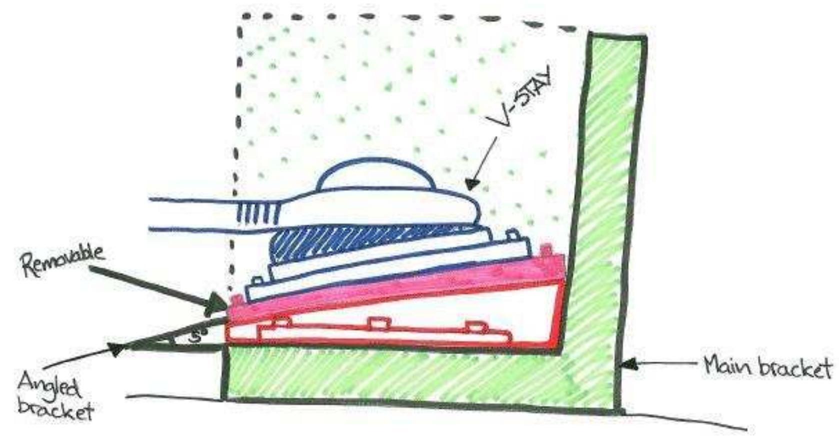


Figure 33: Sketch of main bracket

The rail system is a system made out of four guide rails, eight runner blocks and a separation plate. The horizontal bracket is attached to the rail system with screws (sixteen in total) on each side. The rail system is attached to the platform. The bottom guide rails are screwed down onto the sunken platform plate.

The platform is an assembly containing a main platform, threaded bars with corresponding adjustable nuts and a sunken platform.

Main bracket

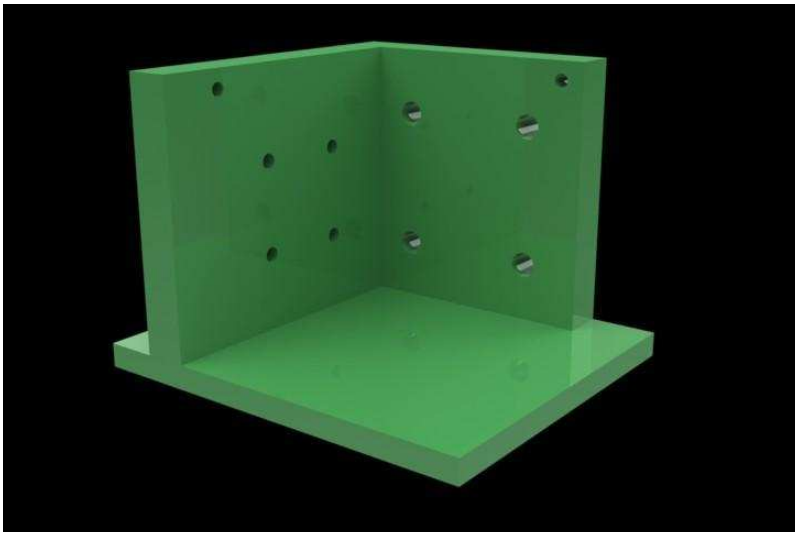


Figure 34: Main bracket

The main bracket in figure is considered to be the core of the system, this is where the cylinders, the angled changeable bracket and the rail system are attached. The main bracket must have solid walls, so that they can withstand the forces given by both the transversal and the longitudinal cylinder. The bracket has got holes on both of the walls, for attachment of the cylinders, and drilled holes in the middle for attachment of the angled changeable bracket.

The base of the bracket is a rectangular platform (originally 250 mm x 310 mm) which is extruded up to 25 mm. The bracket wall is drawn on the outside of the rectangular platform, with a thickness of 45 mm. The wall is extruded upwards with a height of 300 mm from the ground. The length of the main bracket is increased in length on each side (longitudinal side). This is drawn on each side of the base platform (250 mm x 310 mm x 25 mm), and the front is extruded so it has the same length as the angled changeable bracket. The rear platform is extruded outwards 55 mm. These extra lengths are constructed so that the runner blocks will be placed correctly. There are drilled holes on each side of the wall, for mounting of the cylinders and the stabilizing beams/bars. There are tapped holes (M8 x 1.25) through the main bracket for mounting of the carriages. These holes are dimensioned to fit the screws for each part. There are drawn two split lines underneath the base platform. These are drawn 15 mm from each end. The reason for these split lines are mating of the carriages.

<u>Dimensions</u>

Height: 300 mm
Length: 420 mm
Width: 355 mm
Thickness longitudinal wall: 45 mm
Thickness transversal wall: 45 mm
Thickness bottom platform: 25 mm

Calculations

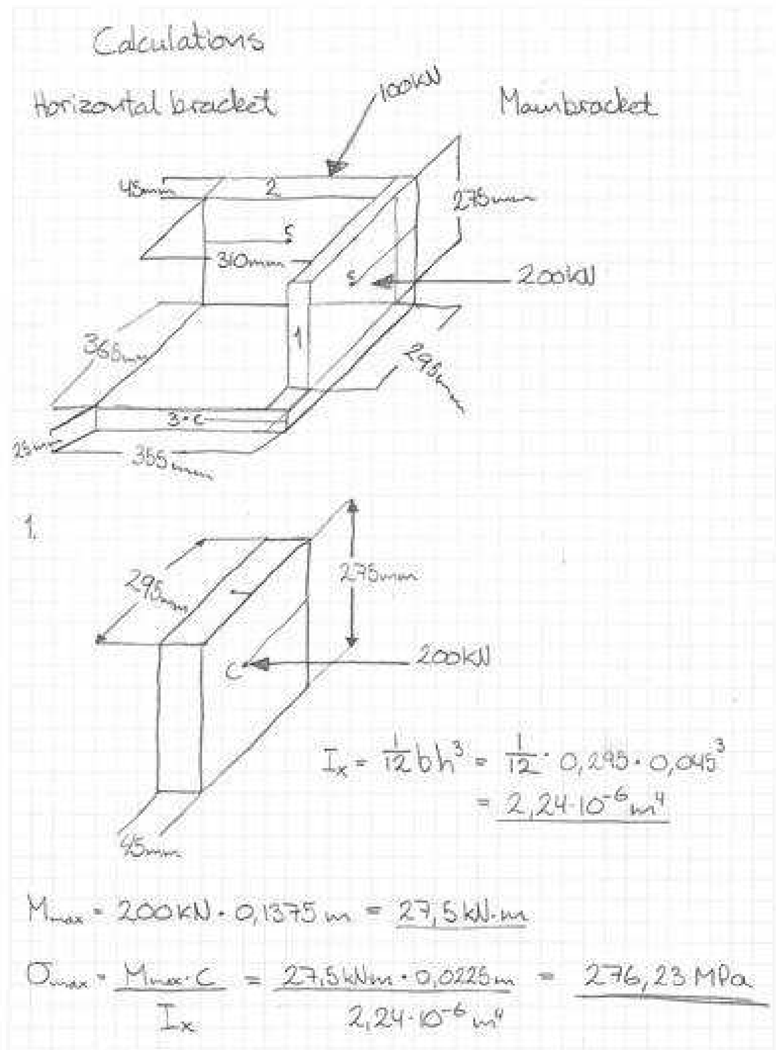


Figure 35: Calculations of main bracket, 200 kN transversal [1]

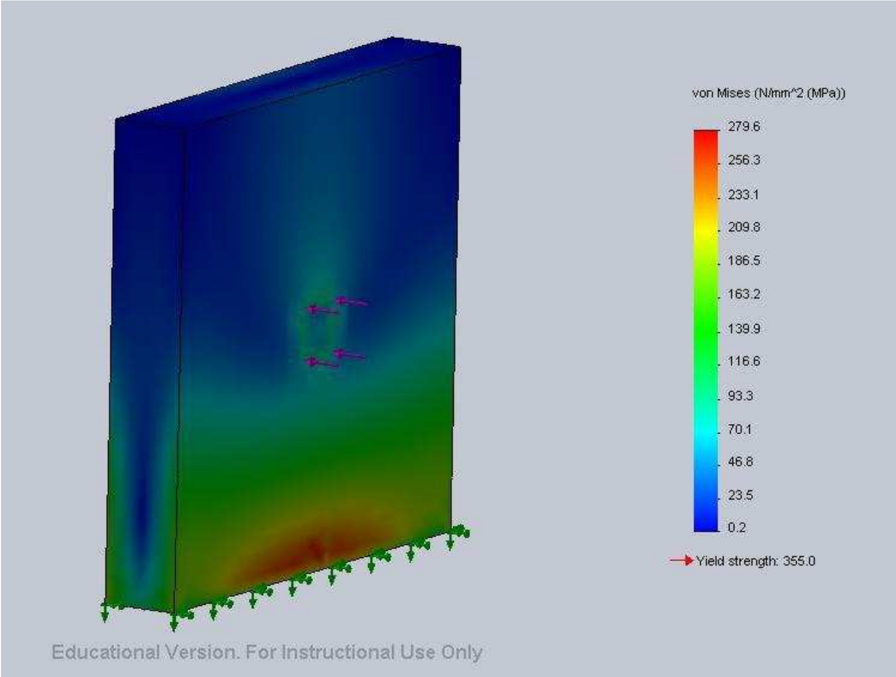


Figure 36: Stress, 200 kN transversal

Calculations

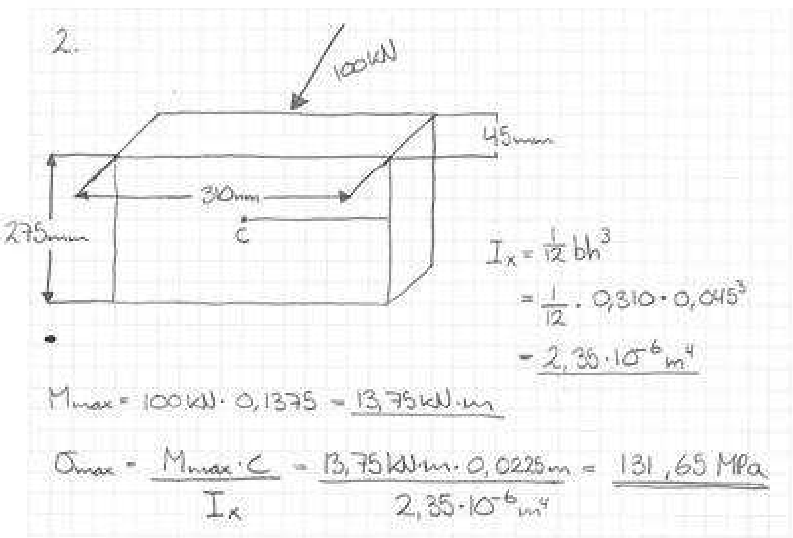


Figure 37: Calculations of main bracket, 100 kN longitudinal [1]

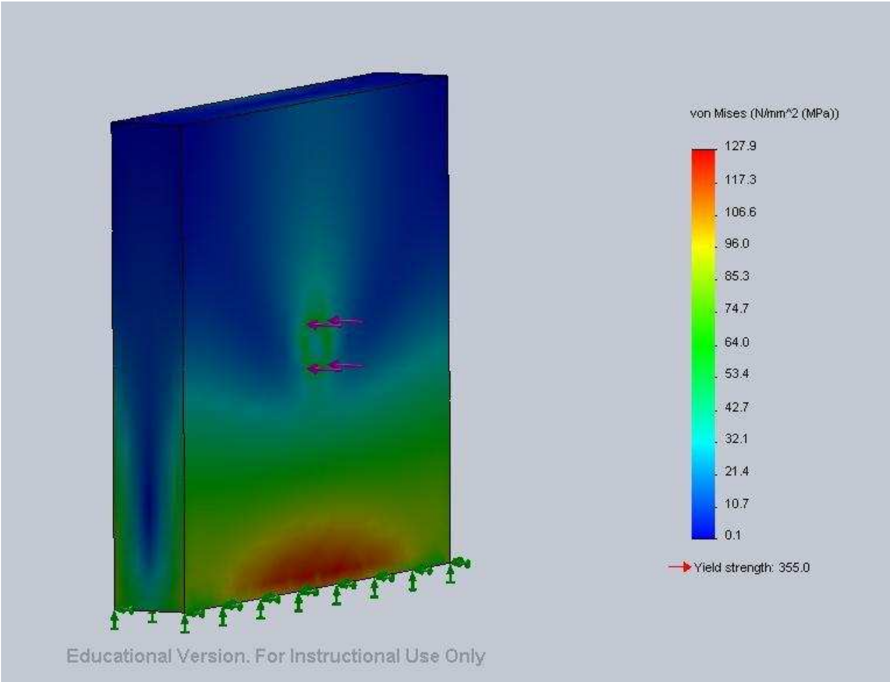


Figure 38: Stress, 100 kN longitudinal

As seen in the hand calculations, the walls themselves are not satisfying the requirements given. By combining the two walls and the bottom plate, the stress concentrations on each wall will be reduced substantially.

Angled changeable bracket

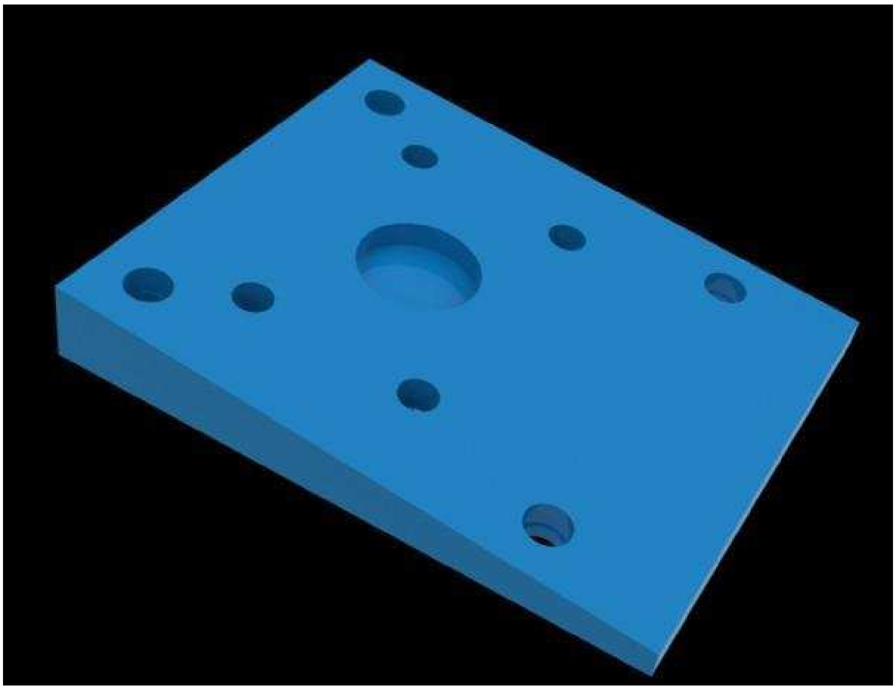


Figure 39: Angled changeable bracket

The first idea was to divide the bracket into two pieces; an angled bracket and a changeable bracket. But after a discussion with Kongsberg Automotive it was decided that it was more convenient to combine the angled and the changeable bracket. The conclusion was made because of the different types of V-stays. The different V-stay types have different flanges and angles, it is therefore more correct to make the changeable and the angled bracket into one changeable bracket (ref. RF14, Requirement specification rev.1.3).

The reason for the bracket being angled is so that the V-stay will be horizontal while mounted in the test rig. The angle of the bracket needs to be the same as for the V-stay. This will result in a zero degree position and the V-stay will be fixed horizontally in the rig (ref. RR5, Requirement specification rev.1.3).

The angled changeable bracket has got a stabilizing hole for the V-stay flange, and drilled holes for attachment. The bracket has got four holes for attachment to the main bracket. The angled changeable bracket needs to have “easy to fasten” screws, because it needs to be changed to cope with the different types of V-stays (ref. RF14.2, Requirement specification rev.1.3).

The angled changeable bracket is designed to fit perfectly inside the main bracket, it is here important to be accurate with tolerances. The bracket needs to be wall to wall with the main bracket. This is so that the forces applied to the system will be transferred to the angled changeable bracket.

The angled changeable bracket is built up from a rectangular sketch, center drawn. This rectangular sketch is in context with the main bracket, so if the main bracket is changed, the angled bracket will follow. This sketch is then extruded upwards 15mm. The angle of the bracket is made by drawing a sketch on the side of the base plate and extruded to the other side of the base plate (up to surface). The angle of this particular bracket is 5°, this is because of the angle in the V-stay. On top of the bracket there are made attachment holes for mounting of the V-stay. Four holes (M16 x 1.5) are also made on top of the bracket, two holes on each side. These holes are designed for attachment of the angled changeable bracket on to the main bracket. These holes are drawn and drilled from a horizontal plane, so that the hole has no angle.

Dimensions

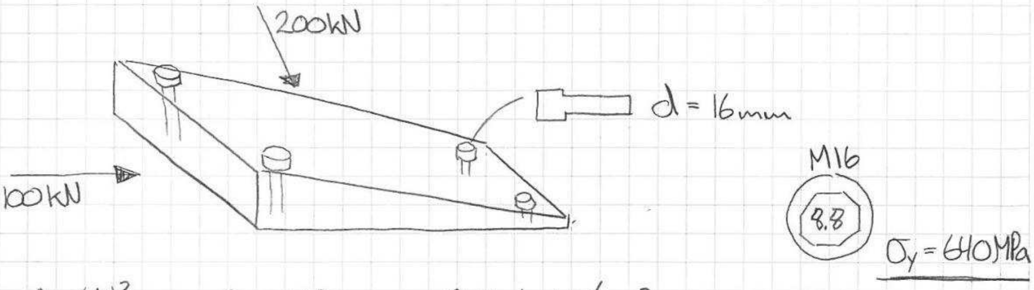
Length: 320 mm
Height at end: 43 mm
Angle: 5°
Width: 270 mm

Calculations - bolt connections

Calculations

Bolt connections

1. Angled changeable bracket and stabilizing beams/bars



$$A = \left(\frac{d}{2}\right)^2 \cdot \pi = \left(\frac{0{,}016}{2}\right)^2 \cdot \pi = 201{,}1 \cdot 10^{-6} m^2$$

200 kN and 100 kN distributed on 4 bolts

$$\frac{200 kN}{7} = 28{,}57 kN \text{ per bolt}$$

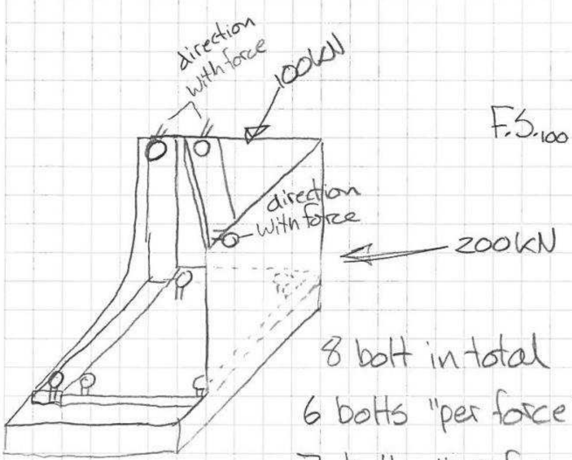
$$\frac{100 kN}{6} = 16{,}67 kN \text{ per bolt}$$

$$\sigma_{200} = \frac{F}{A} = \frac{28{,}57 kN}{201{,}1 \cdot 10^{-6} m^2} = 142{,}1 MPa$$

$$\sigma_{100} = \frac{F}{A} = \frac{16{,}67 kN}{201{,}1 \cdot 10^{-6} m^2} = 82{,}9 MPa$$

$$F.S._{200} = \sigma_y / \sigma_{200} = \frac{640 MPa}{142{,}1 MPa} = \underline{4{,}5}$$

$$F.S._{100} = \sigma_y / \sigma_{100} = \frac{640 MPa}{82{,}9 MPa} = \underline{7{,}7}$$



8 bolt in total

6 bolts "per force" – 100kN force direction

7 bolts "per force" – 200kN force direction

Figure 40: Calculations of bolt-connections [1]

As seen in the hand calculations, one can see that the bolts combined can cope with the forces applied. With a safety factor of 4.5 and 7.7 it is safe to use M16 bolts (8.8) which has yield strength of 640 MPa.

Finite Element Analysis of the horizontal bracket

Finite Element Analyses have been performed with Solid Works Simulation. Two main analyses, one with force applied in longitudinal direction (100 kN), and one with force applied in transversal direction (200 kN). The angled replaceable bracket is fixed, and the forces are applied on each cylinder fastening.

The Finite Element Analysis is performed without stabilizing beam/bars with wall thickness 35 mm and 45 mm and with stabilizing beams/bars, idea 1 and idea 2

By inspecting the different analyses one can easily see that idea 2 is substantially better. By increasing the wall thickness and changing the geometry of the upper stabilizing beam/bar, one can see that the stresses and displacements in the bracket are reduced. Stress is reduced with 23,3 MPa with force applied in longitudinal direction, and 59,5 MPa with force applied in transversal direction. Displacements are reduced with 0,142 mm and 0,3808 mm. The material used in the analysis has yield strength of 355 MPa. Stresses in the bracket with forces applied are under 1/3 of the yield strength, which satisfies the requirement (ref. RF12, Requirement specification rev.1.3).

35 mm wall thickness – 200 kN transversal

Stress

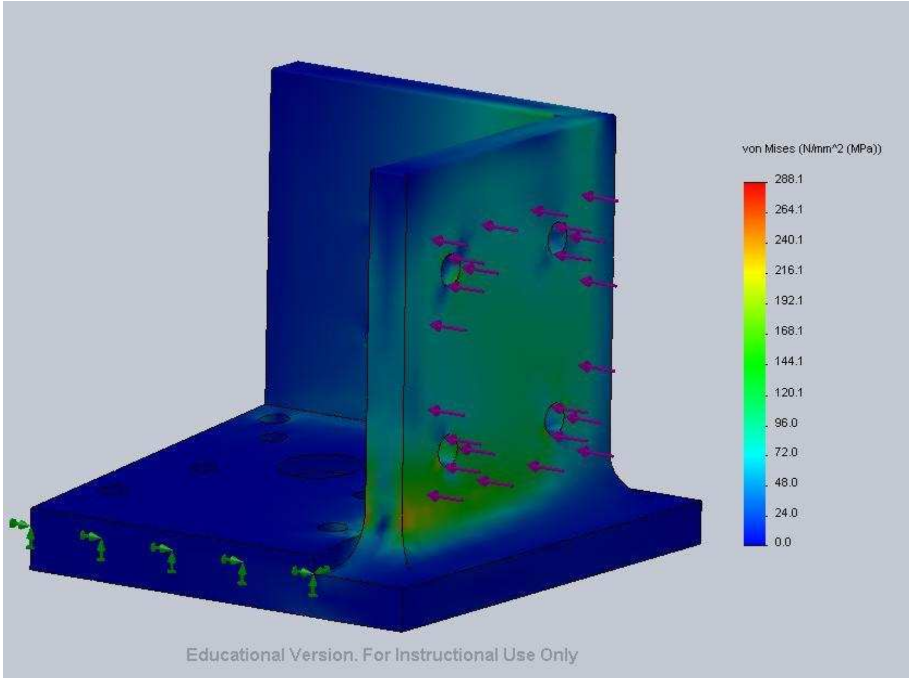


Figure 41: Stress, 200 kN transversal

Displacement

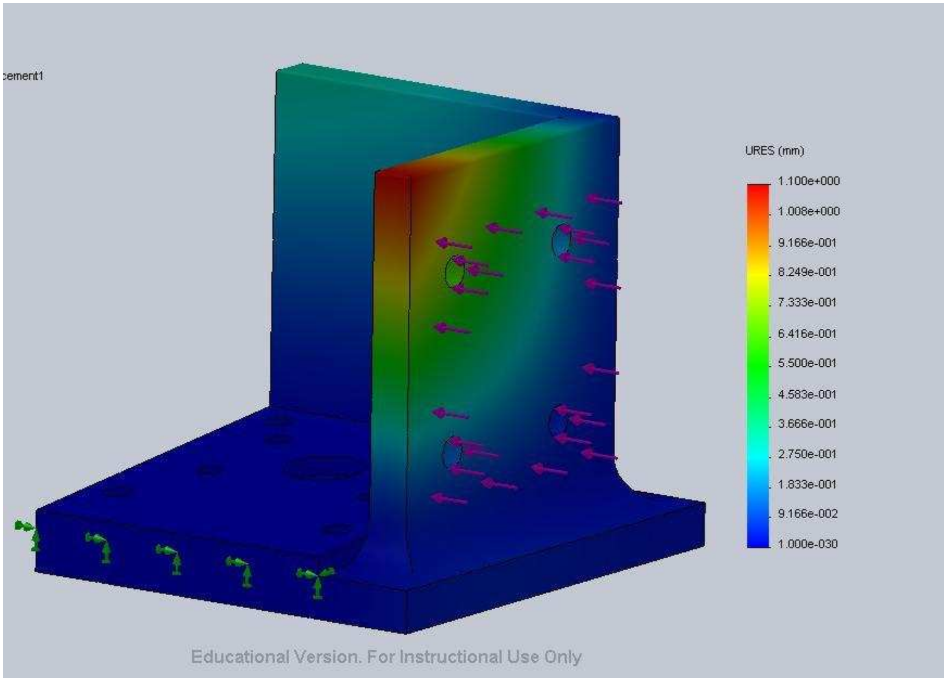


Figure 42: Displacement, 200 kN transversal

35 mm wall thickness – 100 kN longitudinal

Stress

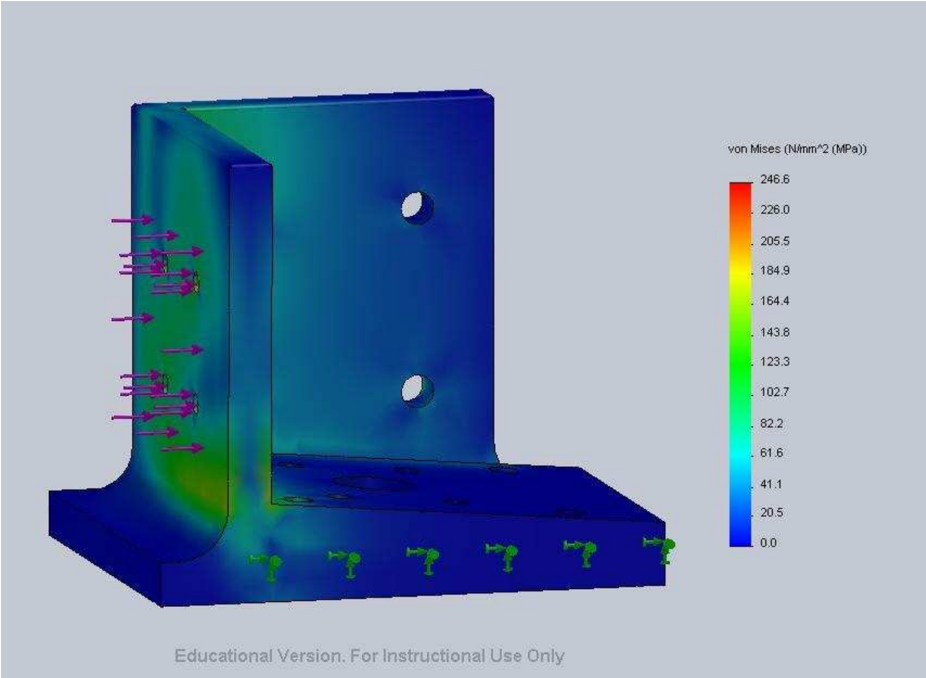


Figure 43: Stress, 100 kN longitudinal

Displacement

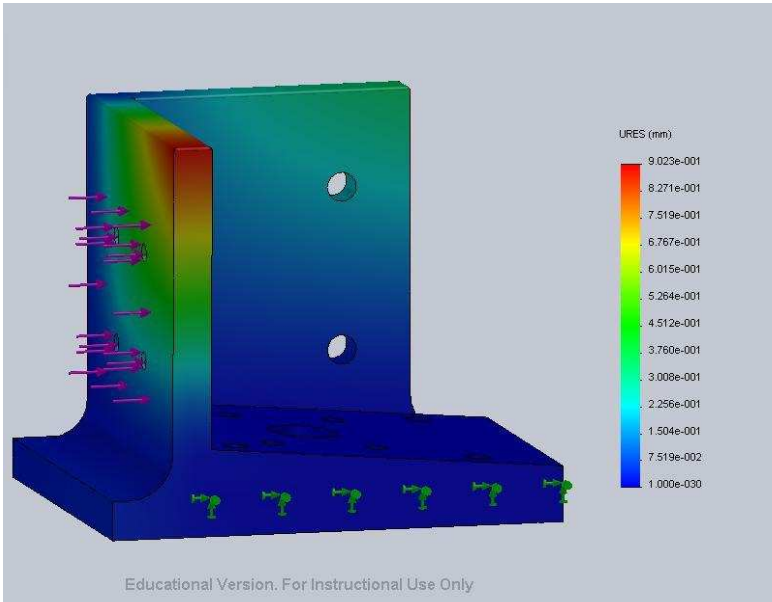


Figure 44: Displacement, 100 kN longitudinal

45 mm wall thickness - 200 kN transversal

Stress

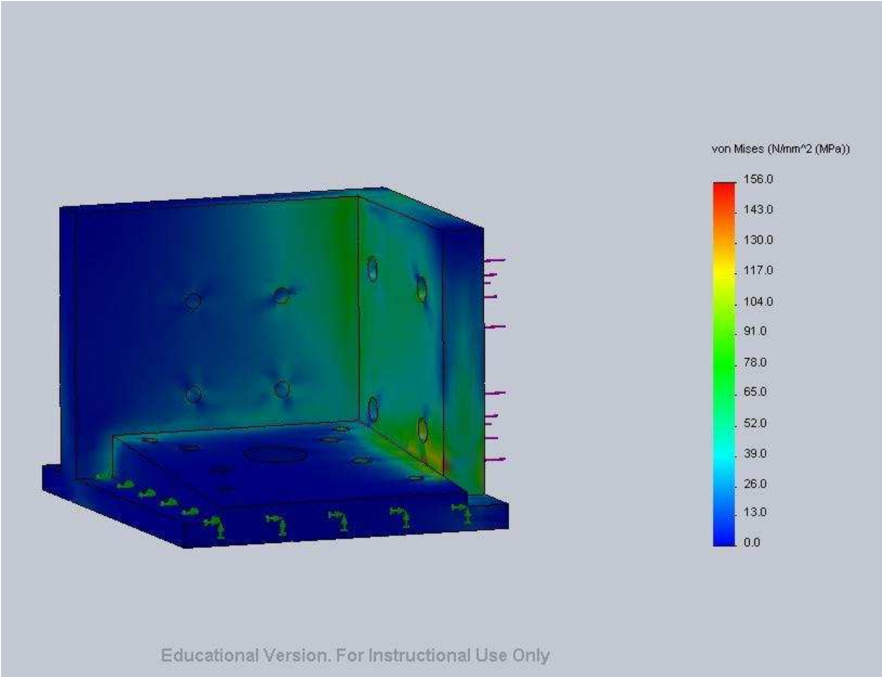


Figure 45: Stress, 200 kN transversal

Displacement

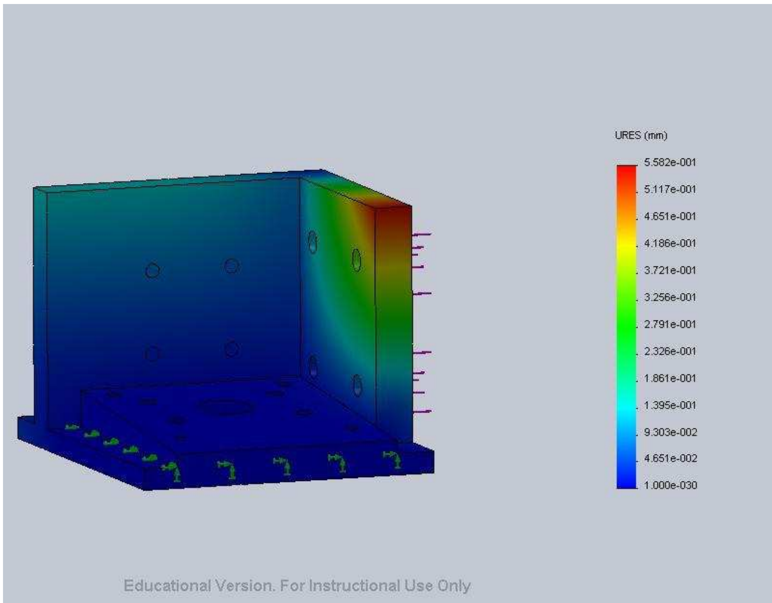


Figure 46: Displacement, 200 kN transversal

45 mm wall thickness – 100 kN longitudinal

Stress

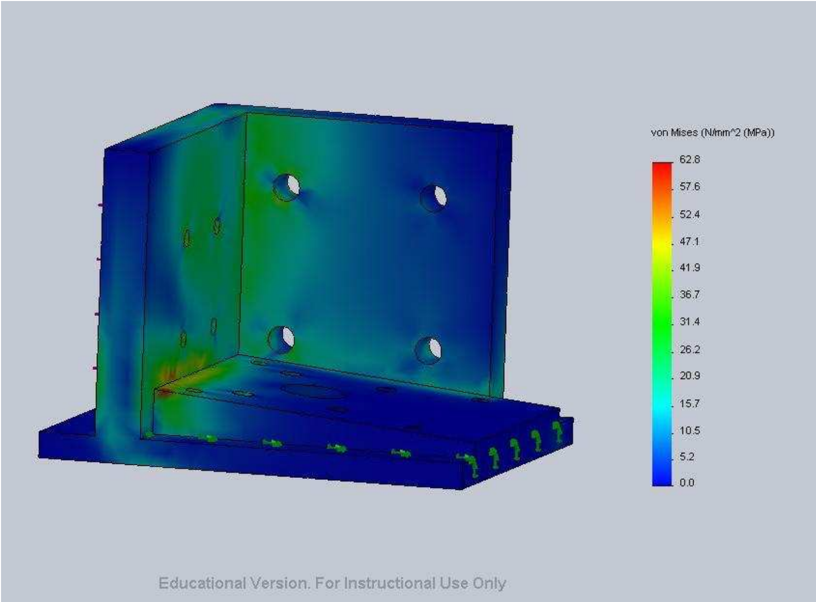


Figure 47: Stress, 100 kN longitudinal

Displacement

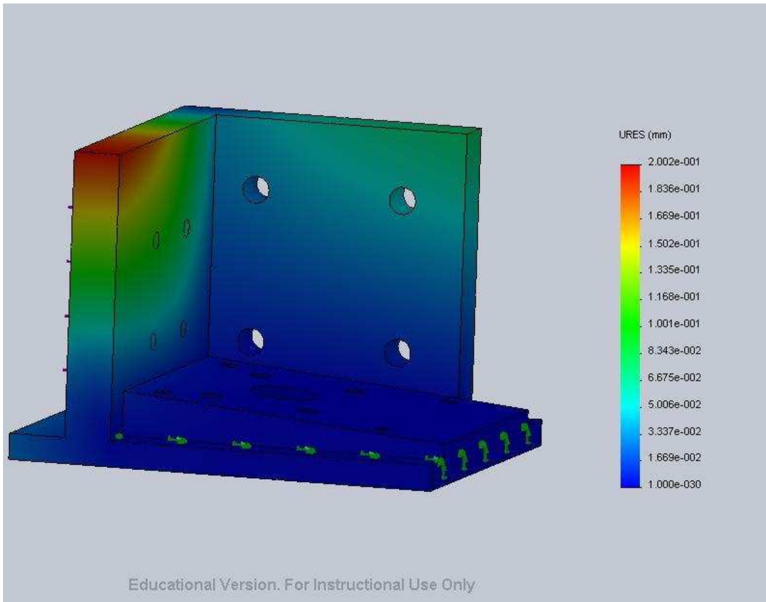


Figure 48: Displacement, 100 kN longitudinal

Stabilizing beams/bars

Top stabilizing beam/bar

The top stabilizing beam/bar is extruded upward 40mm from a trapeze with a width of 50mm. The trapeze is in context with the main bracket. Each end of the trapeze is coincident with the main bracket transversal wall and to the side stabilizing beam/bar. It is then mated to fit the main bracket, coincident top to top, and attached with screws onto the wall (coincident), one screw on each side.

Side stabilizing beam/bar

The side stabilizing beam/bar is extruded outwards 40mm from a sketch which is in context with the main bracket, and has got an attachment plate on each side 40mmx20mm. A triangle is drawn and dimensioned in context with the length and height of the main bracket. The sketch is extruded outwards up to surface of the 40mm bar. The side stabilizing beam/bar is now a massive triangle with attachment plates on each side. Two holes (M16x1.5) are drilled in the attachment plates, one hole on each side (dimensioned to fit the screws). The part is then smoothed out with fillets to get a smooth exterior.

Finite Element Analysis with stabilizing beams/bars-Idea 1

35mm wall thickness – 200 kN transversal

Reduce the stress and displacement. By applying two stress and displacement reducing bars:

Dimensions top bar

Thickness: 40mm
Length: 280mm
Width: 250mm

Dimensions side bar

Thickness: 40mm
Height: 325mm
Length: 320mm
Length of fastening plate: 40mm

Stress

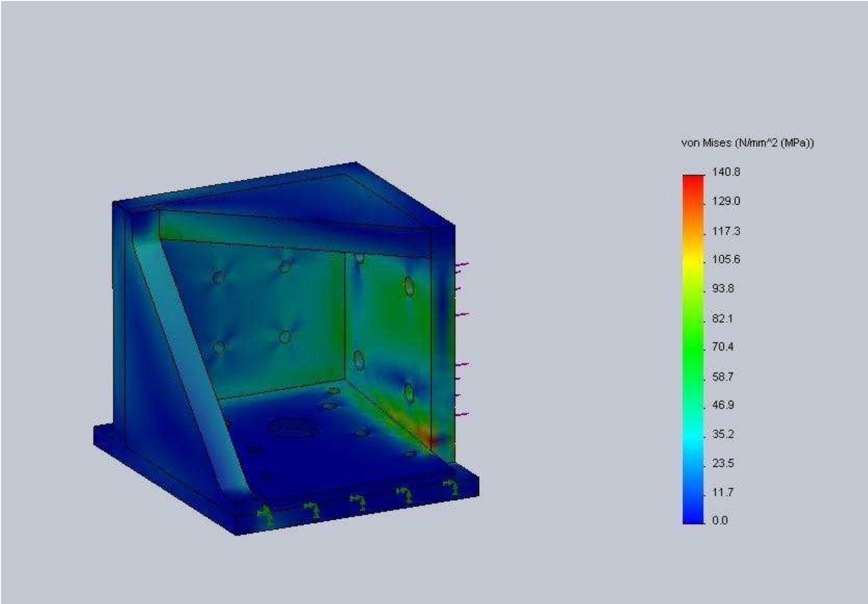


Figure 49: Stress, 200 kN transversal

Displacement

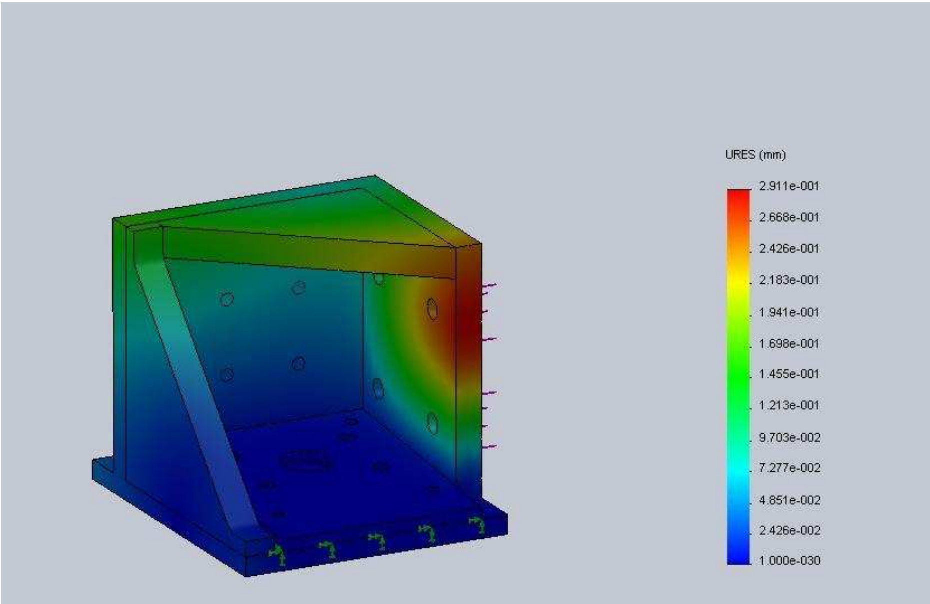


Figure 50: Displacement, 200 kN transversal

35mm wall thickness - 100 kN longitudinal

Stress

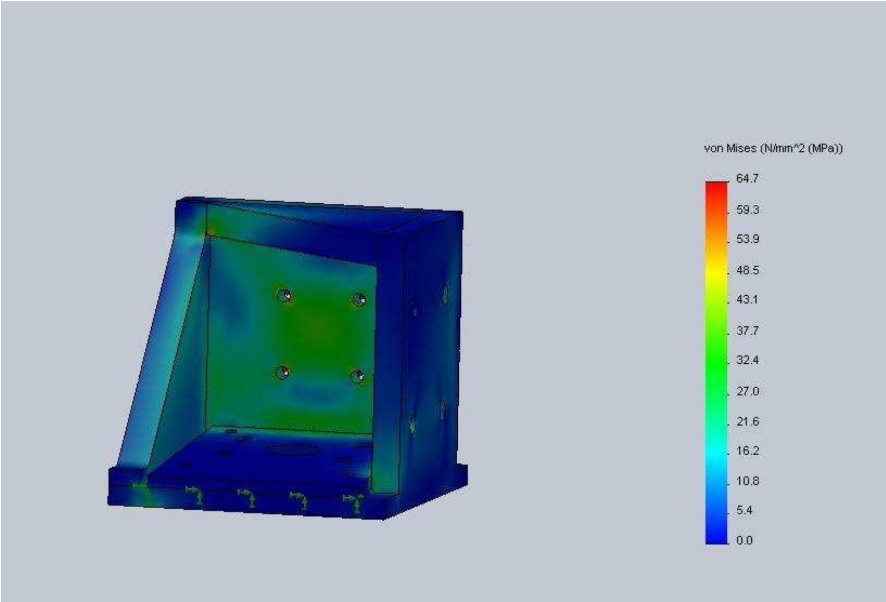


Figure 51: Stress, 100 kN longitudinal

Displacement

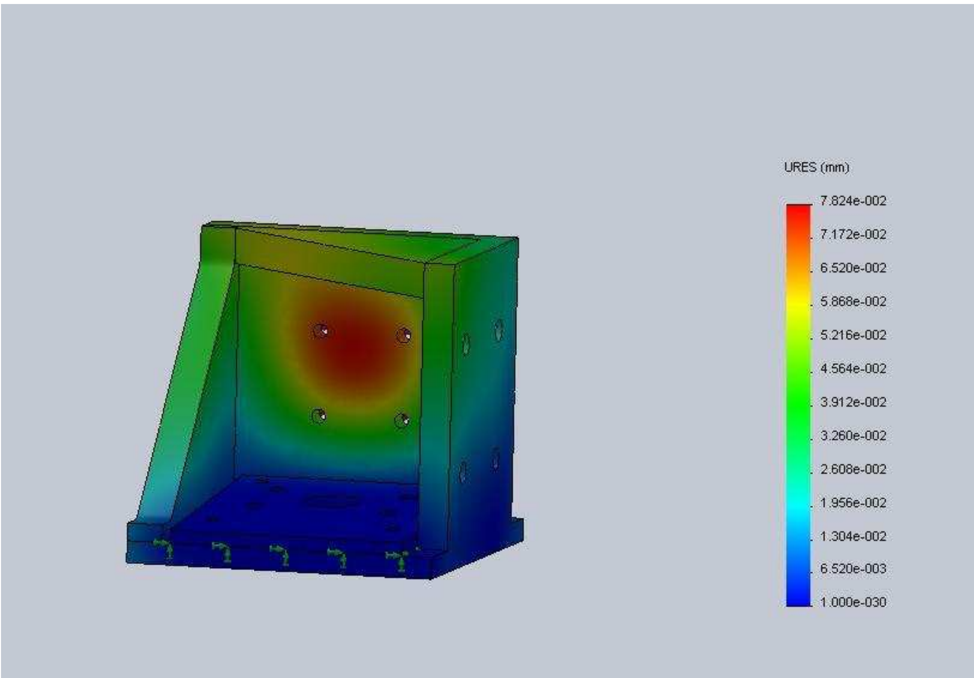


Figure 52: Displacement, 100 kN longitudinal

Finite Element Analysis stabilizing beams/bars -Idea 2 – Main idea

<u>45 mm wall thickness – 200 kN transversal</u>

The wall thickness was increased (from 35 mm to 45 mm), and the height of the bracket walls reduced (from 350 mm to 300 mm). By doing so, one was able to reduce the size of the stabilizing bars, and decrease the stress and displacement.

<u>Dimensions top bar</u>

Thickness: 40 mm
Length: 368 mm
Width: 50 mm

<u>Dimensions side bar</u>

Thickness: 40 mm
Height: 325 mm
Length: 320 mm
Length of fastening plate: 40 mm

Stress

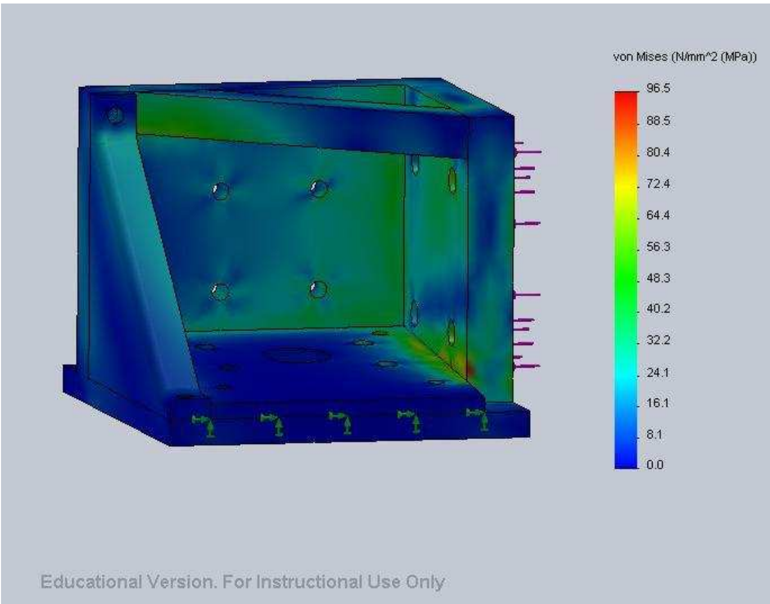


Figure 53: Stress, 200 kN transversal

Displacement

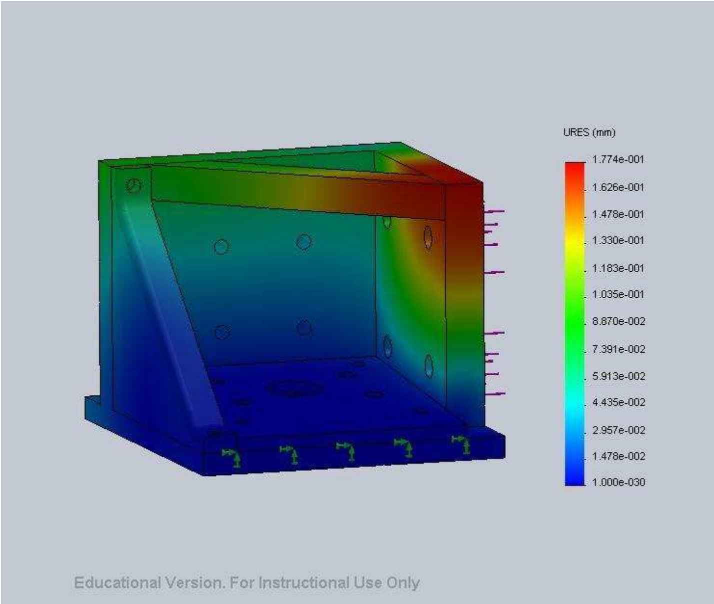


Figure 54: Displacement, 200 kN transversal

45 mm wall thickness – 100 kN longitudinal

Stress

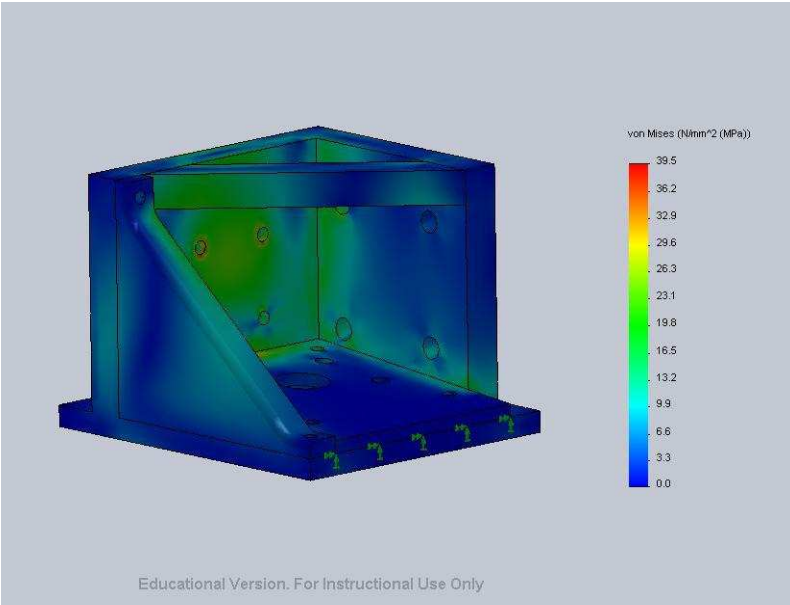


Figure 55: Stress, 100 kN longitudinal

Displacement

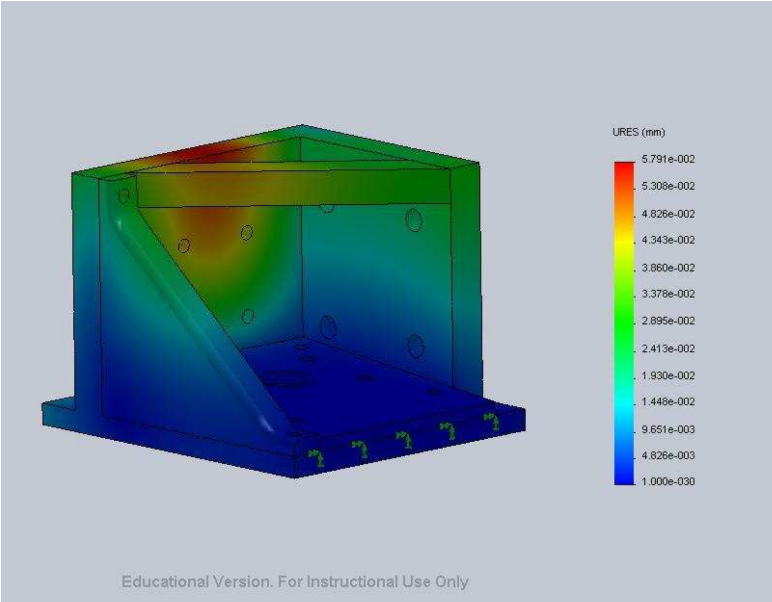


Figure 56: Displacement, 100 kN longitudinal

4.2.2. Rail system

The rail system is mounted beneath the main bracket. The first idea for the rail system was an assembly containing four rails with corresponding carriages (runner blocks). The two bottom rails are attached directly to the rig, while its corresponding carriages are attached to a platform. The two remaining rails and its carriages are attached on top of this platform turning 90 degrees compared to the bottom rails. The top carriages are attached to the main bracket.

By assembling the different components in this way, it will make the system move freely in x- and y-direction. The reason we want the entire system to move freely in both directions is so that almost all the forces applied to the system will be absorbed by the V-stay, since this is the part we want to test.

The carriages in the system will move on the rails with the help of ball bearings. The reason we chose carriages with ball bearings is because we need high precision, the system have very little movement, therefore precision is an important part to consider when choosing the different parts in the system. These rails and carriages will not experience any forces, other than the weight of the brackets and V-stay bottom lying on top of it.

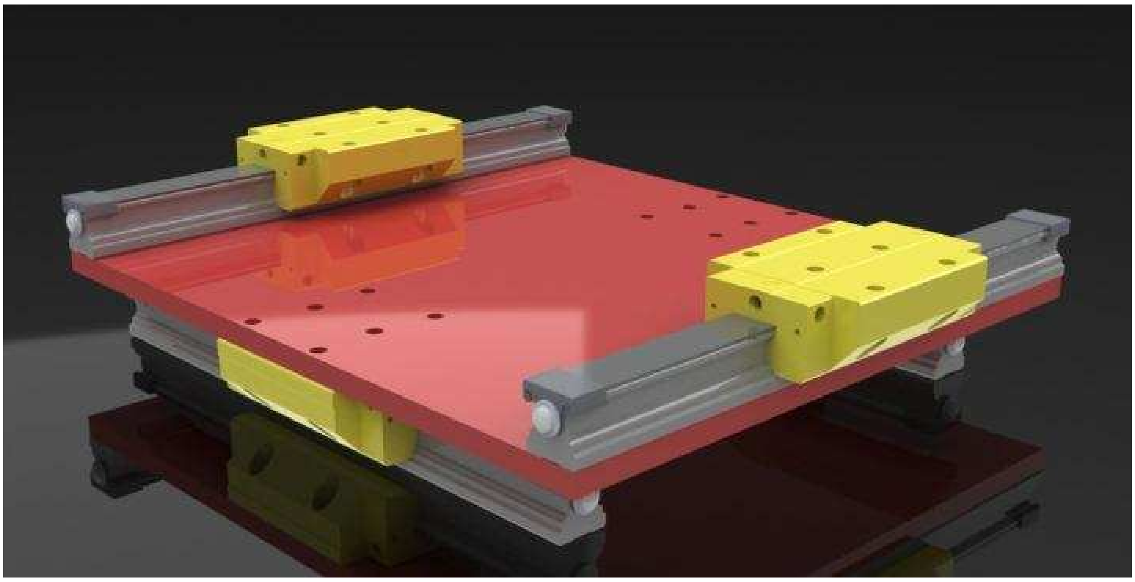


Figure 57: First idea

After consulting with Bosch Rexroth and Elmeko AS, the project came to the conclusion that two carriages on each rail was necessary, the principle and movement of the system will still be the same. By applying one more carriage on each rail, we will stabilize the system more, and get a more accurate movement.

The rail system consists of thirteen different parts (a separations plate, four guide rails and eight carriages).

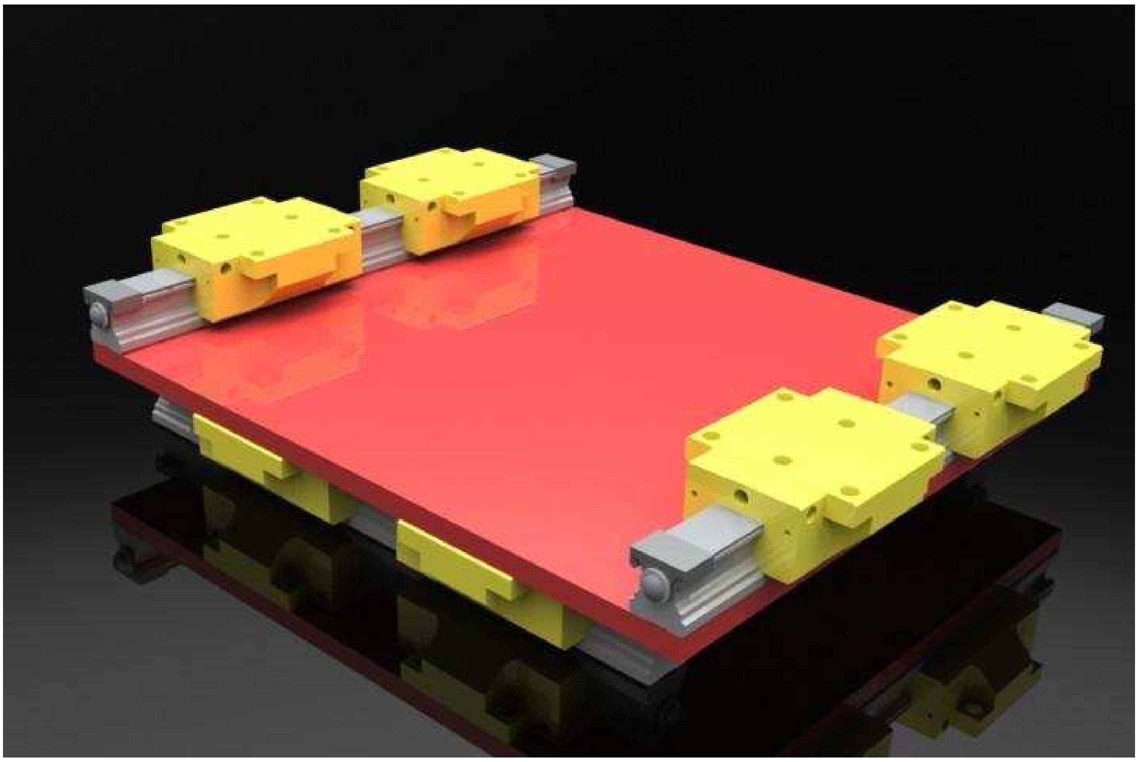


Figure 58: Main idea

Separation plate

The separation plate is extruded upwards from a rectangular center drawn sketch (in context with the length of upper guide rails). The purpose of the separation plate is to separate the top and bottom rail systems. The bottom rail system is facing the longitudinal direction, and the top rail system is facing the transversal direction (making a multiple axis system). The separation plate has got ten drilled holes (M8 x 1.25), five on each side, for attachment of the guide rails. It has also got sixteen drilled holes (M8 x 1.25) on the opposite side, eight on each side. These holes are for attachment of the carriages.

Guide Rails and carriages

The project group chose linear motion systems from Schneeberger, supplied by Elmeko AS. The reasons are because of Schneebergers high performance, tolerances and stability. Elmeko AS is in addition significantly lower in cost compared to other suppliers of linear motion system [2].

The guide rails used in the model are from Bosch Rexroth. These are size 25, and has got length; 296 mm. There are used four guide rails in the rail system design.

The carriages used in the model are from Bosch Rexroth. These are size 25, standard width (70mm) and 86,2mm length. There are used eight carriages in the rail system design, two carriages on each guide rail for better stability.

Ideally, the guide rails and carriages in the model would be Schneeberger products. Luckily, all outer dimensions are the same. It would take a while to achieve 3D models of the rails and carriages that is going to be used, and the decision about using Schneeberger was bound to be made at a very late stage, thus leaving the project group without any options but to leave the model as it is.

Bosch Rexroth

Figure 59: Guide rails R160520431

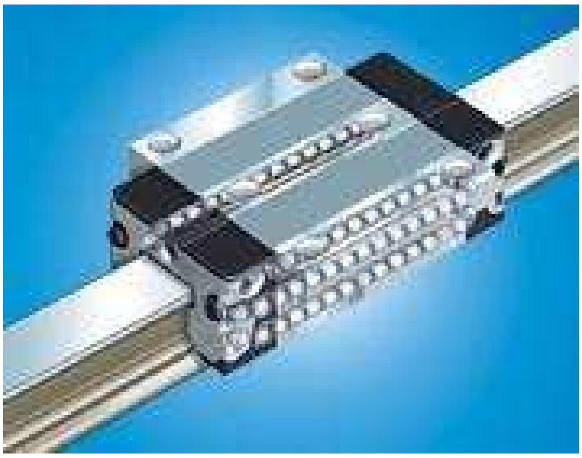


Figure 60: Runner blocks/carriages R165121420

Figure 61: Runner blocks/carriages R165121420

Schneeberger

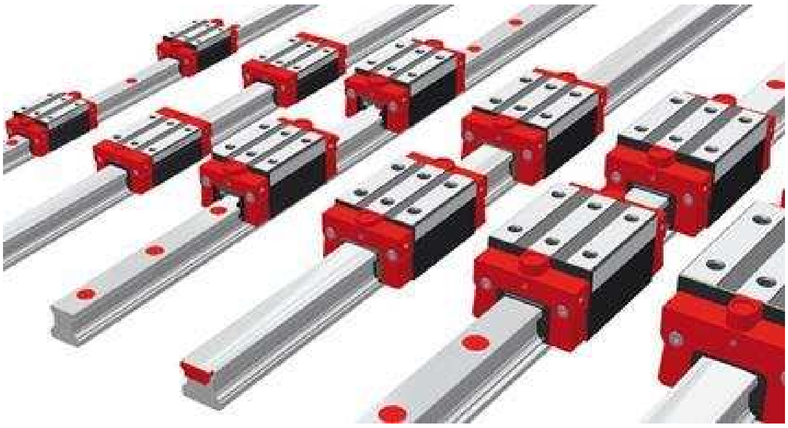


Figure 63: Guide rails BM24

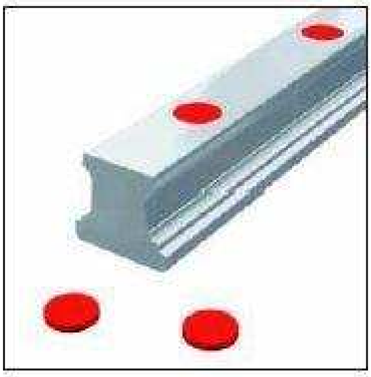


Figure 62: Plugs 32BRK-25

Figure 65: Runner blocks/carriages quality BM25

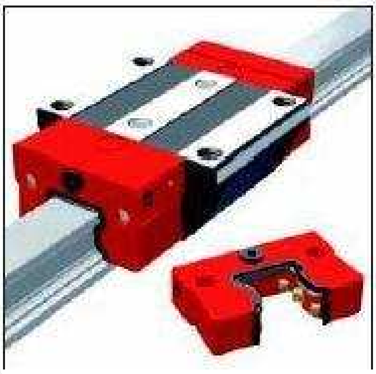


Figure 64: Lubrication plates SPL25-BM

4.2.3. Platform-sunken rail system

The group came up with two ideas; one with welded walls, and one with a plate sunken down and held with eight beams.

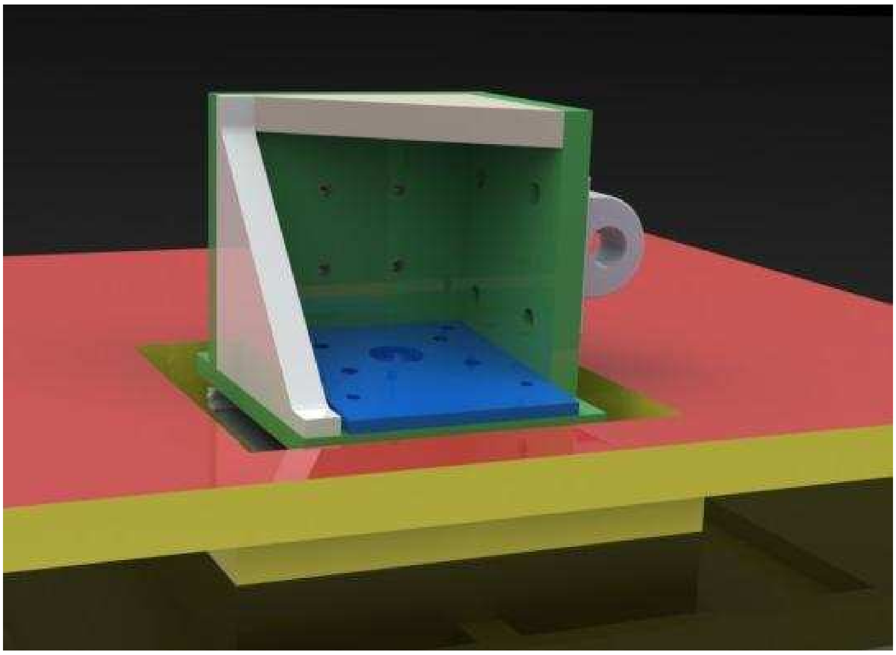


Figure 66: Idea 1 – welded walls

The main idea behind a sunken rails system was to lower the height of the bottom bracket with the rail system, and by doing so being able to mount the cylinders directly to the rig and positioning the V-stay better.
With the first idea we thought of cutting a hole in the platform and by lowering a platform with four welded walls, and mounting the rail system inside.

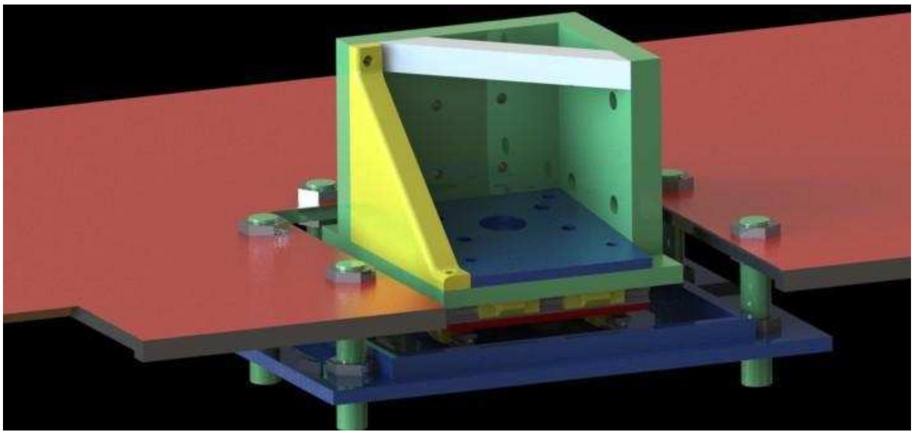


Figure 67: Idea 2 - beams

The bars are mounted around the square cut, and there are six beams in total. The threaded bars with corresponding adjustable nuts on each on each end will hold the sunken platform in place. This is basically the same principle as the first idea, we have sunken a plate/platform and mounted the rail system on it, here the plate is held with the six beams. By using beams, the rail system will not be concealed, it is easy to access incase of service, maintenance and so on.

The entire platform consists of twenty different parts (main platform, six beams/bars with adjustable nuts on each end and a sunken platform).

Main platform

The main platform is built up from a rectangular center drawn sketch (1300 mm x 1800 mm). The sketch is extruded upwards 10 mm. The main platform is then hollowed with a wall thickness of 30 mm. There is made a cut (through all) from a rectangular center drawn sketch (500 mm x 620 mm) on the long side of the main platform. The cut is splitting the long side to make room for the V-stay. There are made two holes on each side of the rectangular cut (six holes in total). These holes are made for the beams/bars. There are made ribs (30 mm x 50 mm) underneath the main platform, to stabilize the structure.

Sunken platform

The sunken platform is extruded upwards 20 mm from a rectangular center drawn sketch (center of rectangular cut in main platform). The rectangular sketch is drawn 50 mm on the outer side of the beams/bars holes on the main platform. The rectangle has a width of 620 mm. The sunken platform has got six drilled holes that are in context with the drilled holes on the main platform. An island is built inside the sunken platform. The island will contain the rail system. The island is built up from a rectangular sketch, 20 mm thickness, 450 mm width and 500 mm length. The sunken platform is mounted to the beams/bars.

Bars for adjustment

The bars are extruded 150 mm up from a circular center drawn sketch (40 mm). They will in reality simply be threaded rods with a length of 150 mm. Nuts on each side of both the rigs platform and the sunken platform will secure the sunken platform in place, and provide easy adjustment of its height.

4.3.Vertical testing

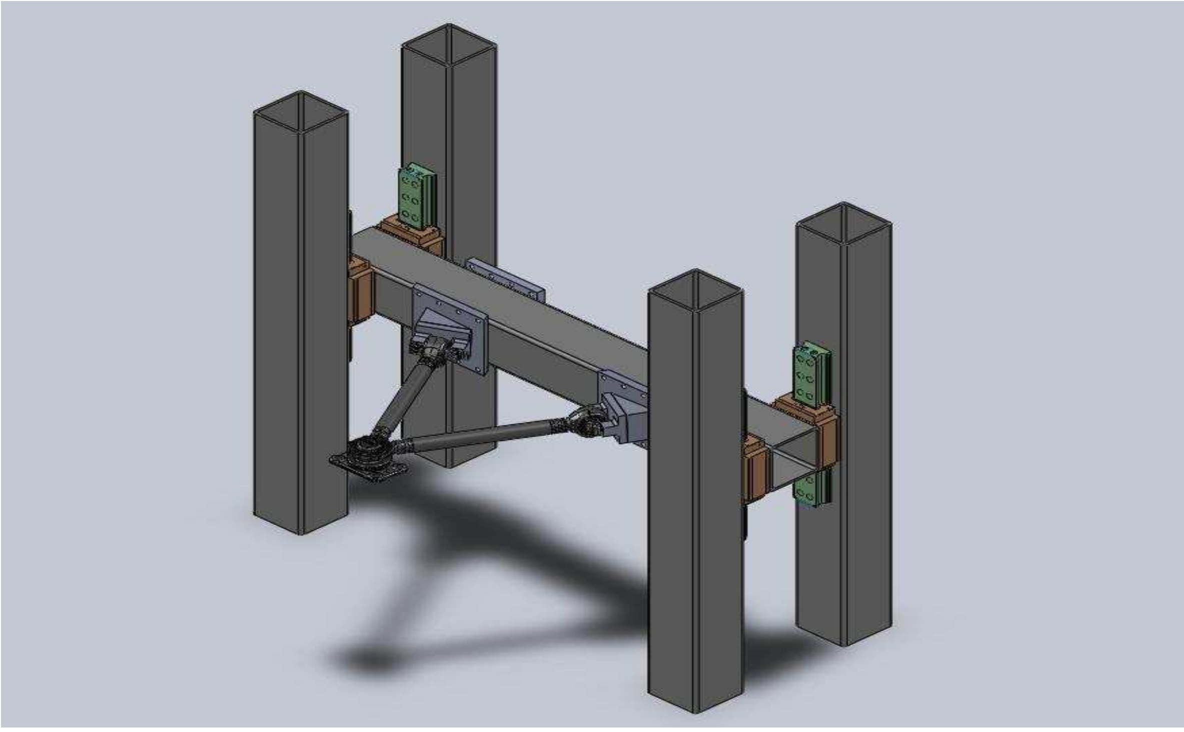


Figure 68: An overview of the vertical testing system

The vertical section is split into different parts.

4.3.1. Horizontal beam

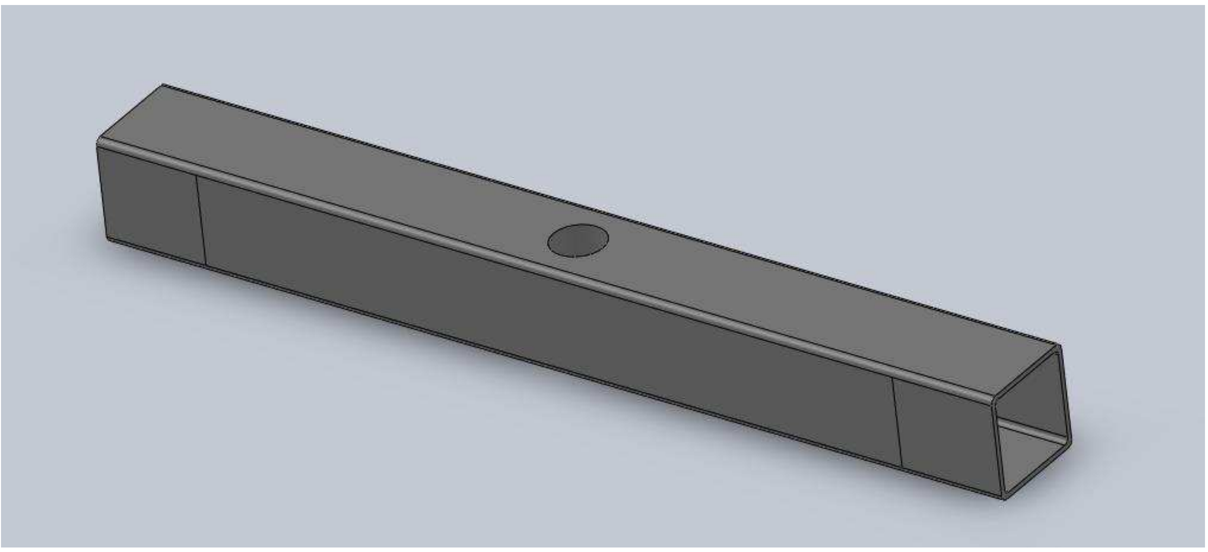


Figure 69: The horizontal beam

The horizontal beam, meant to hold the V-stays legs and make them move up and down, is a 200 x 200 x1790 mm standardized square beam. With its flat surfaces which make up endless possibilities for mounting, relatively light weight and low cost, it fills all our design

needs. The geometry of this type of beam is also simple enough to perform constructional analysis by hand. This gives an advantage regarding whether we can trust FE analysis done by SolidWorks Simulation or not. Two bending stress analysis in particular have to be done. One of them will demonstrate stresses due to maximum force applied longitudinal, and the other will demonstrate maximum force applied transversal, whereas there were some difficulties in the hand calculations for the transversal applied force. The beam will have at least four fixed constraints throughout its length, and since gravity acting on the beam will be the only force acting on the beam while testing vertically, we will neglect this from our analysis. Bending moments due to applied forces will be the dominating factor for stresses in the horizontal beam. The first picture shows the total stress in the beam, and the second picture shows normal stresses in the beams x-direction.
Note: Rails and carriages are included only for fixture purposes, to assure realistic stress distribution.

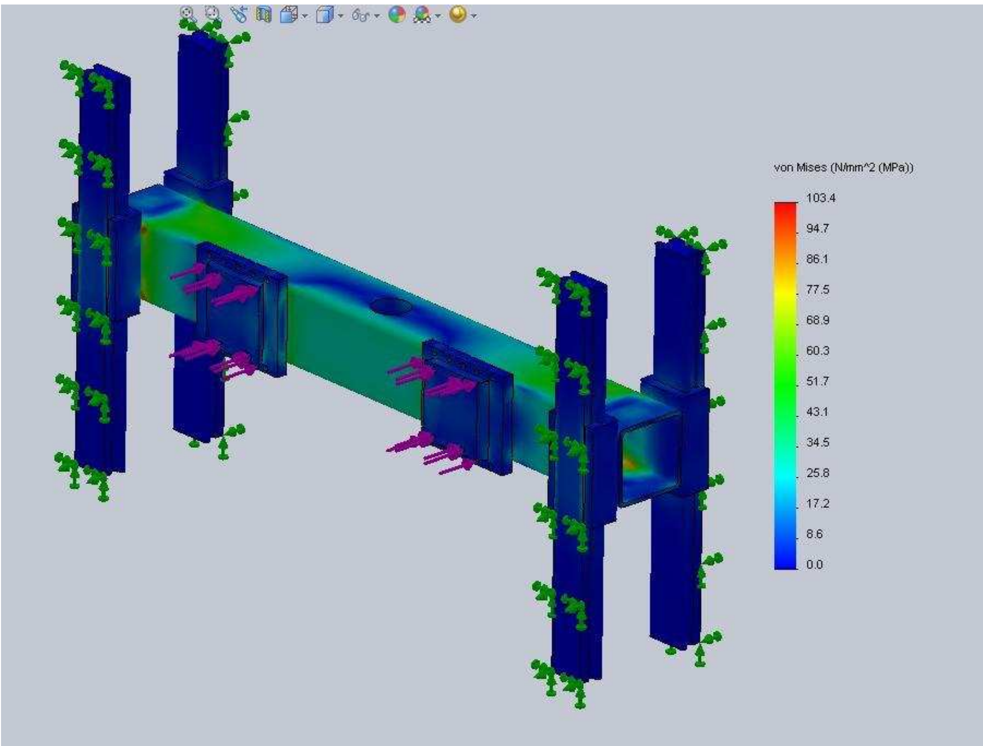


Figure 70: Total von Mises stress

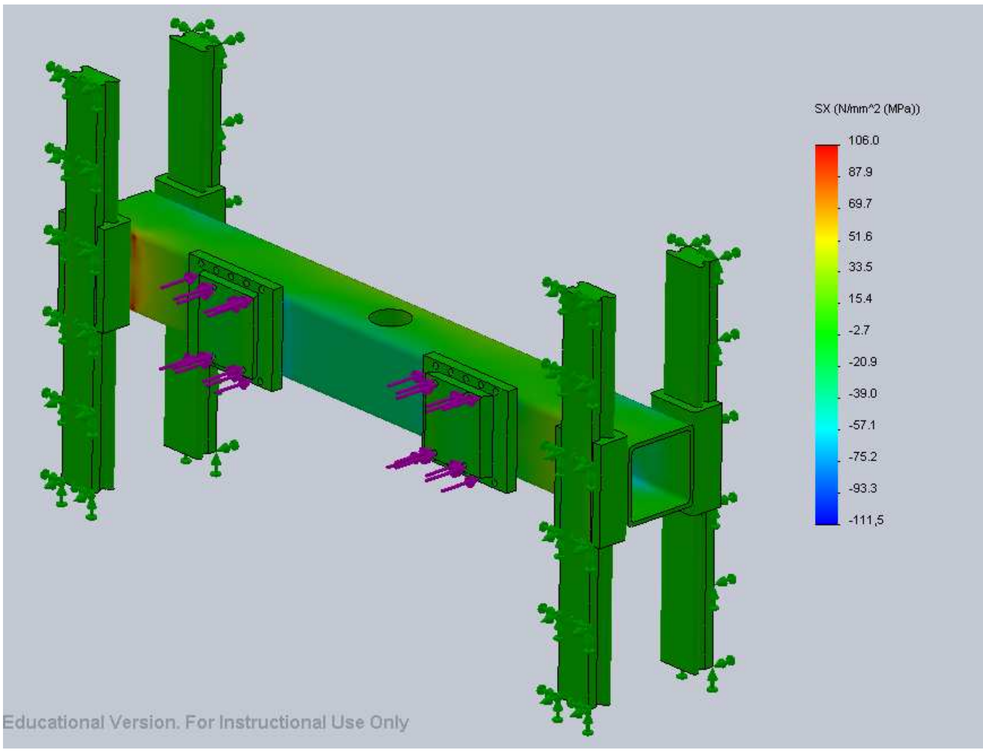


Figure 71: Normal stress in x-direction

As one can see, the total stress and the bending stress is very close in magnitude, which means that as long as the V-stay is positioned right and all brackets are properly designed/made, the V-stay will experience mostly bending stress. Some shear stress will also occur, but according to Von Mises, they will not contribute to a larger total stress. Hand calculations shows that SolidWorks Simulation is not far off:

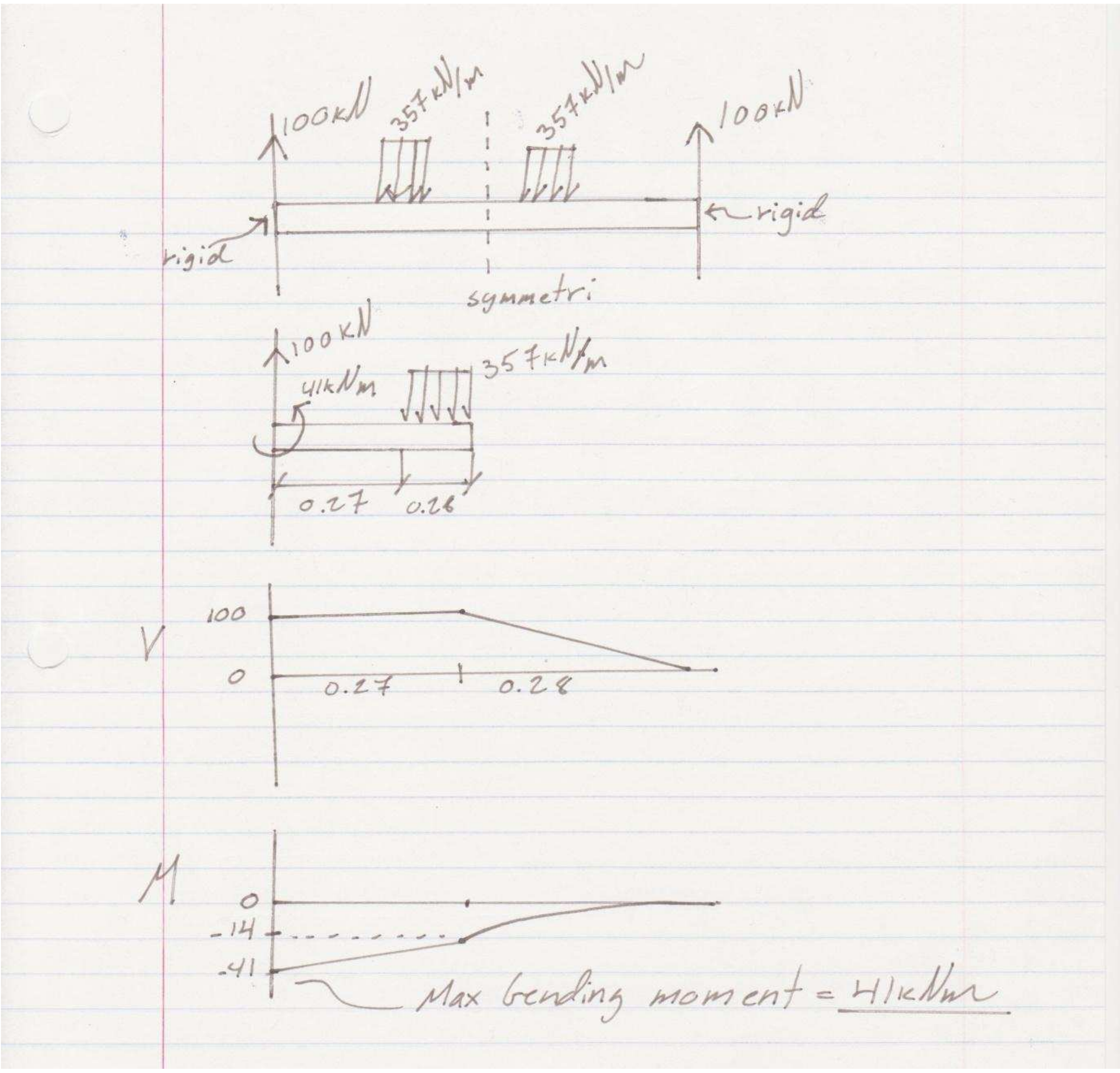


Figure 72: Hand calculations, bending moment [1]

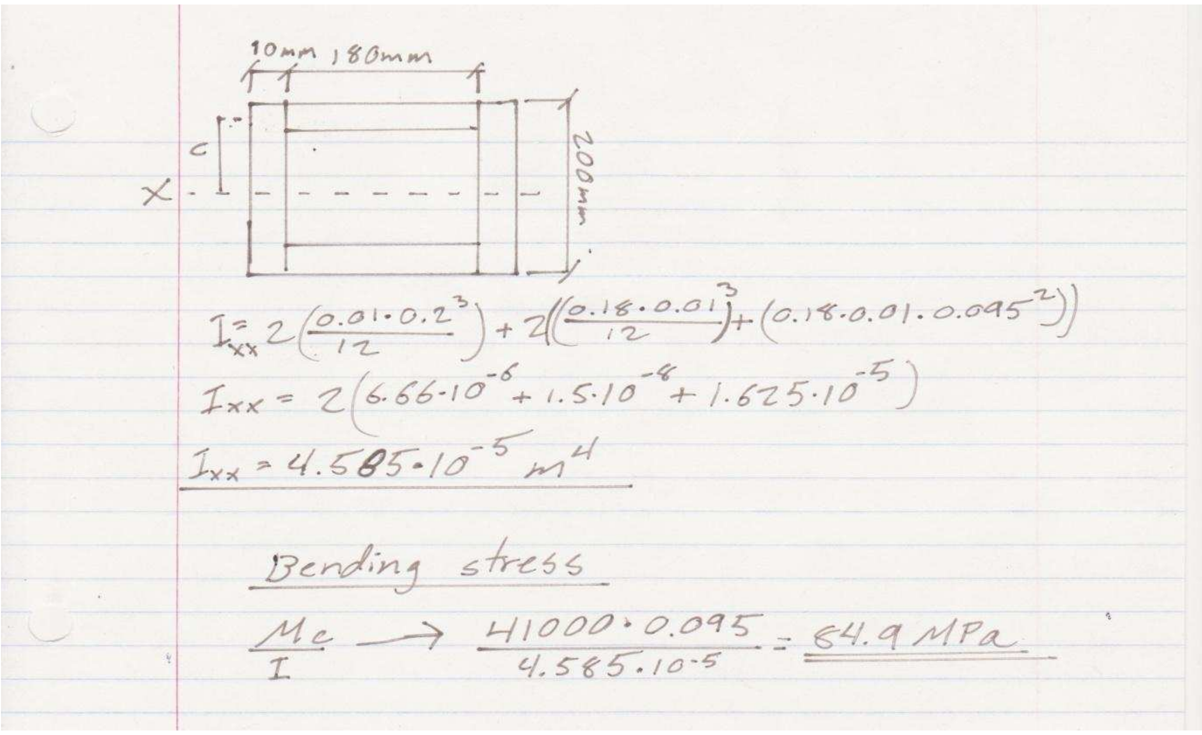


Figure 73: Hand calculations, bending stress [1]

To allow for the vertical cylinder rod to pass through the beam (due to a stabilizing bar hanging on top of the horizontal beam), a 100 mm hole had to be made, which in turn was "filled" with 10 mm walls . This should in theory not do much to the strength of the beam, and it is not considered in calculations. Also, there will be one hole on the top surface on each end of the beam. This is to make it possible to attach/detach and service the rails and carriages described later in the vertical section of this document. These holes do not show in the 3D model, nor in the 2D sketch. This is because the exact size needed for the holes to allow easy access is not yet decided.

4.3.2. The four vertical beams

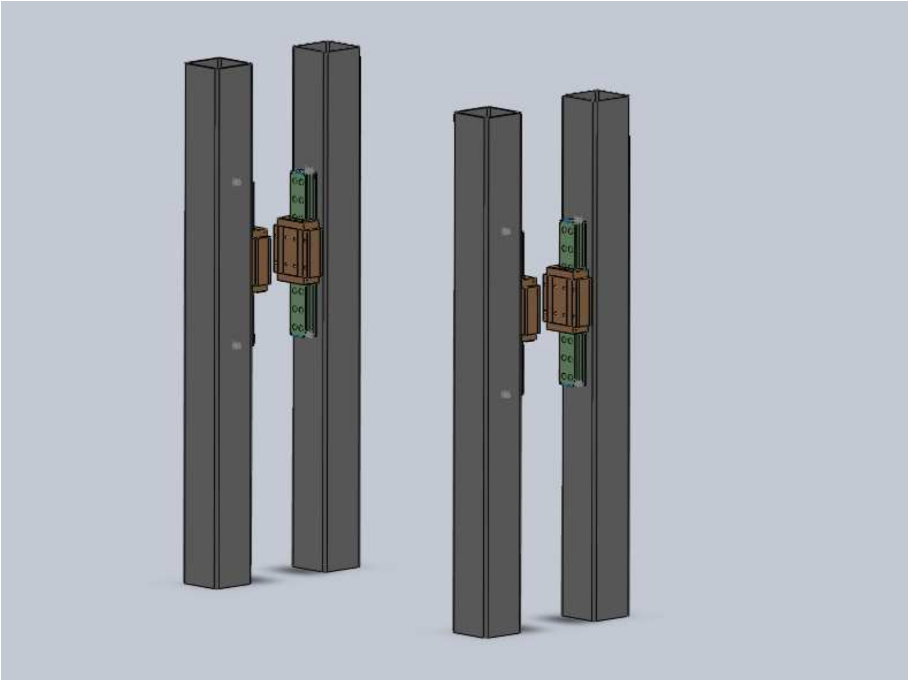


Figure 74: The four vertical beams

Again, for mounting, weight and strength purposes, 200 x 200 mm square beams are used. These will be subjected to mainly bending stresses, very similar to the bending stresses that the horizontal beam is subjected to. Still, separate calculations have been done in the section of this document concerning the frame of the rig.

4.3.3. Rail system

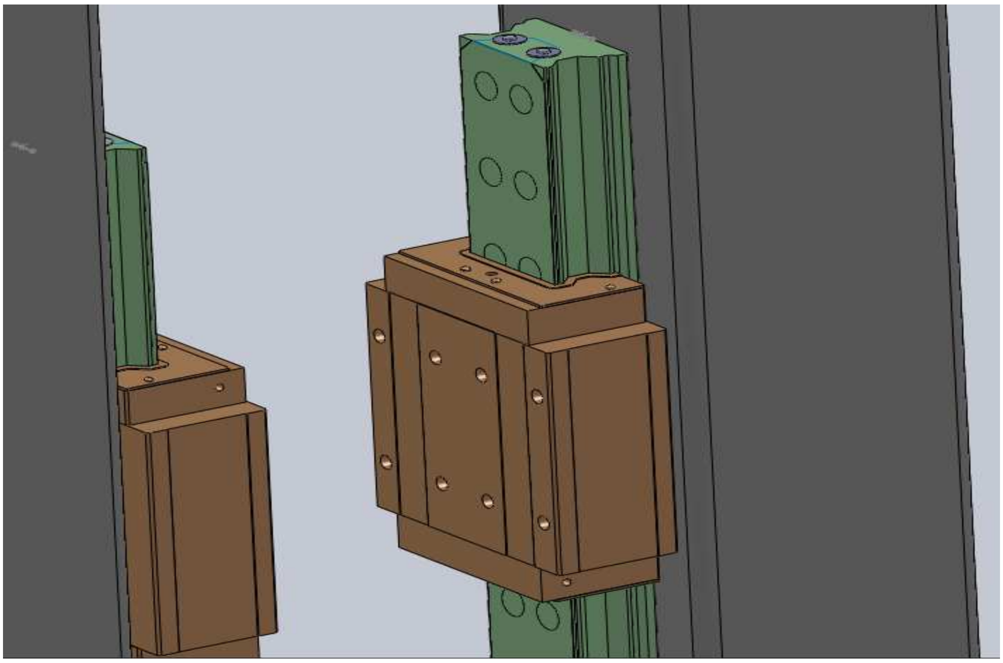


Figure 75: The rail system for vertical testing

The rails and carriages that make it possible for the V-stay's legs to move up and down the vertical beam are the roller bearing type. The option was using ball bearings, which would give less friction, but it would be able to handle significantly less strength. Since "double rails" on each side are used, the rails and carriages will experience little to no yaw, pitch or roll. However, all horizontal forces will be absorbed by the carriages and onto the rails. Luckily, data sheets made it easy to choose the right size rails and carriages.
Similar to the rail system used for horizontal testing, Elmeko will be supplying the project with Schneeberger rail systems. Both rails and carriages supplied by Schneeberger are made from high quality materials, and can safely be compared with products from other suppliers.

4.3.4. Mounting brackets for V-stays legs

Universal brackets for mounting of any V-stay

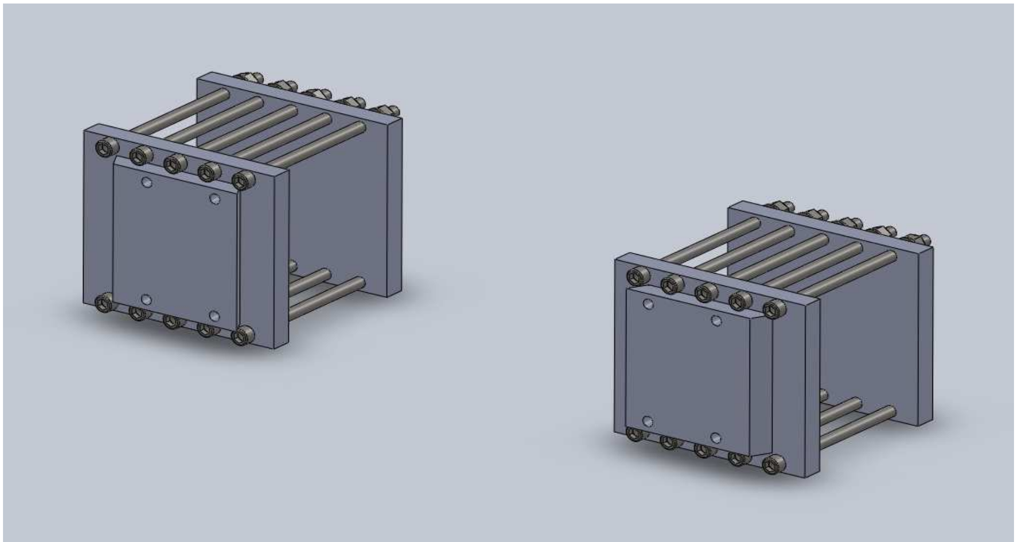


Figure 76: Universal brackets for mounting of any V-stay

To be able to adjust the width of the V-stays mounting points, these brackets are made to be easily loosened and slid sideways on the horizontal beam. When designing these, it was important not to make angles or other features that might be unique for one type of V-stay. Therefore, the mounting surfaces are parallel with the surfaces in contact with the horizontal beam, leaving all angle compensation to the custom made brackets presented on the next page. Because the brackets are so flat, they will not experience a lot of bending moments, so stresses will for the most part be compression stresses on the brackets, and tensile stresses in the four threaded holes and the 10 bolts connecting the brackets to the back plates. The bolts will be at least a grade 8.8 bolts, which means they can withstand approximately 800x0.8=640 MPa. The threads are M16, and the nuts have enough strength and thread engagement (height) to withstand more than the bolts itself. If, and only if washers or other locking solutions allow us to neglect loosening due to vibrations, then the calculations should be pretty easy:

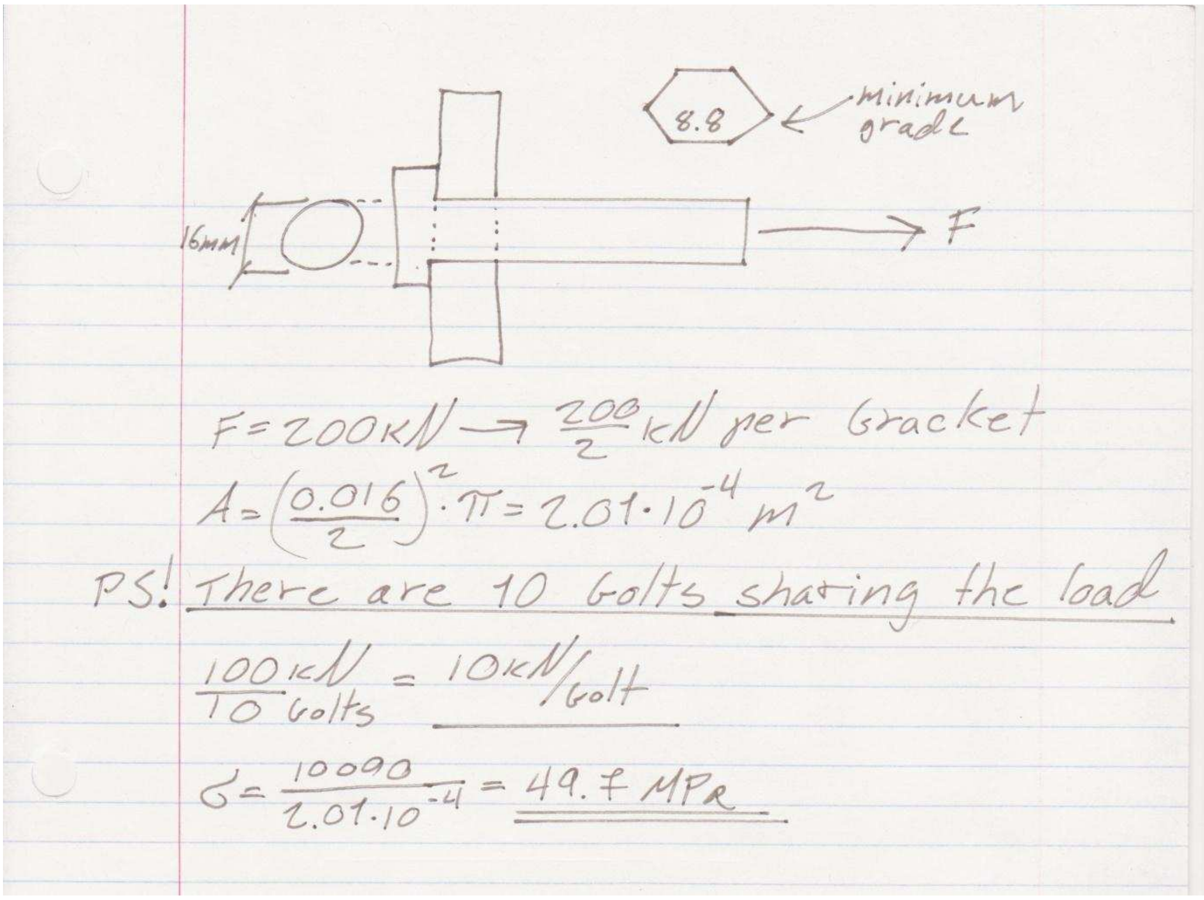


Figure 77: Hand calculations, bolt dimensioning [1]

As seen in the hand calculations, there is no reason to worry about the bolts clamping the two pieces of the universal bracket to the horizontal beam, with a safety factor of 640/49.7=12.9. The reason 10 bolts are used is simply to ensure enough clamping force on the horizontal beam, as experience indicates that even 8 bolts are insufficient. Double sets of clamping brackets may have to be made, time will have to show, and as the calculations showing whether or not it will be necessary is a bit beyond what any member of the MTR group is able to do.

No finite element analyses/SolidWorks Simulations are done on the universal brackets.

Mounting brackets custom made for any V-stay

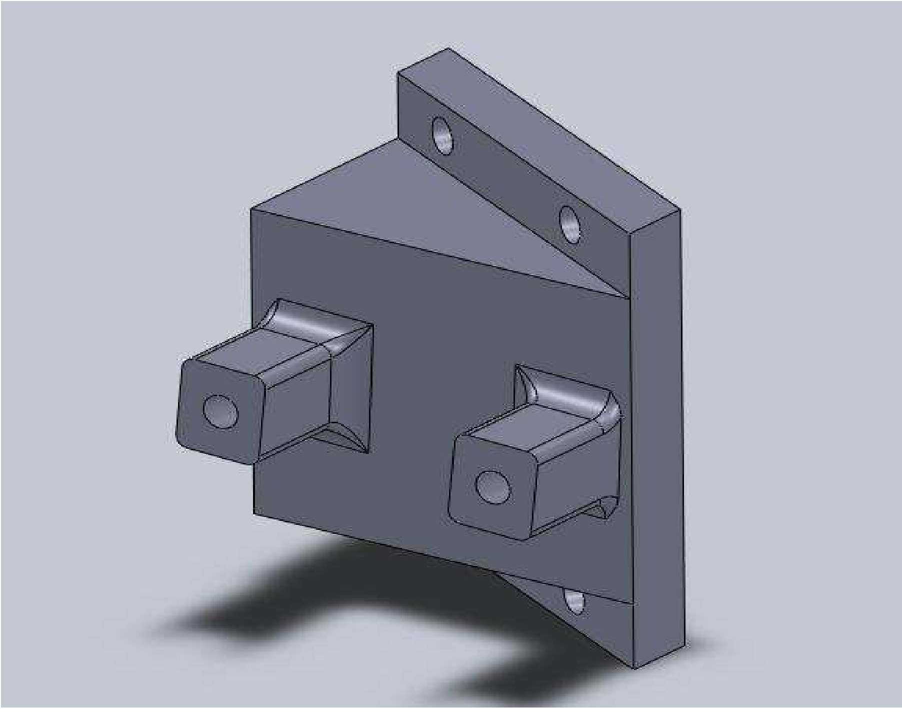


Figure 78: Mounting brackets custom made for any V-stay

The bracket in the picture is made especially for the Volvo V-stay that was used throughout the design of the whole rig. It has angles in almost every direction due to the V-stay’s legs being placed horizontally in the rig. Still, it is designed in a way that forces coming from the V-stay will act normal to a cross section of the mounting pieces (the ones that connect the V-stay to the bracket), so they will experience little no shear stress or bending moments. The whole point about the custom made brackets is that they should be fairly cheap to manufacture, and of course fit into the four threaded holes of the universal bracket no matter what type of V-stay is going into the rig. They should hold up to all applied forces easily, as correct mounting will only cause normal compression and tension stress. However, a simple calculation has been done:

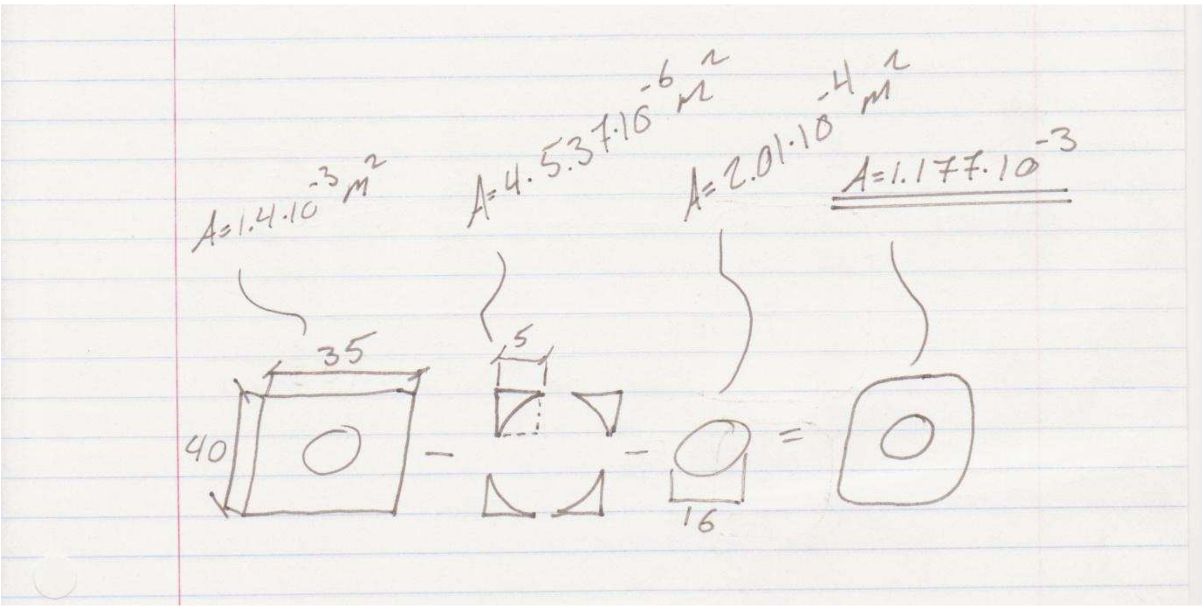


Figure 79: Compression analysis, normal stress [1]

The picture above shows the cross sectional area of which all applied forces will act normal to. Now that the area is found, a stress analysis can be done:

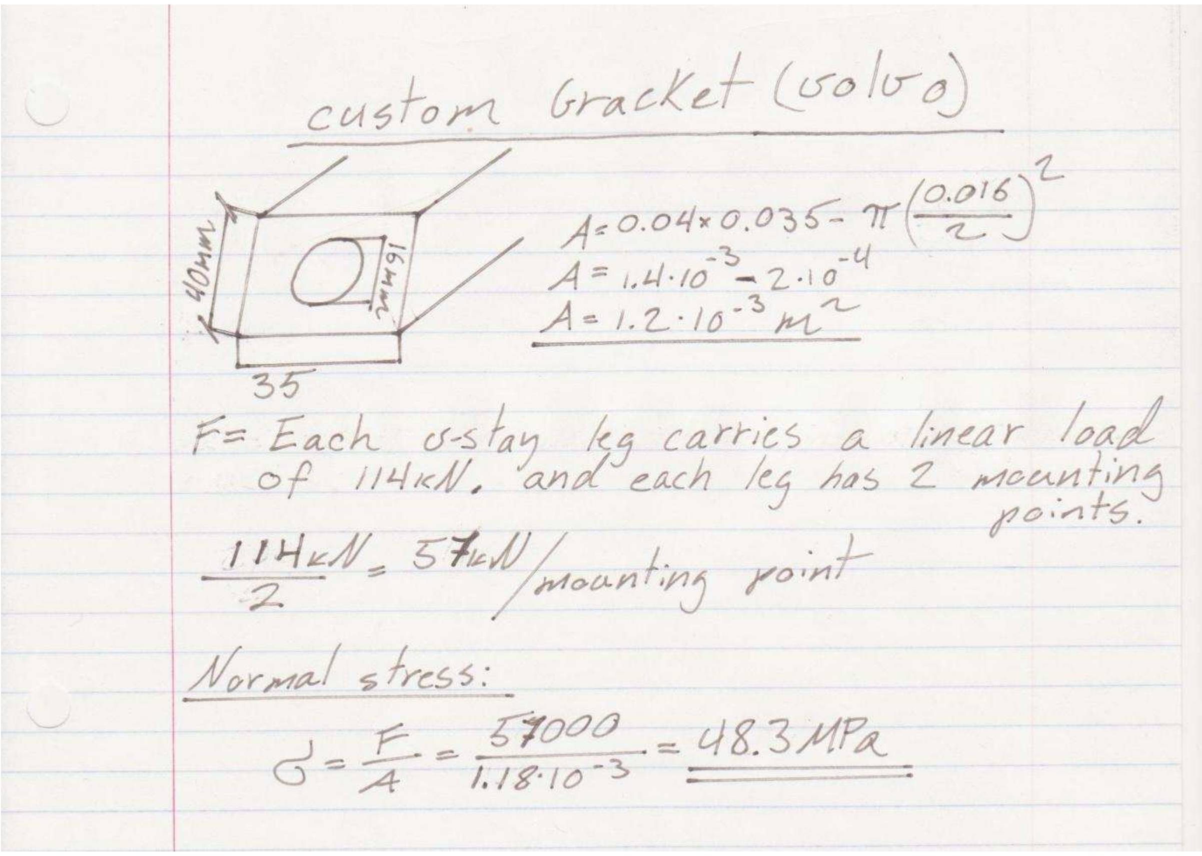


Figure 80: Normal stress [1]

Finite Element Analysis

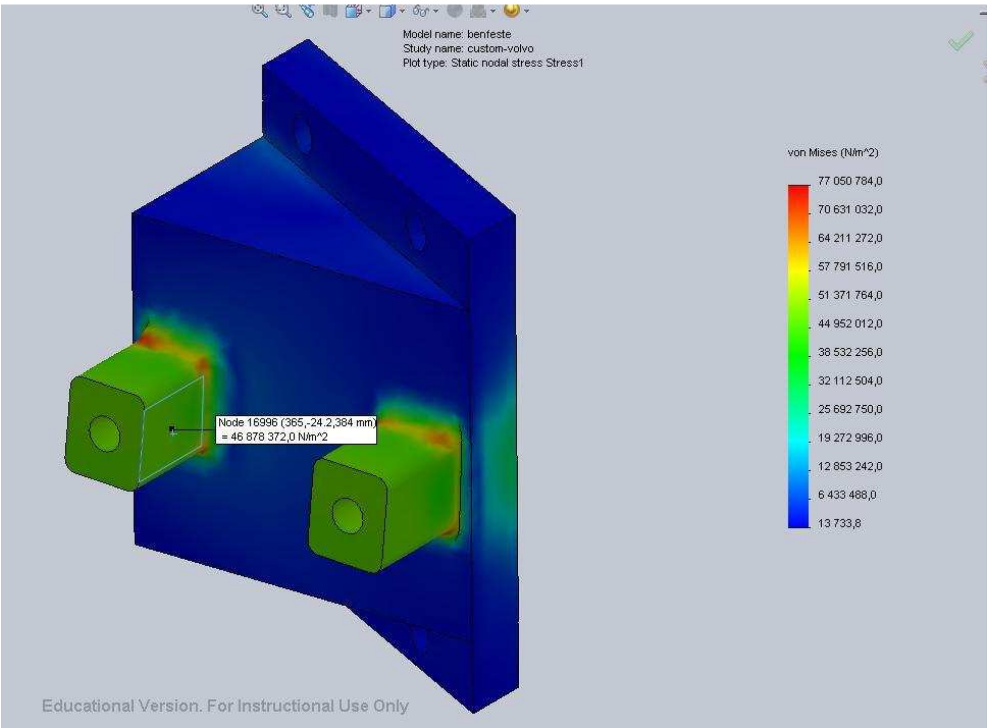


Figure 81: Stress, total force of 114 kN

The picture shows some stress concentrations that was really difficult to avoid. Fillets were used to reduce them significantly, and as far as one can see, there may not be any in the real life product. One node was chosen (showing approximately 47 MPa) on the uniform part of the mounting piece, to confirm the hand calculation was done correctly.
The four bolts connecting the custom made bracket to the universal bracket, will experience 10/4=2.5 times the tensile stress that the ten clamping bolts in the universal bracket will experience. This means the stresses will be 2.5x49.7=124.5MPa, which in turn leaves us with a safety factor of 640/124.5=5.15. Again, this depends on the bolts grades being at least 8.8, thread engagement enough for the bolts to give up before its threads get stripped and loosening due to vibrations have to be neglected/taken account for.

4.3.5. Mounting for vertical cylinder

To make the mounting of the vertical cylinder to be as flexible as possible, there are used a wide-flange beam. Using a wide-flange beam gives the mounting of the vertical cylinder no need of using recurrent bolts that would have been necessary if squared beam where used. To gain more stability the wide-flange beam is in direct contact to the surface.

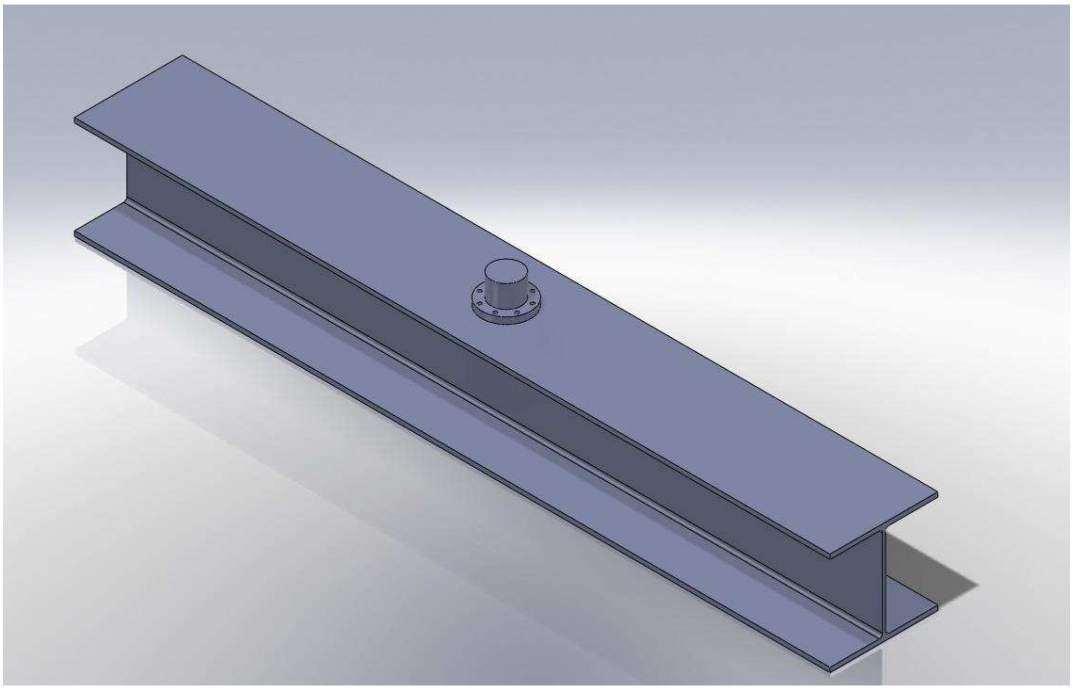


Figure 82: Bottom wide-flange with a test model of cylinder mounting

The figures show the wide-flange beam and a test model of the cylinder mounting and also the dimensions of the beam. Length of beam is 1400 mm.

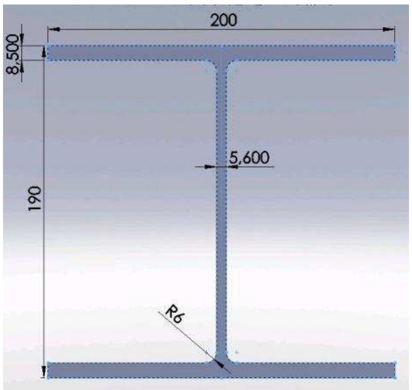


Figure 83: Cross-section dimensions

Finite Element Analysis

In analysis the beam is mounted in each short end. In reality the beam will be welded between the longitudinal beams and at the same time freestanding along with the whole frame. The vertical cylinder must be able to both push and pull. The analysis is divided into both these aspects. The force applied is 5 kN.

Stress

Stress in the beam when the vertical cylinder is pushing. The maximum stress is 6,7 MPa.

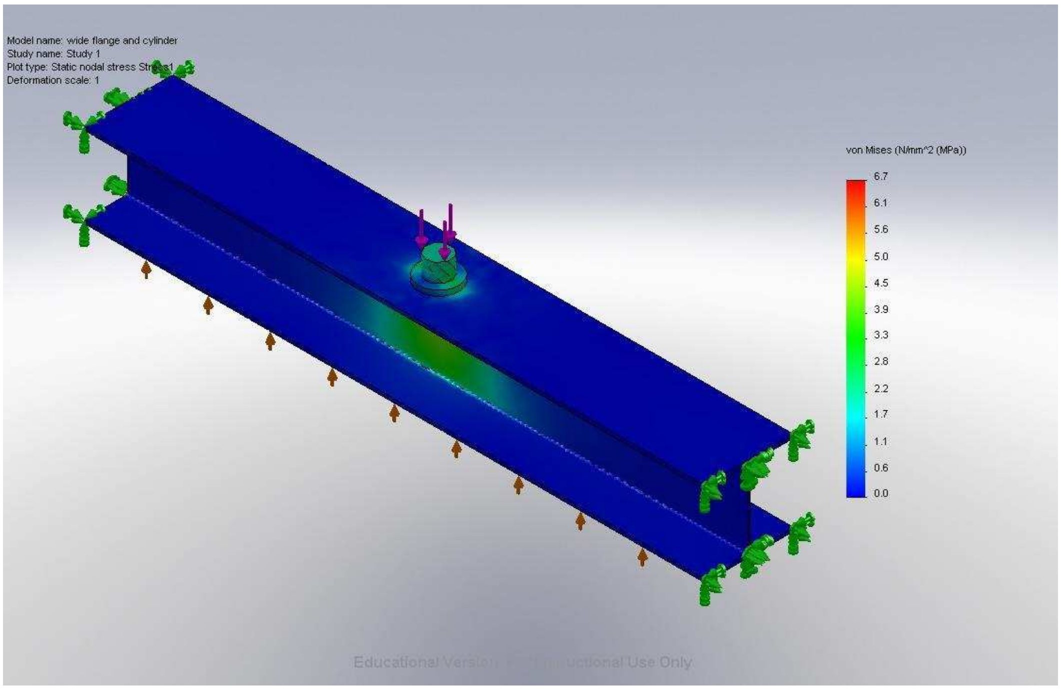


Figure 84: Stress when cylinder is pushing.

Compared to the yield strength there are no danger of fracture.

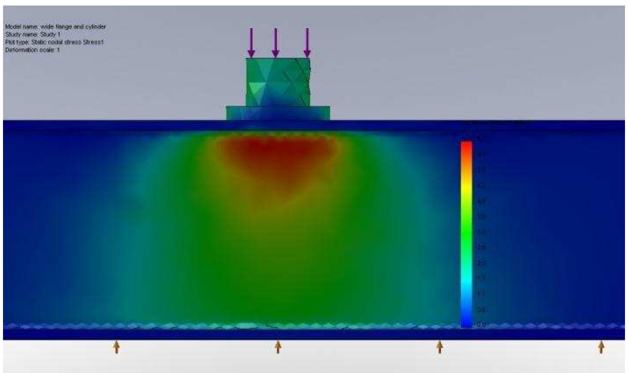


Figure 85: Stress distributed in the wide flange beam, side view

Stress in the beam when the vertical cylinder is pulling. The maximum stress is 7,2 MPa.

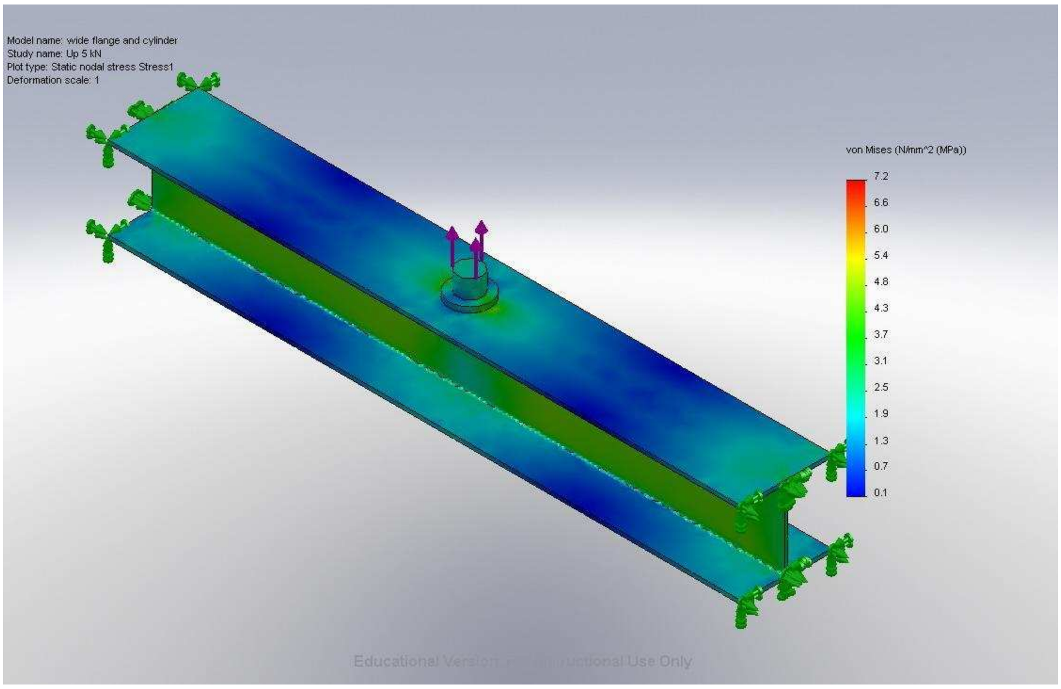


Figure 86: Stress when cylinder is pulling

Compared to the yield strength there are no danger of fracture.

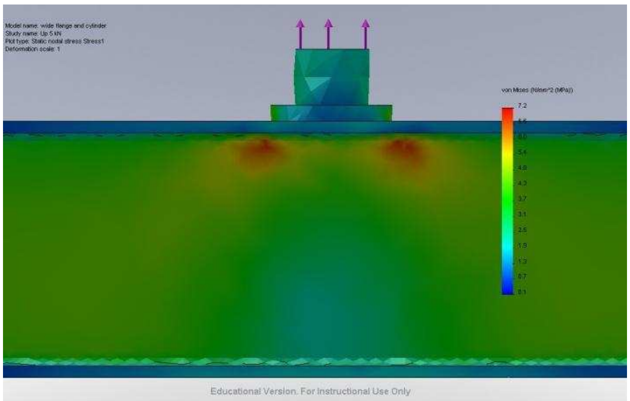


Figure 87: Stress distributed in the wide-flange beam, side view

The figure shows how the stress is distributed in the beam when cylinder is pulling. This analysis is somewhat different from reality. Because the cylinder has to carry the weight of the horizontal beam the V-stay legs are attached to. The figure will be smaller than in analysis.

Displacement

Displacement when vertical cylinder is pushing. Maximum displacement in the beam is 0,004623 mm which is more than acceptable.

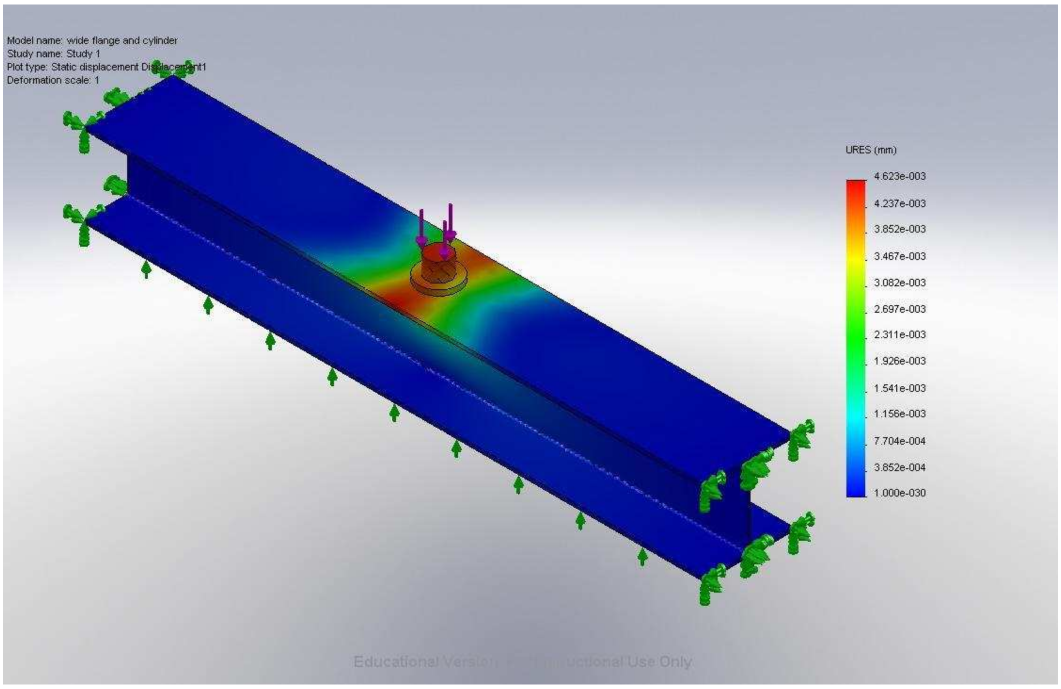


Figure 88: Displacement when cylinder is pushing

Displacement when vertical cylinder is pulling. Maximum displacement is 0,0335 mm. This figure will be reduced in reality when the vertical cylinder must carry the weight of the horizontal beam which is attached to the V-stay legs. But the figure is more than acceptable.

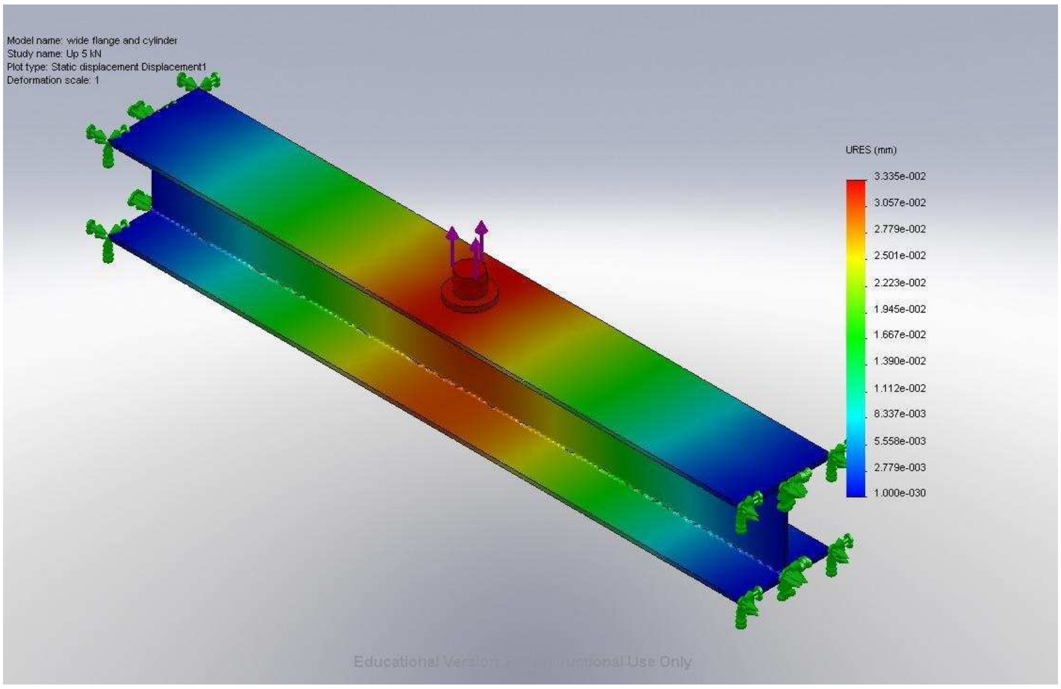


Figure 89: Displacement when cylinder is pulling

4.3.6. Stabilizer bar

The vertical force supply consists of one cylinder. Compared to the longitudinal and transversal force supply this cylinder must have a major stroke. This cylinder must be able to travel 377 mm in positive direction and 63 mm in negative direction, with an frequency of 0,2 – 1 Hz. In this context, upwards is considered positive and downwards is considered negative. This cylinder will mainly be used during the rubber bushing movement test.

The hydraulic cylinder must be able to lift the beam on which the V-stay legs are attached. Because one cylinder alone must lift a 1790 mm beam, the possibility of instability is high, therefore a possible solution to this problem may be a stabilizer bar. The meaning of the bar is to stabilize the beam and force distribution. The bar is build up from a house.

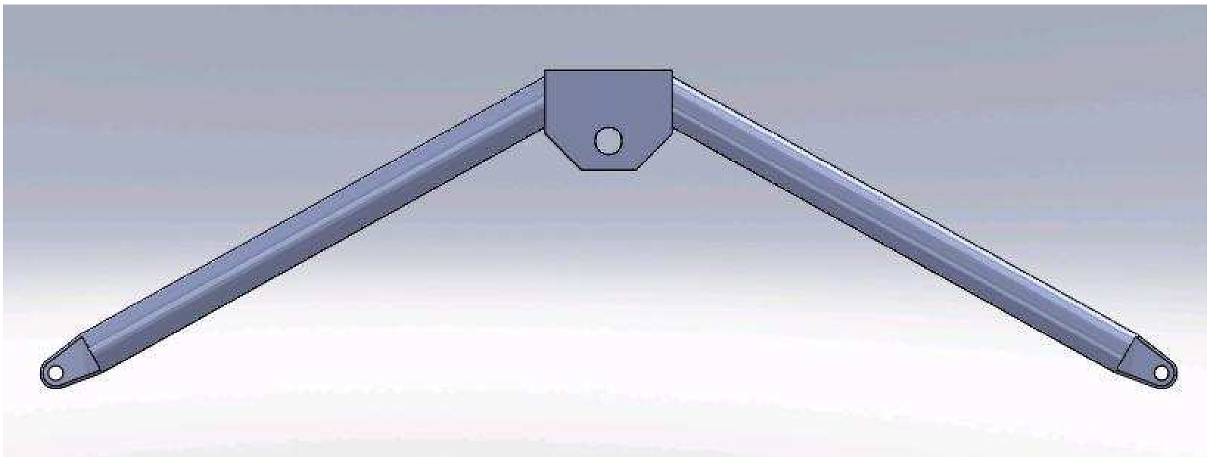


Figure 90: Stabilizer bar

Dimensions

Thickness of house: 5 mm
The outer dimensions of the house are: 110 x 140 x 55 mm
Hole dimensions in house: 30, 25 mm, located 32 mm from bottom of house
Tube dimensions: D 48,30 mm, d 40,3 mm, length 580 mm

The house is welded together by 5 mm thick plates. The angle between the legs is 122 °. The legs are welded to the short walls on the house. This house gives the legs a stabile structure to be welded in and will at the same time save material in compared to using a solid material house, less material costs and less weight. Each leg ends with a mounting point welded into the leg. Hole dimensions on the mountings are 16,25 mm. Both angle and length of legs are partially determined by the V-stay legs attach to the beam. The stabilizer bar should not interfere with V-stay brackets.

The stabilizer bar is the connection between the vertical cylinder and the horizontal beam on which the V-stay legs are attached. The vertical cylinder passes through this horizontal beam.

Brackets for stabilizer bar

<u>Dimensions</u>

Total: 260 x 115 x 30 mm
Hole dimensions: 16,25 mm

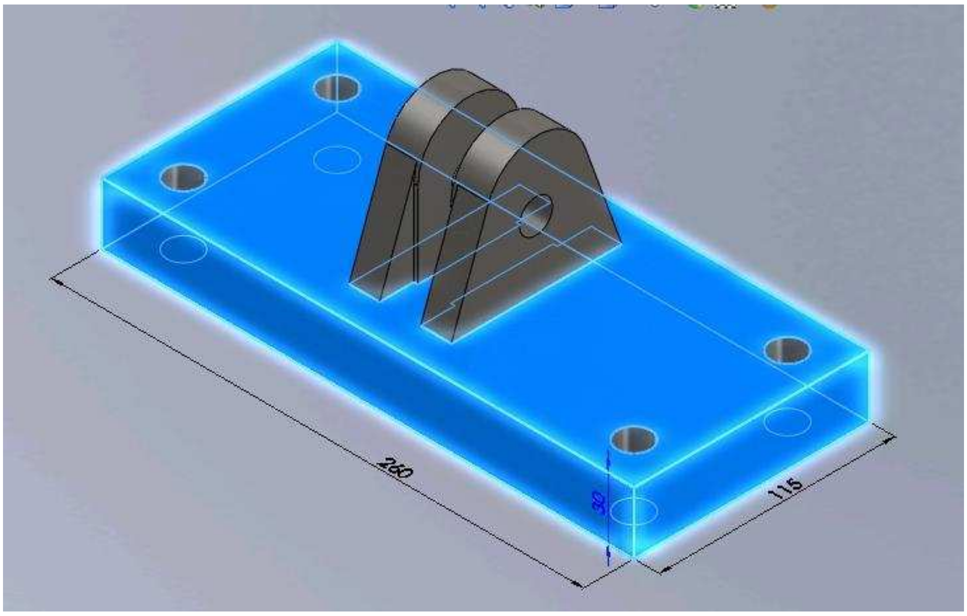


Figure 91: Bracket for stabilizer bar

The brackets must be able to withstand the stress produced by the vertical cylinder. The main task is to keep stabilizer bar in place without creating too much displacement. To be able to mount the brackets to the beam and at the same time not having to drill holes in the beam, clamp brackets are used. This is to get a stabile connection and at the same time preserve the strength of the beam. It also makes the brackets easy to adjust and also easy to replace if broken.

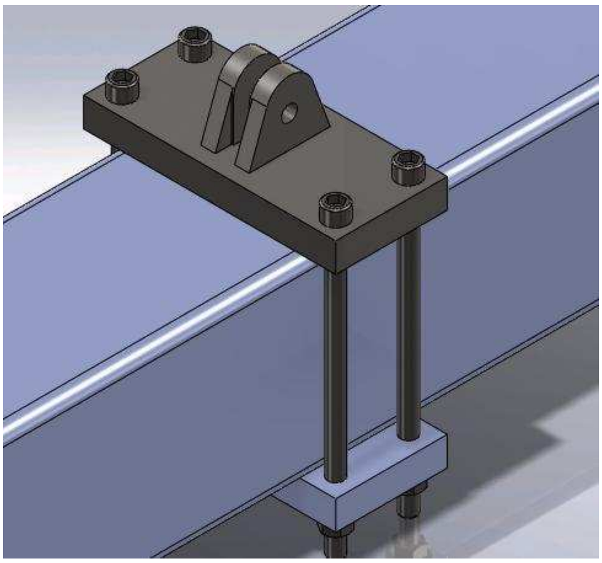


Figure 92: Clamp bracket

Clamp brackets secure the stabilizer bar to the horizontal beam which the V-stay legs are attached to.

Finite Element Analysis

The stresses produced in the rig must be considered in relations with the yield strength of the materials used. The requirement states that the stresses produced in the rig must not exceed 1/3 of the yield strength of materials. At the same time, it is very important to keep the displacement for the system as small as possible.

One of the most important issues in this rig is to reduce the displacement, so that test results become as correct as possible. First of all, the rig must measure stiffness, but will also be used for durability tests.

The force applied is 5 kN, this is what the vertical cylinder must be able to produce. This force will push the stabilizer bar up, and at the same time push the horizontal beam attached to the V-stay legs.

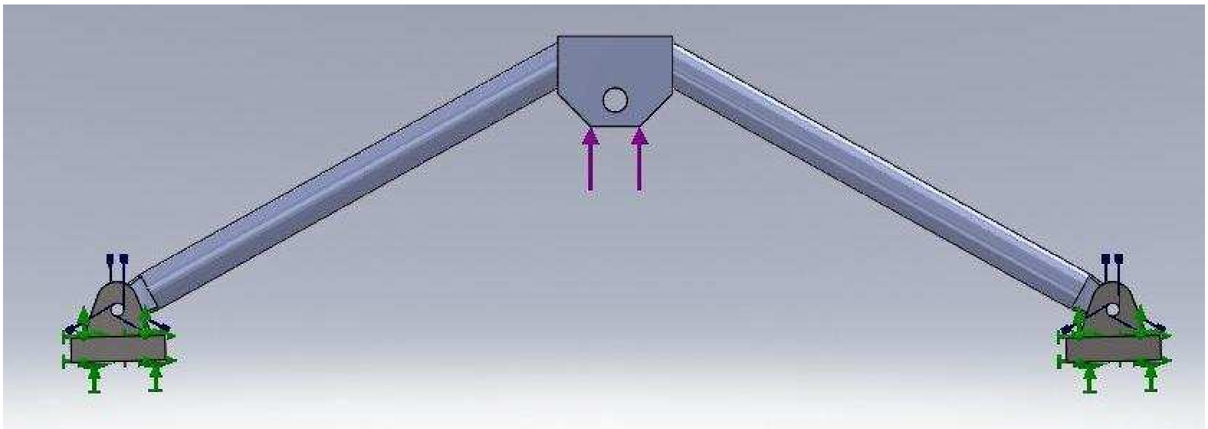


Figure 93: Stabilizer bar with force and fixtures

<u>Stress</u>

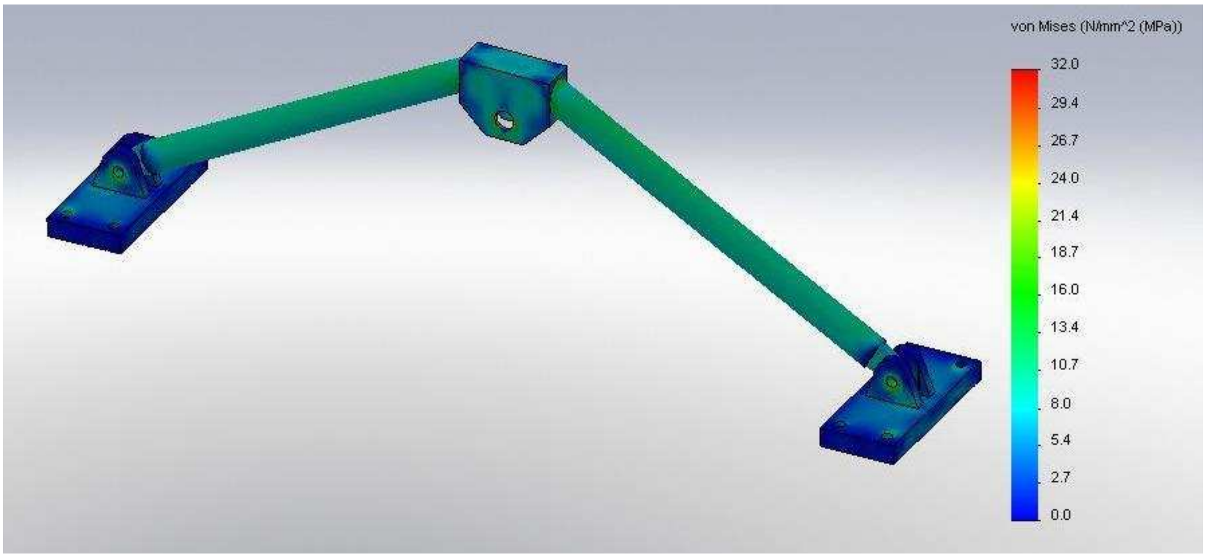


Figure 94: Stress distribution, force 5 kN

The figure shows stress in the bar. Maximum stress is 32 MPa, which is far from the yield strength of the material. The maximum stress is located in the mounting area of between the mounting and the bracket.

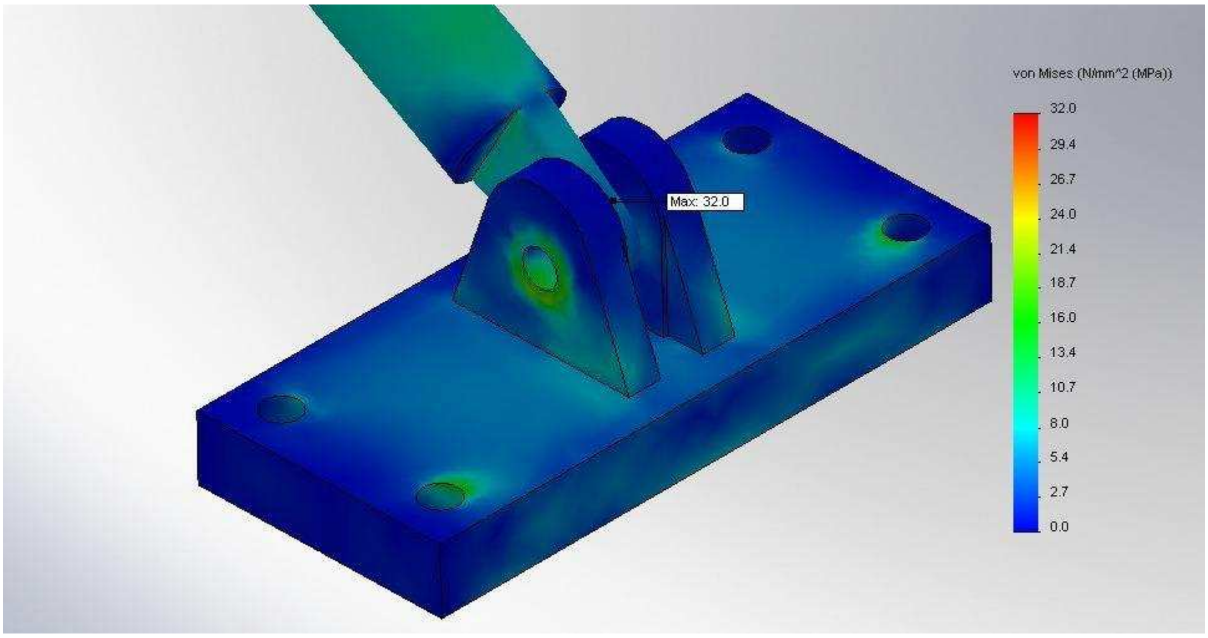


Figure 95: Maximum stress in stabilizer bar

Some stress will also be found in the screw connection between the bracket and the stabilizer bar.

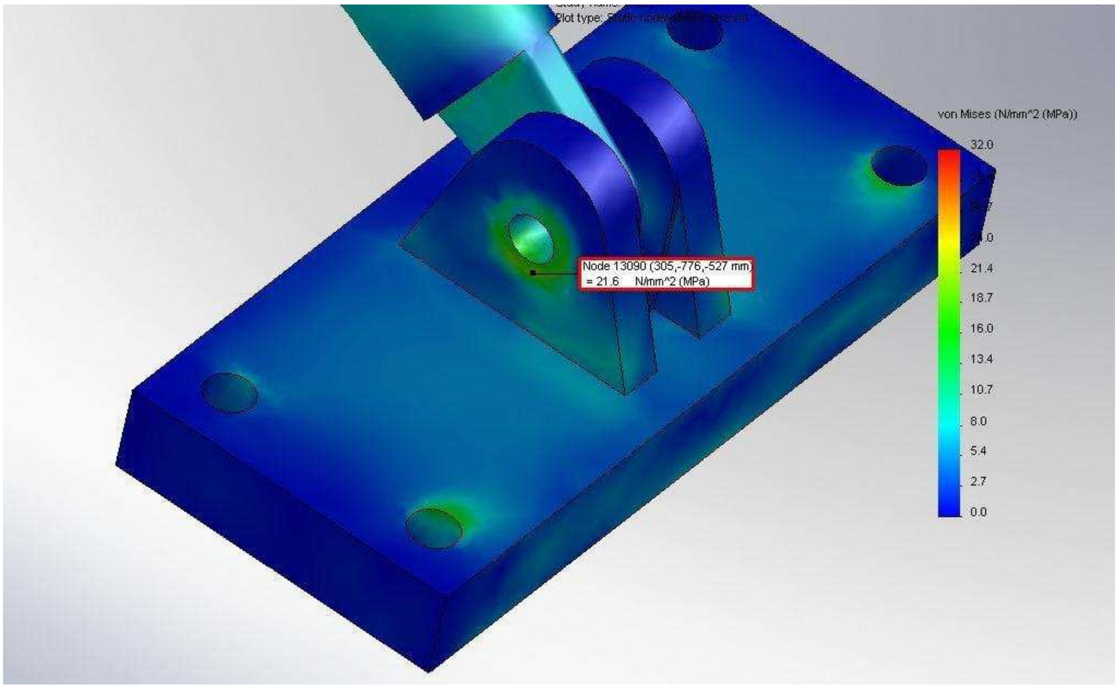


Figure 96: Stress in bracket

Displacement

Now that stress concentration is no problem compared to the yield strength of the material, the next step is to analyze the displacement in the assembly. Since this is a part of a test rig for stiffness measures, a small displacement is of big importance.

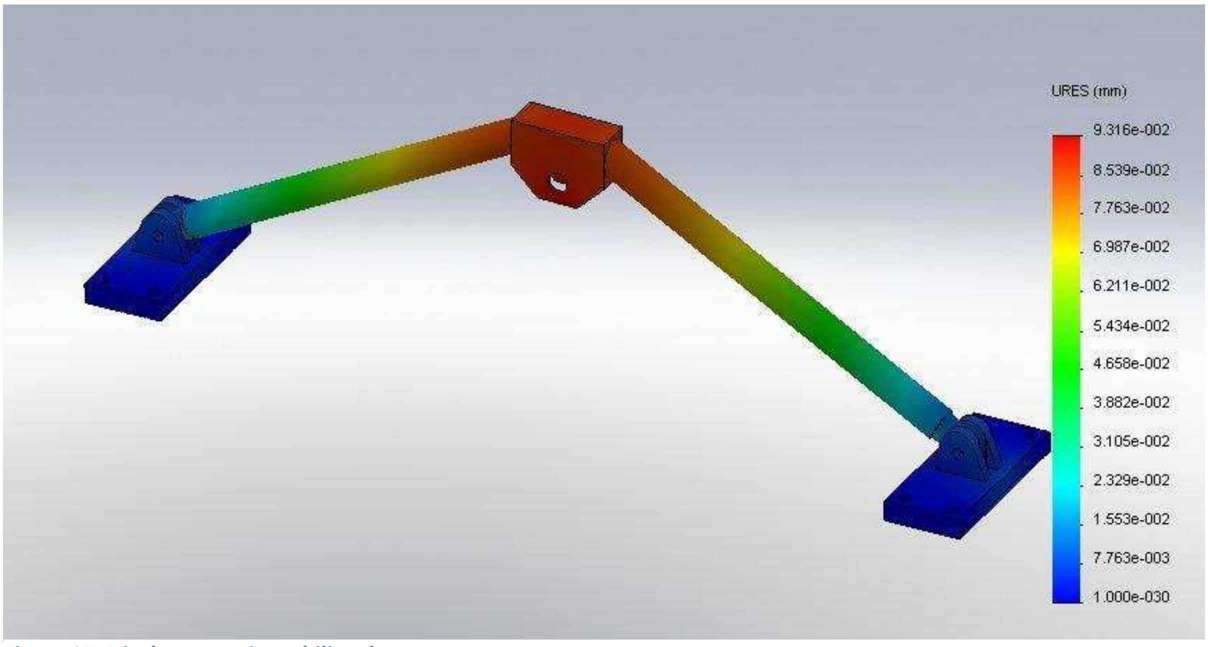


Figure 97: Displacement in stabilizer bar

As shown in figure the maximum displacement in this system is 0,09316 mm. This number is low and acceptable. Most of the displacement is located in the house of the bar, which is natural because of force concentration.

4.4.Protection plates

The protection plates used in the rig will be made out of Lexan plates with 5mm thickness. There will be one plate attached on top of the rig, this plate will be fastened with bolts and therefore easy to open and close.

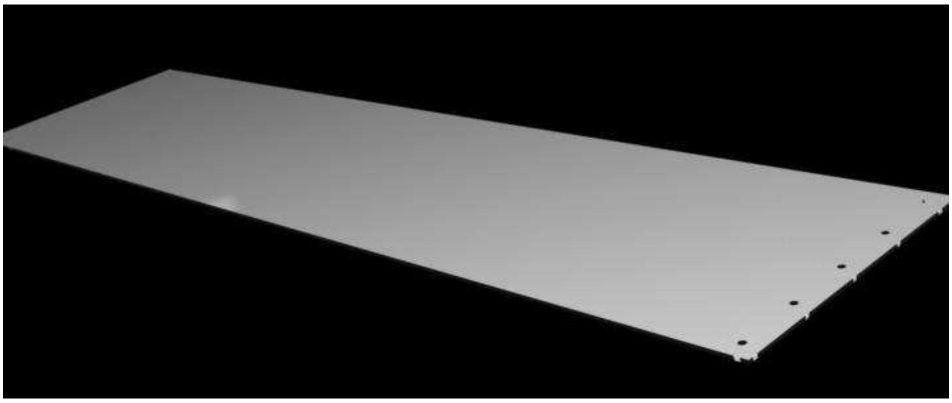


Figure 98: Top protection plate

A similar plate will be attached in front of the rig, closest to the floor. This plate will be fastened with hinges for the same reason as the one on top.

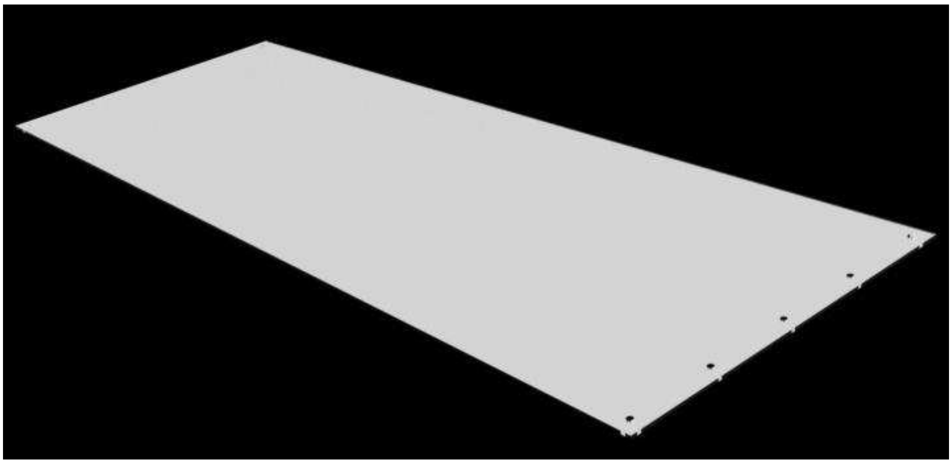


Figure 99: Front protection plate, transversal direction

For the horizontal bracket with corresponding rail system there will be a protective box structure surrounding the bracket and the opening inside the rig. The top plate of the protective box structure will be angled upwards and attached with hinges to the top transversal beam, the side plates will be shaped with the same angle. The entire box will be easy to open and close with the help of two gas cylinders, similar to the ones found under the hood of a car.

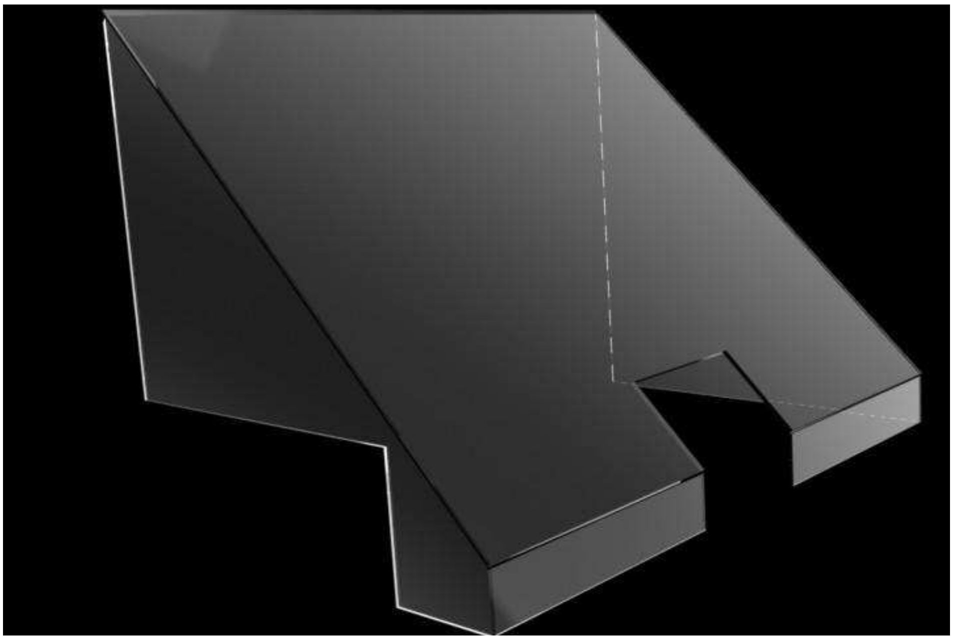


Figure 100: Protection box

The two horizontal cylinders (longitudinal and transversal) will be surrounded by protective box structures. The structures will be fastened directly to the platform and be collinear with the protective box structure for the horizontal bracket. The boxes will surround the cylinders and be fastened to the platform even though the box structure for the horizontal bracket will open and close.

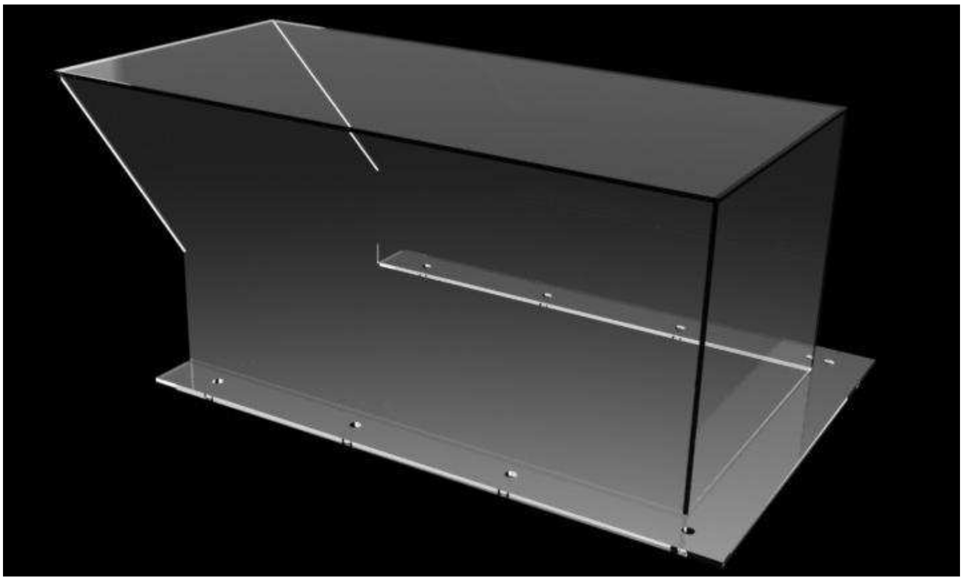


Figure 101: Protection box for longitudinal cylinder

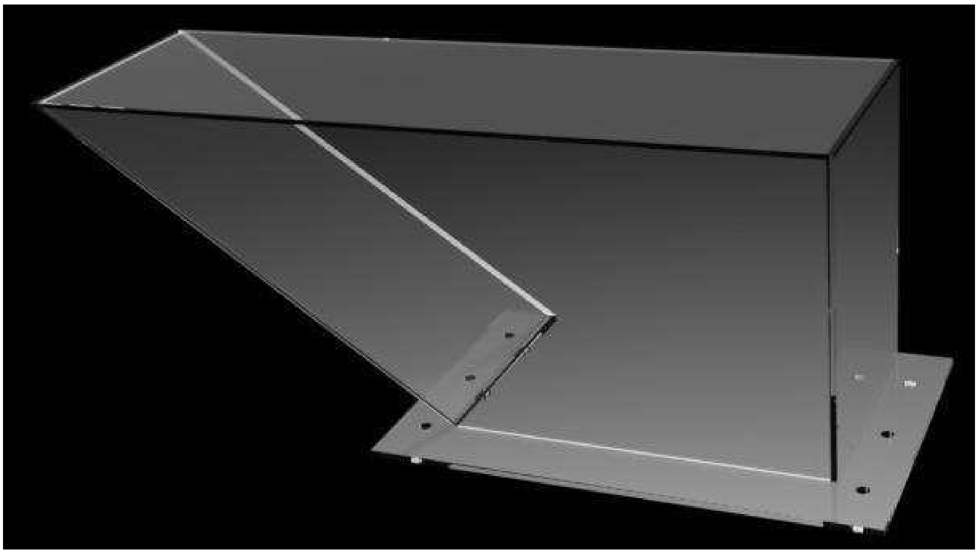


Figure 102: Protection box for transversal cylinder

There will be two hinged doors on the back side of the rig. These doors will be easy to open and close and one will be able to lock them with the help of a locking mechanism (similar to the one will find on a tool box).


Figure 103: Hinged protection plates

4.5.Choice of force supply

Hydraulics is chosen to be the main type of force supply for the movement in the test rig. Kongsberg Automotive has a hydraulic power pack installed, making hydraulics the best and the most cost efficient solution.

4.5.1. Hydraulics - horizontal

All stiffness measurements of the V-stay itself are done while testing horizontally, thus the need for fairly powerful hydraulic cylinders arises. Transversally, a cylinder capable of pushing and pulling at least 200 kN is needed (ref. RF4, Requirement specification rev. 1.3). Longitudinally, a cylinder capable of pushing and pulling 100kN will be sufficient; though the same type of cylinder as for the transversal testing is chosen. The reason for this is that they both seem to be in the same price range, ref. Appendix 4: quotation from Hänchen and Document of concept rev. 1.18, and if they come with interchangeable mounting brackets, they could be swapped temporarily if one of them fails.

The cylinders in mind are the Hänchen RatioTest 320 series with Servofloat quality [3]. These are dedicated test cylinders capable of high frequencies, high forces, tough environment and of course be run with 100% duty cycle(ref. RF2.1 Requirement specification rev. 1.3). They can even handle substantial side forces if necessary, which means that the longitudinal cylinder, which in theory will not experience any side forces, may not have to be mounted with spherical bearings.

To make sure the cylinders will do fine in its intended application, the highest possible pushing and pulling force is taken into account: The cylinders piston diameter and rod diameter are 137 mm and 80 mm, respectively, thus its total area being A=0.00974 m^2. The biggest force it will ever push or pull with is F=200 kN, which gives us the equation P=F/A =200 000/0.00974 = 20.5 MPa =205 bar. This is exactly what the clients’ potential hydraulic pressure is, so one can conclude that the cylinders will meet the requirements regarding force.

Frequencies of f=20 Hz with a stroke of up to L=8 mm(ref. RF19, Requirement specifications rev. 1.3), is desirable for both horizontal cylinders. The piston rod will travel a maximum of 16 mm during one cycle, and if this was to be done 20 times in 1 second (20 Hz), a maximum speed of V=L x f = 0.016 x 20 = 0.32 m/s. This is far from the speed limit, being 4 m/s. Both cylinders will have screwed flanges for attachment and detachment to the horizontal bracket.

Figure 104: Hänchen RatioTest 320 series with Servofloat quality [4]

4.5.2. Hydraulics - vertical

For the vertical testing, a not so powerful, only 5 kN, but still rugged cylinder, designed to run with 100 % duty cycle was needed. The maximum frequency at which it would be run is 1 Hz, and the total stroke 440 mm. The RatioTest 306 cylinder with Servocop quality, ref. Appendix 3 and Document of concept rev. 1.18, supplied by Hänchen, is able to handle speeds up to 1 m/s. After one cycle, the cylinder piston rod has travelled a total of 0,88 m, so if it was run at maximum frequency, a maximum speed of 0,88 m/s is obtained. In other words, the cylinder will do just fine.

This cylinder will be standing vertically, with a flange at its bottom connecting it to the bottom beam of the rig. At the top, it will be mounted to a stabilizer bar, ref. chapter 4.3.6, with the intensions of stabilizing the whole horizontal beam, at which it will be pushing. Male threads on the end of the piston rod will mount it to the stabilizer, which has a built in lever function. This means a cylinder with no spherical bearings or other angle compensating features is going to be used. With this in mind, and the fact that the cylinder construction is designed to handle some side forces, this should make up a safe and durable solution.

Figure 105: RatioTest 306 cylinder with Servocop quality [4]

4.6.Choice of materials

4.6.1. Frame

The material used for the frame is s355J2-H Steel with yield strength of 355 MPa and elastic modulus of 210 GPa [5]. The same goes for the support plates on the side of the rig.

4.6.2. Horizontal bracket

The material used for the horizontal bracket (main bracket, angled changeable bracket and stabilizers) is hot rolled steel plates, S355J2-N.

Dimensions

<u>Main bracket</u>
Angled changeable bracket
45 x 2000 x 1000 mm

<u>Main bracket bottom plate</u>
25 x 360 x 715 mm

<u>Stabilizers</u>
40x360x715mm

4.6.3. Universal and custom made brackets

These brackets will have to be milled to shape, and thus solid blocks of steel are needed. Stress calculations are based on steel having yield strength of at least 355MPa, and displacement calculations are based on steel having a elastic modulus for at least 210 GPa [5].

4.6.4. Bottom wide-flange beam

Material used; 355J2+AR with yield strength of 355 MPa and elastic modulus of 210 GPa [5].

4.6.5. Stabilizer bar

Material used; s355J2H with yield strength of 355 MPa and elastic modulus of 210 GPa [5]

5. Electrical

5.1.LabVIEW

5.1.1. Introduction

This technical part will give a review of the different blocks and functions in LabVIEW. The communication to the hardware is not possible due to the fact that the program has to be in physical connected to the hardware, many of the functions are replaced with various forms of simulators. The project has verified that the program receives signal and are able to analyze these (ref. Test Report 1.4).

Although the project is not able to test the outgoing communication, the program is designed for so this can easily be implemented by Kongsberg Automotive.

Since the project was unable to test the program with actual hardware, simulators was implemented to re-enact the behavior of both cylinder movement and incoming signals. These simulators are to be replaced with drivers for cylinder output and signal acquisition.

In the simulator there are also limitations in terms of frequency. In the simulator the frequency are limited to 5Hz. These limitations will not occur when the control system is connected to real hardware. This was verified during testing.

5.1.2. Methods used in the LabVIEW Program

This section will explain some of the most commonly used methods which were used in the LabVIEW program [6] [7].

In the program there are used only physical wires and connections. One could use global variables in a more extensive manner, but to not disrupt the flow of information and to avoid race condition, physical wires where chosen. The global variables would give a tidier block diagram.

5.1.3. Event structures

An event case is a structure which contains a piece of LabVIEW code. An event case will not execute until a specific action takes place. This can be a push of a button. It is used event structures to execute different parts of the program. This can be to start the main measurement loop or to call the alarm or set up window.

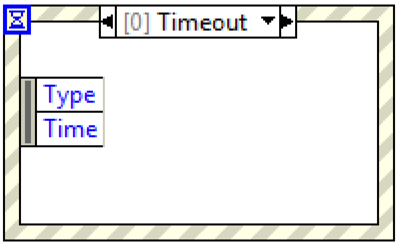


Figure 106: Event structures

5.1.4. Array

An array is used when a series of numbers is needed to be handled as one unit. In the LabVIEW program there is used 1d-arrays.

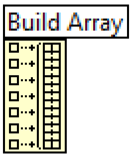


Figure 107: Arrays

5.1.5. Case Structure

A case structure is a structure which consists of either a true/false-state or several states. This structure contains code which will execute if the Boolean states of the case-structure become true.

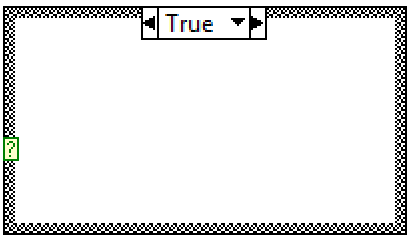


Figure 108: Boolean true loop

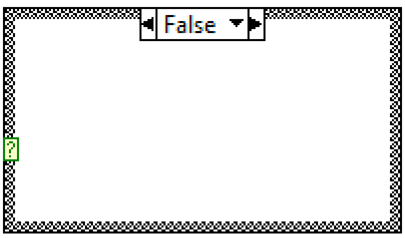


Figure 109: Boolean false loop

5.1.6. While-loop

A while loop is a structure which can iterate an unlimited number of times. A while-loop can be stopped by using a Boolean conditional value [8].

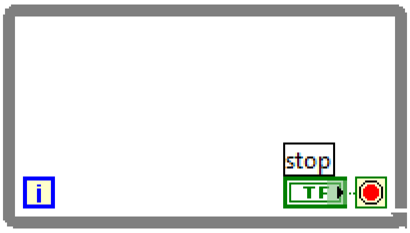


Figure 110: While-loop

5.1.7. Shift registers

Shift registers are special local variables or memory elements available in FOR-loops and WHILE-loops that transfer values from the completion of one iteration to the beginning of the next [8]. In this program the shift registers are mainly used in connection with counters.

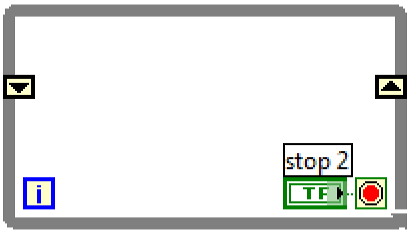


Figure 111: Shift register

5.1.8. Time delay

The time delay is used to ensure a time delay of one second in the program.

Figure 112: Time delay function

5.1.9. Elapsed time

The elapsed time function is used for several functions. The main function is to show the operator how long the test has been run. It is also used to control the functional test.

Figure 113: Elapsed time

5.1.10. Functional blocks in the LabVIEW program

Overview of control system

<u>Front panel</u>

The front panel is designed to be user friendly (ref. RP6, Requirement specification rev. 1.3). The overall layout is that the operating buttons are on the top, information visualization is located in the middle, while the indicators with various parameters are shown at the bottom. The information is shown in two graphs/charts. The chart to the left shows the force, while the chart to the left shows the position (ref. RP7, Requirement specification rev. 1.3).

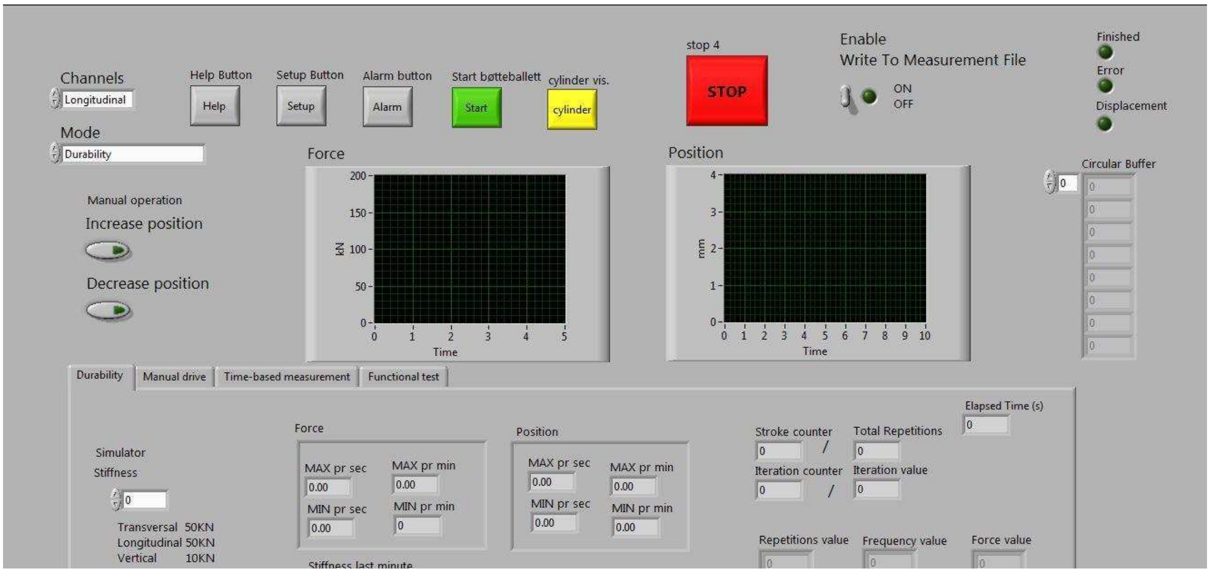


Figure 114: Front panel in LabVIEW

On the top right is the alarm indicators. These are "Finished", "Error" and "Displacement". When a durability test is completed the rig stop and the "finished" indicator will switch on. The "Error"-LED indicates that there is applied force on the cylinder but no movement in the

V-stay. To prevent damage to the rig, the program stops (ref. RP 16, Requirement specification rev. 1.3). The “displacement”-indicator tells the operator when the displacement in the V-stay has passed 130 % of initial value. This indicates breakage in the V-stay and the rig will also stop (ref. RP9, Requirement specification rev. 1.3).

On the left side of the charts, there to buttons marked increase position and decrease position. These are for manual positioning of the cylinders. Above the manual positioning the operator can choose mode and channel. The button layout is set up so that it will be natural for the operator to start with setup and alarm setup before the test is started. The stop button is also made much bigger and easy to find than the other buttons (ref. RP2.3, Requirement specification rev. 1.3).

In durability mode, there are two parameters that need to be set before a test. The upper hand parameter describes the stiffness of the V-stay in the different directions. This control is used to get the simulator function properly and is not going to be a part of the control system in the finished rig.

The lower hand control describes the initial movement of the V-stay. This parameter is basis for the displacement alarm mentioned above.

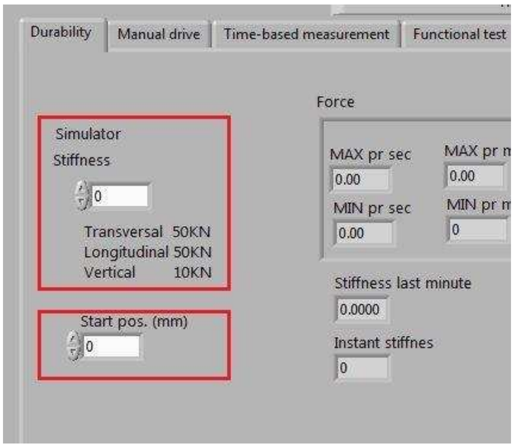


Figure 115: Durability mode

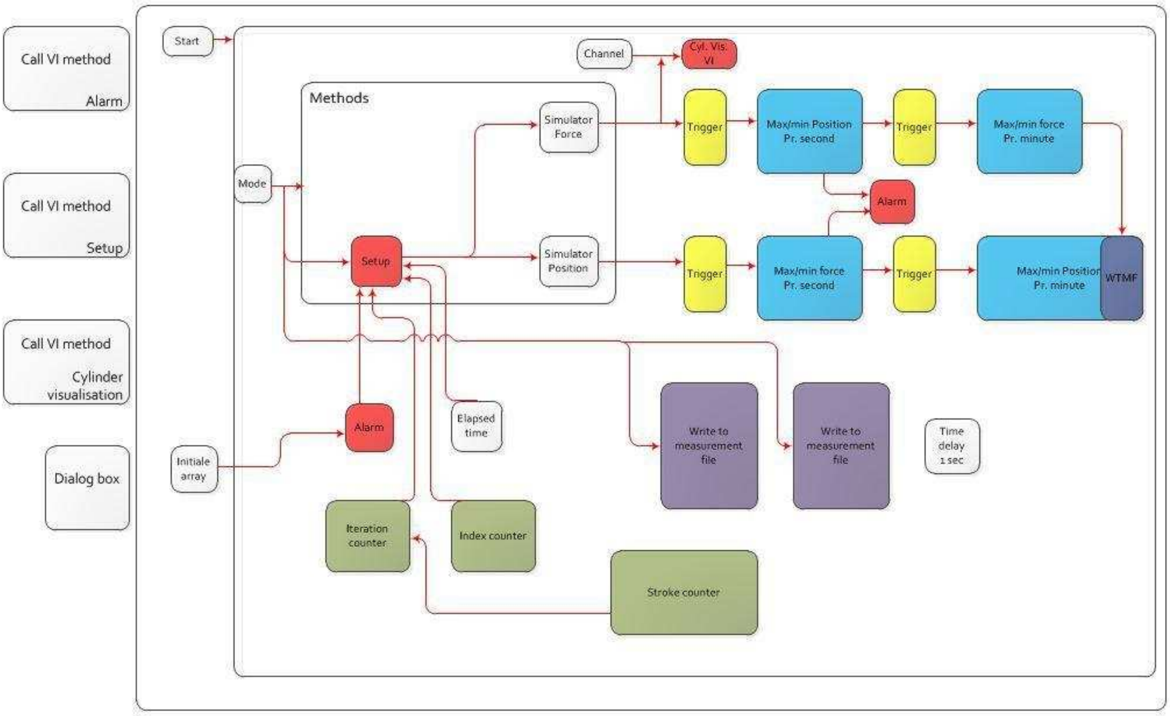


Figure 116: LabVIEW block diagram

Figure above shows a general and simplified overview over the LabVIEW block diagram.

The purpose is to find maximum and minimum values of force and position within a minute. These values are written to a file. Force and position will be used to find stiffness. Values within a minute are not appropriate to use for alarm. It is therefore finding maximum and minimum values within a second. This value is used in the alarm function. This is used in the durability mode. Since Durability testing can last for several months the amount of information needs to be reduced to a more sensible scale.
For the functional test the values are stored continuously due to shorter duration of the test.

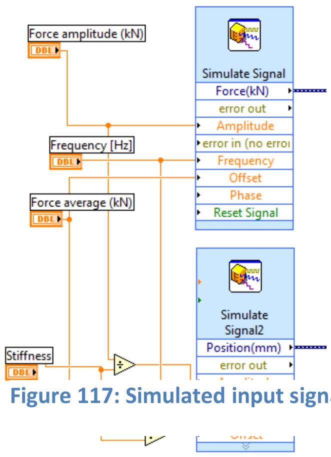


Figure 117: Simulated input signals

Input signal

The project has created a simulated sinus signal. This will be replaced by input from hardware. The simulator has frequency 0,1Hz, and a sample on 10 each second. The signal is divided into force and position (ref. RF13, Requirement specification rev. 1.3). This is because the signals are transferred to a header file. It is necessary to have force and position as two separated channels for further analyzing. During test the simulated signal was replaced by a signal from 0-10V. This signal was scaled and sent in to the program. For more details see test report.

Trigger per second

There is identical triggers per second, to force and position signal.

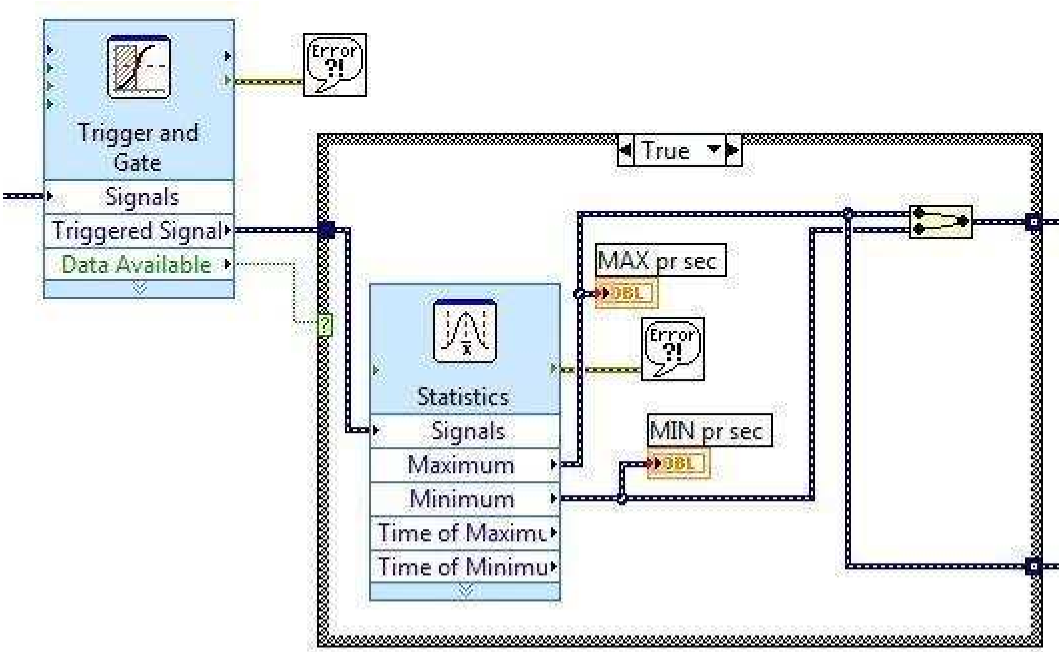


Figure 118: Trigger per second

'Trigger and Gate' function starts trigging immediately, stops after 10 samples, and sends out 10 samples. This means that it start counting immediately to 10 samples, and stores all the sample values during a second into an array. A red circle in the picture shows the array. When the Boolean loop is true, the array is transmitted to the "Statistics" function. The Boolean is true after 10 samples. Then it starts over again with trigging.

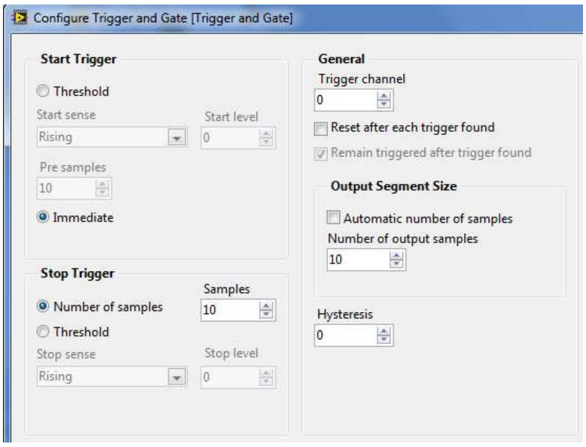


Figure 119: Properties of trigger per second

'Statistics' properties are maximum and minimum value, where the highest value will be stored. The maximum and minimum value is shown in a numeric indicator. The picture below is taken from the front panel. The same procedure applies for the position signal.

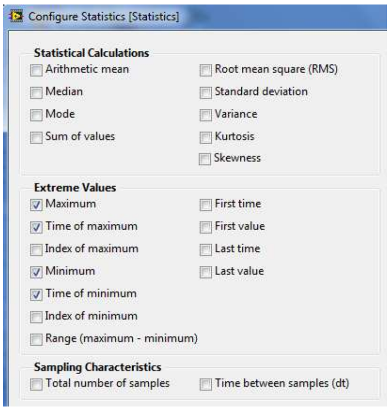


Figure 120: Properties of Statistics

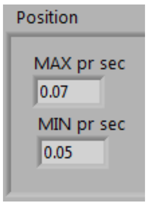


Figure 121: Indicator of max and min position value per second

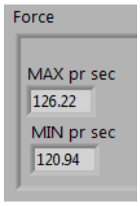


Figure 122: Indicator of max and min force per second

The maximum and minimum value is merged to a vector. This vector is stored in a matrix at the end of the Boolean loop. This matrix rooms 60 vectors, each per second.

Trigger per minute

It is a trigger per minute to force and position signal.

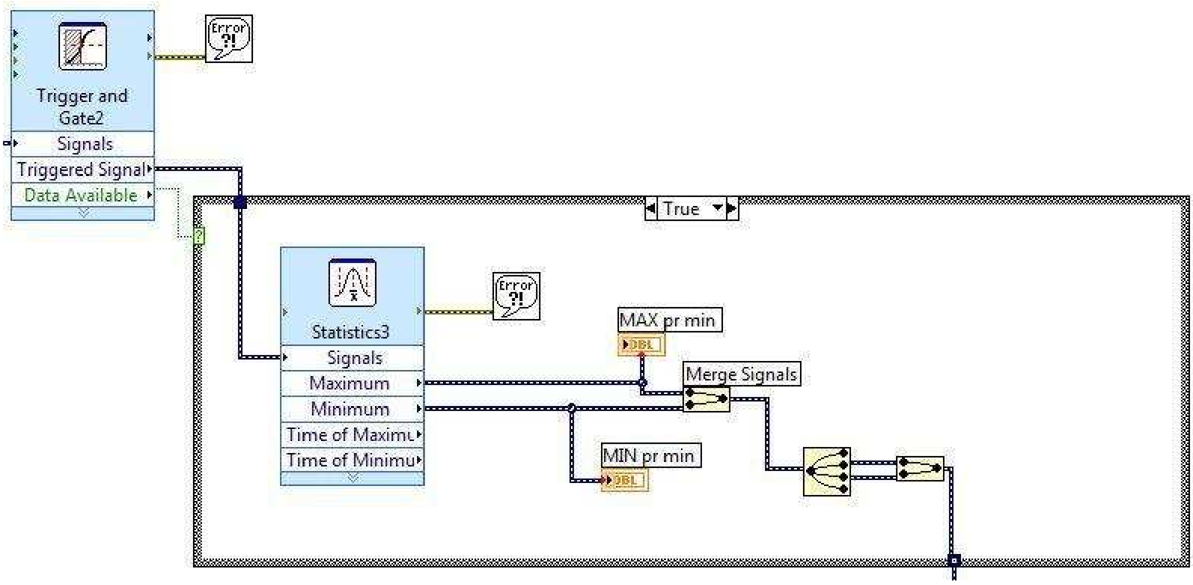


Figure 123: Trigger per minute of force signal.

The 'Trigger and Gate2' functions have properties that start trigging immediately and stops after 60 samples. This means that it starts counting immediately to 60 seconds, and stores all the samples values during a minute into an array. When the Boolean loop is true, the array is transmitted to the 'Statistics3' function. The Boolean is true after 60 samples. This process is the same as trigger per second.

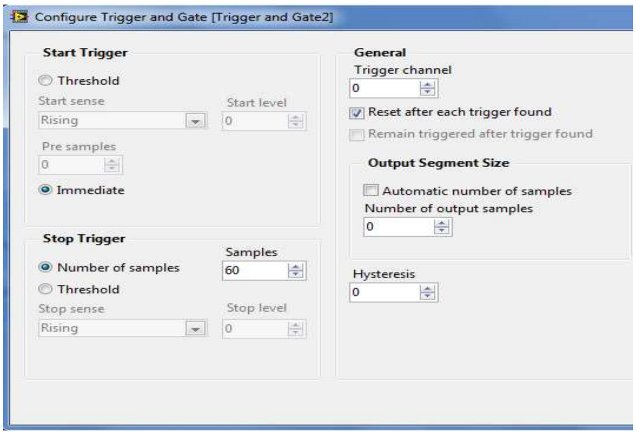


Figure 124: Properties of trigger and gate

In the same way as trigger per second, maximum and minimum values are found in the 'Statistics' function. Maximum and minimum values for force and position are shown in the front panel.

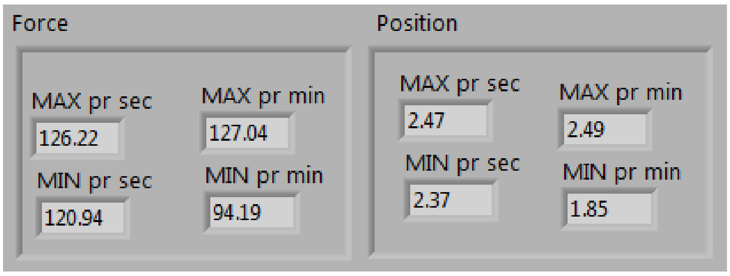


Figure 125: Max and min value per second and minute

During developing this program the group found out that duplicate signals from the maximum and minimum values would appear. This was discovered when analyzing the stored data. It required splitting the signal, to eliminate the duplicate signal. As shown from the figure below, the merged signal from maximum and minimum signal is split. The first output is maximum value, second is the duplicate maximum value and has zero transfer. Third is minimum value and the fourth is the duplicate minimum value.

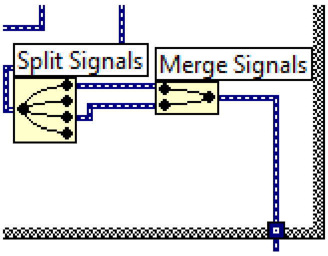


Figure 126: Duplicate signals

There is appropriate to merge the signal from force and position into one vector. The output signal from force is transmitted to the position loop. The force values are stored in an array in the position loop. In additional the position loop consists of functions that write and stores data and calculate stiffness. This is shown in the picture below.

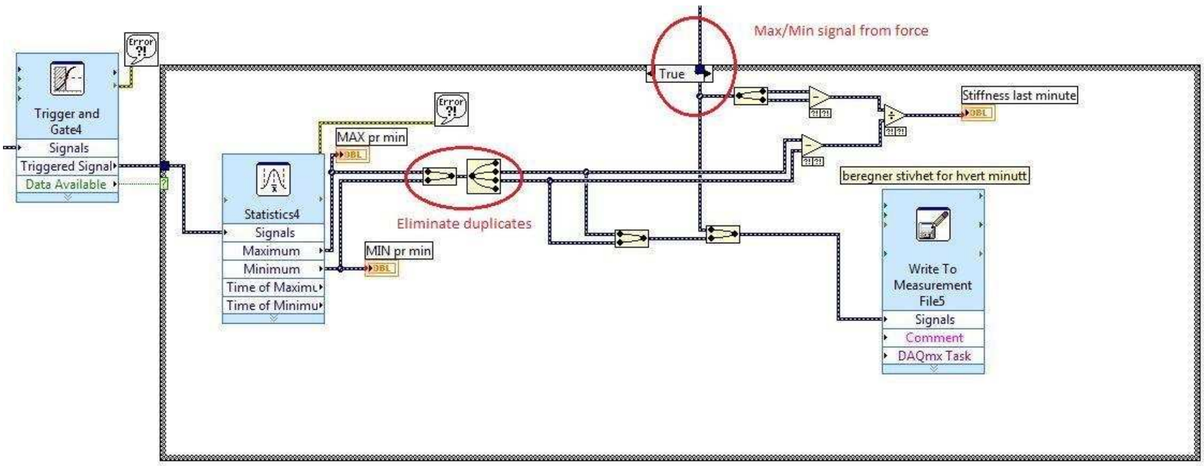


Figure 127: Trigger per second of position signal.

Stiffness, *k,* is well defined as derived of force, *d*F, divided by derived of position, $d\delta$. $\frac{dF}{d\delta} = k$. This is calculated in the loop. The stiffness is shown as a numeric indicator in the front panel, and as a graph, shown in the front panel.

Write to measurement

Force and position signal is merged together and transmitted to a 'Write to measurement' function. This function stores data with header.

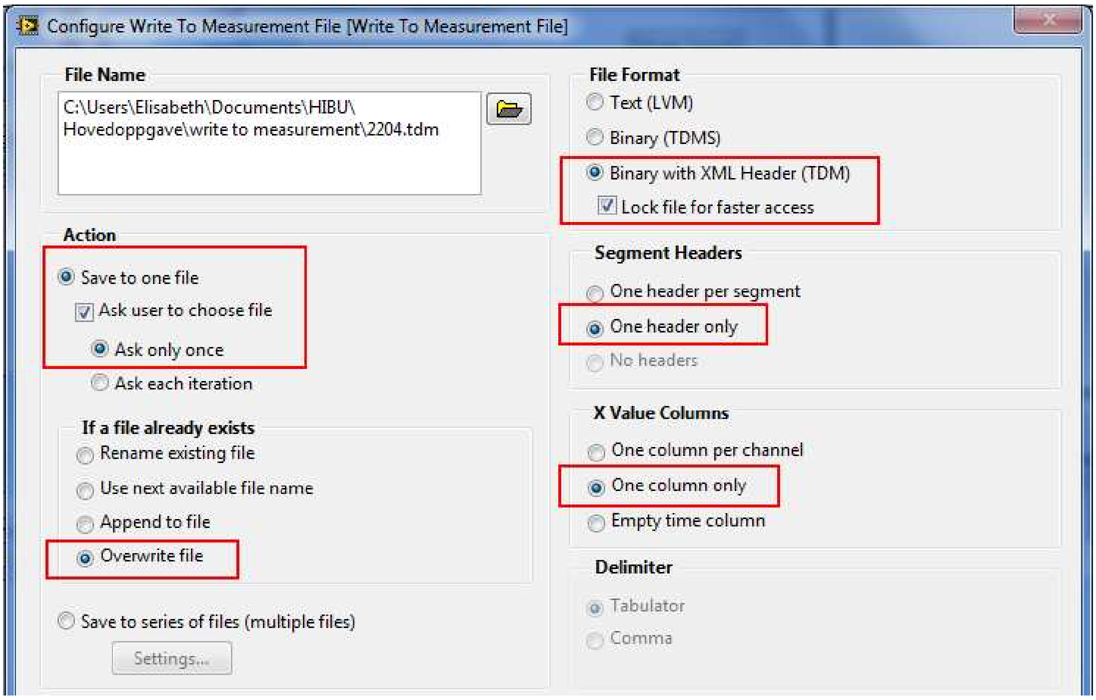


Figure 128:

Properties have several options. All log data needs to be saved in one file, and the operator can decide where to save the file. There is also specified format on the file. This project use DIAdem analysis tool with TDM-format. 'Segment Headers' and 'X Value Columns' defines the setup of the log data.

5.1.11. Counters

There are several counters in the program. They are used to control the progress and sequence. The counters are index counter, stroke counter and iteration counter. These counters are mainly used in “Durability mode” in the rig.
In LabVIEW there is a “count up” VI which is used in all three counters. This is to get a more visually uncluttered layout in the block diagram.

Index counter

The meaning of the index counter is to keep track of the cycles in a durability test. When an iteration/partial cycle is complete, the counter increases with one, switching to the next partial cycle.
When all of the partial cycles are complete, the index counter is reset to zero.
We have used a “count up” VI in LabVIEW for this task. This is to get a more visually uncluttered layout in the block diagram.

Stroke counter

The meaning of the stroke counter is to count every time the cylinder completes a cycle. The stroke counter is connected to the force signal. This is because it is the cylinder which manipulates the V-stay and therefore it is more reasonable to let the stroke counter being attached to the force signal.
The stroke counter counts every time the sine wave crosses the median line/value. It is important that this counter gets an additional input from the offset value to obtain valid values (ref. RI2, Requirement specification 1.3) [7].

Iteration counter

The meaning of the iteration counter is to keep track of the partial cycles/Iterations. The iteration counter is triggered by the stroke counter. Every time the stroke counter gives a positive Boolean value, the iteration counter increases with one. When the iteration counter coincides with set value, the iteration counter resets, and gives a positive Boolean value to the index counter.

5.1.12. Call Sub VI's

In the block diagram there are three event cases which contains a method that launches the FRONT PANEL on the sub VI's. In the program there are three VI's. The first one calls the setup window, the other calls the alarm setup window, while the third method calls the "cylinder visualization" VI. These methods are similar in both cases, except for the VI-path and the call-button.
When the operator pushes the button, the FRONT PANEL of that sub VI pops up, and the operator can set values and parameters for the test. These methods are located outside the main method in an event structure. The reason a while loop is placed around is so the method can execute at all times while the program is running.

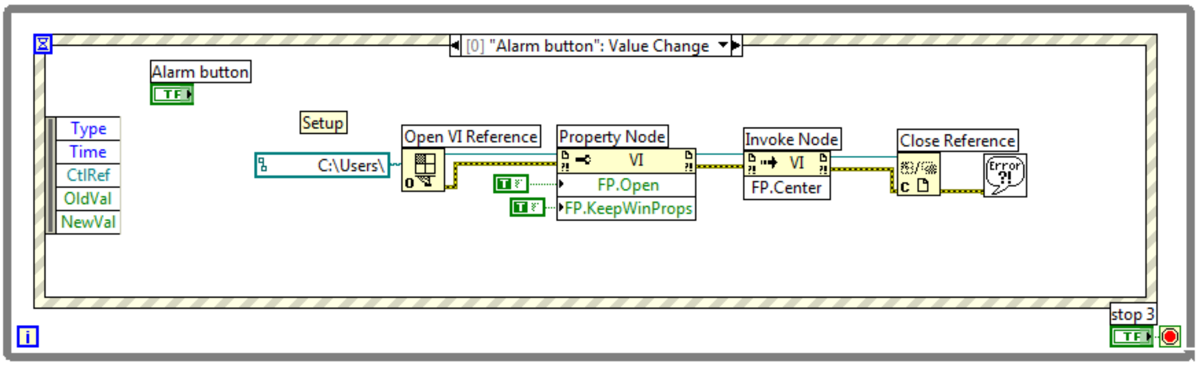


Figure 129: Alarm setup window

5.1.13. Dialog box

Dialog boxes are added in the program as a function as a help-dialog. The dialog boxes are executed when the operator pushes a button in the FRONT PANEL.

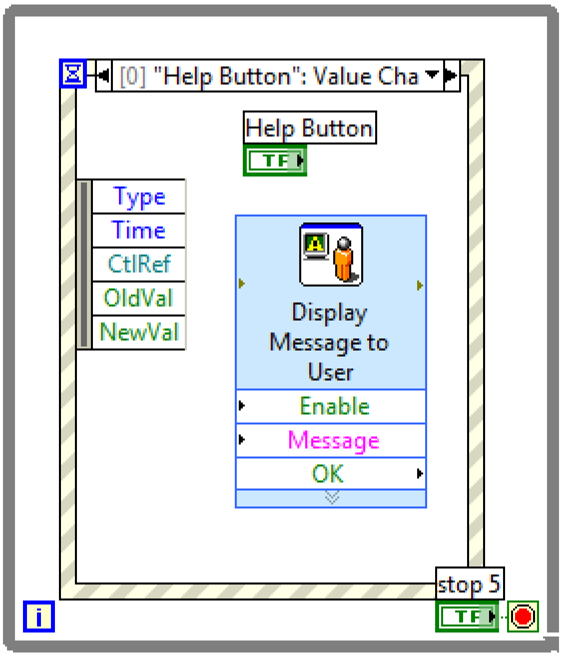


Figure 130: Dialog box

5.1.14. SubVI’s

In the program there are three sub VI’s. The first VI handles the setup conditions for the tests, the second handles the alarm conditions while the third is VI which visualizes how the cylinder will work with the LabVIEW program. The VI’s are used to break the program down in smaller pieces and to obtain a cleaner block diagram. The sub VI is made as an individual VI. The indicators and controls are then linked to terminals. To communicate with this VI in the main program, a function called “call by reference node” is used. The VI shows up as an icon with terminals in the block diagram.

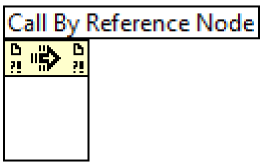


Figure 131: Comunication with VI’s

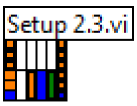


Figure 132:Icon

The sub VI’s are designed to be flexible and dynamical. The achieve this, the terminal patterns in the sub VI are chosen to be larger than needed initially. That way more function can be implemented at the empty terminals on the sub VI without the need to redesign the whole VI [8][7].

Setup

In the setup VI front panel, the operator sets the values and parameters for the tests. The setup VI handles mainly the setup for durability test, due to amount of parameters and values. To get a better overview and a visual representation over all the modes present, there are placed a tab window which contains a tab for each mode.
In the time-based measurement mode the operator sets the position for the cylinder and then sets the time-value for how long the test should last.

The operator sets how many repetitions, and determines the force and the frequency (ref. RI3, Requirement specification rev. 1.3). The operator can also choose to run a series with different power and frequency, and how many repetitions to be included in each part of the series and also how many times these iterations will loop. The control called “loop multiplier” is used to control how many times the cycle will loop. If this multiplier is set to zero, the program will then loop the cycles infinitely.

<table>
<tr><td>Force value</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td>Show force</td></tr>
<tr><td>Frequency value</td><td>Show frequency</td></tr>
<tr><td>Repetitions value</td><td>Show repetitions</td></tr>
<tr><td>Elapsed time clock in</td><td rowspan="3"></td><td rowspan="3">Repetitions total</td><td rowspan="3">Array index</td><td rowspan="3">Stop test</td><td>Elapsed time</td></tr>
<tr><td>Time control</td><td>Remaining time</td></tr>
<tr><td>Tab control</td><td>Index of empty element</td></tr>
</table>

Table 1: Connector layout over the Setup sub VI

Alarm

The alarm VI contains various stop conditions for the rig. This VI also contains the circular buffer which contains values for position for the last sixty seconds. The alarm sub VI is placed on two different locations in the block diagram. The reason is to obtain a tidy block diagram. The Sub VI’s deals with their own independent part of the program and will therefore not affect each other. The alarm setup also contains an optional function that allows the operator to get a Boolean notice after a certain percentage completion.

Counter Value	Start position (position change & self diagnosing)	Measured Position (position change & self diagnosing)	Measured Force (position change & self diagnosing)		Element repetitions
Total repetitions					Counter input
Index counter					Finished (boolean)
Array (circular buffer)					Error (boolean)
Index (circular buffer)					Displacement (boolean)
New element/array (circular buffer)					Array (Circular buffer)

Table 2: Connector layout for the Alarm sub VI

Cylinder visualization

This VI is a simulation which illustrates how the cylinders are located in relation to the V-stay. The selected cylinder will show in this VI. This VI will not be a part of the solution delivered to Kongsberg Automotive, but is implemented to give a visualization of the rig.

Channel In			
Numeric (Value in)			

Table 3: The connector layout for the "cylinder visualization VI"

5.1.15. Modes

There are several different modes to obtain dynamic functionality. These modes can be selected in the front panel. This selector shows which mode that is valid at the current time. Another important task is to set the various case structures to the correct page, and obtain a correct information flow between the various parts of the program.

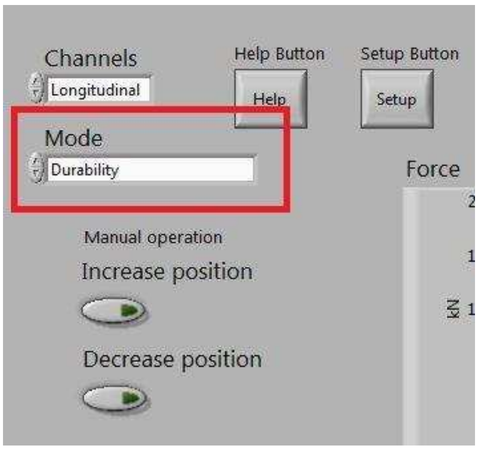


Figure 133: Selection of modes

The mode-selector also controls Tab-windows in the front panel and in the setup Sub VI. This tab-window is implemented to give the operator a better overview over the parameters for the different tests. If this window was neglected there would be a large numbers of indicators not in use, and would be confusing and disturbing to the operator. The mode selector will also set the methods necessary for the chosen test. This is achieved by setting the different methods in the case structures which is controlled by the mode selector.

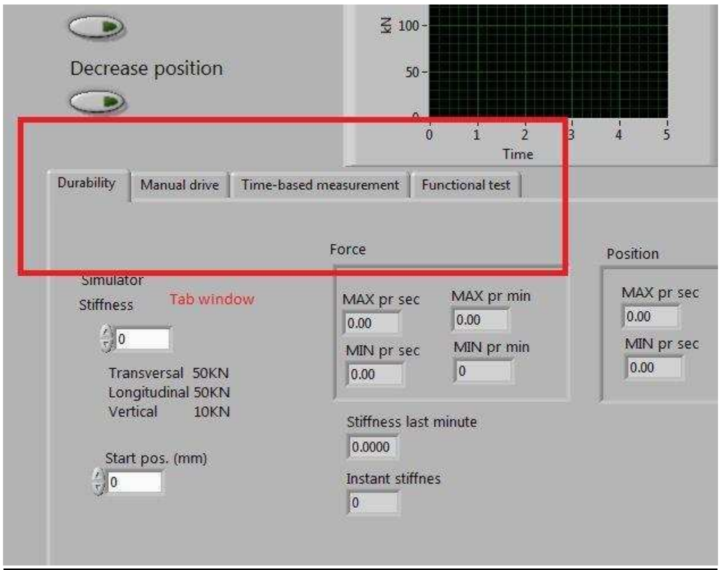


Figure 134: Tab window with selected mode

Durability

In this mode the durability test is performed (ref. RF9, Requirement specification rev 1.3). The operator can choose how many cycles to be run, and determine the force and Frequency. The operator can also choose to run a series with different power and frequency, how many repetitions to be included and how many times these iterations will loop (these are set in the setup window).The simulator set up in the program will be equal to the durability set up in the finished control system. The counters in LabVIEW are able to handle 4.29 Billion strokes (ref. RF17, Requirement specification rev. 1.3).
There is also located a timer which shows the elapsed time (ref. RI5, Requirement specification rev. 1.3), and a stiffness indicator (ref. RI4, Requirement specification rev. 1.3).

Manual mode

In manual mode the operator can manipulate the chosen cylinder manually. This mode can be used when a new V-stay is mounted in the rig. It can also be used in functional tests. The cylinders are operated by the buttons, located on the left besides the graphs in the front panel. The operator can set the position directly or drive the cylinders manually. The operator can also choose the increment of movement for each click on the button.

Time-Based measurement

This mode is used to perform a time based test. The V-stay will be moved to a fixed position to be held for a given time. The rig monitors the change of force used to hold the V-stay in this position. The operators set the durability time of the test, and the starts the program. When this time is reached, the program stops. There is also an indicator that shows remaining time of the test.

Functional test

This mode handles the functional tests (ref. RF10, Requirement specification rev. 1.3). The test rig will only manipulate the V-stay for one cycle, and measure the stiffness. A typical test of the V-stay is to perform a functional test to find the stiffness in the V-stay. Then a durability test is performed to exhaust the bushings. Then a new functional test is performed to check the stiffness again. The difference in stiffness before and after durability test will tell how much the rubber bushings are worn.

5.1.16. Channel-selection

The channel selector is located below the mode selector in the front panel. The channel selector controls which cylinder to test by. The available channels are transversal, longitudinal and vertical. The channel selector is linked to the “cylinder visualization” VI, to simulate how the cylinders works on the V-stay.

5.1.17. Ring buffer

The ring buffer is an array which holds position values for the last sixty seconds. The purpose of this is that the test-personnel can go back in time to check history if the V-stay breaks under tests.

The values in the array are constantly overwritten by new values coming in, so the position values for the last sixty seconds are available. The ring buffer method is located in the “alarm” sub VI, while the buffer indicator is placed in the front panel. This is not the ideal solution, but the project struggled to get the circular buffer functional when placed inside the “alarm” sub VI. To keep a tidier front panel, the buffer indicator is compressed. If the buffer values is needed the indicator can be dragged down to show all 60 values.

5.1.18. Write to measurement file

(ref. RI1, Requirement specification rev. 1.3)Write to measurement file is a report generator which allows the user to save the test data to file. This file can be imported in to LabVIEW for further analysis.
In the front panel there is a switch that allows the user to choose when to enable the Write To Measurement file function.

In the block diagram there are placed two write to measurement VI’s. One (the one placed to the right) is used to log data from a durability test. The other (the one placed to the left) is used for functional testing. The difference between these is that the first saves log data each minute, while the other saves log data continuously. If durability test is chosen, the write to measurement function will automatically be enabled. If the operator wants to sample a piece of the signal with a higher resolution, the write to measurement file switch can be enabled, and this signal will be logged.

It is the mode selector that determines which one of them who will be selected.

5.1.19. Buttons

Below is an overview over the available buttons for the operator.

Start: This button starts the test.
Stop: This button stops the test.
Set up: This button activates the event which calls on the setup front panel.
Alarm: This button activates the event which calls on the Alarm setup front panel.
Help: This button calls a dialog box which contains tips and help.
Enable WTMF: This button activates the “Write to measurement file” option.
Mode: Here the operator can choose which mode to test in.
Channel: Here the operator can choose which channel to test.
Cylinder visualization: This button calls the VI that shows the simulated cylinders in motion.

5.2.DIAdem

DIAdem is an analyzing software tool from National Instrument and is compatible with LabVIEW. DIAdem is able to locate, load, visualize, analyze, and report measurement data.
Log files from LabVIEW or external log files from Microsoft excel can be read in DIAdem.
How to use DIAdem as a working tool can be read in user manual. (ref. DIAdem user manual 1.9)[9] The program includes five main functions: Navigator, View, Analysis, Report and Script. The ‘Navigator’ imports and export data from the hard disk. Files can be found and searched after in the search areas folder. It is then easier to find the data to be working with. The log files that will be used is placed in Data Portal. Each files inculdes several channels like force, position and time.

Figure 135: Menu bar

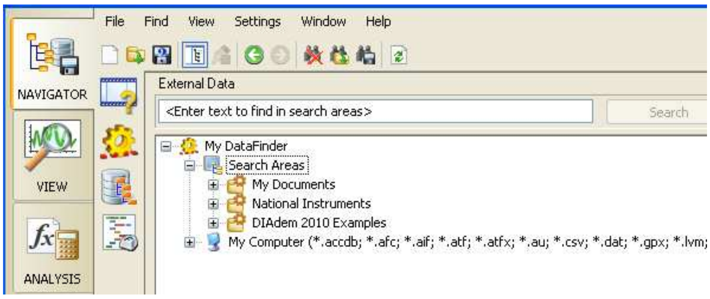


Figure 136: Search area folder in Navigator

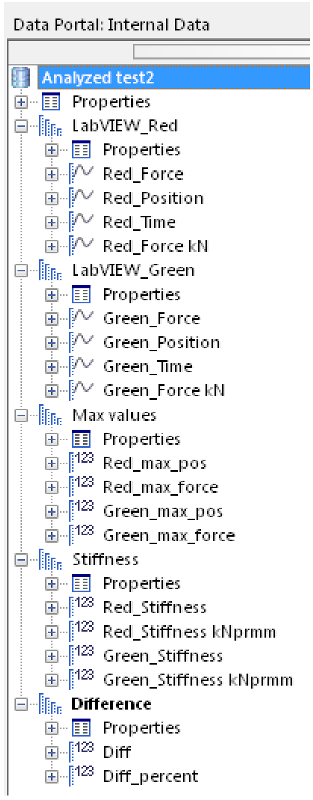


Figure 137: Data Portal

The ‘View’ function show data in a table channel or graphically. It can include synchronized videos or 3D model animations with i.e. graphs. Measured log data on temperature on the bushings can be shown in a graph and be synchronized with a 3D model that shows the temperature scale.

Selected Channels				
Name	Force	Position	Force	Position
Number	1	2	4	5
Length	18144	18144	16848	16848
Unit	N	mm	N	mm
Channel Contents				
1	0.289941	0.000169	0.424086	0.000234
2	-0.410594	0.000169	0.236709	0.000366
3	0.062108	0.000234	-0.278578	0.000234
4	-0.344586	0.000103	-0.057132	0.000366
5	-0.176372	0.000234	-0.110364	0.000497
6	-0.253026	0.000169	-0.721469	0.0003
7	0.015264	3.705749E-05	-0.36162	0.000366
8	-0.235992	0.0003	0.049332	0.000169
9	-0.148691	0.000234	-0.127399	0.000366
10	0.485836	0.000234	0.285683	0.0003
11	-0.329681	0.000103	0.298459	0.000169
12	0.05572	0.000234	0.211158	0.0003
13	-0.082684	0.000103	-0.640556	0.000234

Figure 138: Table channel in View

Analysis function does mathematically calculations and has predefined functions installed. All channels can be used in a calculator to get new channels. For example force and position channels can be used in the calculator to get a channel for stiffness. Predefines functions are for example maximum and minimum or more complicated functions. All new values that are calculated will be saved in the Data Portal.

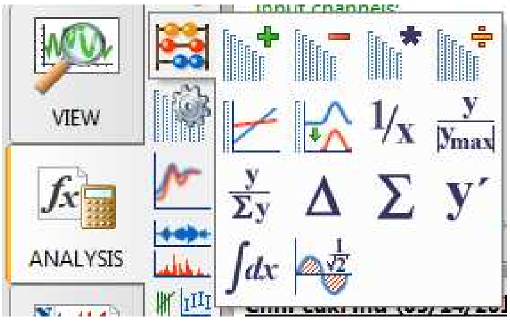


Figure 139: Analysis functions

Report function makes report template which can be saved and reused. This report can include graphs, text, calculated values, pictures and dynamic date and name of test.

Script function use Visual Basic and DIAdem script to do analysis and create a report while recording the work. This script can be run and new log data files will be analyzed and get a report at once.

5.2.1. Analyzing

The result from the test of control system that was done at KA is the basis for this part. The log data that was produced during test is analyzed in DIAdem and the result is written in the test report (ref. Test Report 1.4).

Equipment that was used in the physical test was a potentiometer that gave position signals, a load cell that gave force signal, power supply at 5V and a cabinet with CompactDAQ from National Instrument. Additional equipment was a red springs with high stiffness that compares with a new V-stay and a green spring with lower stiffness constant that compares with a V-stay after a durability test. The potentiometer, load cell and the spring were placed side by side and force was then applied manually.

This part will present the analysis functions from the test. Input channels from LabVIEW were used to calculate stiffness and difference in stiffness of the red and the green spring. During this calculations a script function is enabled and recording all the calculations that is done during work.

Calculations

All the calculated channels are shown in figure below. Channels with name red represents the red spring and channels with name green represents the green spring. The figure shows the DIAdem script that recording renames of the channels.

```
Data.Root.ChannelGroups(1).Name = "LabVIEW_Red"
Data.Root.ChannelGroups(2).Name = "LabVIEW_Green"
Data.Root.ChannelGroups(1).Channels("Force").Name = "Red_Force"
Data.Root.ChannelGroups(1).Channels("Position").Name = "Red_Position"
Data.Root.ChannelGroups(1).Channels("Untitled").Name = "Red_Time"
Data.Root.ChannelGroups(2).Channels("Force").Name = "Green_Force"
Data.Root.ChannelGroups(2).Channels("Position").Name = "Green_Position"
Data.Root.ChannelGroups(2).Channels("Untitled").Name = "Green_Time"
```

Figure 140: Script code of renames of channels

Units

Position signal has unit mm and force signal from the test had unit in N, but a preferred unit is kN. First calculation was to convert the signal to kN by dividing by 1000. This channel has name 'Force kN' in the data portal. Figure below representing script code for this action.

```
Call Calculate("Ch(""Red_Force kN"")=Ch(""[1]/Red_Force"")/1000",NULL,NULL,"") '
```

Figure 141: Convert unit

```
Call Calculate("Ch(""Green_Force kN"")=Ch(""[2]/Green_Force"")/1000",NULL,NULL,"")
```

Figure 142: Convert unit

Stiffness

It is necessary to find stiffness in each measured value and maximum stiffness during functional test. Stiffness, *k,* is defined as derived of force, *d*F, divided by derived of displacement, $d\delta$. (ref. Trigger per minute section in LabVIEW chapter)
This mathematical function is durable for log data from simulator.
The log data from KA and from the physical test had only one channel each for force and position. For this testes the stiffness, *k*, is calculated by maximum values of force and position

$$\frac{maxF}{max\delta} = k$$

Max value folder in the data portal contains maximum values of position and force for each spring. This is calculated by a predefined function in DIAdem, which search for peaks in a graph, called 'Peak Search'. The user manual explains how to use this function (ref. DIAdem user manual 1.9). The script code below shows that the 'Max value' group is added and activated. 'ChnPeakFind' activates the peak search function that finds maximum value, PeakX and PeakY. They are renamed to 'Red_max_pos' and 'Red_max_force'. The same process applies for the green spring.

```
Call Data.Root.ChannelGroups.Add("Max values", 3).Activate()
Call ChnPeakFind("[1]/Red_Position","[1]/Red_Force kN","/PeakX","/PeakY",1,"Max.Peaks","Amplitude") '..
Data.Root.ChannelGroups(3).Channels("PeakX").Name = "Red_max_pos"
Data.Root.ChannelGroups(3).Channels("PeakY").Name = "Red_max_force"
Call ChnPeakFind("[2]/Green_Position","[2]/Green_Force kN","/PeakX","/PeakY",1,"Max.Peaks","Amplitude")
Data.Root.ChannelGroups(3).Channels("PeakX").Name = "Green_max_pos"
Data.Root.ChannelGroups(3).Channels("PeakY").Name = "Green_max_force"
```

Figure 143: Script code of maximum values

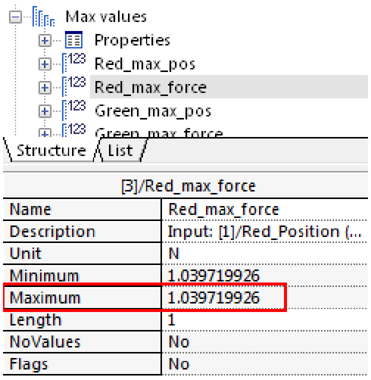


Figure 144: Maximum force value of the red spring and it is calculated to 1.04 kN/mm

The stiffness group includes stiffness values in N/m and kN/mm. For example Red stiffness is calculated.

Difference

It is in interest to know the difference in stiffness in the bushings before and after a durability test. On the basis of that there were calculated difference in stiffness of the red and the green spring. This was done by subtracting red stiffness in kN/mm and green stiffness in kN/mm. The percentage difference is found as well and has value 0,056 %. This is small values, but compared to a V-stay, a spring has much lower stiffness then the bushings located in the V-stay. This is explained more thoroughly in the test report (ref. Test Report 1.4).

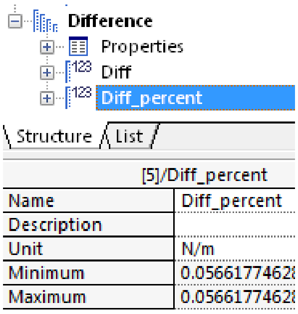


Figure 145: percentage difference in percent

The script shows that a new group is created with name ‘Difference’, and calculating the difference with name ‘Diff’ and percentage difference, ‘Diff percent’.

```
Call Data.Root.ChannelGroups.Add("Difference", 5).Activate()
Call Calculate("Ch(""Diff"")=Ch(""[4]/Red_Stiffness kNprmm"")-Ch(""[4]/Green_Stiffness kNprmm"")",NULL,NULL,"")
Call Calculate("Ch(""Diff_percent"")=Ch(""[5]/Diff"")*100",NULL,NULL,"") '... CalculateFormula,CalculateSymbols
```

Figure 146: Script of stiffness calculation

Report template

The report includes a graph that shows stiffness and numeric indicators on the difference stiffness’. A report is not able to record in a script, but has to be premade and saved as a template. The script says that it uploaded a template. In the script below it is a turquoise line, which is because it is commented away. During the script recorded was enabled it is possible to create a new template, but all the manoeuvres that are done will not be recorded. The turquoise line says that the report is saved as a template and next step was to open the template again. The ‘PicLoad’ line says that the template is uploaded. The ‘PicSaveAs’ line needs to be comments away because there is no interest in saving a template each time the script is running. The only intention is to open a premade template.

```
'Call PicSaveAs(MyFolders(0)&"MTR_Template_ functionalTEST.TDR","") '
Call PicLoad(MyFolders(0)&"MTR_Template_ functionalTEST_kopi.TDR") '.
Call PicUpdate(0)                         '... PicDoubleBuffer
```

Figure 147: Script of upload report template

The report that was made is shown in figure below. The test name and date is dynamic. Date is displayed by the current day by writing ‘Date: @CurrDate@’. Test Name is the name on the first file you drag over to the Data Portal. In this part the first file were named ‘Test2FinalRed’.

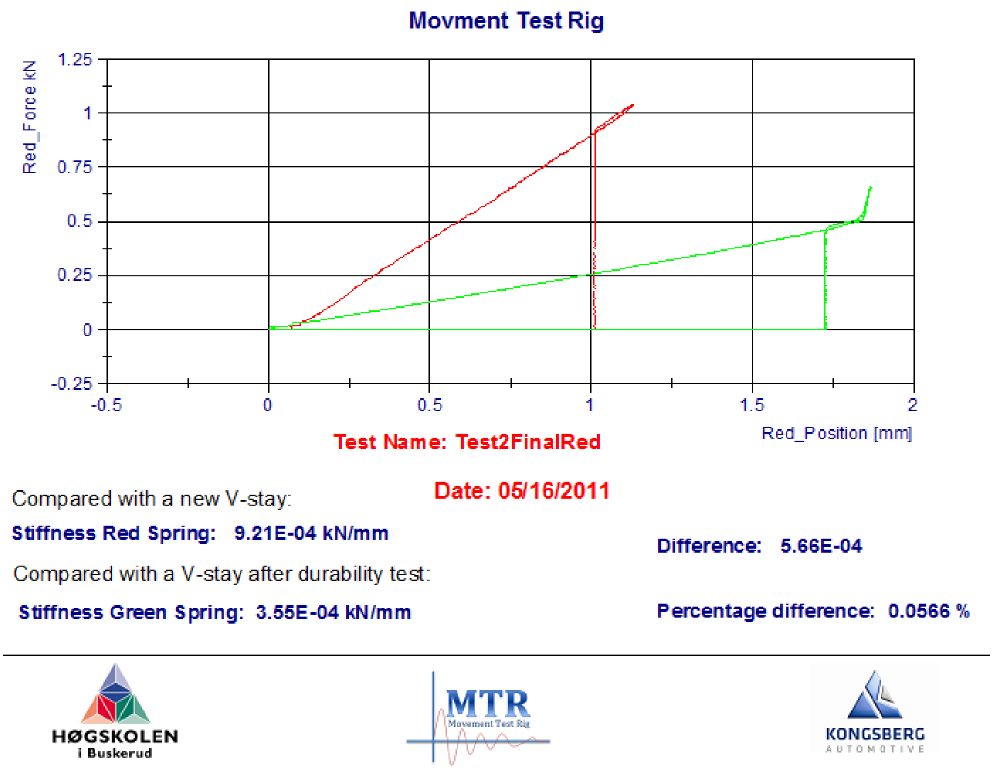


Figure 148: Report

Script

This script is only durable for log data with same format. For this script it needs one channel for force and position. There are also made script for automating calculation and report for existing log data from KA, and for the simulator in LabVIEW. This is because it is depending on the order of the channels. The simulator in LabVIEW creates a maximum and minimum value of the force and position, they have two more channels than the other log data, there is therefore necessary with another script. There is easy to create a new script that is suitable for other log data.

Before running the script it is one thing to notice. Hit the ‘Calculate Quantity-Based’ button, shown in the figure below. This means that the units are included in the calculations. Even if the button is marked during recording the script, this will not be enabled when you run the script. If this button is not marked, the stiffness values will be incorrect. That is because force [kN] divided by position [mm] is not kN/mm, but N/m. The channel with name ‘Red/Green_stiffness’ has wrong value, and this is compensated by the channel ‘Red/Green_stiffness kNprmm’. This channel calculates stiffness $\cdot 10^{-6}$ which gives unit kN/mm.

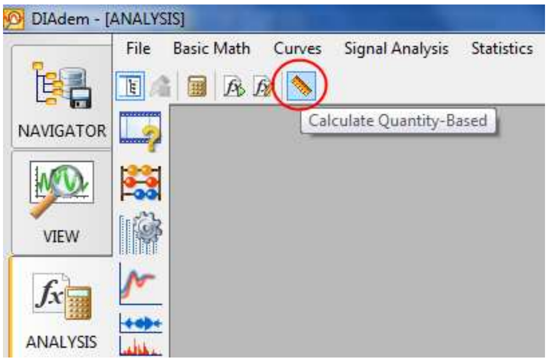


Figure 149: Mark the Calculate Quantity-Based button before using the calculator function

If there is preferred not to allow for the ‘Calculate Quantity-Based’ button, the script must be made without it as well, and stiffness will be calculated without units. All the script that is made in this project is calculated with units. Figure below shows the script.

```
'-------------------------------------------------------------------------------
'-- VBS script file
'-- Created on 05/13/2011 14:12:02
'-- Author: Elisa
'-- Comment: ---
'-------------------------------------------------------------------------------
Option Explicit  'Forces the explicit declaration of all the variables in a script.

Dim MyFolders()
Call InitMyFolders
'-------------------------------------------------------------------------------
Sub InitMyFolders
  ReDim MyFolders(1)
  MyFolders(0)="C:\Users\Elisabeth\Documents\HIBU\Hovedoppgave\Diadem\"
End Sub
'-------------------------------------------------------------------------------
Call Data.Root.Clear()
Call FileNameGet("NAVIGATOR","FileRead")
Call DataFileLoad(FileDlgName) '... DataFilename,FileImportFilter,ImportAction
Call FileNameGet("NAVIGATOR","FileRead")
Call DataFileLoad(FileDlgName) '... DataFilename,FileImportFilter,ImportAction
Data.Root.ChannelGroups(1).Name = "LabVIEW_Red"
Data.Root.ChannelGroups(2).Name = "LabVIEW_Green"
Data.Root.ChannelGroups(1).Channels("Force").Name = "Red_Force"
Data.Root.ChannelGroups(1).Channels("Position").Name = "Red_Position"
Data.Root.ChannelGroups(1).Channels("Untitled").Name = "Red_Time"
Data.Root.ChannelGroups(2).Channels("Force").Name = "Green_Force"
Data.Root.ChannelGroups(2).Channels("Position").Name = "Green_Position"
Data.Root.ChannelGroups(2).Channels("Untitled").Name = "Green_Time"
Call Calculate("Ch(""Red_Force kN"")=Ch(""[1]/Red_Force"")/1000",NULL,NULL,"") '...
Call Data.Move(Data.Root.ChannelGroups(2).Channels("Red_Force kN"),Data.Root.Channel
Call Calculate("Ch(""Green_Force kN"")=Ch(""[2]/Green_Force"")/1000",NULL,NULL,"") '
Call Data.Root.ChannelGroups.Add("Max values", 3).Activate()
Call ChnPeakFind("[1]/Red_Position","[1]/Red_Force kN","/PeakX","/PeakY",1,"Max.Peak
Data.Root.ChannelGroups(3).Channels("PeakX").Name = "Red_max_pos"
Data.Root.ChannelGroups(3).Channels("PeakY").Name = "Red_max_force"
Call ChnPeakFind("[2]/Green_Position","[2]/Green_Force kN","/PeakX","/PeakY",1,"Max.
Data.Root.ChannelGroups(3).Channels("PeakX").Name = "Green_max_pos"
Data.Root.ChannelGroups(3).Channels("PeakY").Name = "Green_max_force"
Call Data.Root.ChannelGroups.Add("Stiffness", 4).Activate()
Call Calculate("Ch(""Red_Stiffness"")=Ch(""[3]/Red_max_force"")/Ch(""[3]/Red_max_pos
Call Calculate("Ch(""Red_Stiffness kNprmm"")=Ch(""[4]/Red_Stiffness"")*10^(-6)",NULL
Call Calculate("Ch(""Green_Stiffness"")=Ch(""[3]/Green_max_force"")/Ch(""[3]/Green_m
Call Calculate("Ch(""Green_Stiffness kNprmm"")=Ch(""[4]/Green_Stiffness"")*10^(-6)",
Call Data.Root.ChannelGroups.Add("Difference", 5).Activate()
Call Calculate("Ch(""Diff"")=Ch(""[4]/Red_Stiffness kNprmm"")-Ch(""[4]/Green_Stiffne
Call Calculate("Ch(""Diff_percent"")=Ch(""[5]/Diff"")*100",NULL,NULL,"") '... Calcul
'Call PicSaveAs(MyFolders(0)&"MTR_Template_ functionalTEST.TDR","") '... PicFile,PIC
Call PicLoad(MyFolders(0)&"MTR_Template_ functionalTEST_kopi.TDR") '... PicFile
Call PicUpdate(0)                          '... PicDoubleBuffer
```

Figure 150: Completed script

5.3. Electrical drawings

In the document of concept (ref. Document of concept rev. 1.18) it was decided to use MOOG portable test controller as controller hardware. The electrical drawing shows the coupling between the hardware's. MOOG delivers a portable test controller. An overall view sees the coupling between MOOG and to the load cells, potentiometers, servo valves and to the computer. The electrical drawings are shown in appendix 2 and in this document. Moog includes different circuit boards. This part represents the different circuit boards that are used in this project, based on the quotation to KA (ref. Appendix 4). The technical information in this part is based on portable test controller datasheet [8]
In the earlier part of the project it was decided to use CompactRIO from National Instrument as input to the portable test controller (ref. Document of concept 1.18).

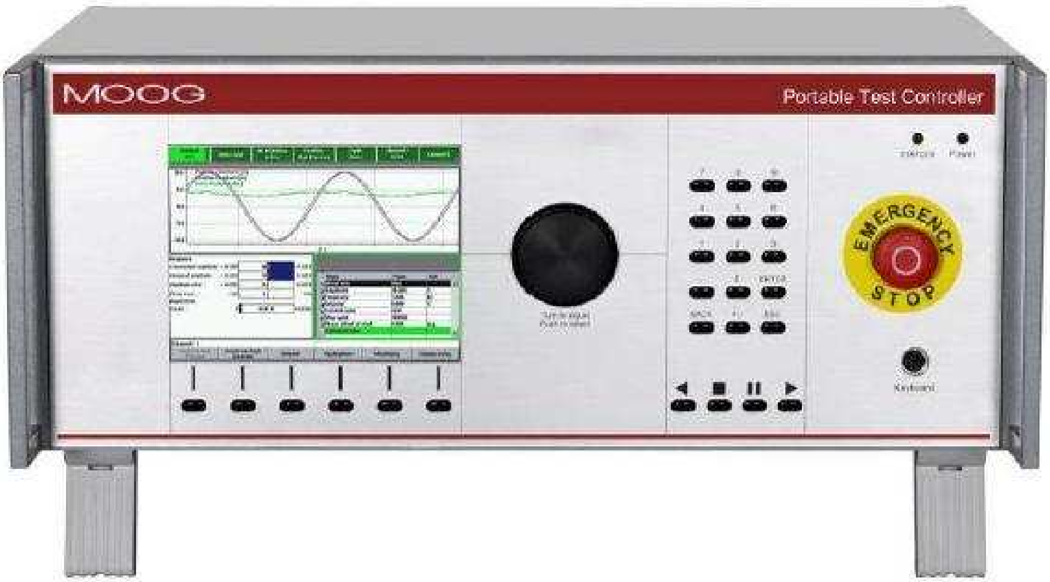


Figure 151: Front of the Portable Test Controller

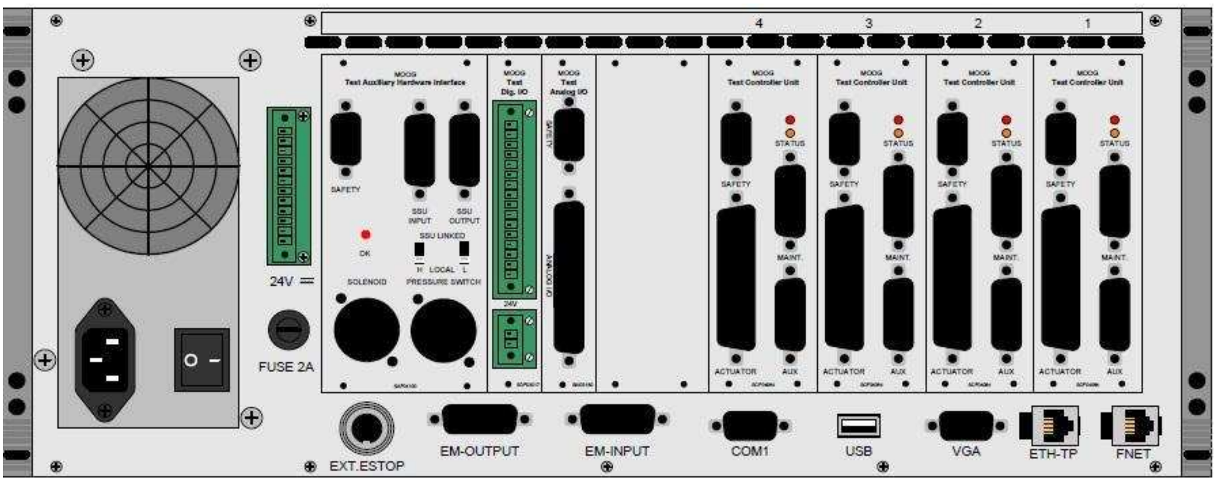


Figure 152: Interfaces of the Portable Test Controller

5.3.1. Circuit boards

An electrical drawing overview is shown in a figure below, and in appendix 2. The circuit boards that is included in MOOG chassis is placed to left. F-net is a RJ45 connector and is plugged to the computer. The external alarm in the rig is connected to EXT.STOP which is integrated in the chassis. This is a 5 pole female connector, type 'Binder'.

Figure 153: EXT ESTOP

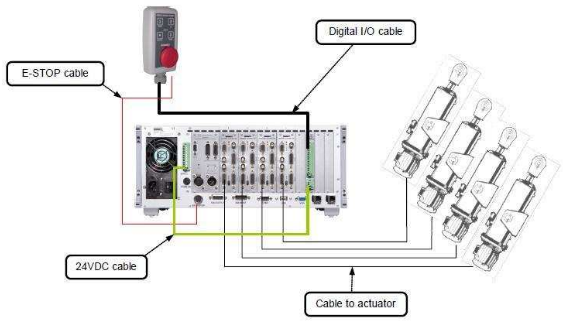


Figure 154: Alarm connection

Figure 154 shows how the alarm is connected. In the figure the alarm is also connected to Digital IO, but that is because the external alarm has other functions. This alarm is not included in this project, so the connection to digital is not necessary

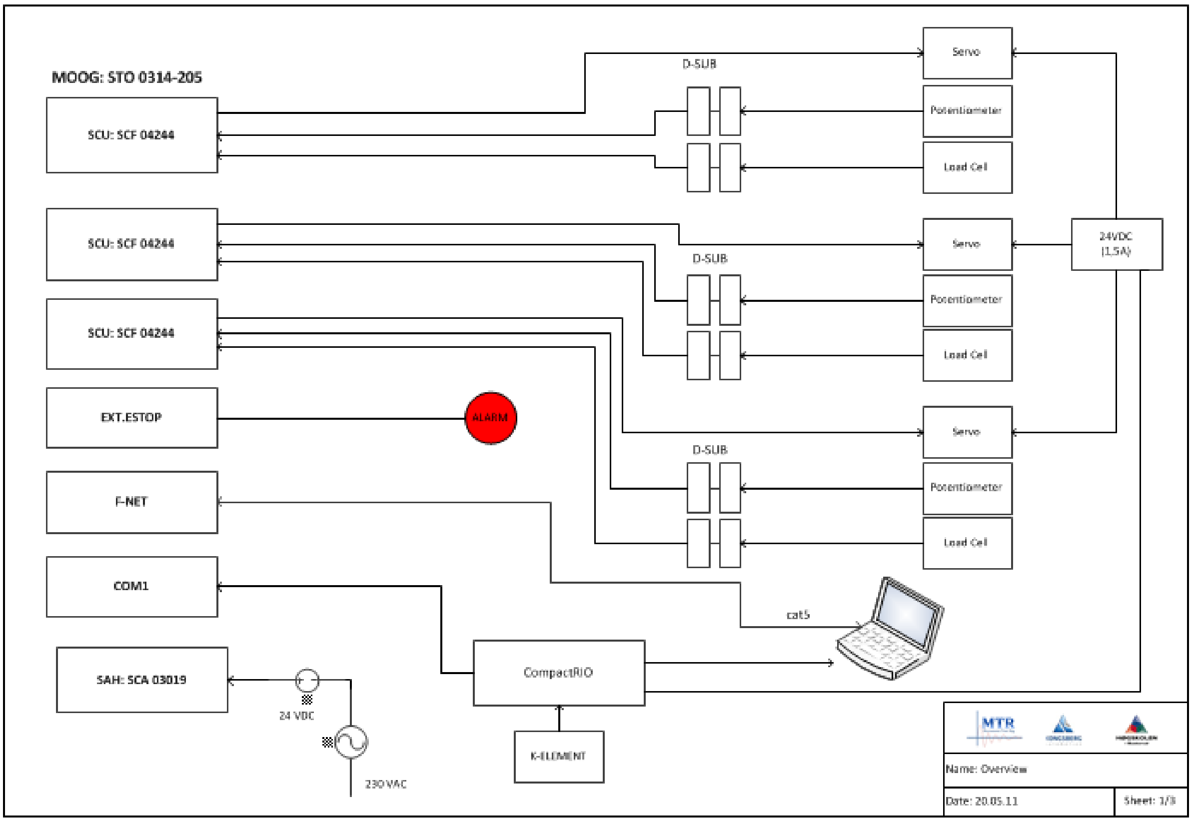


Figure 155: Overview

SAH: SCA 03019

SAH (Hardware interface panel) is the Test Auxiliary Hardware Interface and is integrated in the chassis of the portable test controller. Details about SAH is found in [8], section 4.

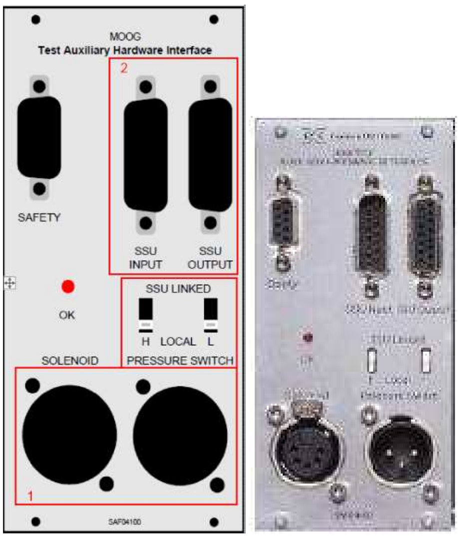


Figure 156: SAH interface

SCU: SCF 04244

There are a SCU (Smart test Controller Unit) for each cylinder and this is the processor interface between the controller and the load cells.

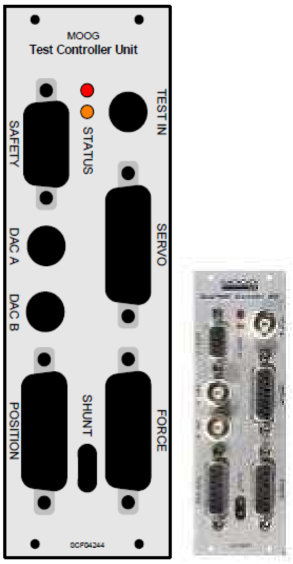


Figure 157: SCU interface

Name	Description
Safety	9 Pins Sub-D (female)
Force	25 Pins Sub-D (female)
Position	15 Pins Sub-D (female)
Servo	9 Pins Sub-D (female)
Test In	BNC
Pos, DACA, DACB	BNC
Shunt	

Table 4: Ports in SCU interface

The project has three cylinders, and there is need for one SCU per cylinder. Details concerning D-subs and pin configuration are located in document, [10], section 5.6.3. The load cell is connected to the force connector. The force connector has available pin for two load cells, but this project only use one for each SCU board. Figure below shows that pin 1, 2,3,4,5,7,10 and 15 are in use [10]. The ellipse in the figure below is a shield and is connected to ground.

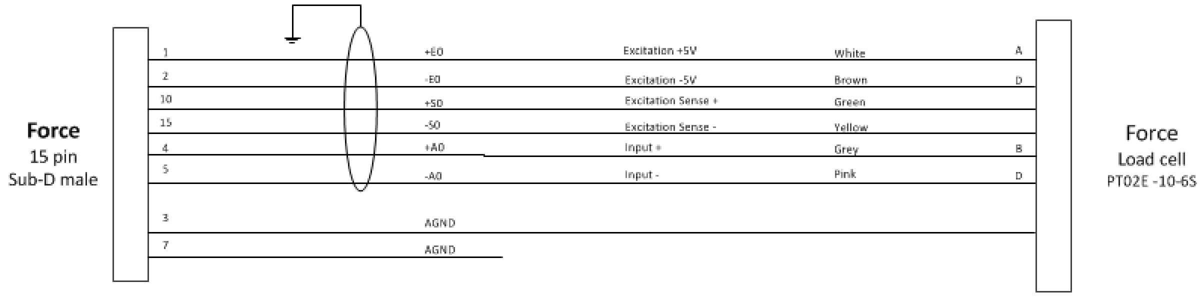


Figure 158: Connection from SCU to load cell

According to data sheet [10] there are three different connections to measure position, pos.LVDT, pos.pot and encoder. This project uses potentiometers and pin for pos.pot is used (pin 6, 8 and 15). Potentiometer reference +/- is connected to the resistor in the potentiometer.

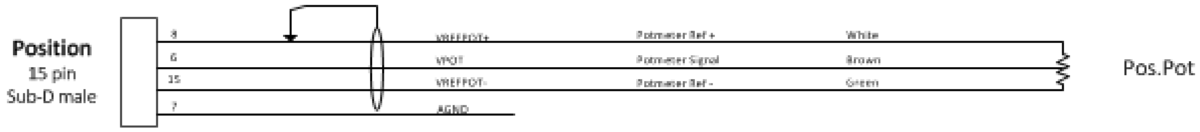


Figure 159: Connection from SCU to potentiometer

The servo valve is connected to the servo connector. It can either be controlled by current or voltage, depending on the servo valve properties. The electrical sheet has voltage as connection. There is applied 24VDC power supply to the servo valve.

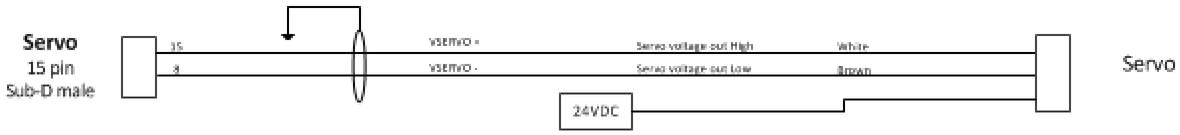


Figure 160: Connection from SCU to servo valve

5.3.2. Load cell

The project was missing the data sheet of load cell from Hänchen. Pins for load cell are standard, and were replaced by another datasheet [11]. The PT02E standard with six pins is used. The connections are shown in the figure below. The Excitation Sense connection from the force port in SCU is not connected to the load cell. This pin is used to decrease the signal in the cables in case of long distance between the controller and load cells. This is not the case for this project.

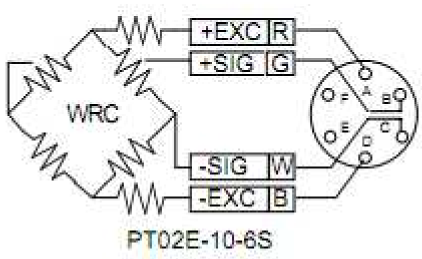


Figure 161: Load cell wiring

5.3.3. National Instrument - CompactRIO

The CompactRIO from National instrument is a real-time controller and reconfigurable chassis [12]. This component is placed between the PC and the MOOG controller. The CompactRIO will be used to control the parameters that are sat in LabVIEW. These parameters are forwarded to the MOOG controller. This unit includes different modules like communication and temperature. There are potential to implement other essential modules.
The computer is connected to network (TCP/IP), Ethernet plug 1, in CompactRIO.

Figure 162: CompactRIO

NI 9870 RS232 Serial Module

CompactRIO communicates with the MOOG controller through COM1 port (RS232), in the serial module (NI9870).

Figure 163: NI9870 serial communication

Picture below show the electrical drawing where CompactRIO communicates with the MOOG controller. NI 9870 module and the COM1 port in the MOOG chassis communicates with the RS232 standard (ref. [10] page 17). RJ50 JACK is the modular plug in NI 9870 module .The COM1 plug is a DB-9 female connector. RJ50 and DB-9 is connected by a S8 serial cable, 10 pin modular delivered from National Instrument [13], [14].

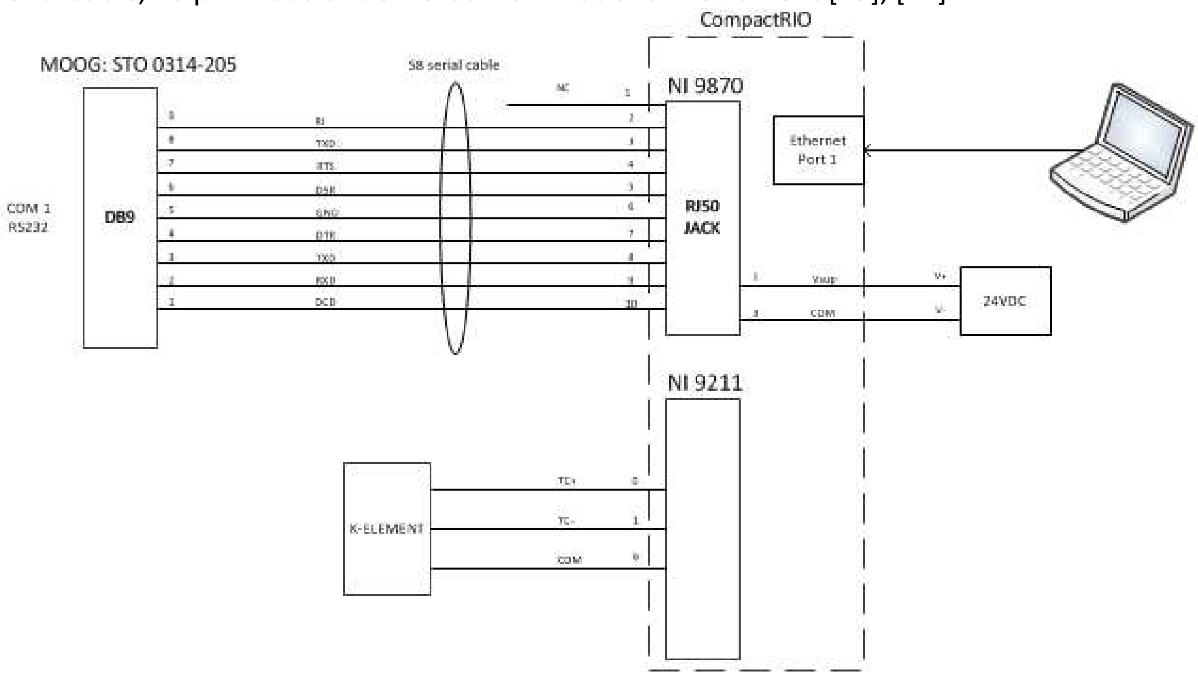


Figure 164: Connection between MOOG and CompactRIO

The NI9870 module is connected to 24VDC power supply. COM is connected to V- which is 0V (ground).

NI 9211 Temperature sensor

NI9211 module is a temperature sensor compatible with K-element. The K-element will be used to measure the bushings and need there for one channel. This module is drawings in the figure below. This module has 4 channels. Compared with other and more expansive modules, this has lower sampling rate and fewest channels. Price against functionality, this was chosen to this project. Figure below shows how to connect the K-element to the NI9211 module. COM is common and connected to ground [15].

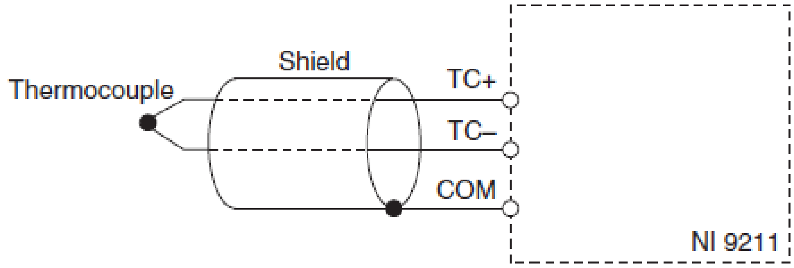


Figure 165: Pins of NI9211

During the latter part of the project, there has been a question whether a unit is needed between the external PC, containing LabVIEW, and the portable test controller.
This unit was to communicate between LabVIEW and the Portable Test Controller. All the parameters and values would be sent from LabVIEW to the Portable Test Controller, and the results should then be sent the other way, from the Portable Test Controller.
The reason this question was asked was that there were doubts whether one could load a control system from a competitive supplier into the Portable Test Controller.
After dialog with Kongsberg Automotive, it was agreed that such unit should be implemented. The most appropriate unit for this was the CompactRIO from National Instrument and since this was device Kongsberg Automotive had knowledge from earlier occasions. To get a solution for the project, a CompactRIO was implemented in the electrical drawings.

According to technical personal at MOOG there is no need for a CompactRIO to communicate between LabVIEW and the Portable Test Controller. However, additional software is needed (Software Development Kit) [16]. This requires some preparations in form of programming.

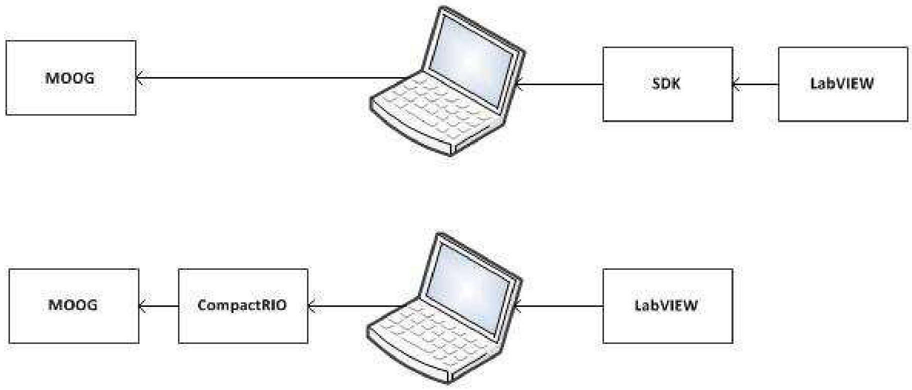


Figure 166: Use of SDK or CompactRIO

Another solution would be to use the MOOG control system software, named TEST SUITE [17] [18]. Arguments for choosing such a solution would be a more standardized control system solution. MOOG will also provide training to the operators.
Another argument is the price. A TEST SUITE solution will be equally priced as a solution with LabVIEW and SDK. These are questions the project unfortunately did not have time to decide, but that most certainly should be considered in the further completion of the rig.

Cabinet

Some of the hardware must be placed inside a cabinet. The Portable Test Controller is a 16" unit and is placed outside.

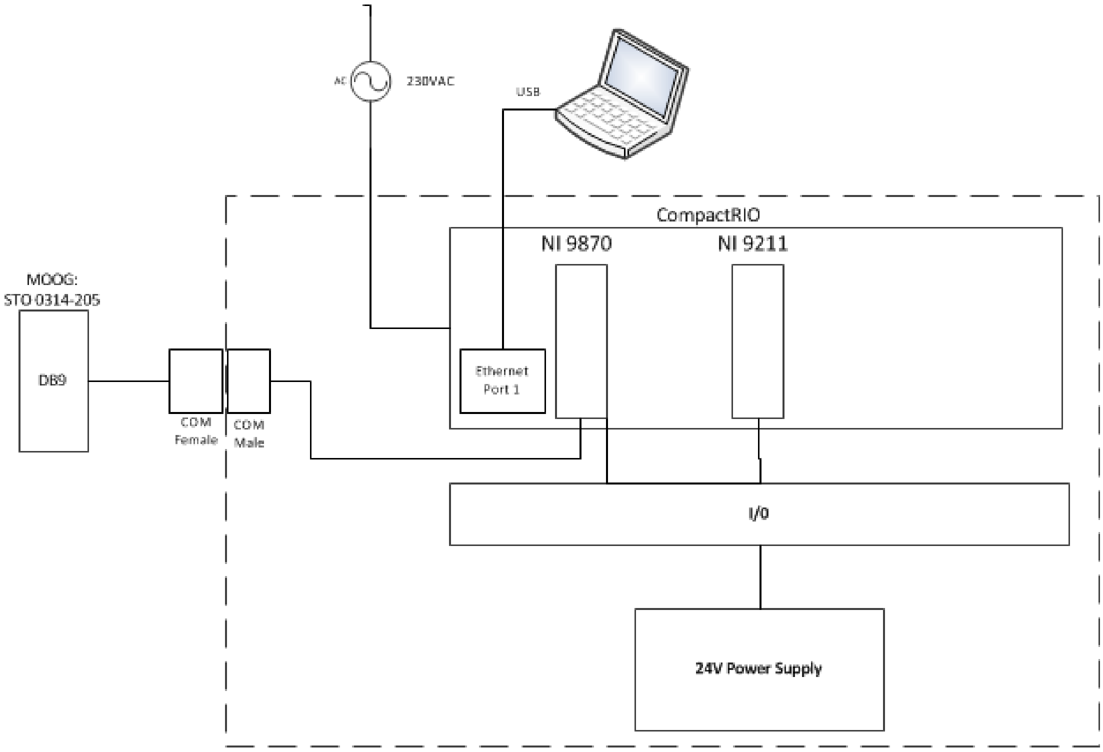


Figure 167: Hardware placed in cabinet

5.3.4. Suggestion for further work and development

Door switches

Another safety feature that can be implemented is safety switches at the protection plates, so that the rig stops when the operator opens the door when a test is running.

Temperature measurement

Another feature that can be implemented at the rig is the ability to measure temperature at the rubber bushings. During a durability test the V-stay will be under constant movement at high frequency. This will lead to an increased temperature in the rubber bushings. If the temperature gets to high the rubber bushings will get brittle and start to fall apart.
If a temperature sensor is placed on the outside of the rubber bushings, these temperature increases can be detected and the rig will stop for a period of time while the rubber bushing cools down. This is implemented in the electrical drawings, but not in the control system. This function can easily be implemented in LabVIEW.

Hydraulic emergency shut off

There is also implemented an emergency stop that is connected to a hydraulic shutoff-valve, which is placed between the hydraulic supply and the servo valve. This is to completely shut off the hydraulic supply if an accident or situation should occur. The emergency button is directly linked to the shut off-valve, which has its own power supply. This is to have an isolated master shut off that is not affected by the control system. If the stop button is pushed, the operator needs to push a reset button to the get the rig to start again.

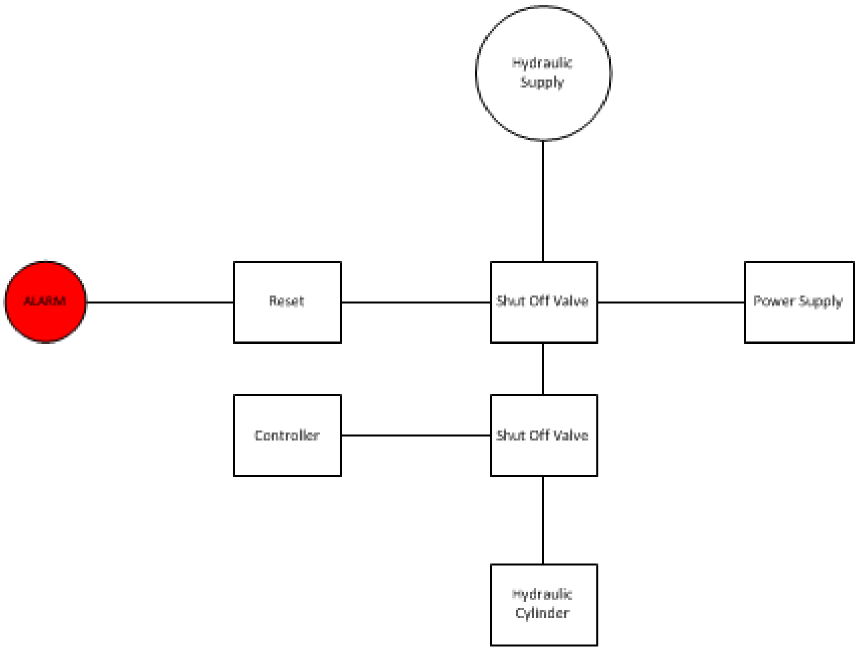


Figure 168: Hydraulic emergency shut off

Communication speed

There are critical that the communication speed between LabVIEW, CompactRIO and the Portable Test Controller is sufficient.

6. Price estimate

All the prices in the budget are exclusive VAT. Cylinders, servo valves, load cells are deliver from Hänchen (17.02.2011). This prices, in Euro, is based on exchange rate of 8, 10.
They reserve the right to change prices at the exchange rate change greater than + / -2.0%. Price on load cells' is based on separate load cell prices from Vishay. Position sensor is included in the cylinder price.

Prices for materials, stabilizer bars and main brackets are delivered from Norsk Stål [19]. Universal back plate, brackets, and custom made bracket are estimated price from KA.

The rail systems are delivered from Elmeko AS and with exchange rate of 8,0.

The prices of the units in the control system, from MOOG, are taken from the quotation that was given to KA 01.11.2010. The quotation are adjusted the project and is used to find price on each module. The prices are in Euro and are converted to NOK with exchange rate of 7, 9 (19.05.11).The chassis is estimated price based on the quotation. The offer was included one SCU, but this product needed three (one each cylinder).

Total price of control system is 210 000 NOK. This is the same price as estimated in the Document of concept rev. 1.18. Additional to the MOOG controller, there is need for CompactRIO from National Instrument. Price on this unit is estimated of KA.

Total price for the movement test rig is 1 034 000 NOK exclusive VAT. The price estimate is shown in figure below and in appendix 4.

	No of units	meters	tons	Price pr unit	Price pr meter	Price pr tons	Total Price	Supplier
Cylinders								
cylinder longitudinal	1			135656,00			135656,00	Hänchen
cylinder transversal	1			150815,00			150815,00	Hänchen
cylinder vertical	1			73725,00			73725,00	Hänchen
Load cell	3			45000,00			135000,00	Hänchen
Servo valve	3			50000,00			150000,00	Hänchen
SUM							**645196,00**	
Materials: s355J2H								
Square beams 200 x 200 x 10mm			2,10168			15078,00	31689,13	norsk Stål
Rectangular beams 100 x 60 x 5mm			0,02956			16269,00	480,91	norsk Stål
Hot rolled plates 1000 x 2000 x 10mm			0,48000			22304,00	10705,92	norsk Stål
SUM							**42875,96**	
Stabilizer bar								
Hot rolled plates 1250 x 2500 x 5mm			0,00179			22100,00	39,60	norsk Stål
Welded pipe		1,160			130,00		150,80	norsk Stål
SUM							**190,40**	
Rail systems								
Rails: MRS-65-C G2-KC L=1000mm	4			3900,00			15600,00	Elmeko AS
Carriages: MRW-65-D G2-V3	4			3950,00			15800,00	Elmeko AS
End piece:EST65-MAC	8			50,00			400,00	Elmeko AS
Mouting tool: MWC-65	1			3400,00			3400,00	Elmeko AS
Lubrication plate:SPL-65-MR	4			220,00			880,00	Elmeko AS
Assembly rail: MRM-65	1			150,00			150,00	Elmeko AS
Plastic plugs,pack of 25 pcs: MRK-65	1			100,00			100,00	Elmeko AS
Rails: BMS-25-N G2-KC L=400mm	4			450,00			1800,00	Elmeko AS
Carriages:BMW-35-A G2-V1	8			900,00			7200,00	Elmeko AS
Plastic plugs,pack of 25 pcs:BRK-25	1			50,00			50,00	Elmeko AS
Lubrication plate:SPL-25-BM	8			200,00			1600,00	Elmeko AS
SUM							**46980,00**	
Brackets								
Main bracket and angled changeable bracket: 45x970x820mm			1,1			16425,00	18067,50	norsk stål
Main bracket bottom plate: 25x420x270mm			0,18			22338,00	4020,84	norsk stål
Main bracked Stabilizers:40x690x325mm			0,29			22338,00	6478,02	norsk stål
Universal backplate, v-stay legs (left and right)	2			5000,00			10000,00	
Universal bracket, v-stay legs (left&right)	2			10000,00			20000,00	
Custom made bracket, volvo v-stay (left&right)	2			15000,00			30000,00	
SUM							**88566,36**	
Controller Hardware								
Chassis STO 03014-205, SAH SCA 03019	1			10266,10			10266,10	MOOG
SCU: SCF 04244	3			38695,30			116085,90	MOOG
Safety cable between SAH and 3 SCU's	1			2763,95			2763,95	MOOG
CompactRIO	1			50000,00			50000,00	NI
SUM							**179115,95**	
Controller Software								
Moog Smart Wave	1			13819,75			13819,75	MOOG
Portabel test controller Services	1			17373,40			17373,40	MOOG
SUM							**31193,15**	
TOTAL							**1034118**	

Figure 169: Total price estimate

7. Conclusion

This rig is now explained down to the smallest relevant technical details. There is a lot of mechanics, electronics, automation, and system engineering involved, and tests and analyses indicate that they will operate together very well. To make a long story short:

The final product is a rig for testing of V-stays. The frame of the rig is made mainly out of standardized square beams, with supporting plates strategically placed for enhanced stiffness. It will test one V-stay at a time, which will be mounted horizontally in the rig while tested. One can basically divide the physical rig into two functional parts, the horizontal system, and the vertical system. Linear motion systems will provide accurate and close to frictionless movement, and hydraulic cylinders will be its force supply. Linear motion systems and hydraulics are key features to both the horizontal and the vertical system.

A highly automated rig was necessary to meet the client’s requirements. The hydraulics will be run from an operator window in LabVIEW, and its cylinders can be told to either push or pull with certain forces, or with certain displacements. Even combinations of these and pre set tests can be done. Simultaneously, load cells and distance measuring systems ensure that all displacements and forces go via LabVIEW, and then recorded and analyzed in DIAdem. An important link between the hydraulics and the operator window is the rig’s regulator, a physical device which acts like a communication link between LabVIEW and the hydraulic cylinders. It can be seen as the brain of the rig. All signals to the hydraulics, as well as outputs from sensors pass through the regulator and provide a steady operation.

These are the main aspects and functions of the rigs technical solutions, solutions that will make testing easy and efficient, and solutions that makes the rig ready to cope with future requirements.

8. Sources

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HØGSKOLEN
i Buskerud

Department of Technology
Kongsberg

Title of document: Test Report rev. 1.4
Course (code/name) SFHO3200 Hovedoppgave med prosjektstyring
Group members: Elisabeth Espås Jenssen Jørgen Heum Larsen Andreas Fossnær Wold Edward Palm Sandaker Stina Andersen
Internal supervisor: Gunnar Flak
Date: 28.04.2011
We confirm that the submitted assignment is entirely our work. Elisabeth Espås Jenssen, Jørgen Heum Larsen, Andreas Fossnær Wold, Edward Palm Sandaker og Stina Andersen

Table of contents

1. The main objective of the test report

The main objective of the test report is to provide a detailed overview of the electrical tests in the project. The document will provide an introduction to the tests methods. The document also includes different tests. It is referred to Requirement specifications rev. 1.3 and the Test specification rev. 1.3.

2. Abbreviations

KA	- Kongsberg Automotive

3. Designations

kN	- Kilo Newton
mm	- Millimetre
kN/mm	- Kilo Newton per millimetre, defined as stiffness
N/m	- Newton per meter, defined as stiffness.
Hz	- Hertz

4. Introduction

This document will study the testing of the requirements (ref. Requirement specification rev. 1.3) on the electric part of the project. The subject to be tested is the control system (LabVIEW), analysis tool (DIAdem), electrical drawings and require from suppliers. Test of control system and analysis tool will be tested in two parts. The first part is testing hardware at KA lab, and the second part is tested with simulator in LabVIEW. Each test has a test planner, which were filled out. The test planner was introduced in the test specification (ref. Test specification rev. 1.3). The test planners are shown in appendix 3.

Verification involves that the system works according to specification, while the validation is that the system works as the client intended.

5. Methods

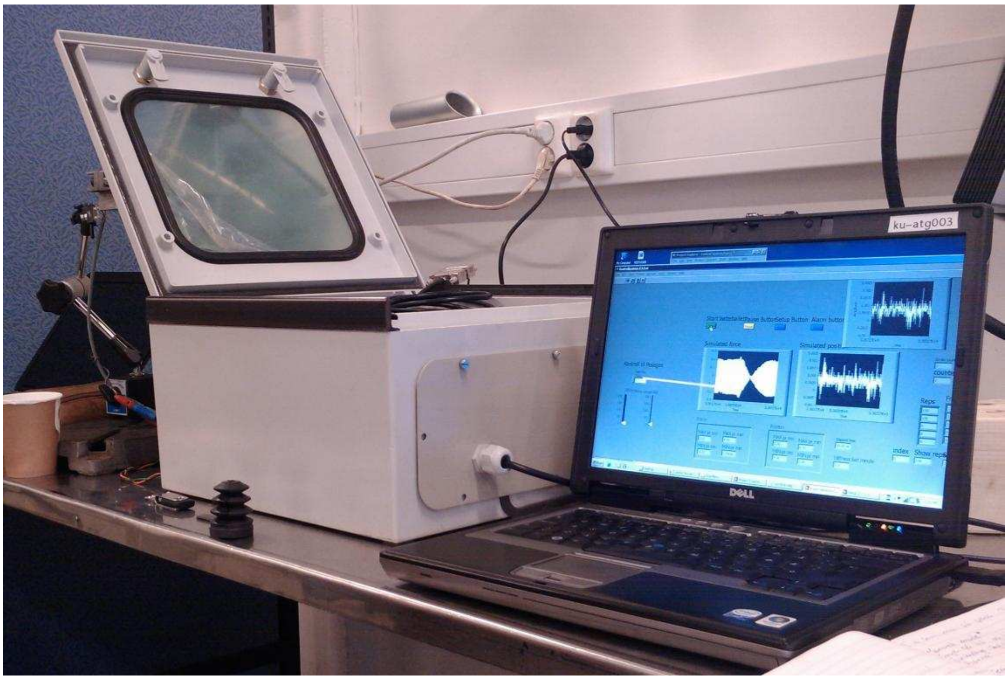
It will be used both static and dynamic testing. The control system and analysis tool will be tested dynamically, while electrical drawings will be tested statically.

LabVIEW will be tested by test the subsystems first, and then test the complete system. DIAdem is tested when a report can be created based on data from the control system. It will also to be tested if a report can be made from test data provided from Kongsberg Automotive. The electrical drawings will be reviewed thoroughly.

5.1. Test Procedure

Every test is to be planned in advance, with proper requirement-ID and Test-ID.
If an error is found, a deviation report will be made. The subject is then to be corrected and tested again until the requirement is verified. A test planner will be filled out for each test.

6. Test of control system at Kongsberg Automotive

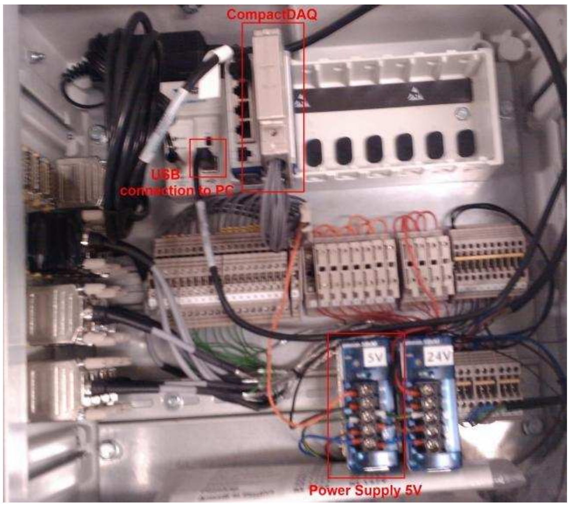


Picture 1: Test set-up

Some of the requirements of the control system where tested at Kongsberg Automotives lab. The objective of the test is to verify the control system on hardware at KA. The simulator function in LabVIEW is replaced with hardware.

Equipment

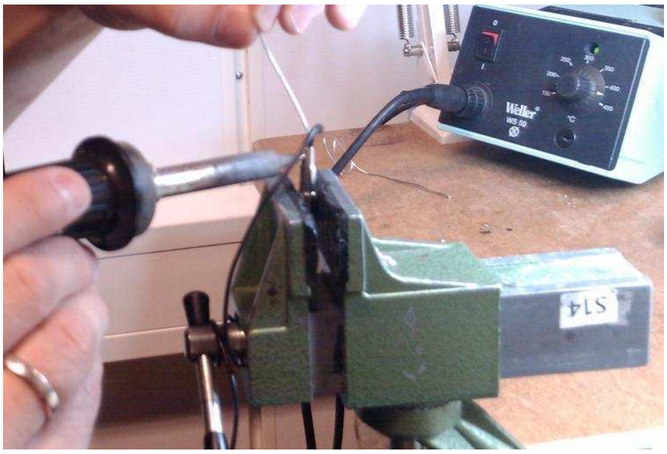
Potentiometer
Load cell
Cables
Cabinet with:
CompactDAQ (National instrument)
PC
Power supply 5V
IO's
Two springs with different stiffness constants.



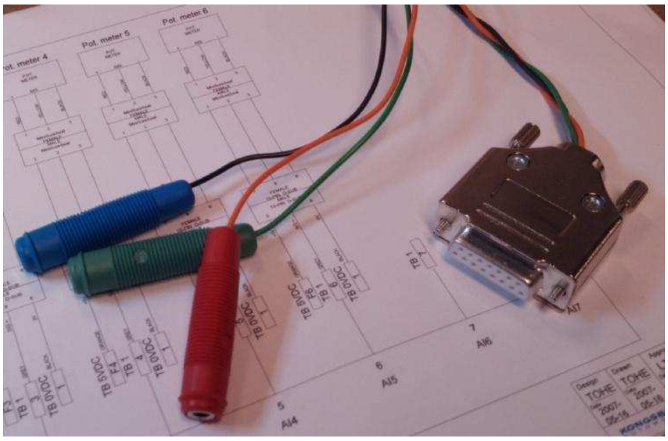
Picture 2: Cabinet with hardware

6.1. Wiring

Three cables were soldered together to a serial port. The green cable was the signal, orange for power and the black to ground.



Picture 3: Soldered cable

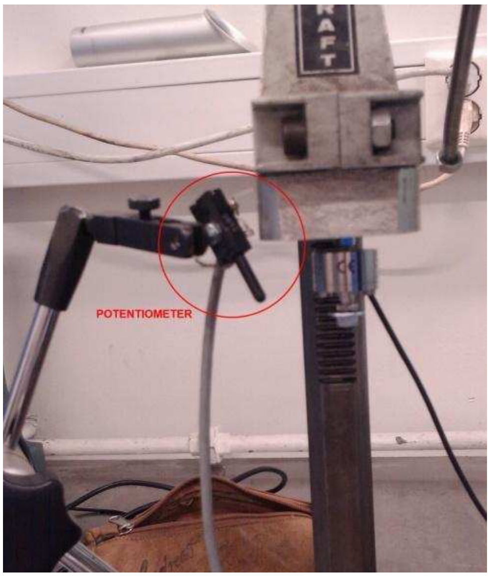


Picture 4:

6.2. Configuration and read signal

The potentiometer and the load cell were coupled to a cabinet. The computer communicated with the compactDAQ through a USB cable. LabVIEW communicates with the hardware through a function called DAQ Assistant.

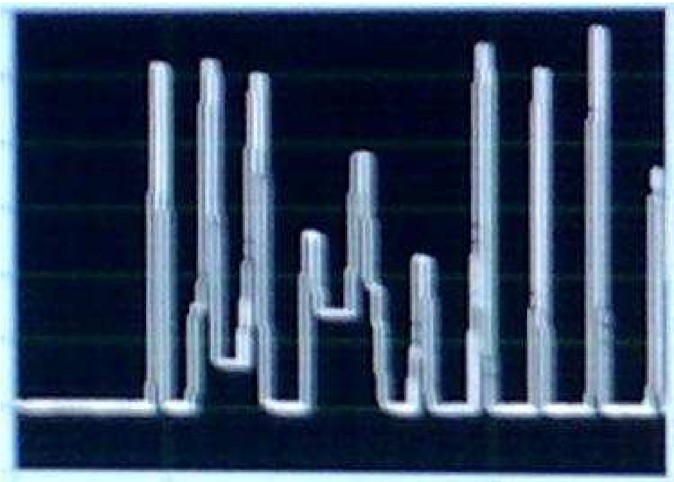
This function is replaced with the two simulators of force and position signal. The signal from potentiometer has value from zero to 5 voltages and gives the signal to position. The load cell gives mV/V signal to Force.



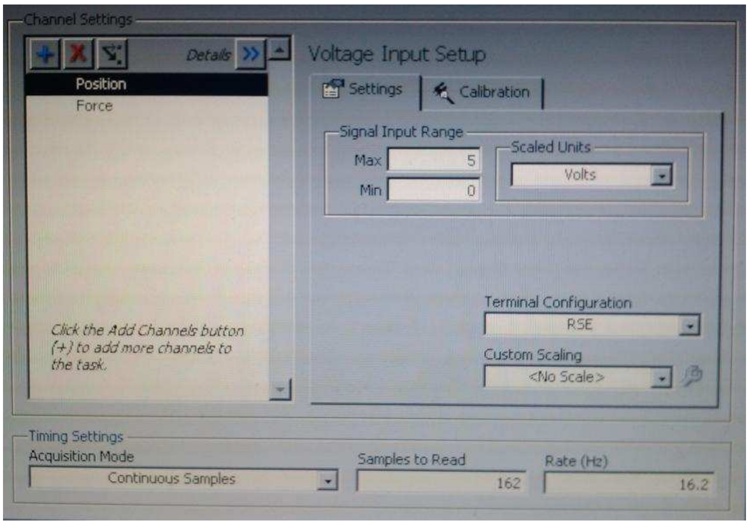
Picture 5: Potentiometer

Trigger and sampling

The trigger needed some adjustment with the sampling and it had to correspond to the frequency in the DAQ Assistant.
First step was to read the voltage signal graphically from potentiometer in the front panel in LabVIEW.

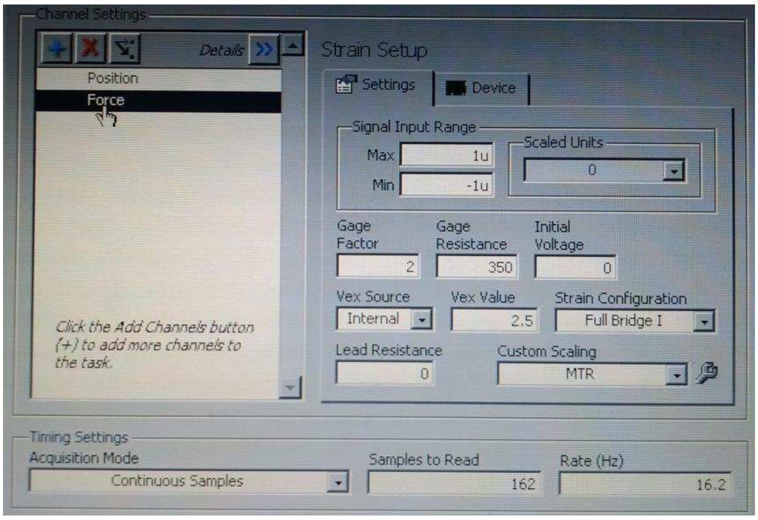

Picture 6: Signal from the potentiometer

Frequency, samples and name of the signal are configured in properties of DAQAssistent.
The force signal was disabled.



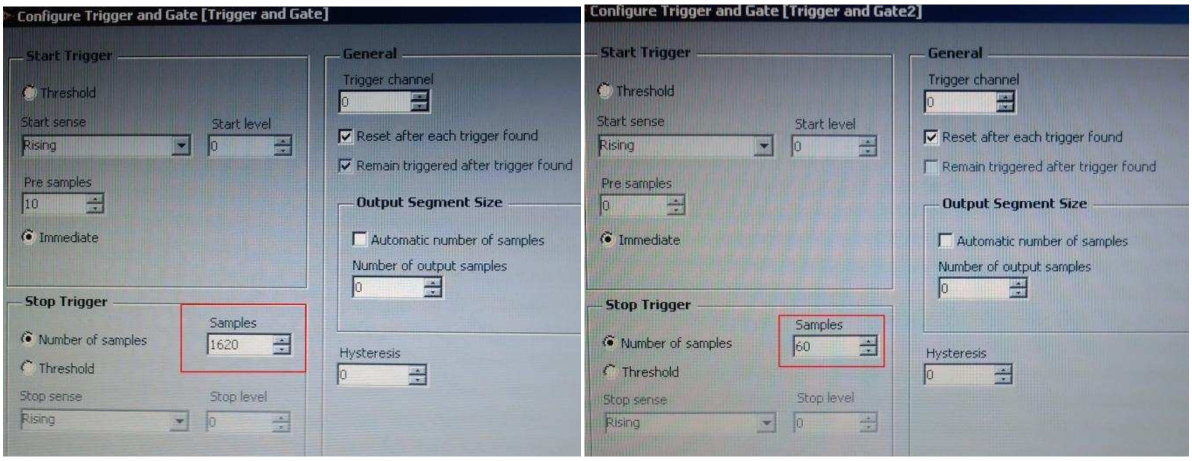
Picture 7: Properties in DAQAssistent of position signal.

Second step was to include the signal from load cell. The challenge was to configure the correct sampling frequency in DAQAssistent and the trigger functions. This was found by running the program and observes the max and min values per second. By probe the signal in the block diagram window we observed the 'dt' signal. One divided by 'dt' gave the sampling frequency, and the value was used to find correct relation to the sampling frequency.



Picture 8: Properties in DAQAssistant of force signal

The trigger functions in LabVIEW needed sampling of 1620 Hz. The sampling frequency was high, because of the frequency on the compactDAQ unit.



Picture 9: Left: Trigger per second with sampling frequency at 1620 Hz. Right: Trigger per minute with sampling frequency at 60 Hz.

Scaling

The voltage signal was scaled to position and force. This could be done in the properties in DAQAssistent or numerical. It was decided to be done numerically. Figure below show the mathematically model of the scaling.

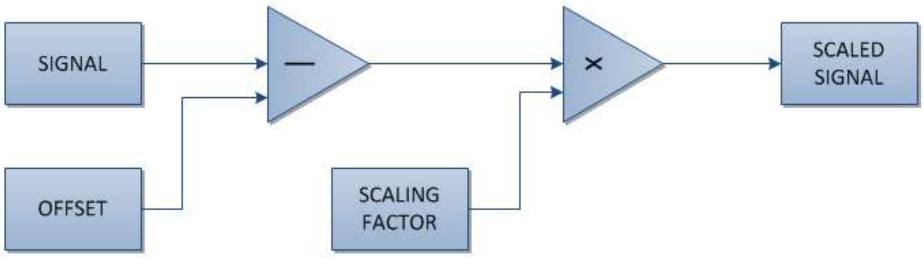


Figure 1

Scaling from potentiometer and load cell must be done separately. Example below is from the load cell. The unscaled signal from DAQAssistant is reading graphically in the front panel and the mean value was observed. This is the offset value. The offset value is subtracted from the signal from CompactDAQ. The scaling factor is calculated and multiplied to the signal and a scaled signal is sent through the system. Figure below display where to set the values in the front panel.

First step was without the load cell. The mean value of the signal is the offset value and is written in the 'Idle voltage' indicator. The signal will now have a mean value on zero. The desired value is written in the 'Idle voltage equal to', which is zero.

Step two is applying an approximation constant load on the load cell. The mean value is written in the 'Calibration Point voltage'. Desired value is written in the 'Calibration Point voltage equal to' indicator. The desired value was found by mathematically calculation in LabVIEW.

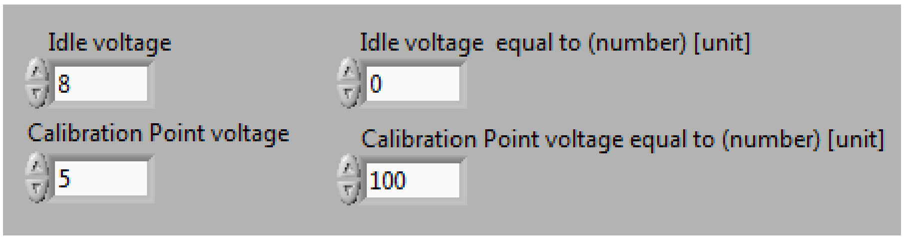


Figure 2: Section from front panel in LabVIEW

Figure 3 show the block diagram and calculation of the scaling factor.

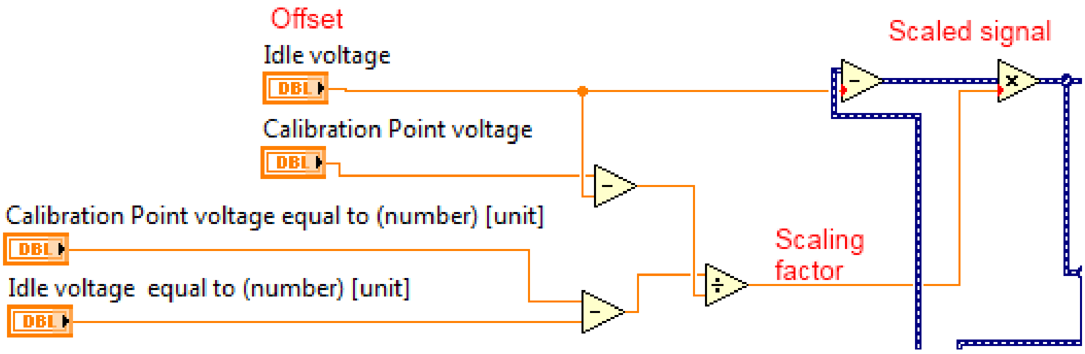


Figure 3: Section from block diagram in LabVIEW

The idle voltage signal is, as mentioned, subtracted from the unscaled signal from DAQAssistant. The difference between measured value with no load, ‘Idle voltage’, and with applied load, ‘Calibration Point voltage’ is the derivate and shown in figure 4 as Δa. The difference between wanted values is the derivate and shown as Δb. The scaling factor is $\frac{\Delta b}{\Delta a}$ and is the slope of the function. This value is multiplied to the signal and results a scaled signal with unit N. The same process is repeated with the signal from the potentiometer and gives unit in mm.

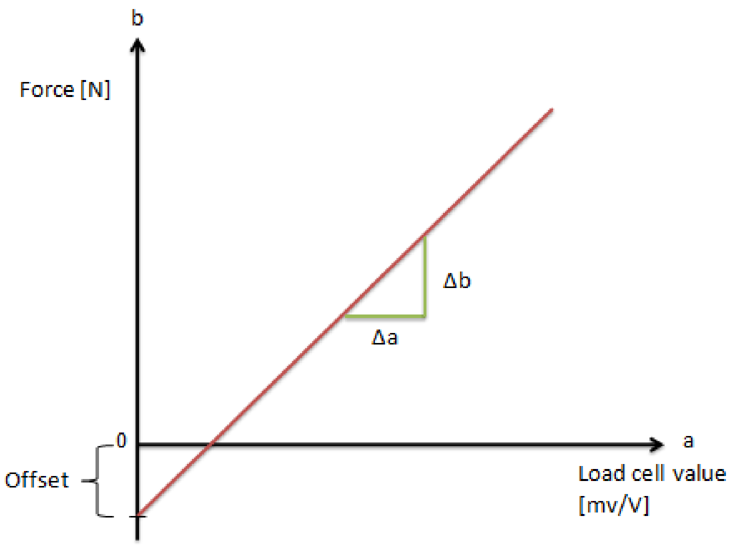


Figure 4 : How to find the slop

6.3. Test of stroke counter

The object of this test was to verify if the program counts correct cycles and repetitions. When the frequency and sampling was correct there was no need for adjustment for the stroke counter.

Result

It was counting cycles and repetitions in accordance with the operating time.

Requirement

TI2 - Run a test and see if it counts
[RI2 - Operator window in LabVIEW must have setup window with stroke counter]

TI5 - Simulate a test and observe the time with a timer
[RI5 - Operator window in LabVIEW must show operating time]

6.4. Test of write to file with header

The object of this test was to test if the program writes observable files with correct headers.
It should contain force, position and time channels with name and unit’s kN/mm and mm.

Result

The time signal needed to be merged into the write to measurement function. Time was included in the simulated signal but not in the DAQAssistant. Another customisation was changing the file format from TDM to LVM. LVM format was also capable to be read in Microsoft Excel format. The LVM file could be read and analysed in DIAdem. Name and unit were not in the signal, because it was not included in LabVIEW. This will be provided in the simulator test.
The LVM file could be read and analysed in DIAdem. The LVM files are dragged over to the Data Portal in DIAdem. This files did not include unit, and there were applied Newton to the force channels and millimetre in the position channels. The untitled channels are time and will not be used in this test. More information regarding analysing in DIAdem is written in the user manual document (ref. DIAdem user manual 1.9).

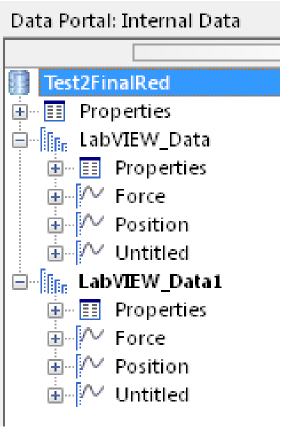


Figure 5: Log data in Data Portal

All the values are visible in a channel table. Figure 6 shows the channel table with force and position for the test with red spring and the green spring.

Selected Channels				
Name	Force	Position	Force	Position
Number	1	2	4	5
Length	18144	18144	16848	16848
Unit	N	mm	N	mm
Channel Contents				
1	0.289941	0.000169	0.424086	0.000234
2	-0.410594	0.000169	0.236709	0.000366
3	0.062108	0.000234	-0.278578	0.000234
4	-0.344586	0.000103	-0.057132	0.000366
5	-0.176372	0.000234	-0.110364	0.000497
6	-0.253026	0.000169	-0.721469	0.0003
7	0.015264	3.705749E-05	-0.36162	0.000366
8	-0.235992	0.0003	0.049332	0.000169
9	-0.148691	0.000234	-0.127399	0.000366
10	0.485836	0.000234	0.285683	0.0003
11	-0.329681	0.000103	0.298459	0.000169
12	0.05572	0.000234	0.211158	0.0003
13	-0.082684	0.000103	-0.640556	0.000234

Figure 6: Channel table with force and position

Require

TI1 - Check the storage function of the control system.
[RI1 - The control system must save test log-data.]

6.5. Total test

The objective of this test was to check if the whole system communicated with each other. The complete system was tested in a functional test when all configurations were done. Additional equipment was two springs with different stiffness constants. The red one had highest stiffness and compared as a new V-stay, and the green one had lowest stiffness and compared as a V-stay after a durability test. The potentiometer, load cell and the spring were placed side by side and there were applied force by hand. The position and force signal will be shown in the graph indicator in LabVIEW.

Result

The force and position signals were following each other which indicated that the signal are correct. The log data files are shown and analyzed in DIAdem.

The values from channel table in figure 6 are analysed (ref. DIAdem user manual 1.9) and maximum stiffness is found for each test. Figure 7 shows a report where maximum stiffness is represented. The red curve is stiffness for the red spring and can be compared as a new v-stay before a durability test. The green curve is the result for the green spring and compared with a V-stay after a durability test. A durability test subjects wear on bushings and the stiffness will decrease as a consequence of this. This is demonstrated in the graph where the green curve has lower stiffness constant then the red one.

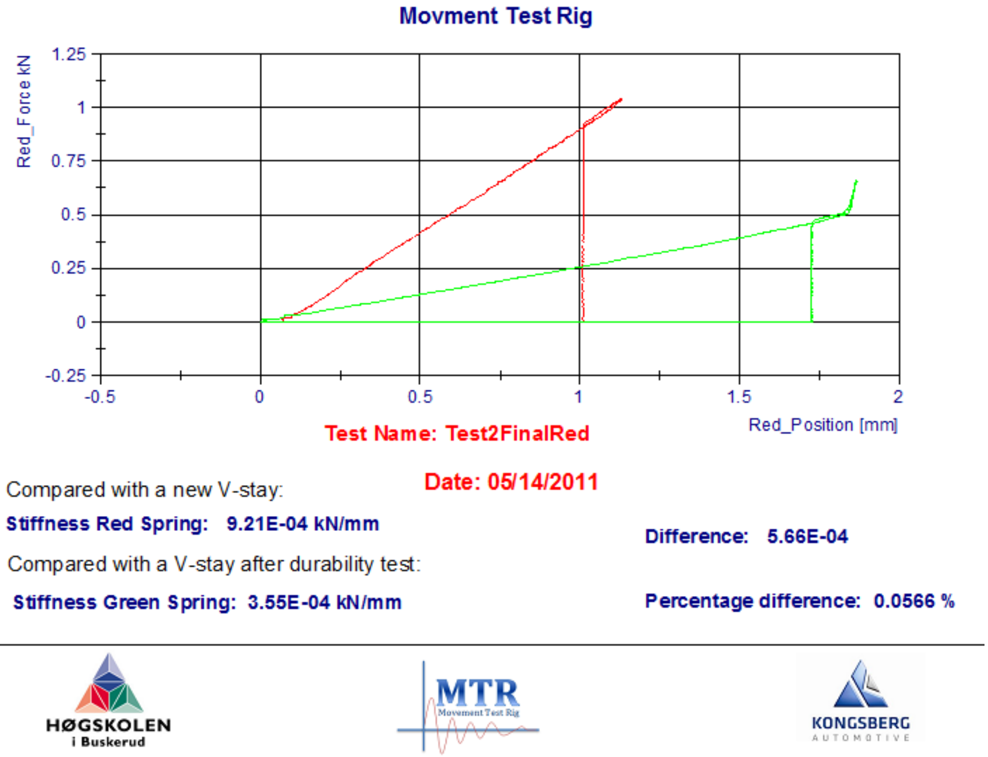


Figure 7 : Report of test of control system done at hardware at KA

There are also done analyses for existing log data from KA (ref. DIAdem user manual 1.9). Log data is from a functional test for a new V-stay and the same V-stay after a durability test.

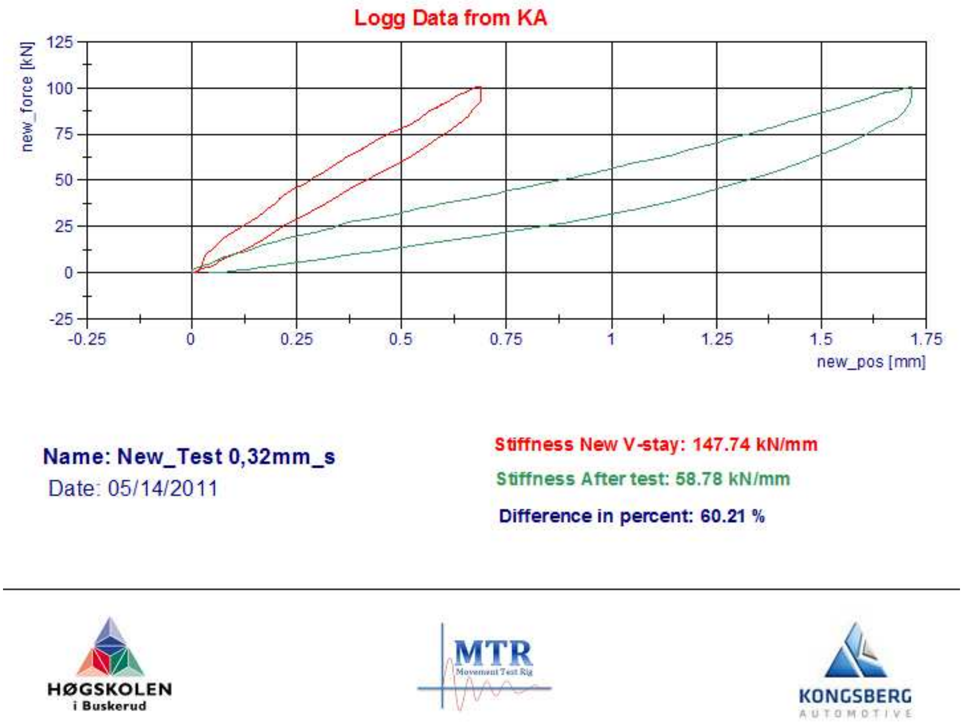


Figure 8: Report of log data from KA

Figure 8 show the result from log data from KA. The red curve represents a new V-stay and the green curve represents the V-stay after a durability test. The red curve has higher stiffness the green curve. This is the same result as the test with the two different springs. Figure 8 show that stiffness from a new V-stay is 147, 74 kN/mm.
Compared with the test with springs and of real V-stays, it is large difference in the stiffness constants. The green spring has stiffness $9{,}21 \cdot 10^{-4}$ kN/mm, which is the same as 921 N/M. The low stiffness in the springs are because the spring is able to be depressed by hand, and the bushings need applied force by a cylinder over time to change stiffness

Requirement

TF10 - Compare with previous results from the same type of test (single measurements). Run a functional test and see if the result is as expected.
[RF10-The rig must be able to perform a functional test]

TP 7 - Simulate, observe and verify results
RP 7 - The control system must be able to show visual presentation of the data

7. Test of control system with simulator

Some of the testes of the control system were tested with the simulator function in LabVIEW instead of the hardware at KA. This part explains how the testes were done and the result.

7.1. Frequency

The setup window includes frequency. The force is depending on what channel to be tested. The test was verified. Applied force is shown in the front panel.

Requirement

TI3 - Simulate a test and observe the frequency
[RI3 - Operator window in LabVIEW must have setup window with frequency]

Requirement

TF17 - Requirements for the supplier
RF 17 - Must go 60 million strokes

7.2. Simulator

A simulator function in LabVIEW was made. The signal was observed and confirmed that it provided good and relevant values. Test specification (ref. Test specification rev 1.3) says that the signal should be compared with V-stay references. This could not be accomplished since the test data and simulator signal were not congruent.
The simulator was also checked with the stiffness value. Force and stiffness parameters were sat to the force and position simulator. The program runs and calculated stiffness. The stiffness indicator shows the same value as the preset stiffness value. This was a check for the simulator.

Requirement

RF13- A functional simulator of the rig must be provide
TF13- Run simulation with force applied and compares results with v-stay references

7.3. User friendly Interface

The objective of this test was to check if the interface in LabVIEW is user friendly.

Result

Another group member with small knowledge in LabVIEW got an introduction in the program. The test person tried to use the program afterwards, and the test person found it easy to understand and use.
The program was also presents to persons at KA. The requirement is satisfied.

Requirement

TP6 - Get others to test whether it is easy to learn and easy to operate
[RP6 - The control system must have a user-friendly interface.]

7.4. Alarm

The objective of this test was to verify that the alarm functions in LabVIEW stops if deviations appear. This was done by manipulating the input signal and check if the system stops.

Result:

the same function.   RP2.3 is tested. It was tested if the emergency stop works. The position value was increased manually, and when the position is 130% more than initial value, the program will stop. The test was complete and verified.

When spring travel reaches a given value in percent, the alarm will be switched on. The program was run and an alarm appears on the front panel. The test was verified.

It is required that the rig is self diagnostic. This test was done by apply force, but no registered displacement. The rig stopped and the test was complete.

Requirement

TP2 - Manipulating input / measurements in the code. Control if the system stops, include emergency stop in electrical forms
[RP2- The rig must contain emergency stop devices]

TP 2.3- Manipulating input / measurements in the code. Control if the system stops, include emergency stop in electrical forms
RP 2.3- Emergency stop device should be implemented in the software

TP 9 - Manipulating input / measurements in the code. Check if the system stops
RP 9 - An alarm must be switched on when spring travel reaches a given value measured in percent

TF16 - Manipulating input / measurements in the code. Determine if the system stops.
[RF16-The rig must be self-diagnosing]

7.5. Stiffness

The objective if this test was to check if the stiffness calculation in LabVIEW block diagram shows numeric indicator of stiffness in use of different tests.

Result:

The program was running and the stiffness indicator show stiffness value. This was done with the simulator, and the stiffness parameter was set for value to force and position simulator. The stiffness indicator was equal to the parameter set up. The operator window is able to show measured stiffness.

The three next testes deal with stiffness in different channels. Longitudinal and transversal channels must measure stiffness (10)-50 kN/mm from 0 to 200 kN. The parameters in setup window were set to 50kN stiffness and 200kN in force. The channel was selected to longitudinal or transversal, depending on type of test. The stiffness indicator in the front panel was observed and displayed 50kN. These requirements were satisfied.

Require TF 8 (ref. Requirement specification rev 1.3) was not verified. It was suppose to show stiffness in degrees. The control panel did not have any indicates in degrees, only in kN/mm. The test was accomplished with conversion of the result.

Requirement

TI4 - Simulate a test and observe if the stiffness corresponds
[RI4 - Operator window in LabVIEW must show stiffness measurements]

TF 6 - Simulate, observe and verify results + comparison with data from KA (estimates in the control system
RF 6 - The rig must measure transversal stiffness, Cy: (10)-50 kN/mm from 0 to 200 kN

TF 7 - Simulate, observe and verify results + comparison with data from KA (estimates in the control system
RF 7 - The rig must measure longitudinal
Stiffness Cx: (10)-50 kN/mm from 0 to 200 kN

TF 8 - Simulate, observe and verify results + comparison with data from KA (estimates in the control system
RF8 - The rig must measure vertical stiffness,
Cz 0-300 N/° from 0 to 20°

7.6. Durability test

There are impossible to make a durability test with length of several months. As an alternative the test was conducted over several hours. This test was done by start the program during the night. If the program was still running the test was complete. Require TF 2.1 and TF9 (ref. Requirement specification rev 1.3) and has the same intentions. In light of this it was only done one test.

Result:

The control system was running for 7, 5 hours (27307 sec). There were not doing any changes of the parameters during test, but the program was still running. This approved that the program has 100% duty cycle. The log data was analyzed in DIAdem. Figure 9 show the report of the durability test. Stiffness during time is represented in the graph.

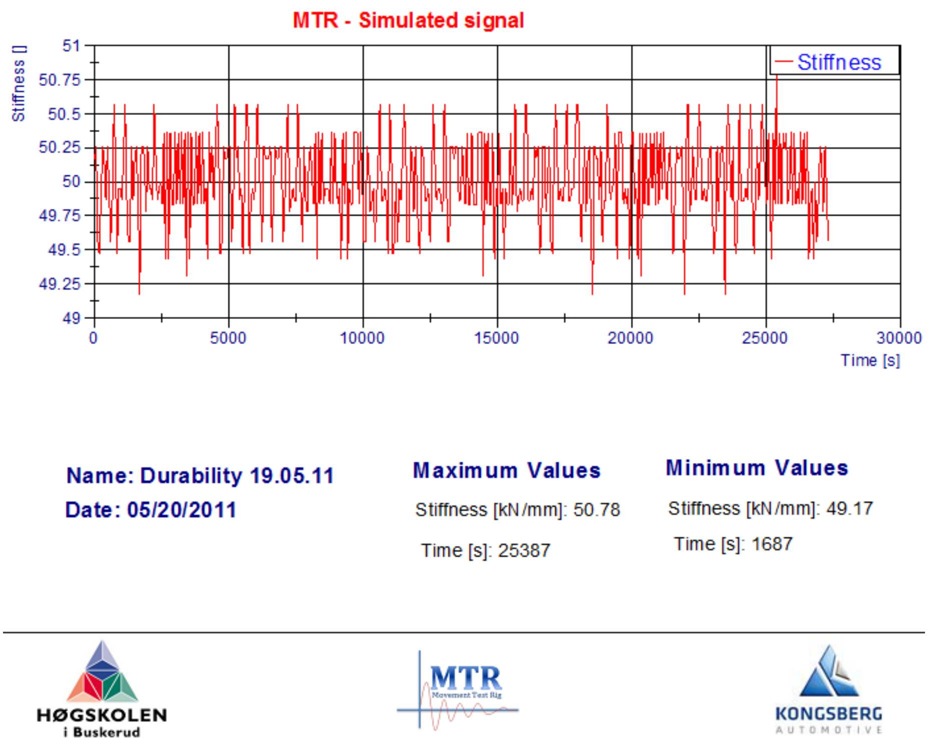


Figure 9: Report from durability test

Requirement

TF 2.1- Simulate, observe and verify results
RF 2.1 -Nonstop movement (100% duty cycle)

TF9 - Simulate, observe and verify results + the control system are running continuously
[RF9-The rig must be able to perform a durability test]

8. Test of DIAdem

The objective of the DIAdem test was to verify that the analyzing tool was able to search from former tests.

Result

DIAdem has a function called ‘Data Finder’ in the ‘Navigator’ menu. (ref .DIAdem user manual 1.9) In the search area in figure 10, there is possible to type inn text to search for.

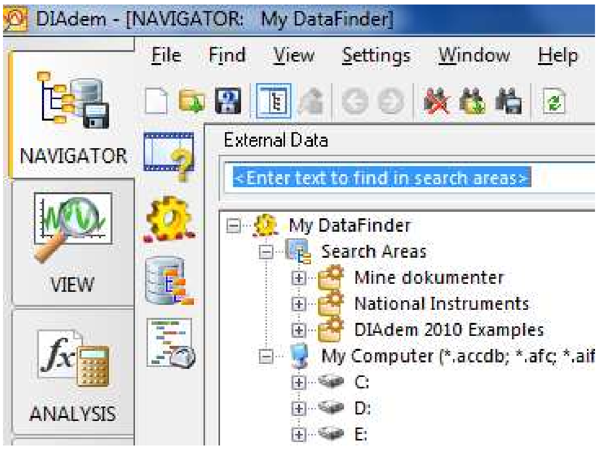


Figure 10: Search area

Requirement

TI6 - Check in the DIAdem whether it is possible to obtain data
[RI6 - The control system must search for data from former tests]

9. Static testing

9.1. Test of electrical drawing

The objective of this test is to verify that an electrical drawing was made correctly. This was done by checking the drawing by a person with knowledge of the subject.

Result:

The electrical drawing was presented to a person at KA. This was done in the last part of the project. The work that was done was correct, but it remained some work before it was complete. Time was a challenge when working on this task. The electrical drawings were developed, but it was never tested by a knowledge person.

Requirement

TF11 - Observe and test the logical outcome of drawings
[RF11- Make electrical drawings]

9.2. Requirement from supplier

The requirement specification (ref. Requirement specification rev 1.3) had several requirements about the chosen hardware. Requirements were taken into consideration during the selection of supplier. A review around the choice of supplier is written in choice of concept documentation (ref. Document of concept 1.18). Sellers and data sheet provides information if the product met the requirements.

Requirement

TF-19 Requirements for the supplier
RF 19- Force supply must be able to produce a maximum load frequency of 20 Hz

TF15- Requirements for the supplier, compare with log data from KA. Identify the target area on beforehand.
RF 15 - Sensors must have minimum 10 times higher resolution than values measured

TF 4 - Simulate, observe and verify results + requirements for the supplier
RF 4 - Force supply must produce static loads up to 200 kN

TF 5- Simulate, observe and verify results + requirements for the supplier
RF 5-Force supply must produce dynamic loads up to 160 kN.

HØGSKOLEN i Buskerud

Department of Technology
Kongsberg

Title of document: LabVIEW user manual rev. 1.1
Course (code/name) SFHO3200 Hovedoppgave med prosjektstyring
Group members: Elisabeth Espås Jenssen Jørgen Heum Larsen Andreas Fossnær Wold Edward Palm Sandaker Stina Andersen
Mentor: Gunnar Flak
Date: 25.05.2011
We confirm that the submitted assignment is entirely our work. Elisabeth Espås Jenssen, Jørgen Heum Larsen, Andreas Fossnær Wold, Edward Palm Sandaker og Stina Andersen

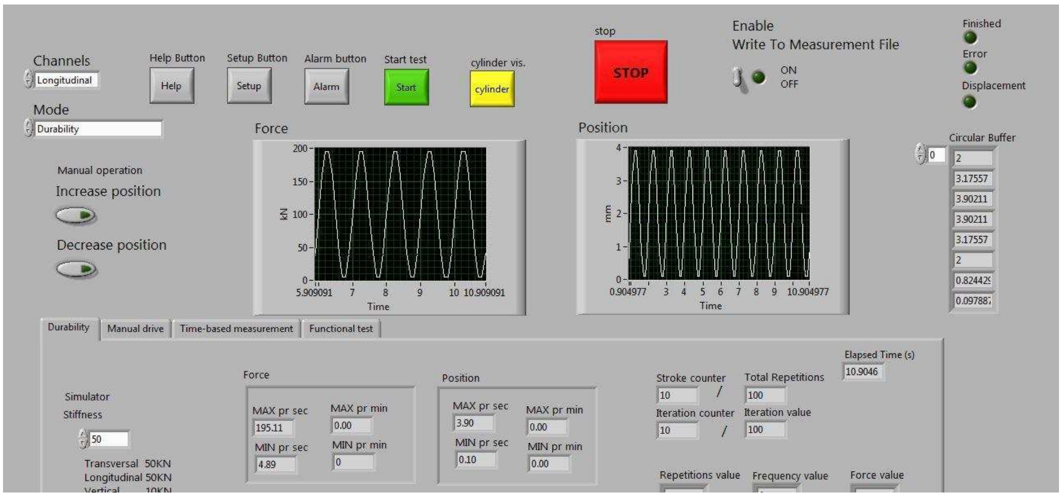
Table of contents

1. Introduction

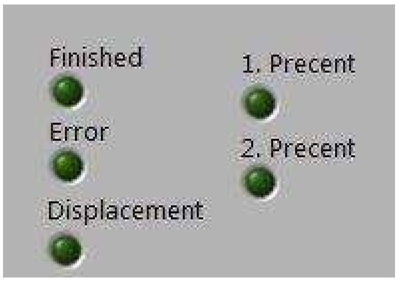
This tutorial will give an explanation on the various tests available and how to set up and run these. There is also an explanation on how log files are created. Force is measured in KN and position is measured in mm. The setup button is primarily used for durability test due to the amount of parameters. In the simulator max frequency is 5 Hz. This is due to the simulator setup.

2. Layout

The project has emphasized that the front panel should be as user friendly as possible. The overall layout is that the operating buttons are on the top, information visualization is located in the middle, while the indicators with various parameters are shown at the bottom. The information is shown in two graphs/charts. The chart to the left shows the force, while the chart to the left shows the position.



On the top right is the alarm indicators. These are 'Finished', 'Error' and 'Displacement'. When a durability test is completed the rig stop and the 'finished' indicator will switch on. The 'Error'-LED indicates that there is applied force on the cylinder but no movement in the V-stay. To prevent damage to the rig, the program stops. The 'displacement'-indicator tells the operator when the displacement in the V-stay has passed 130% of initial value. This indicates breakage in the V-stay and the rig will also stop. The indicators to the right show the operator the percentage completion. This is further explained in the alarm setup.



3. Buttons

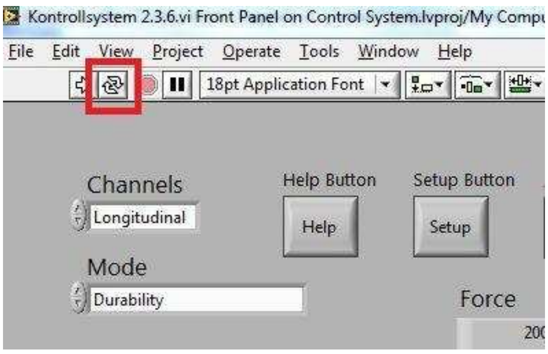
The button layout is set up so that it will be natural for the operator to start with setup and alarm setup before the test is started. The stop button is also made much bigger and easy to find than the other buttons.
On the left side of the charts, there to buttons marked increase position and decrease position. These are for manual positioning of the cylinders.
Above the manual positioning the operator can choose mode and channel.
Here follows an overview over the buttons available for the operator.
Start: This button starts the test.
Stop: This button stops the test.
Set up: This button activates the event which calls on the setup FP.
Alarm: This button activates the event which calls on the Alarm setup FP.
Help: This button calls a dialog box which contains tips and help.
Enable WTMF: This button activates the “Write to measurement file” option.
Mode: Here the operator can choose which mode to test in.
Channel: Here the operator can choose which channel to test.
Cylinder visualization: This button calls the VI that shows the simulated cylinders in motion.

4. Steps to perform a test

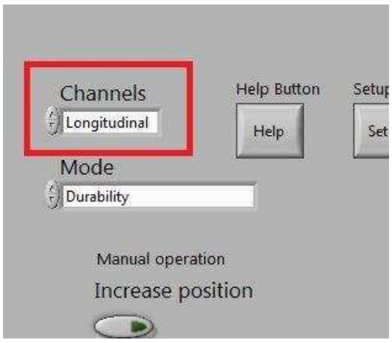
To set up and start a test, the operator follows these steps:

a) Start the program (Run continuously)
b) Choose which channel to test.
c) Choose what mode to be tested.
d) Click the ‘Setup’-button to set the desired values
e) Click the ‘Alarm’-buttons to set your alarm values
f) Click the ‘Start’-button

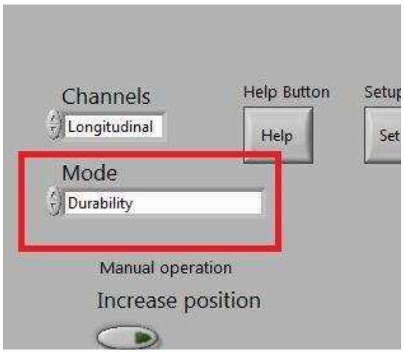
a) To get the program to function at all the operator first need to start LabVIEW by clicking on the ‘Run continuously’ in the top left corner of the screen.



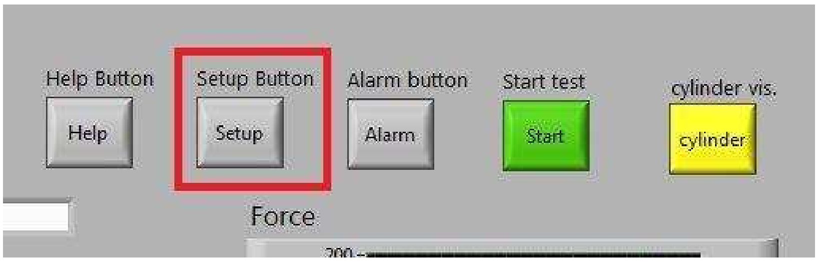
b) Choose which channel (direction).
The operator can test in three directions. These are longitudinal, transversal and vertical. These are selected in the channel-selector.



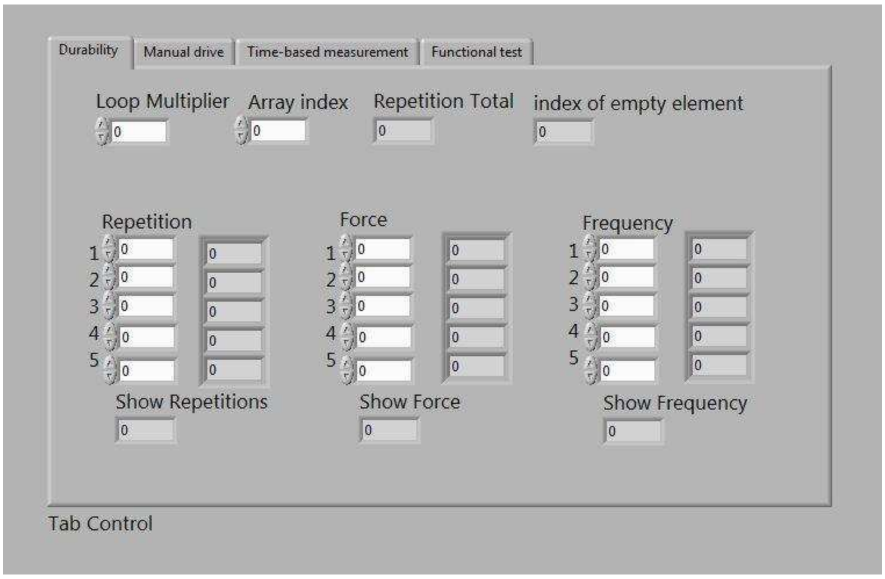
c) Choose what mode to be tested.
This decides what kind of test the operator want to perform. The available tests are durability test, functional test, time-based test and manual drive. The various tests will be described in chapter 8.
The mode selector is located beneath the channel selector.



d) Click the 'Setup'-button to set the desired values

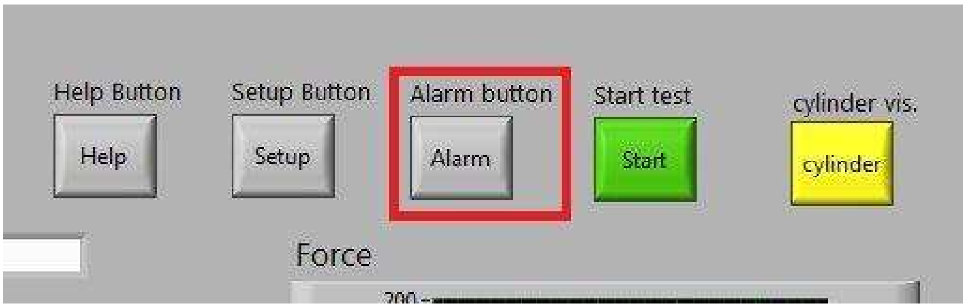


Click the setup button and the setup window will pop up.

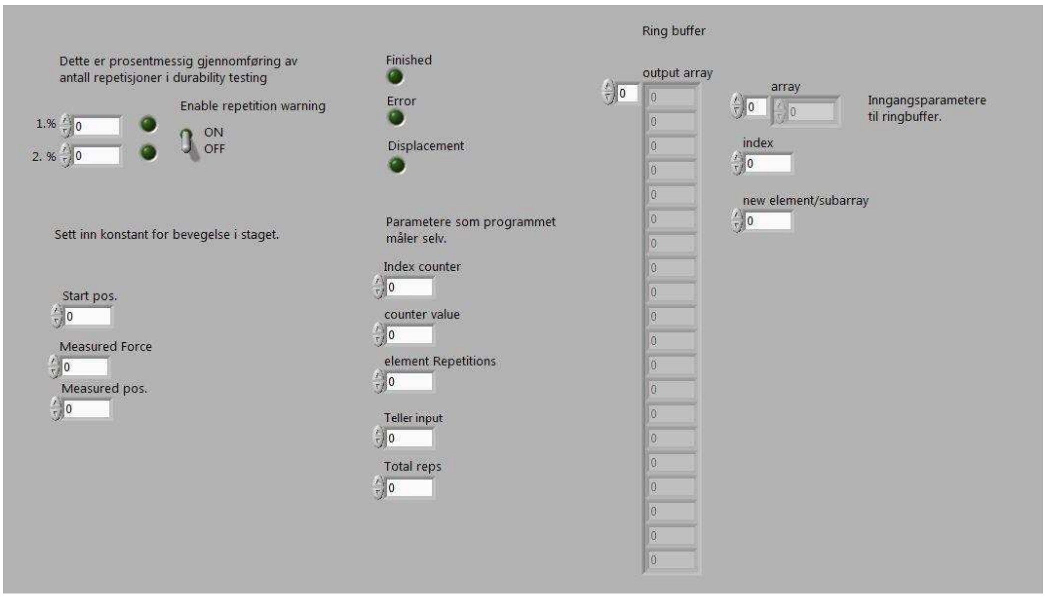


This is the setup window where the operator can set the desired values. Setup for the individual test will be described in more detail further down.

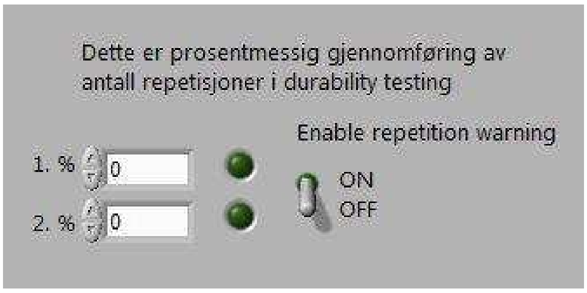
e) Click the 'Alarm'-buttons to set your alarm values.



Click the setup button and the alarm setup window will pop up.

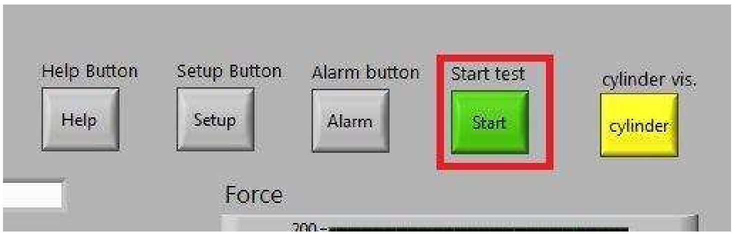


The alarm window contains indicators and controls relevant for alarm conditions in the program.
Many of these controllers are also set in the main front panel, so there is not much work to do for the operator in the alarm setup.



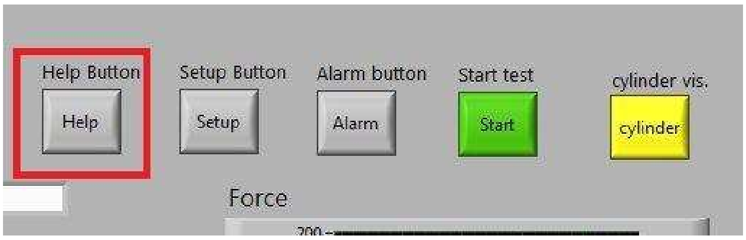
An option for durability test is that the rig gives a signal when the test has reached a given percent of completion. The operator can decide two percent-values. An example is that the indicators lights up at 50% and 75% completed strokes. The value can be set from 0 to 1. (75% = 0.75)
This is alarm is optional and is activated by clicking on the switch.

f) Click the 'Start'-button.
Now the operator has completed the setup for a test and is now ready to start. This is done by clicking the green start button.



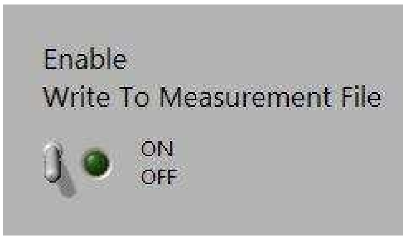
5. Help dialog

These steps are also available for the operator in the LabVIEW program. By clicking the Help-button, a dialog box comes up with a short description on the test setup.



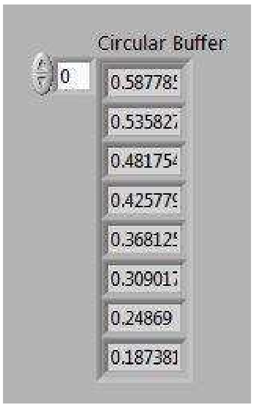
6. Write To Measurement File

The program has a function that writes all log data to an external file for further analysis. This is called 'Write To measurement File'. When a test is started a window will pop up and ask the operator to name and place the saved test file.
If a durability test or a time based test is to be performed this question will come after one minute. When these tests are performed, test values will be stored every minute.
Functional test will log data continuously.
The operator can also activate the 'write to measurement file' switch on the front panel. This will activate a second report which will log data continuously for the period of the time the switch is on.

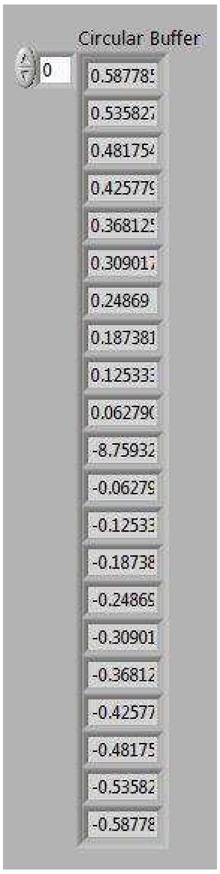


7. Circular buffer

In the program there is a circular buffer which holds the position values for the last sixty seconds.
The buffer is updated every second. If the V-stay should break the operator can look at the values for the last minute to see if there any indicators of breakage previous to the V-stay failure. To save space in the front panel the buffer is compressed.



The operator can without problems extend the array to see the last values.



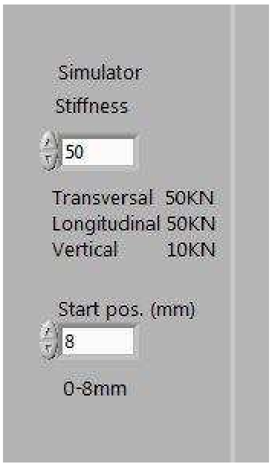
8. Modes

Here follow an explanation of the various types of test that can be performed in this LabVIEW program. The tests available are durability test, functional tests, time-based test and manual drive.
To sort out information from the various modes, controllers and indicators are located in a tab-window. The specific tab-window is selected automatically when the mode is set in the mode selector.

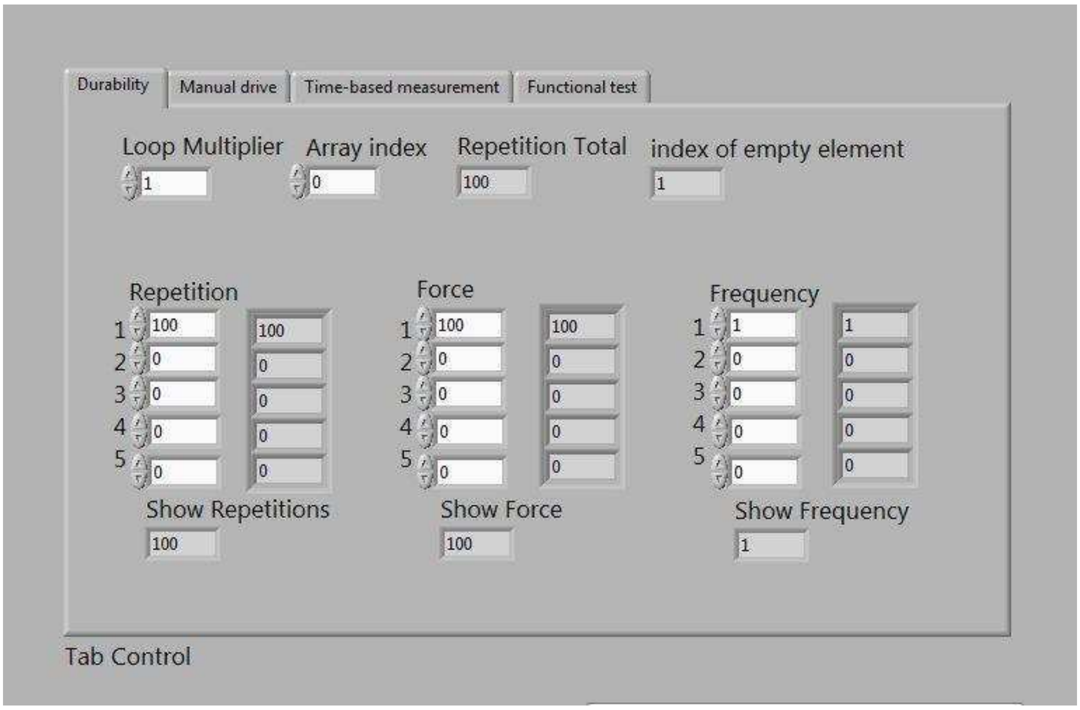
8.1. Durability

Durability testing is used to wear out the rubber-bushings in the V-stay or to check how much a V-stay can handle.
In durability mode, there are two parameters that need to be set before a test.
The upper hand parameter describes the stiffness of the V-stay in the different directions. This control is used to get the simulator function properly and is not going to be a part of the control system in the finished rig.

The lower hand control describes the initial movement of the V-stay. This parameter is basis for the displacement alarm mentioned above.

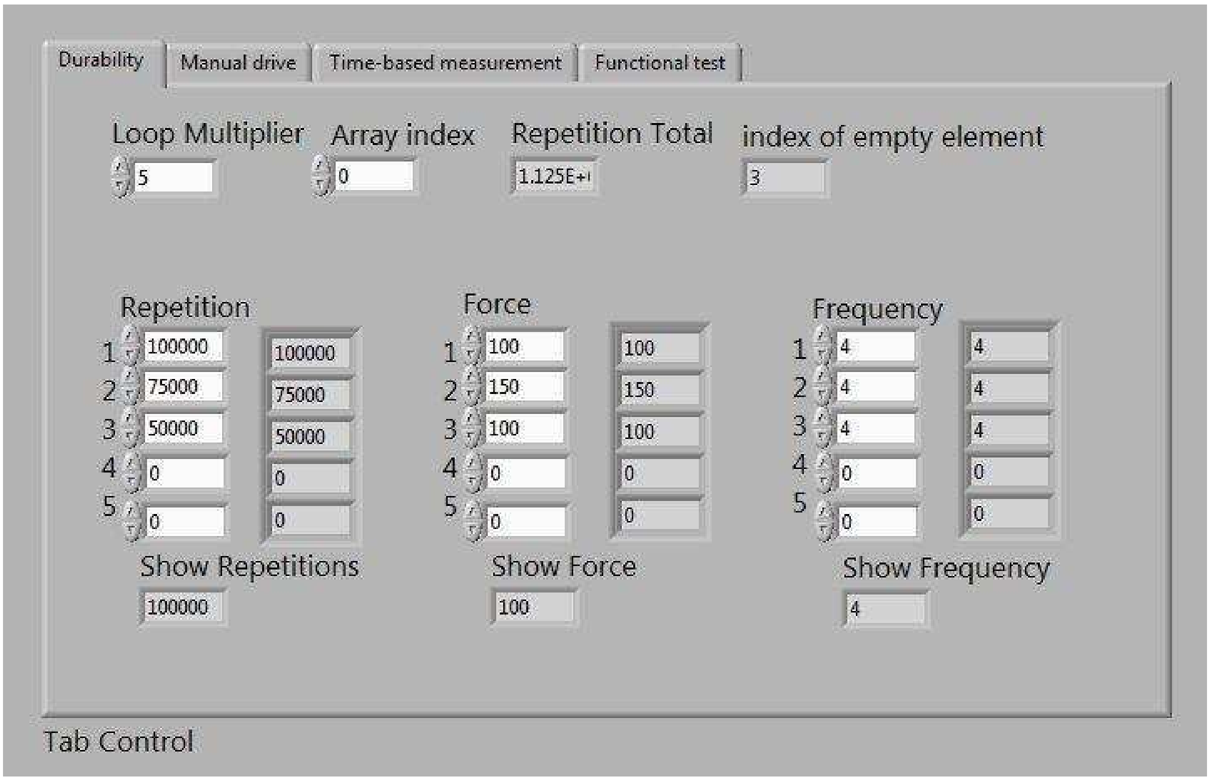


To set up a durability test, the operator needs to set the parameters in the setup window.
NOTE: These parameters have to be set in all tests in order to get position measurements.



In the setup window the operator can set the number of repetitions, amount of force and the frequency. The test can also be run in sequences with different numbers of repetitions

with individual force and frequency for each iteration. The loop multiplier determines how many times this setup will loop over. When the test is finished the program stops.
An example of this setup can be as follows:

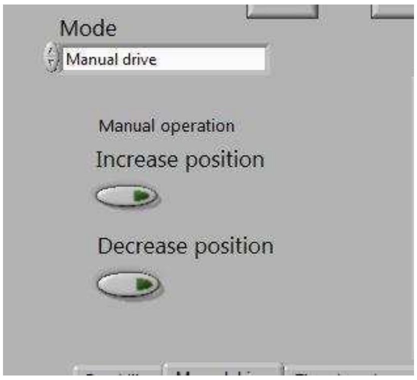


In the front panel, the operator has following information available.

On the bottom right is the information about number of repetitions, force and frequency. On the top right is the stroke counter, iteration counter and total number of repetition and number of repetitions in the ongoing iteration. In the middle the maximum and minimum position and force is displayed. The box to the left shows the values available for each second and the box to the right shows the information available for each minute. Below the position and force indicators are the stiffness indicators. To the far left are the controllers mentioned earlier.

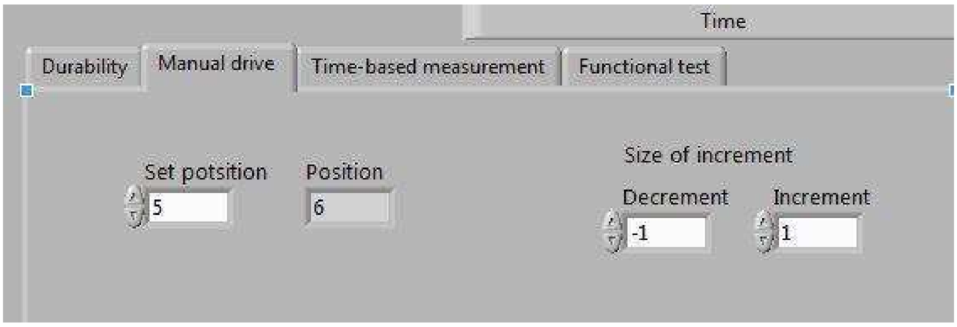
8.2. Manual drive

In manual mode the operator can manually position the cylinder.
To manual operate the cylinder the operator must first select manual drive option in the mode selector and then select which cylinder to move. To manipulate the cylinder, the two buttons located under the mode-selector must be used.



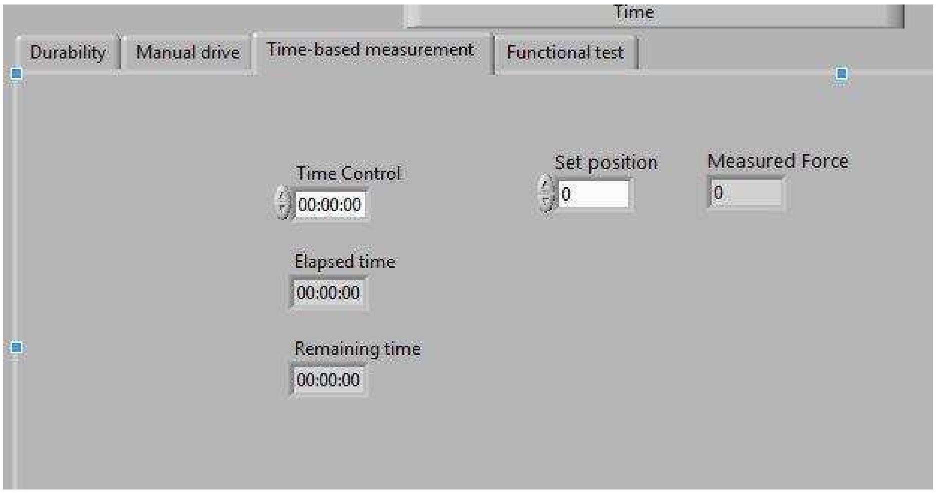
When performing an operation in manual drive, the operator does not have to go through the setup window. The operation is controlled in the tab window located in the front panel. The operator can set the position directly or manipulate the cylinder manually as explained above.
The operator can also choose the increment and decrement on each click. This is done on the two controllers to the right. To set the position directly the control to the left is used.

When operating the cylinder manually, there is no force applied on the cylinder. It is only position that is affected.



8.3. Time-based measurement

The concept with a time-based test is to set the cylinder to desired position and then measure the change of force over time. The cylinder will held the position constant and measure and log the change in force. This test is relevant for the vertical cylinder.

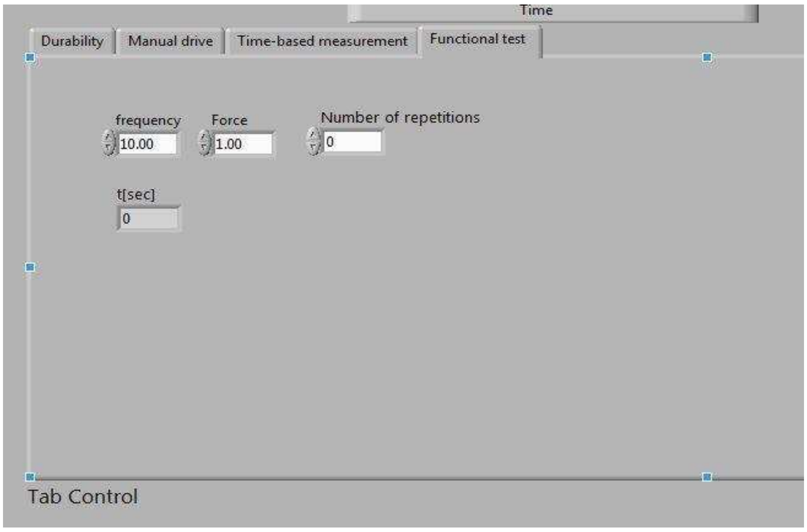


The operator sets desired position and duration of the test.
The indicators show the elapsed time and the remaining time.
The indicator to far right shows the measured force.

8.4. Functional test

The functional test is used to determine the stiffness in a V-stay.
Unlike the durability test the functional test will only do a few or even a single cycle.
Choose the direction to test.
Choose Functional mode in the mode selector.

At the front panel the operator will get this tab window:



The operator sets the desired frequency, force and number of repetition.
The indicator labelled 't[sec]' shows the duration of the test.
Click the start-button.

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Internal supervisor: Gunnar Flak
Date: 21.04.2011
We confirm that the submitted assignment is entirely our work.   Elisabeth Espås Jenssen, Jørgen Heum Larsen, Andreas Fossnær Wold, Edward Palm Sandaker og Stina Andersen

Table of Contents

1. Introduction

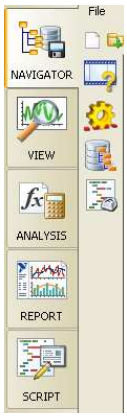


Figure 1

This tutorial is divided into three parts. The first part is learning by doing section. It gives an introduction to the functions that is implemented in DIAdem. It begins with selecting the files you want to analyze, view the files, do some calculations and write a report. The second part is how to create a script of logging data, from Kongsberg Automotive, that automate the calculation and reporting. The third section does the same as the second part, but just in another way. You will create a script of log data from simulator in LabVIEW.

1.1 User Interface

The menu bar at the left shows different groups of functions (figure 1). The Navigator imports and export data from your hard disk. View function edits your data graphically and numerically. Analysis function does mathematical functions and has predefined functions installed. Report function makes report template, you can create one and reuse it. Script function use Visual Basic and DIAdem script to do analysis and create a report while recording.

1.2. Navigator

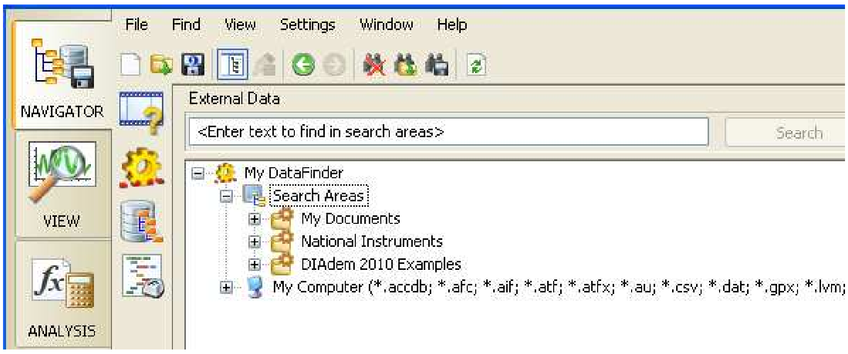


Figure 2

DataFinder / Search files

In the search area you might search for all files in the Search Areas folder. It is then easier to find the data to be working with. All logging files must be placed in Search Areas folder. Save your log data files under my documents.

2. Learning by doing

Drag the TDM-format file in the Navigator over to the Data Portal. If you have data saved in Microsoft Excel format, you may also drag the xls files over to Data Portal. You get a pop-up window that you need to confirm, and then your xls files are converted to TDM files. TDM is a LabVIEW and DIAdem format.

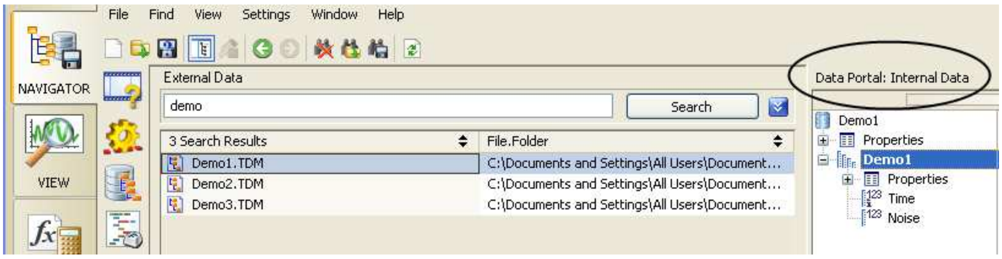


Figure 3

2.1. Viewer

The Viewer function has several options. In this tutorial we choose to do it in one way. The viewer and Analysis are working together and you may calculate mean value in analysis and show it in the graph in the Viewer.
You can see all the data in a channel table, and you may see them graphical. It is a good start to see the data in a table, and you may control that it is the right numbers.

1. Drag the TDM files you need, from Navigator, to the Data Portal.
2. Go to View and click the new layout button.

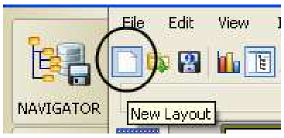


Figure 4: Point 2

3. Table View:
   Either right click the blank area and select Display type 'Channel Table' or click 'Assigned Worksheet Partitions' and then 'Channel table'.

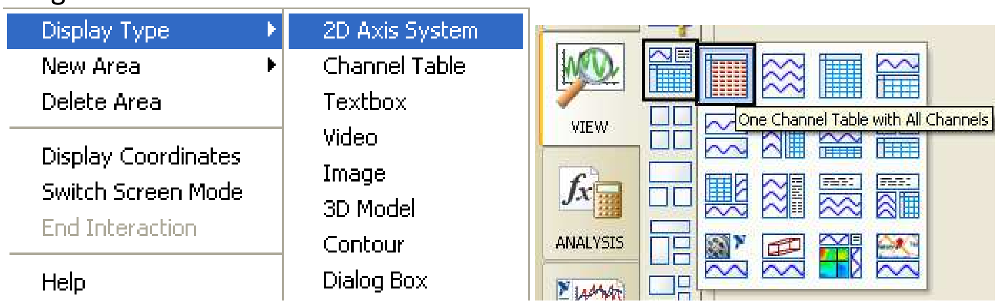
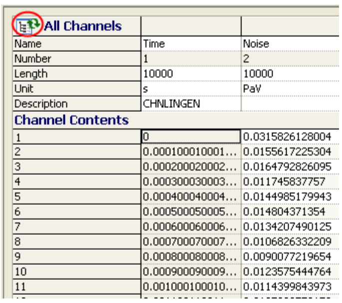


Figure 5: Point 3, two options for opening channel table

All data will be present in a table with headings. If you double click on the point marked with red circle, you may change table settings, and which table columns to be shown. You may change the properties at the headings. Select the correct unit, length and description.



All Channels		
Name	Time	Noise
Number	1	2
Length	10000	10000
Unit	s	PaV
Description	CHNLINGEN	
Channel Contents		
1	0	0.0315826128004
2	0.000100010001...	0.0155617225304
3	0.000200020002...	0.0164792826095
4	0.000300030003...	0.011745837757
5	0.000400040004...	0.0144985179943
6	0.000500050005...	0.014804371354
7	0.000600060006...	0.0134207490125
8	0.000700070007...	0.0106826332209
9	0.000800080008...	0.0090077219654
10	0.000900090009...	0.0123575444764
11	0.001000100010...	0.0114399843973

Figure 6: Point 3

4. Graphical View: Right click on the banner and create a new sheet.

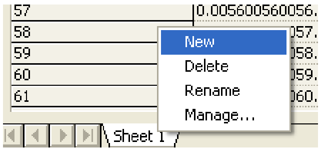


Figure 7: Point 4

5. Choose the worksheet you want on your presentation of data. Either right click and select Display type 2D Axis Systems or select from the menu bar to the left. You will see that there are several options of worksheets. It is also possible to change the worksheet layout later, during working in the Viewer window. Simply right click whatever you are viewing and the same opportunity box appears on your screen.

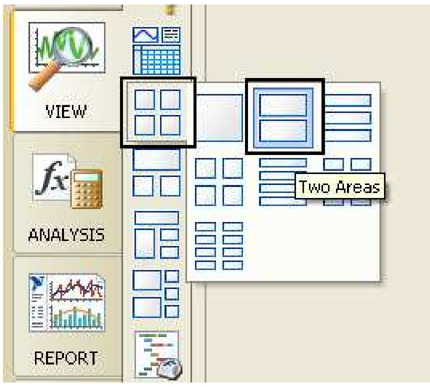


Figure 8: Point 5

6. As seen in the picture above, there are several alternatives to insert to the viewer. Channel table, textbox, video, 3D Model etc. You will also have the opportunity to change this later. In this tutorial we select ‘Two areas’.
7. Select the TDM-files in Data Portal that you want in the graph. Drag them over, and select ‘2D Axis system’ and a graph will appear on your screen.

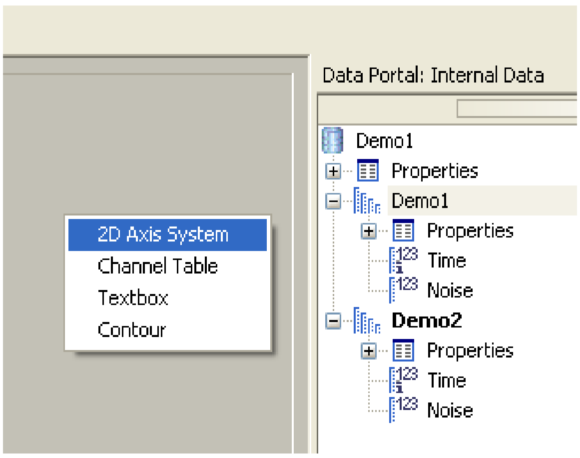


Figure 10: Point 7

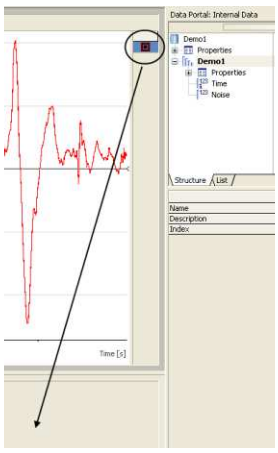


Figure 9: Point 8

8. This graph view can compare a zoomed signal and an original signal. Mark the spot upper right, and drag it down to the empty area, and select ‘2D Axis System’. Now you have two identical graphs above each other.

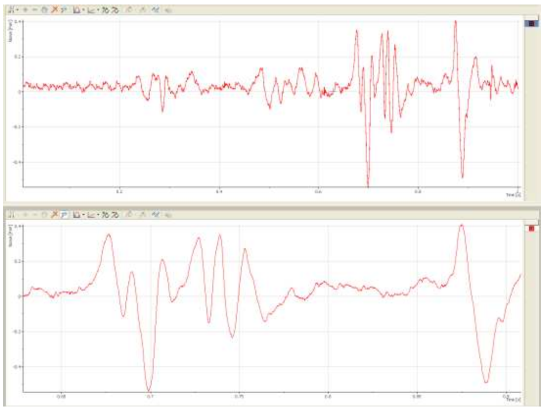


Figure 11: Point 8

9. The following steps are to find maximum values of the signal, and save this into a new file. Click the ‘Maximum Values Cursor’ button, marked with black circle. The picture of a hand is used to slide the signal sideways. This function is named ‘Move’. Click the button one more time for disable.

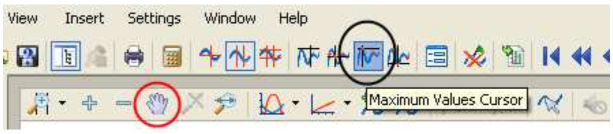


Figure 12: Point 9

Figure 14: Point 10

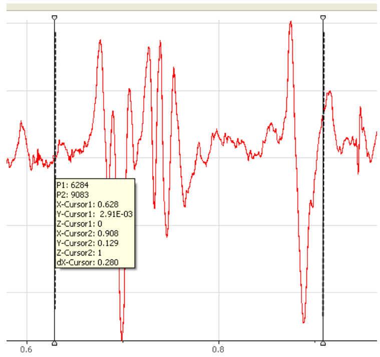


Figure 13: Point 10

10. This step is to mark an interval in the topmost signal. For example the interval with most top values. Click the ‘Band Cursor’ button, and click on the topmost signal. Two vertical lines appears on the graph, drag the two lines in the wanted interval.

11. At the lowest graph, hit the ‘Scroll in Cursor Range’ button. This will zoom in the interval in the lowest graph. Your graph looks like the picture below:

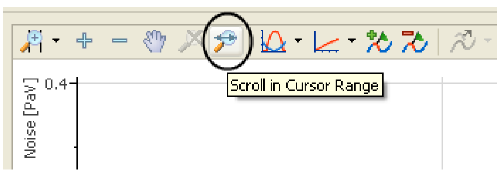


Figure 15: Point 11

12. Use the lower graph to find maximum points. Hit the ‘Crosshair Cursor’ to get the marking lines to cross the signal. The ’Band Cursor’ is now disabled.

13. Immediately after you press the ‘Maximum value cursor’.

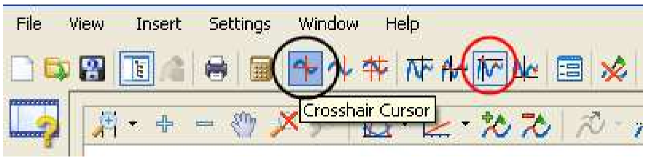


Figure 16: Point 12 and 13

14. Click on the graph below and grab the marking line, move the cursor to a top point (1). When a top point is found click the ‘Set flags’ button (2). It will be marked with a point. Move forward in the graph and find other top points. If you need to slide the signal sideways enable the ‘Move’ button.

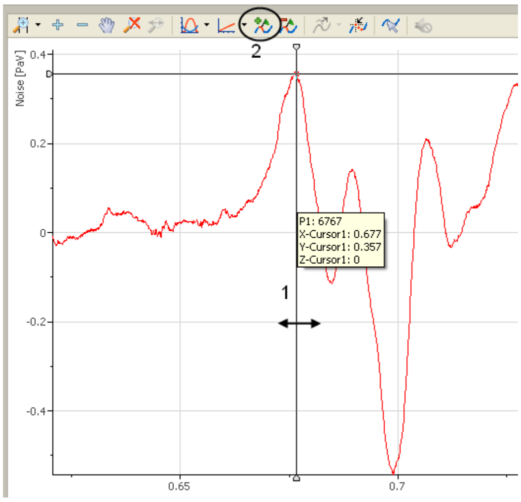


Figure 17: Point 14

15. When all top points are marked, the next step is to save the values in a file. Go to the Data portal and right click on the TDM-file. Select ‘New’ and ‘Group’. Type in the name of the new group, for example ‘Result’.

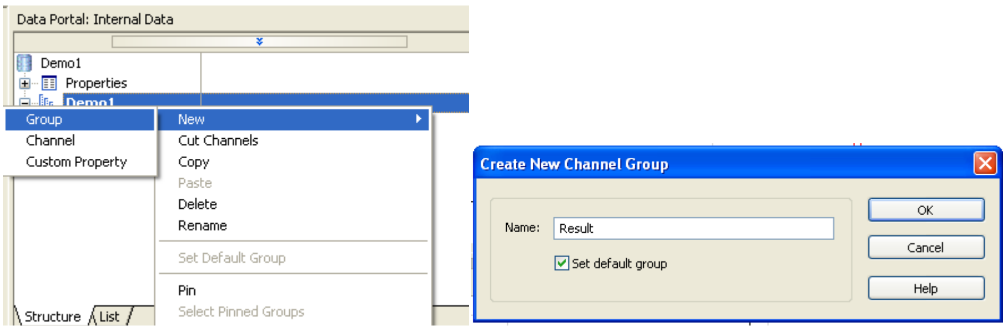


Figure 18: Point 15

16. Press the ‘Flag: Copy Data Points’ button. They are now added to the ‘Result’ group in the Data Portal.

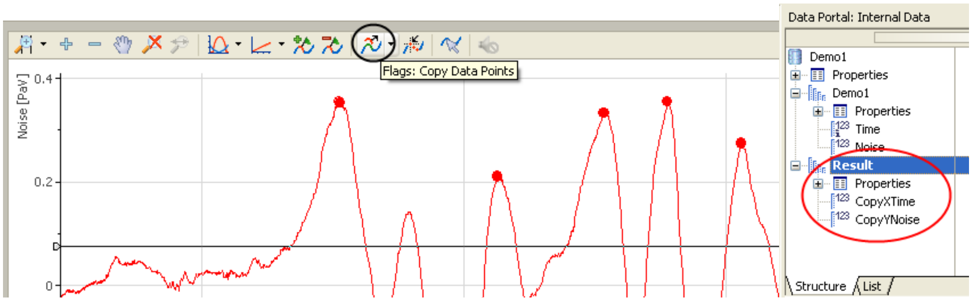


Figure 19: Point 16

This new file may now be used in the next section, Analysis function.

2.2. Report and analysis

In this section you can create a report. It may contain graphs, pictures, text and synchronized videos or graphics.
You may save this report as template, such that you only do it once.

1. Click the chart Wizard.

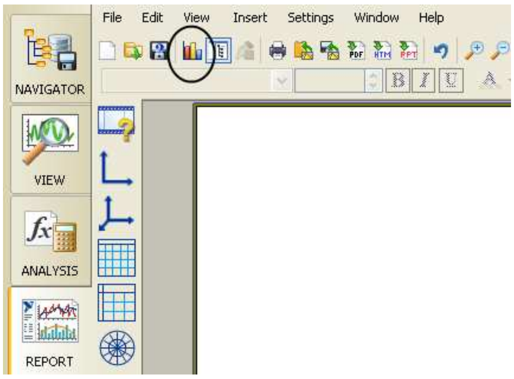


Figure 20: Point 1

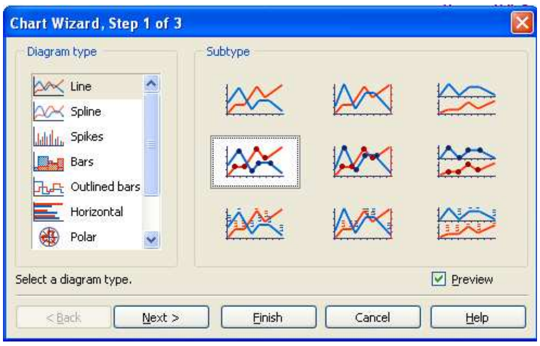


Figure 21: Point 2

You have several options here.

2. In this tutorial we chose the "Line with markers". Press next.
3. Choose the Y-channel you need. Here we select noise. Press next.

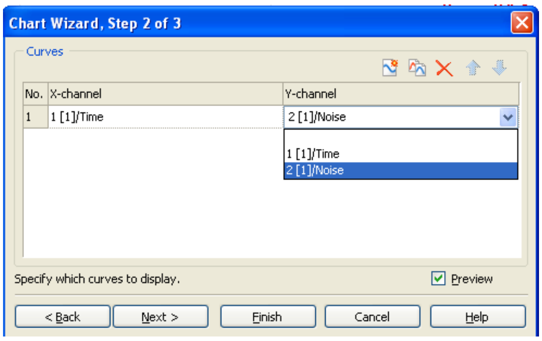


Figure 22: Point 3

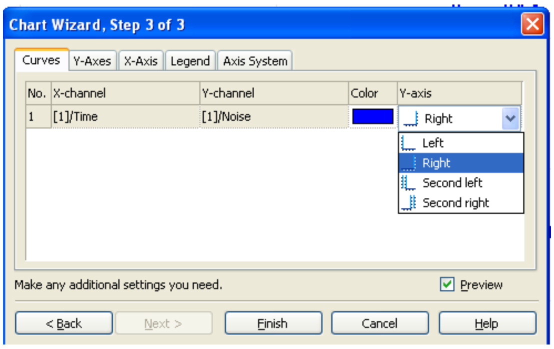


Figure 23: Point 4

4. Change the colour on the graph and where to place the Y-axis. Choose the alignment to right.
5. Select Legend banner and check ‘Display banner’
6. Select Axis System banner and you can change display on your graph, frame and grid colours. Press Finish. You will see the graph under the Chart Wizard process.

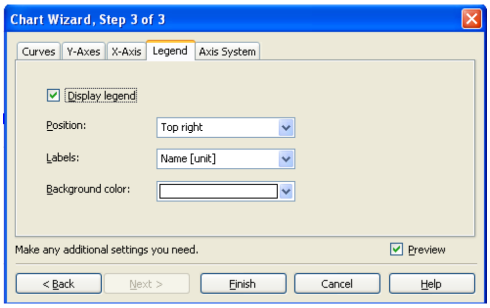


Figure 24: Point 5

7. Right click on the banner on the bottom of the page. Select ‘new’.

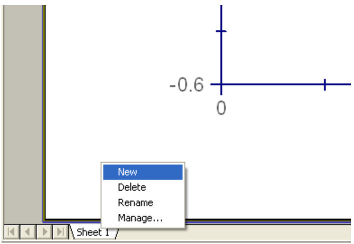


Figure 26: point 7

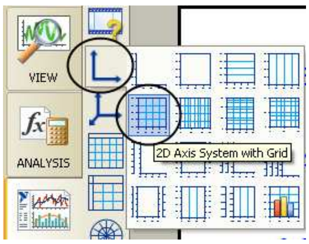


Figure 25: Point 8

8. At the top left select ‘2D axis system with grid’ and drag it out on the page. You may also drag several values into the graph. Mark one and hold ‘Ctrl’ down when selecting another one. Drag them all together into the graph.

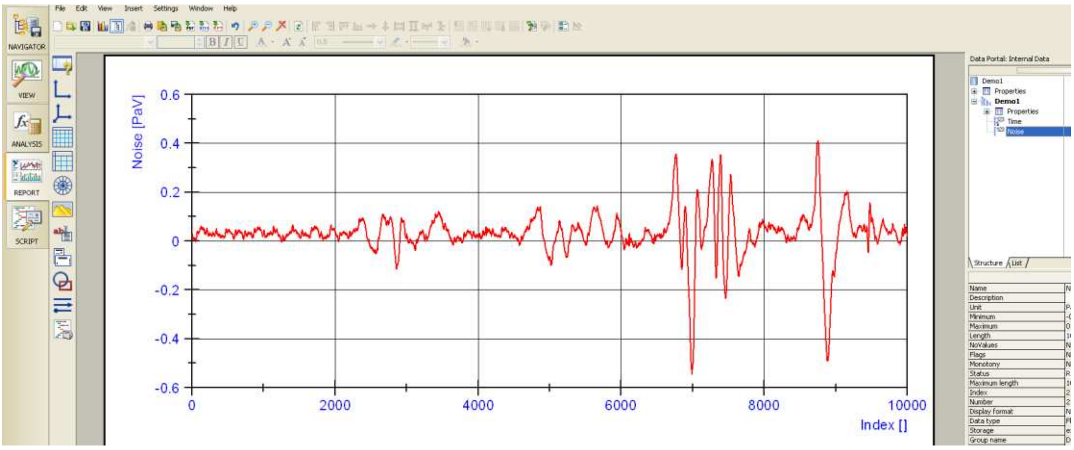


Figure 27: Point 8

9. Double click on the graph, and you can do changes on the graphs.

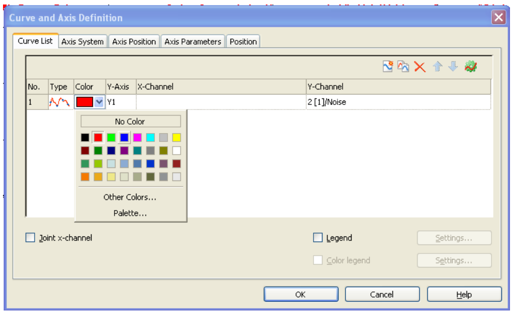


Figure 28: Point 9

10. If you have several graphs you need to expand the Y-axis. Select the ‘Axis Position’ banner. Press the button at the top left. Go back to the ‘CurveList’ banner, and change the Y-axis to Y1, Y2 and Y3. Depending on how many curves that is in the graph.

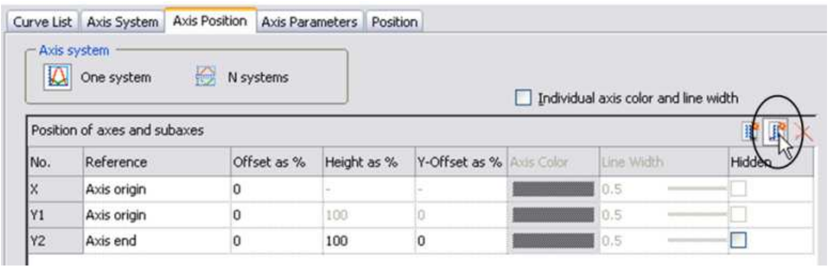


Figure 29: Point 10

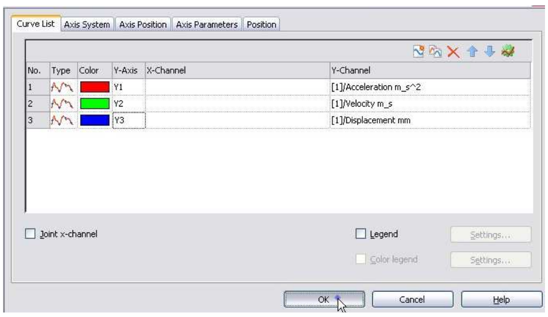


Figure 30: Point 10

11. You may decorate your report with text, line and pictures. Select different functions from the menu bar to the left. Select ‘Graphics’ and upload a picture from your hard drive.

Figure 31: Point 11

12. Select “Text” function. (next under graphics on the menu bar, picture of ‘abc’)Write Date:@CurrDate@, and press enter. Today’s date will appear on the page.

Figure 32: Point 12

13. All values are listed in the table below Data Portal (see picture below). You can drag values into the report. For example maximum value of signal. Mark the ‘Maximum’ and drag it over to the report. Repeat the same with ‘Name’.

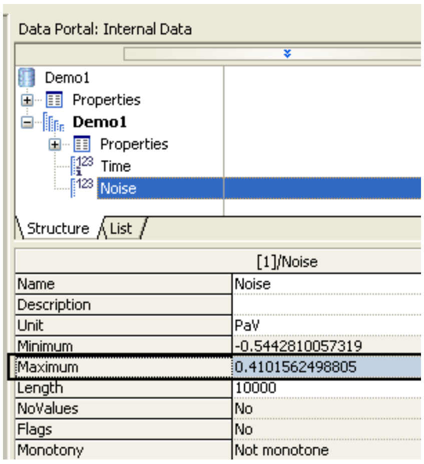


Figure 33: Point 13

14. Double click on ‘Maximum’ text on your report. You can change the text. Write for example position after maximum, in the textbooks. Press OK.

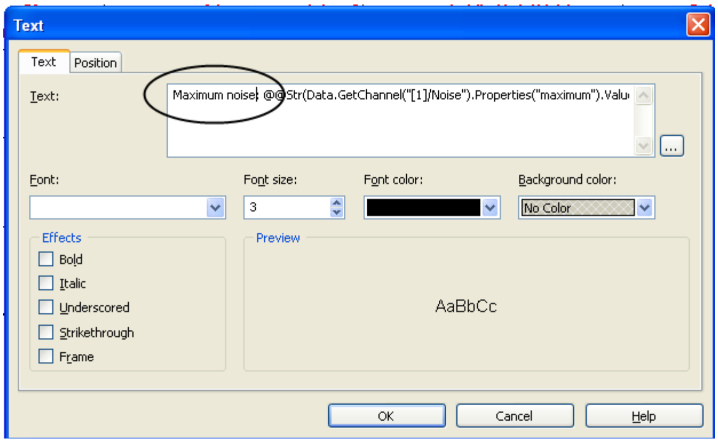


Figure 34: Point 14

The report looks like this.

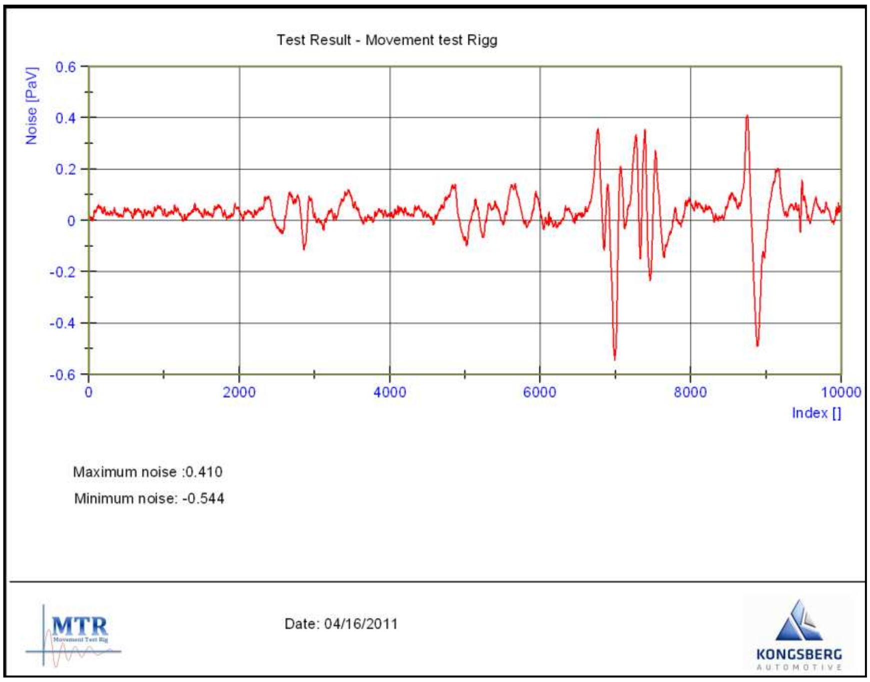


Figure 35: Point 14

15. You can copy the report to the clipboard and paste it into other office applications, like power point presentations.

Figure 36: Point 15

16. You can save reports as templates that are reusable with any data set, and then the output reports are sent to the printer or saved as PDF file or as an HTML file. You

can also copy and paste DIAdem reports into other office applications using the copy to clipboard function.

17. Select File-PDF Export, HTML export
18. Finishing the report. You can change colours and size of the text. Use the menu bar at the top of the window.

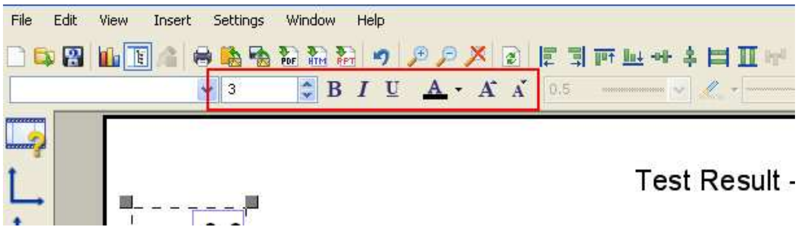


Figure 37: Point 18

3. Automating report and analysis of existing log data

It is possible to create a script that automates reporting from test logging. This section goes through how to automate a report that is adapted to log data from KA.
This section goes through the whole process one more time, because it has to record the work. The functionality will be done in a bit different way then presented in last section, but it is just another way to do it.
It will show automating reporting of two signals. Log data of a new V-stay, before a durability test, and log data of a V-stay after durability test.
It will calculate stiffness, and find difference in stiffness from each value. When this script is done, it is possible to load other log data files, and get the stiffness result.

1. Open a new layout.
2. Select ‘Script’ from the menu bar to the left. And press the ‘Enable recording mode’ button on the menu bar at the top. See the red circle in the picture below. This start recording what you do, and the script will be developed during work.

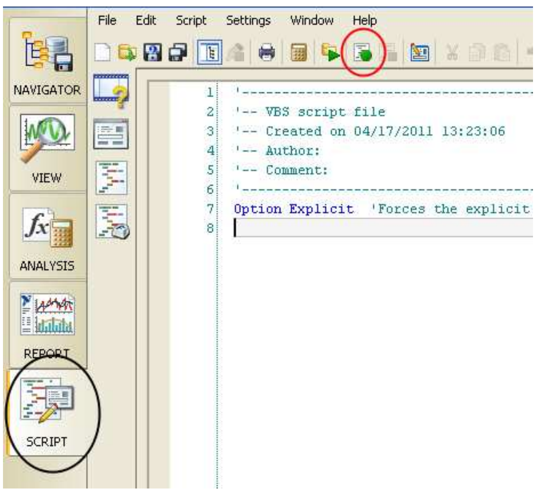


Figure 38: Point 2

3. A 'Configure Recording Mode' box will appear on your screen, type in your name and select OK.

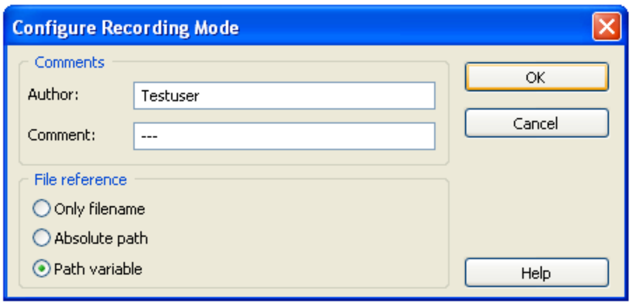


Figure 40: Point 3

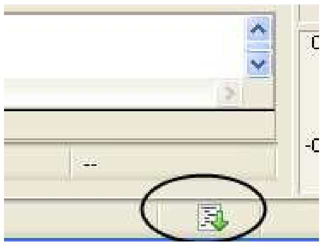


Figure 39: Point 4

4. At the bottom of the page you see a symbol that indicates that recording is enabled.
5. Go back to the Navigator and delete all the data from the Data Portal. Press the 'new sheet' button and press 'No' on the question for save changes. You will now see that the data are removed from the Data Portal. If you go back to the script, you see the first line of code. It says 'Call Data.Root.Clear()'. The code in Blue is Visual Basic script, and the red is DIAdem script. This line means that all data from Data Portal is deleted.

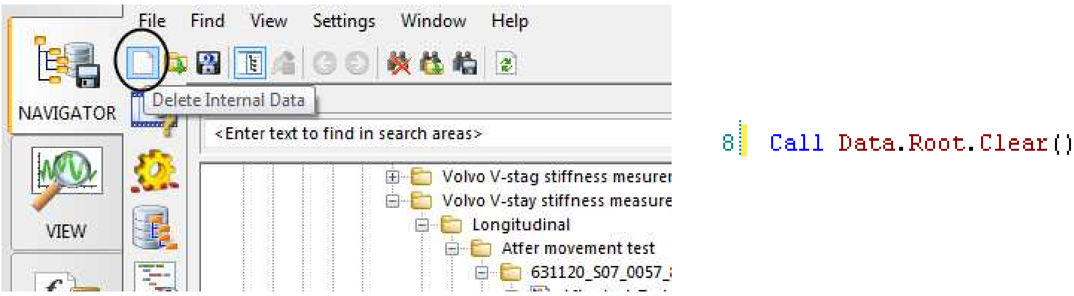


Figure 41: Point 5

6. Go to Navigator and drag two TDM-files back to Data Portal. One file from a before test, and one for after test. As you see from the picture below, all channels are unnamed. Mark the name in the table, and change it to 'new_time'. Channel 1 is time, channel 2 is position and channel 3 is force. Make a difference between the files by giving them the names 'new' and 'after' tests.

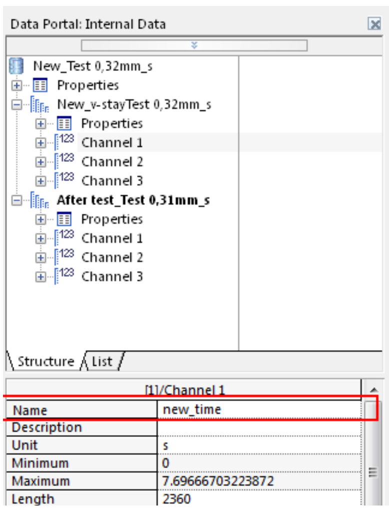


Figure 42: Point 6

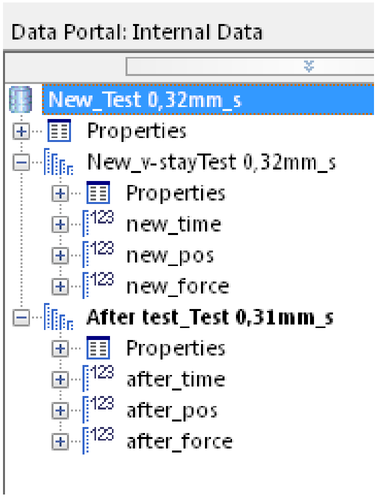


Figure 43: Point 6

7. Go back to Script and you will see the code. ‘DataFileLoad’ loads the file into the Data Portal, and ‘Data.Root.ChannelGroups’ renames the files.

```
Call Data.Root.Clear()
Call DataFileLoad(MyFolders(0)&"New_Test 0,32mm_s.tdm","TDM","") '... Dat
Call DataFileLoad(MyFolders(1)&"After test_Test 0,31mm_s.TDM","TDM","") '
Data.Root.ChannelGroups(1).Channels("Channel 1").Name = "new_time"
Data.Root.ChannelGroups(1).Channels("Channel 2").Name = "new_pos"
Data.Root.ChannelGroups(1).Channels("Channel 3").Name = "new_force"
Data.Root.ChannelGroups(2).Channels("Channel 1").Name = "after_time"
Data.Root.ChannelGroups(2).Channels("Channel 2").Name = "after_pos"
Data.Root.ChannelGroups(2).Channels("Channel 3").Name = "after_force"
```

Figure 44: Point 7

8. Next step is to find maximum value on each of the signals top. Create a new group form Data Portal. Call it ‘Top values’ (see item 15 in doing by learning section)
9. Go to Analysis at the menu bar at the left. Select the Channel functions at the menu bar, and hit the ‘Peak Search’ function. (see picture below)

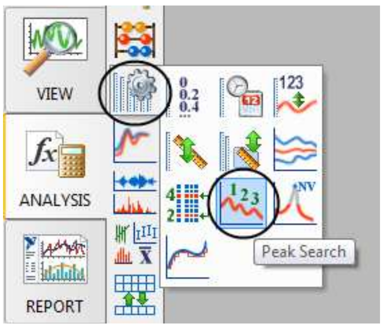


Figure 45: Point 9

The intension is to find stiffness, defined as force applied to the V-stay divided on displacement. This gives position in x-access and force in y-access.

10. Drag the position and force file from Data Portal, and you will see the graph with top point to the left. Click Calculate and OK. Do the same thing with the after_test file. In the Data Portal it is applied four new files in the top value group

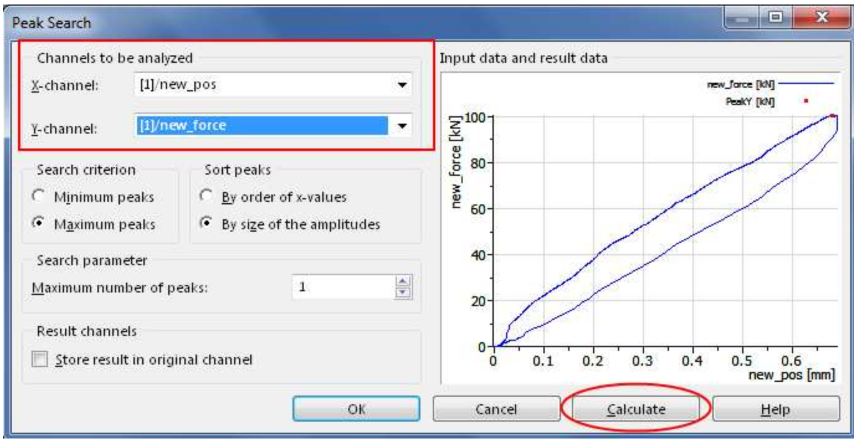


Figure 46: Point 10

Figure 47: Point 10

In the Script you will see the code for creating the new group, and the function that finds top value.

```
Call Data.Root.ChannelGroups.Add("top_values", 3).Activate()
Call ChnPeakFind("[1]/new_pos","[1]/new_force","/PeakX","/PeakY",1,"Max.Peaks","Amplitude") '...
Call ChnPeakFind("[2]/after_pos","[2]/after_force","/PeakX1","/PeakY1",1,"Max.Peaks","Amplitude")
```

Figure 48: Point 10

11. Next step is to find stiffness, defined as force divided by displacement.
    Create a new group called Stiffness (see item 15 in doing by learning section).
12. Go back to Analysing for calculating the values in the TDM-files. First, click the “Calculate Quantity-Based” which says that units are included in the calculations. If you intend to just calculate numbers, then you don’t need to click the “Calculate Quantity-Based” button. But in this step it is necessary. Enabling this button is not recording in the script. Click then on the calculator button (red circle).

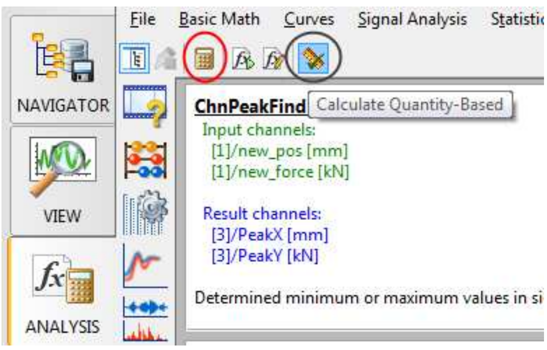


Figure 49: Point 12

13. The Calculator window appears on your screen. Follow six steps to calculate stiffness.
    Step 1: Push the '=' button.
    Step 2: Call it a name, and write 'new_stiffness' between the '(" ")' signs.
    Step 3: Double click on the channel, PeakY, which is the top force value.
    Step 4: Double click on the channel, PeakX, which is top value on position.
    Step 5: Push the 'Calculate' button.
    Step 6: Push the 'Close' button.
    A new channel called 'new_stiffness' is applied to the Data Portal. Repeat the same process for After_test, call it after_stiffness.

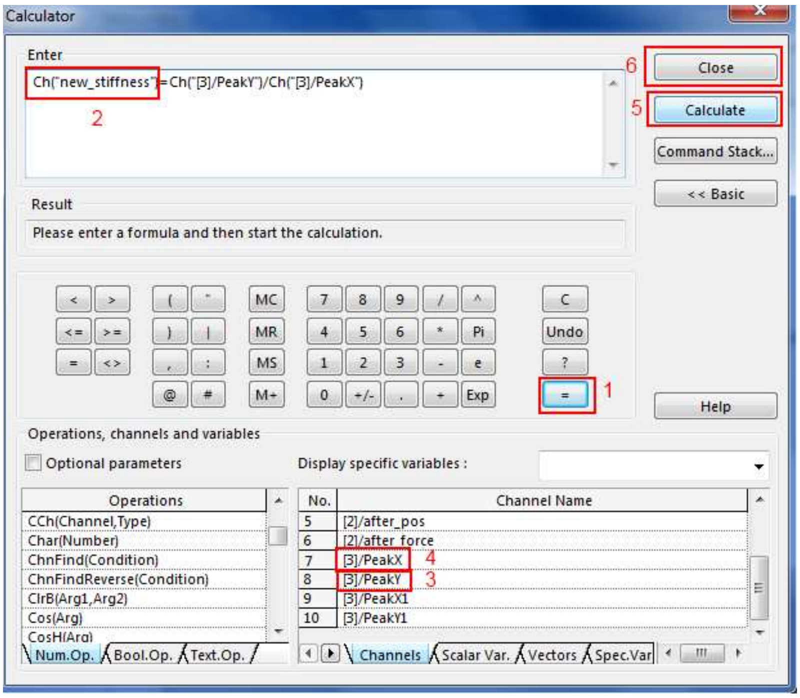


Figure 50: Point 13

14. You will see that the value for stiffness is a large number, that is because the unit for force should be in kN and position in mm. Stiffness now has units of N/m. It is preferred that the unit is kN/mm.
    Do the same step to convert the unit, with the calculator function. Call it 'New_stiffness_kNprmm' , double clik on the New_Stiffness channel and multiplie it with 10^(-6). Repeat the same process with after_stiffness file.

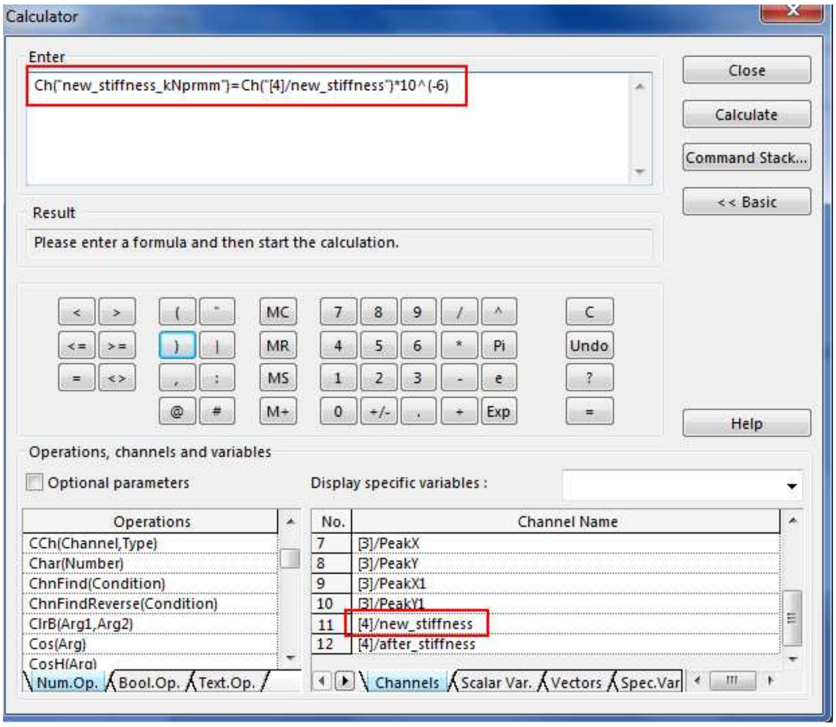


Figure 51: Point 14

You will see from the the table that maximum stiffness value is 147.

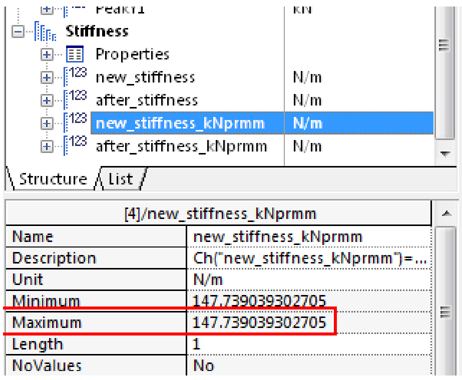


Figure 52: Point 14

In the "SCRIPT" you will see this code:

```
Call Data.Root.ChannelGroups.Add("Stiffness", 4).Activate()
Call Calculate("Ch(""new_stiffness"")=Ch(""[3]/PeakY"")/Ch(""[3]/PeakX"")",NULL,NULL,"") '... Calc
Call Calculate("Ch(""after_stiffness"")=Ch(""[3]/PeakY1"")/Ch(""[3]/PeakX1"")",NULL,NULL,"") '...
Call Calculate("Ch(""new_stiffness_kNprmm"")=Ch(""[4]/new_stiffness"")*10^(-6)",NULL,NULL,"") '...
Call Calculate("Ch(""after_stiffness_kNprmm"")=Ch(""[4]/after_stiffness"")*10^(-6)",NULL,NULL,"")
```

Figure 53: Point 14

15. Next step is to find percent difference between stiffness, before and after test. Create a new group, called difference.
16. This has to be done in two steps.
    Step1: Calculate: 1-(after_test/new_test). Name it "diff"

Step 2: diff*100, name it diff_percent.

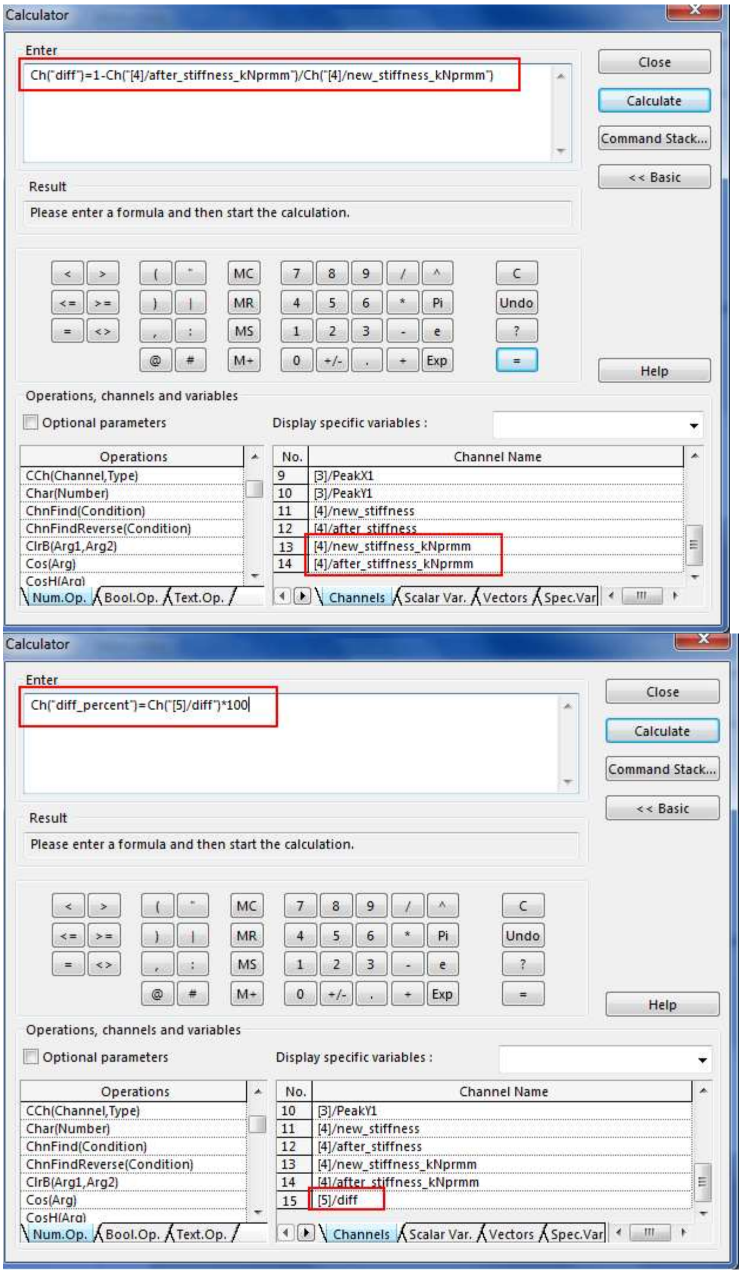


Figure 54: Point 16

All this channels are applied to the Data Portal.

17. ‘diff_percent ‘ has unit ‘1’, change the unit to ‘%’. Click on the box to the left of the unit, in the table. Select “% percent” and click the “Replace” button.

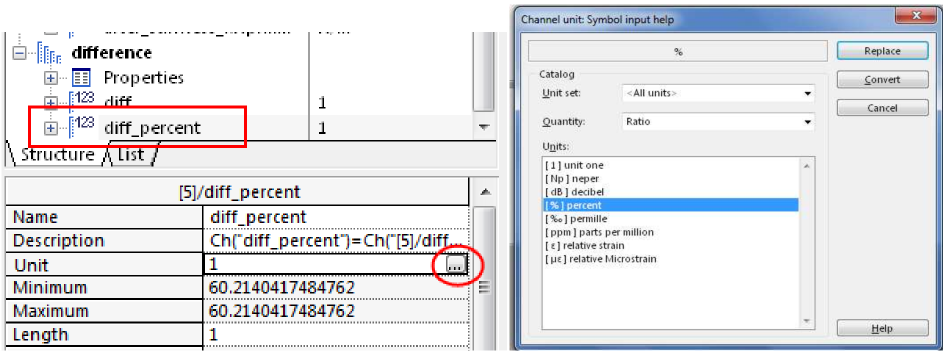


Figure 55: Point 17

You will now see all the new channels in the Data Portal.

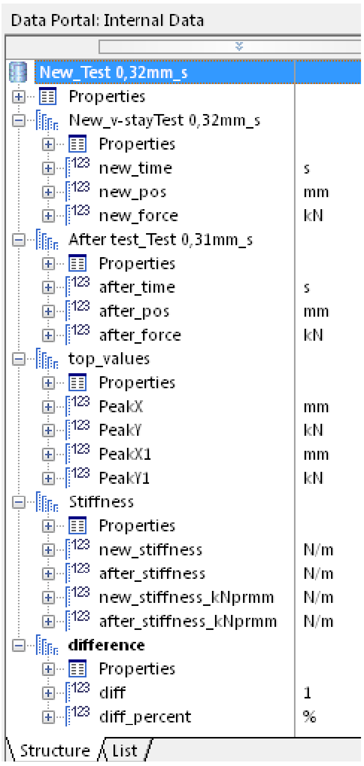


Figure 56: Point 17

18. Go back to Script and you will see all the code:

```
Call Data.Root.ChannelGroups.Add("difference", 5).Activate()
Call Calculate("Ch(""diff"")=1-Ch(""[4]/after_stiffness_kNprmm"")/Ch(""[4]/new_stiffness_kNprmm"")",NULL,NULL,"")
Call Calculate("Ch(""diff_percent"")=Ch(""[5]/diff"")*100",NULL,NULL,"") '... CalculateFormula,CalculateSymbols,C
```

Figure 57: Point 18

19. Next step is to create a report. You have two options, either create a new report, or open a template. You may open the report that you made earlier, but in this section it will be created a new one. The process during making a report will not be recorded, even if the recorder is enabled. Do not stop the recording.
 Go to Report and select ‘New Layout’.

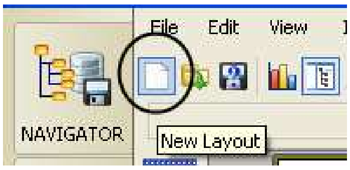


Figure 58: Point 19

20. Select the ‘2D Axis system’ and ‘2D Axis System with Grid’. Drag it over the blank report.

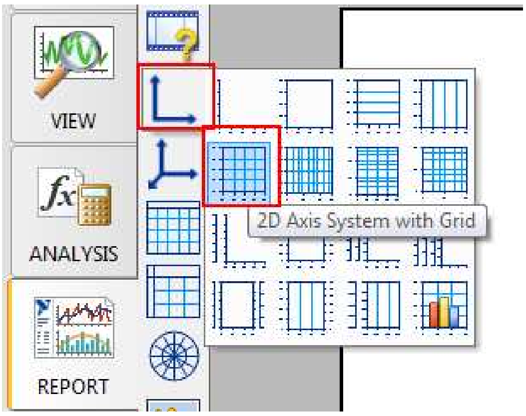


Figure 59: Point 20

Drag the two channels into the graph. ‘new_pos’ and ‘after_pos’. You will see that the graphs look different. You need to change the variables on the Axis.

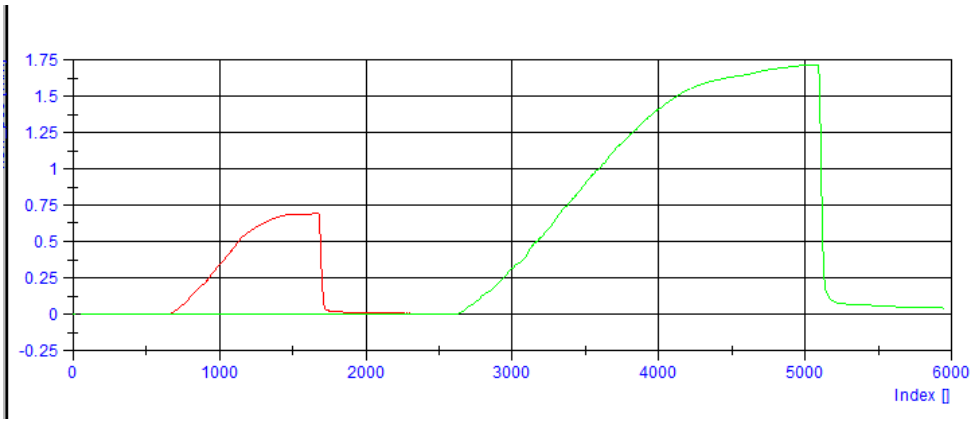


Figure 60: Point 20

21. Double click the graph. Change the Y-channel to new_force and after_force.
The X-Channel must be changed to new_pos and after_pos. Mark the legend sign.

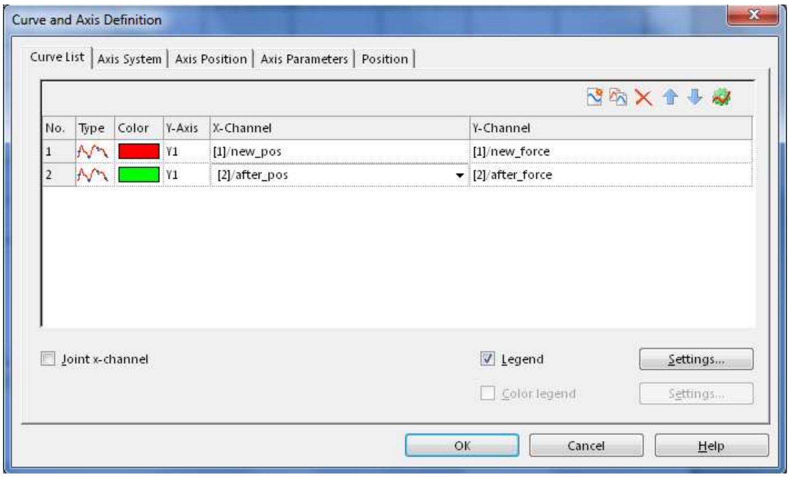


Figure 61: Point 21

The graph looks like the picture below:

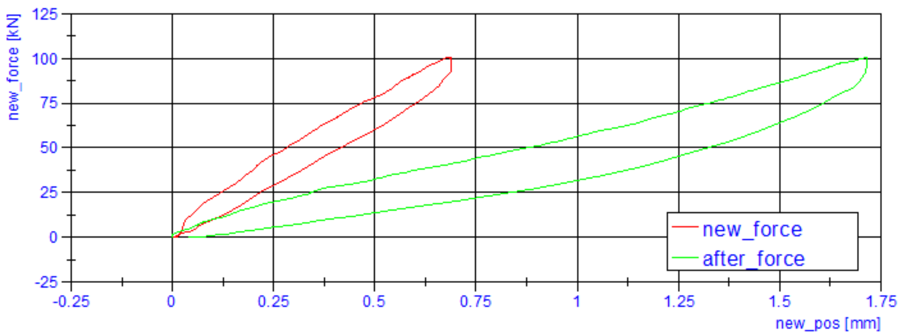


Figure 62: Point 21

22. Mark the ‘new_stiffness_kNprmm’ and mark the ‘maximum’, drag it out to the report.
    Repeat the same process for ‘after_stiffness_kNprmm’ and ‘diff_percent’.

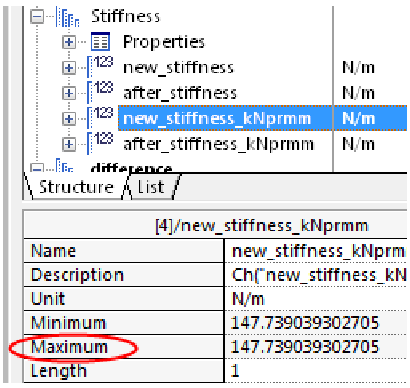


Figure 63: Point 22

23. Double click on the ‘Maximum’ that is typed to the report. A window will appear on your window.

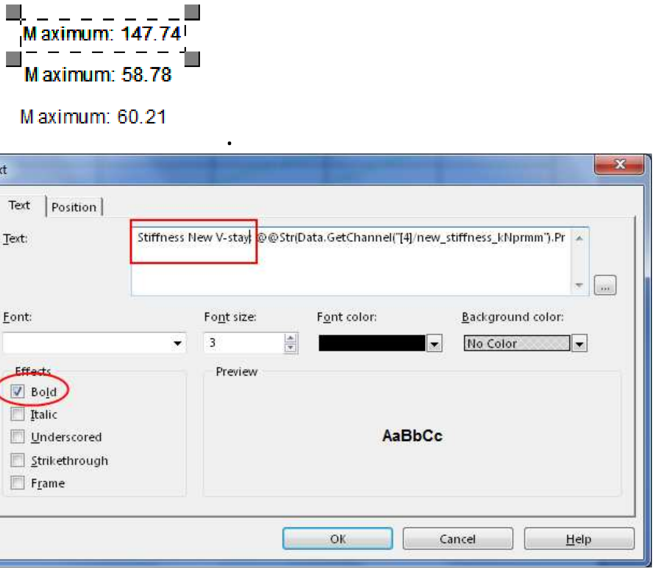


Figure 64: Point 23

Replace the 'Maximum' with 'Stiffness New V-stay' before ':' sign. Mark the 'Bold'. Repeat the process for the other two values.

24. Decorate your report. Repeat step 10 and 11, in chapter report. Your new layout should look like:

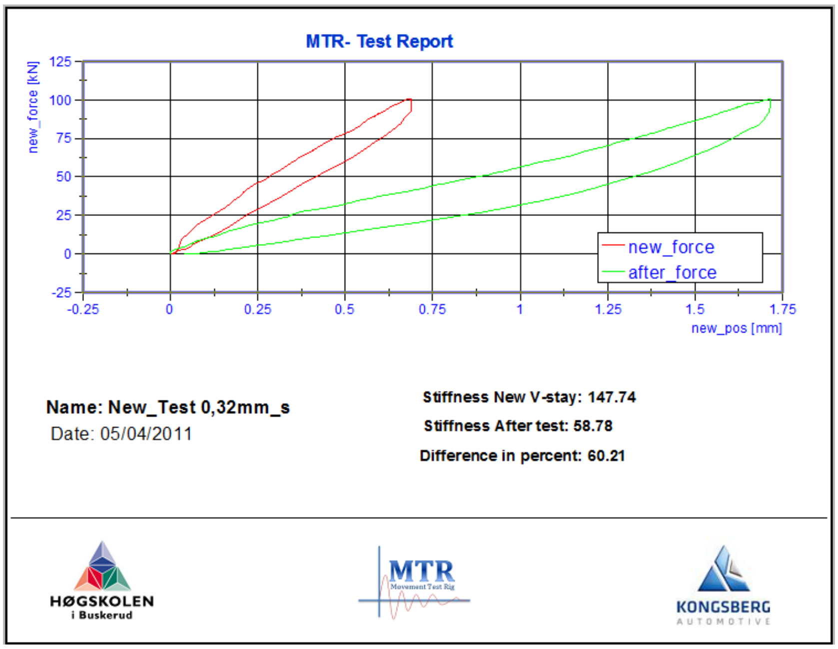


Figure 65: Point 24

25. Save your report with TDR-format.
26. Open the report again.
27. Go back to Script. Comment away the 'Call PicSaveAs' code line. This was created when you saved your report.

```
'Call PicSaveAs(MyFolders(2)&"MTR_template3.TDR","") '... PicFile,PICFileCode
Call PicLoad(MyFolders(2)&"MTR_template3.TDR") '... PicFile
Call PicUpdate(0)                              '... PicDoubleBuffer
```

Figure 66: Point 27

28. Stop recording, by press the ‘Disable Recording Mode’.

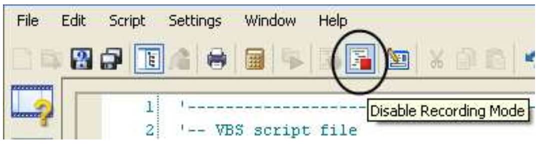


Figure 67: Point 28

29. You can make this report for different TDM-files. This has to be adjusting in the Script. Go back to Script, and make some free space between ‘Call Data.Root.Clear’ and ‘Call DataFileLoad’.
    Type inn ‘Call FileNameGet(‘p1’,’p2’)’. The first parameter is what file you want to load. You can choose from report a layout; report a load data file or another script. In this tutorial we want to load another data file. This data file is located in the Navigator. Type in “NAVIGATOR” in the first parameter, (p1). Next parameter asks if you want to load and read to that file or write to that file and save it. We select to read to that file, and we paste ‘FileRead’ in the next parameter (p2).
    ‘FileNameGet’ will open a window dialog and ask for file name, and as a result, it will get the file name that you choose. That file is going to be stored in a variable called *FileDlgName*. Replace this name inside the parentheses, in the ‘Call DATAFILE LOAD’ code line. This becomes green because it is a DIAdem variable. Do these twice since you need to upload to files (before and after- test)

```
Call Data.Root.Clear()
Call FileNameGet("NAVIGATOR","FileRead")
Call DataFileLoad(FileDlgName) '... DataFile
Call FileNameGet("NAVIGATOR","FileRead")
Call DataFileLoad(FileDlgName) '... DataFile
```

Figure 68: Point 29

30. Go back to report and press the ‘New Layout’ button.
31. Go back to Navigator and press the ‘New Layout’ button.
32. Go to Analysis and make shore the ‘Calculate Quantity-Based’ button is marked. Ref point 12.
    Hit the ‘Run Script’ button. It will run the script and come up with the report.

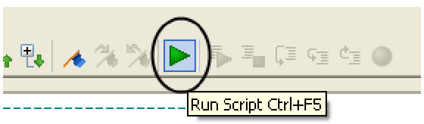


Figure 69: Point 32

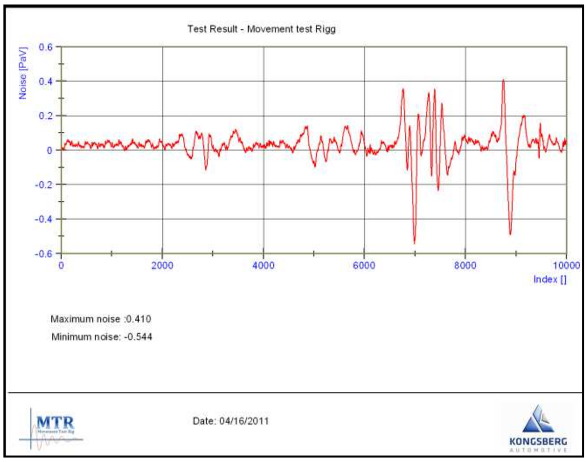


Figure 70: Point 32

33. Run the script again, and select two other TDM-files you want to load, one at a time. You will see that there is a new report with the same report layout. Stiffness and difference values have been changed.
34. Your automating report is now done. Save your script as VBS-format. You can open it, run it, and be used again.

4. Automotive report and analysis of simulated signal from LabVIEW

This section will guide you to analysis stiffness from simulated data from LabVIEW. After ended test in LabVIEW, you will get data stored in a TDM file. The simulator does not automatically get appropriate values of stiffness, before and after durability test. In this section it is concentrated on analyzing data after one simulated test.

1. LabVIEW is not stored data with units. The first thing to do is to add units on the channels. This has to be done before starting the script. The script is not able to change units on the channels, only names. The names are self-explained, and we found it unnecessary to change their names.
2. Drag the TDM-file to Data Portal. You see that LabVIEW creates five channels. Time will automatically appear from LabVIEW. Maximum and minimum value of force and position appears from LabVIEW.

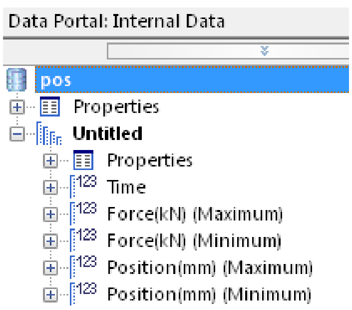


Figure 71: Point 2

3. Next step is to create the script for automating report.
   Go to Script and press the ‘Enable Recording Mode’. And write your name as author.

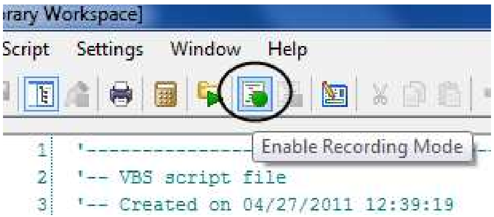


Figure 72: Point 3

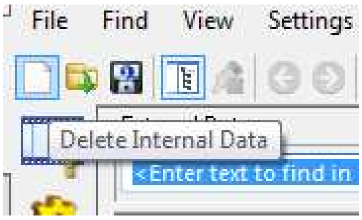


Figure 73: Point 4

4. Go back to navigator and delete internal Data.
   Drag the TDM file that was created from LabVIEW, into the Data Portal.
5. It is decided to find stiffness in each measured value. Stiffness, *k,* is well defined as derived of force, *d*F, divided by derived of displacement, $d\delta$. $\frac{dF}{d\delta} = k$
   First step is to find the difference between maximum and minimum force and position. Go to ‘basic mathematics’ and select ‘Subtract’

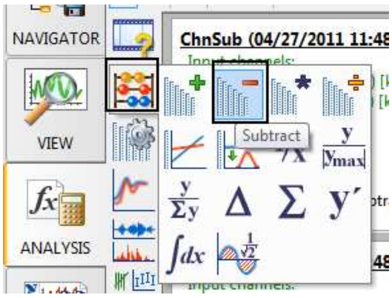


Figure 74: Point 5

A subtract window appears on your screen. You want to subtract maximum from minimum. Drag the maximum channel to the ‘Minuend’ window and the minimum channel to the ‘Subtrahend’. Press Calculate and OK. You will see that a new channel has appeared to the Data Portal, called Subtracted. Right click on it, and rename it to “diff_force”. Repeat this process with the position channels.

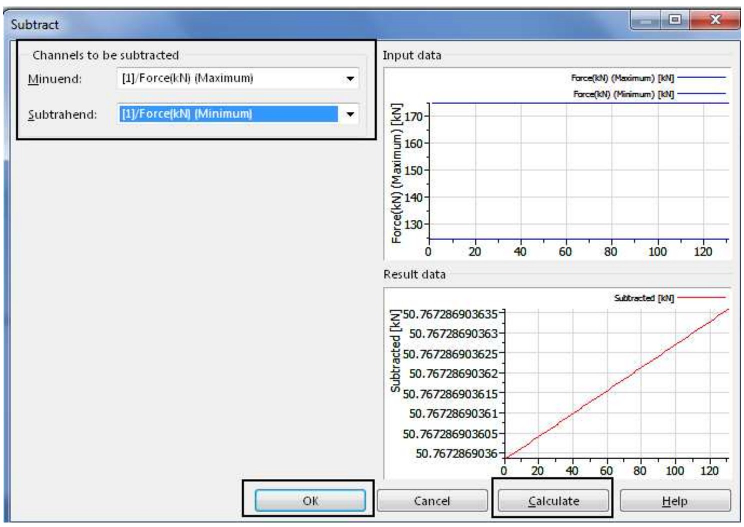


Figure 75: Point 5

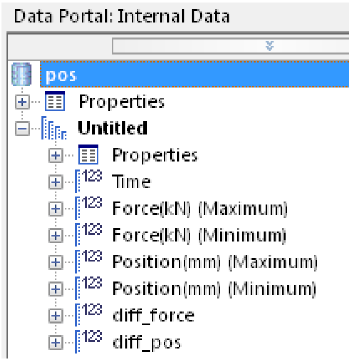


Figure 76: Point 5

```
Option Explicit  'Forces the explicit declaration of all the variables in a script.
Call Data.Root.Clear()
Call DataFileLoad(MyFolders(0)&"pos.tdm","TDM","") '... DataFilename,FileImportFilter,ImportAction
Call ChnSub("[1]/Force(kN) (Maximum)","[1]/Force(kN) (Minimum)","/Subtracted") '... Y,Y1,E
Data.Root.ChannelGroups(1).Channels("Subtracted").Name = "diff_force"
Call ChnSub("[1]/Position(mm) (Maximum)","[1]/Position(mm) (Minimum)","/Subtracted") '... Y,Y1,E
Data.Root.ChannelGroups(1).Channels("Subtracted").Name = "diff_pos"
```

Figure 77: Point 5

In the picture above you will see the code from the scrpt.

6. Next step is to find stiffness. Calculate diff_force divided by diff_pos. Go to Analysis and basic mathematics, and select Divide.

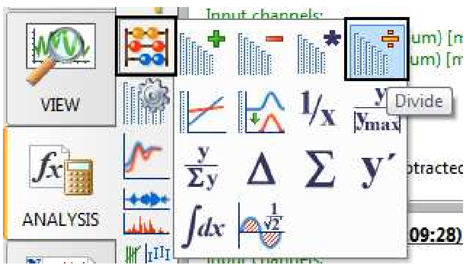


Figure 78: Point 6

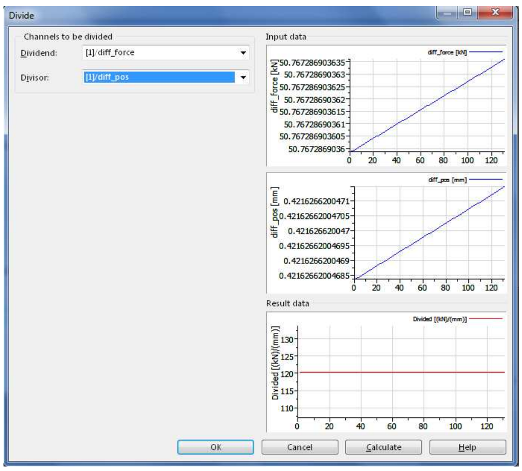


Figure 79: Point 6

Drag the ‘diff_force’ channel into the Dividend, and the ‘diff_pos’ channel into the Divisor. Press Calculate and OK. A new channel is created in the Data Portal, named ‘Divided’. Rename this channel to ‘Stiffness

To overview the stiffness values for each measured values, you may go to View, and drag the channels from Data Portal to the VIEW window. Select ‘Channel Table’.

Selected Channels					
Name	Force(kN) (Maximum)	Force(kN) (Minimum)	Position(mm) (Maxim...	Position(mm) (Minimu...	Stiffness
Number	2	3	4	5	8
Length	65	65	65	65	65
Unit	kN	kN	mm	mm	(kN)/(mm)
Channel Contents					
1	118.877551020408	78.0646340979073	1.45625	0.956291767699365	81.6326530612245
2	118.877551020408	78.0646340979071	1.45625	0.956291767699362	81.6326530612245
3	118.877551020408	78.0646340979069	1.45625	0.95629176769936	81.6326530612246
4	118.877551020408	78.0646340979067	1.57432432432432	1.03382893805336	75.5102040816327
5	118.877551020408	78.0646340979064	1.57432432432432	1.03382893805336	75.5102040816327
6	118.877551020408	78.0646340979062	1.57432432432432	1.03382893805335	75.5102040816327

Figure 80: Point 6

7. Next step is to find the maximum and minimum stiffness during the whole test. Go to Analysis, channel functions and select ‘Peak Search’. The intention is to see stiffness during time. Select time for x-access and stiffness for y-access. Mark for maximum peaks.

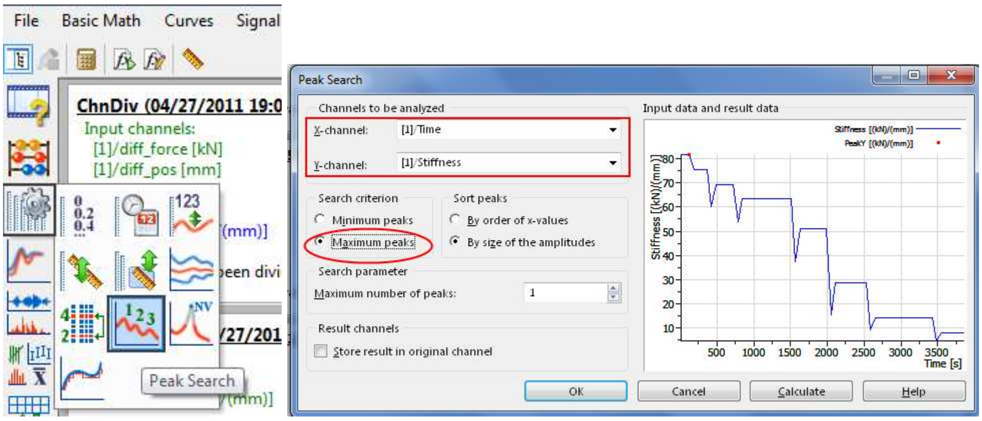


Figure 81: Point 7

8. Two new channels are created in the Data Portal, PeakX and PeakY. Rename PeakX to ‘max_time’, and PeakY to ‘max_stiffness’.

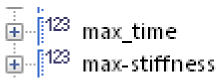


Figure 82: Point 8

9. Repeat the two previous points one more time, but for minimum values. Select minimum peak, insted of maximum peak, in the ’Peak search’ window. Rename the two files in Data Portal to ‘min_time’ and ‘min_stiffness’.

   You now have all the channels you need.

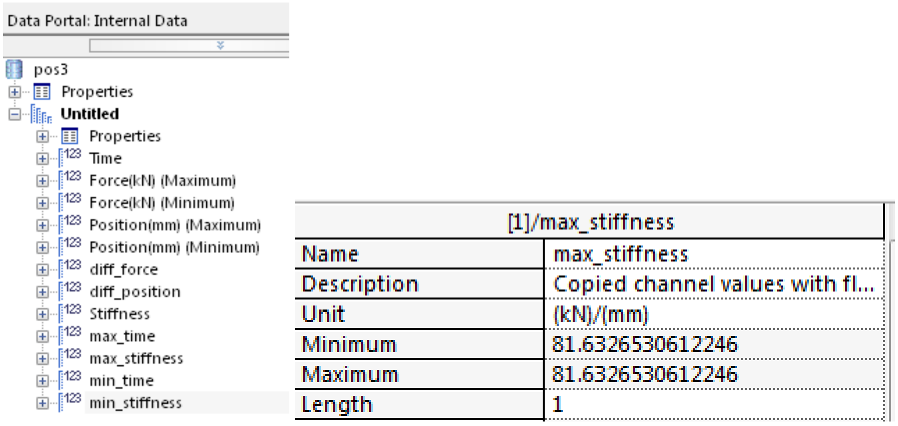


Figure 83: Point 9

You can see from max_stiffness that it has unit kN/mm and only one value with size 81.63.

10. Go to Report and create a new report or open a template. Your new report may look like this:

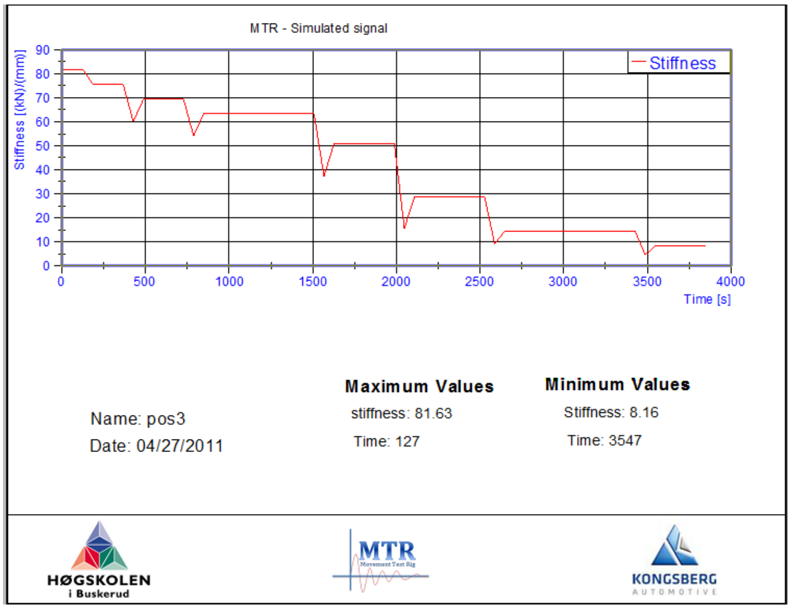


Figure 84: Point 10

11. If you have created a new report. Save it as a template in TDR-format.
12. Save your report with TDR-format.
13. Open the report again.
14. Go back to Script and delete the 'Call PicSaveAs' code line. This was created when you saved your report. If you opened a template, you do not need to do this step.

```
'Call PicSaveAs(MyFolders(1)&"Stiffness_template.TDR","") '... PicI
Call PicLoad(MyFolders(1)&"Stiffness_template.TDR") '... PicFile
Call PicUpdate(0)                         '... PicDoubleBuffer
```

Figure 85: Point 14

15. Stop recording.

Figure 86: Point 15

16. This step is the same as point 25. In the previous chapter, Automating report and analysis of existing log data. Stay in Script and make some free space between ‘Call Data.Root.Clear’ and ‘Call DataFileLoad’.
    Type inn ‘Call FileNameGet(“NAVIGATOR”,”FileRead”)’.
    Replace ‘FileDlgName’ inside the parentheses, in the ‘Call DATAFILE LOAD’ code line.
    Save your Script.

```
Call Data.Root.Clear()
Call FileNameGet("NAVIGATOR","FileRead")
Call DataFileLoad(FileDlgName) '... DataFil
Call ChnSub("[1]/Force(kN)  (Maximum)","[1]/
```

Figure 87: Point 16

17. Next step is to control your script. Go back to report and click the ‘New Layout’ button and a new blank report will come up.
18. Go back to Navigator and press the ‘New Layout’ button and the data portal will be empty.
19. Hit the ‘Run Script’ button. It will run the script and come up with the report.

5. Appendix

SCRIPT code: Automating report and analysis of existing log data

```
Call Data.Root.Clear()
Call FileNameGet("NAVIGATOR","FileRead")
Call DataFileLoad(FileDlgName) '... DataFilename,FileImportFilter,ImportAction
Call FileNameGet("NAVIGATOR","FileRead")
Call DataFileLoad(FileDlgName) '... DataFilename,FileImportFilter,ImportAction
Data.Root.ChannelGroups(1).Channels("Channel 1").Name = "new_time"
Data.Root.ChannelGroups(1).Channels("Channel 2").Name = "new_pos"
Data.Root.ChannelGroups(1).Channels("Channel 3").Name = "new_force"
Data.Root.ChannelGroups(2).Channels("Channel 1").Name = "after_time"
Data.Root.ChannelGroups(2).Channels("Channel 2").Name = "after_pos"
Data.Root.ChannelGroups(2).Channels("Channel 3").Name = "after_force"
Call Data.Root.ChannelGroups.Add("top_values", 3).Activate()
Call ChnPeakFind("[1]/new_pos","[1]/new_force","/PeakX","/PeakY",1,"Max.Peaks","Amplitude") '... XW,Y,E,E,PeakNo,
Call ChnPeakFind("[2]/after_pos","[2]/after_force","/PeakX1","/PeakY1",1,"Max.Peaks","Amplitude") '... XW,Y,E,E,I
Call Data.Root.ChannelGroups.Add("Stiffness", 4).Activate()
Call Calculate("Ch(""new_stiffness"")=Ch(""[3]/PeakY"")/Ch(""[3]/PeakX"")",NULL,NULL,"") '... CalculateFormula,Ca
Call Calculate("Ch(""after_stiffness"")=Ch(""[3]/PeakY1"")/Ch(""[3]/PeakX1"")",NULL,NULL,"") '... CalculateFormul
Call Calculate("Ch(""new_stiffness_kNprmm"")=Ch(""[4]/new_stiffness"")*10^(-6)",NULL,NULL,"") '... CalculateFormu
Call Calculate("Ch(""after_stiffness_kNprmm"")=Ch(""[4]/after_stiffness"")*10^(-6)",NULL,NULL,"") '... CalculateF
Call Data.Root.ChannelGroups.Add("difference", 5).Activate()
Call Calculate("Ch(""diff"")=1-Ch(""[4]/after_stiffness_kNprmm"")/Ch(""[4]/new_stiffness_kNprmm"")",NULL,NULL,"")
Call Calculate("Ch(""diff_percent"")=Ch(""[5]/diff"")*100",NULL,NULL,"") '... CalculateFormula,CalculateSymbols,(
Call PicLoad("Template")                  '... PicFile
Call PicUpdate(0)                         '... PicDoubleBuffer
'Data.Root.Name = "Longitude Test"
'Call PicSaveAs(MyFolders(2)&"MTR_template3.TDR","") '... PicFile,PICFileCode
Call PicLoad(MyFolders(2)&"MTR_template3.TDR") '... PicFile
Call PicUpdate(0)                         '... PicDoubleBuffer
```

SCRIPT code: Automotive report and analysis of simulated signal from LabVIEW

```
Call Data.Root.Clear()
Call FileNameGet("NAVIGATOR","FileRead")
Call DataFileLoad(FileDlgName) '... DataFilename,FileImportFilter,ImportAction
Call ChnSub("[1]/Force(kN) (Maximum)","[1]/Force(kN) (Minimum)","/Subtracted") '... Y,Y1,E
Data.Root.ChannelGroups(1).Channels("Subtracted").Name = "diff_force"
Call ChnSub("[1]/Position(mm) (Maximum)","[1]/Position(mm) (Minimum)","/Subtracted") '... Y,Y1,
Data.Root.ChannelGroups(1).Channels("Subtracted").Name = "diff_pos"
Call ChnDiv("[1]/diff_force","[1]/diff_pos","/Divided") '... Y,Y1,E
Data.Root.ChannelGroups(1).Channels("Divided").Name = "Stiffness"
Call ChnPeakFind("[1]/Time","[1]/Stiffness","/PeakX","/PeakY",1,"Max.Peaks","Amplitude") '... )
Data.Root.ChannelGroups(1).Channels("PeakX").Name = "max_time"
Data.Root.ChannelGroups(1).Channels("PeakY").Name = "max-stiffness"
Call ChnPeakFind("[1]/Time","[1]/Stiffness","/PeakX","/PeakY",1,"Min.Peaks","Amplitude") '... )
Data.Root.ChannelGroups(1).Channels("PeakX").Name = "min_time"
Data.Root.ChannelGroups(1).Channels("PeakY").Name = "min_stiffness"
Call PicLoad(MyFolders(1)&"Stiffness_template2.TDR") '... PicFile
Call PicUpdate(0)                         '... PicDoubleBuffer
```

6. SOURCES

http://zone.ni.com/devzone/cda/tut/p/id/3284 (23.04.2011)
http://www.ni.com/diadem/ (23.04.2011)
Tutorials in DIAdem program.

HØGSKOLEN
i Buskerud

Department of Technology
Kongsberg

Title of document: After analysis rev. 1.3
Course (code/name) SFHO3200 Hovedoppgave med prosjektstyring
Group members: Elisabeth Espås Jenssen Jørgen Heum Larsen Andreas Fossnær Wold Edward Palm Sandaker Stina Andersen
Internal supervisor: Gunnar Flak
Date: 03.05.2011
We confirm that the submitted assignment is entirely our work.   Elisabeth Espås Jenssen, Jørgen Heum Larsen, Andreas Fossnær Wold, Edward Palm Sandaker og Stina Andersen

Table of contents

1. Introduction

One of the products Kongsberg Automotive develops is a V-stay for trucks. This V-stay represents the connection between the rear axle and the frame of the truck. Each V-stay leg is attached to the frame of the truck, while the centre point is attached to the rear axle. To dampen vibrations between the drive axle and the frame, there are rubber bushings in both V-stay legs.

Since this is a critical component in terms of road safety it is very important that these bushings and the V-stay are both tested regularly and thoroughly, before being mounted in a truck.

The solution Kongsberg Automotive has today takes up a lot of time in the existing rigs that are initially intended for other tests. The current solution requires that the operator must set up temporary sensors and electronics, as well as moving the test object manually repeatedly through the test. This makes the tests both time consuming and costly to perform, in addition to that it is difficult to manually manoeuvre the V-stay in the existing rigs. This is due to both the size and weight of the V-stay, where each of the legs measures 70 cm and the V-stay weighing up to 20 kg.

The client also wants to have a test rig which stores data so that results can be looked up for comparison, rather than the current solution where you manually have to go through test results when comparing results. It is also the principal's desire to obtain numerical values and curves that can be used in test reports.

KA has a desire to develop a more compact and flexible test rig. The rig will be able to measure stiffness, displacements and perform single axis fatigue tests. The test rig should be able to test over time to fracture occurs.

2. Achievement

2.1. Project results

This project has given us good insight into what it means to work within a time scale and cost limit. It has been multidisciplinary, and has given us a good knowledge in several fields. The purpose of the project was for us to learn good work habits and project management techniques.

The project has been clearly defined in many areas and not so clear in other areas. But this has given us opportunities to be both creative and learn how to relate to requirements that are set. Very late in the process, it was particularly busy because of some changes in customer needs. Completion of the project was way due when entering the last two weeks. Still, it was important to hear the client out. The requirement specifications were not quite clear on this issue. We see the importance of having a well-defined project.

The main projects’ goal was to develop a new test rig. The technical baggage the group members had after two years of schooling was the basis for how this would be resolved.

There was no time to do a risk analysis. The risk analysis was supposed to be completed early in February according to the schedule, but since much of the equipment was not in place before the end of the project, there was not enough time to do the risk analysis.

2.2.Real costs

The project exceeds the first cost budget some. The few things the first cost budget did not include was using of telephone. Private telephones were used to call suppliers in Norway and abroad.

2.3.Evaluations of the product

Regarding the requirements given, a rig that satisfies all major customer needs is designed. Requirements such as compactness, flexibility, automation and user friendliness have been given particularly much weight. The best way to really evaluate the final product would be comparing it with an existing rig in need of improvement, in which we have been doing continuously during our concept development.

Our client has now got a compact and custom made test rig, for easy V-stay testing in many years to come.

3. Project implementation

3.1.Working procedures

The planning of the project went very well from the beginning and until January. In the beginning of January, after the first presentation, the productivity slowed down for a while. There were some elements of uncertainty about the project. It was somewhat difficult to get fully started with the work and members of the group hesitated a bit. In this period there was a lot of researching. The challenge was to develop a good concept that the client could approve. The client was not satisfied with the first edition of the concept and it needed further development. This was a turning point of the project. From here on the productivity went up and commitment was high.

We had some challenges concerning the complete 3D-model. The project group did not choose a supplier for hydraulic cylinders until the end, and did not receive CAD files from our supplier of choice. Because of this we were not able to implement 3D- models of the chosen cylinders to the complete 3D-model.
The project group discussed how we could visualize the test rig as if it was in use. Our idea was to implement the V-stay into the complete 3D-model and simulate the movements in

the V-stay when subjected to the given forces. Unfortunately the V-stay 3D-model was to complex and could therefore not be subject to forces.

When the project group to making the 2D drawings of the entire test rig and all the parts we met some challenges concerning the complexity of the process. Our background and basic education about the subject was not sufficient. We made some drafts at first, and after a briefing with Kongsberg Automotive we made the 2D drawings more detailed. The project group learned a good deal after this process.

The control system was made in LabVIEW. We had knowledge of the program, but had never used it before. LabVIEW is a huge program with a lot of functions, so the biggest challenge was to learn how to use the program. This has taken much time, but we are now familiar with the program and found it interesting and enjoyable to work with. This activity took some more time than what was planned. The functionality in the control system now satisfies the requirements from the client. The control system was tested at Kongsberg Automotive. As planned, this was time-consuming. Good teamwork ensured that the implementation of the software went as planned.

DIAdem, from National Instrument, is an analyzing tool. This program was unknown and we had to learn how to use this program as well. In the same way as LabVIEW, DIAdem is a great program and a lot of hours were spent learning how to use it. DIAdem is a great analyzing tool, and it is easy to use. It will do the analyzing work for KA much easier. For instance, a script has been made to make it possible for KA to implement their former log data into DIAdem.

3.2.Co-operation: internal and external

The teamwork internal in the project has been quite good. All of the group members have taken responsibility to get the job done. We have learned that the important issue by working in a project is to cooperate and split the differences. We all have our different opinions on things, but in the end, it contributes to well-considered decisions. This co-operation has been a success.

We have learned to trust our co-members of the group to do what must be done to make things work.

It has been of high importance to gain a good working relationship with our client. The client has been most welcoming and helpful in all cases. Kongsberg Automotive have clearly been involved in the project and it is important for the people involved to have a successful result. All criticism has been constructive and helpful. Although we have had monthly meetings with the client it has occasionally happened that we had to stop by on short notice, this has never been a problem, rather the other way around.

3.3.Project administration

Weekly meeting with our internal supervisor has been held. Everybody had to participate by writing meeting notices and meeting minutes. This has been a good opportunity to learn how to structure meetings.

Even though we have not literally followed each step in the project model, this has been more of a guideline for the whole process. The goal was to complete the project in a professional manner, and within the time limits set.

It can be time consuming to work in a group, and in many cases we would have been better off working individually. The important part is to find a combination that suites all members and gives the project best efficiency. The working through the project has consisted of both teamwork and individual work. The first half of the project consisted almost exclusively of collective work. During the second half of project there was more individual work due to more specialization within the fields of knowledge.

Time buffers are important to have in case of delays. For instance, an unfortunate effect of not getting offers from all suppliers of hydraulics was that the choice of hydraulic cylinders was postponed several times. When evaluating now, we know that this decision should have been taken earlier in the project. There have been both small and big changes in the time and resource schedule. It is challenging to plan a project and this has been a process of learning. The time and resource schedule is an important part of a project.

There was some uncertainty about the electrical drawing. We had never made an electrical drawing before, and it was scheduled to do this during the whole process. This activity was postponed, and most of its focus in the end of the project. The reason for this was that much of the focus was given to LabVIEW and DIAdem programming. We got the data sheet from MOOG portable test controller, which was then compared to a suggestion that was given to KA in the end of 2010. This was the fundament of the electrical drawing. The electrical drawing is missing detailed information regarding load cells, potentiometers and servo valves, another effect of the earlier mentioned choice of supplier, and lack thereof.
It was desirable to use the same supplier for hydraulic cylinders and load cells, since the type of hydraulic cylinders needed for the rig are usually available with integrated load cells. The choice of cylinders was done in the last part of the project, which gave consequences to the electrical drawing. The data sheet for the load cells never came, and so the electrical drawing had to be made without pin numbers of the connection between the controller and the load cells. Based on our assumptions and time constraints, we are satisfied with the result.

Appendix list

1. 2D-drawing
2. Electrical drawings
3. Test planner
4. Quotation