CHALMERS

Development of Heavy Duty Trailer Drawbar

Utveckling av dragstång till tunga fordon

Degree project in the Bachelor of Science in Engineering Programme

Mechanical Engineering

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PREFACE

This report is a bachelor thesis which is the last part of our studies at the Mechanical Engineering program at Chalmers University of Technology with focus on machine design. The thesis comprises 15 credits and is executed at the institution Materials and manufacturing technology. The thesis has been done at ÅF in the HCT-project.

We would like to give great thanks to Dennis Persson at ÅF who has been our supervisor in the project, without his support we would not been able to complete the thesis. Our thanks also go to Marcus Persson who has assisted with knowledge and support (when Dennis was not around).

We would also like to thank our supervisor, Gert Persson, associate Professor and Deputy Head of Department at the institution Materials and Manufacturing technology, for the support and counsel.

Gothenburg, June 2016

William Nordkil & Filip Sandberg

SUMMARY

ÅF AB is one of Sweden's largest consulting company that have a partnership in the automotive industry with Volvo AB to create longer and heavier truck combinations. Within this project their own trailers have been developed to create a 27,3 meter long vehicle combination which is one out of several vehicle combinations used in order to increase legal load and length restrictions within Sweden. This work focuses on the drawbar to the trailer which is a center axle trailer with a rigid drawbar. This work involves developing a new drawbar without the problems of today, where a withdrawal is made of the chassis frame sides lower flange to fit the drawbar, while maintaining strength and low weight. With a side track in developing proposals on the basis of the UNECE regulation R-55.

The work started with feasibility studies as well as meetings and interviews with people familiar with the project and similar projects to get an idea of what is available today. This was done to get ideas for creating new concepts that are not already available today. A specification was developed with the help of data obtained from meetings and studies.

The first sketches of concepts were designed and crossed to bring out new concepts. Then the created concepts were evaluated by CAD and FEM models using the CAD program Creo where stress images and calculations were inspected. A number of meetings were held to make and validate choices and designs.

A winning concept was developed and several concepts with potential for development.
To the Directive R-55 a best-case scenario was developed with the help of meetings with senior designers within the industry as well as an alternative solution when the best scenario may not be implemented.

SAMMANFATTNING

ÅF AB är ett av Sveriges största konsultföretag som har ett samarbete inom fordonsindustrin med Volvo AB för att skapa längre och tyngre lastbilskombinationer. Inom detta projekt har egna trailers tagits fram för att skapa en 27,3 meter lång fordonskombination, som är en av flera fordonskombinationer att göra tester på för att öka laglig last och längd inom Sverige. Detta arbete fokuserar på dragstången till lastbilssläpet som är en kärra med stel dragstång. Arbetet går ut på att ta fram en ny dragstång utan de brister som finns i dagens lösning med bibehållen hållfasthet och låg vikt. Med en sidogren att ta fram förslag på underlag till UNECE-direktivet R-55.

Arbetet startade med förstudier samt möten och intervjuer med personer som är insatta i projektet och liknande projekt för att få en uppfattning av vad som finns på marknaden. Detta gjordes för att få idéer för att skapa egna nya koncept som inte redan finns idag. En kravspecifikation togs fram med hjälp av underlag som erhållits från möten och undersökningar. Efter brainstorming och matriser ritades enklare skisser upp och korsades för att få fram nya koncept.

Därefter utvärderades koncepten genom CAD och FEM-modeller med hjälp av programmet CREO där spänningsbilder och beräkningar togs fram. Ett antal möten hades för att göra och validera, val och konstruktioner. . Efter att ha tagit fram flera koncept med utvecklingspotential valdes några ut att utvecklas vidare innan ett slutgiltligt resultat togs.

Till direktiv R-55 togs fram ett bästa scenario med hjälp av möten med seniora konstruktörer inom branschen samt en alternativ lösning då det bästa scenariot inte säkert går att implementera.

Table of Contents

NOMENCLATURE

Fifth Wheel - A turntable on the trucks rear end, dollys and links where a semitrailer is connected with its king pin.
King pin - The connection on a semitrailer which is connected to the trucks fifth wheel.
Dolly - Small wagon with a fifth wheel and a drawbar (that makes it possible to connect a semitrailer to a truck without a fifth wheel).
Bogie - A combination of two axles with a maximum distance of 2 meters between the axles to spread out the pressure on the road on four wheels instead of two. Which allow you to carry more weight because of maximum axle pressure.
BK - Load classes of Swedish roads (=Bärighetsklass), The BK classes and the loading limits is described by these classes and can be found at Transportstyrelsen (1).
HCT - High Capacity Transports
DUO^2 - A HCT-project with focus on general cargo transports.
ETT - The first prototype HCT-truck that could transport one more pile (=En Trave Till) of timber logs which was 90 tonnes and 30 meter.
EMS - the European modular system, a concept system to combine existing modules to create longer and heavier combinations to create more effective transports. Currently used in Sweden, Denmark, Finland and Holland (2).
Duo-CAT - Where CAT=Center Axle Trailer (Duo-Kärra in Swedish), a vehicle combination consisting a truck with two center axle trailers.
UNECE - United Nations Economic Commission for Europe, a commission to encourage economic cooperation among its member states.
R-55 - R55 is a regulation that describes how the connection and the connection point between the truck and trailer should be designed.
Swap body – An exchangeable container place on the truck or trailer.
DNV – Det Norske Veritas, a norweigan company that is known certification of the offshore industry

1 INTRODUCTION

This chapter shows the scope of the project.

1.1 Background

To reduce the fuel consumption of the truck transports on the roads there are studies which shows that heavier and longer transports reduces the fuel-consumption of transports. The development of longer and heavier trucks at Volvo started with the ETT-truck when the storm Gudrun, which was the greatest storm during the 2000’s, blew down great areas of the Swedish forest. Because of the storm, a big volume of timber had to be carried out of the forest to different lumber mills. Since timber is a perishable it has to be taken care of in time before it dries out or rottens, the huge amount of timber had to be delivered before the time ran out. In order to do it faster than with normal trucks, an increased amount of loading capacity would be needed. This led to the idea of the HCT-project.

The HCT-project started at Volvo together with ÅF AB in 2007 with the vision to change the Swedish law of length of truck combinations to 34 m from 25.25 m and increase the weight to 90 tonnes. One problem with heavier and longer vehicle-combinations is the strength of the roads. Which is divided into three BK-classes: BK1, BK2 and BK3 where BK1 applies to 95% off the Swedish road network. This is why the DUO^2- and ETT-projects started in cooperation with Volvo Group Truck Technology. These projects are vehicle combinations that drive as field tests. A field test is a longer test where the vehicle is used by a company in normal conditions for its use. The reason for the field tests is not just to see that these longer and heavier combinations can be driven but it is also to see that the roads can handle the trucks and test new equipment for both truck and trailer. Since the tests have shown very positive results, a new BK-class will probably be created. Which will allow a standard length of a truck to carry 74 tonnes for certain roads. However all roads in Sweden have road managers who decide the BK-class of the roads and the managers are usually local. HCT includes all combinations of truck and trailer that exceeds the limits that is today in form of weight and length for a Swedish standard truck.

One of the vehicle combinations in the DUO^2-Project is a truck with two center axle trailers, named DUO-CAT. Each trailer is connected to the truck/trailer with a rigid drawbar. This carriage transports goods between Gothenburg and Helsingborg. The combination can have a weight up to 66 tonnes and is 27.3 meter long. In the frame sides of the trailer where the drawbars are attached the flanges are removed to fit in the today's version of drawbar. The removal of the flange creates unwanted stress concentrations. Figure 1.1 shows two different pairs of frame sides, the left pair shows the frame sides with nothing cut away from the flanges and the right pair have a length of 1710mm of the flanges cut away from the front end of the trailers frame sides. This does not only cause stress concentrations, it is an additional step in the process of producing the trailer and having the flanges intact will also make the trailer more stable.

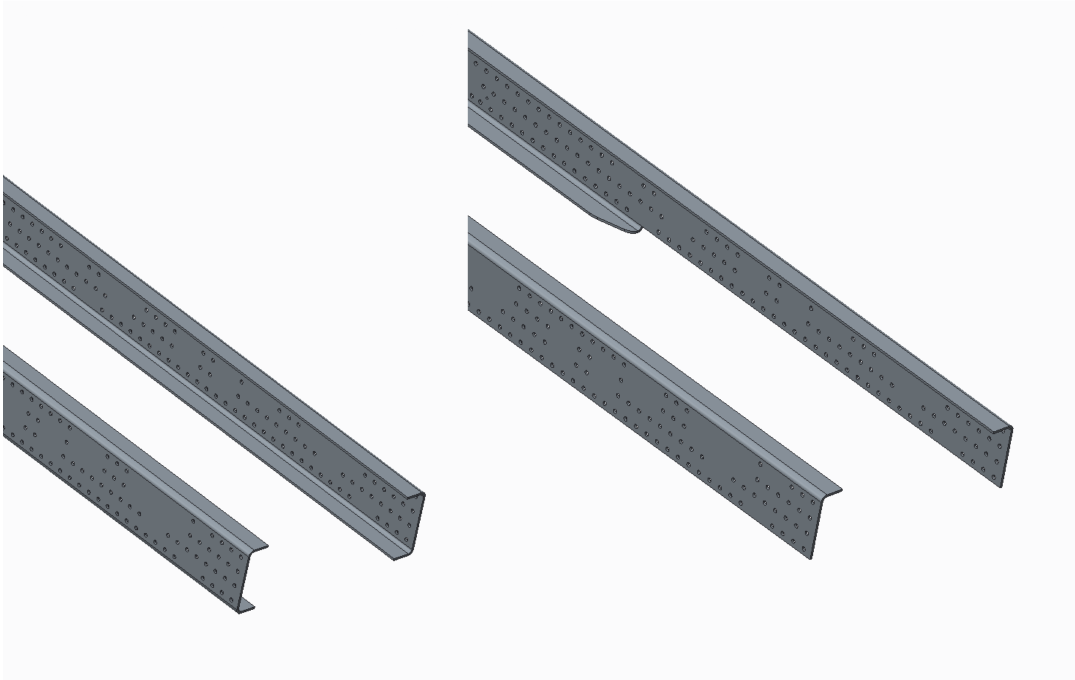

Figure 1.1: Difference between frame sides with flanges (left) and with cut off flanges (right)

Another problem with rigid drawbars is to determine what counts as an integrated part of the chassis and not. There is a UNECE regulation about drawbars and towing couplings which describes how a coupling device should be designed in order to be certified. If the drawbar counts as an integrated part of the trailer chassis this regulation can be skipped. Then it is up to the manufacturer to ensure the strength of the drawbar. To define it as an integrated part the drawbar is today welded to the chassis frame in some small areas. The argumentation for the welds is that you cannot remove the drawbar without damaging the drawbar. But welds changes the materials properties and is an unwanted process when the drawbar is assembled.

1.2 Purpose

To develop a new concept for a drawbar that does not require any withdrawal of the bottom flanges in the frame sides, while maintaining strength and low weight. At the same time find a basis of how to classify if drawbars can count as an integrated part of the chassis or not.

1.3 Delimitations

- The distance between the truck and the trailer is set to 745 mm to prevent collision between the swap bodies when taking curves.
- The connection is placed 1900mm from the end of the container under the carriage (see number one in figure 1.2) this is to get close to the wheels to create less moment in the chassis of the truck.

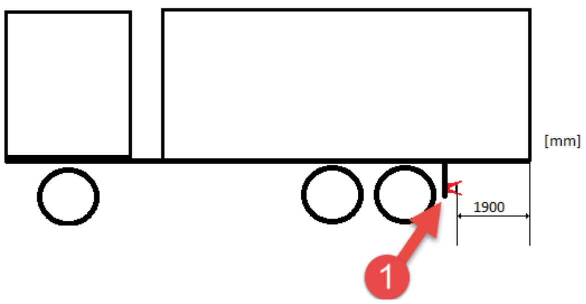

Figure 1.2: Under mounted towing coupling shown as number one

- The trailers will be equipped with a swap body carriage.
- The requested drawbar will be a rigid construction to be able to transfer vertical loads through the drawbar.
- The material used in the drawbar is High-Strength steels from SSAB which is a partner in DUO[2].
- The forces the drawbar should be able to sustain are described by the regulation R55 by UNECE unless the drawbar is welded to the chassis (3). If a drawbar is welded to the chassis it will be considered as a part of the chassis and does not have to apply to the regulations.
- Standard bolts and rivets from Volvo will be used.

1.4 Problem Statement

- Is it possible to avoid the removal of the lower flange of the chassis frame sides?
- Which parts of the Norwegian standard RP-C203 with respect due to welding and bolted connections is possible to apply to UNECE-R55?
    - Chap 2.4.10
    - Chap 2.9
    - Appendix A1-A4
- Is it possible to make the new drawbar lighter than the old one?

As time permits:

- Could the amount of connection elements be reduced without reducing the strength?
- Chapter 4.3 in RP-C203 will be analyzed, is it possible to apply any of this to R55?
- Can the fatigue calculations and fatigue tests be done in a better way?

2 THEORETICAL REFERENCES

To understand the problem that was about to be faced some information and background were needed.

2.1 Drawbars

There are two types of drawbars, rigid and hinged. The rigid drawbar is able to absorb vertical force and is also able to transfer some of the trailers weight to the trucks bogie. The hinged drawbar is used when the front wheel pair on the trailer is hinged as well. Between the rigid and the hinged drawbar there is a weight difference. Since the hinged drawbar only has to absorb longitudinal forces it can be made lighter than the rigid which is relatively heavy. This is because it is easier to absorb longitudinal forces than vertical forces.

2.1.1 Earlier drawbars

Two drawbars have been made earlier for the Duo^2-project. The two drawbars are similar to each other, where the second version is straight up an improvement from the first version. The drawbars are made of sheet metal with a thickness of six or eight mm. The steel comes from SSAB which is a well-known steel provider in Sweden (4). In figure 2.1 the different colors display different parts of the drawbar. The white part (number 1) is the drawbar eye which is connected with yellow brackets (number 2) to the green drawbar (number 3). The drawbar is then connected with red side plates (number 4) to the frame sides as well as with the blue inner plates (number 5) which is connected with white brackets (number 6) to the frame sides.

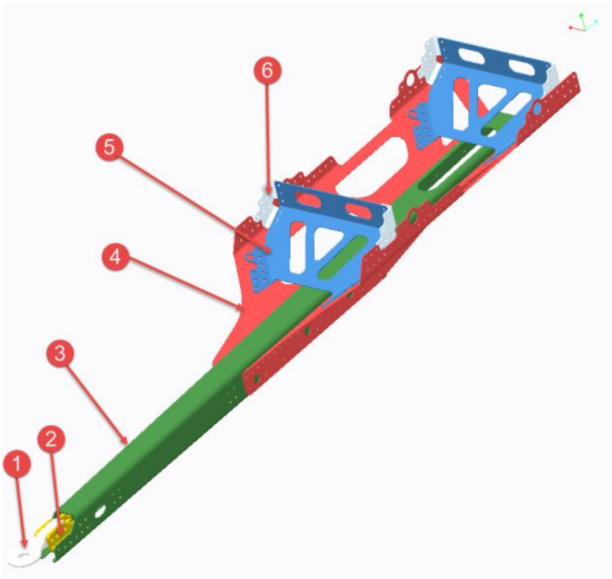

Figure 2.1: The second version of the drawbar

When bending a material there is a limit of how small the radius can be. SSAB have listed recommendation of radius to different steels. For example, if the steel Strenx 700 MC with a thickness of eight mm is used, the recommended inner bending radius for a 90 degree bend is 1.6 times the thickness (5). Also, the bigger the radius the less stress concentrations.

No unnecessary welds have been used, which makes the assembly easier and takes less time. In order to save weight big holes are made in areas with low stresses. Corners in the drawbar have big radius in order to prevent stress concentrations.

2.2 DUO Trucks

There are different types of trucks and trailers, especially the connection between them. It is not like a car where it almost only exist one kind of connection between the car and the trailer. As shown in figure 2.2 there are three combinations that are rather common. The first one, A, is like a car where the trailer is connected with a drawbar to the truck. Combination B shows a trailer which is called semitrailer connected to the truck. There is a fifth wheel mounted on the truck where the semitrailer is connected to with its king pin. The last combination, C, is a dolly that's connected with a drawbar to the truck. Then on the dolly it is possible to mount a semitrailer. This is one of the combinations used in EMS.

The Duo project uses two different combinations, the Duo-CAT and the Duo-Trailer. The Duo-CAT uses two center axle trailers with a drawbar as combination A in figure 2.2 shows, one connected to the truck and one to the first trailer. The Duo-Trailer uses two semitrailers, one of them connected to the truck as combination B shows. The second semitrailer is connected to the first semitrailer with a dolly. This ends up in a mix between Combination B and C.

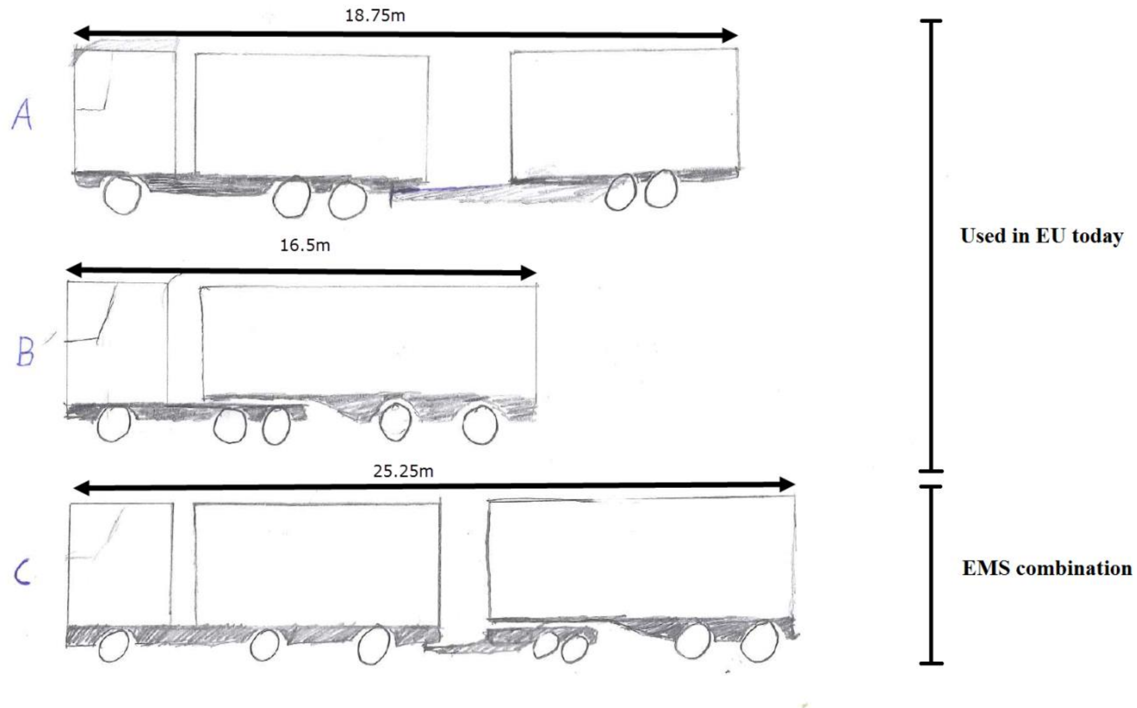

Figure 2.2: Different truck combinations

2.3 Morphological Matrix

Some concepts were needed to be generated to have something to work with. One way to do this is to divide the product into different areas and then find solutions to the stated area. For an example, a person wants to buy a car, but the person does not know what car to buy. With this function chart called Morphological matrix in table 2.1 it is easy to make different combinations (6). One choice from every row should be picked and when that is done the new idea for a combination is made. For example, a red, front wheel driven, sedan, or an all-wheel driven, black, SUV. This can create combinations and in that way new concepts that no one thought of before.

Table 2.1: Example of a Morphological matrix

Functions	Solution					
Colour	red	green	blue	black	white	yellow
Drive type	Front wheel drive	Rear wheel drive	All wheel drive			
type of car	Station wagon	Sedan	SUV			

2.4 Concept screening matrix (Pugh)

Often when there is a product that's going to be developed, there will be some concepts to choose between. A concept screening matrix is a good help when deciding which concepts that are worth further work (6). It is possible to pick what seems to be the best concept but in order to let all the details that the customer wants, it is easier to put everything in a concept screening matrix. All the criteria's are listed in table 2.2. These are criteria's that are set to the product. In this example there are five concepts where concept A is a reference concept. A reference concept is needed to have something to compare the other concepts with.

Table 2.2: Example of a concept screening matrix

	Concepts				
Selection Criteria	**A (Reference)**	**B**	**C**	**D**	**E**
Criteria 1	0	0	+	-	0
Criteria 2	0	0	+	+	0
Criteria 3	0	+	-	+	0
Criteria 4	0	+	-	+	0
Criteria 5	0	0	-	+	0
Criteria 6	0	0	0	0	+
Criteria 7	0	0	0	0	+
Criteria 8	0	-	0	+	-
Sum +'s	0	2	2	5	2
Sum -'s	0	1	3	1	1
Net Score	0	1	-1	4	1

Every concept is now compared with the reference concept for each criteria to see if the other concept is better or worse than the reference. If a concept is better than the reference it gets a "+", if it is worse it gets a "-". In some cases a concept is equal to the reference, if that happens it gets a "0". After all the criteria's and concepts have been compared and evaluated it is time to sum up the +'s and the -'s. The difference between the amount of +'s and the amount of -'s gives the score and the concept with highest score "wins" the matrix. This matrix can be used to get rid of obvious bad concepts and give an objective opinion.

2.5 Kinnarps

Kinnarps produces office furniture and handles the whole distribution of furniture by them self. Kinnarps have been studying on double combination vehicles to optimize the transportation over own routes and creates own trailers with swap bodies to get greater volumes in the trailers for the furniture, and the trailers also uses rigid drawbars.

2.5.1 Information about Kinnarps

Assar Jarlsson took over Kinnarps during the 1970's together with his siblings from his father and mother who started creating furniture in Kinnarp during the world war two. He started early to evolve the logistics at Kinnarps and has been working with it since then. Both within the factory and the transport solutions to customers and from the suppliers of material.

Something very unique with Kinnarps is that instead of using emballage, Kinnarps use blankets and cardboards to optimize the fill ratio and the blankets and cardboards are returned to be reused for next transport.

At Kinnarps Assar was early to create lower chassis, he lowered the trailer with 3 decimeter to create more space for the swap body which increases the effective loading space with 10% (7). The first double combination project to increase the efficiency of the transport solutions of the furniture got shutdown, since it was only allowed to ride at the speed of 40km/h. 1984 started the double combination 2 which was named axle-link who is the mother of the Duo-Trailer, the axle-link uses a dolly between the trailers like the ETT-truck who was the start of the HCT-project on Volvo.

2.5.2 Study visit

The guide was Assar Jarlsson who was early with Duo-Trailers, he started a project during the late 70s to import double combination trailers. Anders Lindell, who drives a truck created by Volvo with a 3-axle center axle trailer with a rigid drawbar designed by the DUO^2-project was also able to answer questions about the current drawbar.

During the meeting before the tour in the factory, Assar talked about the importance of theloadingspace since not all transports are heavy but need more volumes. A typical example is grocery-transports which are rather light but requires bigger volumes.

During the visit there was a meeting with some from the DUO^2-project group, Kinnarps and Transportstyrelsen. The meeting discussed how to increase the range of the Swedish standards so the DUO^2-truck will be included in the Swedish standards for length and weight of a truck.

One part of the schedule was a tour around the production at Kinnarps. Kinnarps were proud to present the automatic forklifts used in the factory, which were early implemented to the production to improve the logistic flow in the factory. The logistic solutions of the factory and transportation out to customer were impressive, the runtime for a product took six days from start of production of a product to out loading the product to a swap body. 80% of the production is going straight to customer without any time spent on a warehouse.

The tour ended at Kinnarps trailer and truck workshop where Kinnarps does maintenance of the trailers. At the workshop there was some time to inspect the drawbars and get a better understanding of how a drawbar can be designed.

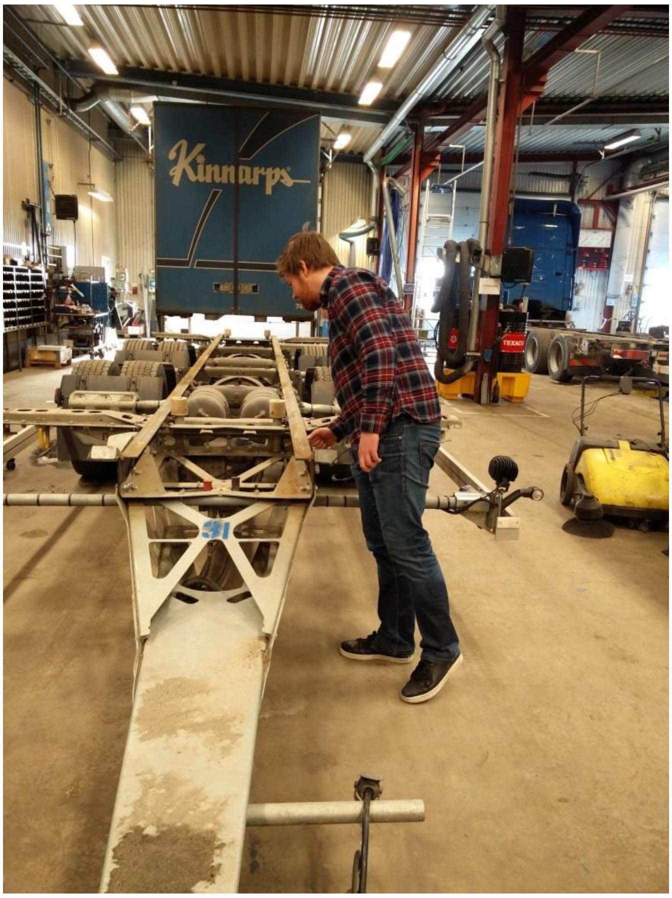

Figure 2.3: Inspection of a drawbar

2.6 VBG-group

VBG-group develop truck equipment and is a major supplier of couplings used on trucks and trailers, VBG also manufacture hinged drawbars.

The factory were introduced and the major part of the production was automatic production by robots and just a few moments of the production was done by hand. The host was Bolennarth Svensson who is also the secretary of the R-55 group for UNECE regulations regarding vehicle couplings. Bolennarth informed about the problem to define if a drawbar is a simple design, integrated with the chassis of the trailer or a separate part. If the drawbar is either a simple design or considered as an integrated part of the chassis the regulations are different and the drawbar can be verified with calculations and does not need to be tested (8).

Bolennarth also talked about how the trailer or truck closest to the cavity in the road springs the major parts of the spike loads to the next trailer making only the two closest units applied to the force of the road bump. This is because of the materials elastic modululus that will even out the forces. With even longer vehicle combinations the length of the combination does not affect the spike loads as much.

2.6.1 R55

R55 is a UNECE international regulation for mechanical coupling devices and components that shall be met in order to be regarded as mutually compatible internationally. Motor vehicles and trailers combined intend to form articulated vehicles according to the convention of road traffic (Vienna 1968), where the trailers vertical load imposed on the motor vehicle by the trailer does not exceed 200 kN. The regulation applies to both regulation and non-regulation components and devices.

The R-55 regulation was first written 1958 and is currently being rewritten and the new definition of the calculations required to get certificated are not yet decided. The problem with today's fatigue test and calculations is the constant amplitude that frequently is used which does not symbolize the loads of the real world. To partly compensate for this a frequency offset is used on the two dimensional fatigue tests.

An interesting problem statement is how one is supposed to tighten the drawbar or chassis when doing fatigue tests. Today the regulation R-55 in Annex 6 says one should tighten it as stiff as possible, though does this reflect the real world case?

Something that usually is not considered is that a slender drawbar would not affect the connections to the chassis as much when the trailer is provoked with bumps and holes in the road, which reduces the spike loads which are the greatest forces the drawbar will be applied by. But this is not possible since a slender drawbar will not work according to the regulation of today.

2.6.2 RP:C203

RP:C203 is a Norwegian offshore standard that presents recommendations of fatigue analyses and fracture mechanics of steels that is based on tests. This is to construct after to ensure a calculated fatigue life cycle on offshore constructions. This standard will be analyzed due to connections and fatigue analyses and a suggestion of what is possible to apply to the R55 regulation will be made.

3 METHODOLOGY

From February to June a result will be generated through the methodology shown below.

3.1 Studying older drawbars and identifying customer needs

In order to be able to develop a new drawbar some background information was needed. In this case, discussion with the supervisor (which acted as the customer) took place to be able to obtain the needs for the new drawbar. These needs were compared with the current drawbar to see what was missing.

3.2 Generate new concepts

With the background gained from the supervisor and the study of current drawbar a function analysis was made with help of a Morphological matrix. Brainstorming with help of the matrix revealed new concepts. These concepts were sketched and also a light FE-analysis were made on the concepts to see how the stresses behaved. With help from the supervisor and a concept screening matrix the concepts were evaluated to see which concepts worth continue working with.

3.3 Evaluate the R55 regulation for drawbars & couplings

Today there is no clear definition of what counts as an integrated part of the chassis. To be able to use the drawbar on public roads it needs to be inspected. In the R-55 regulation it says that the drawbar have to meet some criteria's. But this can be skipped if the drawbar counts as an integrated part of the chassis. The Norwegian offshore standard DNV: RP-C203 was studied to see if anything from there could be applied on the R55 regulation, to get a clearer definition of how connections should be treated with respect to fatigue analysis. With this results a suggestions should be made of how to define if a drawbar should be an integrated part of the trailer chassis or not.

3.4 Development of concepts

When the evaluations of the concepts were done, a more complete model was made in the program CREO Parametrics, which is the CAD-program that has been used. These concepts were studied in an FE-analysis with respect to some predetermined loads. The FE-analysis gave information on where the models could or had to be changed to gain a better result. To decide which concept that was going to be the final concept another matrix were used. With this and other involved in the project such as the supervisor a winning concept were chosen.

3.5 Presentation of final concept

The presentation of the work and the final concept were made with a presentation to people involved in the project from different companies. Another presentation was held toward Chalmers in front of the examiner and other students. A written report was handed in as well. In these presentations an evaluation of the standard RP-C203 was presented to see if anything could be applied on the R55 regulation for drawbars & couplings.

4 GATHERING INFORMATION

The gathering of information was mainly made by doing study visits and interviewing people who have worked with the drawbar earlier.

4.1 Examining Trucks

A study visit to Kinnarps was made, since Kinnarps have trucks and trailers with rigid drawbars that are similar to the Duo-CAT's. Also some visits to the workshop at Volvo GTT were made to see and study a truck. The actual Duo-CAT is driving in traffic and is used for deliveries so the opportunity to see the trailers was made once only.

4.2 Requirements

To list a specification of requirements the supervisor who acts as the customer answered some questions regarding what the drawbar has to manage. The answers are listed in a specification of requirements below in table 4.1.

Table 4.1: Specification of requirements

Able to handle a vertical Load	Demand	30kN
Able to handle a longitudinal Load	Demand	84kN
Able to turn the truck with respect to trailer	Demand	90deg
Length from swap body to draw eyes center	Demand	2679mm
Length between the frame sides and the center of the towing eye	Demand	2252.5mm
Length between draw coupling and swap body(truck or trailer)	Demand	1900mm
Length between the bottom of the flanges and the top of the drawbar eye	Demand	503mm
Length between top of frame sides and bottom of the drawbar	Demand	<638mm
Distance between swap bodies Truck-Trailer	Demand	745mm
Angle between top of swap bodies without impact	Demand	6deg
Rivet size, bolt size	Demand	M14
Type of draw eye	Demand	VBG DBE153
Fatigue cycles	Demand	$2*10^6$
Max stresses	Demand	300MPa
Rigid drawbar	Demand	
Solid flanges	Demand	
Integrated drawbar with frame sides	Demand	
Material	Request	SSABs Strenx 700
Weight	Request	<390kg

All the different distances listed in the specification of requirements have to be exact, if the values are too small, the truck will impact with the trailer. If a value is too big the length of the combination will exceed the accepted length for the vehicle.

The testing forces applied in the calculations are calculated by formulas taken from the R-55 regulation as could be seen in the equations below.

$$V = \frac{a \cdot C \cdot X^2}{L^2} \; [kN] \qquad (1)$$

$$D_c = g \frac{T \cdot C}{T + C} \; [kN] \qquad (2)$$

Values of formulas

V	Vertical value for the force applied on the drawbar eye
Dc	Horizontal value for the force applied on the drawbar eye
a=1.8m/s^2	Equivalent vertical acceleration at the coupling for the suspension
X=7.82m	Represents the loading area
L=6.72m	The distance between the drawbar eye and the axles center
C=20tonnes	Mass of the CAT-trailer in
G= 9.81m/s^2	Acceleration due to gravity
T=26tonnes	Technically permissible maximum mass of the towing vehicle, including the maximum allowed force implied by the CAT-trailer.

The vertical value, V and the horizontal value Dc is then multiplied with 0.6 to get the Amplitude which should be used when testing the drawbar. The value listed above will give the Vertical force = 30kN and the horizontal force = 84kN as seen in the specification of requirements (3). The lengths as well as the forces can be seen in figure 4.1.

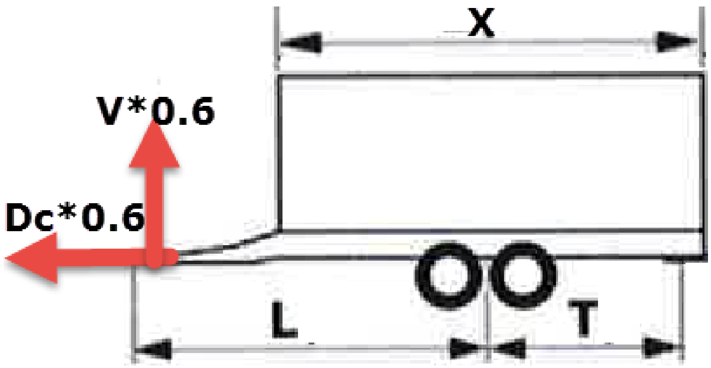

Figure 4.1: Lengths and forces on a center axle trailer

The reason that M14 rivets and bolts will be used is because of the size of the holes in the frame sides. An exception is made with the drawbar eye, the loads and stresses in the drawbar eye require M20 bolts.

Highest stresses allowed with 300 MPa are based on the construction of earlier drawbar. The purpose says that the new drawbar should have retained strength and the calculations on the old drawbar had a maximum of 300 MPa. This to make static calculations though with a amplitude allowed will represent the fatigue calculations.

5 CONCEPT GENERATION

To create concepts brainstorming and a Morphological matrix were used.

5.1 Brainstorming with use of a Morphological matrix

It was decided that the concept generation would be made with help from a Morphological matrix. First of all every possible attachment (how the different parts could be connected to each other) were listed below in figure 5.1. There will be no space to place a connection on top of the frames because of the swap body, therefor the top were removed. The bottom of the drawbar was also removed because of the clearance to the ground. A round profile of the drawbar will lead to a complicated connection between both the drawbar eye and the drawbar as well as between the drawbar and the frame sides. Therefor the round profile was expelled. A discussion between the square profile and the conic profile took place. A square profile looks almost the same as a conic profile, so what are the pros and cons. Pros with a conic profile is that it will tighten up in the front which leads to less material needed to connect the drawbar eye. It also gets wider in the back which makes the connection plates between the drawbar and the frames shorter and with a smaller bending radius. This weighs up the cons with a special bracket in the front for the drawbar eye. These pros and cons are based on today's drawbar only. Also, a rectangular profile gets a wider profile in the front which could make a difference on how much the truck will be able to turn. From this matrix, eight possible concepts were sketched up.

Table 5.1: Morphological matrix applied on the project

Connecting parts	**Solution**			
Frame connection	Inside	Outside	Bottom	~~Top~~
Drawbar connection	Top	Outside	~~Bottom~~	
Drawbar	Square profile	~~Round Profile~~	Conic Profile	V-shaped profile
Draw eye Connection	Special Bracket	Bent plates	Brackets	Slimmer Drawbar

5.2 Concepts generated

The concepts were focused on the connection between the drawbar and the chassis frame sides since the main goal is to make a drawbar where there is no need to cut off the bottom flanges. Since the flanges are pointed inwards, the red plates (shown in figure 2.1) are used in these concepts because the connections on the outside of the frames do not need to be changed. In the following eight concepts the parts are marked with numbers and are in different colors. Number 1, 2 and 4 are the same part throughout every concept with an exception in concept 7, where number one is the drawbar, number two is the side plates and four is the frame sides. Number three is the part that changes through the concepts and is explained in each concepts.

5.2.1 Concept 1

Concept 1 shown in figure 5.1 uses a conic profile of the drawbar with the red plates. There is a bent plate on the inside that goes between the two frame sides, shown as number 3. It is connected with bolts to the bottom flanges of the frame sides. The plate which is connected between the frame sides is then connected with a C-profile to the red plates. Where the back of the C-profile is connected to the bottom of the plates connected to the frame sides. Then the flanges of the C-profile are connected to the red plates. There will be at least two of these combinations connected between the drawbar and the frames, one in the front and one further back.

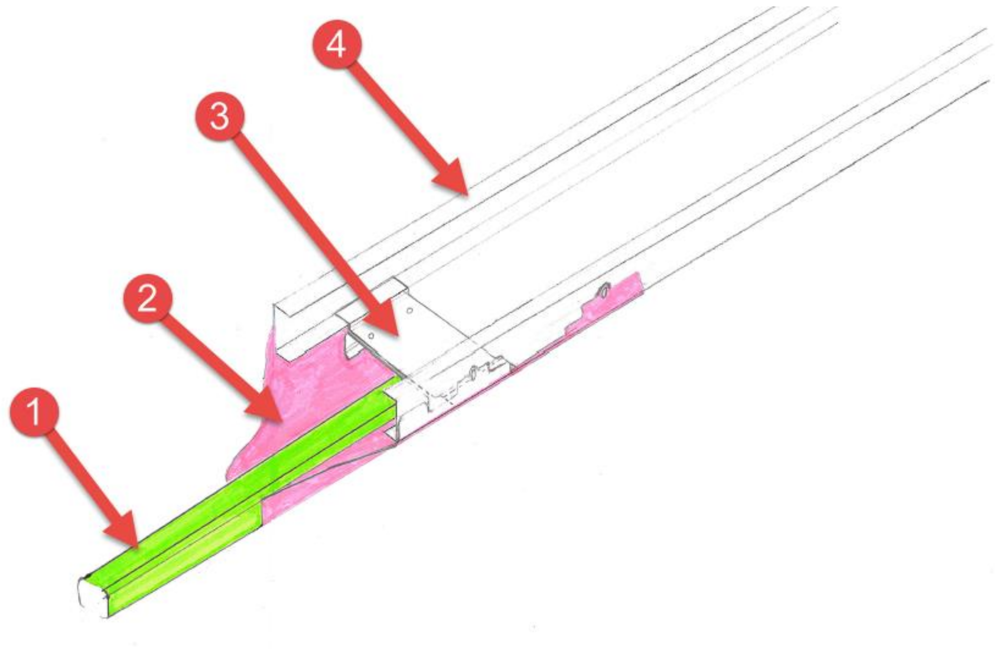

Figure 5.1: Concept 1

5.2.2 Concept 2

As the first concept, this one also uses the conic profile of the drawbar as well as the red plates to connect the outside of the frames with the drawbar seen in figure 5.2. This concept uses one plate connected to the bottom flanges and to the red plates shown as number 3 in figure 5.2. It is a C-profile with the back connected to the bottom flanges of the frame sides and the flanges of the C-profile are connected to the red outer plates. The blue plate is supposed to be as long as the drawbar stretches itself under the frames.

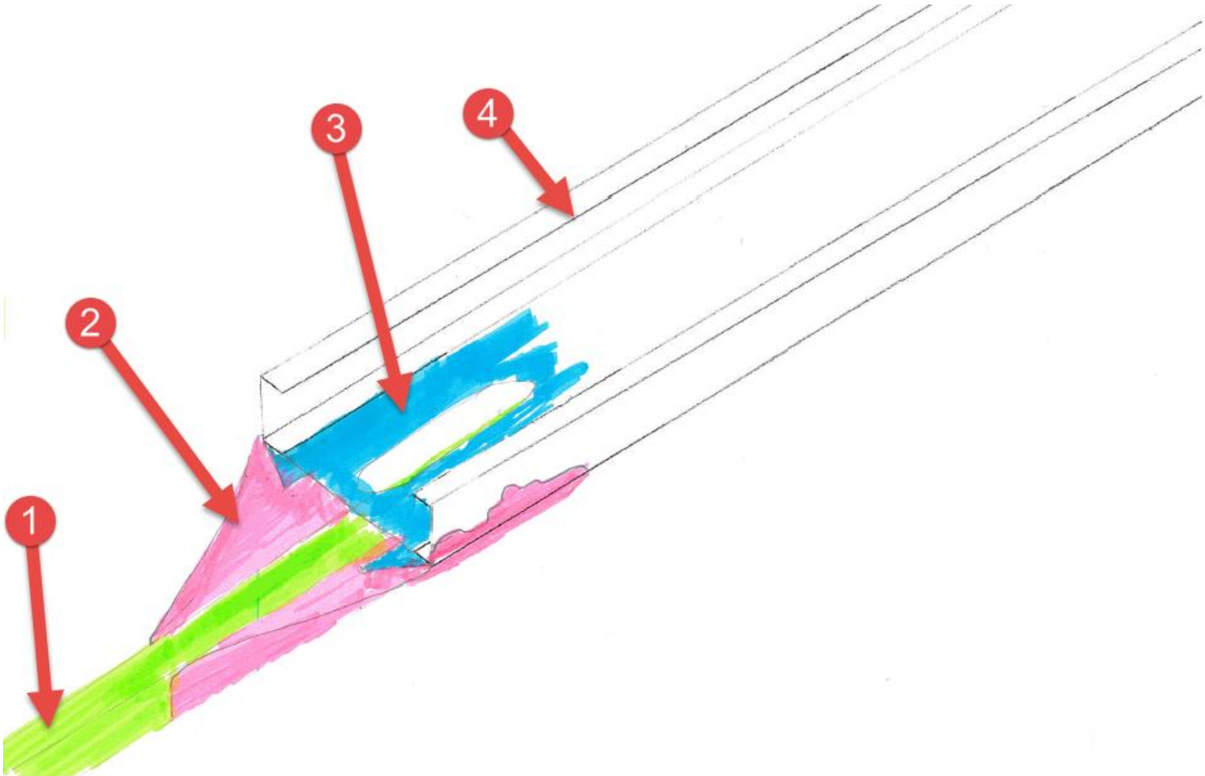

Figure 5.2: Concept 2

5.2.3 Concept 3

This concept has a plate attached to the bottom flanges but on top of the flanges seen in figure 5.3 as number 3. Then it curves over the flanges and down to the red plates where it is connected with bolts.

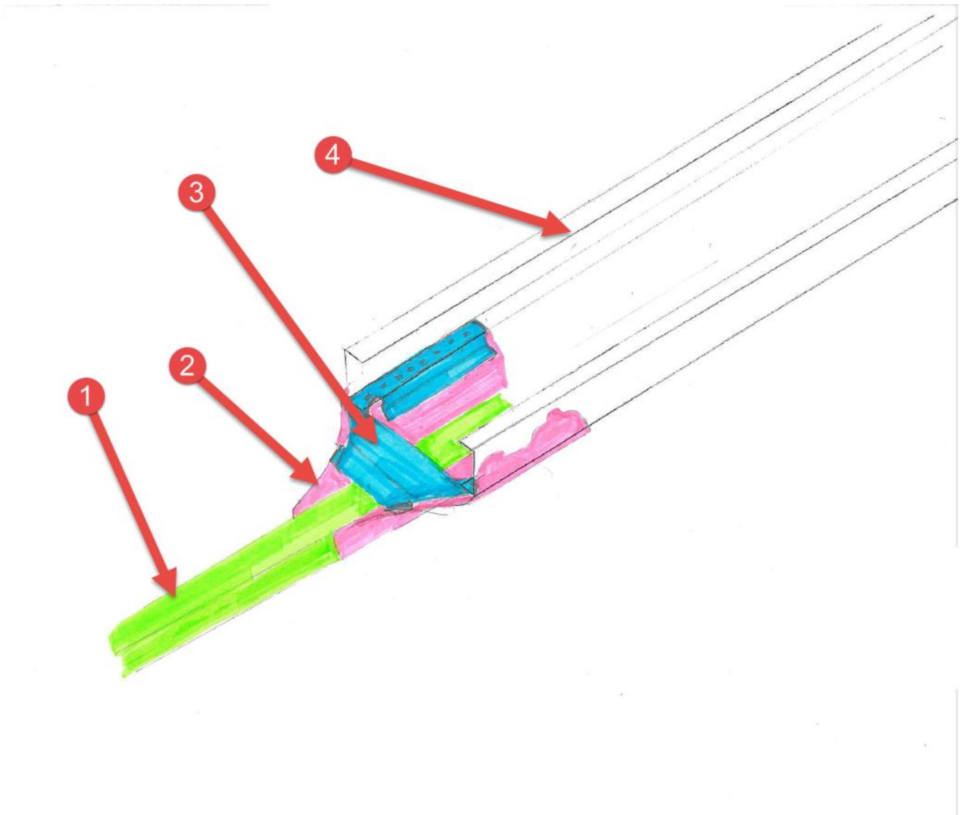

Figure 5.3: Concept 3

5.2.4 Concept 4

Concept 4 in figure 5.4 is similar to the second concept. It has the red plates and the conic drawbar. The huge difference is that the blue plate (number three) is not connected to the red plates. It is connected between the inside of the frame sides.

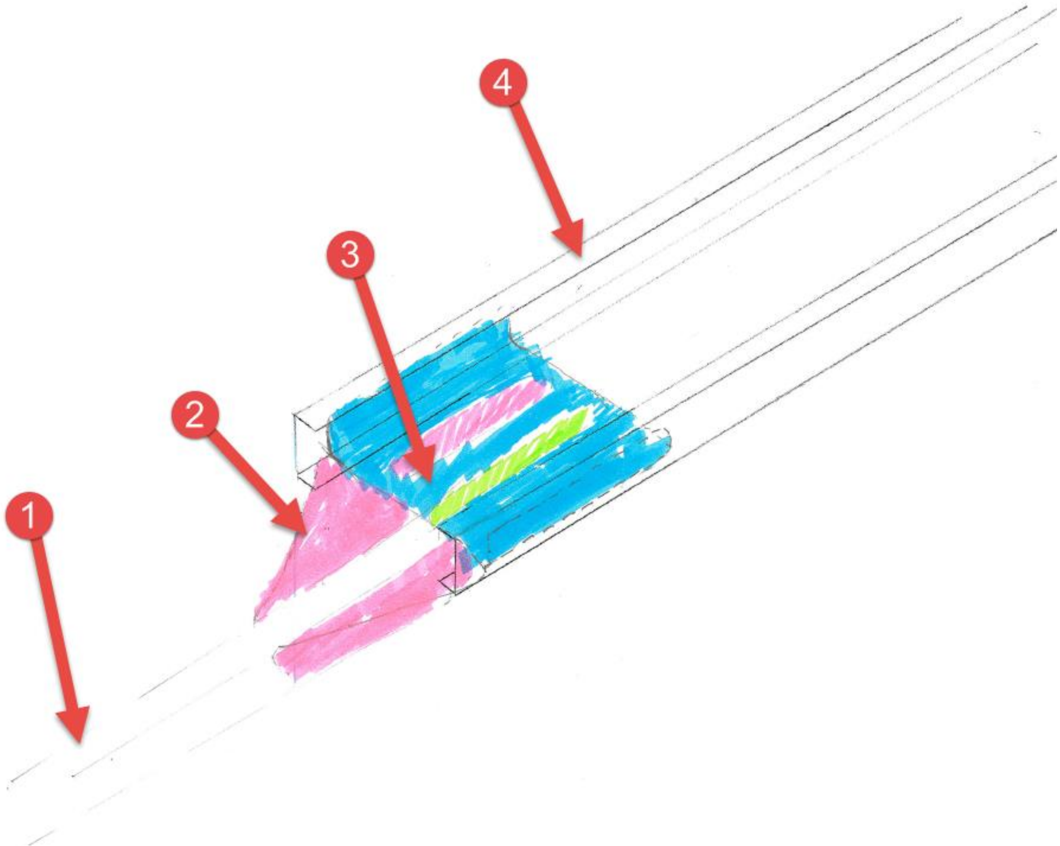

Figure 5.4: Concept 4

5.2.5 Concept 5

A concept with inspiration from earlier drawbars. But instead of using the white consoles shown in figure 2.1 to connect the blue plate from the same figure to the frames, this concept uses the existing cross beams shown in figure 5.5 as number three. Which might make this concept a little lighter than the existing drawbar.

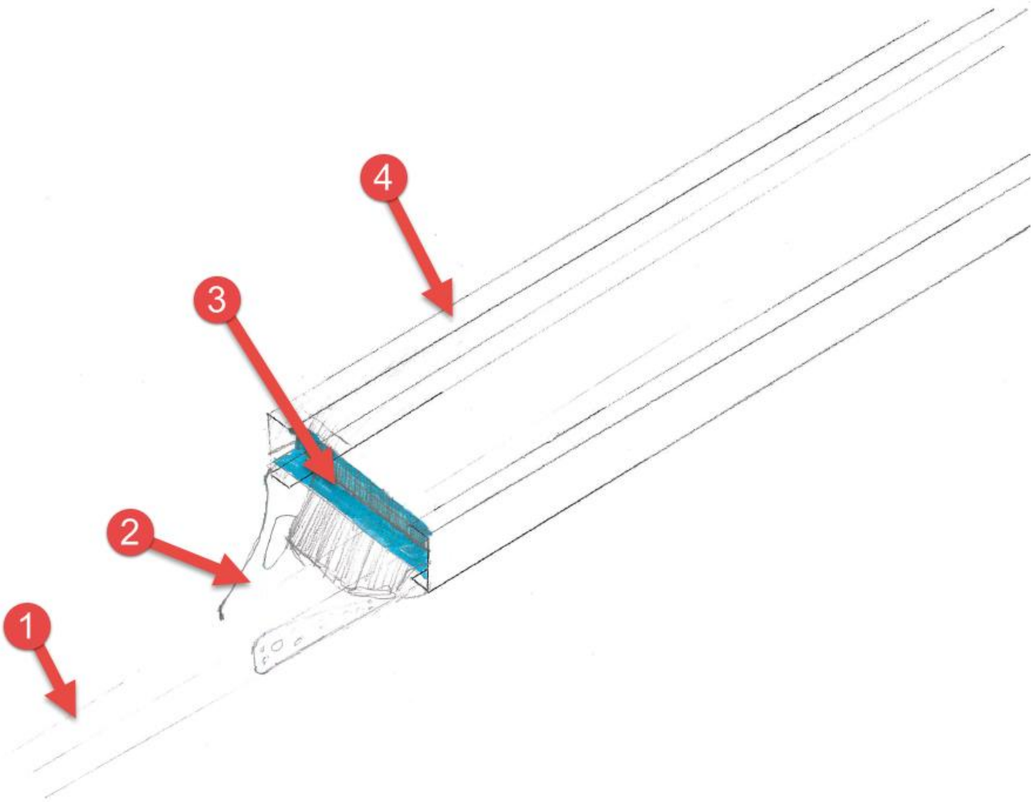

Figure 5.5: Concept 5

5.2.6 Concept 6

This concept has a plate bent number 3 over the flanges and connected to the holes of today in the frame sides shown in figure 5.6. This prevents holes in the flanges which could give less stress concentrations. Since the plate bends over the short edges of the flanges it will not be able to apply another plate further back of the drawbar. This will make the drawbar heavier than needed, because of the long plate.

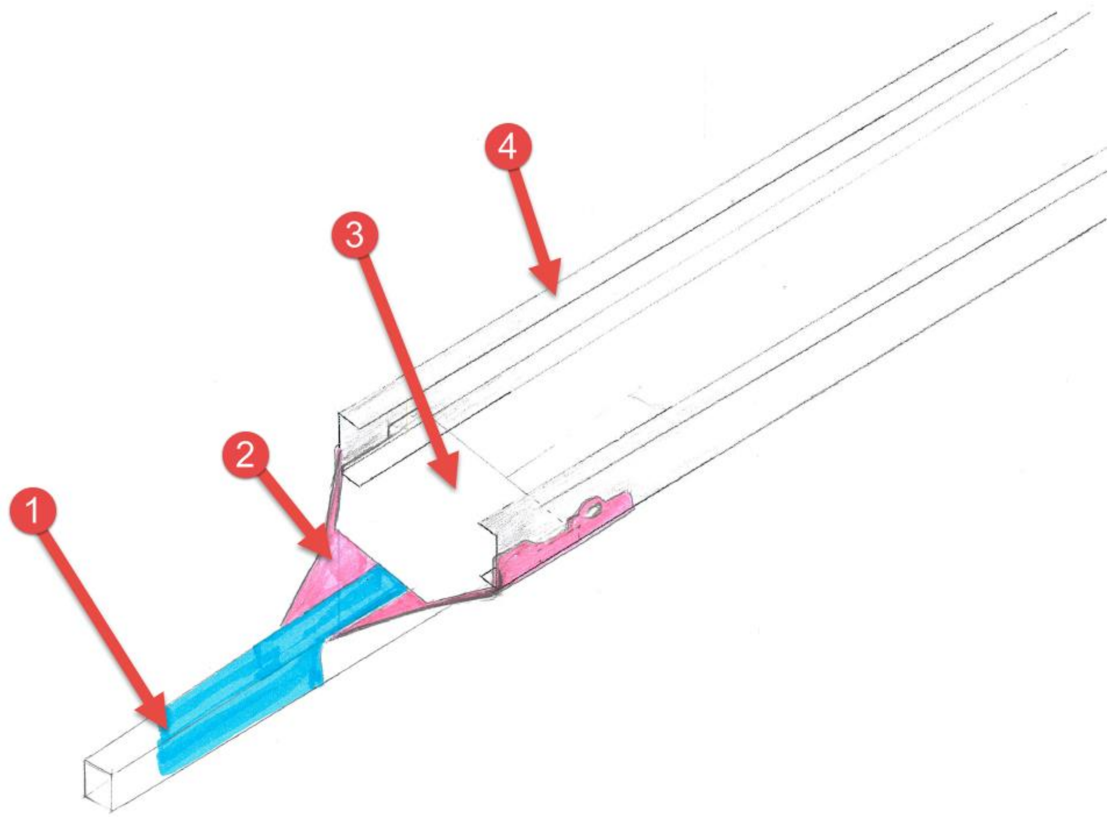

Figure 5.6: Concept 6

5.2.7 Concept 7

Shown in figure 5.7 is concept 7 which uses a whole new idea of a drawbar. Instead of the conic profile used in the other concepts, this has a V-shaped drawbar number 1 constructed by two U-beams. This makes it easy to have a thinner front and a wider back. It is connected with beams number 3 to the existing cross beams.

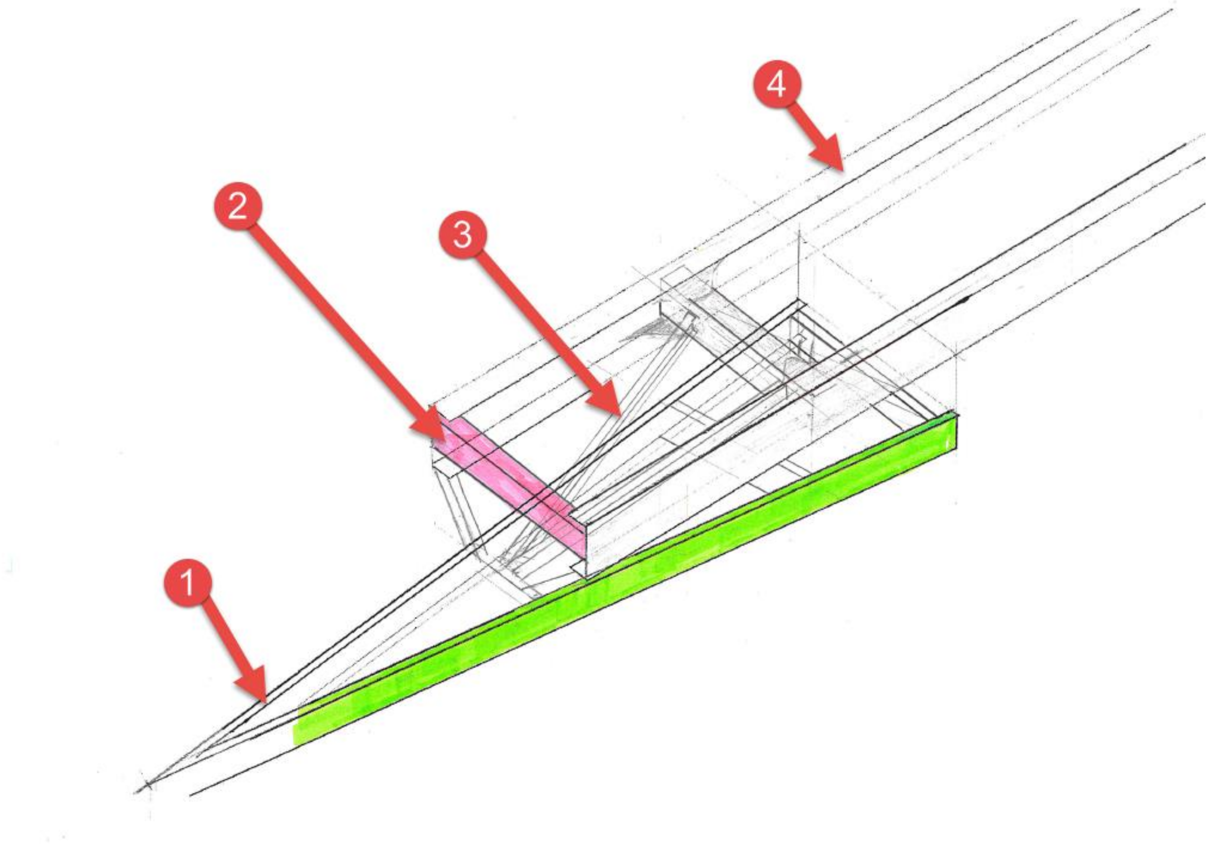

Figure 5.7: Concept 7

5.2.8 Concept 8

Concept 8 in figure 5.8 got some influences by the pneumatic lift (number three) of the rear bogie axle. This concept also created some thoughts of how to use the tetrahedral, which is commonly used in construction cranes to be able to carry heavy loads while still being very light.

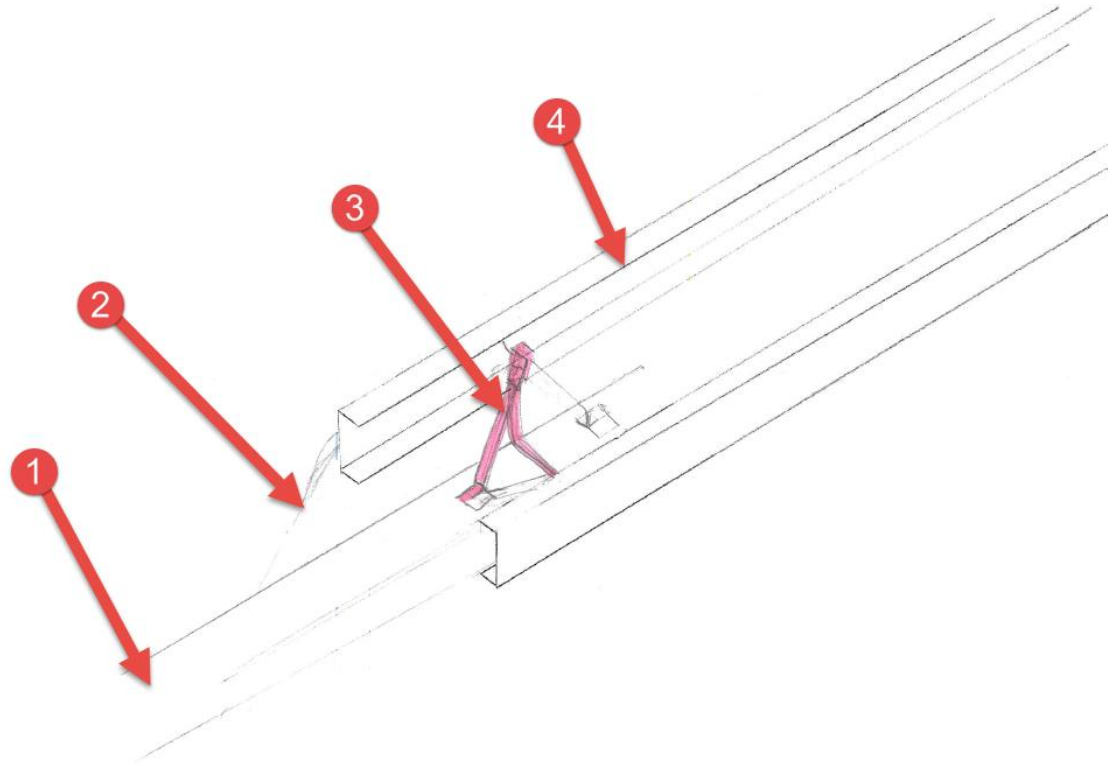

Figure 5.8: Concept 8

6 EVALUATING SKETCHES

Some of these concepts from the sketches are rather similar to each other. Concept 2 and concept 3 is an example of that. Some of the concepts were mixed with each other to gain better concepts. Then the new concepts were sketched up in Creo Parametrics and for the calculations the module in Creo called Creo Simulate were used to get a FE-analyze of the concepts. This was made to see how the stresses would behave and to get something to work with in the upcoming selection of concepts.

6.1 Draft CAD-constructed concepts

Like in other CAD-programs it can be decided in which way anyone wants to build models. Solid modeling and surface modeling are example of that. Since the drawbar was designed of sheet metal the model were created with the tool sheet metal in Creo. It allows the constructor to design the model directly with plates as it will be built when manufactured. If a bend is needed the constructor places a bend with desired angle where it is supposed to be.

Some of the concepts made in Creo do not satisfy the requirements for length. The reason for the shorter concepts was because it would still give a decent image of how the stresses would behave and it saved time when making the CAD-model of these concepts. The figures listed below of concept 2.1-2.6 are FE-analyzes of the concepts. The concepts 2.1 -2.4 were clamped in all directions in the back of the chassis U-beam, this was a quick way of analyze how the stresses would appear.

6.1.1 Concept 2.1

Concept 2.1 seen in figure 6.1 was what was thought to be the best solution between the concepts that uses holes in the bottom flanges of the frame sides (Concept 1-3). The reason for only do one of these three concepts was time saving. The stresses were high at the red areas, when applied to the vertical force it created a bending moment in the transfer to the chassis. This was why the high stress areas appeared in the front and in the back marked with arrows of the connection. At stress concentration areas there were also high stresses such as near holes, low radiuses and also over bends.

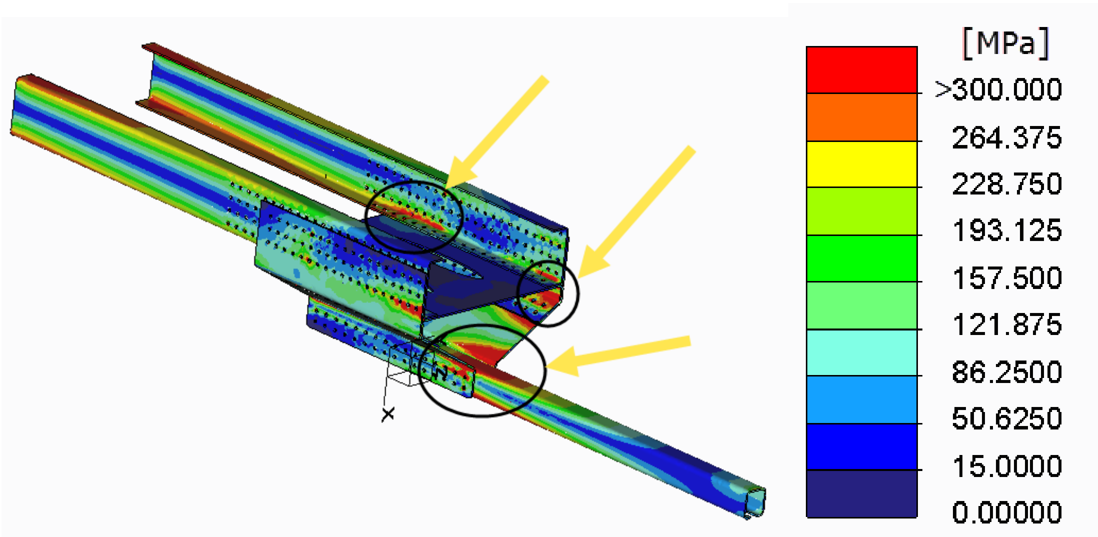

Figure 6.1: Concept 2.1

6.1.2 Concept 2.2

Concept 2.2 was built with consoles to make a stronger connection between the outer plates and the drawbar. The concept does not connect the outer plates to each other like the other concepts which left the existing crossbeams to take up a lot of forces. The stresses appeared also here in the back and the front marked with arrows as shown in figure 6.2 because of the moment from the force applied in the other end. Similar to concept 2.1 most high stress areas are over the bends.

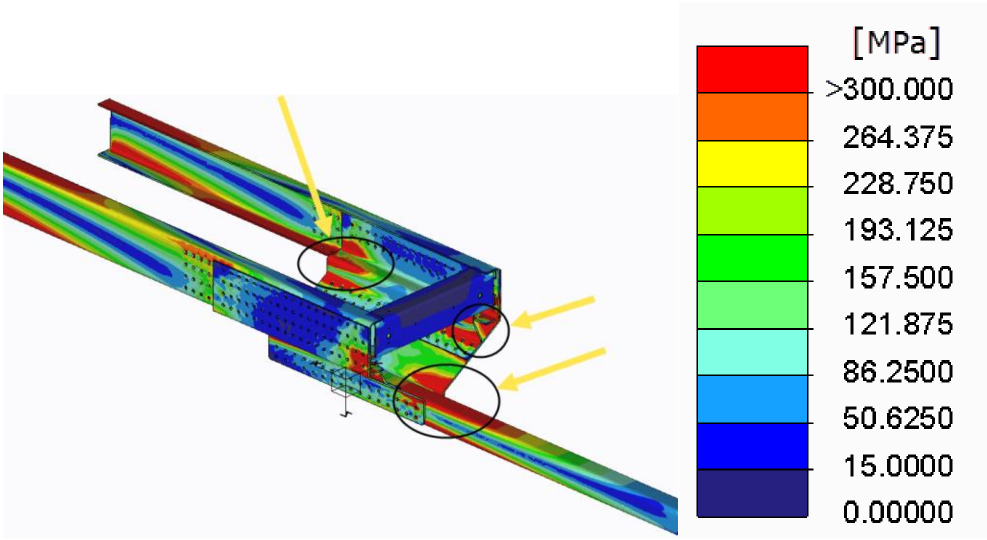

Figure 6.2: Concept 2.2

6.1.3 Concept 2.3

Concept 2.3 was the evaluation of concept 5 where the plates were attached to the crossbeams of the frame. This concept did not have the same high stress problems (marked with arrow in figure 6.3) in the drawbar as in the other concepts. This since the outer plates were extended to support the drawbar.

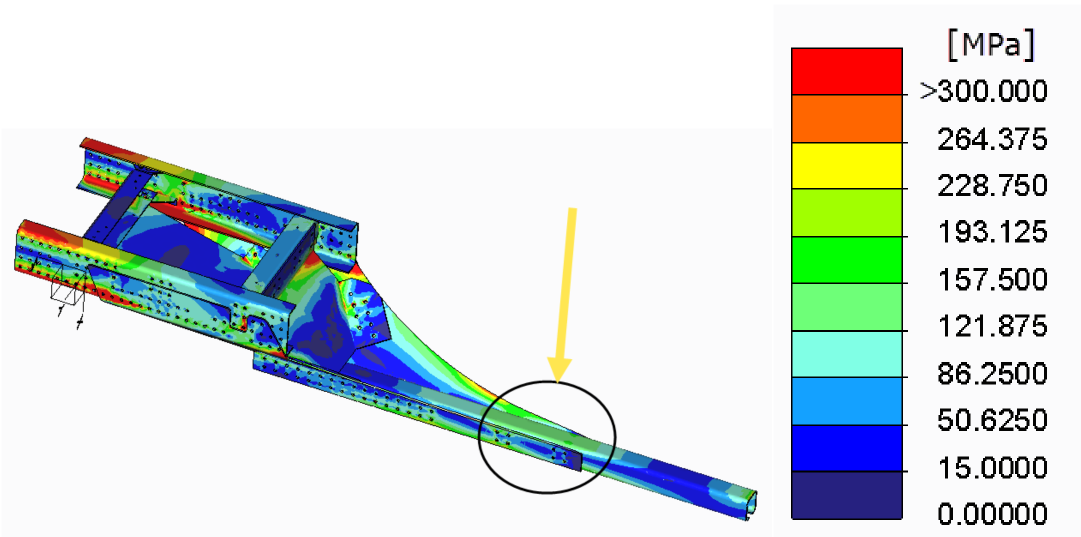

Figure 6.3: Concept 2.3

6.1.4 Concept 2.4

Concept 2.4 was inspired by construction cranes to make tetrahedrons since this makes a very light construction as it sustains high forces at the same time. This concept shown in figure 6.4 was an evaluation from the concept 8. Question was if this concept can sustain the fatigue forces and a big problem was how to connect the beams without welding. The highest stresses in concept 2.4 appeared at the welded parts marked with arrows which were hard to assemble without welds. The same stresses as in the earlier concepts appeared at the top front end of the outer plate over the bend.

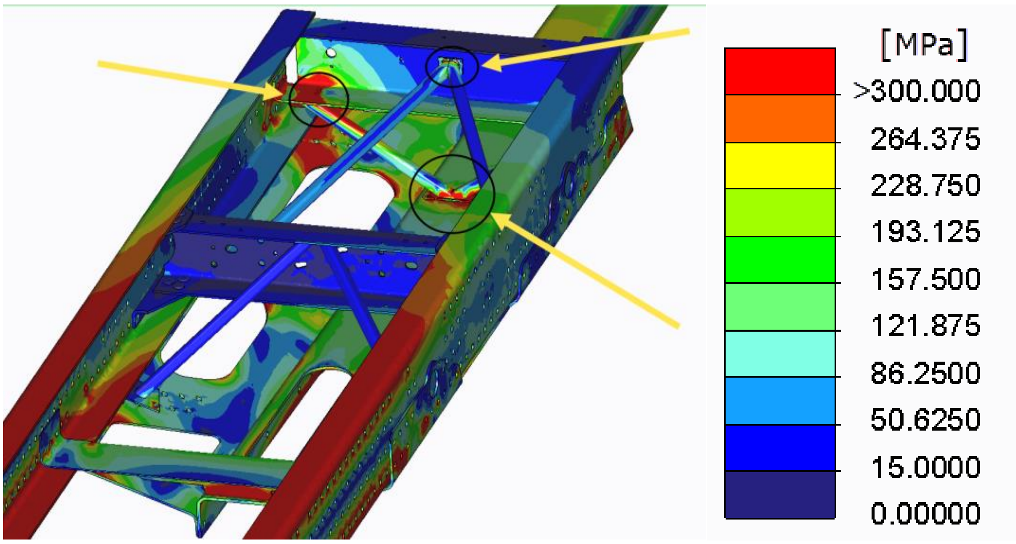

Figure 6.4: Concept 2.4

6.1.5 Concept 2.5

Concept 2.5 shown in figure 6.5 was the V-shaped drawbar from concept 7. It was connected to the frame sides with outer plates and also with plates from the crossbeam in the V-shaped drawbar to the crossbeams in the frame sides. A notable change is that it is only one half of the concept that is shown. If the drawbar is cut in half as in the figure, the other half is just a mirror of this one. Which means there is symmetry between them. This was made to halve the calculation time. This could be done by all of the concepts but it was not realized until this concept. When one half of the concept is analyzed the forces applied have to be halved as well. The V-beam seems like a strong contestant since the most forces are absorbed without high stresses.

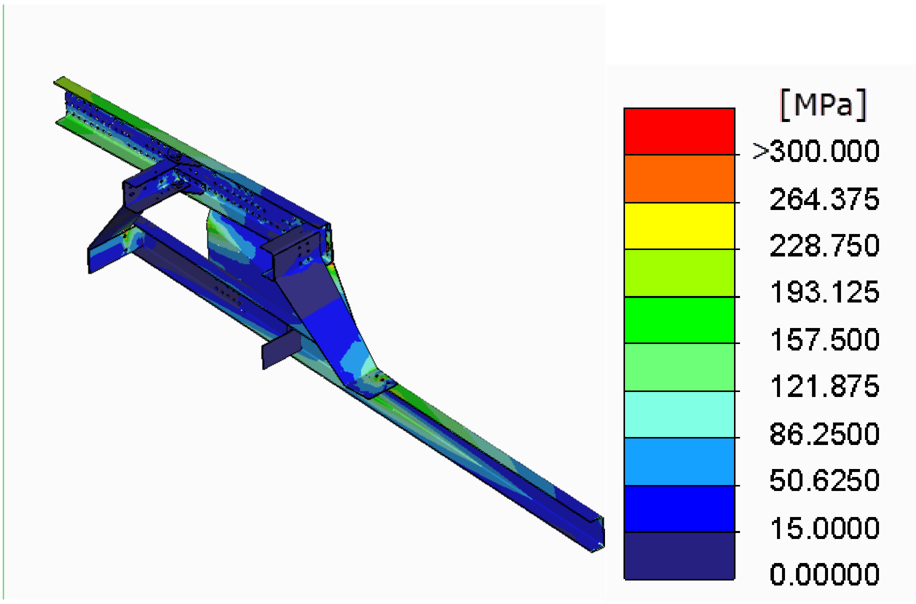

Figure 6.5: Concept 2.5

6.1.6 Concept 2.6

The concept 2.6 is a combination of the concepts 1 and 3, this was made to avoid the holes in the flanges. The middle plate marked with an arrow in the left figure in figure 6.6 does not give much support in this concept and can probably be removed. To give extra support to the flange the lower bottom plate was extended under the flange similar to a vise to clamp the edges as can be seen to the right in figure 6.6 also marked with a circle.

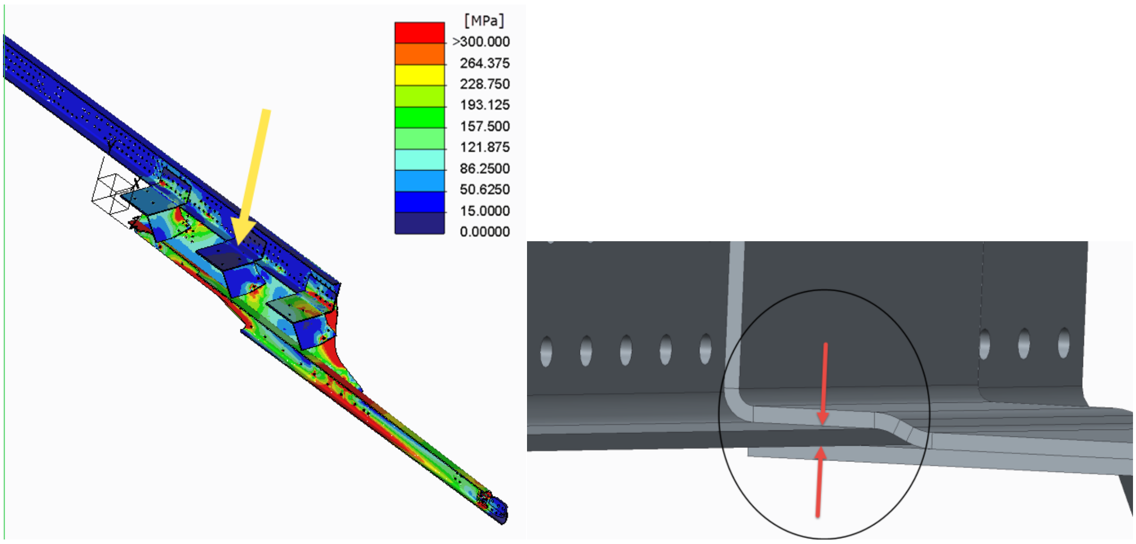

Figure 6.6: Concept 2.6 to the left and the clamping function of the concept to the right

6.2 Reducing number of concepts

The legend values (the color scale used in the FE-analyze where different colors describes different values of the stresses) were set to 15 MPa as the lower limit and 300 MPa as the upper limit to get the same color scheme of the models to make it easier to compare the concepts. The lower limit was set to be able to see where there was low or none stresses and also because if the value was set to 0 the span for the colors would be too wide. When the final concept was chosen, the areas with low stresses could be cut away to save material and make the construction lighter. 300 MPa was set to represent the fatigue limit the drawbar would be dimensioned against. The legend can be seen in figure 6.1-6.6 in chapter 6.1.

The concepts were evaluated with the concept screen matrix shown in table 6.1. Things like weight and strength was hard to know before the final concepts were made as a CAD-model. But the basic CAD-models made it possible to get an estimation when comparing with the reference drawbar. There were no bigger differences between the concepts when the points were summed up. This led to a discussion with the supervisor. The supervisor is a more experienced person who has worked in the business for a time and done a couple of FE-analyzes. The expertise from the supervisor was used and a discussion ended up in which concepts were thought to have a chance to become a wining concept. The discussions result was reflected in a plus, minus or a zero at the engineering assessment criteria.

Table 6.1: Concept screening matrix

	Todays drawbar as reference	2.1	2.2	2.3	2.4	2.5	2.6
Weight	0	-	+	0	+	+	0
Number of parts	0	+	+	+	-	+	0
Complexity(parts)	0	0	0	0	0	0	0
Complexity(assembly)	0	-	0	0	0	0	0
Estimated strength	0	0	-	0	0	0	0
Welded areas	0	0	0	0	-	0	0
Solid frame flanges	0	-	+	+	+	+	+
Impact when turning	0	0	0	0	0	-	0
Compatible with large bending radius	0	-	-	0	0	0	0
Able to use rivets	0	0	0	0	0	0	0
Engineering assessment	0	-	-	+	+	0	+
Plus's	0	1	3	3	3	3	2
Minus's	0	5	3	0	2	1	0
Sum	0	-4	0	3	1	2	2

As seen in the matrix, concept 2.1 got a really bad result and the decision to not work further with that concept was strengthened by Bengt Kölqvist from Volvos frame group who was contacted about making holes in the flanges (9). Bengt recommended to not having holes in the flanges since the flanges are sensitive to concentration stresses and are most common to risks of cracks and breakdown. As well as the purpose that says not to cut away anything from the flanges. Since the estimated strength of concept 2.2 does not live up to the requirements, this concept was chosen to not work further with. The four last concepts were decided to continue working with.

7 FINAL CONCEPTS

The final concepts are better versions of the concepts that did not get eliminated in the concept screening matrix from chapter 6.2.

7.1 Constraints

To calculate the model, constraints were needed so the model is locked in space and does not have any degrees of freedom. To make the calculations shorter, the calculations were made on half a model since there was symmetry on the drawbar and the drawbar was locked sideways in Z-direction on all cut surfaces as number 1 shows in figure 7.1. It is called a symmetry constraint. The swap body will make the upper side of the frame side more stable and to simulate the top side (number 2) is locked in Y-direction. Since it had to be locked in all directions, the last direction was locked at the very end of the frame side in X-direction (number 3). And when it was placed so far to the back there would not be any disturbance in the calculations and as well as it would not give inaccurate stresses.

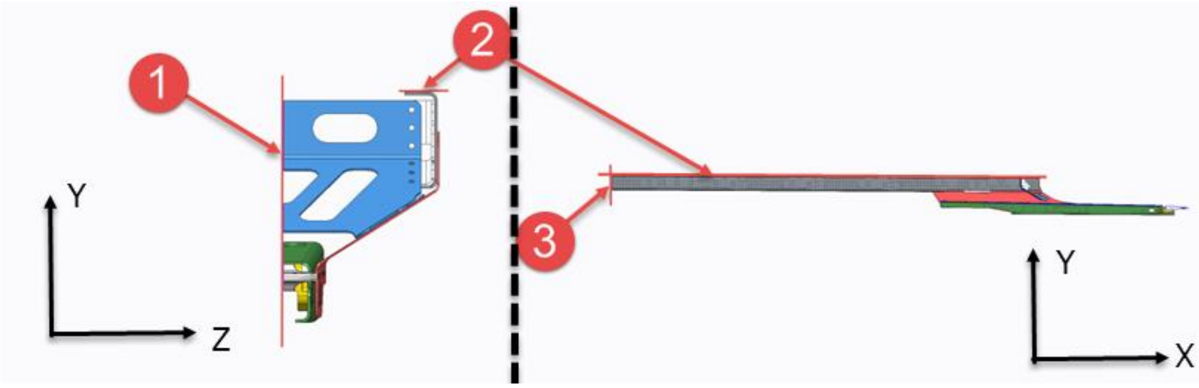

Figure 7.1: Placed displacement constraints

7.2 Concept 2.3

This was the concept where the existing crossbeams between the frame sides were included in the drawbar shown in figure 7.2. To improve this concept it was decided to use the existing bar between the drawbar eye and the frame sides which can be seen in figure 2.1 as number 3. This conic profiled bar is used in the second version of the drawbar and is an improvement from the first version. The more important part was to focus on the connection between the bar and the frame sides. The plates connected to the crossbeams are further away from the connection point in the frame sides because of the flanges. If there are no flanges, the plates can be connected to a bracket or a crossbeam much closer to the connection point in the frame sides. This created a bigger bending moment and because of that higher stresses.

Figure 7.2: Concept 2.3 in full

The most crucial stresses are shown in figure 7.3. To avoid these stresses the crossbeam were thickened from six millimeter to 10 millimeter, but the stresses remained. The red areas marked with arrows have stresses around 400 MPa which is too high, the areas where the higher stresses were, were in radius and bends near the edges. The crossbeams function was to hold the frame sides together and when the force was applied the frame sides want to bend out which affected the crossbeams. With the stress problem in mind, it was decided to not work further with this concept.

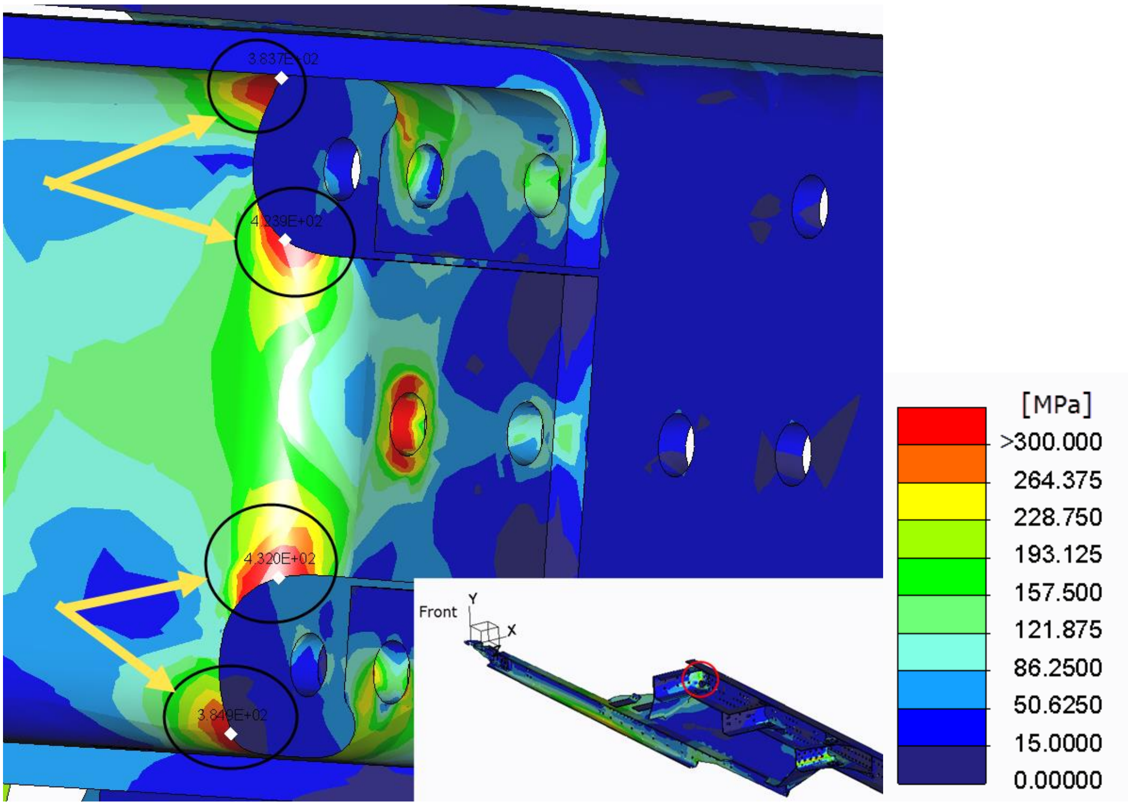

Figure 7.3: Close look on stress problem in concept 2.3

7.3 Concept 2.4

The idea of using a framework was very interesting. But it is hard to assemble the beams in a frame work without welding. Therefor it was decided to wait with this concept and improve it if it were any time left. It ended up with no time left to improve the concept.

7.4 Concept 2.6

Concept 2.6 is shown as it looks in full in figure 7.4

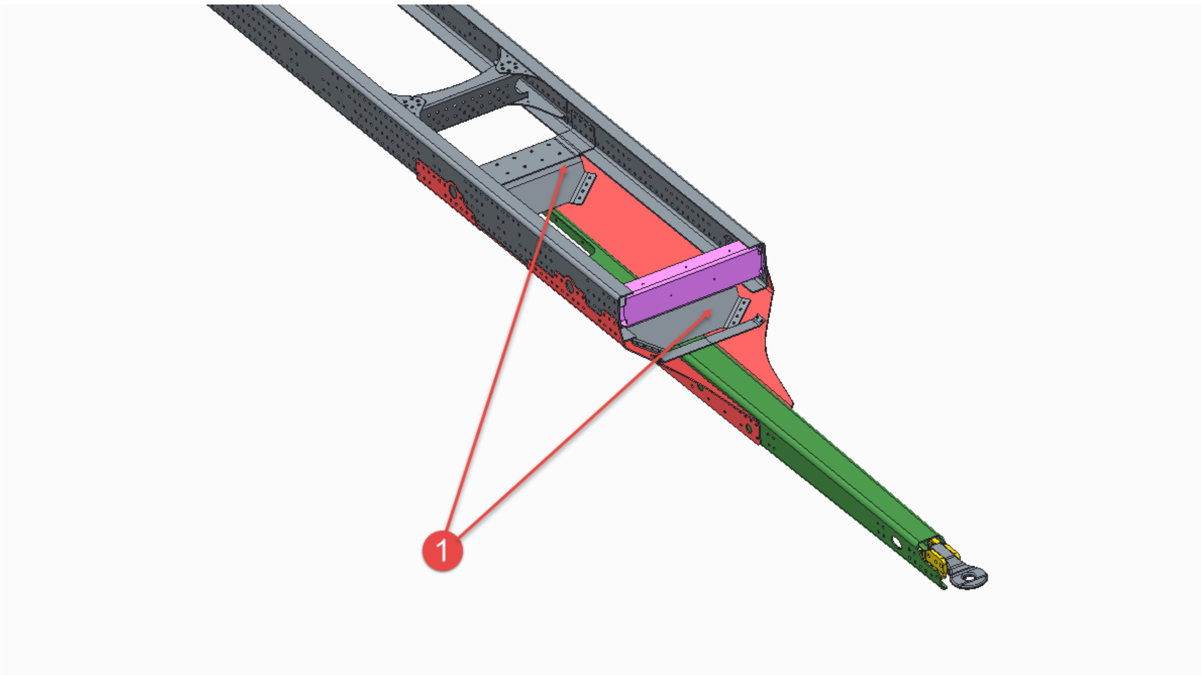

Figure 7.4: Concept 2.6 in full

Concept 2.6 got similar function to a vise, where it clamps the flange of the chassis frame as seen in figure 7.5, it is fitted as shown with number one in figure 7.3. This concept needed a little more material than the existing drawbar.

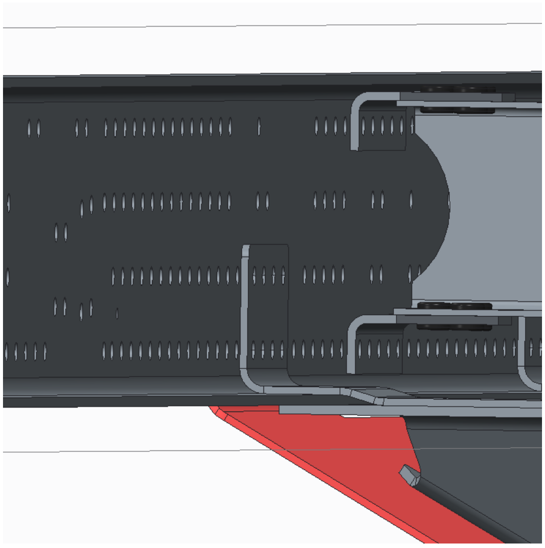

Figure 7.5: Back end of one of the clamps

This concept was built with two horizontal plates that clamp the flanges. While analyzing, it can be seen that the vertical force was the major problem to transfer from the beam to the frame sides. As seen to the right in figure 7.6 the plate bends up which creates big stresses in the bend marked with an arrow (these deformations are scaled). The picture was taken from the same view, it was the vertical force that makes the drawbars look different. This makes a vertical plate a better choice to use because of the moment of inertia see equation 3 (10), where B is the horizontal length and H is the vertical length, which leads to concept 2.3. With this conclusion focus were put on the other concepts.

$$I = \frac{BH^3}{12}$$

3

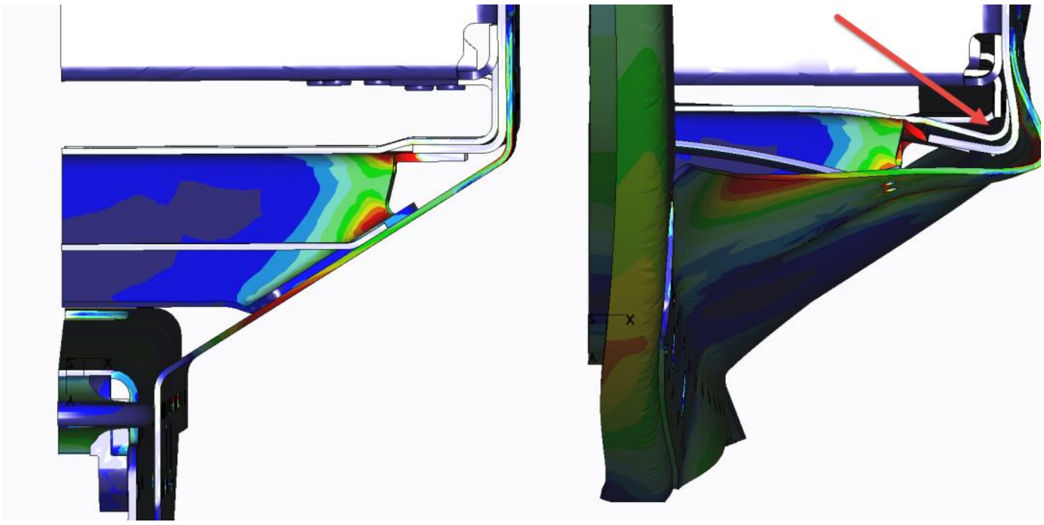

Figure 7.6: Without deformation to the left and deformed to the right

7.5 Concept 2.5, two different versions

The drawbar was constructed by two U-beams. The height of the U-beam had to be lower than 172mm and got dimensioned to 170mm to get enough clearance above and under the drawbar. To dimension the flange Anders Isaksson at SSAB was contacted. The flange of the U-beams was by Anders Isaksson, who referred to the manual made by SSAB (11), recommended to be six to seven times the thickness of the plate. To strengthen the U-beam it is possible to make it a C-profile which is as a U-profile with flanges on the flanges. Problem with a C-profile is that dirt can gather at the ends of the beam and in that way make a trap for water, and water is relatively heavy as well as it induces rust. The new profile of the drawbeam also needed a new construction to fit the drawbar eye to the new drawbar. VBG:s assembly instructions requires that the drawbar eye must be fitted with three M20 bolts with quality 10.9 and needs at least 12mm of steel to be fixed in on each side (12). The fastening of the drawbar eye got dimensioned by 20mm thick steel plates that were bent to the right angle.

The outer plate had to be reconstructed to fit the new drawbar and two variants with the small difference of where to place the bend, as can be seen in figure 7.7. The difference between the two types was that in the left drawbar (concept F1) the bend goes from the front top to the bottom at back and vice versa with the right drawbar (concept F2) The bend is marked with a red line. The reason that there is a pink part in these concepts is because it is pink in Creo taken from another trailer.

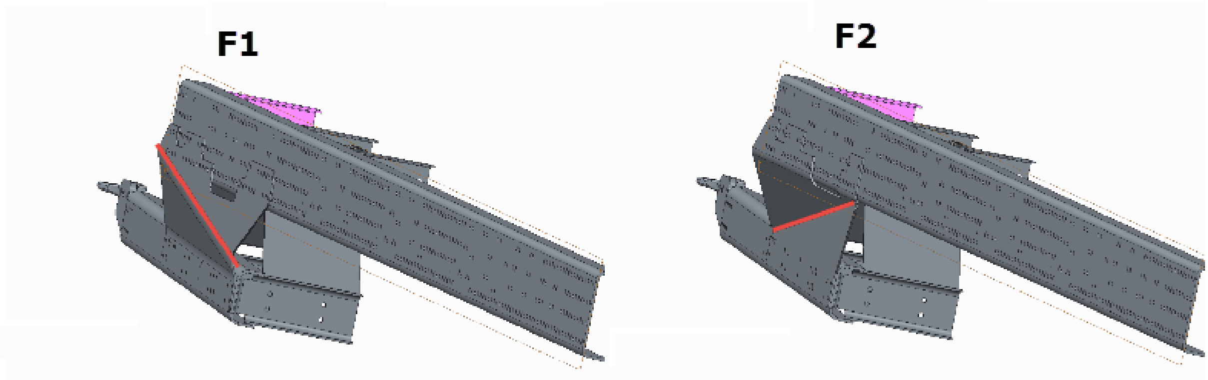

Figure 7.7: Two different side plates where concept F1 is to the left and F2 to the right

This small change made great difference in which were the stresses appeared as can be seen in figure 7.8.

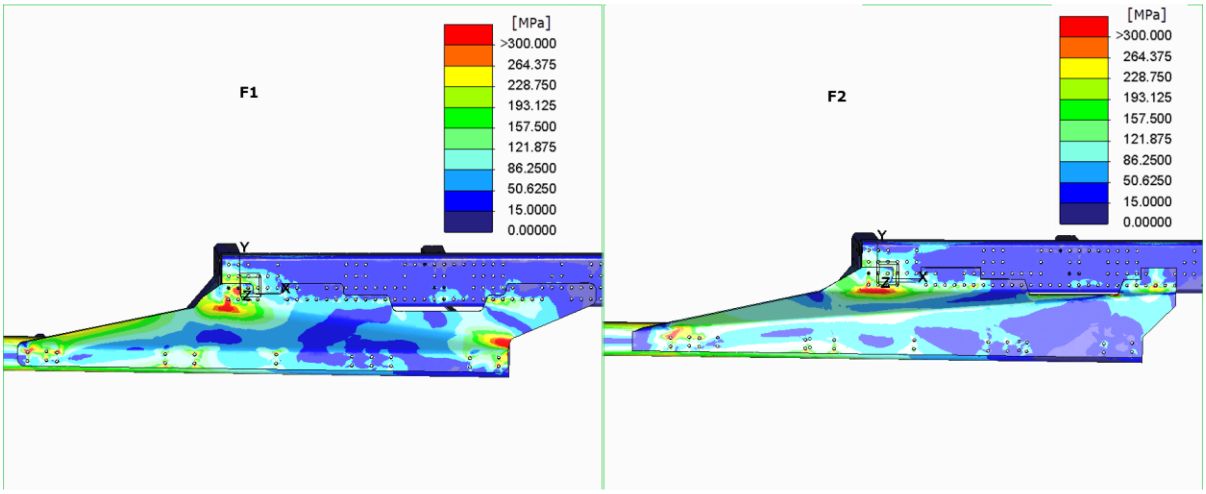

Figure 7.8: Overview of the stress image on the side plates

Concept F2 in figure 7.9 had no areas at the back of the side plates where there were high stress areas. This differs from concept F1 which got high stresses over the bend marked with a circle. Concept F2 got a much shorter outer plate at the back end to make the bends possible. If it was longer, the horizontal bend (marked with a red line) would cross the angled bend (black line) which would be an issue when manufacturing. The lines are marked with arrows as well. Stresses over a bend are more sensitive than stresses running through a bend which can be seen in concept F1 in figure 7.9.

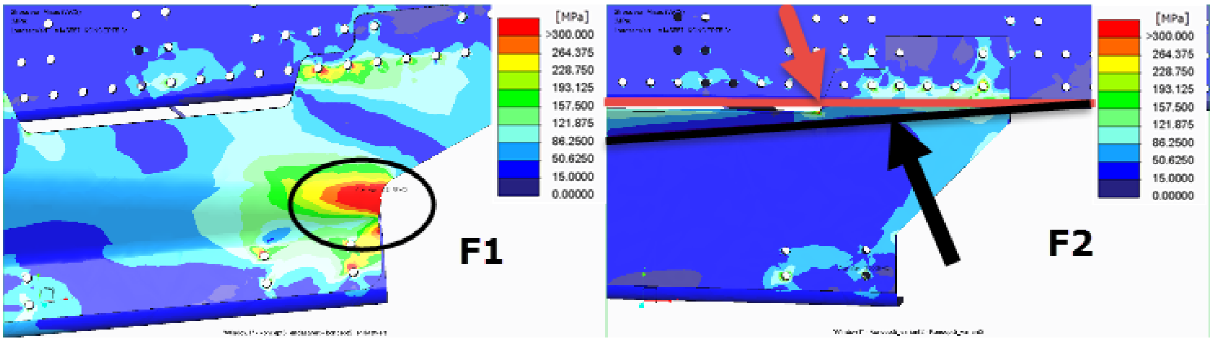

Figure 7.9: Stress image at the back end of the side plates

The front top end of the outer plate got high stresses over the bend in both versions as shown in figure 7.10 with arrows. The stresses here were similar in both variants. The reason for the high stresses over the bend was because when the force was applied the plates wanted to bend together, the center of rotation was at the back of the side plate which made it bend more at the front. Since the side plate is connected with bolts, the high stress area was under the first bolt holes where the biggest moment appears.

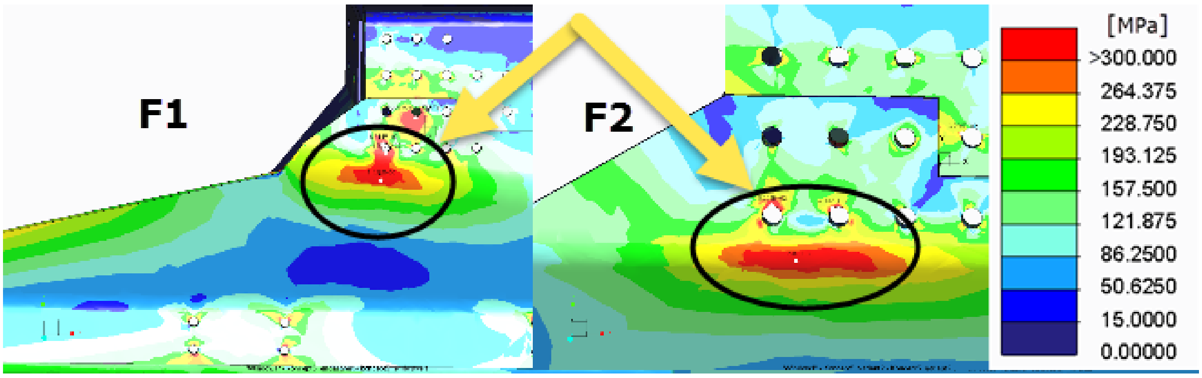

Figure 7.10: Front top stress image

The next difference between the two versions is at the front where the side plates are connected to the drawbar. Concept F1 absorbs almost no stresses, only near the holes. But with the fastener command used in Creo Simulate there is no friction between the bolt and the plate. That means that the stresses near the holes aren't exactly trustworthy.

Concept F2 had a more distributed stress area at the front on the plate which is shown in figure 7.11 in the circle. The drawbar got some high stress areas as well. The reason for the higher stresses is because the drawbar wants to bend because of the vertical force at this point, which can be seen in figure 7.12. The deformation was around four millimeter.

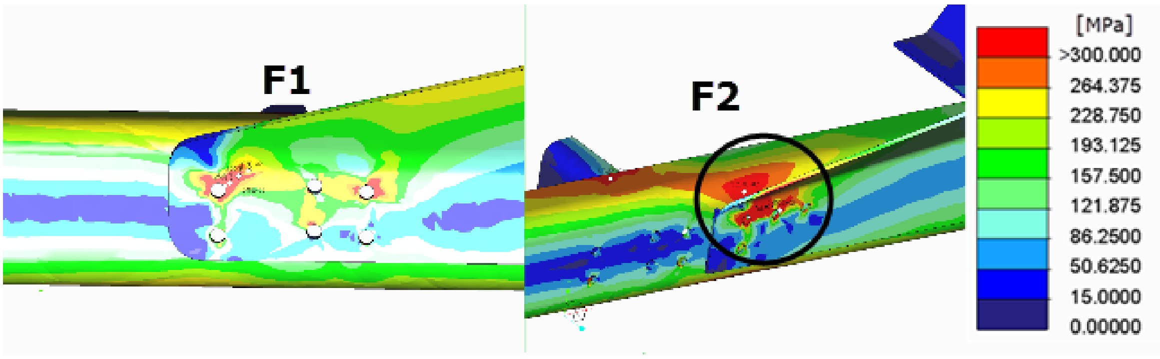

Figure 7.11: Stress image at the connection at the front of the drawbar

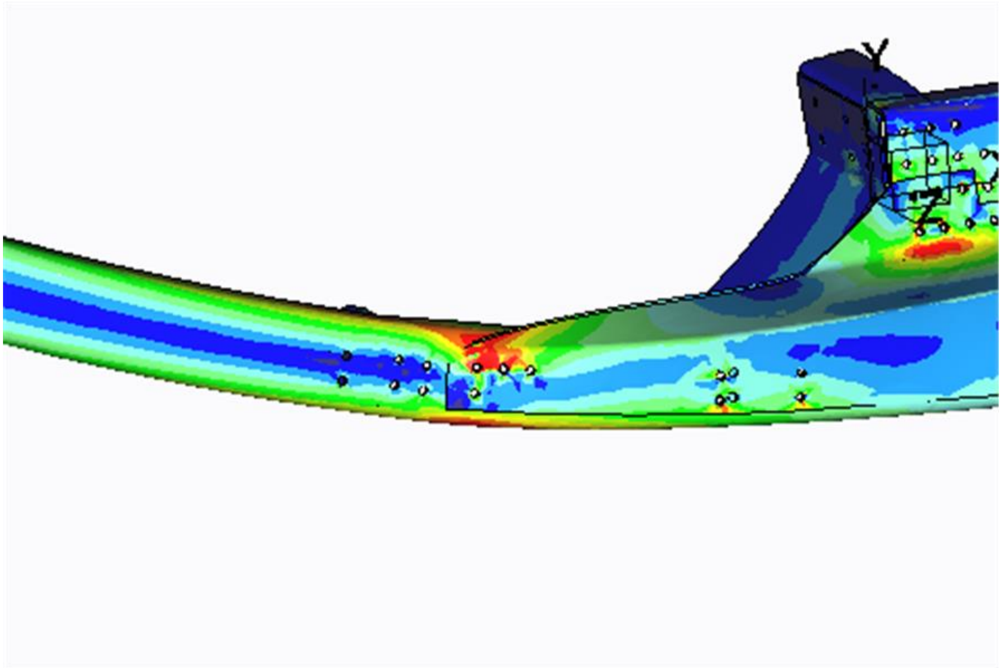

Figure 7.12: Deformed Drawbar

Both of the versions showed no impossible areas with stresses that could not be fixed. Since these concepts with a V-formed drawbar differs from the conic profiled bar, it made it more interesting to work with. Both of the versions were therefor continued working with.

7.6 Analyzing space of under run protection and lamps

The under run protection marked as number 1 (which works like a shield to protect a driver in a car if the car happens to drive in to the truck) and lamps marked as number 2 on the back of the truck requires a lot of space with 6 degrees tilt between the truck and trailer with the same ability to turn 180 degrees. These parts make the space fitted for the plates on the side of the drawbar heavily reduced. An analysis was made by mounting the drawbar on the under mounted coupling of the truck to measure the space available for the profile of the side plate, see figure 7.13.

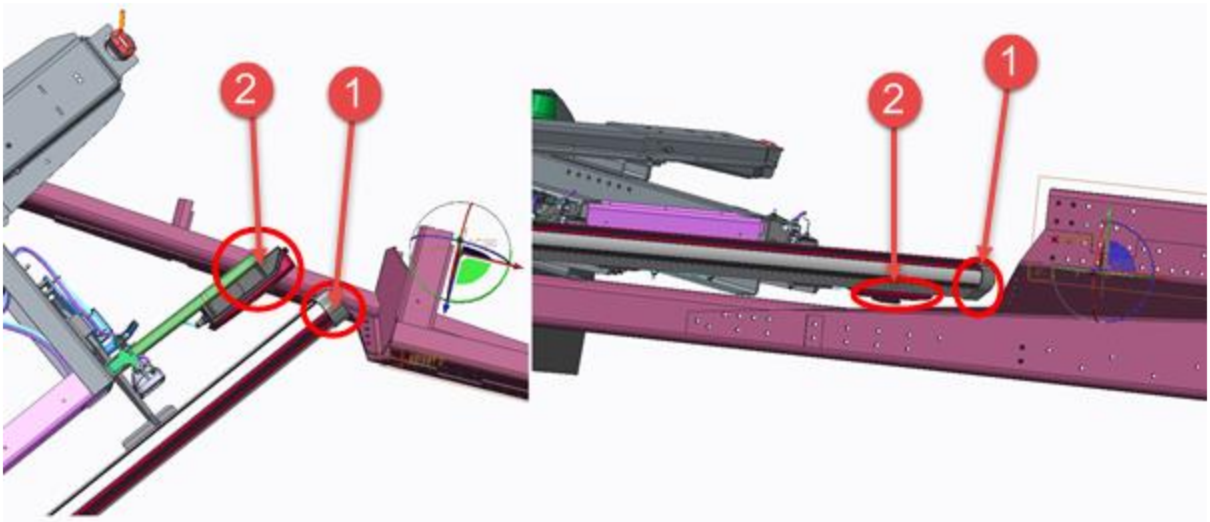

Figure 7.13: Analyze of under run protection and lamps, at critical turning angle with 6 degrees angle between truck and trailer

By analyzing both the drawbar of today and the new concept one realizes that a drawbar constructed with a V-shape reduces the space available for the plates on the sides of the construction.

Critical points of the lamps and the under run protection were measured and plotted. The graph in figure 7.14 shows the critical points. The front of the side plates were designed after this graph where the marked area shows how the plate can be designed. The graph starts at the end of the trailers frame side and is measured from the top of the drawbar (L=0, h=200mm).

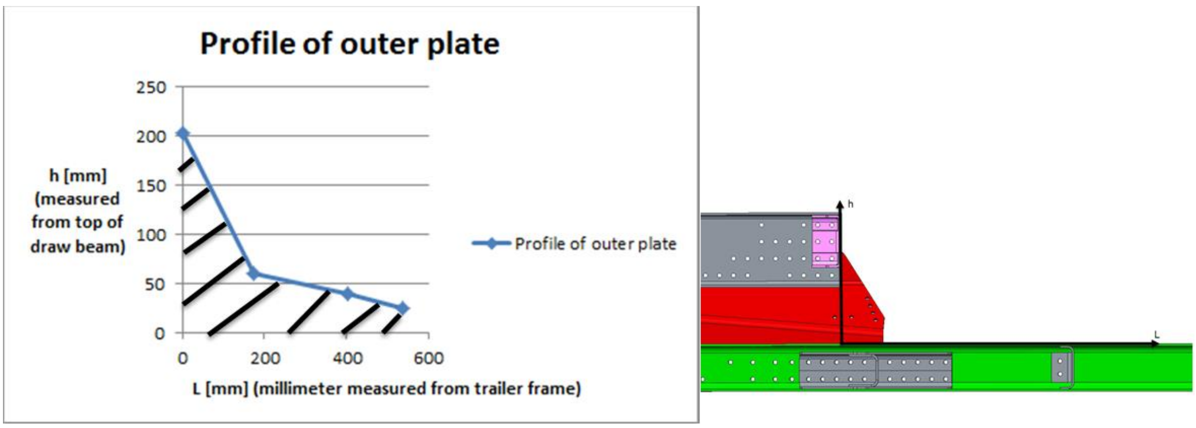

Figure 7.14: Critical points of under run protection plotted to the left and the coordinate system of the graph to the right

7.7 Consulting of constraints

To analyze constraints a meeting was held with the department of structural mechanics at ÅF to make sure the FEM-calculations and the constraints set for the calculations were properly set. Jonas Zachrison (13), who was the representative of the department, thought that the three main constraints was a great conservative solution (see figure 7.1).

Zachrison presented how to make bolt connections with beam elements which is described in chapter 7.7.1. At vulnerable points one should make calculations by hand at the measured forces to make sure the bolts can handle the stresses. Since the forces of friction and preloading is not included which Creo module's calculations.

Bolts exposed to high forces, could be considered as a group with nearby bolts and calculated as a group since the group will work together. These bolts needs to be calculated by hand though to make sure the bolts can handle the forces together since Creo Simulate cannot handle these calculations. When making groups of bolts one should consider great care so that the result really reflects how the bolts will work when used on a drawbar.

About the load spike that comes up in the loading scheme presented by earlier works, more analysis should be made to consider how often these loads appear and if it requires fatigue dimensioning. There are well created models of how to calculate the loads, so that the model will not have to be dimensioned against amplitude of the max loads that only occur when the trailer goes over road irregularities like bumps and cavities.

About a special case in one model was a problem with supporting surfaces,m as could be seen in figure 7.15, where the beam (blue one and where the arrow points) ignores the supporting surface and deforms through the flange of the supporting surface. In this particular case a bonded interface was made to make sure the surfaces would not cross each other. Because if it is an actual model the blue crossbeam will not deform through the flange.

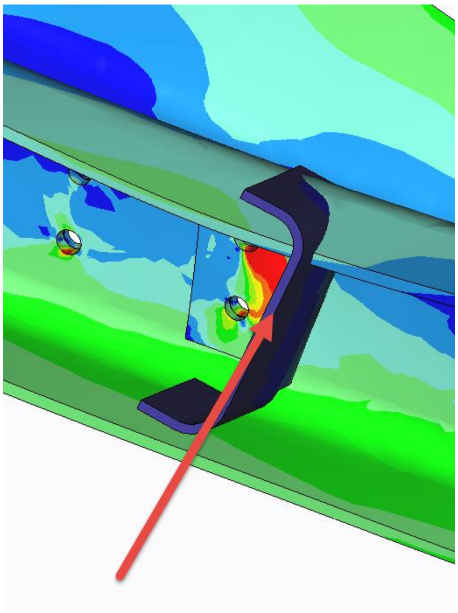

Figure 7.15: Deformed crossbeam (blue) through flange

7.7.1 Rigid vs. Beam elements

The module Creo Simulate has a tool called Fastener which simulates a bolt that connect two plates together. The problem with this command is that it is not able to connect more than two plates. If there needs to be three plates together or more, another command has to be used. One way to do it is by using a rigid link, which is a rather simple command to use. The rigid link fixes the surfaces to each other, making them move with each other. But in reality the bolt and hole would deform at least a little bit. As seen in figure 7.16 the hole to the left in the rigid figure absorbs most of the stresses (red means high amount of stress) instead of spreading out the work to another hole and bolt. This is why the Beam element is a better way of simulating a bolted connection. The stress image in the model with the beam element becomes more realistic because of the stress uptake between the two holes. In the way this model is modeled, the connections should share a more equal amount of stress uptake than in the rigid model (in this case there is a pulling force below the holes).

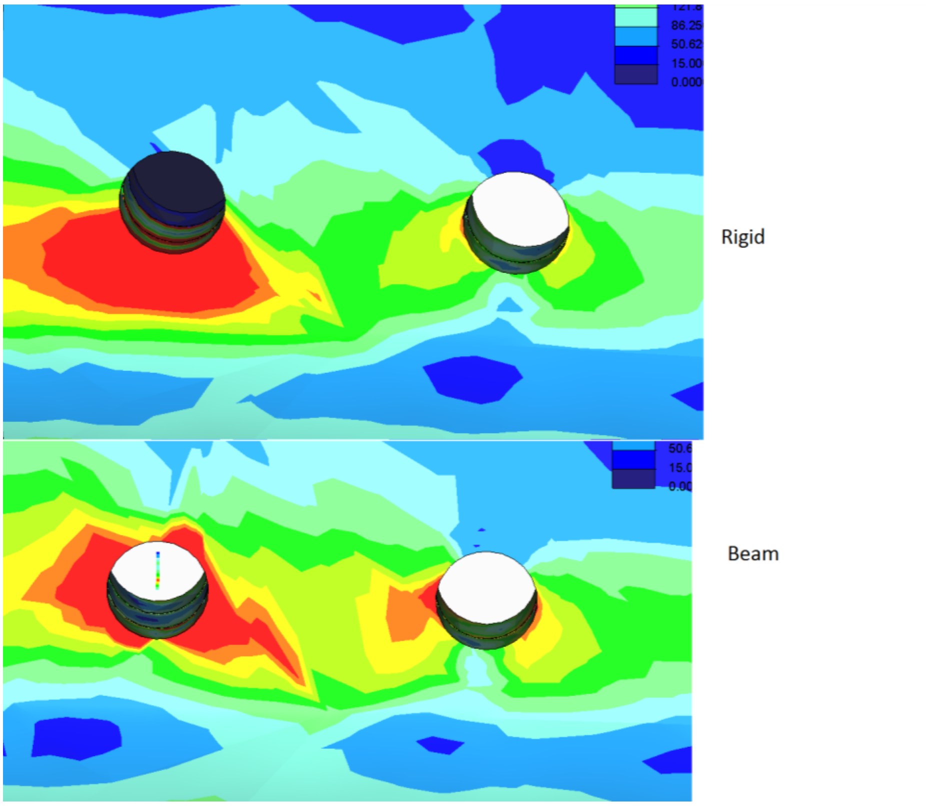

Figure 7.16: Stress image over two holes, upper holes with rigid link, lower with beams

The beam version is structured with weighted links and beam elements between them. A weighted link is used to connect an area or different points to one common point. The weighted links (circular number 2 or red lines in figure 7.17) connects the edge of the circle at the surface of the hole to a point in the circle's center. This is done at both of the ends of the hole. Since this method is used to connect plates, there are surfaces of the different plates that coincidences. At these spots there's no need for two different links. What to do is to connect both of the circles edges to one center point. When all the circles edges are connected to different center points the simulated beam elements (circular number 1, the green line) are connected between the different points. One beam element is between two points. In this model there will be two beam elements, one beam between the first and second point and one beam between the second and third point (box numbers). The different points or contact surfaces are numbered with the square numbers. A simulated has a function of a normal beam. The beam has an assigned cross section, as in this case the radius is assigned since the beam has a circular cross section.

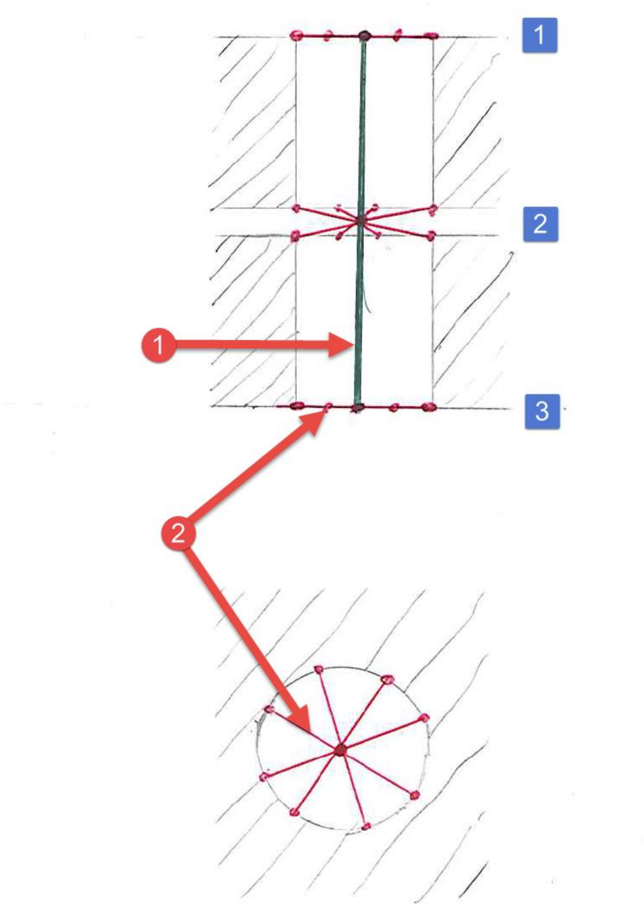

Figure 7.17: Construction of a beam element

7.8 Improvement of Concept F1

Concept F1 is one of the concepts with a V-beam. This concept has crossbeams in the V-beam as well as in the side plates which can be seen as the orange parts in figure 7.18 marked with arrows.

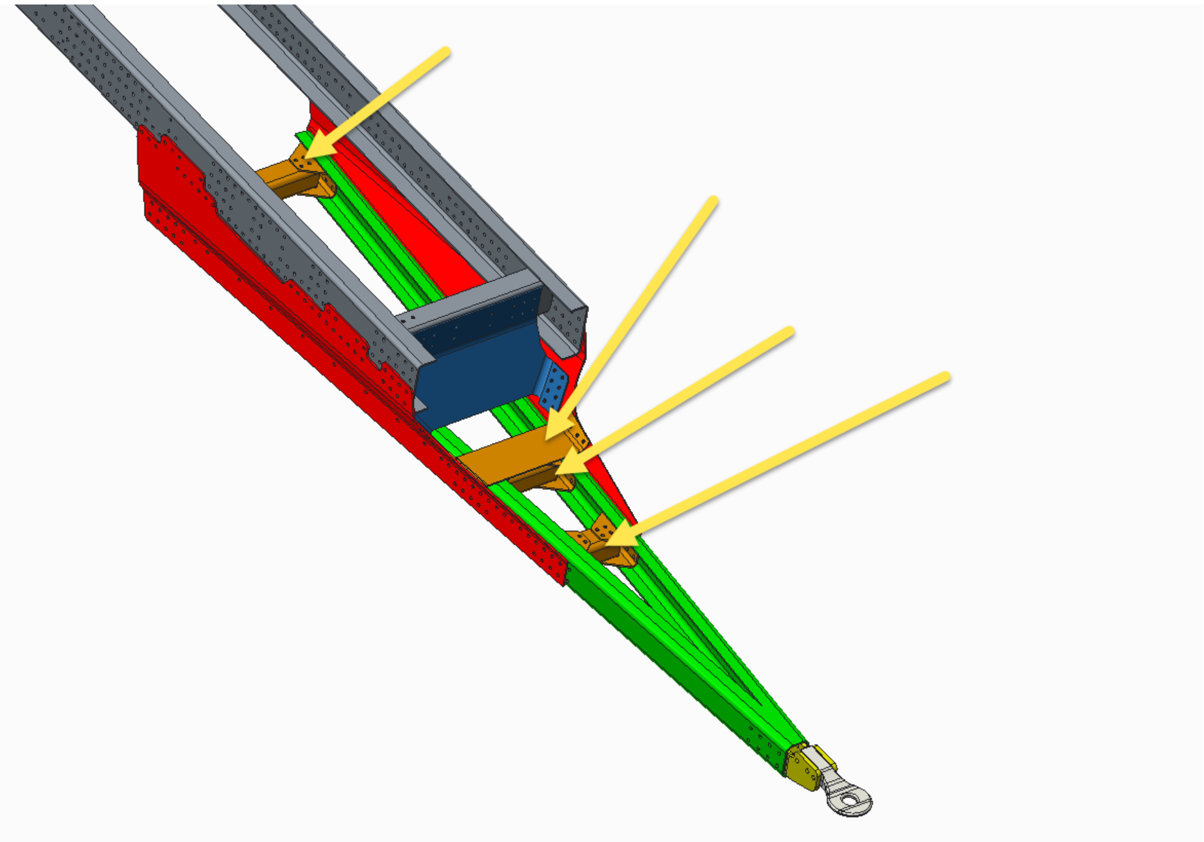

Figure 7.18: Concept F1 in full

One big change that were made to the drawbar is that the drawbar was moved 300 millimeter backwards in the direction as arrow numbered with 1 shows. to get a more vertical line at the back end of the plate which gave a significantly better stress image as shown in figure 7.19. From left as it were before and to the right as it looks after the movement of the bar. The area at the back end of the side plate where there was a big stress issue is now one of the areas where there is no need to be worried about any cracks or other failures shown in the circle. There is a change of the design as well, it was made because it cannot be connected further back at the frame sides.

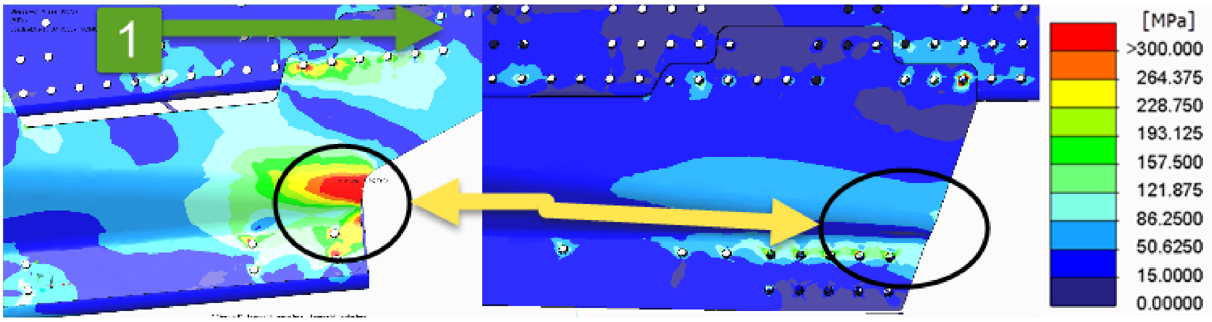

Figure 7.19: Stress changes in the back of concept F1

A major upgrade from the first version of the drawbar is the crossbeams between the U-beams in the V-beam. The crossbeams purpose is to keep the V-beam together as the side plates wants to bend out the V-beam. This new crossbeam is an almost lookalike design from one of the existing crossbeams in the chassis frame side shown in figure 7.20. It was developed because the old crossbeam was too weak. The connection point on the sides where it will be assembled to the V-beam is larger (bigger connection area) which leads to a more distributed area for the stresses which was the problem with the old crossbeam. One negative part is the weight increase. It also requires more parts and uses more bolts when assembling. But no better solution was found at the time and since the old crossbeam could not handle the forces a new crossbeam had to be developed as said earlier. Since it is the same angle between the V-beam through its entire length, the brackets for the crossbeam can be used on all three crossbeams. The only thing that is needed to change is the length of the beam between the brackets.

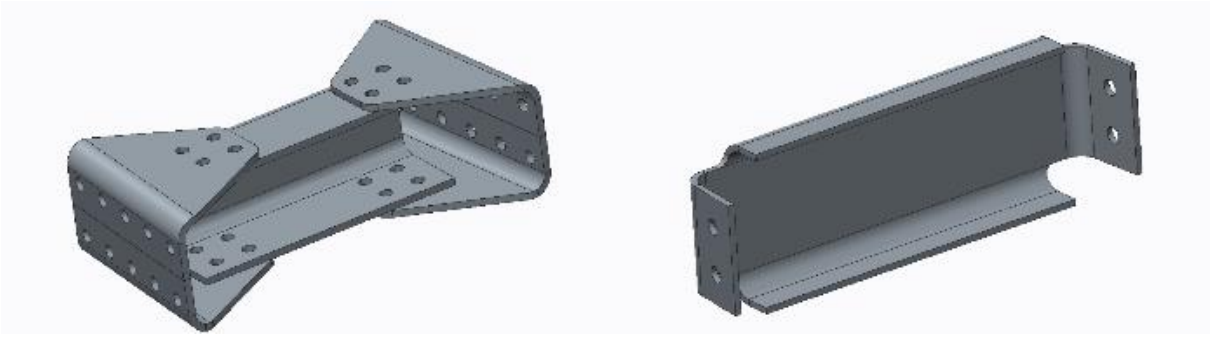

Figure 7.20: comparison between new (left) and old (right) crossbeam which is fitted between the beams in the V-beam

The side plates were modified in the front with respect to the under run protection which made it more vulnerable to stresses as the side plates bends out as shown in figure 7.5. To avoid the out bending of the side plate as shown in figure 7.5 another crossbeam was added, but this crossbeam is connected in the side plates (shown as number 1 in figure 7.21). The plate connected to the frame sides (number 2) is working to absorb the vertical force from the drawbar eye as well as it is working as another crossbeam. The most critical part here is the area within the circle. But the stresses are only 30 MPa over the limit which is acceptable as todays drawbar has similar stresses.

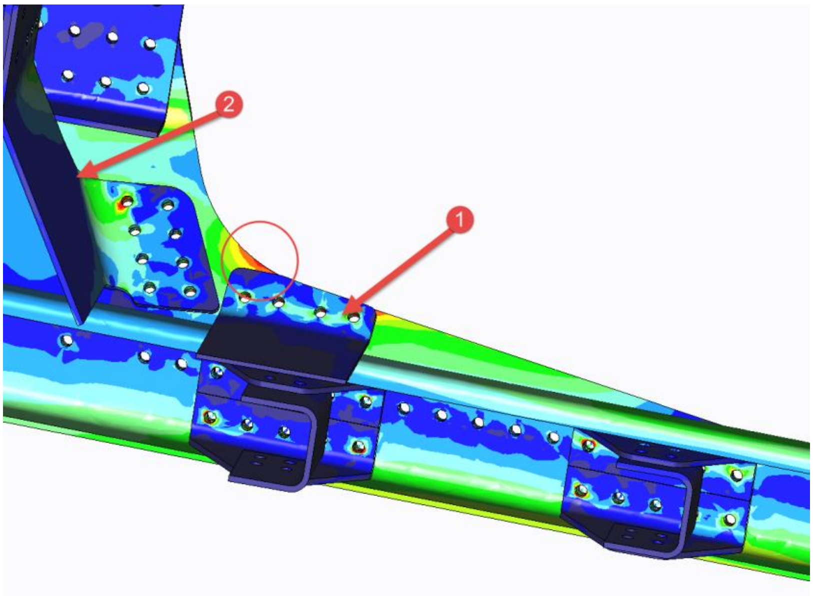

Figure 7.21: Inside of the drawbar showing crossbeams in side plates

Since there are some areas with “dead material”, areas which is exposed to none or minor stresses, these areas can be cut away to make the concepts lighter. A lighter part is always desired in this industry. Special places where material could be cut away were in the side plates, front of the bar and some of the crossbeams, shown in figure 7.22 with arrows.

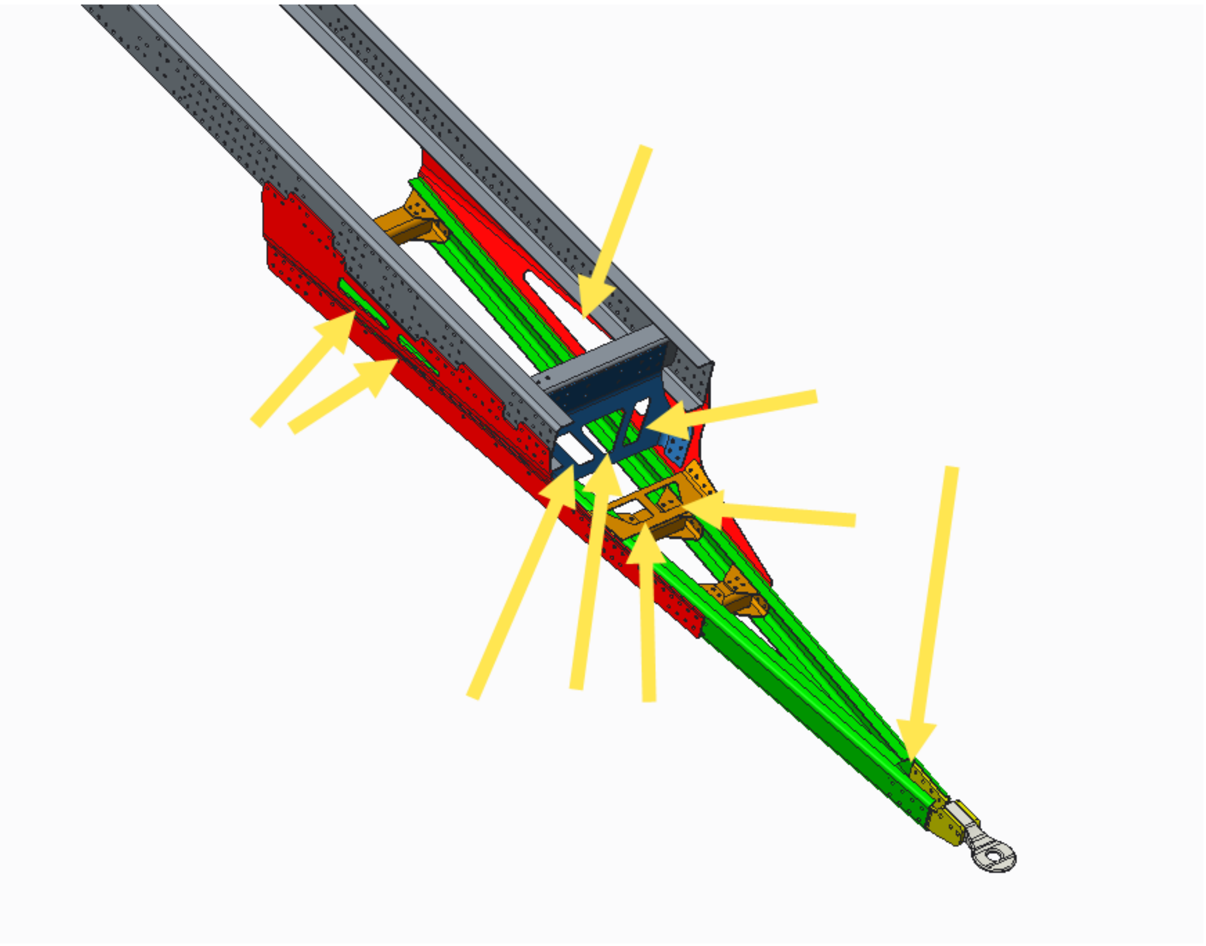

Figure 7.22: Concept F1 with cut away material

7.9 Improvement of Concept F2

With further analyzing, the plate in the back could be established unnecessary and could be removed with negligible differences in the stresses, and one of the crossbeams were adjusted seen in figure 7.23 with arrows.

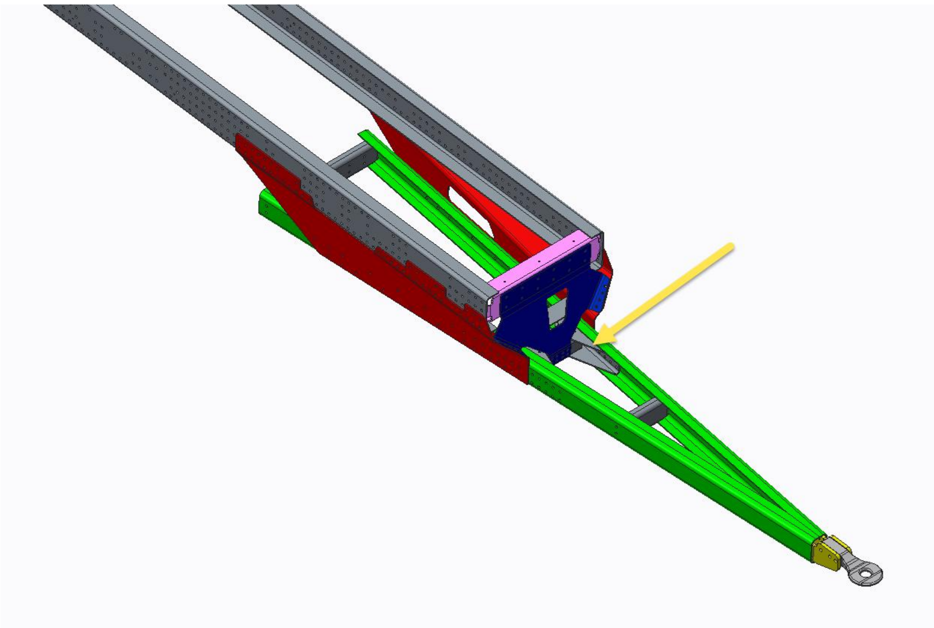

Figure 7.23: Concept F2 in full

The critical spot in the front of the outer plate got reduced by creating a stabilizing plate behind the plate attached to the crossbeam of the chassis as can be seen in figure 7.24 marked with a black arrow. This was made to prevent deflection of the outer plate which creates high stresses in the bends of the outer plate. The crossbeams in the drawbar got evolved to give greater stability in the drawbar.

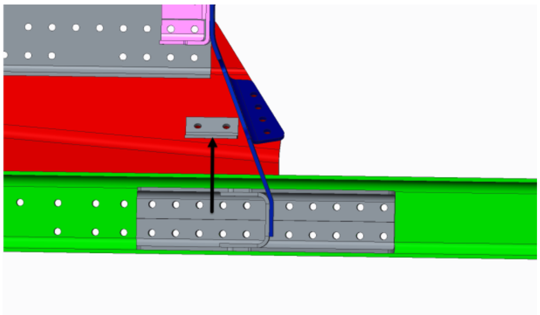

Figure 7.24: Pointing at a crossbeam connected to the side plate

The critical stress spots in this concept is marked in the figure 7.25

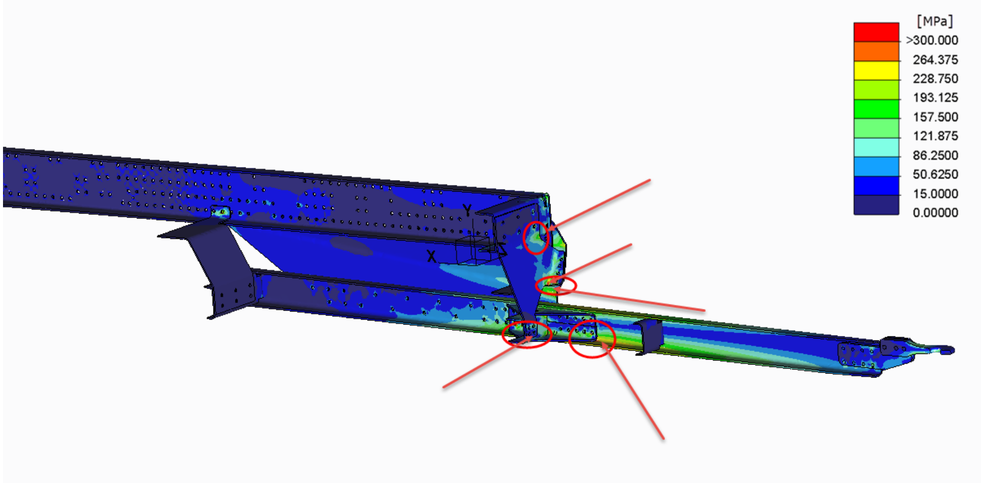

Figure 7.25: Critical areas in concept F2

The front plate that is created to support against deflecting the outer plate sustain high stresses in the bends outer edges and around the bolts (figure 7.26). The stresses around the bolts might be possible to analyze further with calculations made by hand. To consider if the group of these close connected bolts, calculated with friction can sustain the forces exposed to. Regarding the bend there must be low stresses, since the only thing that might change this force is the support from the friction which will not change the stresses that much.

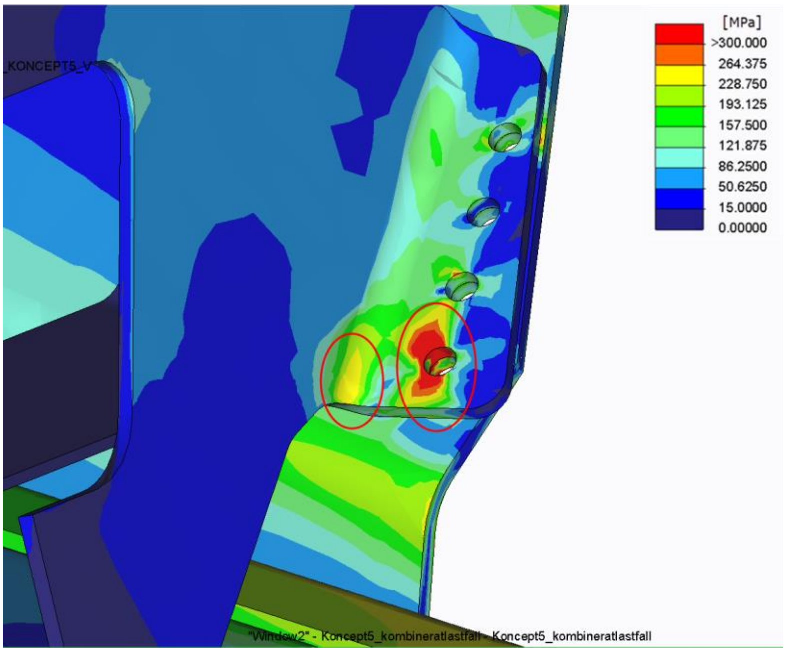

Figure 7.26: Closer look of the plate connected to the side plate

The V-beam gets high stresses on the bottom where the support of the evolved crossbeam ends. These stresses with the new crossbeam in the V-beam were only 304 MPa which was really close to the allowed limit seen in figure 7.27. Making the crossbeams connection bracket even longer might lower the forces even more but it was not tested.

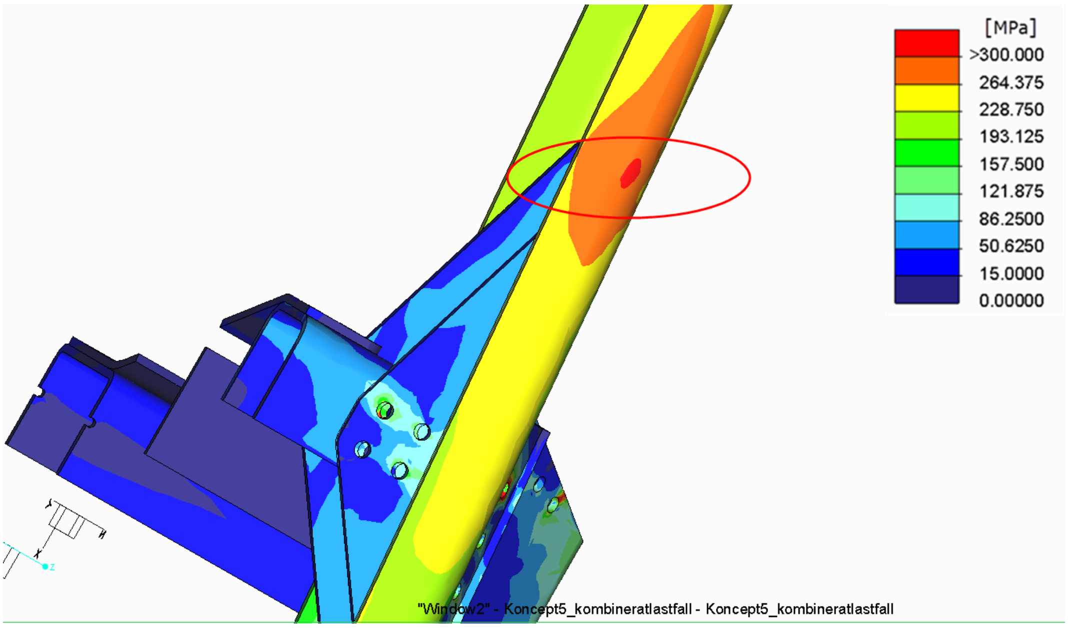

Figure 7.27: stress area on the V-beam

A test was made with an over dimensioned crossbeam with too big of a radius to fit in with bolts (the head of the crosses the radius of the bend) to test if the stresses would go down under the limit (see figure 7.28 to the right marked with a red arrow). As can be seen in the figure 7.28 there is still a small area with high concentrated stresses up to almost 500 MPa shown in the top red circle which is way over the allowed limit. The crossbeams are the dimensioning factor in this model and also when the crossbeams thickness were increased the stresses still got too high.

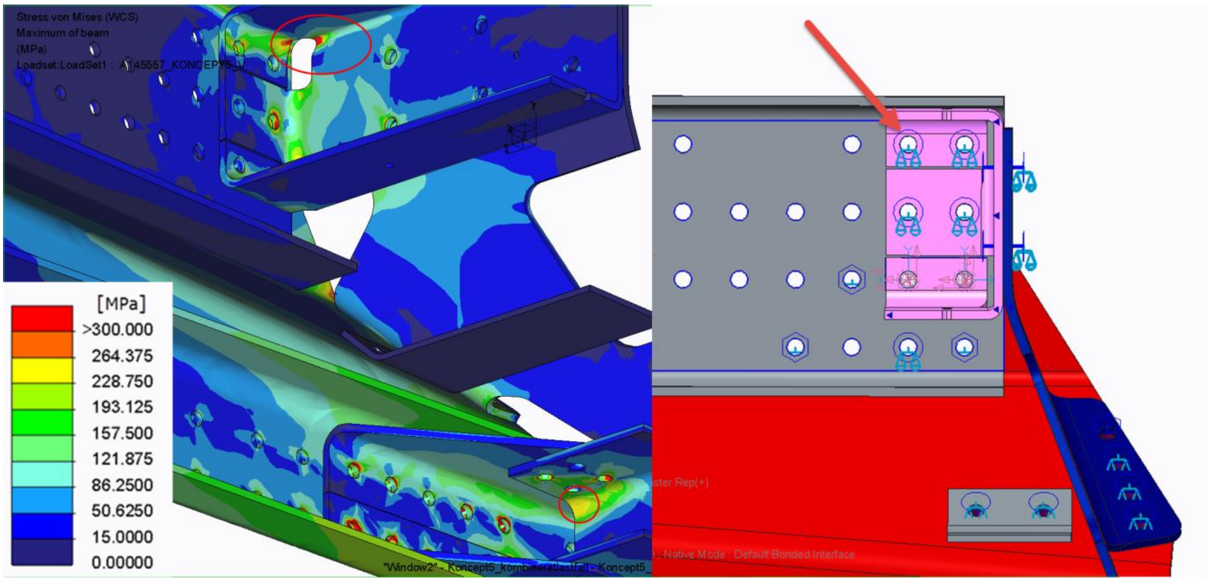

Figure 7.28: Biggest stress issue in concept F2 to the left, bolts crossing radius to the right

A few holes were made to lighten the concept on areas with low stresses to lighten the concept that has a final weight at approximately 350 kg.

7.10 Concept F1 or concept F2

Between the two concepts there are still no bigger differences. None of the versions needed a back plate between the V-bar and the chassis frame sides which is good since that lowers the weight of the concept. The shape of the side plate is the one that differs. An overall shorter side plate is used on concept F2 than concept F1. A problem with concept F2, which is the same problem as in concept 2.3, is that stresses appear in the first ten millimeter thick crossbeam of the chassis frames. These stresses are around 500 MPa which was mentioned earlier. For that reason, to be able to keep the strength of today's drawbar concept F1 is the only concept which could match the strength of today's drawbar and is because of that chosen as the winning concept.

8 CONCLUSION

8.1 Winning Concept

The final conclusion is that it is possible to create a drawbar without removal of the frame sides flanges as requested in the purpose. Though Creo does not take friction in our calculations which is assumed to make the stresses in the image fairly high compared to the reality. The concept V-beam showed good result in transferring the forces the drawbar has to sustain to the trailer, which is why this concept was the winning one. More specific of the two concepts, Concept F1 was the winning concept.

The keeping of the inner flanges resulted in a weight gain and also since the winning concept is measured on a vertical force of 30 kN compared to today's drawbar which was measured on 25 kN the weight difference is almost 70 kg.

If it is desired to work further with the concept one should see if it is possible to remove more material from the drawbar to lower the weight. Also all the bolts should be calculated by hand so that the friction between the bolt head and the plates can be involved as well.

8.2 Suggestions to R-55 regulation

Considering the standard DNV:RP-C203, that has been analyzed with respect to connections and the meeting with Benny Liljeblad at Volvo. The best case scenario is to remove the exceptions of simple design and integrated part of the chassis.

If the exceptions of integrated part should remain a part of the regulation, it should have a clearer definition to make rivets and huck-spin bolts preferred rather than welding.
Welds should be used carefully when constructing in high strength steels and no repairs should be made by welding without hard restrictions.

This since when welding, the material is heated up so high that recrystallization of the grain structure starts around the weld, which reduces the strength of the steel and the quick cooling makes the steel more brittle similar to quenching to quick. This connection does also need cutting processing to take apart which could work as a definition. To disassemble a weld one must use a cutting tool like a circular saw. A rivet has to be drilled away and a huck-spin bolt has special tools to get rid of it.

About the fatigue calculations it should be stated how the calculations should be done. A well-known model which could be used is the Miner's rule which substitutes the differences of the loads created. If a load scheme over how a drawbar is loaded during its lifetime could be made one could make an estimated constant to make this calculations even easier.
The calculations should then be applied to a S-N curve, an example would be equation 4 which is taken from the RP:C203 chapter 2.4 (14).

$$\log N = 17.446 - 4.70 \log \Delta\sigma \qquad (4)$$

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