Krank Engineering

Engineering Design Report: Volkswagen Type 1

Front suspension beam extension

7 June 2013

Issue #	Date	Notes	Prepared by:	Approved by:
0	9 May 2013	Draft for comment	Matt McLeod	
1	4 June 2013	First release	Matt McLeod	
2	7 June 2013	Second release	Matt McLeod	

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Introduction

A front beam extension has been designed for a Type 1 Volkswagen. This structure is installed between the vehicle chassis and the beam axles in order to lengthen the wheelbase and lower the vehicle for aesthetic purposes.

This report describes the process employed to arrive at the final design and the results of Finite Element Analysis (FEA) of the structure under loading conditions specified in Vehicle Standards Bulletin 14.

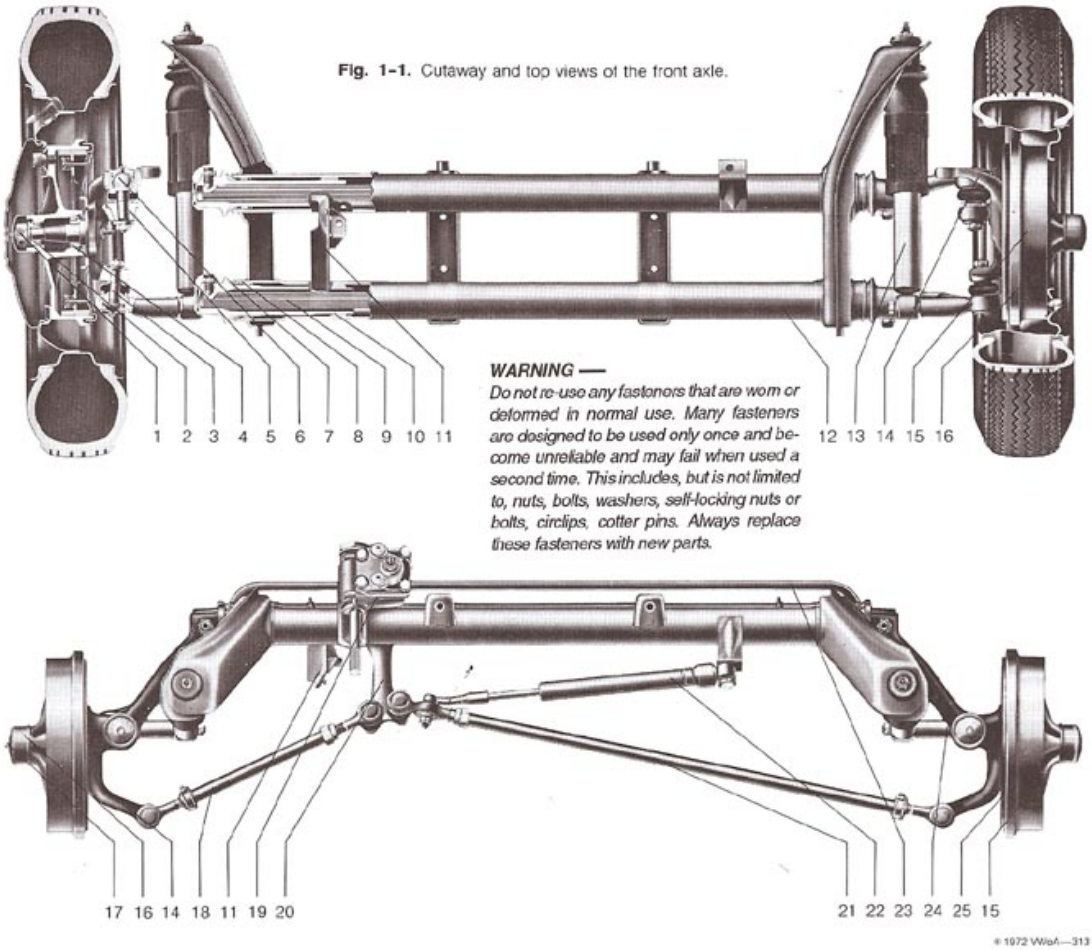
Assumptions

Various assumptions were made during the design of the component. These will be described in the report and summarized in the following table for quick reference:

Ref #	Page	Section	Description
1	4	Tyre Load Estimates	Front/rear weight distribution at laden mass – front = 45% / rear = 55% (due to rear engine)
2	4	Tyre Load Estimates	Left/right weight distribution at laden mass = 50%/50%
3	4	Tyre Load Estimates	Centre of gravity height of laden vehicle = 500mm (no data was located to support this assumption)

Background

The standard Type 1 front axle is a rigid beam with pivoting members that provide suspension movement, steering movement and rotational movement of the wheels. The steering gearbox and steering linkage are mounted on the front axle. The axle beam itself is a welded assembly consisting of two large parallel steel tubes and a number of heave-gauge steel stampings. It is solidly bolted to the frame head. The axle beam tubes contain the torsion bars and their bearings and mounts. The shock absorbers are mounted on welded, stamped steel uprights.



1. Wheel bearing clamp nut
2. Outer wheel bearing
3. Lower ball joint
4. Inner wheel bearing
5. Eccentric camber adjusting bushing
6. Upper ball joint
7. Torsion arm seal
8. Torsion arm needle bearing
9. Torsion bar
10. Plastic seat and metal bushing
11. Steering lock stop
12. Front axle beam
13. Shock absorber
14. Steering knuckle
15. Brake drum
16. Dust cap
17. Speedometer cable
18. Left tie rod
19. Steering gearbox
20. Drop arm
21. Right tie rod
22. Steering damper
23. Stabilizer bar
24. Torsion arm
25. Brake backing plate

Figure 1 - Standard Type 1 front axle arrangement (left-hand drive shown)

A beam extension is a steel structure constructed to fit between the beam axle and the frame head. Beam extensions are favoured by modifiers of Type 1 vehicles looking for a longer, sleeker appearance.

Figure 2 - Type 1 with beam extension fitted (left-hand drive shown)

Design Process

Tyre load estimates

An estimate of the tyre loads for the vehicle was made using handbook information (from http://www.carfolio.com) and some assumptions.

The laden mass of the vehicle was calculated at 1065kg using the process described in VSB 14. This is the sum of the vehicle mass (739kg), four (4) passengers at 68kg each, and 4 x luggage at 13.6kg each.

The assumptions were:

1. Front/rear weight distribution at laden mass – front = 45% / rear = 55% (due to rear engine)
2. Left/right weight distribution at laden mass = 50%/50%
3. Centre of gravity height of laden vehicle = 500mm (no data was located to support this assumption)

Using the laden mass and the assumptions above, the static tyre loads were calculated:
(example: Left Front = (laden mass x 9.81) x (Front Weight Distribution) x (Left/Right Weight Distribution

Left Front = (1065 x 9.81) x (0.45) x (0.5) = 2351 N

Left front	2351 N
Right front	2351 N
Left rear	2873 N
Right rear	2873 N

Suspension loading requirements

VSB14 Section LS *Tyres, Rims, Suspension and Steering*, Code LS3 *Front Suspension and Steering Modification (Design)* suggests component stress levels as follows:

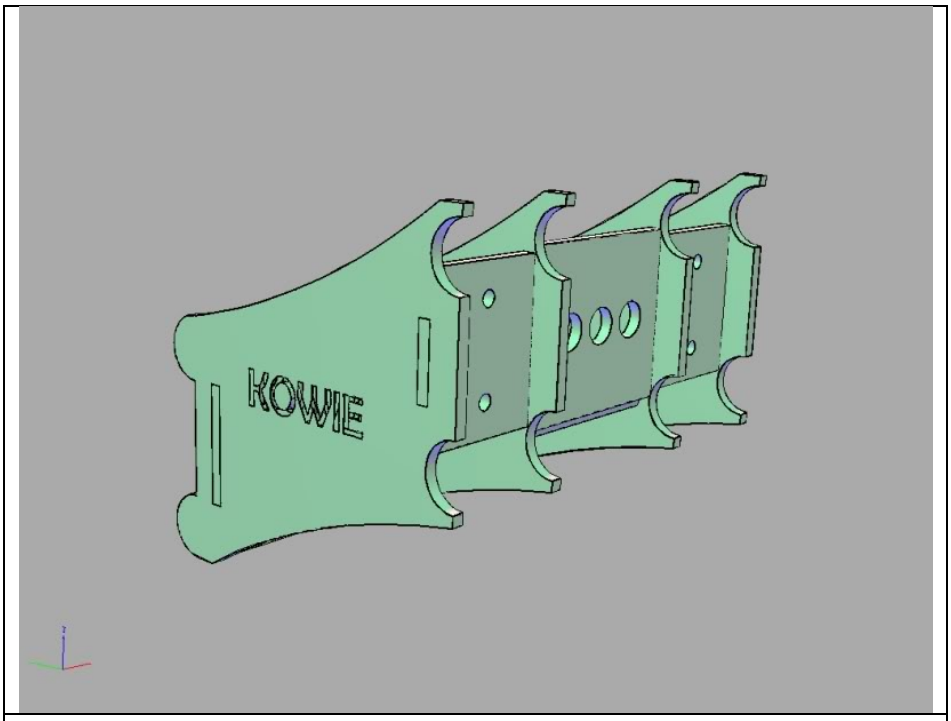
- Bump loads: 4g vertical (9404 N vertical load in this case)
- Overturning loads: 2g vertical with 2.5g side load (4702 N vertical and 5877 N side load in this case)
- Skid loads: 2g vertical with 1.2g longitudinal (4702 N vertical and 2821 N longitudinal in this case)

Refer to the diagrams in Appendix 1 for pictorial depictions of the loading conditions.

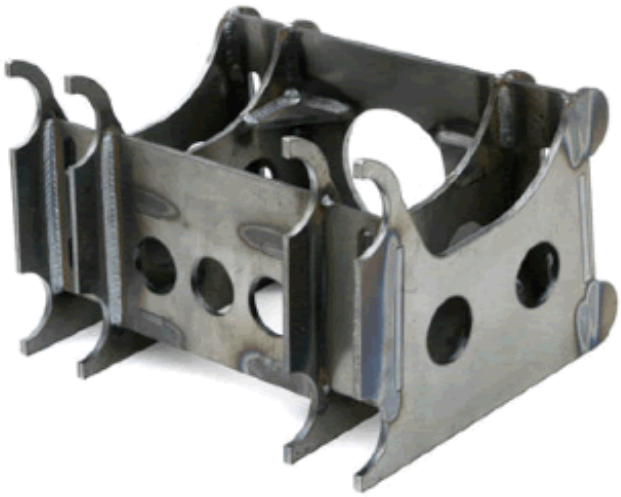
Existing examples of Volkswagen Type 1 beam extensions

A survey of existing structures was conducted on the internet. The following photographs and diagrams show typical examples of beam extensions either commercially available overseas, or constructed by individual enthusiasts for their own vehicles:

Volkswagen Type 1
Front Suspension
Beam Extension

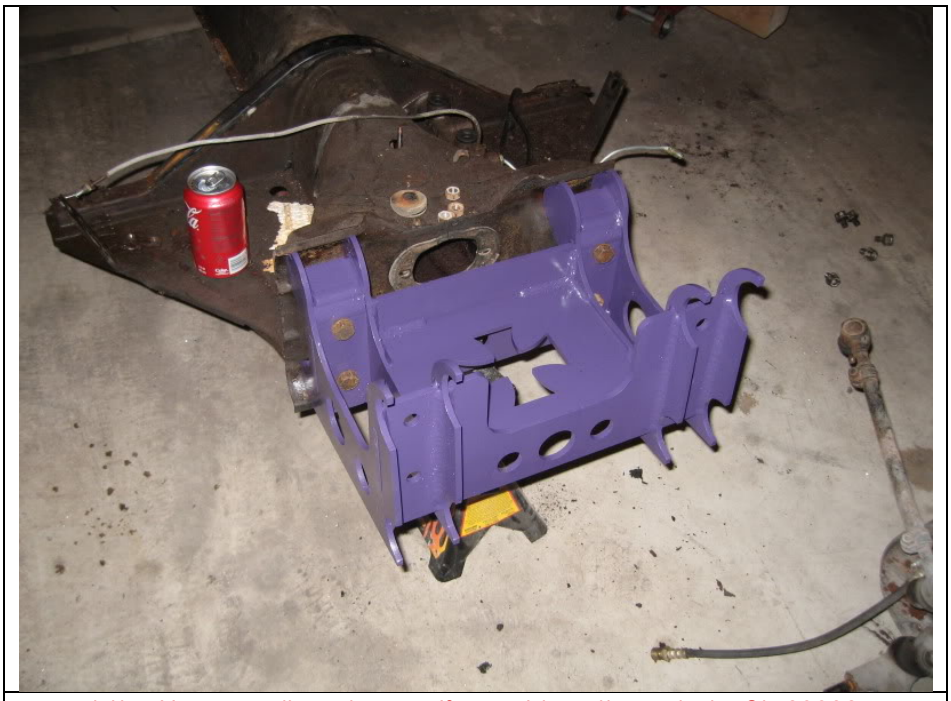


http://oldschool-vw.blogspot.com.au/



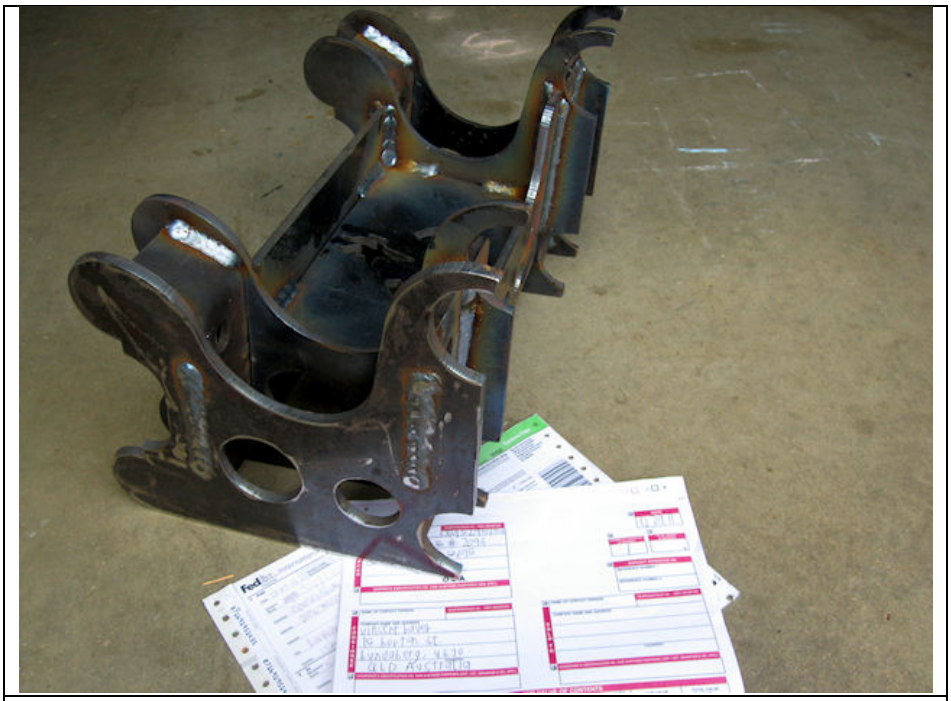
http://www.peglegmetalwerks.com/beamext.html

Volkswagen Type 1 Front Suspension Beam Extension



http://www.volksrods.com/forum/showthread.php?t=29832

http://www.thesamba.com/vw/classifieds/detail.php?id=967484



http://forums.aussieveedubbers.com/viewtopic.php?tid=94538

Client desired geometry

The client's request was for the beam extension to extend the wheelbase approximately 150mm and lower the vehicle approximately 150mm. These were purely aesthetic considerations.

As a result, the following side profile geometry was developed to achieve the client's desired geometry while adequately clearing existing steering and suspension components.

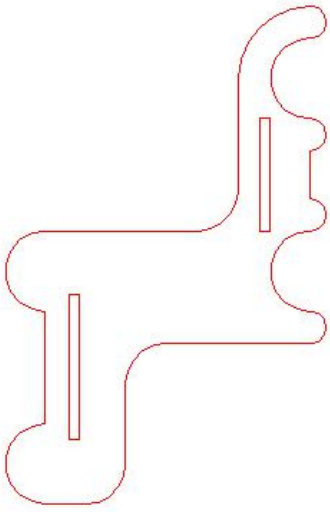


Figure 3 - beam extension side profile

This basic profile was designed with two vertical slots as seen in Figure 3. These were intended to permit the horizontal members to be slid through the four side plates, providing simple and fast alignment of the part for assembly welding. The horizontal members also provide a bearing surface between the beam axle/beam extension and beam extension/frame head.

An initial version of the design is shown in Figures 4, 5 and 6:

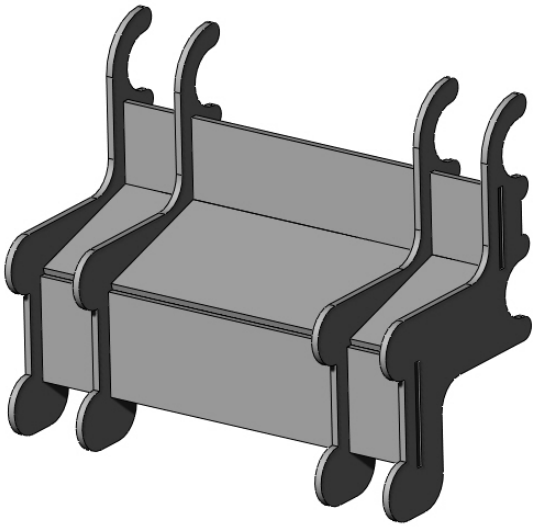


Figure 4 - Initial beam extension concept

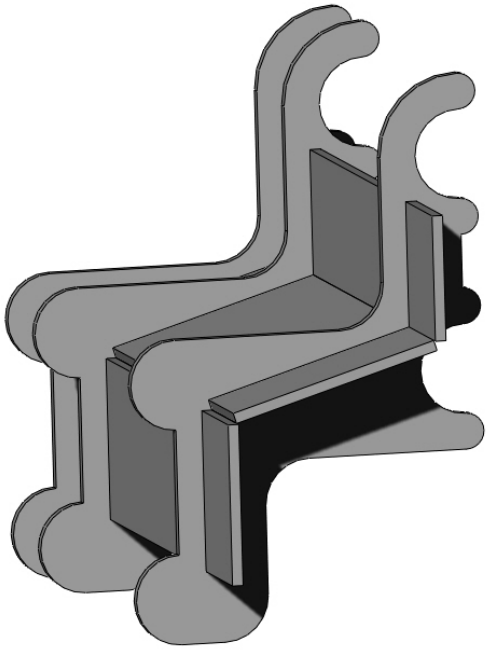


Figure 5 - Initial beam extension concept

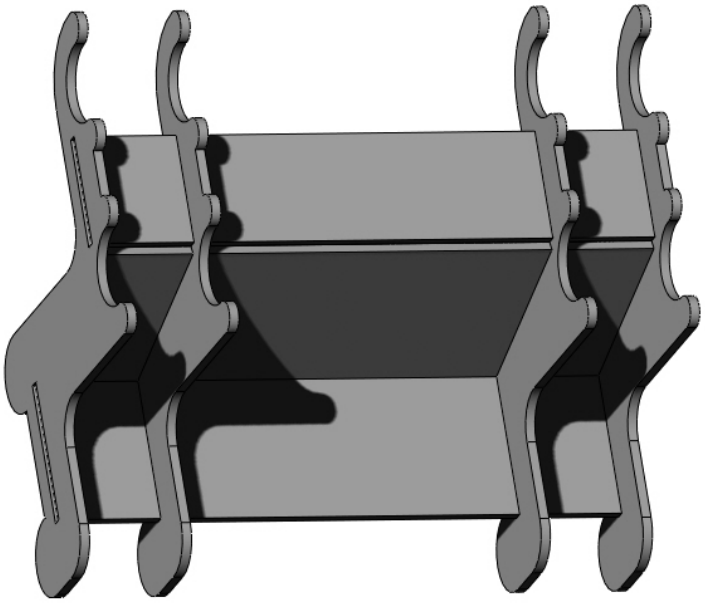


Figure 6 - Initial beam extension concept

Analysis Process

Using the model shown in Figure 3, Finite Element Analysis was commenced using the VSB14 recommended loading scenarios and the tyre loading estimates:

Loading scenarios:

- Bump loads: 4g vertical (9404 N vertical load in this case)
- Overturning loads: 2g vertical with 2.5g side load (4702 N vertical and 5877 N side load in this case)
- Skid loads: 2g vertical with 1.2g longitudinal (4702 N vertical and 2821 N longitudinal in this case)

Estimated tyre loads:

Left front	2351 N
Right front	2351 N
Left rear	2873 N
Right rear	2873 N

Material properties:

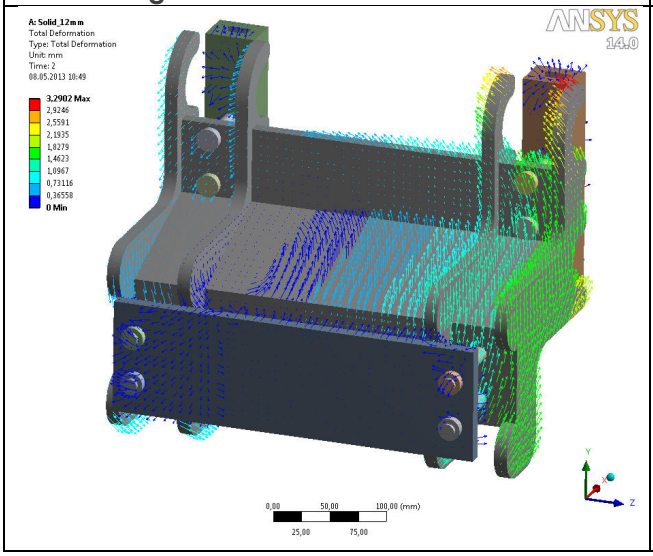
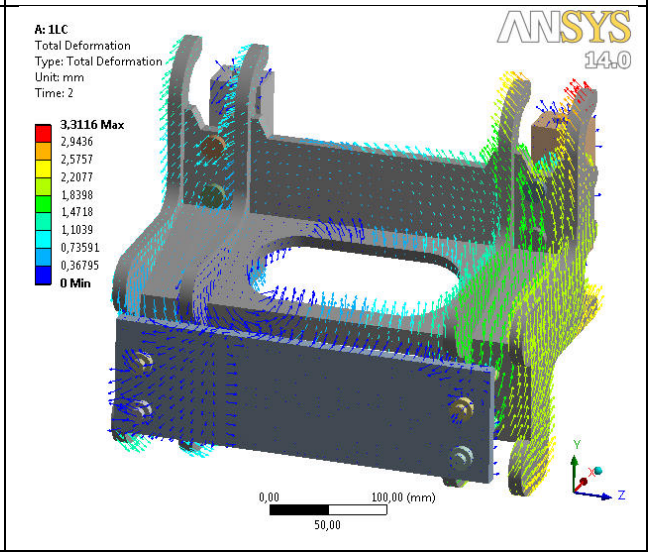
Material:	Structural mild steel
Grade:	AS/NZS 3678 350MPa

Analysis Software and configuration:

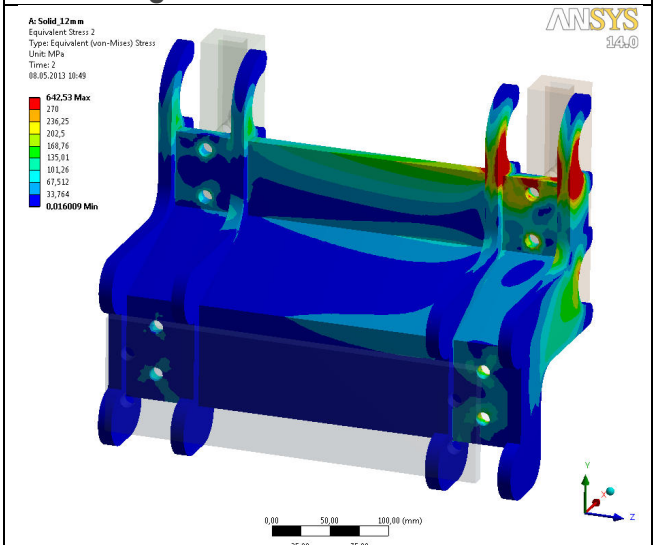
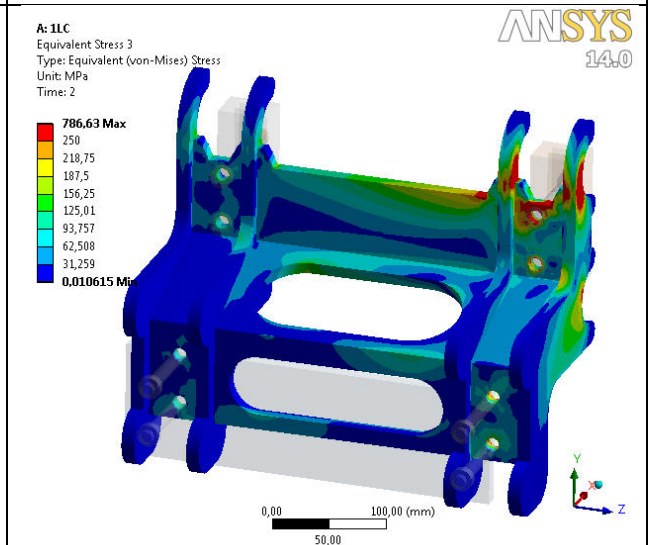
ANSYS Workbench 14	Static Structural Analysis

Analysis Results

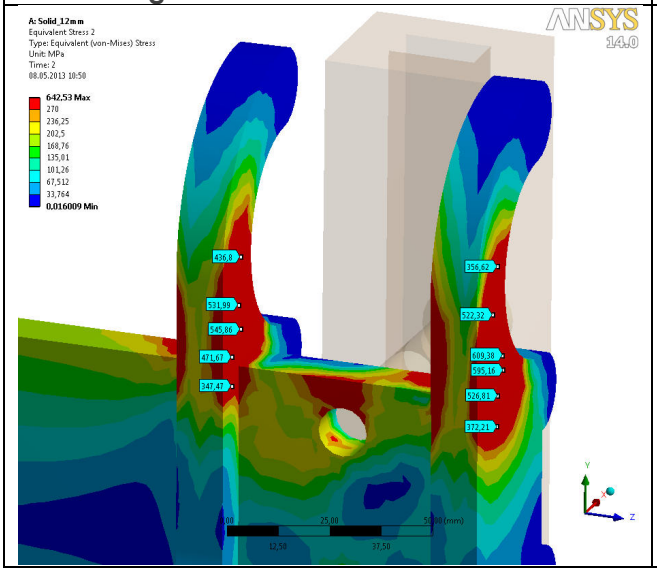
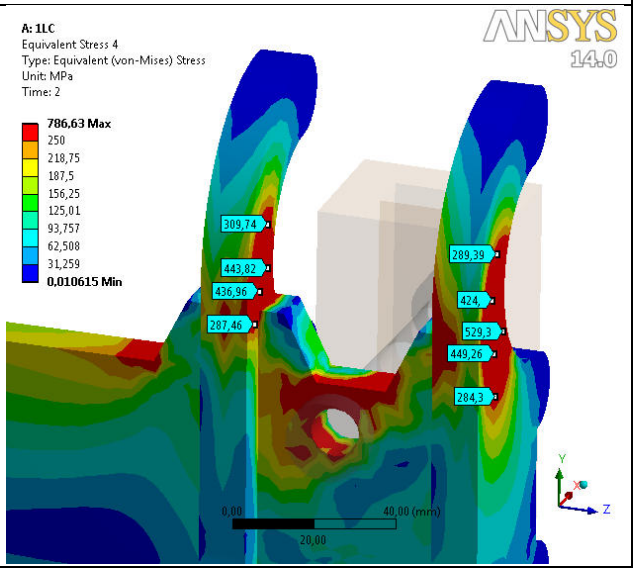
The finite element analysis (FEA) of initial beam extension design for the first load case is performed taking into account bolt pretension.

Initial Design	Final Version
	

Displacements vector field

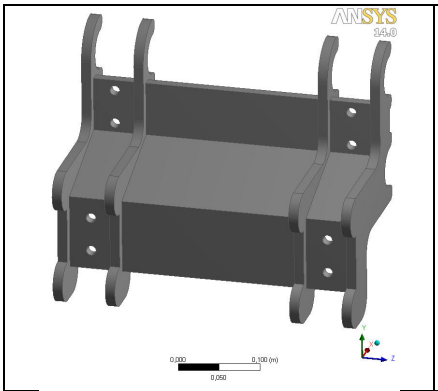
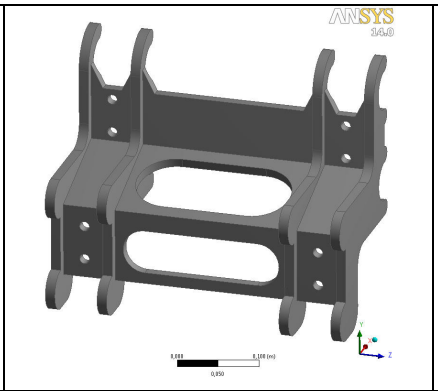
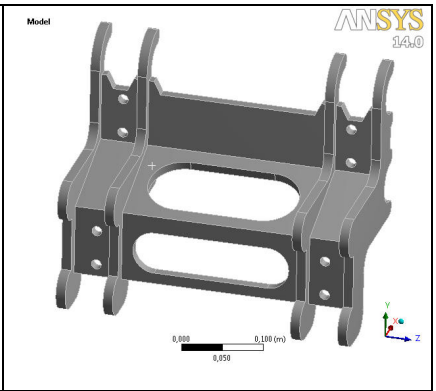
Initial Design	Final Version
	

Equivalent stresses distribution

Initial Design	Final Version
	

Equivalent stresses distribution

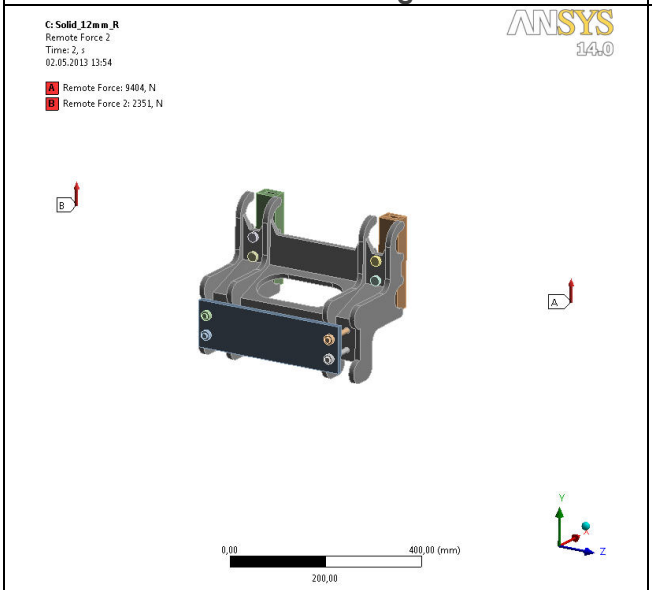
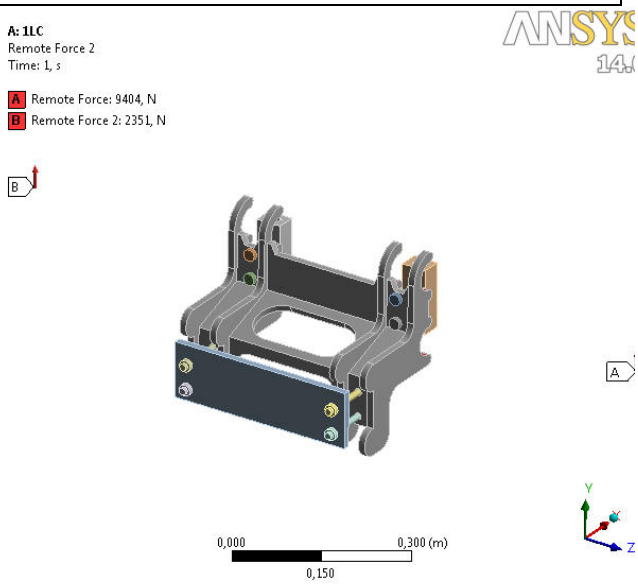
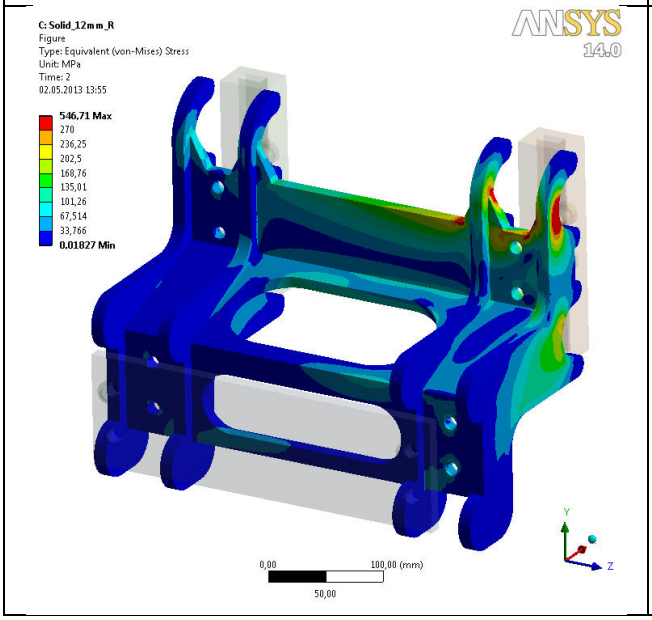
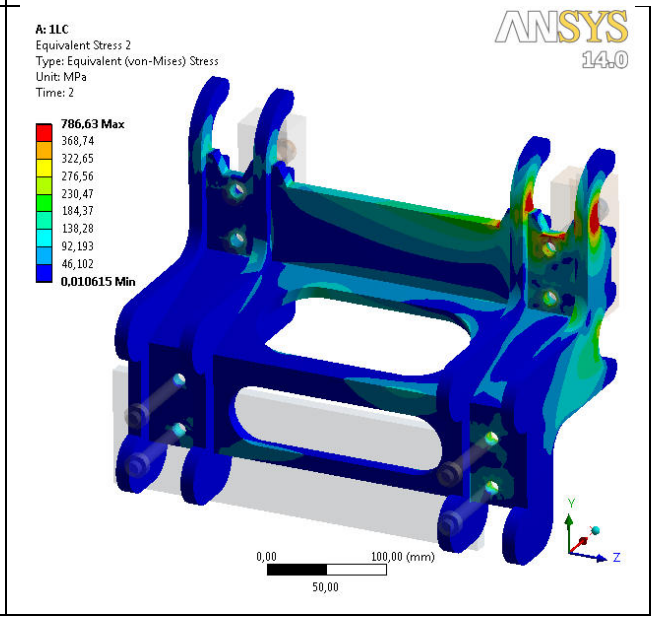
Based on calculations results the geometry of the beam extension was modified.

		
Initial design (mass 17.46 kg)	First modification (mass 15.1 kg) Modified for reduced stress	Final version (mass 14.95 kg) Optimized for manufacture

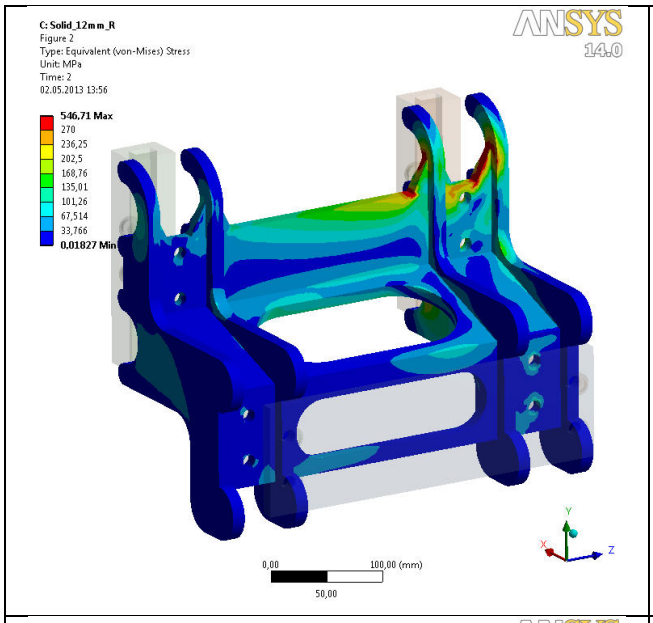
Below the FEA results for the 3 load cases are presented.

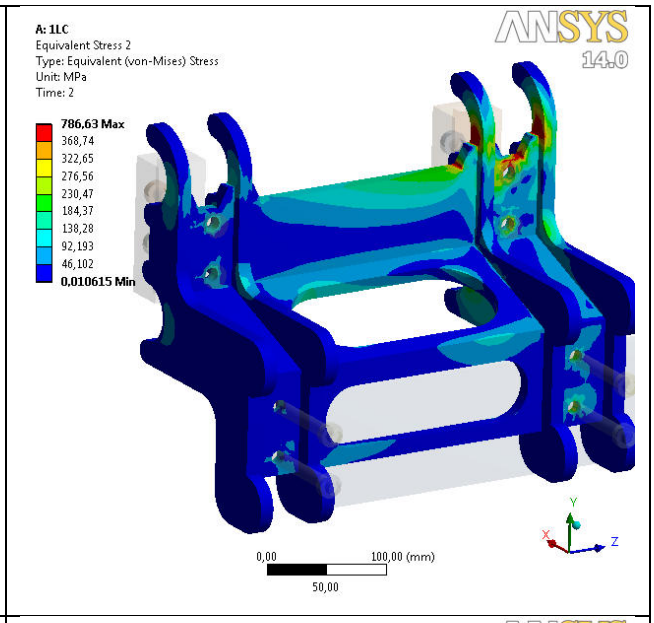
Volkswagen Type 1 Front Suspension Beam Extension

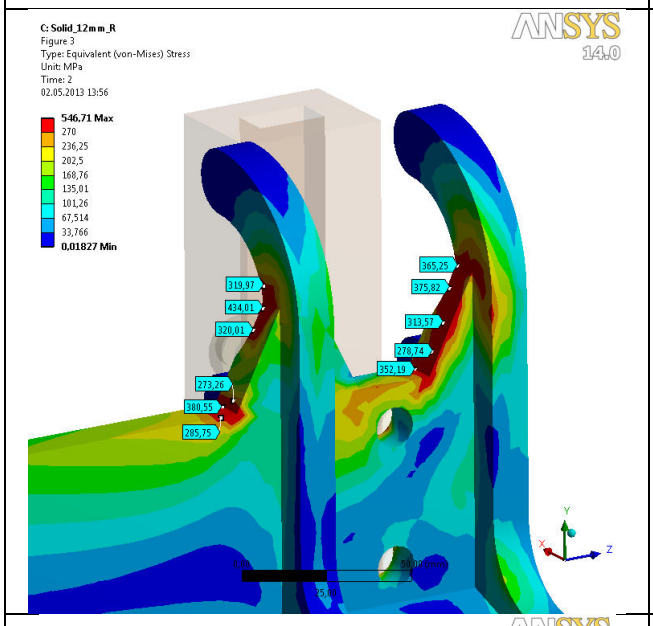
Loading Case 1: Bump loads: 4g vertical

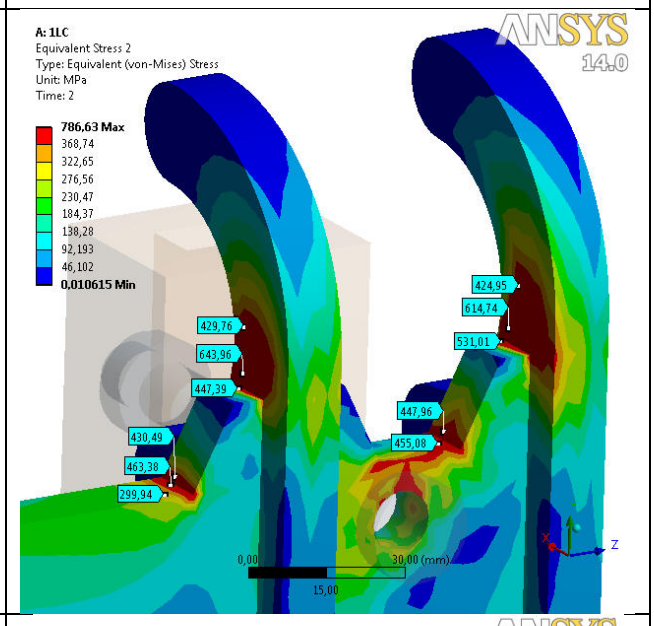
Modified Design	Final Version
	
	

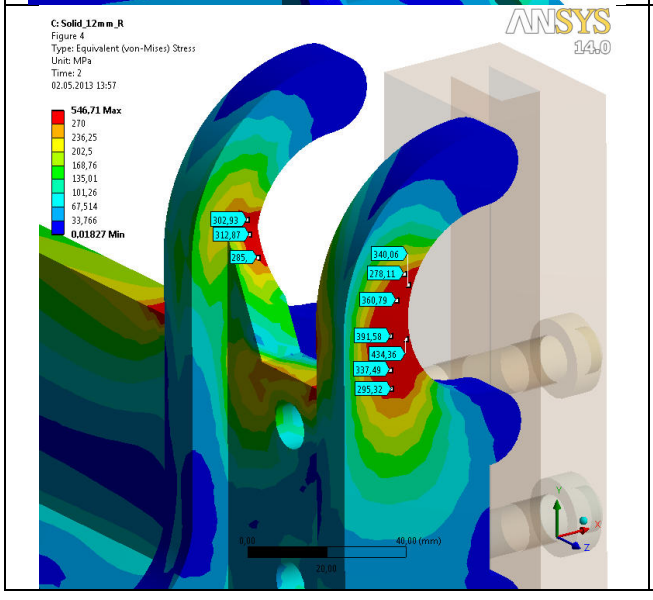
Volkswagen Type 1 Front Suspension Beam Extension

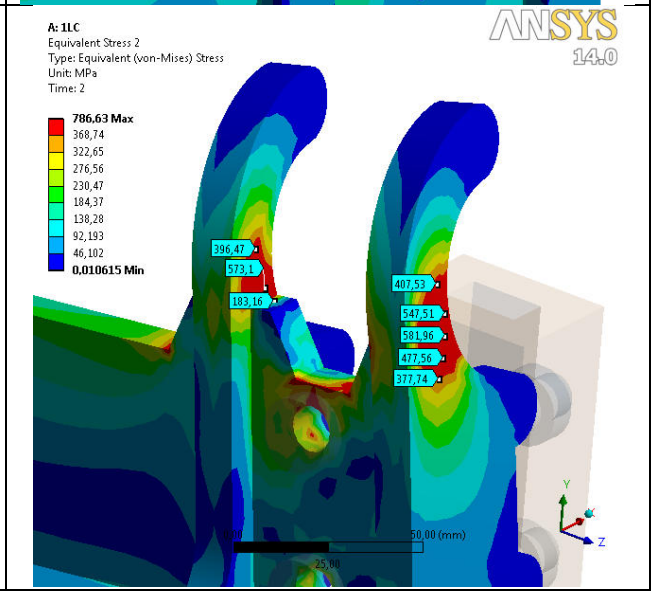






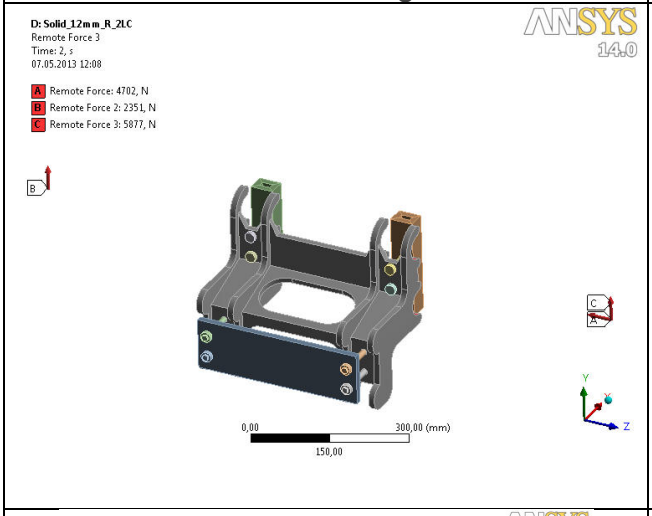
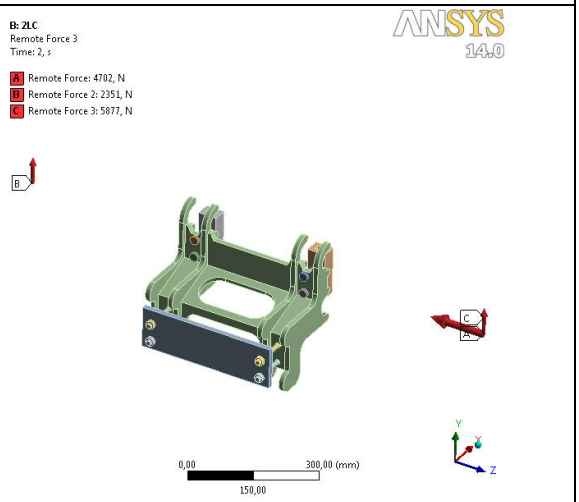
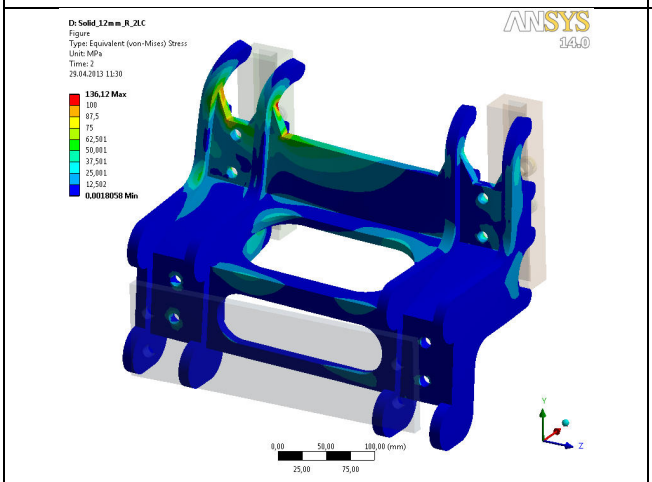
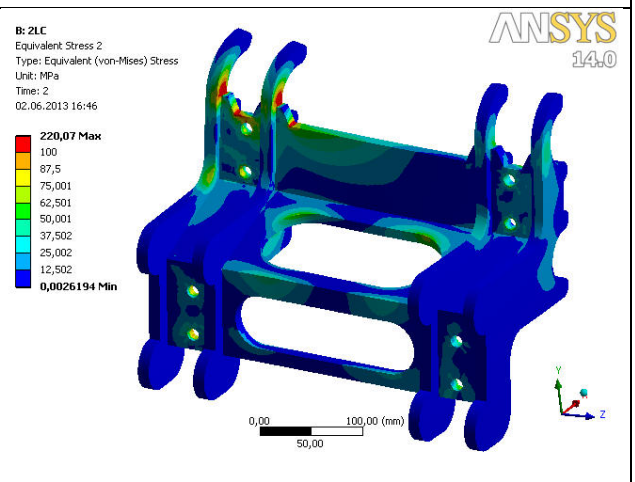
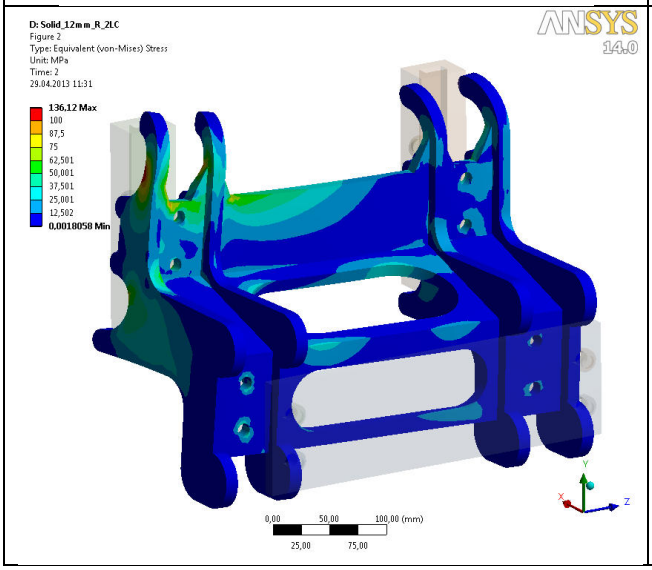
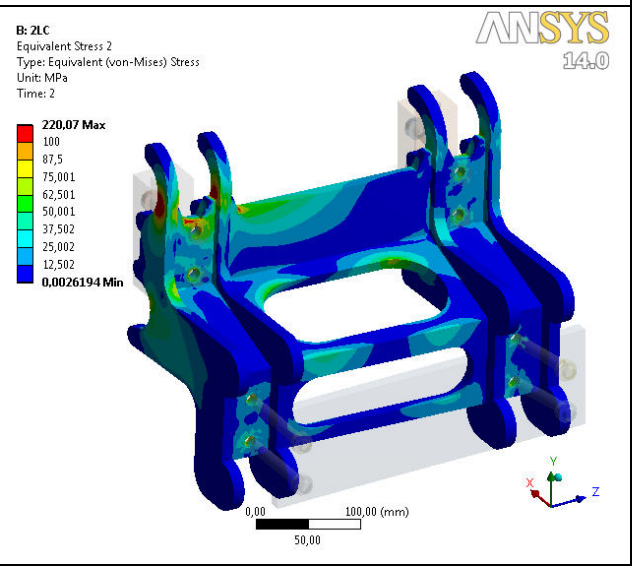




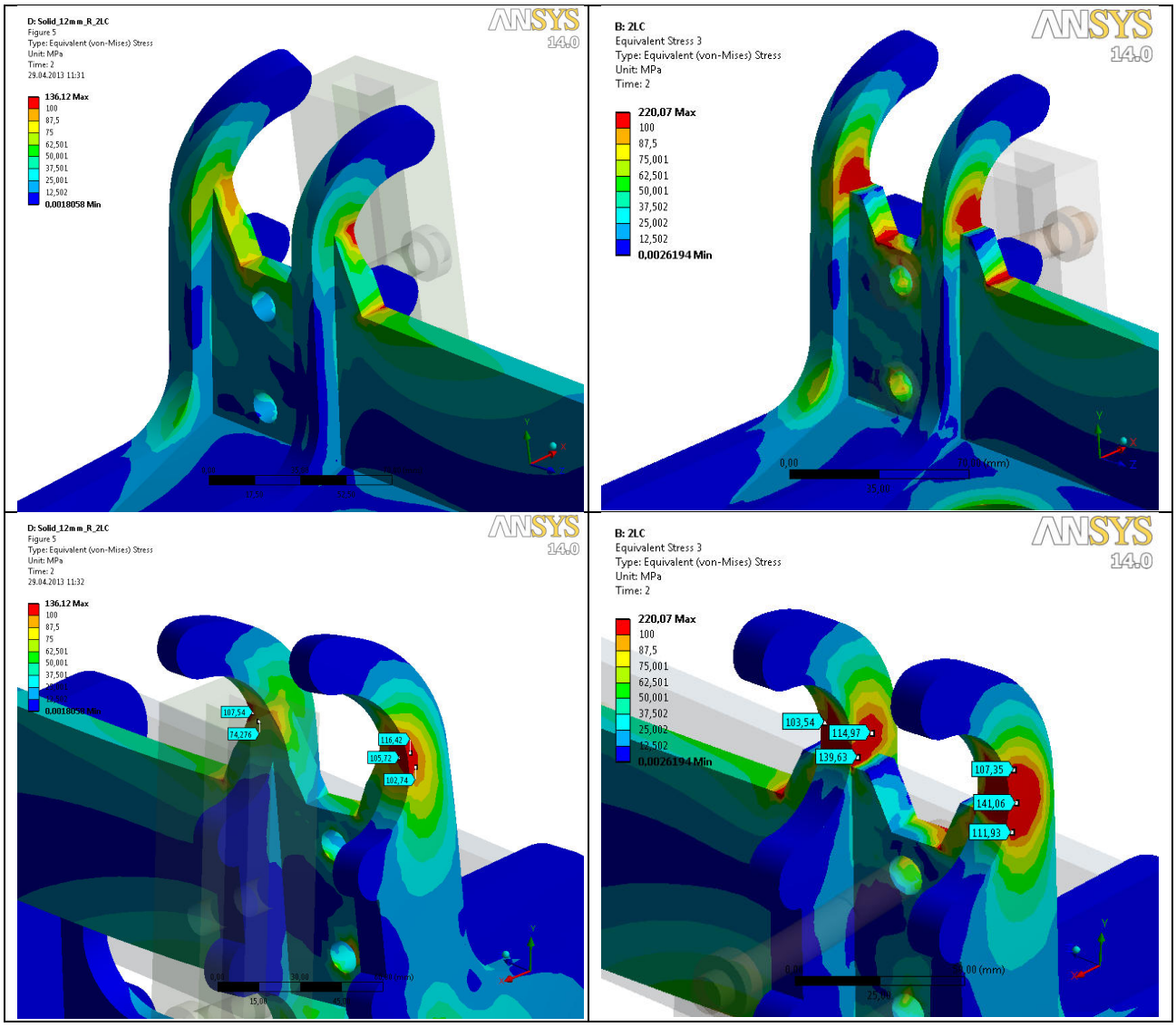


Volkswagen Type 1 Front Suspension Beam Extension

Loading Case 2: Overturning loads: 2g vertical with 2.5g side load

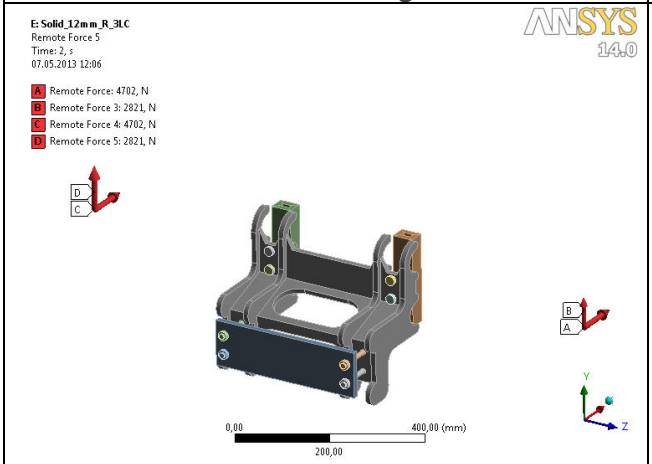
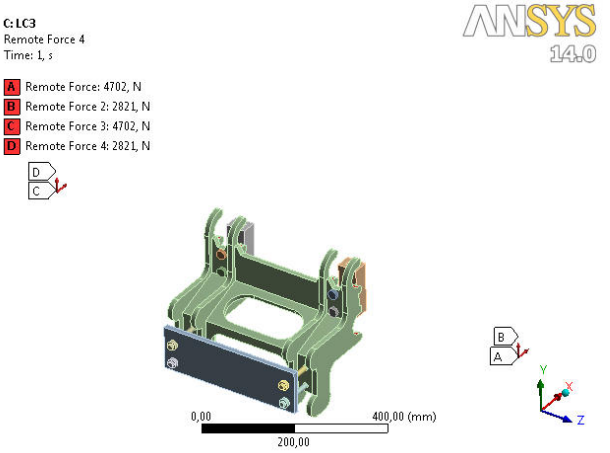
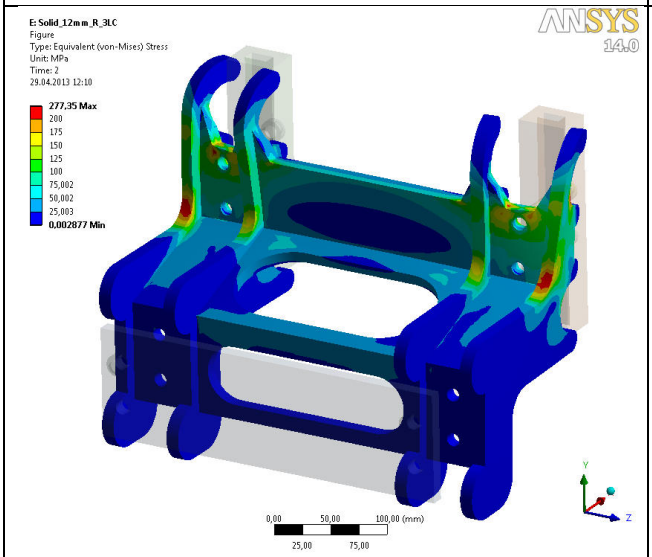
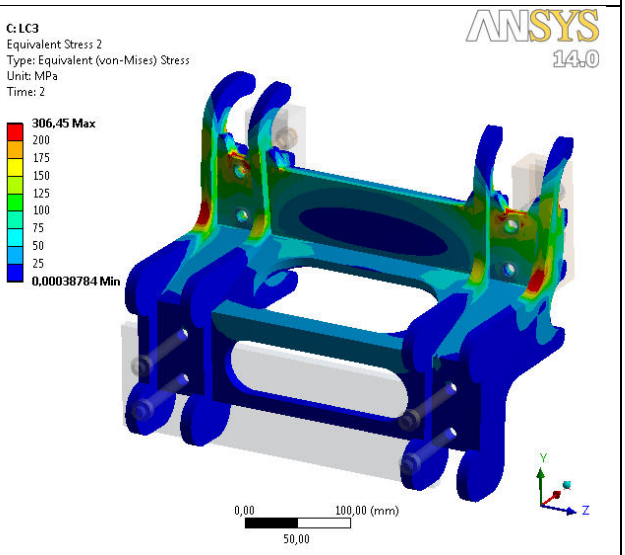
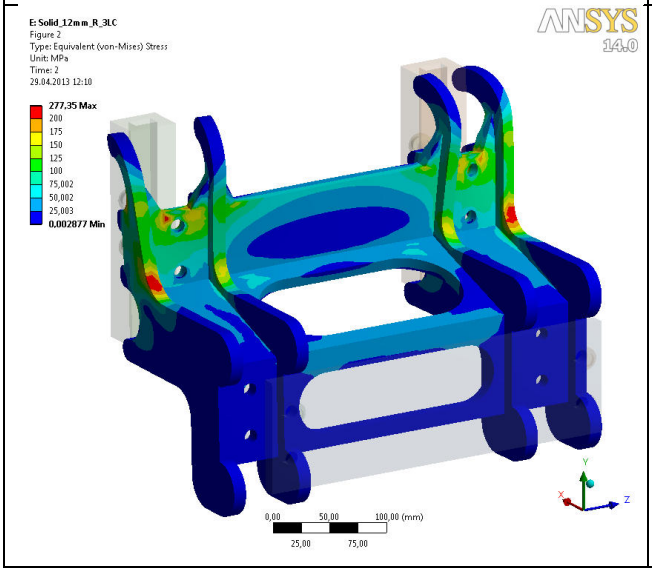
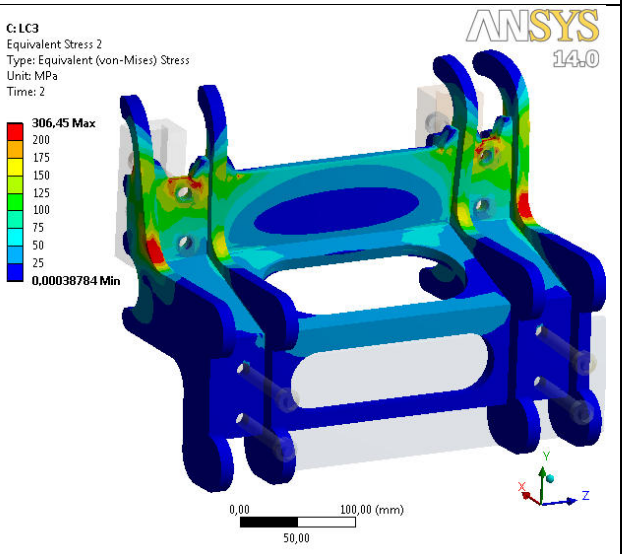
Modified Design	Final Version
	
	
	

Volkswagen Type 1 Front Suspension Beam Extension

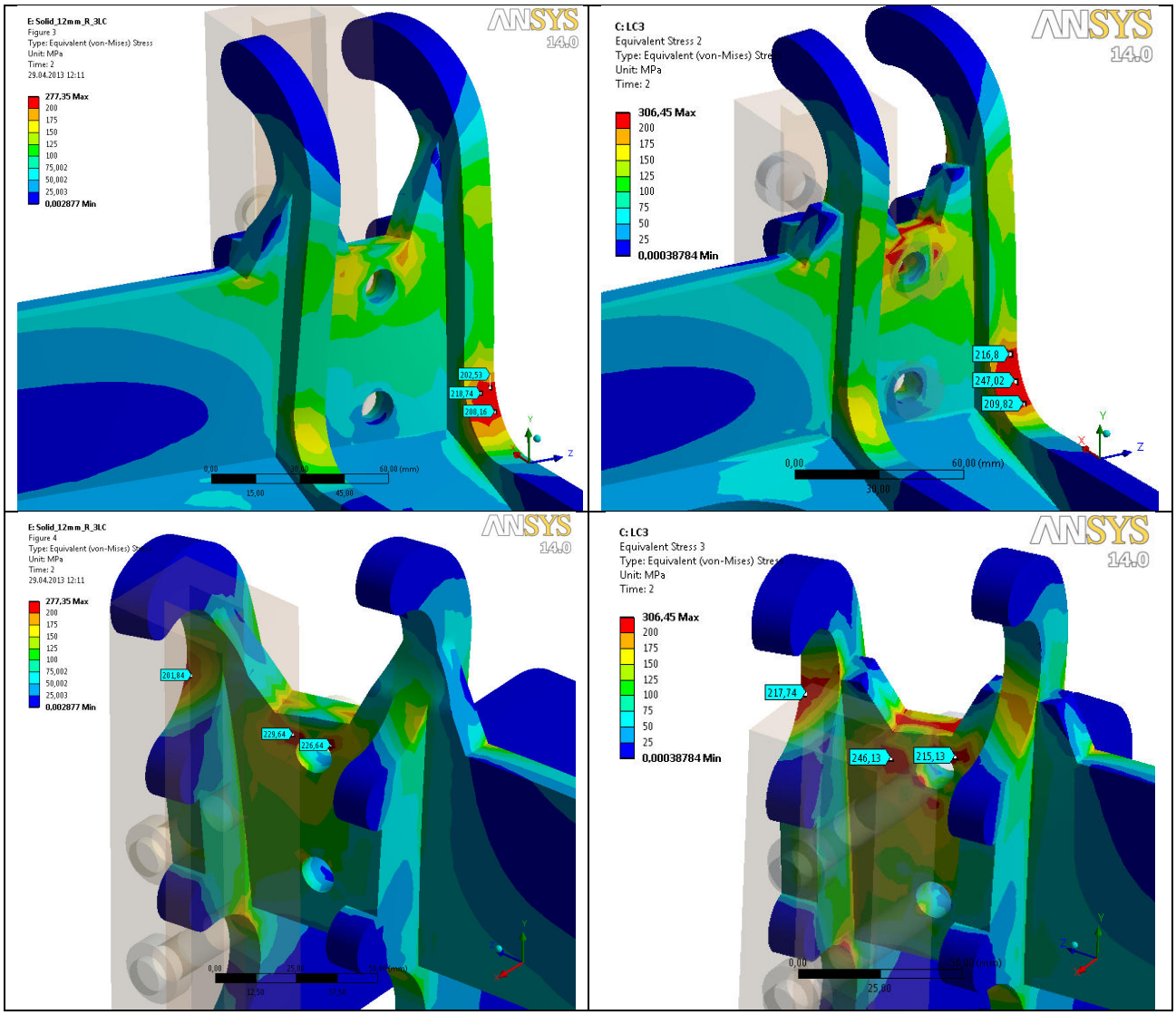


Volkswagen Type 1 Front Suspension Beam Extension

Loading Case 3: Skid loads: 2g vertical with 1.2g longitudinal

Modified Design	Final Version
	
	
	

Volkswagen Type 1 Front Suspension Beam Extension



Analysis Interpretation

Loading Case 1: Bump loads: 4g vertical
In the event of an extreme "pothole" event, the model predicts stresses exceeding the yield stress of the proposed structural steel material.

However, considering the bounds of model accuracy, the similar level of predicted stress versus material yield stress, and the low probability of such an extreme loading condition, it is proposed the design is sufficient for Loading Case 1.

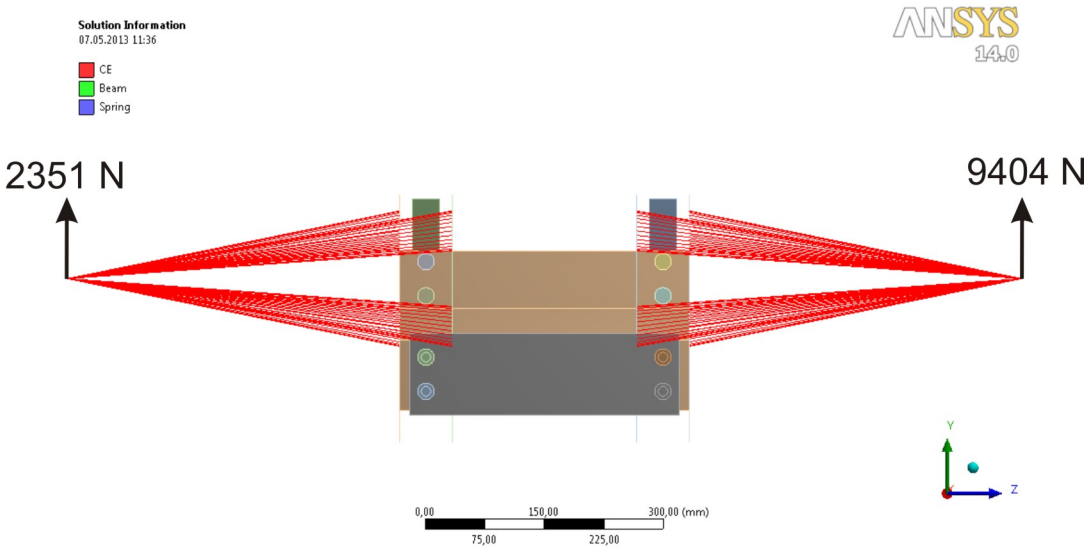
Loading Case 2: Overturning loads: 2g vertical with 2.5g side load
In the event of an overturning event, the model predicts stresses substantially lower than the yield stress of the proposed structural steel material.

It is proposed the design is sufficient for Loading Case 2.

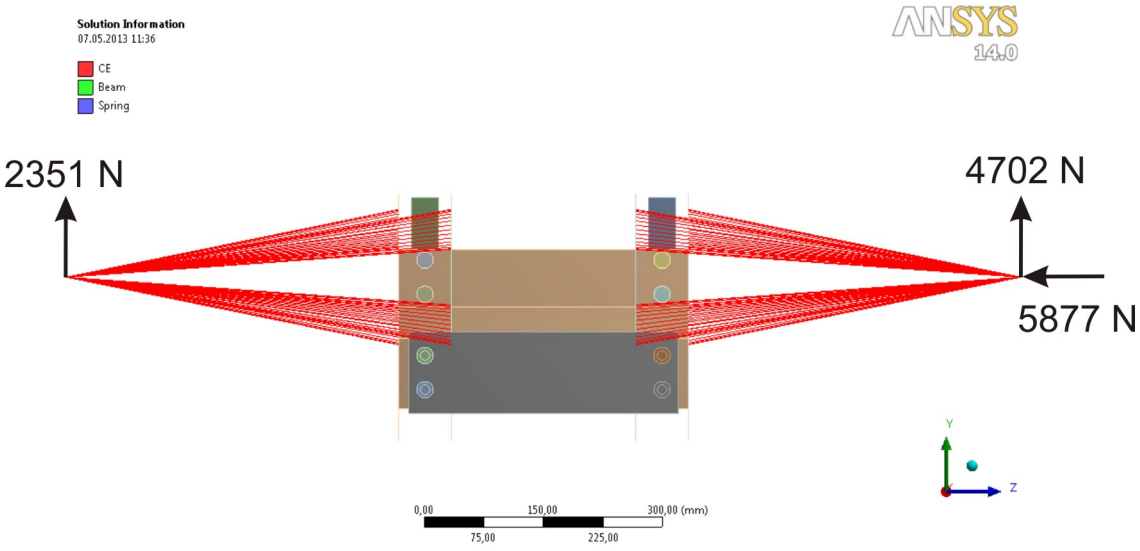
Loading Case 3: Skid loads: 2g vertical with 1.2g longitudinal
In the event of a skid event, the model predicts stresses substantially lower than the yield stress of the proposed structural steel material.

It is proposed the design is sufficient for Loading Case 3.

Appendix 1 – Loading Scenarios

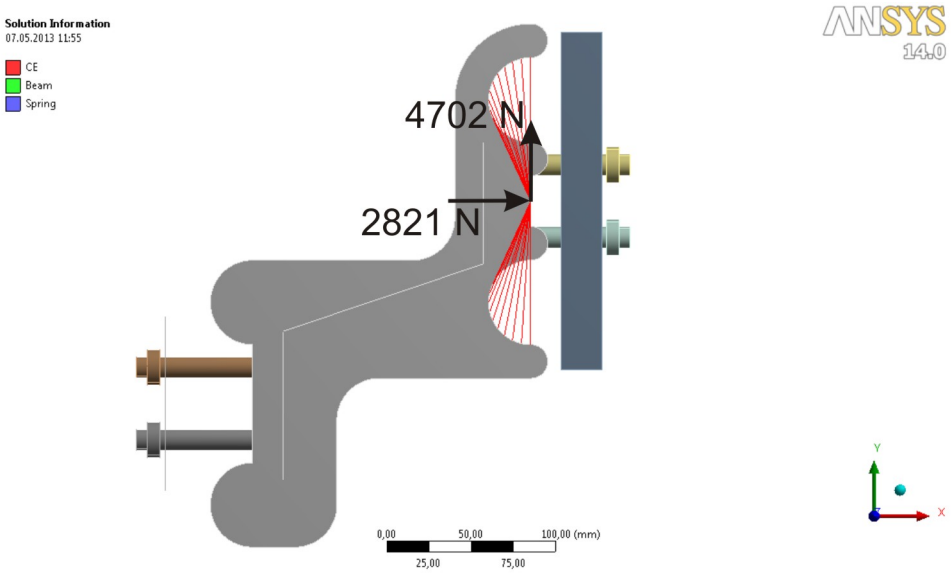


First Load Case: Bump loads: 4g vertical (9404 N vertical load in this case)



Second Load Case: Overturning loads: 2g vertical with 2.5g side load
(4702 N vertical and 5877 N side load in this case)

Volkswagen Type 1 Front Suspension Beam Extension



Third Load Case: Skid loads: 2g vertical with 1.2g longitudinal to both sides (4702 N vertical and 2821 N longitudinal in this case)