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THEORETICAL STUDIES USED AT A TOWING ASSEMBLY. PART II

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Abstract: *This paper contains experimental determinations for a complex coupling consisting of a towbar (for Audi Q5), a transverse frame to grip on vehicle chassis and the necessary elements for fitting (flanges, screw-nut system, welding). It was proceeded first with the conception and design of all components but also the assembly and fastening system. The experimental determination was made on a MTS traction machine. It was determined experimentally the behavior of the towing assembly in compression conditions (braking). For the tests it was developed and used some different devices to fit the towing assembly on the traction machine table. Towing assembly contains also fastening elements by welding. Finally, it was done a comparison of theoretical and experimental results; further work will follow on some optimization of the components from the studied assembly.*
Keywords: *towbar, displacement, load, stress*

1. INTRODUCTION

The current paper dynamic tests at a towing assembly used at Audi Q5 vehicle, fig. 1. The experimental determinations were made by a MTS traction machine. It was considered that the car is in braking time and it has a trailer without brake which presses the whole towing assembly.
From the beginning we should know that these results on this paper will be compared with some results from another paper which has experimental determinations on a similar towing assembly.
In other studies, it has been shown the higher brake force introduces the higher stresses in the towing assembly. If the car with trailer have a frontal crash, then appear the greater stresses in the towing assembly, and the speed is higher so the stresses are higher.

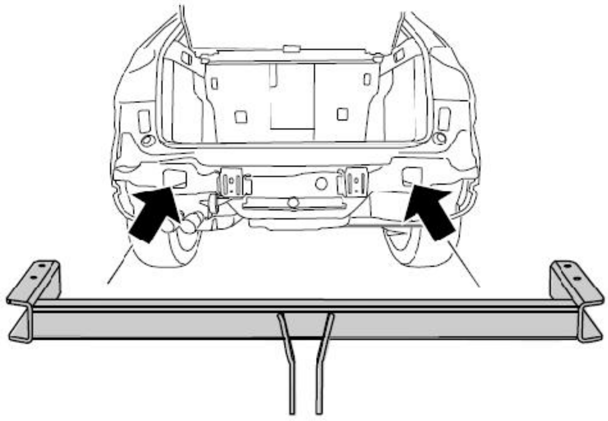

Figure 1: Audi Q5 – towing assembly

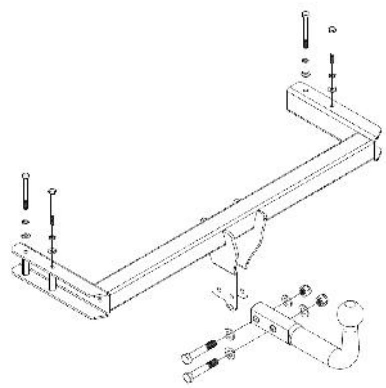

Figure 2: Towing components

The towing assembly is assembled on the vehicle with 4 screws M10x100, and it contains two pairs of flanges and a square pipe in the middle, figure 1 and figure 2. The all 4 flanges are welded on the square pipe and the towball is fixed with two M12x70 screws and two M12 nuts. All components are from S355J2 material. Theoretical studies comply exactly as catching real constraints on vehicle.

2. EXPERIMENTAL DETERMINATIONS

In general, this type of towing assembly is tested with an approximate 7,5 [kN] load at $2x10^6$ cycles, on all three axes, the name of the test is Carlos. In picture no. 4 is appeared a sample from this test and there they can see the areas where appear cracks after the $2x10^6$ cycles, at a dynamic load. The pink color represents regions where the maximum stresses appear.

Figure 3: Towing assembly on the test bench

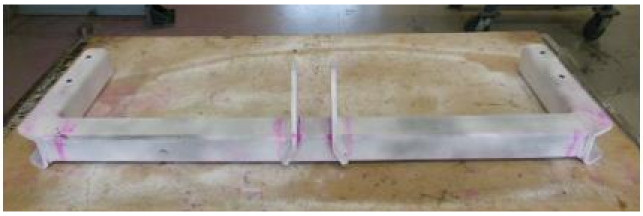

Figure 4: Towing crossbar

In our tests we tested a little bit differently. It simulated only the moment when the car is braking and the trail pushes the car entering stress on the towing assembly. The loads were: 7,5 [kN] – 20 cycles, 15 [kN] – 10 cycles, 25 [kN] – 10 cycles and 50 [kN] – 5 cycles.
For the experimental determinations, there were used some devices to adapt this type of project at the traction machine. There was made a rigid base plate with 20 [mm] thickness, fig. 5, and two other devices to fix the towing assembly, fig. 6.

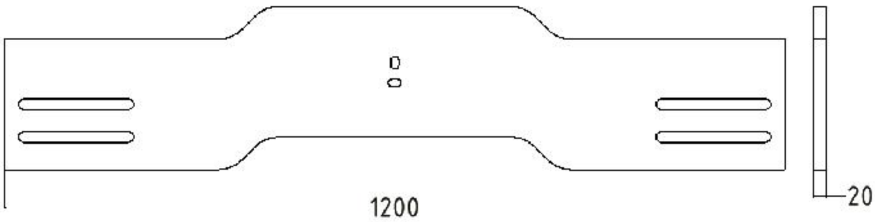

Figure 5: Rigid base plate

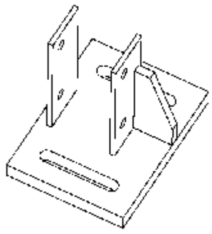

Figure 6: Left – Right devices

Most of the parts of the devices are made by a cutting laser machine and after that they are welded to form a new component, fig. 6. The sample is fixed with 2 devices (fig. 6), then the two devices will be fixed on the rigid base plate (fig. 5) and finally, all assembly will be fixed on the traction machine, fig. 7 and fig. 8.

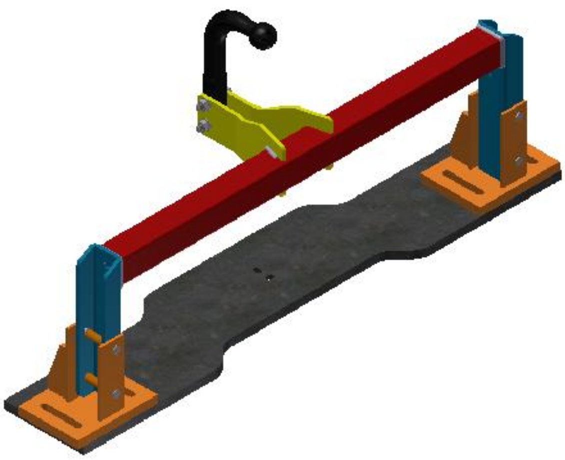

Figure 7: Assembly for traction machine

Figure 8: MTS traction machine

The assembly from figure 7 will be fixed on the support of traction machine with 2 screws. The rigid base plate has 2 holes to be fixed on the traction machine support.

The traction machine is from MTS (fig. 8) and it has 1.000 [kN] maximum capacity. This machine was adapted to do cycles and to give diagrams.
All the assembly was tested at the all loads until it was destroyed. The towing assembly was not broken, but the material was in plastic region. For the 7,5, 15 and 25 [kN] load the assembly worked only in elastic region, but it remained residual stress field.

Figure 9: Vertical caliper measurement

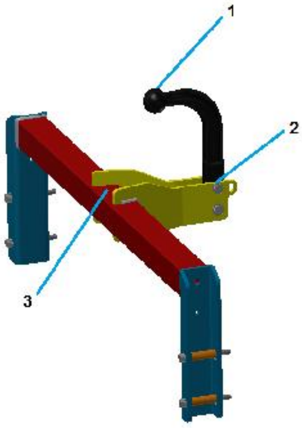

Figure 10: The 3 points measured

Before and after the tests the towing assembly was measured with a vertical caliper (fig. 9) in 3 points (fig. 10), to see the deformations resulting from residual stress. The results are in Table 1, where it can be seen the measurement before and after the 4 tests and in figure 12 it can see how the towing assembly is fixed on the traction machine. For the last column from Table 1, *Ball displacement*, the values were read from diagrams.

Table 1: Experimental determinations values

Load [kN]	Point	Before test [mm]	After test [mm]	Measured deformation [mm]	Ball displacement [mm]
7,5 – 20 cycles	1	514,70	512,76	1,94	5,43
	2	312,60	311,36	1,24	-
	3	310,62	310,78	**-0,16**	-
15 – 10 cycles	1	512,76	511,84	0,92	8,37
	2	311,36	311,16	0,20	-
	3	310,78	311,70	**-0,92**	-
25 – 10 cycles	1	511,84	511,00	0,84	14,06
	2	311,16	310,82	0,34	-
	3	311,70	310,74	0,96	-
50 – 5 cycles	1	511,00	497,00	14	35,00
	2	310,82	308,64	2,18	-
	3	310,74	309,32	1,42	-

For the last test (at 50 [kN]) the towing assembly could not touch 50 [kN] because it was in plastic region, the maximum load was 42 [kN]. After this load the material started to flow, the strain was very high and there was only one cycle.

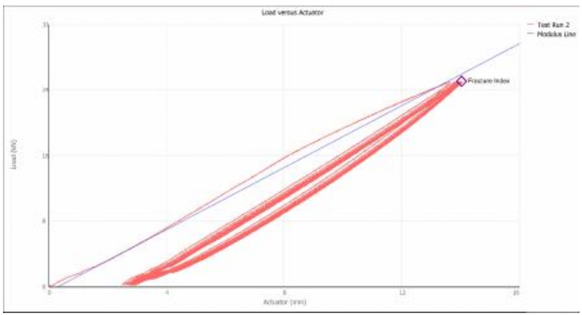

Figure 11: Load – Displacement diagram

Figure 12: Towing assembly fixed on traction machine support

In figure 11 is attached a diagram from traction machine with 25 [kN] load and 10 cycles. For all the tests the traction machine gives this type of diagrams. On diagrams, it can read the maximum load and the maximum displacement. The dates for Table 1 are from these diagrams. Only for 50 [kN] test the diagram appears without cycles, it shows like a normal diagram load – strain or stress – strain.

For simple traction, the machine can make the stress and strain diagram, if it is known the section area.

In Table 1 are 2 negative values because in the square pipe appears a torsion strain, higher than bending strain and the edge of the pipe is moving up. After a higher load the pipe starts to bend and the deformations are positive.

After the last test, when the load was the highest and material was in plastic region, it was discovered that the most deformed part of the assembly was the towbar, and only the towbar was in plastic region. In the past, the same authors demonstrated the strongest section for the towbar is with trapezoidal section and the weakest is with rhombic section. In these experiments, there was used a towbar with round section which is between the two others, but it is the cheapest solution, fig. 13.

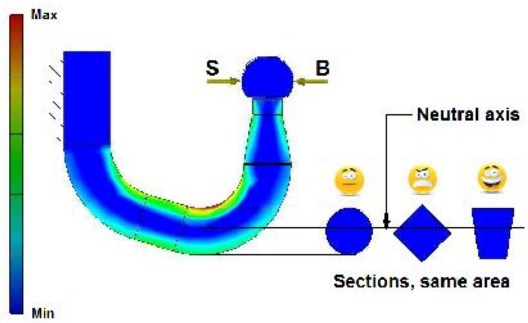

Figure 13: Different sections for towbar

Maybe if we used a towbar with trapezoidal section, the assembly could have been tested at a higher load.

3. CONCLUSION

Table 3: Comparison experimental determinations & FEA

Load [kN]	Point	Experimental Strains [mm]	Virtual Strains [mm]	After test (with load) [mm]
7,5	**1**	5,43	2,03	522,95
15	**1**	8,37	4,06	524,98
25	**1**	14,06	6,77	527,69
50	**1**	35,00	13,54	534,46

In the paper with Finite Element Analysis it was mentioned that the comparison between the both of tests will be attached in this paper, and in the previous table are the values for each load.
It could be read, on the diagrams from traction machine, only the displacement of the ball.

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