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Finite Element Method and Experimental Determinations in Study of Autovehicles Towbars

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Abstract

The work consists in comparing two methods for determining the displacements of the spheres occurred in the towbars used for vehicles, under stress of different forces. First method consists in obtaining the results with Inventor software, and the second consists in experimental determination on a traction machine.

Key words: *towbar, normal stress, force, finite element, displacement*

Introduction

This work is a continuation of a study in which it was calculated the maximum stress in the critical area of the towbar. We studied the behavior of the towbar material at forces of 5, 10, 15, 25 and 50 [kN].

Towbar studied is U-shaped, with circular section, and is used to VOLKSWAGEN TRANSPORTER. Diameter of the bar from which the towbar is made is Ø45 [mm], and the material used is S355 (OL52).

Towbar modeling was done in Inventor software; this software offers also a simulation with finite element method hence resulting displacements occurred after traction.

For the experiments were made five products, respecting the dimensions of the virtual model. They were subjected individually to a force F of 5, 10, 15, 25, 50 [kN].

Displacements Obtained with Finite Element Method with INVENTOR

After creating the model in INVENTOR software, it was started the procedure for determining the displacements. It was considered the towbar embedded on its tail and acted with force *F*, perpendicular on the tail and oriented to the centre of the sphere, the force being in the plane given by the axis of the tail of the hook and the centre of the sphere (figure 1 and figure 2).

Figure 1 shows the value of the maximum displacement, when acted on a circular section towbar with a force of 5 kN.

Also, it is observed that the maximum displacement value is not on the direction of force *F*. The maximum value of the arrow is the point D on the sphere of the towbar, farthest from the point

T (denoted on figure 1), point T being the place where maximum stress of the material occurs, following the traction.

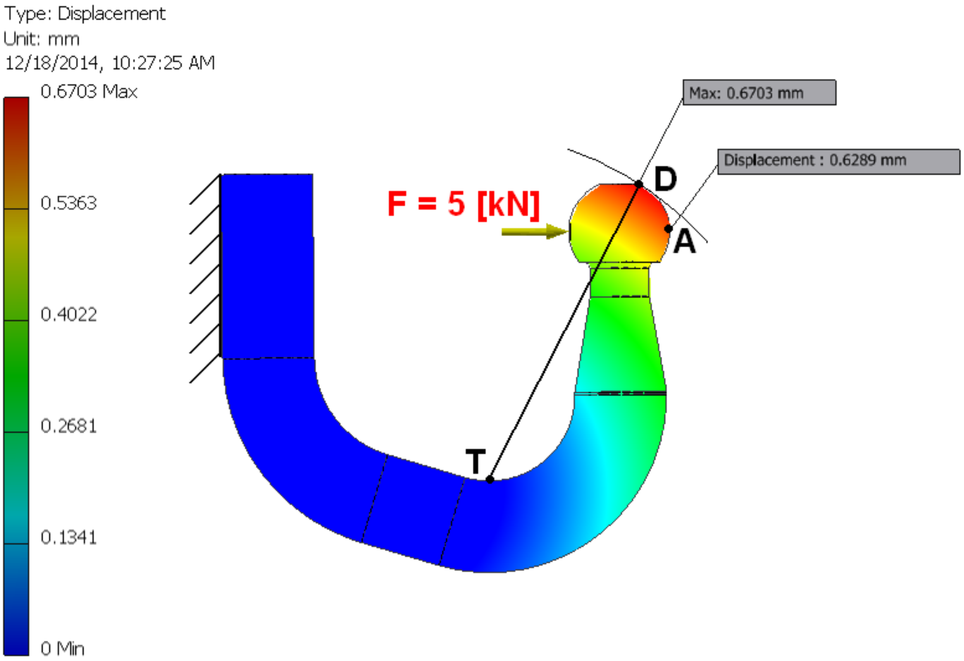

Fig.1. Towbar U shape with F = 5 [kN]

Essential in the work is the displacement of the sphere corresponding to the direction of the force F considering the point A on the sphere, the farthest from the tail of the towbar. The value of displacement of point A can be read also from Figure 1 and Figure 2.

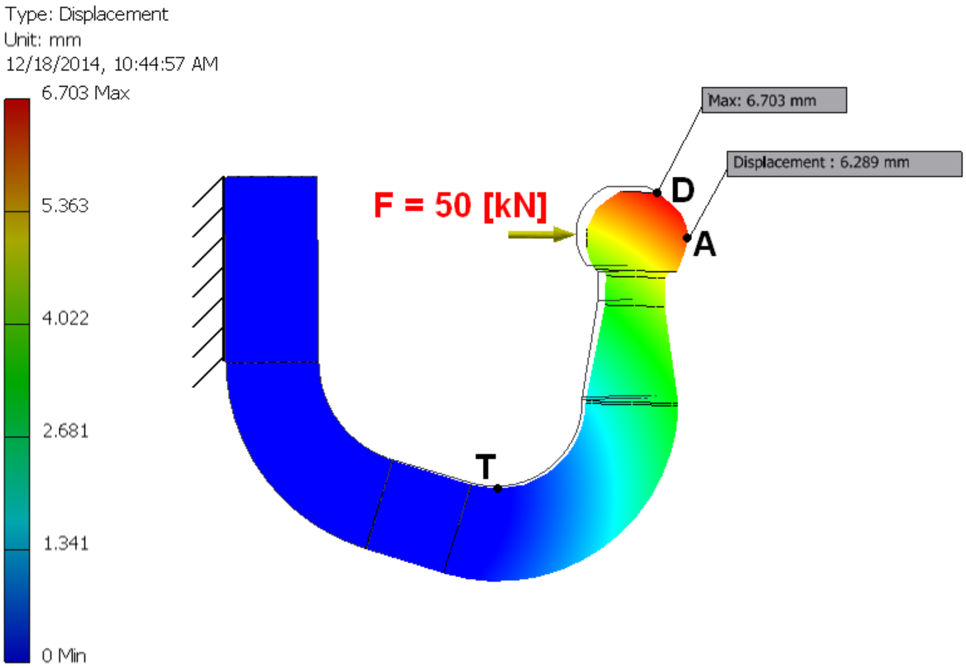

Fig.2. Towbar U shape with F = 50 [kN]

Figure 2 shows the values of maximum displacement (point D), and the displacement corresponding to the direction of force *F* (point A).

The other values of the displacements of point A, corresponding to forces of 10, 15 and 25 [kN] are attached in Table 1.

In the diagram shown in Figure 3, it can be observed the linear variation of displacement of the sphere of the towbar with the increasing force *F*.

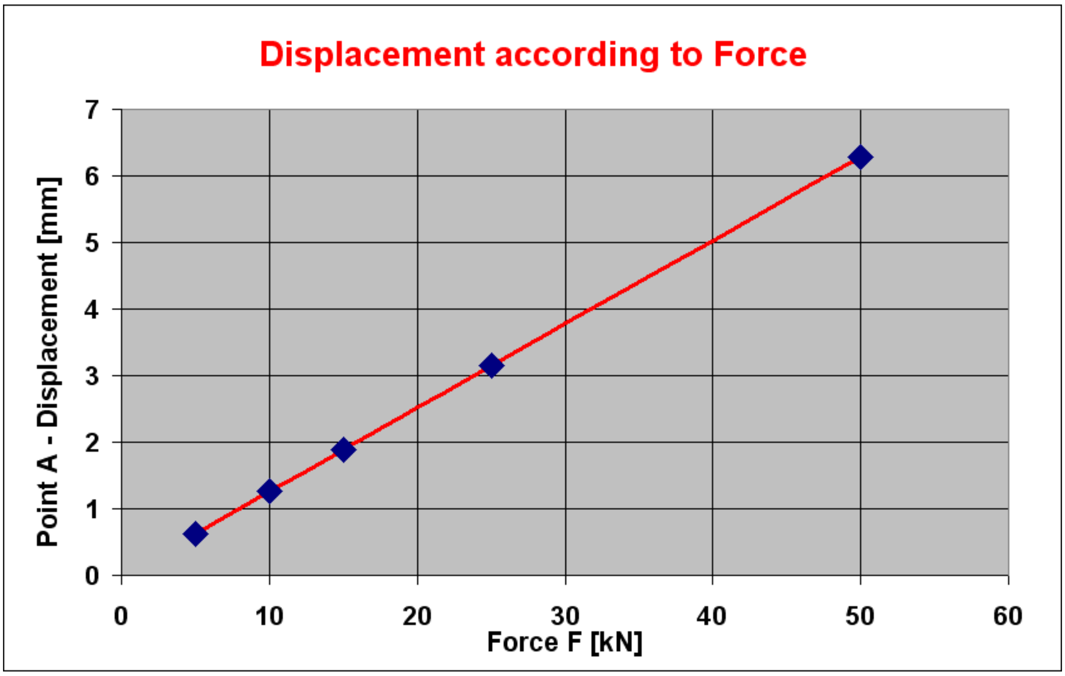

Fig.3. Diagram

Displacements Obtained by Experimental Method

To achieve most accurate experimental determinations, five prototypes towbar were built, similar to the virtual study, each being subject once to a single force. Values of the force at which the towbars were studied are the same, namely 5, 10, 15, 25 and 50 [kN].

Experimental tests were performed on a traction machine with maximum capacity of 1000 [kN], Figure 5.

To be attached to the traction machine, the towbars were equipped with adjustments performed in their spheres and their tails (figure 4). In these adjustments there were introduced two devices, which were fastened in the jaws of the traction machine (figure 5).

Fig. 4. Towbar prototype and adjusted

Fig. 5. Towbar attached in traction machine

For each test on the towbars it was obtained a diagram Force – Displacement. From these it could be read the force acting on the towbar and the resulting displacement.

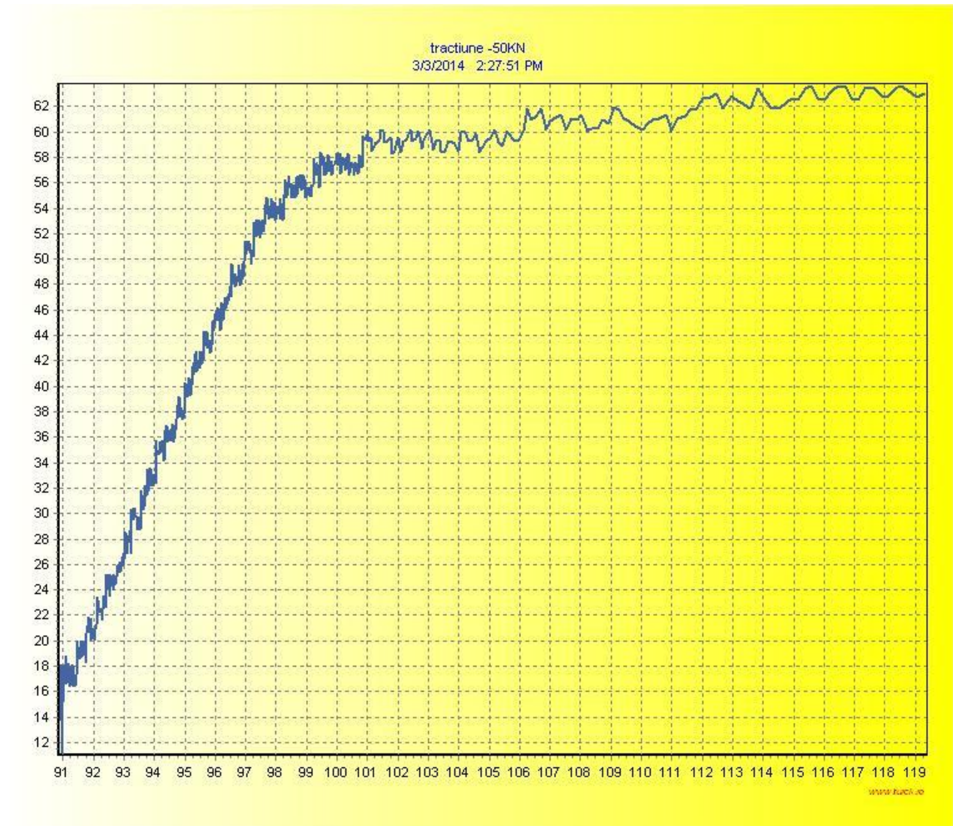

Fig. 6. Diagram from traction machine for F=50 [kN]

In the diagram shown above (figure 6), it can be noticed the entry of the towbar material into the plastic region, when the force has a small variation and the displacement is very high.

Interpretation of the Results and Comments

In Table 1 are comparatively presented the values of the displacements of the sphere of the towbar obtained from INVENTOR software and experimentally.

Table 1. Compared results

Force F [kN]	**INVENTOR Displacement [mm]**	**EXPERIMENTAL Displacement [mm]**
5	0.629	1.5
10	1.258	1.8
15	1.887	2.3
25	3.145	3.5
50	6.289	28

In the diagram in Figure 3 it can be seen a linear increase of displacement, with increasing force. At a force of 50 [kN], this increase cannot be linear, because in reality the material enters in the plastic region and deformation is chaotic

For value of the force of 5 and 10 [kN] there is a difference of over 50% between the two methods. This problem is due to the traction machine, which is not able to work at very low forces, these meaning 0,5 and 1%.

Between the virtual and experimental values of displacement at 15 and 25 force [kN], there are not big differences; however, for better accuracy of results, a traction machine with much smaller maximum traction capacity is needed.

The greatest difference between the results occurs when force of 50 [kN] acts on the towbar. Because of the towbar entering in the plastic region, it undergoes an uncontrolled displacement. INVENTOR software was not able to provide such a displacement and chose to deform the towbar as if it was still in the elastic deformation region.

Another justification for the appearance of the differences in the results may be that, in the software it was considered the towbar embedded on the tail, and in the experiment the towbar is articulated in the two adjustments.

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Metoda elementului finit şi determinări experimentale în studiul cârligelor de tracţiune de la autovehicule

Rezumat

Cârligul de remorcare ales pentru studiu este unul în formă de U, iar acesta se testează simuland accelerarea autovehiculului cu tot remorcă. Modelul realizat este supus la valori diferite ale forţei F: 5 kN, 10 kN, 15 kN, 25 kN şi respectiv 50 kN, rezultând anumite valori ale deplasării sferei.

Analiza cu metoda elementului finit este realizată în soft-ul Inventor, program în care s-a realizat şi modelul cârligului.

După determinarea virtuală a deplasărilor, s-au executat fizic 5 (cinci) cârlige de remorcare şi s-au testat pe maşina de tracţiune la aceleaşi valori ale forţei F: 5 kN, 10 kN, 15 kN, 25 kN şi respectiv 50 kN. Valorile deplasărilor corespunzatoare fiecărei valori a forţei F se citesc de pe diagramele rezultate de la maşina de tracţiune.

Se observă de pe diagrama obţinută de la maşina de tracţiune că la valoarea forţei F de 50 de kN, în testarea experimentală, materialul cârligului este intrat deja în zona de deformare plastică, iar deplasarea sferei este foarte mare; acest lucru nu apare în analiza virtuală cu metoda elementului finit, soft-ul fiind incapabil de a face distincţia dintre zona elastică şi zona plastică. Rezultatele deplasărilor sferei cârligului de remorcare, obţinute pe cale experimentală şi virtuală, la valorile forţei F de 15 kN respectiv 25 kN sunt foarte apropiate:

- $F = 15$ [kN] => $\delta_{virtual} = 1,89$ [mm] ; $\delta_{experimental} = 2,3$ [mm];
- $F = 25$ [kN] => $\delta_{virtual} = 3,15$ [mm] ; $\delta_{experimental} = 3,5$ [mm].