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Stress Determination on Motor Vehicles Towbars Using INVENTOR Software. Practical Calculation Method

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Abstract

The work consists in comparing two methods for determining the maximum stress occurred in the towbars used for vehicles. The towbars have different sections shapes, but the value of their area is the same.

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

Introduction

The towbar represents the connection between the vehicle (puller vehicle) and trailer (towed vehicle); therefore, to prevent traffic accidents, it must be sized appropriately, depending on destination, for each category of vehicle.

For study in this work, it was chosen a U-shaped towbar, like the one used for VOLKSWAGEN TRANSPORTER (fig. 1). Most towbars use as pre-form a bar with circular section. Lately, it could be seen an increase in using as raw material the bar with trapezoidal section, calculations showing it is more convenient. But this form of the towbar complicates a lot the manufacturing technology compared with the circular section.

The design was done in Inventor software that includes a module of simulation using finite elements method, part of the project that was done later.

Fig.1. Towbar U shape on VW Transporter

Stress Determination Using the Finite Elements Method with INVENTOR

Manufacturing technology of the towbars with circular section is the most effective, offering the lowest cost of production. However, in continuation of this study, it is shown that this section is not the optimal in terms of stress.

In Figure 2 is shown the value of the maximum stress, when applying a 5 kN force to a circular section towbar.

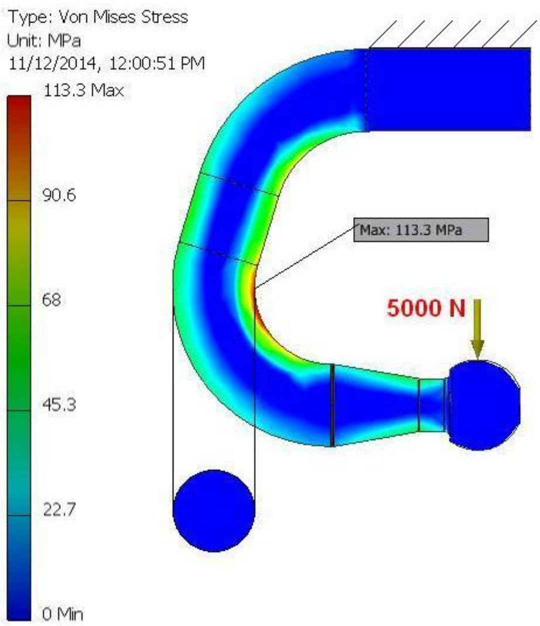

Fig. 2. Towbar U shape and circular section

Figure 3 suggests creation of a quadrate section, having an area equal as the circular section model, but this proves to be a weaker solution, offering a much bigger maximum stress.

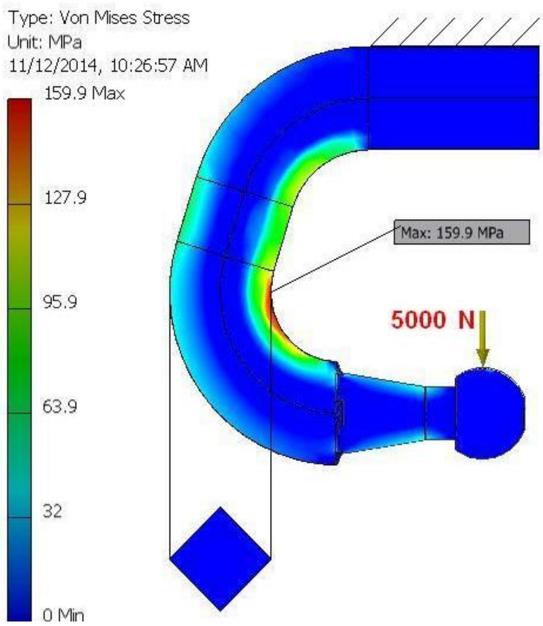

Fig. 3. Towbar U shape and quadrate section

Besides the fact that the quadrate section bended on an edge is inadequate in terms of maximum stress, it is very complex to manufacture; this is proven by the absence of such towbars on the market.

Finally, the third solution that was studied, with a trapezoidal section of the towbar bended on the large base of the trapezium (fig. 4.), offers the safest option functionally. It can be seen a significant decrease of the tension in the critical zone, compared with the circular section.

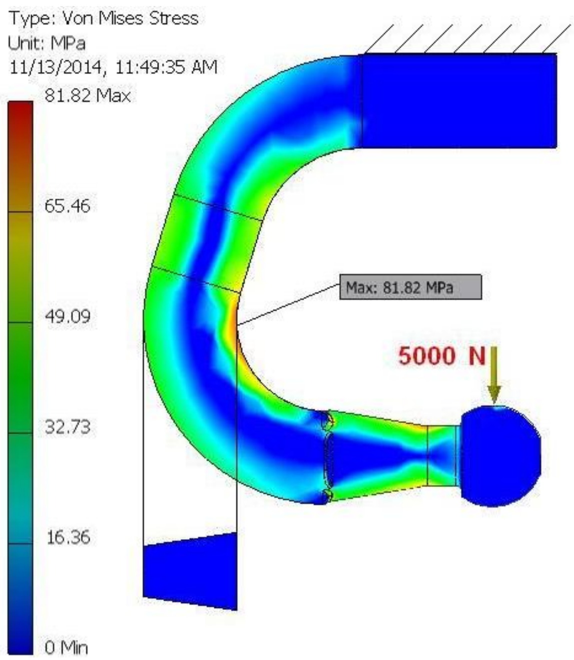

Fig. 4. Towbar U shape and trapezoidal section

This towbar has the disadvantage of the manufacturing cost much higher than the towbar with circular section.

Figures 2, 3, 4 show the maximum values of the tension corresponding to each section, at the same force of 5000 N.

Stress Determination Using Classic Calculation

Material strength calculations for each variant of towbar with specific section were done using the theory of Winkler, for all geometries of the section using the same formula, but with variable parameters.

Because of the small ratio (below 5) between the bending radius of the medium fiber and the diameter of the bar from which the towbar is made, Navier's formula cannot be used in the application.

In Figure 5 are shown the bending diagrams corresponding to each towbar with their own sections, the same as in the simulations with Finite Elements Method; in the same figure are introduced the maximum stresses.

The stress resulted from the action of the traction force is the same because of the constant area of the three different sections:

$$\sigma_{tr} = F / A = 3.1 \text{ [MPa]} \quad (1)$$

To calculate the bending stress of the towbars with the three different sections, it was used the formula:

$$\sigma_{i1} = \frac{M_i}{A \cdot e} \cdot \frac{J_1}{R_1} = \frac{F \cdot (l + R)}{A \cdot e} \cdot \frac{J_1}{R_1} \qquad (2)$$

The obtained bending stresses are:

- circular section: σ_{tr} = 110 [MPa];

- quadrate section: σ_{tr} = 151.2 [MPa];

- trapezoidal section: σ_{tr} = 75.4 [MPa].

The maximum stresses appeared in the critical areas are obtained with:

$$\sigma_1 = \sigma_{i1} + \sigma_{tr} \qquad (3)$$

The maximum stress values are:

- circular section: σ_1 = 113.1 [MPa];

- quadrate section: σ_1 = 154.3 [MPa];

- trapezoidal section: σ_1 = 78.5 [MPa].

The results obtained using classic material strength calculation show that the best variant is the one with trapezoidal section and the worst is the one with quadrate section folded on an edge.

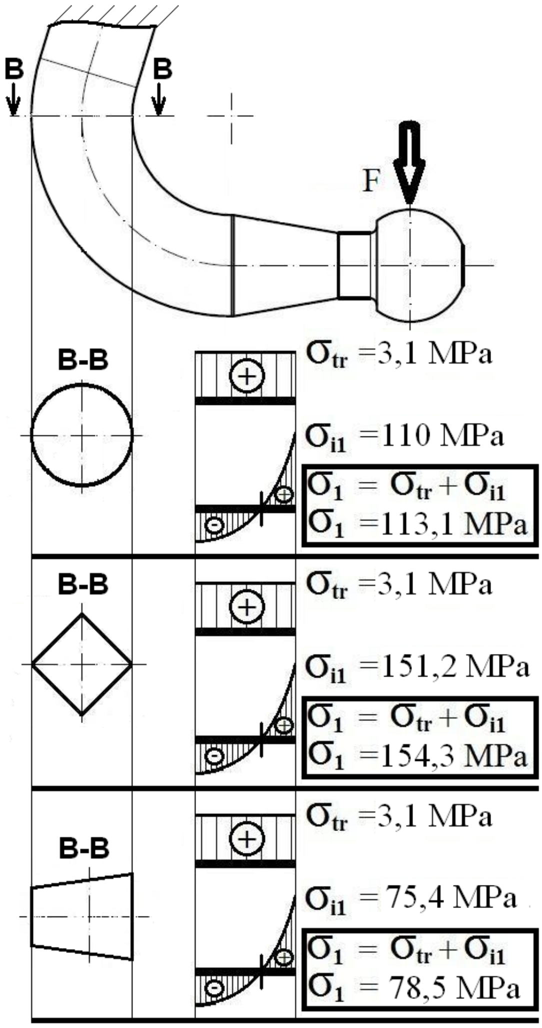

Fig.5. Diagrams & stress values

Results Interpretation and Comments

A very important aspect to be noticed from this study is the fact that, for the same material, with same section area but with different geometry of the section, completely different values of the stress are obtained.

In Table 1 are comparatively shown the stresses appeared in the critical areas as effect of action on the spheres of the towbars with a force of 5000 N.

Table 1. Comparation of the results

SECTION / METHOD	MEF INVENTOR [MPa]	CLASSICAL CALCULATION [MPa]
CIRCULAR	113.3	113.1
SQUARE	159.9	154.3
TRAPEZOIDAL	81.8	78.5

The results obtained using the two different methods are very similar. A difference of 5.6 [MPa] appears for the towbar with quadrate section, though it is not significant.

Both calculation methods confirm that the safest in functionality, with the lowest value of the stress in the critical zone, is the towbar with trapezoidal section. As well, the less performing variant out of the three studied, is the one with quadrate section bended on an edge.

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Determinarea stării de tensiune la cârligele de remorcare ale autovehiculelor cu soft-ul INVENTOR. Metodă practică de calcul

Rezumat

În prima etapă s-au ales dimensiunile cârligului de remorcare, apoi s-a creat modelul în soft-ul Inventor, având secţiunea circulară. În modulul simulării cu metoda elementelor finite, ale aceluiaşi soft Inventor, s-a configurat cea de-a doua etapă, încercarea statică.

Pe modelul proiectat s-a acţionat pe sfera cârligului cu forţa F de 5 kN, iar rezultatele obţinute sunt:

- *tensiunea maximă:* $\sigma_{max} = 113,3$ *[MPa];*
- *deplasarea maximă:* $\delta_{max} = 0,677$ *[mm].*

În fine, cea de-a treia etapă constă în încercarea de a se optimiza pe cât posibil secţiunea cârligului, păstrand aceeaşi valoare a ariei secţiunii, rezultand aceeaşi masă a cârligului; s-a ales o secţiune în formă de patrat, îndoit după o muchie şi încă una trapezoidală.

După determinarea tensiunilor în soft-ul Inventor, pentru diferite secţiuni, a urmat calculul clasic de stabilire a tensiunilor maxime apărute în zona critică, aplicându-se teoria lui Winkler.

Rezultatele obţinute prin cele două metode diferite sunt foarte asemănătoare. Cârligul cu forma trapezoidală a secţiunii are valoarea tensiunii maxime cea mai mică, comparativ cu celelalte două variante constructive; cârligul cu forma patrată a secţiunii şi îndoit în jurul unei muchii oferă cea mai slabă variantă constructivă dintre cele trei studiate, dând valoarea cea mai mare a tensiunii în zona critică.