Designing a Chassis-Type Structure Form using Beams of Equal Resistance

ION FLORIN POPA
Department of Material Sciences, Mechatronics and Robotics
VALAHIA University from Târgoviste
Bd. Carol I nr. 2, Târgoviste, Dâmbovita
ROMANIA
p.florin.ro@gmail.com

Abstract: The scope of this paper is to show a method of modelling the beams (girder) of equal resistance, given the fact that this type of structure suits best to the requirements regarding resistance, constructive simplicity, (when an open profile of the structure is used) and polyfunctionality. By using the NISA solver and the expert language EUCLID, it has been determined the deformation areas, the tension areas and the displacement area of the chassis-type structure.

Key-Words: chassis-type structure, beam (girder) of equal resistance, Mathematical modelling

1 Introduction

The chassis panel is one of the main parts of the motor vehicle; engine transmission, suspension, shafts steering and body are mounted on the chassis. The chassis frame assures the supporting connexion between front and rear shaft; it takes over all kind of stress which appear during driving traction, bend, oscillation and torsion. The conditions provided for a chassis frame of an off-road motor vehicle are:
- reduced mass, high stiffness to support stress;
- simple construction which allows an easy mounting and fixing of other units and body;
- the diversity of mounting possibilities shall assure an optimal arrangement of the motor vehicle’s components so that the centre of gravity is low and maintains the prescribed ground clearance level;
- a low prime cost; - an increased flexibility to twisting strength.

2 Modelling of the chassis type structure form with beams of equal resistance

The modelling of the chassis type structure form, assumes an optimal dimensioning of the chassis frame components depending on the stress values existing on the whole structure. In this manner, an equal resistance type of structure is obtained.

The side member is considered as a beam leaned against the axle shafts by means of flexible elements.

The modelling assumes following steps:
- applying the stress obtained by calculation, on the whole length of the chassis beam;
- calculation of the cutting force diagrams “T” and of bend moments “M” on the whole length of the chassis beam;
- calculation of the resistance manner of the “W” beam profile, from the equal resistance condition;
- modelling of the beam profile geometric dimensions;

From economical point of view, the beams with variable section have a considerable practical importance.

For a beam with constant section, the calculation resistance $\theta_{\text{max}}$ is obtained only in the extreme fibres of the section with maximum bend moment; in all the other sections the material is not stressed to its possibilities.

Therefore, in order to realise a beam with a small quantity of material the dimensions of the transversal sections can be reduced, according to the decrease of the bending moment. When a variation of transversal sections dimensions is chosen where in each transversal section of the beam the maximum normal tension is the same, we obtain a GER for bend.

The form of the equal resistance beam for a maximum unitar effort is given by following relation:

$$W_z(x) = \frac{M_i(x)}{\sigma_{\text{max}}}, \quad (1)$$

where $M_i(x)$ and $W_z(x)$ are functions of the diagram having as the abscissa the position of the section.

A certain form of the section being imposed, so that its dimensions shall be determined by a single parameter, from equation (1) the law of variation for this parameter
will be obtained throughout the whole length of the beam: for a beam of rectangular section, with constant width \(b\) and variable height \(h(x)\), related to the beam abscissa, the relation (1) becomes:

\[
\frac{b \cdot h^2(x)}{6} = \frac{P \cdot x}{\sigma_{\text{max}}} \Rightarrow h(x) = \sqrt{\frac{6 \cdot P}{b \cdot \sigma_{\text{max}}} \cdot x}
\]

(2)

The height GER will vary following a parabolic law. Near the free end of the beam, the bending moment has low values. Here the section height results from the resistance condition given by the equation:

\[
\frac{3 \cdot P}{2 \cdot b \cdot h} = \sigma_{\text{max}}
\]

(3)

where:

\[
h = \frac{3 \cdot P}{2 \cdot b \cdot \sigma_{\text{max}}}
\]

(4)

In practical cases, due to the difficulties to realize the ideal form of equal resistance, forms close to this are admitted for the beams. For the metal beams with compound section, forms can be used where the height varies and the base area is maintained constant. The determination of the transversal section dimensions results from the resistance condition:

\[
W_{\text{necessary}} = \frac{M_{\text{max}}}{\sigma_a}
\]

(5)

The beam section is built up on bases of economical, technological and constructive consideration.

### 3 Determination of the static bend produced by payload. Modelling of the side-member form

Hereunder, the calculations have been made for an Aro 10 chassis, with in-larged wheelbase. The motor vehicle is loaded to the constructive payload and is on a smooth, horizontal running track.

The forces obtained from the equilibrium condition of the moments, will act upon the sidemember. These forces are:

\[
F_{pf} = 357,98 \text{ daN} \\
F_{ps} = F_{ps1} + F_{ps2} = 567 \text{ daN}
\]

where

\[
F_{ps1}=266,67\text{daN} \\
F_{ps2}=300,33\text{daN}
\]

Fig.1 shows the cutting forces diagram and the bending moment diagram for this calculation manner.

The sidemember has an imposed form of its section; so the sidemember diameter can be determined by means of a single parameter and then from equation (1) you can obtain the variation law of this parameter throughout the length of the beam. Therefore, a sidemember of equal resistance can be realized.

For the sidemember a “U” profile is used, having the section as shown in Fig.2.
This profile has a constant width of the section $B = 70\text{mm}$, and a thickness of the material of $g = 3\text{mm}$. The steel is OL37. The resistance admitted for this material is $1200 \text{daN/cm}^2$. The variation law of the resistance mode (manner) throughout the length of the side member is shown in Table 1.

<table>
<thead>
<tr>
<th>Coord. X [mm]</th>
<th>$M_i(x)$ [daNm]</th>
<th>$W_z(x)$ [cm$^3$]</th>
<th>$H(x)$ [mm]</th>
</tr>
</thead>
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<tr>
<td>-430</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-120</td>
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<td>1,93</td>
<td>14,2</td>
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<td>6,05</td>
<td>32,9</td>
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<tr>
<td>815</td>
<td>115,65</td>
<td>9,63</td>
<td>47,8</td>
</tr>
<tr>
<td>840</td>
<td>118,25</td>
<td>9,85</td>
<td>48,5</td>
</tr>
</tbody>
</table>

Table 1

The resistance mode for the given profile is as in the relation (6):

$$W_z = \frac{B \cdot H^3 - b \cdot h^3}{6 \cdot H} \quad (6)$$

where replacing:

$$h = H - 2g \quad (7)$$

we obtain:

$$W_{z(x)} = \frac{B \cdot H^3(x) - b \cdot (H(x) \cdot 2 \cdot g)^3}{6 \cdot H(x)} \quad (8)$$

Equalling the relations (1) with (8) we obtain the dimensional parameter variation $H$ of the side member according to the bending moment applied as shown:

$$H^3(x) + 40,2 \cdot H^2(x) - [24,12 + 0,0166 \cdot M_i(x)] \cdot H(x) + 4,824 = 0 \quad (9)$$
Starting with the results formerly obtained, a mathematical modelling of the chassis form was achieved, using the facilities of the expert language EUCLID, for defining the geometry and the preprocessor NISA for defining the chassis structure, in order to discreteting it.

Further, using the solver NISA the deforming areas, the tension areas and the displacement areas resulted from the imposed loads and coercions, have been determined, in order to optimize the studied structure. Fig. 3 shows the discreted structure of the chassis.

4 Conclusion
Following results have been obtained:
- the suggested chassis has an increased rigidity (compared to the serial chassis)
- the max bend deformation arch is below 2mm, in most sever stress conditions;
- the economical efficiency of the side member section of equal resistance is higher compared to those of the serial chassis;
- the increase of efficiency of the suggested side member profile, involves a mass reducing of 4.6kg/side member;
- simmulation of the chassis behaviour using NISA program, permitted the side member sections optimization and their rational use according to the external solicitations applied.

The resistance mode of the side member increases with 12.7% in the main zone, with 22.5% in the frontal axle zone and with 38.2% in the rear axle zone.

References: