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СОПРОТИВЛЕНИЕ И ТВЕРДОСТЬ МЕТАЛЛИЧЕСКИХ ВИНТОВЫХ СПИРАЛЬНЫХ ПРУЖИН Ф31ММ, ПРЕДНАЗНАЧЕННЫХ ДЛЯ ПОДВЕСНЫХ ТЕЛЕЖЕК Y25LSDI, УСТАНОВЛЕННЫХ НА ТОВАРНЫХ ВАГОНАХ

On the strength and reliability of Φ31mm metallic helical springs, used for Y25Lsdi bogie suspension mounted at freight cars

Generalities

The elastic metallic elements, under the form of helical springs, torsion springs and laminated springs, are used, on a large scale, as suspension elements, for railway vehicles. Just as the other types of elastic elements used for suspensions, the metallic springs are machinery parts with a high degree of elasticity. Due to their elasticity, these elements stock a deformation energy, the greatest part of which, when the load action ceases, being given back to the mechanical system, as kinetic energy. The above mentioned characteristic, as well as, the conditions imposed to suspension (in vertical and horizontal planes, the space available for spring mounting, type of load impact) lead to different types of springs [1], [8], [3], [5], [4].

Compared with the laminated springs, the helical springs, as well as, the torsion springs have a high degree of material economy, the manufacturing and repairing technology is, relatively, simple, need no maintenance operations and are sensitive to small disturbances.

Finite element method for stress analysis by ALGOR program

Presentation of ALGOR program

In order to establish the compatibility pf the analyzed model, several analytical techniques are available. The Superview IV Results program permits access to these techniques, offering, at the same time, both gross stresses, in local coordinates, and many values derived from them. The derived values include von Mises and Tresca criteria, stresses minimum and maximum principal, as well as, the elements specific results. Because the accuracy of analytical results depends on the way the digitization was chosen and MEF parameters were applied, Superview IV Results program offers an estimation of precision in common nodal points [6]. This value of precision helps to establish the model compatibility.

Further, the following stresses offered by the program, will be defined:

Von Mises stress

The results will be displayed under the form of Von Mises equivalent stresses. They can be displayed for surface elements (2-D, plates, etc.) and for volume elements.

The equation used is the following:

$$\sigma_e = \sqrt{0,5 \cdot \left[(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2 \right] + 3 \cdot \left(\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2 \right)} \qquad (1.1)$$

Where, σ_X, σ_Y and σ_Z are axial stresses, in global directions, and τ_{XY}, τ_{YZ}, τ_{XZ} (Fig. 1.1) are cross forces. The Von Mises stress is, always, positive. Depending on the stresses principal σ_1, σ_2 and σ_3 , Von Mises equivalent stress is given by the relation:

$$\sigma_e = \sqrt{0,5 \cdot \left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \right]} \qquad (1.2)$$

Mohr Circle

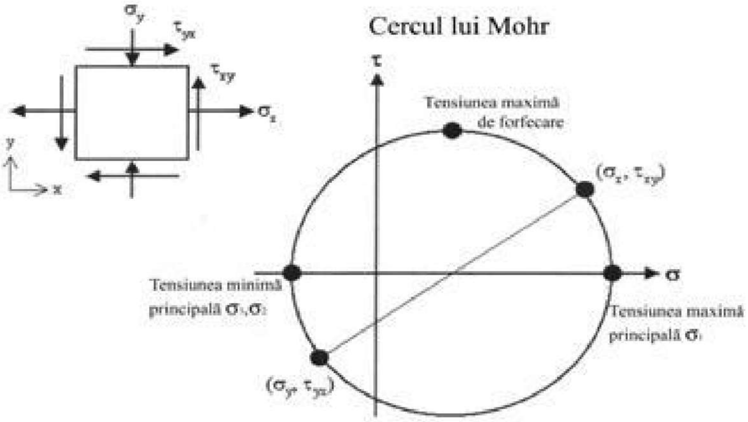

Fig. 1.1. Stress condition of an element and
Mohr Circle - minimum principal stress (σ_3)

Displays the minimum principal stresses (σ_3). It can be displayed for surface elements (2-D, plates, etc.) and for volume elements. The sign (+) indicates an elongation and the sign (-), a compression (Fig. 1.1).

- intermediate principal stress (σ_2)

Displays the intermediate principal stresses (σ_2). This is the stress in normal direction, at stresses minimum and maximum principal. It can be displayed for surface elements (2-D, plates, etc.) and for volume elements. The sign (+) indicates an elongation and the sign (-), a compression (Fig. 1.1).

- maximum principal stress (σ_1)

Displays the maximum principal stresses (σ_1). It can be displayed for surface elements (2-D, plates, etc.) and for volume elements. The sign (+) indicates an elongation and the sign (-), a compression (Fig. 1.1).

- Stresses tensor

It displays, in the selected direction, the stress components. It, practically, uses both the stress tensor and the local components of stress. The stress tensor can be displayed for surface elements (2-D, plates, etc.) and for volume elements.

Direction xx – the components of the stress tensor which represents the normal stress in the direction x. The sign (+) indicates elongation, the sign (-), compression.

Direction yy – the components of the stress tensor which represents the normal stress in the direction y. The sign (+) indicates elongation, the sign (-), compression.

Direction zz – the components of the stress tensor which represents the normal stress in the direction z. The sign (+) indicates elongation, the sign (-), compression.

Direction xy – the components of the stress tensor which represents the shearing stress in the plane xy (x indicates the normal direction; y indicates the direction of the shearing stress). The sign (+) indicates elongation, the sign (-), compression.

Direction yz – the components of the stress tensor which represents the shearing stress in the plane yz (y indicates the normal direction; z indicates the direction of the shearing stress). The sign (+) indicates elongation, the sign (-), compression.

Direction zx – the components of the stress tensor which represents the shearing stress in the plane zx (z indicates the normal direction; x indicates the direction of the shearing stress. The sign (+) indicates elongation, the sign (-), compression.

Calculation for Y25Lsdi bogie suspension helical springs

The calculation was done for the helical springs of the bogie suspension, used for freight cars, with coils having a diameter of Ø 31mm. The load impact type is of axial compression. The analyzed spring was supported, in transversal section, on the end of the bogie pivot, the compression forces being applied on the opposite end, according to the operational situation.

The spring was digitized in volume elements (brick and tetrahedron), with 3483 nodal points, having 7485 digitization elements; the force applied was of 49000N.

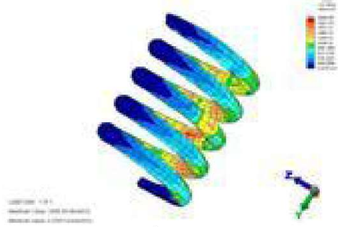

Fig. 2.1

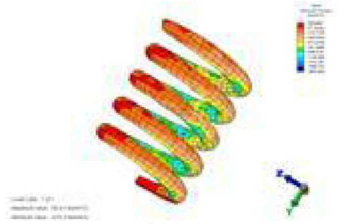

Fig. 2.2

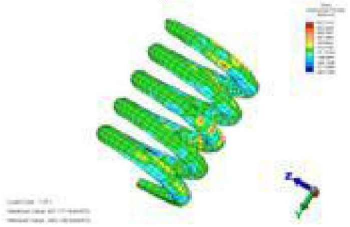

Fig. 2.3

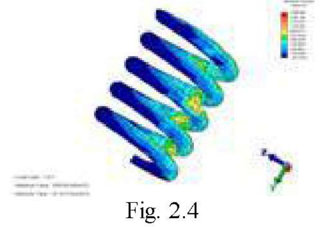

Fig. 2.4

The mechanical characteristics of 50CrV4 steel used for springs are the following:

yield limit $R_{p02} = 1511$ N/mm^2

fracture strength $R_m = 1636$ N/mm^2

The maximum tensile stresses, in all analyzed situations, are with, at least, 24% under the yield limit value of 1511 N/mm^2, this way, the possibility of a crack occurrence being eliminated.

The results are presented in Table 2.1 and in figures 2.1 – 2.4

Table 2.1.

Calculated stresses	Spring Ø 31mm	
	σ_{max} [N/mm^2]	σ_{min} [N/mm^2]
Von Mises stresses	1672	0,27
Stresses maximum principal	1150	-28,14
Stresses intermediate principal	408	-37,17
Stresses minimum principal	156,40	-1128,58

The spring camber is of 100mm.

A theoretical calculation, obviously, demonstrates that, since the admissible values required by the materials used for fabrication are not exceeded, the spring will resist in operation.

Endurance tests

Table 3.1 presents the pulse operation of Φ31mm metallic helical springs used for Y25Lsdi bogie suspension, at freight cars [5], [9].

The endurance tests presented in Table 3.1 were performed in accordance with German norms DB no. Fwg 696.0.02.023.002. These norms comply with the European ones.

Table 3.1

Compression springs (exterior Φ31)					
Load increment	Length under static load [mm]	Upper stroke [mm]	Lower stroke [mm]	Stroke [mm]	Number of cycles
1.	$L_1 = 200$	$L_0 = 210.5$	$L_u = 189.5$	±10.5	$2.0 \text{ x } 10^6$
2.	$L_1 = 200$	$L_0 = 212.6$	$L_u = 187.4$	±12.6	$1.0 \text{ x } 10^6$
3.	$L_1 = 200$	$L_0 = 216.7$	$L_u = 183.3$	±16.7	$1.0 \text{ x } 10^6$

During the endurance tests, the pulse operation was checked-up and the number of cycles was counted. The results of these tests are presented in Table 3.2.

Table 3.2.

Compression springs (exterior) Ø 31		
Spring no.	Number of cycles	Remarks
1	4000000	Load increment 1-3 passed
2	4000000	Load increment 1-3 passed
3	4000000	Load increment 1-3 passed

Analyzing the experimental results, we have come to the conclusion that the …31mm springs positively answered to the endurance tests and, that no defects, cracks or fractures were found out.

Conclusions

As a conclusion, we may state that the Ø 31mm springs have presented calculated stresses positioned within the limits imposed by the mechanical characteristics of 50CrV5 steel. A corresponding reliability of these types of elastic elements for railway vehicles bogies can be obtained and guaranteed by means of strictly observing the mechanical characteristics of the material. In other words, an adequate reliability can be obtained by means of observing the manufacturing technology, the thermal treatment rules, as well as, the peening treatment technology.

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