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Issue Article

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THE STRESSED AND DEFORMED STATE OF A LOADED TENSION SPRING

Abstract: *The results of numerical simulation of the cylindrical spring stretching process are presented in the article. The dependences of the degree of stress and strain of the material along the coordinate planes on the spring displacement are obtained.*

Key words: *spring, component, displacement, strain, stress.*
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Introduction

Tension springs are elastic elements of machines and mechanisms used to perform reciprocating movements, for example, executive organs [1]. During operation, the spring undergoes a combined deformation, in the form of bending and torsion [2], which disappears after the load is removed. Repeated variable loads on the tension spring cause a material fatigue effect characterized by the accumulation of micro damages in the material [3-5]. Therefore, the calculation of stresses and strains in the material is important for determining changes in geometric parameters and durability of the spring [6-10].

For a full-fledged analysis of the loaded state of the tension spring, calculated von Mises stress values were recorded from a three-dimensional model of the elastic element and strain values of the material along the coordinate planes were compared.

Materials and methods

To determine the degree of stress and strain of the loaded cylindrical spring, a mathematical calculation was performed in a special application. The spring model consisted of a wire with a diameter of 10 mm wound in a spiral. The outer diameter of the spring model was 100 mm with 3 coils. The axial spring pitch was adopted by 30 mm. AISI 4340 steel was adopted as the material of the cylindrical tension spring. A constant load acted on the model along the Z axis, leading to the stretching of the spring by a predetermined distance relative to the total length of the spring (by 20 mm). The load cycle was applied once in the calculation.

Orientation of the spring model in space is shown in the Fig. 1.

Figure 1. Orientation of the spring model in space.

Results and discussion

The results of calculating the loaded state of the cylindrical tension spring are shown in the Figs. 2-4.

Along the length of the spiral, when the spring is loaded, a cyclic displacement of the coils occurs. In this case, the displacement of the spring is carried out asymmetrically. On the one hand, the displacement of each coil occurs by a distance of 7 mm, on the other hand, the displacement of each coil occurs by 1.5 mm.

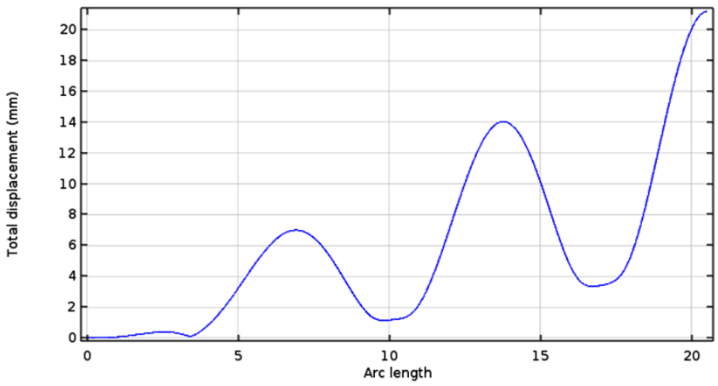
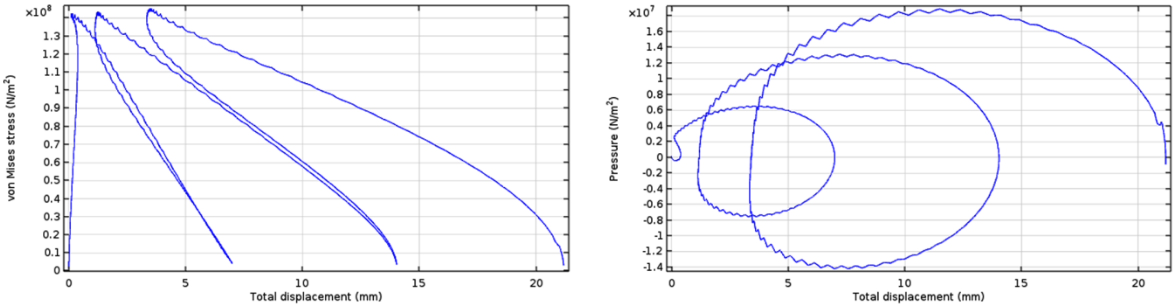


Figure 2. The dependence of the total displacement of the spring on the length of the spiral.

The stress characteristic of the tension spring material can be traced by the change in the von Mises stress and pressure values from the length of the spiral. Each coil of the spring is subjected to almost the same maximum stress. At the same time, each subsequent coil of the spring is loaded more smoothly along the length of the spiral. Loading cycles from the minimum value (relaxation zone, smoothed function) to the maximum value are marked. The dependence of pressure in the material on the total displacement of the spring demonstrates the nature of deformation of the material. Positive pressure values determine the tensile strain, negative values determine the compression strain. Thus, it can be seen that the spring undergoes both stretching and compression to the same extent.



a b

Figure 3. The dependences: von Mises stress on the total displacement of the spring (a) and pressure on the total displacement of the spring (b).

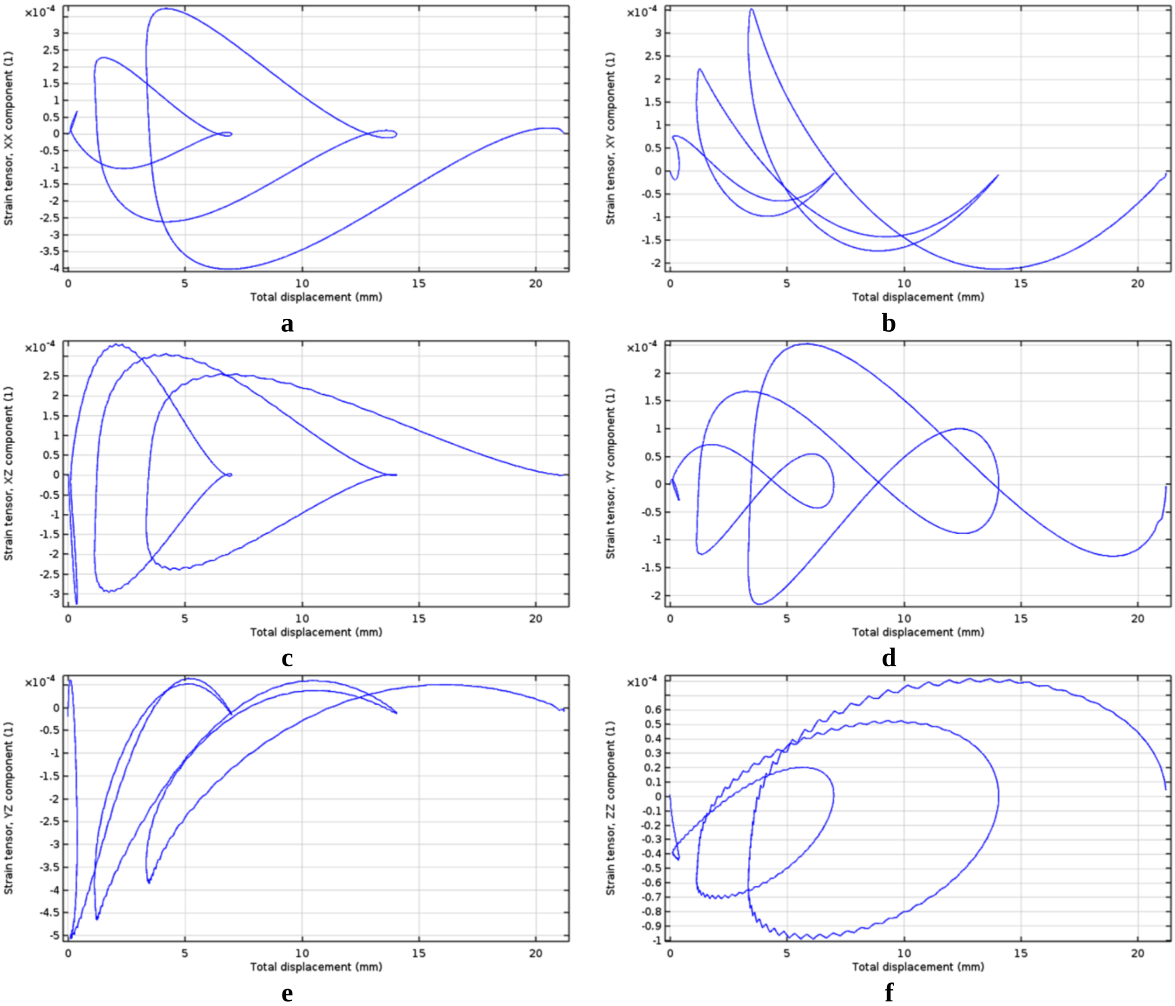


Figure 4. The dependencies: strain tensor, XX component on the total displacement of the spring (a); strain tensor, XY component on the total displacement of the spring (b); strain tensor, XZ component on the total displacement of the spring (c); strain tensor, YY component on the total displacement of the spring (d); strain tensor, YZ component on the total displacement of the spring (e); strain tensor, ZZ component on the total displacement of the spring (f).

A more detailed description of the nature of deformation of the spring material is provided by the components of the strain tensor.

The strain tensor is a tensor that characterizes compression or stretching and shape change at each point of the body during deformation.

In each case, the value of strain along the coordinate planes is no more than 0.001. Stretching and compression deformations of the material are noted for all components of the strain tensor. Each subsequent coil of the spring is subjected to strain to a greater extent, with the exception of material strain occurring in the XZ plane. The greatest strain is noted in the YZ plane in the form of a predominant compression of the spring material. At the same time, the functions of changing the shape of the loaded spring in the YY and ZZ planes are unique, compared with the same type of changing the shape of the loaded spring in other planes.

Conclusion

Based on the analysis of the calculation results, the following can be noted:

1. The stretching of the cylindrical spring is accompanied by a cyclic displacement of the material along the length of the spiral.

2. In the loaded spring, there are local relaxation zones of the material, marked when the elastic element is displaced by 7, 14 and 22 mm, relative to the length of the spiral. At the same time, in the least loaded zones of the spring material, the smoothness of the stress dependence on the displacement value is noted.

3. The degree and type of strain were determined by the strain tensor. The spring is most deformed in the YZ plane with a predominance of compression deformation. For the remaining components of the tensor, an almost uniform symmetrical compression and stretching of the spring material is observed.

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