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Analysis of Stress-Strain State of the Plate Spring

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***Abstract*— The plate spring is the most important elastic element of friction automotive connectors. Therefore the analysis of the tension and deflection springs of great importance. In this paper, in the software package Autodesk Inventor, we made a model of the plane plate spring, and did the analysis of the stress-strain state and presented the results. Also we did the analysis of the influence of the thickness of the spring and the values of the outer and inner diameter on the intensity of stresses and displacements and corresponding conclusions were drawn.**

***Keywords*— couplings, springs, stress, strain**

I. INTRODUCTION

Friction, clutch, couplings are used to for transmission of torque from input to output shaft. Function of these couplings is performed by friction force between friction surfaces. Tuning on of these coupling is performed by coupling of friction surfaces, and turning of is performed by decoupling of frictions surfaces. [1] – [5].

Design shape of car clutch coupling has evolved during the history influenced by many different factors: available materials, wanted action velocity, wanted speed of the vehicles, innovations in clutches design and possibility of choosing advanced materials used for friction surfaces.

Clutch and its turning on mechanism consist of many components which are used for force transmission: springs, rods, braces, brackets and etc. The most important part of the clutch is Belleville spring. This spring makes necessary load between pressure plate, friction disk and fly-wheel.

Belleville spring consist of circular disks with conic shape. Cross-section of Belleville spring circular disk is shown in Figure 1.

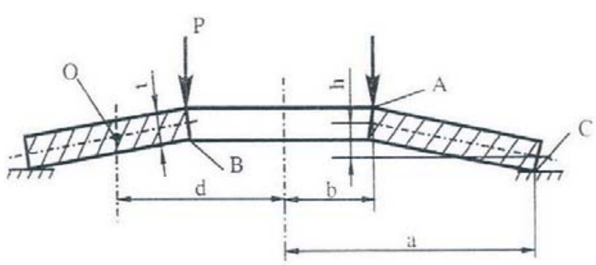

Fig. 9 Cross-section of Belleville spring

When the spring is loaded, as indicated, the disc tends to lose its conic shape. That is an elastic deformation which represents the essence of spring frictional effects [1].

Characteristic of load - deflection disc spring depends on the change of the relations of the initial height of the cone (h) and disk thickness (t). It is assumed that the spring is usually dependent on the step-carriers or mats are placed so that it is possible to achieve the deflection is greater than the height of the cone (h).

II. STRESS AND STRAIN ANALYSIS OF BELLEVILLE SPRING

Systems for computer-aided design or CAD systems are assemblage of software tools and technologies that the engineers provide a number of benefits during the work on the development of products design. Inventor software is primarily intended for the needs of design in mechanical engineering. In addition it allows modeling of parts, generation of technical documentation and various calculations and simulations.

The chosen Belleville spring, according to standard DIN 2093 [3], has following dimensions: h=1,0 mm, t=2,2 mm, a=20,2 mm, b=10,7 mm (dimensions are given on Fig. 1). Chosen material characteristics, Č 4830 (50CrV4), are: $E=2{,}1\cdot 10^5$ MPa; ν=0,3.

In modeling the Belleville springs it is starting from sketching half-section. Revolution of half section is performed. Model shown in Figure 2 is the final result of preformed operation in Inventor.

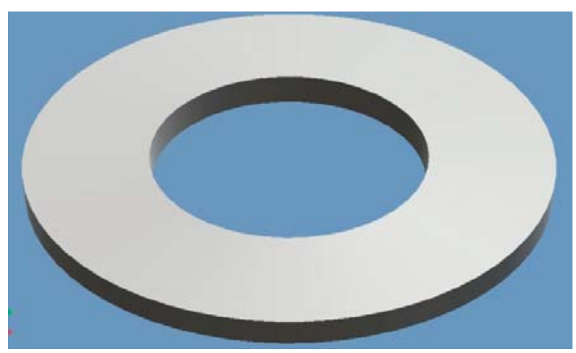

Fig. 2 CAD model of Belleville spring

Autodesk Inventor software is used to analyze the stress state Belleville springs with finite element method. Analysis of the load in Autodesk Inventor helps in understanding the functioning of the mechanical parts under load, so that it can check whether the part operates within the specified conditions, without failure.

In order to do analysis of selected Belleville spring, it is necessary to generate a finite element mesh (Figure 3).

The mesh can be created manually or automatically, or be automatically created meshes can be manually changed.

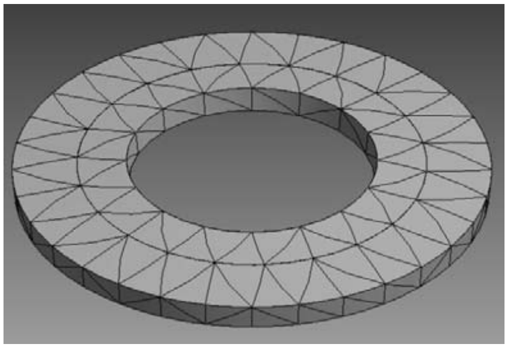

Fig. 3 Mesh generation

The force which is required for bringing the spring into a flat position is equal to F = 10712.520 N [4]. This force is set to act vertically in the axial spring direction equally distributed at all points along the upper edge of the inner springs and vertically upwards evenly distributed in all points of the lower outer edge (Figure 4).

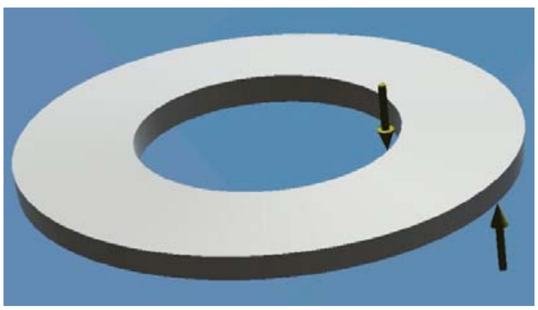

Fig. 4 Load schematics

Based on the constraints imposed by the applied program was defined and fixed point precisely those on which are carried imagined rotation of each cross section of the spring. They are located on the center line of each characteristic cross-section and at a certain distance d from the axis of the spring (Figure 5).

Distance of point O (about which rotation center of the spring cross-section) from the axis of the analyzed spring is d = 14,80 mm [4].

About this fact should be taken into account when considering the results obtained displacement as the total deflection certain point springs obtained by adding the appropriate deflection points with internal and external parties in relation to a fixed point O.

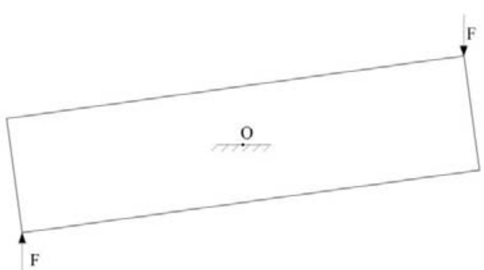

Fig. 5 Constraints used in the analysis

Stress and strain state is shown respectively in Figures 6 and 7.

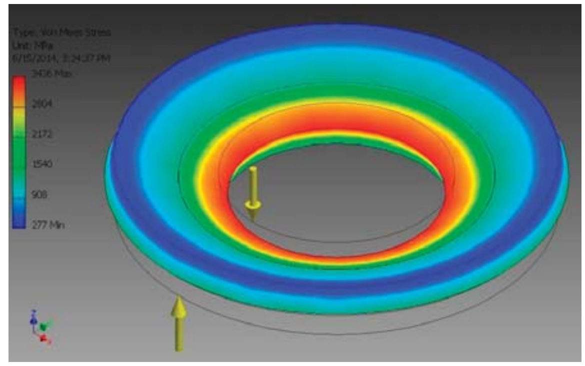

Fig. 6 Von Misses stress of Belleville spring

From Figure 6 it can be seen that the distribution of the equivalent stress corresponds to the expected distribution: maximum stress values are in the upper inner edge of the spring, followed by stresses in the lower outer edge and the lower inner edge, and the lowest stress are in the upper outer edges.

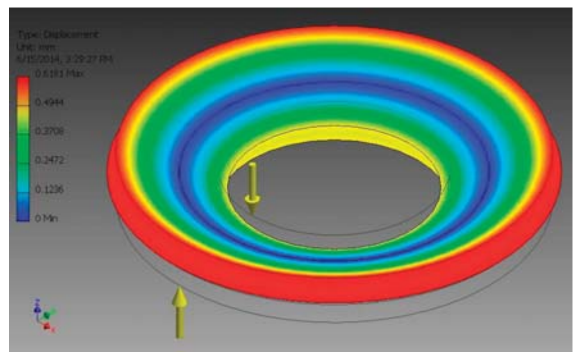

Fig. 7 Displacements of Belleville spring

The analysis results of displacement (Figure 7) shows that the spring under the influence of the given force F, came almost aligned position corresponding analytical calculations [4].

III. Analysis of the Thickness Influence on Stress and Strain

It is known that the shape of the characteristic curve Belleville springs (representing the dependence of force and spring acting distance) depends on the ratio of free height of the spring to the plate thickness t. If the ratio h/t small characteristic line is almost straight, while the curvature increases with increasing h/t. In the other words, with the same mechanical loads that are exposed springs, thinner disc will have greater bending characteristic lines than it will have a thick disk.

Certainly ratio h/t have an influence on the stress - strain state of the spring. Here is analyzed three different values of the spring width (defined by standard DIN 2093) of 1.5 mm, 2.2 mm and 3 mm. For these three values there are three different ratios between h and t, h/t = 0.33; 0.45 and 0.67, while the other dimensions of the spring as well as the load the same in all cases.

By comparing the stress values obtained using finite element method for spring plate thickness (Figure 8), it can be concluded that with decreasing thickness of the spring stresses are increasing, while with increasing thickness leads to their decline, which was in line of expectations [5]. In the case of small thickness of spring (t = 1.5 mm) stress values are far above the maximum allowed value so that, for a given load, this variant is not applicable in practice. On the other hand, increasing the spring plate thickness at t = 3.0 mm, significantly reduces the maximum stress for about 40% below the allowable stress values.

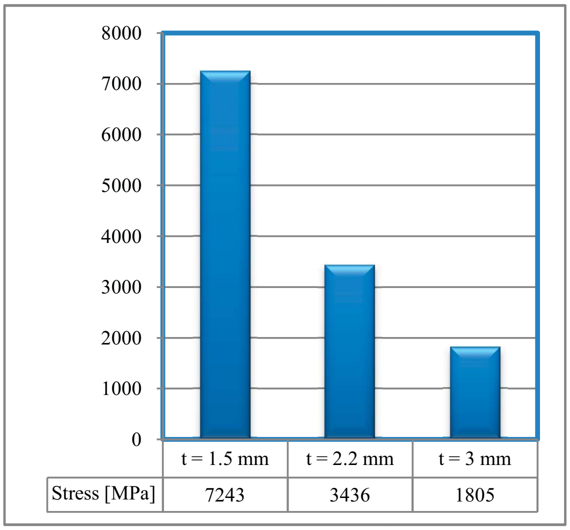

Fig. 8 The stress of Belleville spring dependent from thickness t

Similar conclusions can be drawn from the analysis of the obtained displacement values (Figure 9).

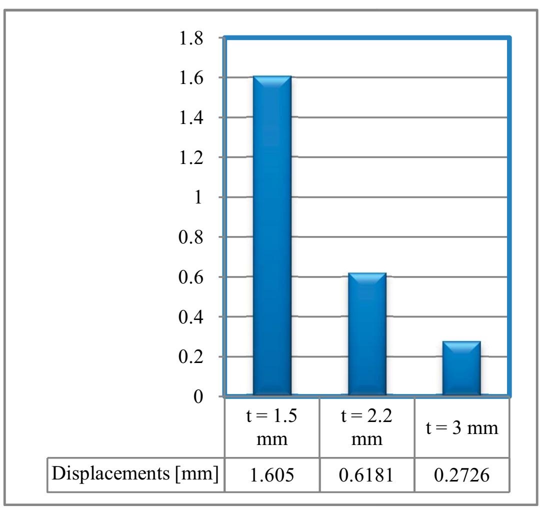

Fig. 9 The displacement of Belleville spring dependent from thickness t

IV. Analysis of Influence Inner and Outer Diameter of Spring Disk on Stress and Strain

The ratio between the outer and inner diameter of the spring is in the range of 1.5 to 3.5. However, choosing the size ratio of outer to inner diameter D / d = 2 achieves the best utilization of materials. For this reason, here are analyzed three springs of different values of the external and internal diameter, but the ratio of D/d =2.

Comparison of results of stress for different diameters of Belleville springs (Figure 10), it can be concluded that with the increase in the value of the outer and inner diameter stress values decreasing [5].

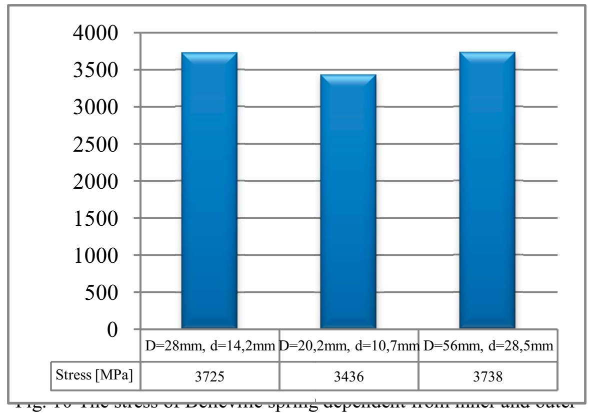

Fig. 10 The stress of Belleville spring dependent from inner and outer diameter of the spring disk

The influence on the value of the diameter of the spring deflection or deformation of the spring is shown in Figure 11.

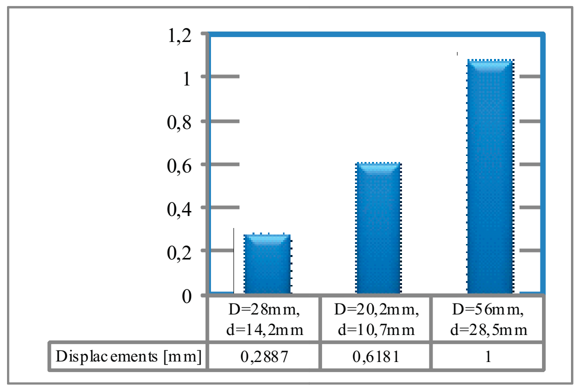

Fig. 11 The displacement of Belleville spring dependent from inner and outer diameter of the spring disk

V. Conclusions

Based on the results of stress analysis Belleville springs using Autodesk Inventor, it can be concluded that the developed and displayed calculation system of Belleville springs, using the finite element method, can be fully applied in practice. The introductions of different constellations load relatively quickly can be obtained stress conditions, i.e. various alternative solutions based on all solutions can be used for seeking an optimal solution.

Numerical analysis of regular Belleville springs results are obtained displacement has quite well match with the values obtained by using analytical methods. Also is confirmed the expected stress distribution on Belleville spring with noticeable highest intensity on the upper inner edge of the spring.

Analysis of the thickness influence on the springs and the values of the outer and inner diameter of the intensity of stresses and displacements, it was concluded that, if measures of the springs are less than the defined value for a given load, the stresses are far above the maximum allowed value, which is unacceptable in practice. On the other hand, only a small increase in the thickness of the spring above the recommended standard values leads to a significant reduction in stress values.

Successfully conducted analyses of the stress-strain state of Belleville springs are the confirmation that the

Autodesk Inventor can be used for modeling and analysis different types of springs.

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