

REVIEW PAPER ON BELLEVILLE SPRING THROUGH NUMERICAL AND SIMULATION APPROACH

Ritika Bhamore¹, Purushottam Kumar Sahu²

¹Research Scholar BM College of Technology, Indore

²Associate Professor BM College of Technology, Indore

Abstract - In present work an standard Belleville spring is considered for numerical analysis of force with respect to its maximum displacement of twice that of its height the results obtained are quite satisfying the one which are proposed by Almen J O [1] in 1936 and is modelled in CATIA v5r12 software and then further analysed in ANSYS 14.0 simulation software. For proper analysis the displacement is provided to the upper edge of the spring and rest all directions for that edge are fully constrained. The base edges are also provided with fully constrained motion in vertical direction but having free boundary condition in rest of the directions. The results in form of reaction force are then obtained through ANSYS solver.

For validation 4 different cases of different height to thickness ratio are considered which are $h/t=0.4$, $h/t=0.7$, $h/t=1.4$, $h/t=2.83$ respectively. It is then concluded that FEA results are in good agreement with the numerically obtained data and can be considered for this kind of application in future too. Different graphs representing load-deflection curves are drawn and percentage deviation of FEA results with respect to numerical results are studied and summarized in conclusion.

Keywords— Belleville Spring, FEA, CATIA, ANSYS, Load deflection curves, h/t ratio.

INTRODUCTION

A. Definition

The Belleville spring, or disk spring, is a truncated shallow conical shell of uniform thickness. It may be simpler to think of it as an annular plate that has been dished slightly into the shape of a cone. Such a spring is shown in Figure 1.1



Figure 1.1: Belleville spring

The Belleville spring is usually loaded only at its edges by circumferentially uniform loads, axial in direction and with a sense such that they tend to reduce the cone angle.

In most cases the edges are completely free to move. However, certain applications require that either the outer edge be restrained from radial expansion, as would be the case if the spring were inserted in a cylinder, or that the inner edge be restrained from radial contraction, as would be the case if a shaft were inserted through the spring. Some applications may require that both of these restrictions be imposed.

B. Characteristics of Belleville Springs

The simplest type of spring, a prismatic tension specimen, exhibits a characteristic which is typical of structural members in the elastic range: a linear load deflection curve. Accordingly, the helical spring, the volute spring, the ring spring, and most common springs have a straight relationship between load and deflection. On the other hand, Belleville spring usually have a nonlinear relationship between load and deflection, and it is possible to design Belleville springs with many differently shaped load deflection curves. By varying the fundamental parameters, it is possible to obtain positive, zero, and even negative spring rates in given portions of the load deflection curve.

Most authorities report that the most important parameter in varying the shape of the load -deflection curve is the ratio of the free cone height, d , to the shell thickness, h . For values of d/h near 2.0, a curve such as that labeled "A" in "Fig. 2 will occur.

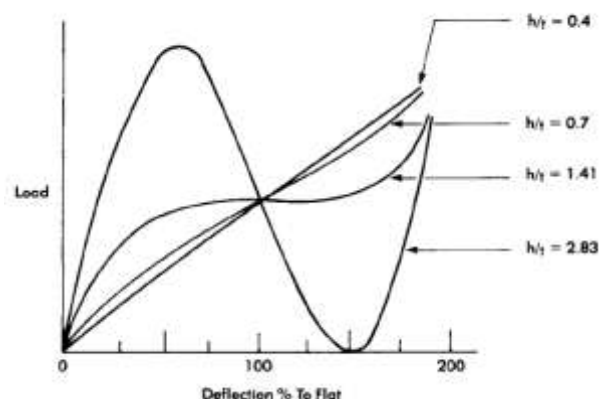


Figure 1.2 Force deflection curve of Belleville spring

This curve demonstrates the characteristic which is a result of instability of the cone as the cone angle is

reduced to the vicinity of zero. Consequently, large additional deflections occur in this region accompanied by a decrease in load. Of course, once the spring has reached a stable position after, increase in deflection is accompanied by increase in load. For values of d/h near 1.5, this action is reduced to the point that after a certain load, deflection is increased considerably with no appreciable change in load, as is shown by curve, "B" in Fig.2. This type of Belleville spring is the so-called "constant-load" spring. For values of d/h less than 1.5, increasing load is accompanied by increasing deflection, as is shown by curves and "0" in Fig.1.2. It is interesting to note that Ryan has found that for values of d/h between 0.11 and 0.17 the Belleville spring exhibits a linear load-deflection over a considerable range.

LITERATURE REVIEW

Almen, J. O. (1936) [1] the authors derived the formulas presented in this paper with the intention that the formulas will aid the designer in arriving at suitable characteristics by choice of spring geometry.

The formula for the load is

$$P = \frac{E \times \delta}{(1 - \sigma^2)M a^2} [(h - \delta) \left(h - \frac{\delta}{2}\right) t + t^2]$$

Karakaya, S. (2012) [2] the study examined disc springs with different section geometry and hybrid composite disc springs with finite elements method. Dubey, H. K., & Bhope, D. V. (2012) [3] This work presents an analysis of the stresses and deflections of a diaphragm spring using the finite element method. Zala, R. G., & Gawande, K. R. (2018) [4] In this work, the safe design of the disc spring washer is evaluated using a given condition analysis method. This study also validates the use of existing analytical methods to evaluate the safety of the self-locking washer design. Krishnasamy, K., Masse, F., & Simon, O. (2018). [5] This article describes the different levels of simulation needed to access the fatigue index of the diaphragm spring. It is also performed in different situations of the vehicle life: normal conditions, parking, overload condition. In simulation, a great importance is attached to the correlation by the measurement adaptation. Senthil Kumar, P. S., Srinivasan, P., Palati, K. K., & Mallela, G. (2015). [6] the Belleville dual clutch was examined for its various parameters such as drag torque, response time, interface temperature and friction disk wear rate through a series of mathematical models. Rupnar A, Babar A, Karale A, Gundawar S (2016) [7] The paper contains the design and analysis of the diaphragm spring used to generate the clamping force. The single disc clutch is designed for the forced draft vehicle and is based on theoretical calculation results. The CATIA V5.0 3D modeling software is used for diaphragm spring design. Structural analysis is performed to determine the distribution of constraints on the model. With the analysis results, we check whether the design is safe or not, and

compare the result with the theoretical calculation and the theoretical results. The structure analysis uses the HYPERMESH software.

LITERATURE REVIEW

NUMERICAL ANALYSIS:

The following equation reflects the relationship between the load and deflection in case of Belleville springs as given by Almen, J. O. (1936) [1]

$$P = \frac{E \times \delta}{(1 - \sigma^2)M a^2} [(h - \delta) \left(h - \frac{\delta}{2}\right) t + t^2]$$

$$\sigma = \frac{E\delta}{(1 - \delta^2)(d_o/2)^2 M} \left[c_1 \left(h - \frac{\delta}{2}\right) + c_2 t \right]$$

Where:-

F = axial load (N),

δ = deflection (mm),

t = thickness of the washer (mm),

h= free height minus thickness (mm),

E = modulus of elasticity (N),

σ = stress at inside circumference (N),

d_o = outside diameter of washer (mm),

d_i = inside diameter of washer (mm), and

μ = Poisson's ratio.

The constants M, C1, and C2 are given by the equations:-

$$M = \frac{6}{\pi \log_e \left(\frac{d_o}{d_i}\right)} \left(\frac{\frac{d_o}{d_i} - 1}{\frac{d_o}{d_i}} \right)^2$$

$$c_1 = \frac{6}{\pi \log_e \left(\frac{d_o}{d_i}\right)} \left[\frac{\frac{d_o}{d_i} - 1}{\log_e \left(\frac{d_o}{d_i}\right)} - 1 \right]$$

$$c_2 = \frac{6}{\pi \log_e \left(\frac{d_o}{d_i}\right)} \left[\frac{\frac{d_o}{d_i} - 1}{2} \right]$$

Modelling of Belleville Washer:

The CATIA v5r12 software is used in present work for modelling of Disc/Belleville spring washer, the model is created in part design workbench of CATIA v5r12

software in which first a 2D sketch is made using sketching module the detailed dimensions are shown in the figure 5.1 below.

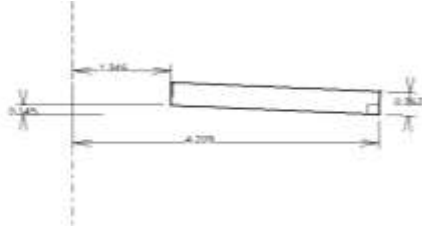


Figure 4.1: Dimensions of washer for $h/t = 0.4$

Only half side sketch is created in the sketch workbench and it is then rotated with respect to the axis of the sketch by using the CATIA 3D workbench tool called revolve tool.

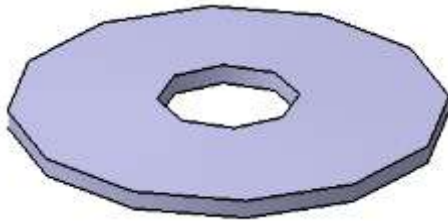


Figure 4.2: Model of Belleville washer

References:

1. Almen, J. O. (1936). The uniform-section disk spring. In ASME(Vol. 58, pp. 305-314).
2. Karakaya, Ş. (2012). Investigation of hybrid and different cross-section composite disc springs using finite element method. Transactions of the Canadian Society for Mechanical Engineering, 36(4), 399-412
3. Dubey, H. K., &Bhope, D. V. (2012). Stress and Deflection Analysis of Belleville Spring. IOSR J Mech Civil Eng, 2(5), 1-6p.
4. Zala, R. G., &Gawande, K. R. (2018). Disc Spring Washer: Design and Axisymmetric analysis using ANSYS. Trends in Machine Design, 4(3), 21-25.
5. Krishnasamy, K., Masse, F., & Simon, O. (2018). Fatigue analysis of Diaphragm spring in double dry clutch including manufacturing process. Procedia engineering, 213, 606-612.
6. Karaduman, A., &Yıldız, A. R. (2018). Optimal Design of Finger Slots Of Clutch Diaphragm