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Finite Element Analysis of Rectangular Cross Section Spring Washer

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Helical spring washers are very common in industrial assembly of components subjected to dynamic conditions. They are used to prevent the loosening of nut and bolt assemblies. Due to the typical loading conditions the analysis of these washers requires a treatment other than that laid down for springs. Various national and international standards cover such washers in terms of dimensional parameters and testing methods. The available literature and standards do not cover the load-deformation analysis of helical spring washers. Here, an attempt has been made to understand the their load-deformation behavior using finite element analysis. A special test rig was designed and developed to obtain the actual load-deflection characteristics of the washer. A comparison of the results obtained through both the approaches is given in this paper.

Keywords: FEA, Helical Spring Washer, Stress Analysis.

Introduction

Nut and bolt assemblies are very commonly used for fastening machine components. The action of this washer is like that of a helical spring. But due to loading conditions different than those in helical spring, the load-deflection analysis of such a washer does not follow that for a helical spring.

A spring is an element which is acting as an elastic machine element, it deflects under the subject of action of the force and it regains to its original shape and strucure when the load is not applied. Helical Spring washer and springs are used in machine designs to sustain force, give flexibility, and absorb the energy. Helical Springs are produced for different kind of applications like as compression, extension and constant force.

Depending upon the application, a spring may be in a static or dynamic condition mode. A Helical Spring is usually considered to be static & dynamic if a change in deflection or load occurs only a few times. Therefore load-deflection characteristics, calculated using spring equation, vary substantially from those obtained by actual measurement. The national and international standards specify the dimensions along with initial height of the washer. Test load is also specified for each washer size to check for permanent deformation [1][2][3]. But from application point of view the most important data is the load exerted by the washer on the nut when the nut is screwed to completely compress the washer. This load is responsible for providing the friction torque necessary to prevent loosening of the assembly.

The designer faces the task of calculating this force while designing a nut, bolt and spring washer assembly. This data is not included in the standards referred herein. Also there is no analytical method available to determine it. FEM approach has been successfully used in analysis of bolted joints in earlier research work [4].

Analytical Treatement

The analytical treatment of a helical coil spring is not applicable to helical spring washers. The helical compression spring has squared ends due to which the load line coincides with the spring axis. Therefore every cross-section of wire is subjected to the same twisting moment.

In case of a helical spring washer the loading is at the two corners of the washer. Hence the twisting moment on each wire cross-section is different. For comparison the load-deflection characteristics, calculated using the spring equation as well as determined by actual measurement, are given in Table 1 and Fig 1.2. The data clearly indicate that the unacceptable inconsistency in the results.

Table 1: Comparison of load obtained by using helical spring equation and that obtained by actual measurement.

Load in Newton	Deflection by Spring Equation mm	Deflection by Measurement mm
100	0.16	0.225
200	0.32	0.550
300	0.48	0.775
400	0.64	1.050
500	0.80	1.300
600	0.96	1.525

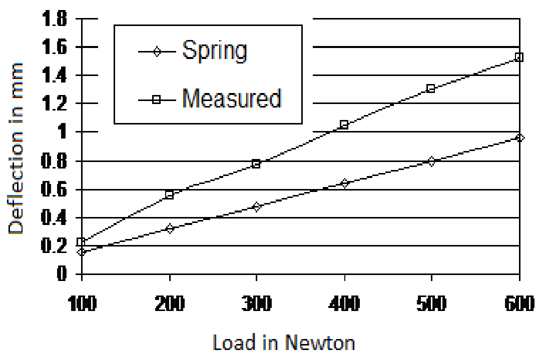

Fig 1.1: Comparison of load values obtained by spring equation with measured values.

Test Rig

A simple test rig was developed to determine the actual load-deflection characteristics of the washer. As shown in Fig. 1.2, the rig consists of a hollow cylinder mounted on a base plate.

The inner diameter of the cylinder is slightly more than the outer diameter of the washer. A cylindrical rod moves vertically up and down in the hollow cylinder with close sliding fit. The movement is ensured to be with minimum friction by lubricating the assembly. The washer is placed at the bottom of the hollow cylinder.

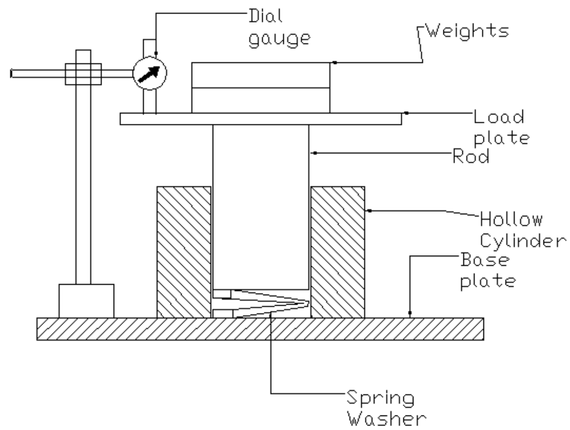

Figure 1.2 Schematicof the test rig for measurement of deflection of washer under axial load.

The hollow cylinder and the rod press the washer on lower and upper sides respectively, ensuring that the washer is compressed between two parallel surfaces, which are both, normal to its axis. The rod carries a disc for application of load. A dial gauge is used to measure the vertical movement of the rod and plate assembly, which corresponds to the deflection of the washer. This dial gauge has a least count of 25 microns.

Finite Element Analysis

The finite element analysis was done on ANSYS 8.0. The key steps in the analysis were: selection of appropriate element, setting the material properties, preparation of the model, mesh generation, application of boundary conditions and load, solution and plotting of results.

Selection of Element

The importance of selecting the appropriate element cannot be overemphasized. For the analysis of the washer Solid 92 (10 nodes) was selected. This element is suitable for structural analysis. During meshing this element gives the option of dividing the inner and outer boundaries into different number of segments. This was an important consideration in the present problem due to the typical geometry of the washer.

Material Properties

Spring washers are generally made of spring steel (0.6-0.7% carbon steel, oil tempered). The relevant properties used in the analysis were the Young's Modulus of elasticity E and the Poisson's ratio ν. The value of E used in the analysis was 2.06 x 10^{11} N/m^2 and that for the Poisson's ratio was 0.3.

Preparation of Model

The geometry of the helical spring washer is typical. The best way can be to sweep the wire cross-section along a helix, keeping the two perpendicular to each other. But this option is not available in ANSYS. Therefore ten points were identified on the washer surface in two groups as shown in Fig 1.3.

The first group had five points corresponding to inner helix of the lower surface of the washer. The second group also had five points corresponding to the outer helix of the lower surface of the washer. The points in each group were joined using arcs created by three-points method. The individual arcs obtained in this manner were added using Boolean operation. In this manner four line identities were obtained: the outer helix, the inner helix and the two edges, as shown in Fig 1.4. Using these line identities the required area was created as shown in Fig 1.5. Extruding the obtained area along the normal created the volume of the solid model as shown in Fig 1.6.

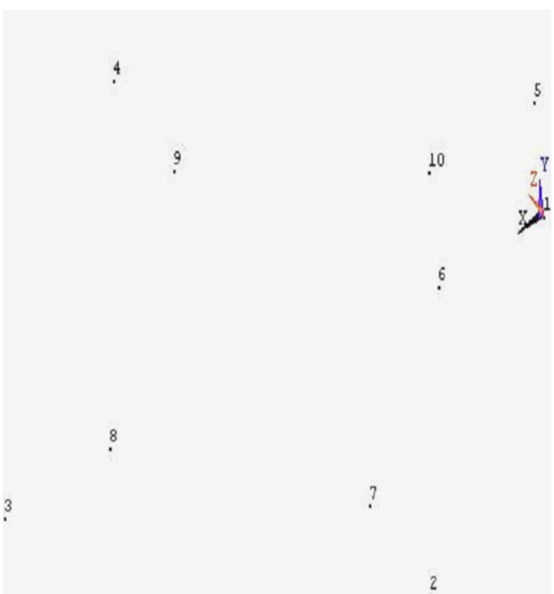

Fig. 1.3: Identifying the key points.

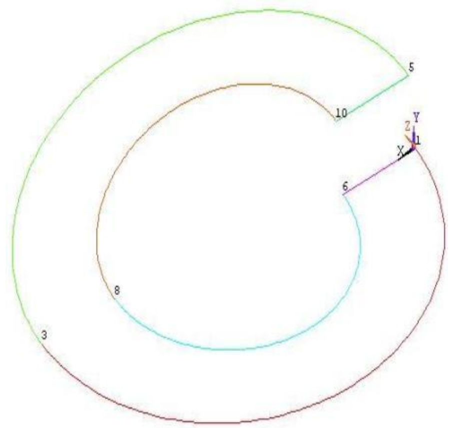

Fig. 1.4: Generation of the basic curves.

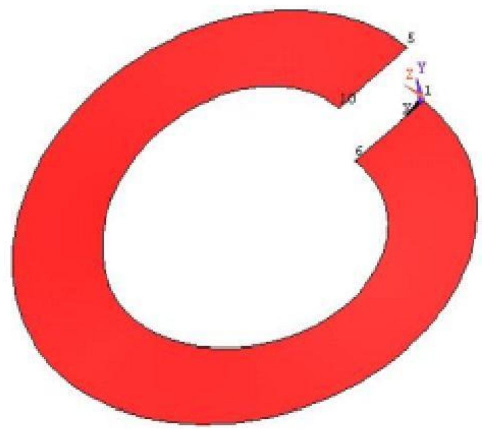

Fig. 1.5: Generation of area by fill curves.

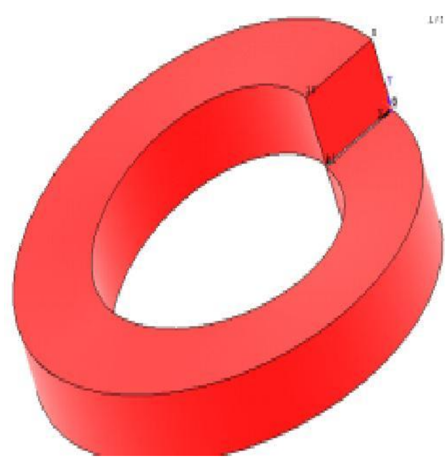

Fig. 1.6: Generation of solid by extrude.

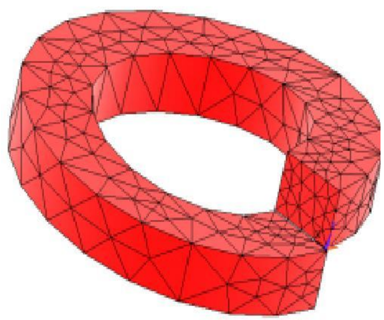

Fig. 1.7: Generation of meshing.

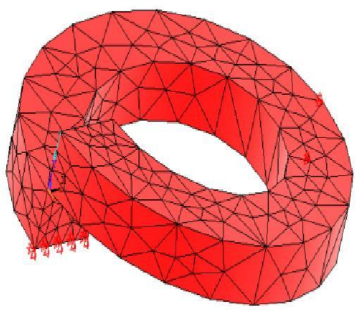

Fig. 1.8: Applying boundry conditions.

Results of FEA

With the model and loading described in previous section, load-deflection characteristics were determined. Variation of stress and deformation in the model are shown in Fig 1.9. The results for load-deformation are given in Table 2. Comparison between the load-deflection characteristics, obtained by FEA and actual measurement, shown in Fig 1.10.

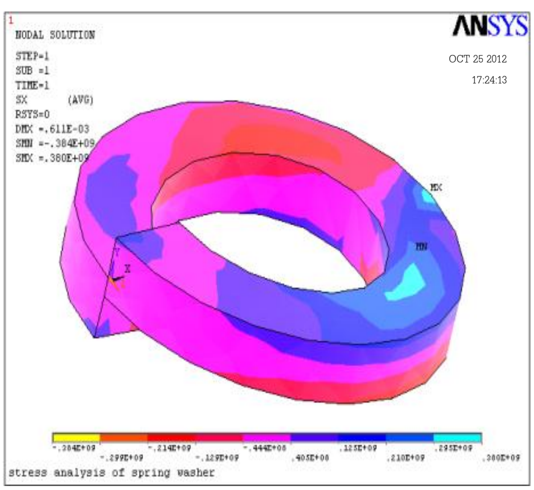

Fig. 1.9: Variation of Stress and Deformation in the Model.

Table 2. Load-Deflection Characteristics Obtained by FEA.

Helical Spring Washer		
Load in Newton	Deflection by Measurement (mm)	Deflection by FEA (mm)
100	0.225	0.277
200	0.550	0.562
300	0.775	0.836
400	1.050	1.108
500	1.300	1.384
600	1.525	1.661

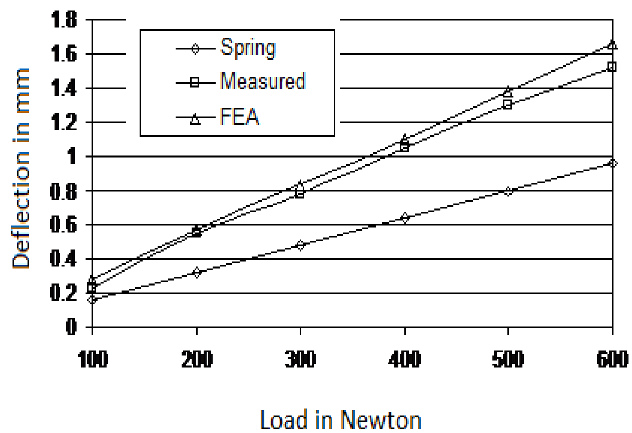

Fig. 1.10: Comparison of deflection values obtained by Spring equation, FEA and actual measurement.

Conclusions

The theoretically calculated values of deformation of a helical spring washer using the helical spring equation do not match with the practically observed values. This is due to different loading conditions in the two cases. Therefore the deflection was determined using finite element method. The actual load-deflection characteristics were obtained using a specially developed test rig. The values obtained by FEM and those obtained by actual measurement show good agreement. This approach should prove useful to designers involved in design of threaded assemblies subjected to dynamic load environment. It offers a simple and direct method of estimation of axial force provided by a helical spring washer under assembled condition. This load valued is critical in estimation and prediction of loosening of the assembly under dynamic conditions. The variations in the results obtained by FEA and direct measurement may be attributed to (1) Variation in modulus of elasticity and Poisson's ratio use in FEA, (2) Loading conditions and meshing used in FEA and (3) Errors in direct measurement. The FEA results may be further refined by investigating other loading possibilities and by using better meshing. Some improvement may be achieved through use of more exact values of elasticity and Poisson's ratio. Lastly, the test rig employed for direct measurement can be further refined to yield more accurate load-deflection data.

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Author Bibliography

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