Experimental Analysis of the Influence of Elastomer Coating on Parameters of Helical Spring with Rectangular Cross Section

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Abstract— *This paper analyzes the effectiveness of damping resonance vibrations of a rectangular cross section helical spring using a new method of elastomer coatings made of highly-damping material covering its whole length and last coils, as well as the influence of these coatings on the maximum values of dynamic stresses and the values of natural vibration frequencies of springs. The mathematical model derived in the paper allows users to calculate the effectiveness of dynamic stress reduction both in the spring and the coating itself, for arbitrary geometrical and material properties of coatings.*

Keywords— Helical Spring, Dynamic Stress, Spring Constant, Damping

I. Introduction

A mechanical spring may be defined as an elastic body whose primary function is to deflect or distort under load (or to absorb energy) and which recovers its original shape when released after being distorted".

Springs, in general, are designed to absorb and store energy and than release it. Hence, the strain energy of the material becomes a major factor in designing the springs. The relationship of the specific strain energy can be expressed as $U = \sigma 2/\rho E$, Where σ is the strength, ρ is the density and E the Young's modulus of the spring material.

Compression springs are open-coil helical springs wound or constructed to oppose compression along the axis of wind. Helical Compression Springs are the most common spring configuration. Generally, they are either placed over a rod or fitted inside a hole. When you put a load on a compression spring, making it shorter, it pushes back against the load and tries to get back to its original length. Compression springs offer resistance to linear compressing forces (push), and are in fact one of the most efficient energy storage devices.

Compression springs should be stress relieved to remove residual forming stresses produced by the coiling operation. Depending on the design and limitations, compression springs may be categorized according to stress level as follows:

1) Springs which can be compressed solid without permanent set, so that an extra operation for removing set is not needed. These springs are designed with torsional stress levels when compressed solidthat do not exceed about 40 percent of the minimum tensile strength of the material.
2) Springs which can be compressed solid without further permanent set aftert set has initially been removed. These may be preset by the spring manufacturer as an added operation or that may be pre set later by the user prior to or during the assembly operation. These are springs designed with torsional stress levels when compressed solid that usually do not exceed 60 percent of the minimum tensile strength of thr material.
3) Springs which can not be compressed solid without some further permanent set taking place because set can not be completely removed in advance. These springs involve torsional stress levels which exceed 60 percent of the minimum tensile strength of the material. The spring manufacturer will usually advise the user of the maximum allowable spring deflection without set whenever springs are specified in this category.

In designing compression springs the space allotted governs the diamensional limits of a spring with regard to allowable solid height and outside and inside diameters. These diamensional limits together with the load and deflection requirements, determine the stress level. It is extremely important to consider carefully the space allotted to insure that the spring will function properly to begin with, thereby avoiding costly design changes.

A. *End connections for compression helical springs:*

The end connections for compression helical springs are sutaibly formed in order to apply the load. Various forms of end connections are shown in fig.

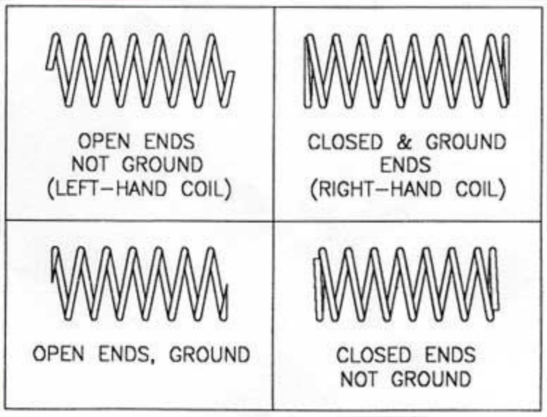


Fig. 1: Various types of spring ends

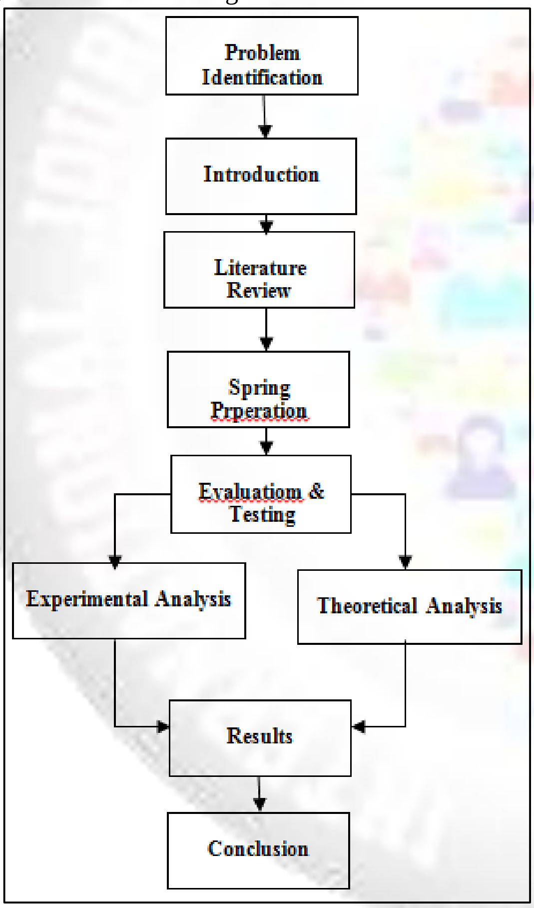
In all springs, the end coils produce an eccentric application of the load, increasing the stress on one side of the spring. Under certain conditions, especially where the number of coils is small, this effect must be taken into account. The nearest approach to an axial load is secured by sauared and ground ends, where the end turns are squared and then ground perpendicular to the helix axis. It may be noted that part of the coil which is in contact with the seat does not contribute to spring action and hence arev termed as inactive coils. The turns which impart spring are known as active turns. As the load increases, the number of inactive coils also increases due to seating of the end coils and the amount of increase varies from 0.5 to 1 turn at the usual working loads.

B. Elastomer:

An Elastomer is a polymer with viscoelasticity and very weak inter- molecular forces, generally having low Young's modulus and high failure strain compared with other materials. The term which is derived from elastic polymer, is often used interchangeably with the term rubber, although the latter is preferred when referring to vulcanisates. Each of the monomers which link to form the polymer is usually made of carbon, hydrogen, oxygen and silicon.Elastomers are amorphous polymers existing above their glass transition temperature, so that considerable segmental motion is possible. At ambient temperatures, rubbers are thus relatively soft and deformable. Their primary uses are for seals, adhesives and molded flexible parts. Application areas for different types of rubber are manifold and cover segments as diverse as tyres, shoe soles as well as dampening and insulating elements.

II. FLOW CHART

The project is carried out according to the following flow chart, which is shown in fig.



III. EXPERIMENTAL TESTING

A. Preparation of Spring

Preparation of spring is one of the key factors and there are many critical factors involved with spring preparation such as material composition, wire dimensions, no. of coils and helix angle, elastomer material etc. All of these paramerters are discussed below:

For the current project, a open coil helical spring of rectangular cross section of material high carbon spring steel are considered. There are two main types of spring steels in this group are used with an absolute majority of all flat spring. However, both are susceptible to hydrogen embrittlement even when plated and baked afterward.

Sae 1070-1090 high carbon blue tempered and polished spring steel is a standerd material for conventional springs. It is the lowest cost material and best suited for applications that have a protected environment, as carbon steel corrodes if not lubricated or atmospherically sealed. Additional corrosion protection can be added with a special finish. Products are supplied with an oil dip finish providing adequate protection for shipment and shelf storage. Carbon steel is highly magnetic and is typically blue in colour.

To prepare the spring in this project work a rectangular coil helical spring is used with elastomer coating on whole spring and on its end coils also. To coat the spring a heat shrinkable wire sleeve is used. Heat shrinkable sleeve is a corrosion protective coating for wires in the form of a wraparound or tubular sleeve that is field applied. Also in this project this coating will help to reduce the vibration damping on the spring. A heat shrinkable sleeve starts out with a thick extruded polyolefin sheet (polyethylene or polypropylene) that is formulated to be cross linkable. After extruding the thick sheet, it is taken to the "beam" where it is passed under a unit that subjects the sheet to electron irradiation. The irradiationprocess cross links the poluolefin. This improves the molecular sturucture such that the polyolefin will work as part of a heat shrinkable sleeve and provide the required level of mechanical protection while in service. It makes the polyolefin perform more like a tough, heat resistant, elastic material or rubber, rather than like a plastic material.

Fig. 2: Spring with full coating and ends coated

To wrap the spring with elastomer wire sleeve is done by covering the spring coils with sleeve and then give the heat to the spring with the help of hot air gun. By doing this the sleeve will fix to the coils and gains the shape of the coils perfectly.

Then the spring will tested on the spring testing machine one by one with fully coating, with only ends coating and without coating and then comparing the experimental results with the theoretical results.

The theoretical results are computed with the following equations given below:

$$\text{Deflection } \delta : \frac{2.45\, P\, D^3\, n}{C\, b^3\, (h-0.56b)} \quad \text{N/mm}$$

$$\text{Stress } \tau : \frac{P\, D\, (3h+1.8\, b)}{2\, b^2\, h^2} \quad \text{N/mm}^2$$

$$\text{Frequancy } f_n : \sqrt{k/m} \quad \text{Hz}$$

Where,
P : Maximum Load
D : Mean Diameter
n : No. of coils
C : Modulus of rigidity
b : Spring wire width
h : Spring wire thickness
K : Wahl;s correction factor

$$K : \frac{4S-1}{4S-4} + \frac{0.615}{S}$$

$$S : \text{Spring Index} : \frac{D}{h}$$

IV. Results

The spring were tested by experimentally and theoretically according to coating height ratios.

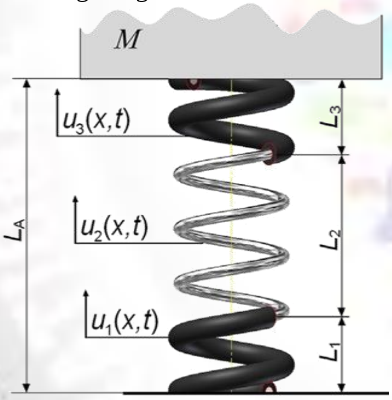


Fig. 3: Spring ends coating with coating length ratio

The following tables show the results of the analysis :

Parameters	Values
Wire Thicknesss "h"	5.26 mm
Wire Width "b"	7.05 mm
Wire Length	975 mm
Inner Diameter	44 mm
Outer Diameter	59 mm
Mean Diameter	51.5 mm
No. of coils	14 (active), 2 (total)
Free Length	300 mm
Wire cross sectional area	37.083 mm^2
Spring Mass	670 gm

Table 1: Spring Specifications

The Spring were tested theoretically and the results were obtained as shown in table (2):

Coating height ratio	With Fully Coated	With Ends Coated	Without Coating
0.1	1.132	1.198	2.235
0.2	2.247	2.295	3.527
0.3	3.43	3.831	3.987

Table (2) : Frequancy Hz

All the results were taken under 1000 N load on the spring.

Coating height ratio	With Fully Coated	With Ends Coated	Without Coating
0.1	615.18	629.97	675.82
0.2	660.87	697.52	713.8
0.3	721.82	753.9	767.8

Table 3: Stress Mpa

The Spring were tested experimentally and the results were obtained as shown in table (4):

Coating height ratio	With Fully Coated	With Ends Coated	Without Coating
0.1	1.115	1.147	2.201
0.2	2.214	2.257	3.125
0.3	3.278	3.541	3.873

Table 4: Frequancy Hz

Coating height ratio	With Fully Coated	With Ends Coated	Without Coating
0.1	587.478	603.25	647.97
0.2	651.41	673.54	697.54
0.3	704.35	735.41	754.23

Table 5: Stress Mpa

The theoretical and experimental results were compared and plotted in the graph:

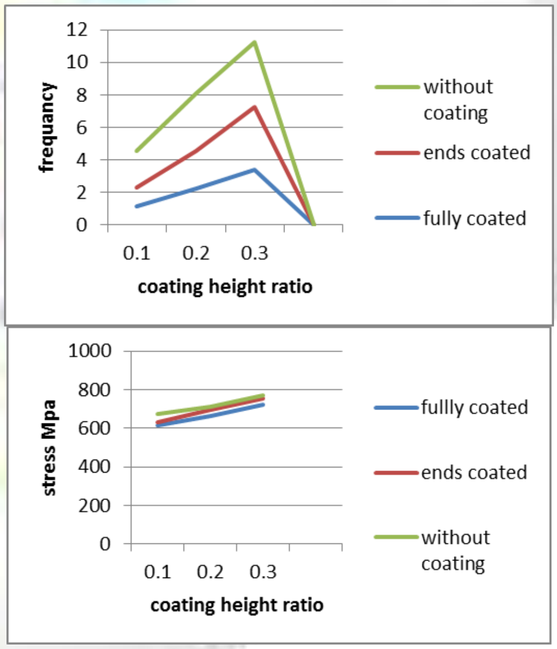


Fig. 4: Graphs

V. Conclusion

The Helical spring with rectangular cross section were studied and tested for variable conditions. Variations were observed in the comparision of results which are more ambiguous than expected therefore the validation is being carried out and it is expected to be rectified soon.

Also the spring were coated by wire sleeve, so it is difficult to achieve same degree of accuracy in coating. There is minor differences between results of different conditions of coating, but these differences can be more effective if this experiment is performed under good working conditions.

So there is huge scope for studying effects of all these parameters on mechanical behaviours of spring with elastomer coating.

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