Helical spring parameter optimization using FEA and Analytical results

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ABSTRACT

A coil spring, also known as a helical spring, is a mechanical device which is typically used to store energy and subsequently release it, to absorb shock, or to maintain a force between contacting surfaces. They are made of an elastic material formed into the shape of a helix which returns to its natural length when unloaded.[1] Under tension or compression, the material (wire) of a coil spring undergoes torsion. The spring characteristics therefore depend on the shear modulus, not Young's Modulus. Helical springs are used in many engineering applications due to their importance. The absorption of the loads takes place in the form of elastic energy. Coil springs are manufactured from rods which are coiled in the form of a helix. The design parameters of a coil spring are the rod diameter, spring diameter and the number of coil turns per unit length. Compression springs may be cylindrical, conical, tapered, concave or convex in shape. Vehicle suspension system is made out of springs that have basic role in power transfer, vehicle motion and driving.[2]

Keyword -*Coil spring, Design of spring, FEA, Helical spring,*

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1. TYPES OF SPRING

1.1 Helical springs.

The helical springs are made up of a wire coiled in the form of a helix and are primarily intended for compressive or tensile loads. The cross-section of the wire from which the spring is made may be circular, square or rectangular. The two forms of helical springs are compression helical spring as shown in Fig. (a) and tension helical spring in fig (b).The helical springs are said to be closely coiled when the spring wire is coiled so close that the plane containing each turn is nearly at right angles to the axis of the helix and the wire is subjected to torsion. In other words, in a closely coiled helical spring, the helix angle is very small, it is usually less than 10°. The major stresses produced in helical springs are shear stresses due to twisting. The load applied is parallel to or along the axis of the spring.

In open coiled helical springs the spring wire is coiled in such a way that there is a gap between the two consecutive turns, as a result of which the helix angle is large. Since the application of open coiled helical springs are limited, therefore our discussion shall confine to closely coiled helical springs only. A helical compression spring is an open-pitch spring which is used to resist applied compression forces or to store energy. It can be made in a variety of configurations and from different shapes of wire, depending on the application. Round, high-carbon-steel wire is the most common spring material, but other shapes and compositions may be required by space and environmental conditions.

Usually the spring has a uniform coil diameter for its entire length. Conical, barrel, and hourglass shapes are a few of the special shapes used to meet particular load-deflection requirements.

Helical compression springs are stressed in the torsional mode. The stresses, in the elastic range, are not uniform about the wire‟s cross section. The stress is greatest at the surface of the wire and, in particular, at the inside diameter (ID) of the spring.

In some circumstances, residual bending stresses are present as well. In such cases, the bending stresses become negligible after set is removed (or the elastic limit is exceeded) and the stresses are redistributed more uniformly about the cross section.

Fig.1 (a) Compression spring[14] (b) Tension spring[14]

Helical springs have the following advantages:

1. These are easy to manufacture.
2. These are available in wide range.
3. These are reliable.
4. These have constant spring rate.
5. Their performance can be predicted more accurately
6. Their characteristics can be varied by changing dimensions

1.2 Conical and volute springs

The conical and volute springs, as shown in Fig are used in special applications where a telescoping spring or a spring with a spring rate that increases with the load is desired. The conical spring, as shown in Fig. (a) is wound with a uniform pitch whereas the volute springs, as shown in Fig. (b) are wound in the form of parabolic with constant pitch and lead angles. The springs may be made either partially or completely telescoping. In either case, the number of active coils gradually decreases. The decreasing number of coils results in an increasing spring rate. This characteristic is sometimes utilized in vibration problems where springs are used to support a body that has a varying mass.

The major stresses produced in conical and volute springs are also shear stresses due to twisting.

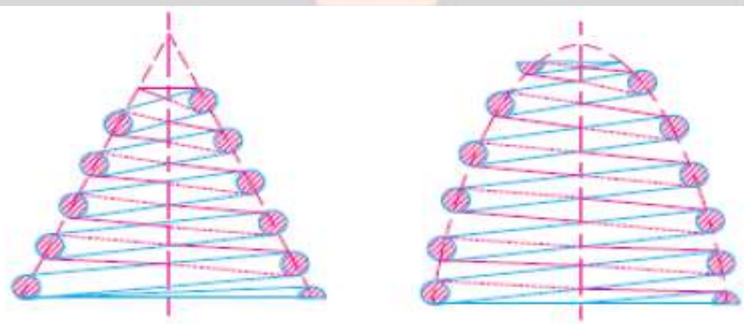

Fig 2.(a) Conical spring[14] (b) Volute springs[14]

1.3 Torsion springs

These springs may be of helical or spiral type as shown in Fig.3 The helical type may be used only in applications where the load tends to wind up the spring and are used in various electrical mechanisms. The spiral type is also used where the load tends to increase the number of coils and when made of flat strip are used in watches and clocks.

The major stresses produced in torsion springs are tensile and compressive due to bending.

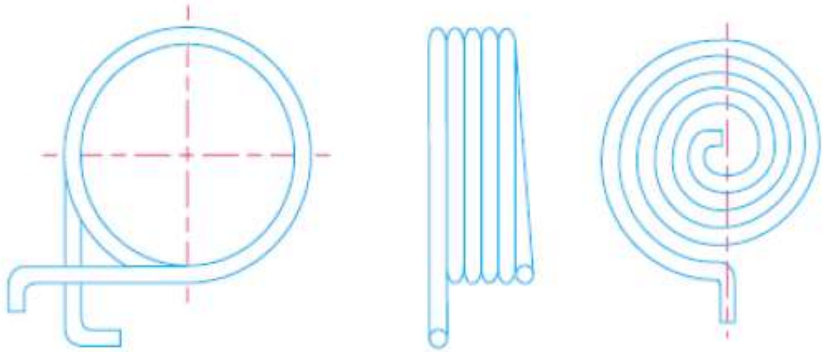

Fig 3.Torsion springs[14]

1.4 Laminated or leaf springs

The laminated or leaf spring (also known as flat spring or carriage spring) consists of a number of flat plates (known as leaves) of varying lengths held together by means of clamps and bolts, as shown in Fig.4. These are mostly used in automobiles.

The major stresses produced in leaf springs are tensile and compressive stresses.

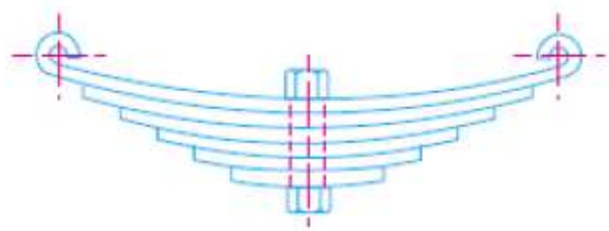

Fig 4 Leaf springs[14]

1.5 Disc or Belleville springs

These springs consist of a number of conical discs held together against slipping by a central bolt or tube as shown in Fig. These springs are used in applications where high spring rates and compact spring units are required.

The major stresses produced in disc or bellevile springs are tensile and compressive stresses.

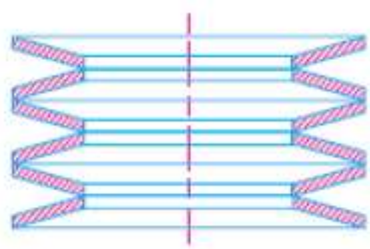

Fig 5 Disc spring[14]

1.6 Special purpose springs

These springs are air or liquid springs, rubber springs, ring springs etc. The fluids (air or liquid) can behave as a compression spring. These springs are used for special types of application only.

1.7 Terminology:

The definitions that follow are for terms which have evolved and are commonly used in the spring industry. Figure 6.5 shows the relationships among the characteristics.

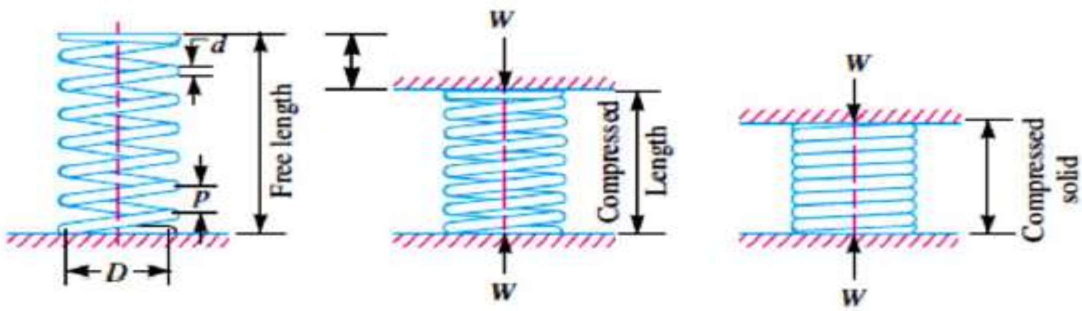

Fig 6 Terminology of spring[14]

The outside diameter (OD) is specified when a spring operates in a cavity. The inside diameter is specified when the spring is to operate over a rod. The mean diameter D is either OD minus the wire size or ID plus the wire size.
The coil diameter increases when a spring is compressed. The increase, though small, must be considered whenever clearances could be a problem. The diameter increase is a function of the spring pitch and follows the equation.

1. Spring Index. Spring index C is the ratio of the mean diameter to the wire diameter (or to the radial dimension if the wire is rectangular). The preferred range of index is 5 to 9, but ranges as low as 3 and as high as 15 are commercially feasible. The very low indices are hard to produce and require special setup techniques. High indices are difficult to control and can lead to spring tangling.
2. Free Length. Free length Lf is the overall length measured parallel to the axis when the spring is in a free, or unloaded, state. If loads are not given, the free length should be specified. If they are given, then free length should be a reference dimension which can be varied to meet the load requirements.
3. Types of Ends. Four basic types of ends are used: closed (squared) ends, closed (squared) ends ground, plain ends, and plain ends ground. Illustrates the various end conditions. Closed and ground springs are normally supplied with a ground bearing surface of 270 to 330°.
4. Number of Coils. The number of coils is defined by either the total number of coils Nt or the number of active coils Na. The difference between Nt and Na equals the number of inactive coils, which are those end coils that do not deflect during service.
5. Solid Height. The solid height Ls is the length of the spring when it is loaded with enough force to close all the coils. For ground springs, Ls = Ntd. For unground springs, Ls = (Nt + 1)d.
6. Direction of the Helix. Springs can be made with the helix direction either right or left hand. Illustrates how to define the direction. Springs that are nested one inside the other should have opposite helix directions. If a spring is to be assembled onto a screw thread, the direction of the helix must be opposite to that of the thread.
7. Spring Rate. Spring rate k is the change in load per unit deflection.
8. Pitch. The pitch of the coil is defined as the axial distance between adjacent coils in uncompressed state.

1.8 Objectives of spring:

1. To provide Cushioning, to absorb, or to control the energy due to shock and vibration. Car springs or railway buffers to control energy, springs-supports and vibration dampers.
2. To Control motion .Maintaining contact between two elements (cam and its follower) Creation of the necessary pressure in a friction device (a brake or a clutch).
3. To Measure forces. Spring balances, gages.
4. To Storing of energy.
5. In clocks or starters .The clock has spiral type of spring which is wound to coil and then the stored energy helps gradual recoil of the spring when in operation. Nowadays we do not find much use of the winding clocks.

Wire Diameter d. Round wire is the most economical form. Rectangular wire is used in situations where space is limited, usually to reduce solid height.

2. SPRING MATERIALS

Springs are resilient structures designed to undergo large deflections within their elastic range. It follows that the materials used in springs must have an extensive elastic range. Some materials are well known as spring materials. Although they are not specifically designed alloys, they do have the elastic range required. In steels, the medium- and high-carbon grades are suitable for springs. Beryllium copper and phosphor bronze are used when a copper base alloy is required. The high-nickel alloys are used when high strength must be maintained in an elevated-temperature environment. The selection of material is always a cost-benefit decision. Some factors to be considered are costs, availability, formability, fatigue strength, corrosion resistance, stress relaxation, and electric conductivity. The right selection is usually a compromise among these factors.

2.1 Some commonly used materials in helical springs are as below-

One of the important considerations in spring design is the choice of the spring material. Some of the common spring materials are given below.

1. **Hard-drawn wire**:- This is cold drawn, cheapest spring steel. Normally used for low stress and static load. The material is not suitable at subzero temperatures or at temperatures above 1200C.
2. **Oil-tempered wire**:- It is a cold drawn, quenched, tempered, and general purpose spring steel. It is not suitable for fatigue or sudden loads, at subzero temperatures and at temperatures above 1800C.
3. **Chrome Vanadium**:-This alloy spring steel is used for high stress conditions and at high temperature up to 2200C. It is good for fatigue resistance and long endurance for shock and impact loads.
4. **Chrome Silicon**:-This material can be used for highly stressed springs. It offers excellent service for long life, shock loading and for temperature up to 2500C.
5. **Music wire**:-This spring material is most widely used for small springs. It is the toughest and has highest tensile strength and can withstand repeated loading at high stresses. It cannot be used at subzero temperatures or at temperatures above 1200C. a. Stainless steel. Widely used alloy spring materials like Phosphor Bronze / Spring Brass.

It has good corrosion resistance and electrical conductivity. it is commonly used for contacts in electrical switches. Spring brass can be used at subzero temperatures.

2.2 Selection of Material for Spring Construction: Following are the spring constrain for selection of spring material

1. **Space limitations**: Do you have adequate space in the mechanism to use economical materials such as oil-tempered ASTM A229 spring wire? If your space is limited by design and you need maximum energy and mass, you should consider using materials such as music wire, ASTM A228 chrome vanadium or chrome silicon steel wire.

2. **Economy**: Will economical materials such as ASTM A229 wire suffice for the intended application? 3. Corrosion resistance: If the spring is used in a corrosive environment, you may select materials such as 17-7 PH stainless steel or the other stainless steels (301, 302, 303, 304, etc.).

4. **Electrical conductivity**: If you require the spring to carry electric current, materials such as beryllium copper and phosphorous bronze are available.

5. **Temperature range**: Whereas low temperatures induced by weather are seldom a consideration, high-temperature applications will call for materials such as 301 and 302 stainless steel, nickel chrome A286, 17-7 PH, Inconel 600, and Inconel X750. Design stresses should be as low as possible for springs designed for use at high operating temperatures. Also Shock loads, high endurance limit, and high strength: materials such as music wire, chrome vanadium, chrome silicon, 17-7 stainless steel, and beryllium copper are indicated for these applications.

3. PROBLEM DEFINATION

To find the problem of failure in tractor seat helical tension springs and try to replace it by helical compression springs using stress and fatigue analysis.

Fig. 7 Point of fracture of existing spring[14]

The failure of tension spring is at the hook end and it is due to un uniform ness of material and due to heat treatment processes. Due to wavy loads there are sudden fractures. Due to excessive loading causes failure of tension springs.

Fig 8 Tractor seat[14]

Objectives:-

1. Study existing design of helical spring also its properties
2. Design and manufacturing the helical compression spring.
3. Carry out dimensional optimization the helical compression spring.
4. Carry out the fatigue life analysis and stress analysis of helical spring.
5. To study effect of different springs during analysis.

4. PLANNING FOR PROJECT SATGE II

4.1 Introduction to FEM:-

The FEA simulates the loading conditions of a design and determines the design response in those conditions. It can be used in new product design as well as in existing product refinement. A model is divided into a finite number of regions/divisions called elements. These elements can be of predefined shapes, such as triangular, quadrilateral, hexahedron, tetrahedron, and so on. The predefined shape of an element helps define the equations that describe how the element will respond to certain loads. The sum of the responses of all elements in a model gives the total response of the complete model.

4.2 CAD Modeling

CAD modeling of any project is one of the most time consuming process. One cannot shoot directly from the form sketches to finite element model. CAD modeling is the base of any project. The finite element software will consider shapes, whatever is made in CAD model. Although most of the CAD modeling software have capabilities of analysis to some extent and most of finite element software have capabilities of generating a CAD model directly for the purpose of analysis, but their off domain capabilities are not sufficient for large and complicated models which include many typical shapes of the product. The CAD models of the spring were prepared in CATIA V5 R16 and the analysis and comparison of results are performed using ANSYS 14.0.

4.3 Introduction to ANSYS Workbench.

ANSYS is one of the most powerful engineering design and analysis software. ANSYS is a finite element method based package used to analyze the finite element method (FEM) problems. The models can either be imported from other modeling software or can be created within ANSYS. In this work Solid works package is used for modeling and ANSYS is used for analysis of steel spring. ANSYS software is available.

4.4 Application of ANSYS.

During the late seventies, a large number of simulations in the design process of nuclear power plants were performed using ANSYS. Most of the load cases were transient and Temperature-dependent. Including varied pressure cycles. A number of geometries were represented by axis symmetric two-dimensional models e.g. structures such as nozzles Also three-dimensional transient calculations were performed with a very large amount of computer resources. Several batch jobs that took a couple of weeks to obtain the final results of the analysis existed. In the case of linear static analysis for complex structural components without transient effects, shell or volume models with an increased Number of elements were created. Before detailed analysis became commonplace, beam element models were used to study the behavior of complex structural components. The main benefit was to receive a very quick answer regarding the global stress distribution. The most tedious and time-consuming work of those models was to calculate the moments of inertia and find the right orientation, due to poor capability of plots showing the element coordinate systems. Furthermore, post-processing of the results was complicated because no graphic algorithms were available for beam elements to show the stresses. With the continued development of computer hardware, shell elements were used to model thin structures in combination with beam elements to simulate the boundary conditions. To solve models with large numbers of elements, the so-called substructure technique was used. It was possible to subdivide structures into discrete parts represented only by a stiffness matrix generated from a separate finite element Model. Using this procedure, the parts of the structures were combined numerically to form the complete component. A number of calculations had to be made before the results could be shown. ANSYS can be used to solve most of the stress distribution problems. The leaf springs are analyzed for static strength &

deflection using finite element analysis. The leaf spring geometry and loading is symmetric. Hence, the model is limited to one and half. The general purpose FEA software ANSYS version 14.0 is used for the present work. The three-dimensional structures of the leaf spring is hyper meshed and divided into a number of 8-noded, 3-D brick elements and the interleaf contact part of the leaf spring is created using 3-D surface to surface contact elements approximately in the order of 20000. The results of FE analysis are compared with the test results under simulated loading conditions.

4.5 Finite Element Formation

Two CAD models has prepared for this particular research depend on the position of helical spring by using Pro-E Platform. The Models are prepared in such way that, It will take all real boundary conditions. Fig. shows the CAD Model.

4.6 Introduction to Modeling

The word "modeling" comes from the Latin word modulus. It describes a typical human way of coping with the reality. A model is a simplified version of something that is real. Modeling is the process of producing a model and Geometrical modeling is defined as the complete representation of an object with the graphical and non-graphical information. A model is similar to but simpler than the system it represents. One purpose of a model is to enable the analyst to predict the effect of changes to the system. On the one hand, a model should be a close approximation to the real system and in corporate most of its salient features. On the other hand, it should not be so complex that it is impossible to understand and experiment with it. A good model is a judicious strade offs „between real and simplicity. An important issue in modeling is model validity. Model validation techniques include simulating the model under known input conditions and comparing model output with system output. Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software. Typically, simulation models are stochastic and dynamic. Now day computer software is rapidly growing in the field of modeling like CATIA, PROE, UG, CAD etc. Due to rapid growing in computer based modeling, it becomes very easy to design and analyze the object before manufacturing the original one.

Work to be done in Stage II:-Following path is followed for the proceeding project work for project stage II

Table 1 Proposed Project stage II planning

Sr. No.	Month	Task to be done
1	November 2018	Review research paper proceeding and paper publication on project stage I
2	December 2018	Design calculation for Helical spring.
3	January 2019	FEA analysis and simulation with the design.
4	February 2019	Final research paper proceeding and paper publication on project stage II
5	March 2019	Report writing under guidance of project guide
6	April 2019	Report writing with guidance from project guide and final presentation preparation.

REFERENCES

[1] Supriya Rahul Burgul, "Fatigue Analysis for Helical Compression Spring for Determining Design Alternatives for Enhanced Life and Performance", International Journal for Technological Research in Engineering (IJTRE) Volume 2, Issue 7, March-2015

[2].Vikram Vakte, "Simulation of Helical Spring Used In Tractor Seat Application", International Journal of Modern Trends in Engineering, 24 July 2015 1958–1962

[3] Vikram Vakte, "Analysis and Comparison of Helical Spring Used in Tractor Seat Application", International Engineering Research Journal (2015) 4400–4403

[4] Jinhee Lee, "Free Vibration Analysis of cylindrical helical spring By pseudo spectral method", „Journal of sound & Vibration‟, 2007, 302,185-196.

[5].A.M.YU,Y.Hao, " Free Vibration Analysis of cylindrical helical spring with non-circular cross section", „Journal of sound & Vibration‟,2011,330,2628-2639.

[6].Mohamed Taktak, "Dynamic optimization design of cylindrical helical spring". „Applied Acoustic‟, 2014, 77,178-183.

[7] .Aimin Yu. "Formulation and evaluation of an analytical study for cylindrical helical spring". „AMSS‟, 2010, 23, 0894-9166.

[8] Youli Zhu,Yanli Wang, "Failure analysis of a helical compression spring for a heavy vehicle‟s suspension system", 2014, 2,169-173

[9].Y. Prawoto, M. Ikeda, S.K. Manville, A. Nishikawa,"Design and failure modes of automotive suspension springs." Engineering Failure Analysis 15 (2008) 1155–1174.

[10]. Reza Mirzaeifar, Reginald DesRoches "A combined analytical, numerical, and experimental study of shape-memory-alloy helical springs".„International Journal of Solids and Structures‟, 2011, 48,611-628.

[11].B. Pyttel, "Fatigue behavior of helical compression springs at very high number of cycles –Investigation of various influences", International Journal of Fatigue 60 (2014) 101-109

[14]Design of machine Element, V.B. Bhandari, Edition 2001, Tata Mc Graw Hill.

[15] Mr. kayast Pratik ,"A spring FEA analysis for tractor seat",IJARIIE publication, Vol.4 Issue2.

[15] www.freefullpdf.com

[16] www.wikepedia.com