A Review on Design and Analysis of Helical Compression Spring for Suspension System

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I. INTRODUCTION

For any suspension system, spring is a very important element. In suspension system springs are mainly used for absorbing shock energy as well as restoring the initial position of part upon displacement for initiating the given function. The spring supports weight of the vehicle, maintain ride height and absorb road shocks. Most commonly used springs in suspension systems are Helical coil compression springs. Suspension system springs work on two cycles compression cycle and extension cycle. The compression cycle controls the motion of the vehicles unsprung weight while extension cycle controls heavier sprung weight**.** The important problem faced by automotive is that the vehicle handling becomes difficult and leads to uncomfortable ride when spring bouncing is uncontrolled.

A. Design of Helical Compression spring for suspension system

Design of Helical compression spring involves following

1. Modes of loading: i.e.static load /alternating load
2. The force deflection characteristic requirement for given application.
3. Required life for springs subjected to alternating loads.
4. Environmental conditions such as corrosive atmosphere and temperature
5. Desired economy
6. Space into which the spring must fit and operate.
7. Required accuracy & reliability

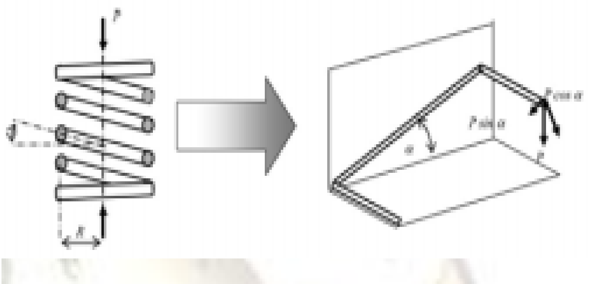

Figure 1: Wound and Unwound helical compression spring

B. Design Procedure

If P is the force acting on the helical compression spring then it induces torsional shear stress then the torsional moment M_t is given by,

$$M_t = \frac{PD}{2}$$

The torsional shear stress in the spring wire is given by,

$$\tau_1 = \frac{8PD}{\pi d^3}$$

In addition to or this, there is direct or transverse shear stress in the spring wire and stress concentration at the inside fiber of the coil. All these forces result into superimposition of all these stresses. They are shown in the figure below.

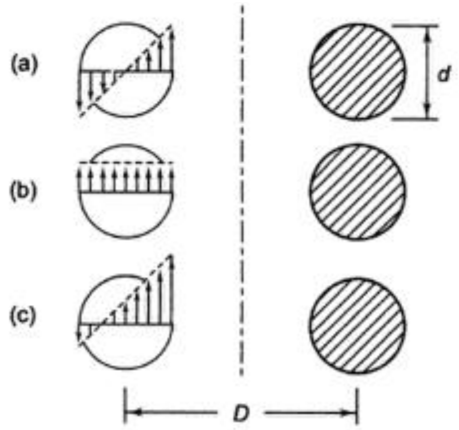

Figure 2: Stressess in Spring wire (a) Pure torsional stress (b) Direct Shear Stress (c) Combined torsinal , Direct & Curvature Shear Stress

To consider the effect of direct shear stress and stress concentration due to curvature effect, the above equation is modified,

$$\tau = K\left(\frac{8PD}{\pi\, d^3}\right)$$

K= stress Factor/ Wahl factor

$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

Where C= Spring Index,

The Load deflection equation is given by,

$$\delta = \frac{8PD^3N}{Gd^4}$$

The Rate of spring is given by

$$K = \frac{P}{\delta}$$

And hence spring rate

$$K = \frac{Gd^4}{8D^3\,N}$$

C. Buckling Effect of spring

If the spring is too long compared to mean coil diameter it may buckle at comparatively low axial forces, so spring should be designed buckle proof if is not possible then it must be guided in a sleeve or over an arbor

$$\frac{\text{Free Length}}{\text{Mean Coil Diameter}} \leq 2.6 \qquad \text{(Guide not necessary)}$$

$$\frac{\text{Free Length}}{\text{Mean Coil Diameter}} \geq 2.6 \qquad \text{(Guide necessary)}$$

D. Spring design against Fluctuating Loading

If the spring is subjected to an external fluctuating force which changes its magnitude from P_{max} to P_{min} in load cycle ,then mean force P_m and force amplitude P_a are given by,

$$P_m = \frac{1}{2}\left(P_{max} + P_{min}\right)$$

$$P_a = \frac{1}{2}\left(P_{max} - P_{min}\right)$$

The mean stress (τ_m) is calculated from mean force (P_m) by using shear stress correction factor (Ks)

E. Design Optimization of the Helical Compression spring

There are various methods developed to optimize the design of helical spring. The design optimization may lead to various different methods like

1. Minimum weight optimization of helical spring by using Harmony search algorithm: This is one of the heuristic optimization method in which work is based on the natural or artificial phenomenon. Harmony search algorithm work base on the improvisation of music. As helical spring is widely used for many application weight reduction of the spring plays important role in cost saving and performance efficiency. The performance algorithm is illustrated with optimization of helical spring as front suspension spring of Maruti 800 for minimum weight
2. Helical spring design optimization with monotonicity analysis.In this method without numerical iterative computations this technique eliminates combinations of constraints which cannot be active at the optimum
3. One of the important method of helical spring optimization is to optimize spring coil diameter for that we can use mathematical model of the spring and optimization with the help of response surface methodology and design of experiments. Response surface methodology is a statistical approach of design of experiments, is being applied with combined probabilistic design to optimize the design responses in the case of simultaneous variations of its design parameters
4. Helical spring design optimization with nature inspired algorithm for dynamic conditions: in this method nature inspired algorithms namely Simulated Annealing (SA), Fire fly (FA) and Cuckoo Search (CS) are proposed to get dynamic optimal solution for a helical spring design problem.

F. Various parameters affecting Spring Coil Deign

1.Raw material selection
2.Raw material Defect
3.Heat Treatment
4.Spring geometry
5.Design Parameters

a. Operating Mode
b. Imperfections on inside diameter of spring
c. Stress Peening
d. Operating Temperature

G. Finite Element Analysis

FEA has the ability to reduce error caused by the simplification of equation. FEA based design include How the model should be constructed, selection of element type, accuracy of result and fast run of the model. For Coil spring FEA can be obtained by creating 3D parts of coil spring its seats followed by meshing the parts with 3D solid elements. More accurate results can be achieved by finer meshing with higher order element.A 3D beam element is usually selected to model and a coil spring and seat. Material properties of the spring are set very high to act as rigid. The contact between coil and seat and coil itself , is detected by gap elements. FEA model is created each time a coil/seat is modified and the simulation will be repeated until all requirements are satisfied.

H. Failure analysis of Helical Compression coil spring

To improve performance of the spring it is necessary to understand the behavior of the material.Heat and surface treatments can significantly improve the fatigue life of spring.

I. Different reasons of spring failure analysis are:

1. Raw material Defects: The typical raw material defect is the existence of foreign material inside the steel, such as non metallic inclusions. In general there are two types of foreign materials that can be trapped inside the steel solution: large imperfections such as spinells and smaller imperfections such as inclusions that are caused by alloying elements.
2. Surface imperfections: Surface imperfections can occur as small hardening crack, tool marks, scale embedded to the base material during cold drawing. Poorly shot peened surfaces can also be considered as surface imperfections.
3. Improper Heat Treatment: Prolonged Heating can cause prior austenite grain size to grow significantly. Improper heat treatment can result in to microstructure becoming pearlite instead of required martensite.Bainetic formation is another form of improper heat treatment
4. Corrosion: Corrosion is the more common cause of spring breakage. However recent coating technology has reached a point where it is able to protect a metal from even hardest cold stone chipping
5. Decarburization: It is more severe in the entire list of defects.

CONCLUSION

1. It is seen that a mathematical model can be designed for specific application with the help of basic theory associated with it.
2. The factors that affect the spring strength are design parameters, material Selection, Raw material Defect, spring geometry and surface imperfections.
3. The spring design can be optimizes with the help of various methods enlisted above & there are more soon. In general spring design can be optimized with the help of natural data algorithm and linear / non linear programming.
4. It is seen that design parameters i.e. Operating modes, Operating temperature, shot peening and imperfections on inside the coil spring affect directly on fatigue life of spring, as we seen as temperature increases the modulus and torsional yield strength of spring material decreases so process parameters plays important role in spring Design
5. Material selection plays very important role in spring design with material, we can vary different design parameters according to material and applications to get optimum design.

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