Analytic Analysis of Helical Conical Spring

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Abstract— **Spring is an important mechanical component used in automobile industries and many other applications like as in some types of pen mechanism for writing. In the present study the analytical analysis of helical conical spring is carried out and the material is spring steel according to specification of IS 4454 Grade 3. Conical Compression Springs are cone shaped springs designed to provide a near constant spring rate and a solid height lower than a normal spring The simulated results of the present study are compared with the available experimental data from a spring industry. The numerical simulation results for deformation and analytical stress are calculated under various loading conditions. It was found that that the analytical results for deformation shows the good agreement with the available experimental data. The spring component which we used for analysis has 500,000 cycle duration. So for safety of spring we will ensure during analysis through analytical method that maximum stress generation in spring should be less than the spring fatigue strength corresponding to their generation cycle**

Keywords— ***Helical spring, FEM analysis, Stress analysis, fatigue Strength***

I. INTRODUCTION

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. A.M Whal stated about mechanical spring that it is a kind of elastic body which distorted it's shape or deflected under a load condition (to absorb energy) and after removing the load condition it regain its original shape [1]. In human history non coiled spring is used like as arrow and bow. During the Bronze Age many cultures used more sophisticated spring device as by the spread of tweezers. In the 15th century, coiled spring was appeared in door locks. In that century first power- clocks was appeared [6][7][8]and by the 16th the first large watches were evolved. Further he goes to classify the main functions of spring as one of the four things which was to apply force, to provide load control, to support the structure, to absorb the shock. This broad understanding includes things that by which as springs are not being normally thought by the people. To minimize the fatigue failure or to improve the fatigue strength, various processes is done like heat treatment processes. Lath martensitic structures usually have a higher strength, and improving toughness [11]. The other factor which is investigated to increase the fatigue strength is shot peening. In this case residual compressive stresses are induced in the surface layers. Concomitantly, work hardening takes place. Also, the accompanying surface roughness may initiate undesirable cracking which may be countered by the residual compressive stresses. However, these stresses can fade during cycling with the surface stress concentrations becoming more dominant than the residual stress field, allowing the fatigue cracks to initiate and subsequently propagate.[12][13][14][15].The surface coating on component is also used to increase the fatigue strength like Coating materials deposited onto various substrates have been extensively used in the aerospace, automotive and petrochemical fields, in recent years.

II. MATERIAL

The material taken for the front axle is structural steel. This material has following properties

1. *MECHANICAL PROPERTIES:*

Table.1 Mechanical properties of spring material

Young's Modulus	210790 MPa
Poisson's Ratio	0.29526
Bulk Modulus	171590 MPa
Shear Modulus	81370 MPa
Tensile Ultimate Strength	1430 MPa

2. *Chemical properties:*

Table.2 Chemical properties of Spring material

Carbon percent	0.75 - 1.0
Silicon percent	0.15 – 0.35
Manganese Max percent	0.8
Sulphur, Max percent	0.030
Phosphorus, Max percent	0.030
Sulphur + Phosphorus, Max percent	0.050
Copper, Max percent	0.12

III. EXPERIMENTAL DETAIL

The test of industrial spring deflection and fatigue life is carried out in a computerized spring endurance testing machine. The details of machine and component are below.

Fig.1 computerized spring endurance testing machine

1. *Machine specification:*

STROKE : 93.60

RPM : 180

The data detail is according to IS4454 grade 3.

Table.3 Spring design specification

CHARACTERISTICS	SPECIFIED
Wire Diameter	7.5 mm
I.D 1 (lower internal diameter of one side of spring)	33.5 + 0.5mm
I.D 2 (higher internal diameter of other side of spring)	40.5 + 0.5mm
O.D (outer diameter of spring)	56.5mm MAX
Free length	238.5±2.0mm
Coil direction	R.H (Right hand)
Ends	Squared and ground ends (270^0)
Total coils	17.6
Solid length	133.7mm MAX

The experimental results obtained on computerized endurance testing machine corresponding to various load condition.

Table.4. Experimental detail of Load vs Deflection

LOAD IN Kgf	**LOAD (N) in Newton(after multiplication of Kgf by 9.8)**	**DEFLECTION (MM)**
38	372.4	20
76	744.8	40
132.9	1302.42	67
149.1	1461.18	73
186	1822.8	85
222	2175.6	95

The duration of cycle (specified fatigue cycle for component) is : 5,00,000 Cycles.

IV. METHODLOGY

Now we find the deflection result by analytical method with the help of deflection formula of conical spring:[2]

$$\delta = \frac{2wn\left(D_1^2 + D_2^2\right)(D_1 + D_2)}{Gd^4}$$

D_1 = small mean coil diameter of spring and D_2 = large mean coil diameter of spring.

δ= deflection of conical spring

W= load applied

d= diameter of wire

n= number of active coil turns

Table.5 Parameter for estimation of Spring Deflection

D_1	41.5mm
D_2	48.5mm
d	7.5mm
G	81.370 $\times 10^9$ pa
n	16.9

With the help of formula the deflection results for various load conditions as mention in experimental data, is given in table:

Table.6 Detail of Load vs Deflection

LOAD(N)	DEFLECTION(mm) by analytical method
372.4	17.9
744.8	35.81
1302.42	62.62
1461.18	70.26
1822.8	87.65
2175.6	104.61

We can plot these variations of deflection results. The plotting graph of deflection results by analytical method will be look like as below:

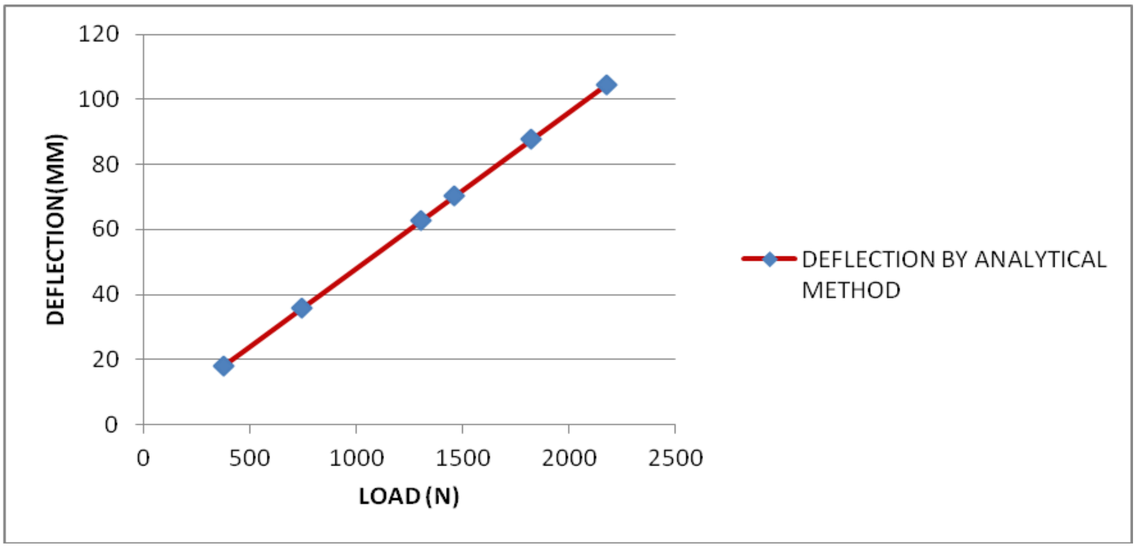

Fig.2 Load vs Deflection (by Analytical method)

There are various methods to calculate deflection,

1. FEM method
2. Analytical method
3. Experimental method

By these methods we have found the deflection results and also plotted the graphs.

Now we will compare Analytical method results with the experimental deflection results corresponding their load condition. This comparison will be in the form of percentage error

$$\% \text{ Error} = \frac{\text{Expected value} - \text{Experimental value}}{\text{Experimental value}} \times 100$$

Table.7 %Error in Deflection results by different techniques to the experimental result

LOAD(N)	DEFLECTION(MM) by experimental method	%ERROR(by analytical method) to experimental results
372.4	20	10.45%
744.8	40	10.47%
1302.42	67	6.5%
1461.8	73	3.7%
1822.8	85	3.1%
2175.6	95	10.1%

V. CONCLUSION

Under this work, there are following results are concluded:

- There is some error in result comparison of deflection by Analytical method to the experimental results. Which is approximately to 10%
- The %Error is going to decrease as input load increase up to the limit of 1461.8N.
- The %Error is also going to decrease as input load increase but up to limit 1822.8N.

The overall work shows that our estimating results are closed to available experimental results with the under considering of safe design of spring.

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