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Design And Analysis Of Two Wheeler Suspension System By FEA Approach

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Abstract - *The Suspension system is the most important part in any vehicle. It handles shock impulse and dissipates kinetic energy. It reduces the amplitude of disturbances and improved ride quality. The spring is compressed quickly when the wheel strikes the bump. The compressed spring rebound to its normal dimension when load is removed. The spring goes down below its normal height when the weight of the vehicle pushes the spring down. This, in turn, causes the spring to rebound again. The spring bouncing process occurs over and over every less each time, until the up-and-down movement finally stops. The vehicle handling becomes very difficult and leads to uncomfortable ride when bouncing is allowed uncontrolled. Hence, the designing of spring in a suspension system is very crucial. The present work is carried out on helical spring where, modelling, analysis and testing of suspension spring is done to replace the existing design of helical spring used in popular two wheeler vehicle. The different designs of springs are modelled by reducing the diameter of the existing spring. The analysis is carried out by considering bike mass, loads, and no of persons seated on bike. The stress and deflections of the helical spring are determined by using finite element analysis approach. The comparative study is carried out between baseline spring and new design of spring by constant material. The results from finite element analysis are compared to the experimental values. A typical two wheeler suspension spring (spring for Hero Splendor 125 cc) is selected for the application. The solid model of spring is developed in CATIA and the analysis part is carried out in ANSYS.*

Key Words: *Helical Spring, Finite Element Analysis, CATIA, ANSYS*

I. INTRODUCTION

The aim of this project is to contribute to the development of an enhanced automotive coil springby evaluating existing manufacturing processes and relating this to fatigue properties and residual stresses in the components. The development of a coil spring that is 15% lighter and which can operate at 20% higher stresses will bring about a major revolution in the manufacturing of automotive suspensions. This could result not only in a lighter vehicle but also a reduction in space required by suspensions, which could open the way for new, less drag resistant front body panels.In vehicle suspension system, helical compression coil spring is one of the primary elastic component.

A spring is an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. It is an elastic object used to store mechanical energy. Springs are usually made out of spring steel. Small springs can be wound from pre-hardened stock, while larger ones are made from annealed steel and hardened after fabrication. Some non-ferrous metals are also used including phosphor bronze and titanium for parts requiring corrosion resistance and beryllium copper for springs carrying electrical current (because of its low electrical resistance). When a spring is compressed or stretched, the force it exerts is proportional to its change in length.

II. OBJECTIVE

i. Study the exiting design of helical spring of two wheeler (e.g. Hero Splendor 125 cc)
ii. Model the existing design of spring in CATIA software& carry out analysis in ANSYS.
iii. Carry out the test on existing design and compare with FEA results.
iv. Reduce the diameter of spring and prepare two different designs.
v. Analyse the new designs in ANSYS and compare the results with baseline model.
vi. Propose the optimised design (cost effective and less weight) of spring for two-wheeler.

A. Problem Definition

Helical springs are the most important part in the two wheeler suspension system. Every organisation wants to reduce the cost of the material used in the different parts. Most of the time due to continuous loading, the spring manufacturer used more factor of safety to design the spring. But, keeping higher factor of safety, the cost of material used to manufacture the spring becomes high. Therefore, our project aim is to keep minimum factor of safety for suitable operation of helical spring. The reduction in material leads to reduction in overall cost of the springs.

III. METHODOLOGY

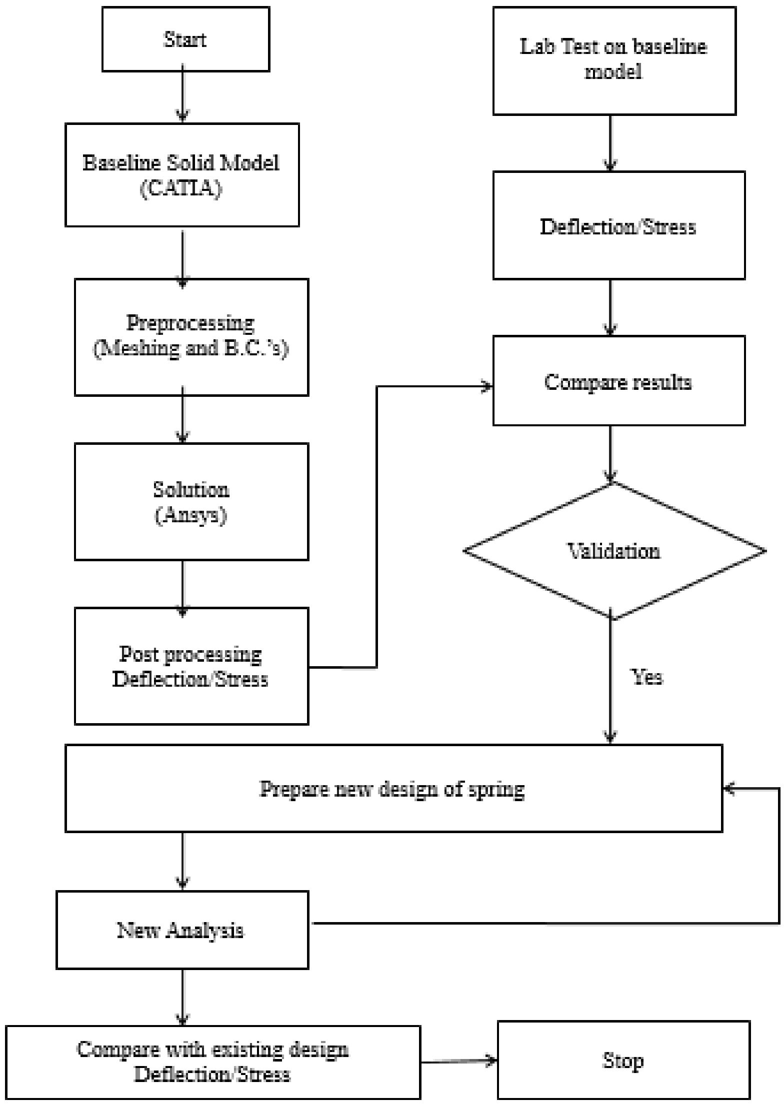

Figure 3.1 Methodology Flowchart

IV. SIMULATION

A. Material Properties

High-carbon spring steels are the most commonly used of all springs materials. This material is preferred to others because they are least expensive, readily available, easily worked, and most popular. These materials are not satisfactory for high or low temperatures or for shock or impact loading. Also this is the general purpose spring steels and should only be used where life accuracy and deflection are not too important.

1. Nominal Mechanical Properties

- Young's Modulus: 206000 MPa
- Modulus of Rigidity: 85000 MPa
- Density: 7800 kg/m^3
- Poisson's Ratio: 0.33
- Tensile yield strength = 250 MPa

Table 4.1 Standard Dimensions of Baseline Model of the Spring

Parameter	Dimension
Upper outer diameter	50 mm
Lower outer diameter	50 mm
Height of the spring	230 mm
Diameter of spring wire	7 mm
Pitch	8mm

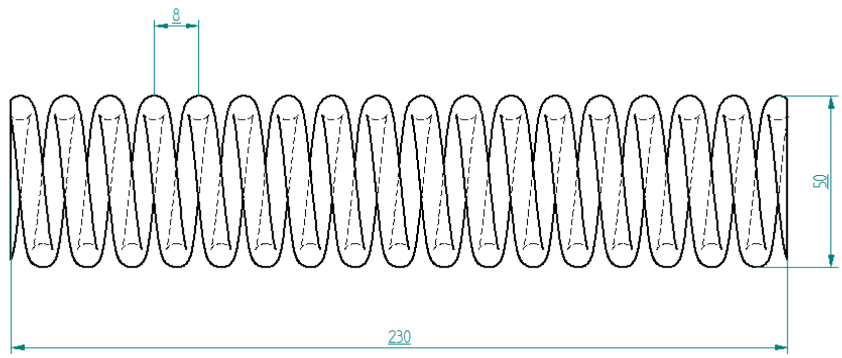

Figure 4.1 2D Drafting of Helical Spring - Baseline Design

B. Calculations

1. Baseline Helical Spring

a) Samplecalculation for the helical spring:

D= Mean Coil Diameter, mm = 43 mm

d= Wire Diameter, mm = 7 mm

N = number of active coils = 18

P = Axial force, N = 200Kg = 200 x 9.81 = 1962 N

(1) Spring index,
$C=D/d$= 43/7 = 6.143

(2) Wahl's stress factor,
k = [(4C−1)/ (14C–4)+(0.615/C)]
k = 1.294

(3) Maximum shear stress,
τ= (k×8PD)/πd3
= (1.294 x 8 x 1962 x 43)/ (3.14 x 7^3)
τ= 810.9MPa.

(4) Deflection of spring,
δ=8PD^3N/Gd^4
δ= (8×1962×43^3×18)/ (1.6e5×$7^{4)}$
δ = 58.47 mm.

2. New Design of Helical Spring

a) Sample calculation for the helical spring:

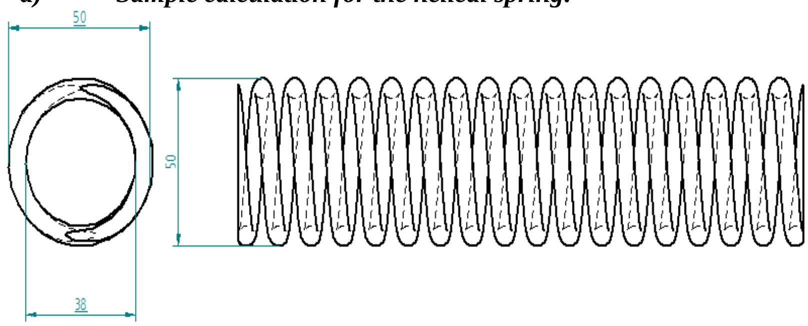

Figure 4.2 2D Drafting of the Design-Model-6mm

D= Mean Coil Diameter, mm = 43 mm
d= Wire Diameter, mm = 6 mm
N = number of active coils = 18
P = Axial force, N = 200Kg = 200 x 9.81 = 1962 N

(1) Spring index
$C=D/d$ = 43/6 = 7.16

(2) Wahl's stress factor,
$k = [(4C-1)/(14C-4) + (0.615/C)]$
$k = 1.247$

(3) Maximum shear stress,
$\tau = (k\times 8PD)/\pi d3$
$= (1.247 \times 8 \times 1962 \times 43)/(3.14 \times 6^3)$
$\tau = 1240.9$MPa.

(4) Deflection of spring,
$\delta = 8PD^3N/Gd^4$
$\delta = (8\times 1962\times 43^3\times 18)/(1.6e5\times 6^4)$
$\delta = 108.32$ mm.

C. Finite Element Analysis Approach

The finite element analysis includes pre-processing, solution and post processing. Following are the most important steps to be followed during analysis.

- CAD Modelling
- Pre-processing -
  - Importing CAD model in ANSYS
  - Meshing,
  - Material Assignment,
  - Assigning element types,
  - Assigning loading and boundary conditions,
  - Assigning time steps
- Solution -
  - Run the FEA model
- Post-processing -
  - Observe the displacement
  - Observed animation of displacement
  - If animation is logical as per applied boundary conditions, then proceed to record stresses.
  - Record von-Mises stress for all parts

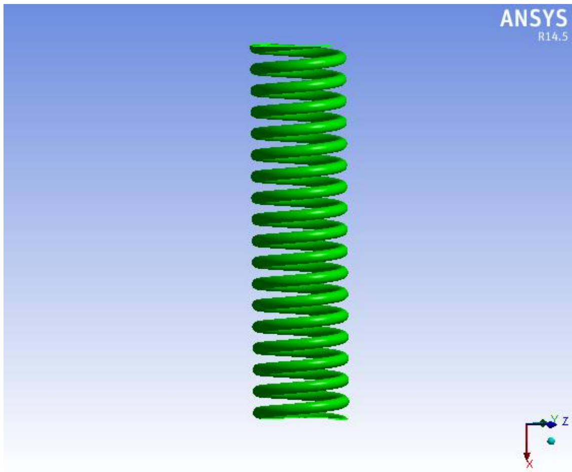

Figure IV.3 CAD Model – Diameter- 6mm

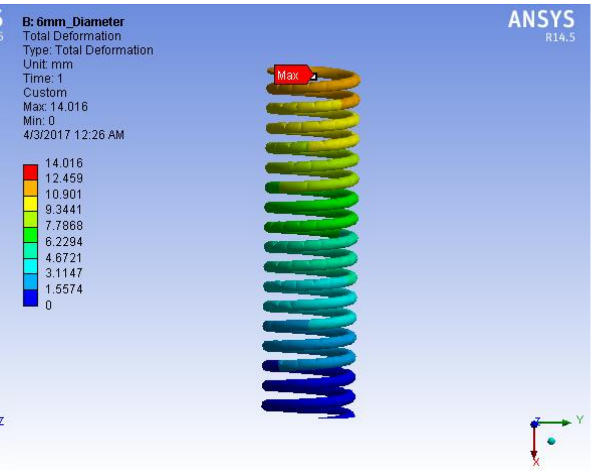

Figure IV.4 Total Deformation Contour Plots Diameter-6mm

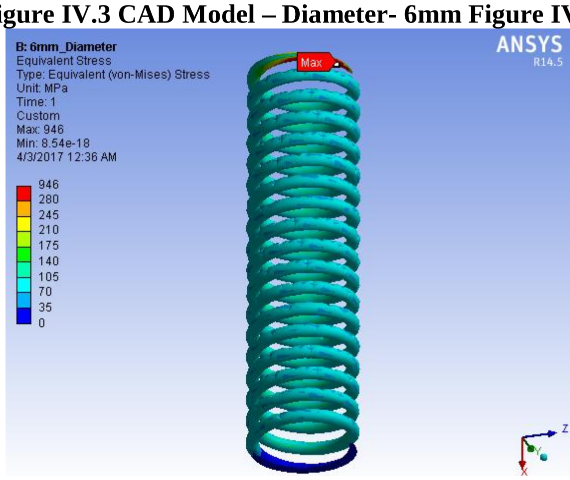

Figure IV.5 Von-Mises Stress Contour Plots Diameter-6mm

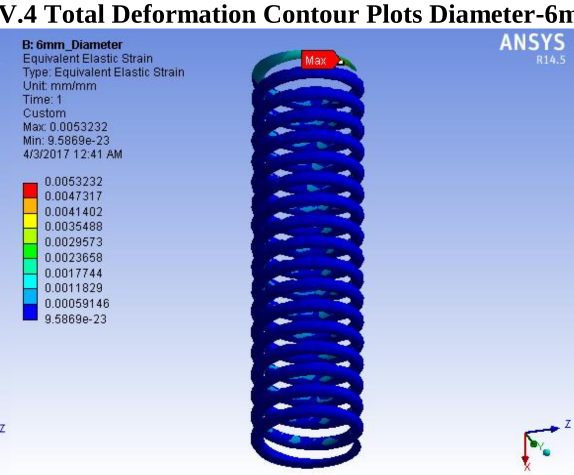

Figure IV.6 Equivalent Elastic Strain Contour Plots Diameter-6mm

D. Summary Table (From Finite Element Analysis)

Table 4.2 Summary Table (From Finite Element Analysis)

Sr. No.	Description	Mass, Kg	Deflection, mm	Von-Mises stress, MPa
1	Baseline Design-1	0.711	6.99	204
2	Design-2	0.535	14.02	280
3	Design-3	0.379	30.44	340

V. EXPERIMENTAL VALIDATION

Table 5.1 Experimental Readings

Sr. No.	Description	Mass, Kg	Deflection, mm	Von-Mises stress, MPa
1	Baseline Design-1	0.711	8	210
			7	
			8	
2	Design-2	0.535	15	300
			14	
			13	
3	Design-3	0.379	35	380
			34	
			32	

VI. RESULTS AND DISCUSSION

It is observed from the results that maximum stresses are developed at extreme ends of the helical spring. The maximum deformation in helical spring is observed up to 7 mm. The Von-Mises stress in the helical spring for the maximum load of 100 Kg is 204MPa. The total weight of the helical spring is 0.711 kg. Therefore, the von-mises stress in the spring is below their yield strength of the material. **Hence, there is maximum scope to reduce the mass of the suspension system in baseline design.**

Table 6.1 Deflection Results (FEA & Experimental)

FEA	Design-1		Design-2		Design-3	
Time (s)	Load (N)	Deflection (mm)	Load (N)	Deflection (mm)	Load (N)	Deflection (mm)
0.1	100	0.69926	100	1.4016	100	3.0448
0.2	200	1.3985	200	2.8032	200	6.0896
0.3	300	2.0978	300	4.2049	300	9.1343
0.4	400	2.7971	400	5.6065	400	12.179
0.5	500	3.4963	500	7.0081	500	15.224
0.6	600	4.1956	600	8.4097	600	18.269
0.7	700	4.8949	700	9.8113	700	21.313
0.8	800	5.5941	800	11.213	800	24.358
0.9	900	6.2934	900	12.615	900	27.403
1	1000	6.9926	1000	14.016	1000	30.448
Experimental	Design-1		Design-2		Design-3	
Time (s)	Load (N)	Deflection (mm)	Load (N)	Deflection (mm)	Load (N)	Deflection (mm)
0.1	100	0.8	100	1.5	100	3.5
0.2	200	1.6	200	3	200	7
0.3	300	2.4	300	4.5	300	10.5
0.4	400	3.2	400	6	400	14
0.5	500	4	500	7.5	500	17.5
0.6	600	4.8	600	9	600	21
0.7	700	5.6	700	10.5	700	24.5
0.8	800	6.4	800	12	800	28
0.9	900	7.2	900	13.5	900	31.5
1	1000	8	1000	15	1000	35

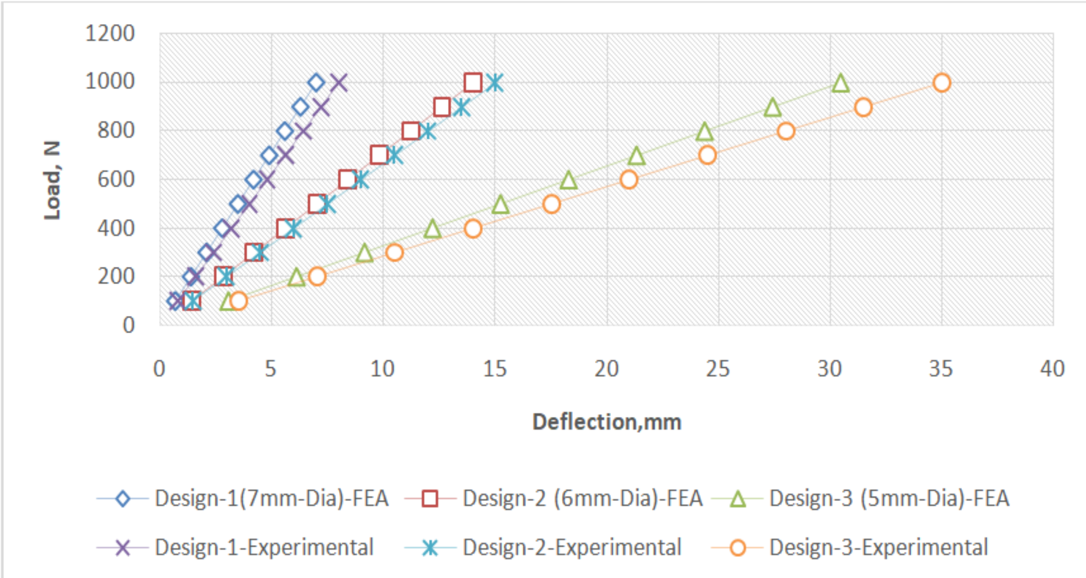

Figure6.1 Load Vs. Deflection (FEA & Exprerimental)

The maximum deformation in design-2 of helical spring is observed up to 14 mm. The Von-Mises stress in the helical spring for the maximum load of 100 Kg is 240MPa. The total weight of the helical spring is 0.535 kg. Therefore, the von-mises stress in the spring is below their yield strength of the material. **Hence, the design-2 is safe for the applied loading conditions.**

The maximum deformation in design-3 of helical spring is observed up to 30 mm. The Von-Mises stress in the helical spring for the maximum load of 100 Kg is 340MPa. The total weight of the helical spring is 0.379 kg. Therefore, the von-mises stress in the spring is above their yield strength of the material. But, the stresses are below their ultimate tensile strength of material. **Hence, there are chances of permanent deformation of the design-3. Therefore, design-3 is not suitable for our application.**

If we compare the masses of the three designs, the design-2 of the helical spring lighter than baseline design-1. **The designs-2 is 25% lighter in weight than design-1.**

The following table and graph shows values of Von-Mises stress for the Finite element analysis and Experimental setup for the helical spring.

Table 6.2 Stress Results (FEA & Experimental)

FEA	Design-1		Design-2		Design-3	
Time (s)	Load (N)	Stress (N/mm^2)	Load (N)	Stress (N/mm^2)	Load (N)	Stress (N/mm^2)
0.1	100	20.4	100	28	100	34
0.2	200	40.8	200	56	200	68
0.3	300	61.2	300	84	300	102
0.4	400	81.6	400	112	400	136
0.5	500	102	500	140	500	170
0.6	600	122.4	600	168	600	204
0.7	700	142.8	700	196	700	238
0.8	800	163.2	800	224	800	272
0.9	900	183.6	900	252	900	306
1	1000	204	1000	280	1000	340

Experimental	Design-1		Design-2		Design-3	
Time (s)	Load (N)	Stress (N/mm^2)	Load (N)	Stress (N/mm^2)	Load (N)	Stress (N/mm^2)
0.1	100	21	100	30	100	38
0.2	200	42	200	60	200	76
0.3	300	63	300	90	300	114
0.4	400	84	400	120	400	152
0.5	500	105	500	150	500	190
0.6	600	126	600	180	600	228
0.7	700	147	700	210	700	266
0.8	800	168	800	240	800	304
0.9	900	189	900	270	900	342
1	1000	210	1000	300	1000	380

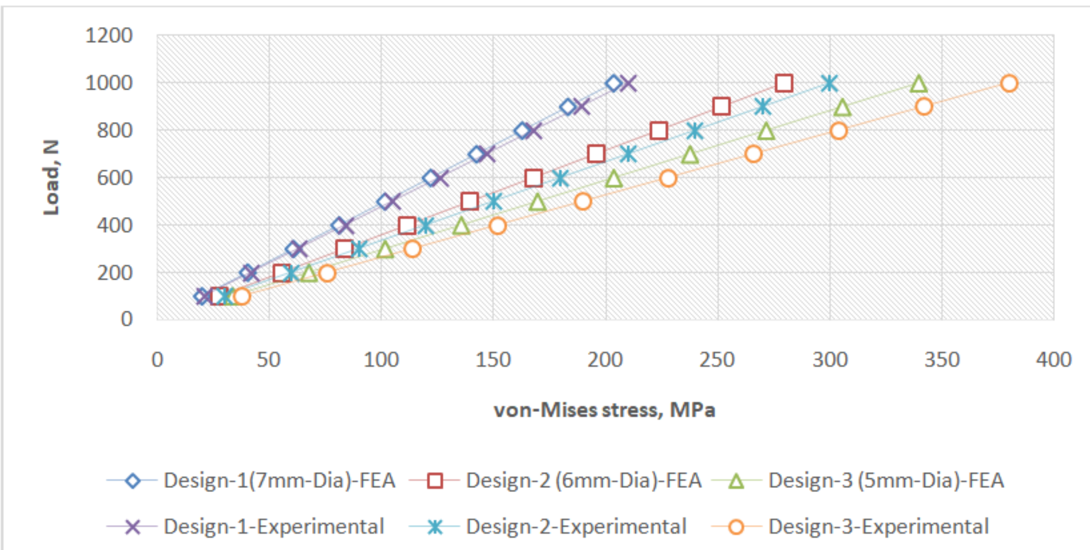

Figure6.2 Load Vs Stress (FEA & Experimental)

VII. CONCLUSIONS

The comparative study of the suspension system helical coil spring with the three different designs has reached at the following conclusion:

i. The deflection in modified design-2 of the helical spring is slightly higher than that of baseline design.
ii. Maximum von-Misesstress is increase in a very minimal amount but, it is less than yield strength of material.
iii. The mass of the design-2 is 25% lighter than baseline design-1.
iv. Design -2 with wire diameter -6 mm is efficient for the applied loading conditions and stands out to be efficient design for spring especially at higher loads.
v. **Thus, stainless steel with design-2 is most suitable optimized design of helical spring for manufacturing.**

VIII. NOMENCLATURE

FEA	Finite Element Analysis
VSS	Vehicle Suspension System
CATIA	Computer Aided Three-dimensional Interactive Application
C	Spring Index
Τ	Maximum Shear Stress
Δ	Deflection Of The Spring
K	Wahl's Stress Factor
K	Stiffness

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