DESIGN AND ANALYSIS OF WAVE SPRING FOR TWO WHEELER REAR SUSPENSION SYSTEM

Mr. Krupesh H. Dave[1], Mr. Bhavik M. Padhiyar[2]

[1]PG Scholar, [2]Asst. Professor, Mechanical Engineering Department, SAL College of Engineering, Ahmedabad-380060.

ABSTRACT

Since many years there is so many research work done on helical spring due to its vast range of working and reliability in various sector, like machines, automobiles etc. All researcher have modified design, changed materials for various purpose. But the conventional spring still in use. Now, with change in time and technology better to find alternative option for it. Wave spring which is different from conventional design, was first conceptualized by the SMALLEY Industries, U.S.A. in 1990's for purpose of to keep machine component connected by spring pressure. They use the Hooke's law while designing of it.Wave spring occupies 50% less space than conventional spring, also it have long lasting effectiveness and good durability. For the two wheeler rear suspension system wave spring is designed with the same dimensions of helical spring. The spring is designed and analyzed both theoretically and numerically. Load is considered as the bike weight and two person weight. Structural steel and copper alloy are taken as the spring material. In theoretical analysis the analytical equations are used where as in numerical analysis the structural and fatigue analysis is performed. This present study focuses on the selection of the best spring with the best material for the two wheeler rear suspension system. Soild works is used for the designing of the spring and analysis is performed by the ANSYS.

Key words: Wave spring, Rear suspension, Structural analysis, Modified design.

1) INTRODUCTION

Spring is defined as "An elastic body, whose function is to distort when loaded and recover its original shape when load is removed." Springs generally used to absorb shock and to give force in many mechanism. Whenspring used in the suspension system, it absorbs shocks/ vibrations, and when it used in brakes/clutches it applies the force. There are many springs are available which is generally use, like Helical Spring, Conical and Volute Spring, Torsion Spring, Leaf Spring, Disc Spring Etc. these are commonly used spring. Wave Spring is a new design concept in the spring world.

1.1 Wave Spring

It is also known as coiled wave spring or scro wave spring. It is made up of pre hardened flat wire in a process called on-edge-coiling (edge winding) during this process, waves are added to give it a spring effect. The number of turns and waves can be easily adjusted to accommodate stronger force or meet specific requirement.

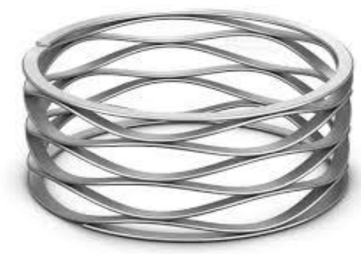


Fig. 1 wave spring

1.2 Advantages of Wave Spring

1) Wave Springs offer the unique advantage of space saving when used to replace coil springs.

2) By reducing spring operating height, wave springs also produce a decrease in the spring cavity.

3) With a smaller assembly size and less material used in the manufacturing process, a cost savings is realized. Etc. can be the advantages of wave spring over the helical spring

1) Theoretical Analysis of springs

In theoretical analysis the stress, deflection and the spring rate is calculated by the analytical formulas. The dimensions and material properties are given in Table-1 and Table-2 respectively.

2.1 Spring Specifications

Here the dimensions of helical and wave spring are taken as the same. Materials are taken as structural steel and copper alloyfor both the spring.

Table 1: Dimensions of the spring

PARAMETERS	COIL SPRING	WAVE SPRING
Wire Diameter of Spring (d)	7 mm	7 mm
Outer Diameter of Spring (D_{out})	50 mm	50 mm
Inner Diameter of Spring (D_{in})	36 mm	36 mm
Mean Diameter of Spring (D_m)	43 mm	43 mm
Free Length (L_f)	229 mm	229 mm
Active Coils (n)	16	-
Number of Total Coils (N)	18	18
Pitch (p)	12.94 mm	-
Solid Length (L_s)	138.13mm	-
Number of waves per turn (Z)	-	2.5
Radial width (b)	-	7mm
Thickness of material (t)	-	4mm

Table 2: Material properties

Properties	Density of material ($kg \div m^3$)	Poisson's ratio	Young's modulus (E) (N/mm^2)	Shear modulus (G) (N/mm^2)	Yield strength (N/mm^2)	Ultimate tensile strength (N/mm^2)
Structural steel	7850	0.3	200×10^3	7.6923×10^3	250	460
Copper alloy	8300	0.34	110×10^3	4.1045×10^3	280	430

2.2 Helical spring analytical formulae:

- **Stress in helical spring**

$\tau = K \times (8\ W\ D_m \div \pi\ d^2)$……………………………..(1)

Here, K = whal's stress factor
$= (4C-1) \div (4C-4) + (0.615) \div C$

τ = Max. Shear stress
D_m = Mean dia. Of the spring
W = Load on the spring
d = Diameter of the spring wire

- **Deflection of the helical spring**

$\delta = 8\ W\ C^3 n \div G\ d$ ………………………………….(2)

δ = Deflection of spring
G = Modulus of rigidity
n = Number of turns

- **Spring rate**

$k = G\ d \div 8\ C^3\ n$ ………………………………. (3)

k = Spring rate
d = Diameter of the spring wire

2.3Wave spring analytical formulae:

- **Operating stress**

$S = 3\pi\ P\ D_m \div 4\ b\ t^2\ N^2$ …………………………..(4)

D_m = Mean dia. Of the spring
b = Radial width
t = Thickness of spring wire
N = Number of coils
P = Load on the spring

- **Deflection**

$\delta = (P\ K\ Z\ D_m^3 \div E\ b\ t^3 N^4) \times (D_{in} \div D_{out})$ ……………(5)

Z = Number of waves per turn
E = Modulus of Elasticity
K = Multiple wave factor

	Helical spring	Wave spring

- **Spring rate**

$$R = \left(\frac{E\, b\, t^3\, N^4}{K\, Z\, D_m^3} \right) \times \left(\frac{D_{out}}{D_{in}} \right) \text{ ....(6)}$$

D_{in} = Inner dia. of spring
D_{out} = Outer dia. of spring

- **Multiple wave factor (K)** [15]

The value of multiple wave factor varies with the number of waves per turn (N).

Table 3 : Value of multiple wave factor

N	2 – 4	4.5 – 6.5	7 – 9.5	10 - & over
K	3.88	2.9	2.3	2.13

2.5 Load applied on the spring

Load applied on the spring is calculated as below,

Let, the weight of the bike = 125kg

Weight of two person sitting on the bike = 150kg (approx.)

Total weight = 275kg

As we know that rear suspension of bike can bear the 65% of load, then load is = 165kg

As we considering the dynamic loading condition load will be double = 330kg

Convert the load in newton unit = 330kg × 9.8

=3234 Newton

For single shock absorber spring load will be half = 3234 / 2 = 1617 N

Thus our load will be taken as, **W = 1617 N**

2.5 Result comparison

Now, take the dimensions from the Table: 1 and properties of material from Table: 2 and then put them into Equations (1), (2), (3), (4), (5) and (6) and we will obtain the result as shown in the Table: 4.

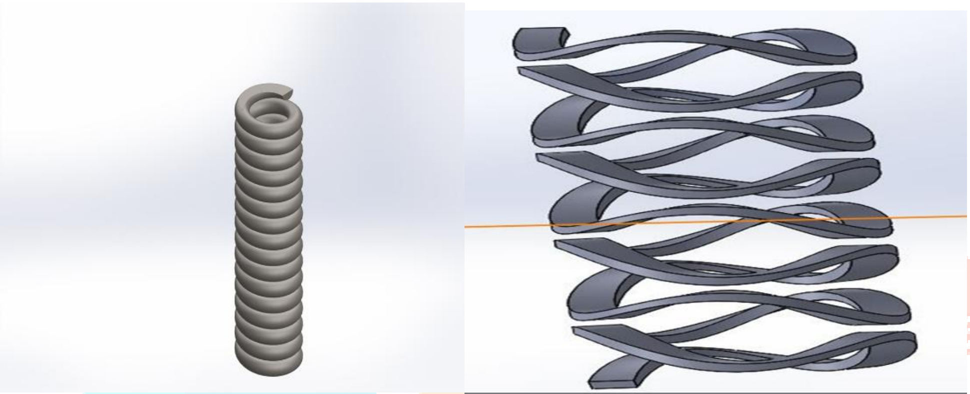
Parameters	Stress (N/mm^2)	Deflection (mm)	Spring rate	Stress (N/mm2)	Deflection(mm)	Spring rate
Structural steel	4504.64	8.897	181.74	233.92	16.450	98.48
Copper alloy	4504.64	16.67	97.00	233.92	29.80	54.167

Table 4: Theoretical result comparison

2) Numerical analysis of spring

Design of the spring is done by using the soild works and analysis is performed by ANSYS. There is two analysis is performed in the ansys 1) structural analysis and 2) fatigue analysis.

3.1 Model of the coil spring and wave spring



(a) (b)

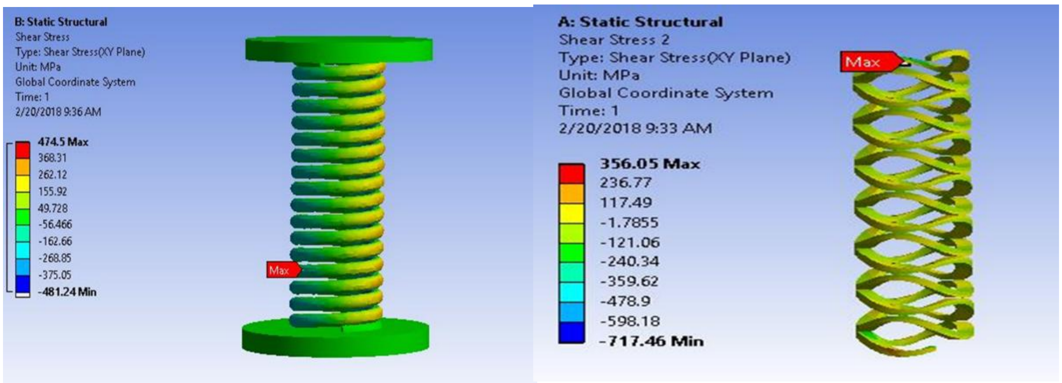
Fig. 2 (a) Model of coil spring (b) Model of wave spring

3.2 Boundary condition of springs

(a) (b)

Fig. 3 (a) Load on coil spring (b) Load on wave spring

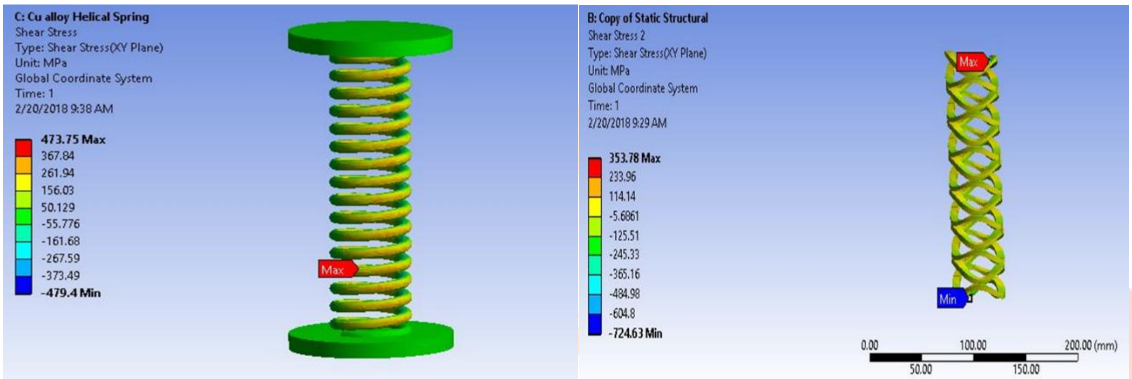
3.3 Stress analysis of spring for structural steel material



(a) (b)

Fig. 4 (a) Shear stress in helical spring (b) Shear stress in wave spring

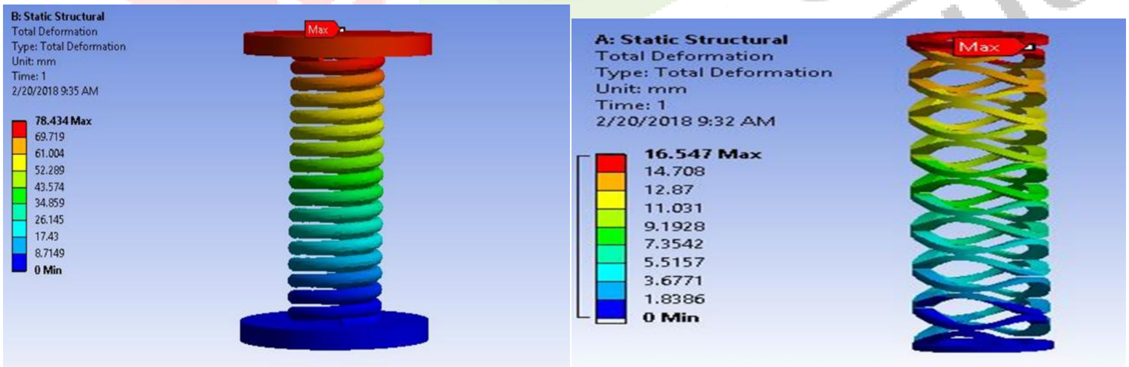
3.4 Stress analysis of spring for copper alloy material



(a) (b)

Fig. 5 (a) Shear stress in helical spring (b) Shear stress in wave spring

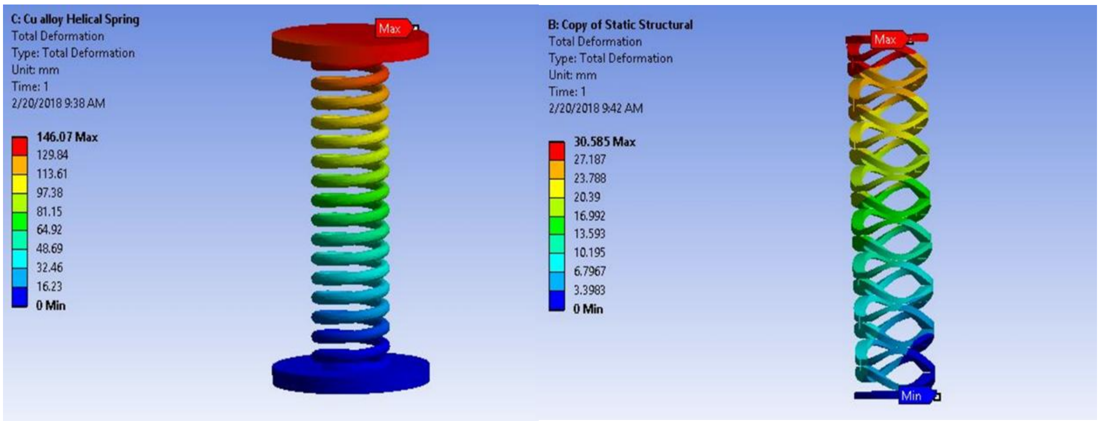
3.5 Deflection analysis of spring for structural steel material



(a) (b)

Fig. 6 (a) Deflection in the helical spring (b) Deflection in the wave spring

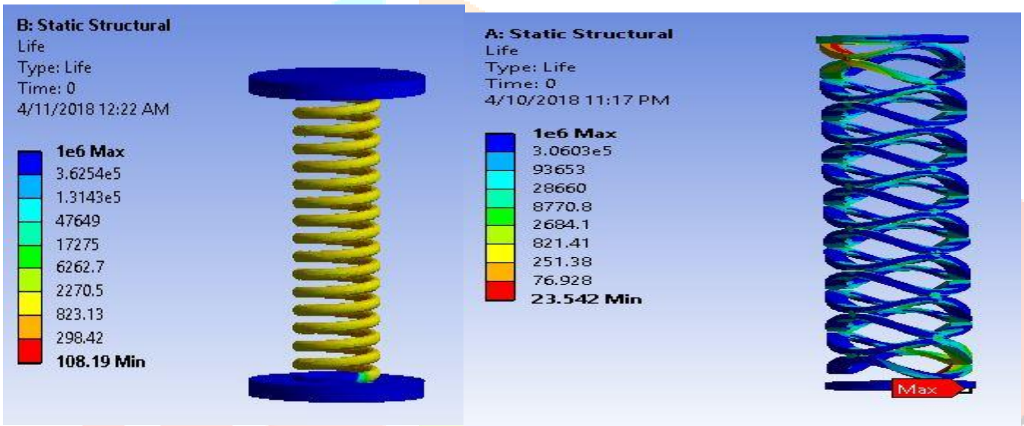
3.6 Deflection analysis for the copper alloy material



(a) (b)

Fig. 7 (a) Deflection in the helical spring (b) Deflection in the wave spring

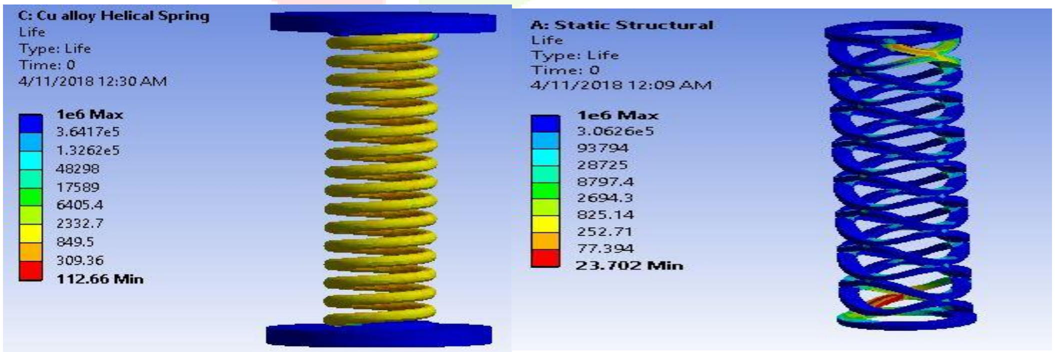
3.7 Fatigue life of spring for structural steel material



(a) (b)

Fig. 8 (a) Life of helical spring (b) Life of wave spring

3.8 Fatigue life of spring for copper alloy material



(a) (b)

Fig. 9 (a) Life of helical spring (b) Life of wave spring

3.9 Result comparison

From the above analysis we will write the data in the tabular form it will show as below

Table 5: Analytical result comparison

Material / Spring type	Shear stress in structural steel material	Shear stress in copper alloy material	Deflection in structural steel	Deflection in copper alloy
Helical spring	474.5 Mpa	473.75 Mpa	78.43 mm	146.07 mm
Wave spring	356.05 Mpa	353.78 Mpa	16.54 mm	30.58 mm

3) Result & Discussion

After performing the theoretical and analytical analysis, we can see from the Table 4 and Table 5 that the wave spring have less deflection and less stress produced for both the material. But among them structural steel is very suitable than copper alloy material. The comparison of the theoretical and analytical result is leads to the validation of the result.

4) Conclusion

The deformation in wave spring of structural steel is less than coil spring of both material. But the stress produced in the wave spring of structural steel is negligibly more. So we can say that wave spring is best suitably option to replace the helical spring from the two wheeler rear suspension system.

5) Future scope

In this Present research paper wave spring with rectangular cross section is used to compare with circular cross section of the helical spring, but instead of using the rectangular shape one can change the shape of cross section and then can do further analysis. Also by reducing total number of turns in spring and increasing number of waves per turn further analysis can be performed.

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