Design and analysis of a two wheeler shock absorber coil spring

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Abstract - *A suspension system is a mechanical device which is used to smooth out or damped shock impulse and dissipate kinetic energy. In vehicles, the problem happens while driving on bumping road condition so the rider feels uncomforted. Hence the design of spring in shock absorber is very important. In this project, spring is designed and the 3D model is created using modeling software CATIA. Static analysis is done on the spring by varying materials as oil tempered spring steel and beryllium copper. The analysis is done by considering load of bike weight, load of single person and load of two persons. In this analysis, maximum shear stress and total deformation is calculated using ANSYS software and the comparison is made on two material.*

Key Words: **Shock Absorber, Automotive, CAD, FEA, ANSYS, spring.**

1. INTRODUCTION

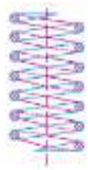
A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. The various important applications of springs are as follows:

1. To cushion, absorb or control energy due to either shock or vibration as in car springs, railway buffers, air-craft landing gears, shock absorbers and vibration dampers.
2. To apply forces, as in brakes, clutches and spring loaded valves.
3. To control motion by maintaining contact between two elements as in cams and followers.
4. To measure forces, as in spring balances and engine indicators.
5. To store energy, as in watches, toys, etc.

In short, Suspension system or shock absorber is a mechanical device designed to smooth out or damp shock impulse, and dissipate kinetic energy. The shock absorbers duty is to absorb or dissipate energy. In a vehicle, it reduces the effect of traveling over rough ground, leading to improved ride quality, and increase in comfort due to substantially reduced amplitude of disturbances. When a vehicle is traveling on a level road and the wheels strike a bump, the spring is compressed quickly. The compressed spring will attempt to return to its normal loaded length and, in so doing, will rebound past its normal height, causing the body to be lifted. The weight of the vehicle will then push the spring down below its normal loaded height. This, in turn, causes the spring to rebound again. This bouncing process is repeated over and over, a little less each time, until the up-and-down movement finally stops. If bouncing is allowed to go uncontrolled, it will not only cause an uncomfortable ride but will make handling of the vehicle very difficult. So, the design of spring is important for the rider's safety.

2. HELICAL SPRING

The helical springs are made up of a wire coiled in the form of a helix and is 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.



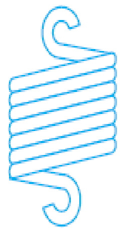


Fig. 1.1: Compression helical spring
Fig.1.2: Tension Helical spring

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 coil helical springs only.

The helical springs have the following advantages:

(a) These are easy to manufacture.

(b) These are available in wide range.

(c) These are reliable.

(d) These have constant spring rate.

(e) Their performance can be predicted more accurately.

(f) Their characteristics can be varied by changing dimensions.

3. Material for helical coil spring:

The material of the spring should have high fatigue strength, high ductility, high resilience and it should be creep resistant. It largely depends upon the service for which they are used i.e. severe service, average service or light service.

Severe service means rapid continuous loading where the ratio of minimum to maximum load (or stress) is one-half or less, as in automotive valve springs.

Average service includes the same stress range as in severe service but with only intermittent operation, as in engine governor springs and automobile suspension springs.

Light service includes springs subjected to loads that are static or very infrequently varied, as in safety valve springs. The springs are mostly made from oil-tempered carbon steel wires containing 0.60 to 0.70 percent carbon and 0.60 to 1.0 percent manganese. Music wire is used for small springs. Non-ferrous materials like phosphor bronze, beryllium copper, Monel metal, brass etc., may be used in special cases to increase fatigue resistance, temperature resistance and corrosion resistance. Table 1.1 shows the values of allowable shear stress, modulus of rigidity and modulus of elasticity for various materials used for springs. The helical springs are either cold formed or hot formed depending upon the size of the wire. Wires of small sizes (less than 10 mm diameter) are usually wound cold whereas larger size wires are wound hot. The strength of the wires varies with size, smaller size wires have greater strength and less ductility, due to the greater degree of cold working.

Table 1: Values of allowable shear stress, Modulus of elasticity and Modulus of rigidity for various spring materials.

Material	Allowable shear stress (τ) MPa			Modulus of rigidity (G) kN/m²	Modulus of elasticity (E) kN/mm²
	Severe service	Average service	Light service		
1. Carbon steel					
(a) Upto to 2.125 mm dia.	420	525	651		
(b) 2.125 to 4.625 mm	385	483	595		
(c) 4.625 to 8.00 mm	336	420	525		
(d) 8.00 to 13.25 mm	294	364	455		
(e) 13.25 to 24.25 mm	252	315	392	80	210
(f) 24.25 to 38.00 mm	224	280	350		
2. Music wire	392	490	612		
3. Oil tempered wire	336	420	525		
4. Hard-drawn spring wire	280	350	437.5		
5. Stainless-steel wire	280	350	437.5	70	196
6. Monel metal	196	245	306	44	105
7. Phosphor bronze	196	245	306	44	105
8. Brass	140	175	219	35	100

The analysis of spring is done on the ANSYS workbench 14.5 and deformation of the spring and maximum shear stress is calculated. This two results for oil tempered spring steel and beryllium copper is compared for bike load plus two persons, bike load plus one person and only bike load.

3.1 Design calculations

The design calculations plays important role in accuracy and validation of the experiment. All the design parameters are taken as arbitrary and may vary as per the two wheeler size and rider's weight. The weight of the rider is assumed to be 60 kg.

The calculations for the material 1 are shown below. The design calculations are done as per the standard design data book for the oil tempered spring steel and Beryllium Copper.

3.1.1 Oil Tempered Spring Steel

Material-spring steel (0.85%C - 0.95%C) (cold drawn steel wire)

Ultimate tensile strength, $S_{ut} = 1138\ N/mm^2$

Modulus of rigidity, $G = 78600\ N/mm^2$

Permissible shear stress, $\tau_c = 0.5\ S_{ut}$

$= 0.5 \times 1138$

$= 569\ N/mm^2$

Now, the mass of the system to be analysed is assumed as follows:

Mass of the bike = 110kg

Mass of one person = 60kg

Mass of two person = 120kg

Mass of bike + two persons = 230kg

Out of total mass 65% mass is on the rear suspension =138 kg

Dynamic mass and rear suspension = 2×138

= 276 kg

The mass on 1 shock absorber $= \frac{276}{2}$

= 138 kg

= 1353.78 N

Let spring index, $C = \frac{D}{d}$

= 6

Wahl's shock stress factor,

$$k = \frac{4c-4}{4c-1} + \frac{0.615}{c}$$

$$= \frac{20}{23} + \frac{0.615}{6}$$

k = 1.2525

Now,

$$\tau = \frac{k(8WC)}{\pi d^2}$$

$$569 = \frac{1.2525(8 \times 1353.78 \times 6)}{\pi d^2}$$

d = 6.7476

d = 7 mm

D = d$\times c$ = 7$\times$ 6= 42 mm

Now,

$$\delta = \frac{8WD^3n}{Gd^4}$$

$$\delta = \frac{(8 \times 1353.78 \times 42^3 \times 15)}{78600 \times 7^4}$$

$$\delta = 63.21\ mm$$

$$\delta \cong 64\ mm$$

Total number of turns,

n_t = n + 2 =17 - (plain and ground ends)

Solid length of spring,

$L_S = n_t \times d$

=17$\times$7

=119 mm

The axial gap between two turns when maximum load applied is 1mm,

= (17-1) $\times$ 1

=16mm

Free length of spring,

L_f = solid length + deflection + axial gap

= 119 + 64 + 16

L_f = 199 mm

= $L_s + \delta_{max} \times$(m-1) $\times$clearance

Pitch of spring,

$$P = \frac{\text{free length}}{N_t - 1}$$

$$= \frac{199}{16}$$

= 12.4375

4. Bike Load plus Two Persons:

In this, the load applied on the spring is 1353 N and one side of the spring is kept fixed. And deformation as well as maximum shear stress is calculated for both the materials.

4.1.1 Oil tempered spring steel

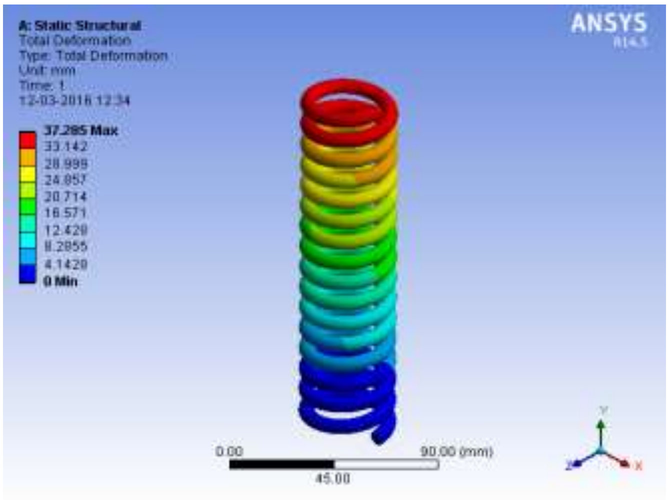


Fig.3. Total Deformation Oil tempered spring steel

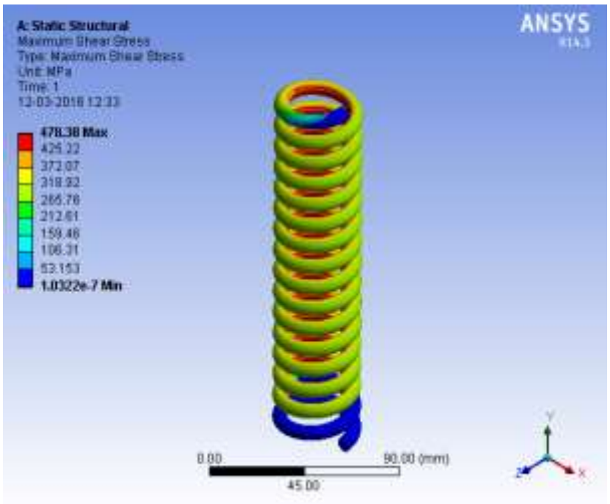


Fig. 4. Maximum shear stress Oil tempered spring steel

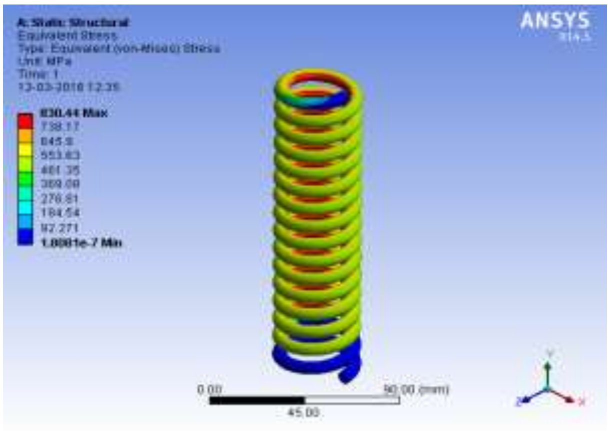


Fig. 5. Equivalent (Von-Mises) stress Oil tempered spring steel

4.1.2 Beryllium Copper

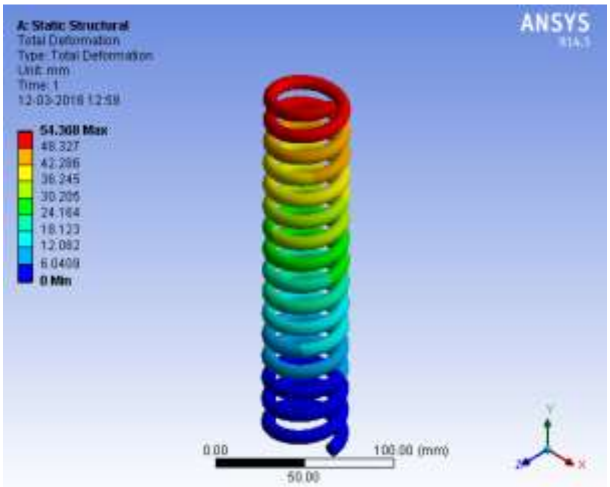


Fig. 6. Deformation for Beryllium Copper

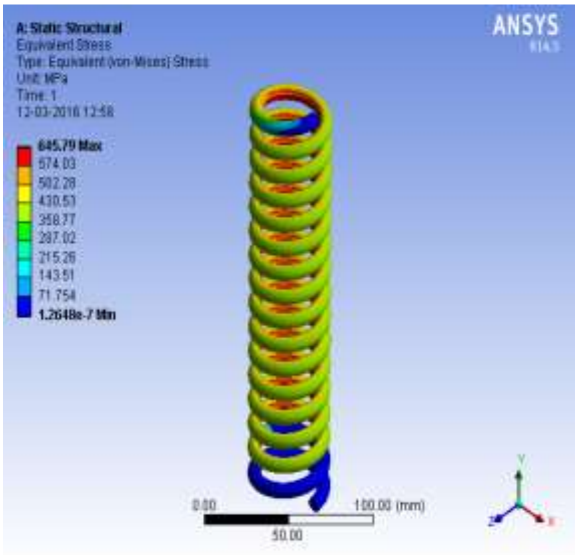


Fig. 7. Equivalent (Von-Mises) Stress for Beryllium Copper

4.2 Bike Load plus One Person

In this, the load applied on the spring is 1275 N and one side of the spring is kept fixed. And deformation as well as maximum shear stress is calculated for both the materials.

4.2.1 For oil tempered spring steel

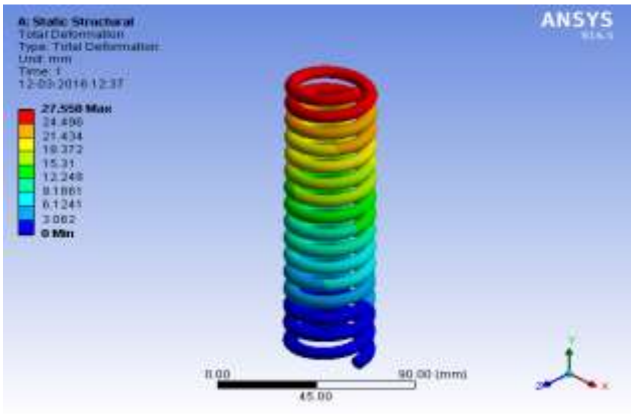


Fig. 8. Deformation for Oil tempered spring steel

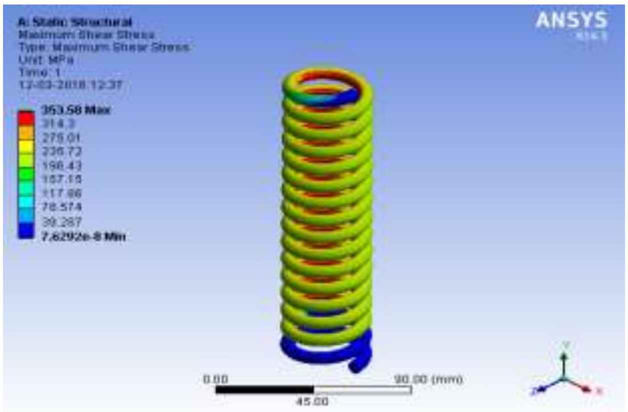


Fig. 9. Maximum Shear Stress Oil tempered spring steel

4.2.2 For Beryllium Copper

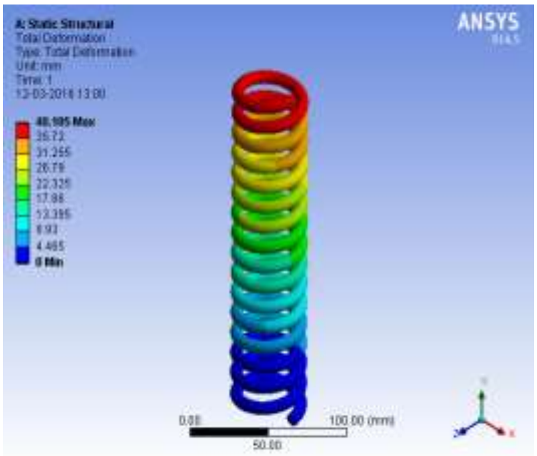


Fig. 9. Deformation for Beryllium Copper

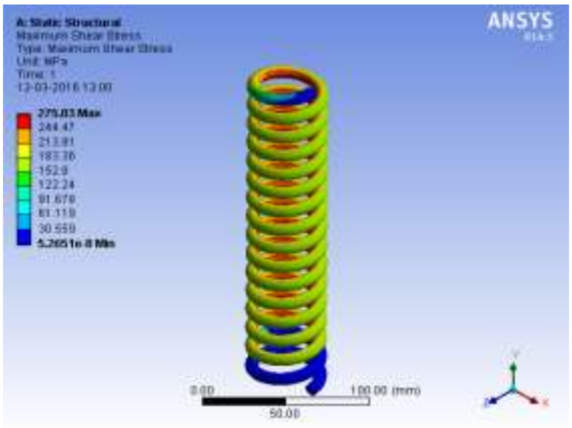


Fig. 10. Maximum shear stress for Beryllium Copper

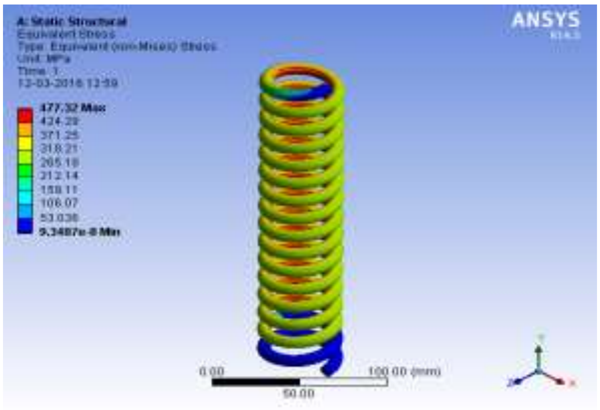


Fig. 11. Equivalent (Von-Mises) stress for Beryllium Copper

4.3 Bike Load

In this, the load applied on the spring is 797 N and one side of the spring is kept fixed. And deformation as well as maximum shear stress is calculated for both the materials.

8.3.1 For oil tempered spring steel

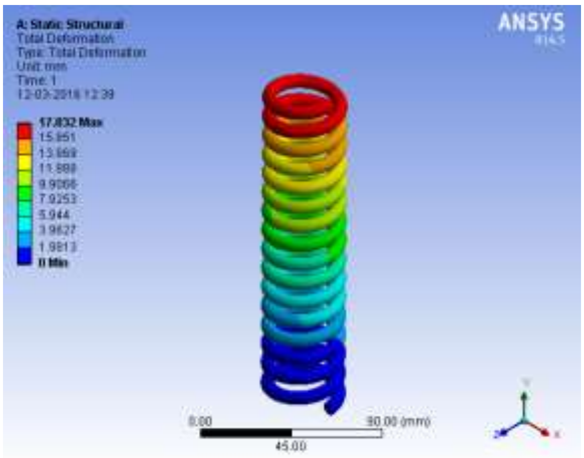


Fig. 12. Deformation for Oil tempered spring steel

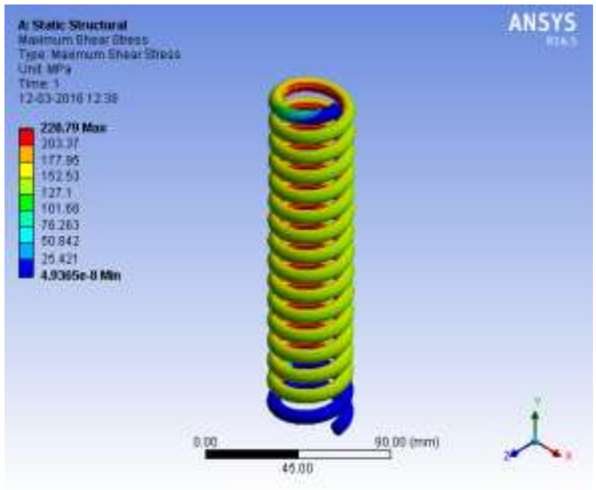


Fig. 13. Maximum Shear Stress for Oil tempered spring steel

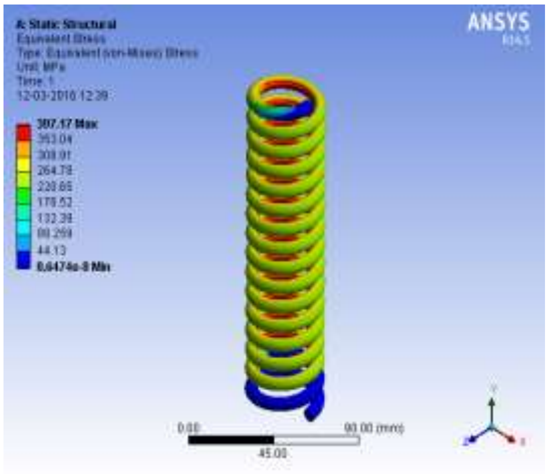


Fig. 14. Equivalent (Von-Mises) stress for Oil tempered spring steel

8.3.2. For Beryllium Copper

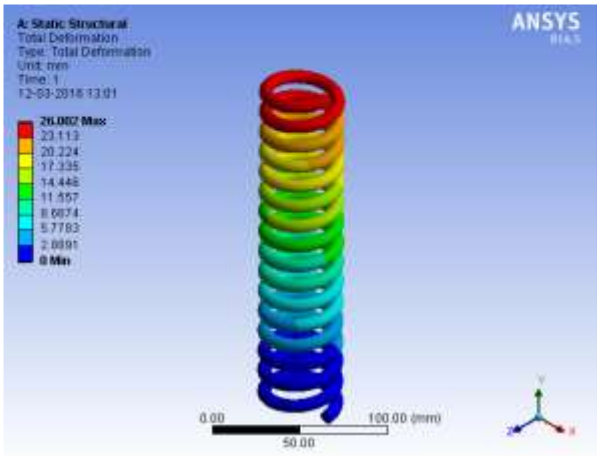


Fig.14 . Deformation for Beryllium Copper

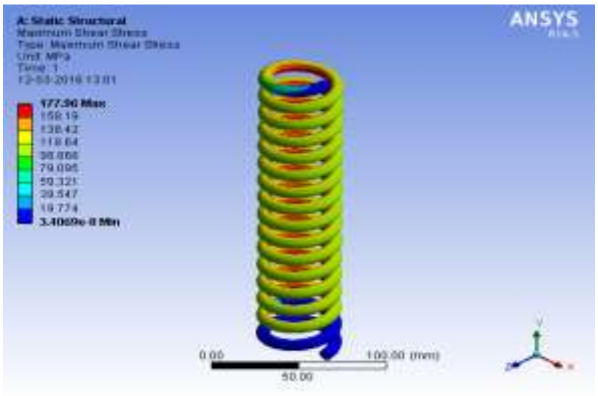


Fig. 15. Maximum Shear Stress for Beryllium Copper

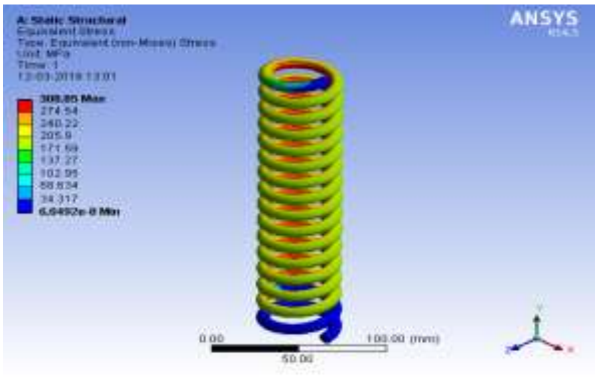


Fig. 16. Equivalent (Von-Mises) stress for Beryllium Copper

Table 2. Results of static analysis

Sr. no.	Loading Condition	Material	Total Deformation (mm)	Share stress Equivalent
1.	Bike load plus 2 persons	Beryllium Copper	54.368	372.1
		Oil tempered spring steel	37.285	478.38
2.	Bike load plus one person	Beryllium copper	40.185	275.03
		Oil tempered spring steel	27.558	353.58
3.	Bike load	Beryllium copper	26.002	177.96
		Oil tempered spring steel	17.832	228.79

5. CONCLUSIONS

From the above results, we conclude the following:

1. From the result we conclude that, the total deformation of the oil tempered spring steel is greater than the beryllium copper. So we can say that the stiffness of the spring steel material is better than the beryllium copper.

2. But the stresses developed in oil tempered spring steel is more than the beryllium copper, so we conclude that the beryllium copper is safe material for the maximum loading as compared to oil tempered spring steel.

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