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# "DESIGN AND ANALYSIS OF HELICAL COMPRESSION SPRING USED IN SUSPENSION SYSTEM BY FINITE ELEMENT ANALYSIS METHOD"

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**ABSTRACT -** *Suspension spring are the spring shock absorbs and linkage which are used to connect vehicle and allow relative motion between them, spring is an important element in rear suspension system. During loaded condition the weight of the vehicle acts on the spring, pushes it down where its springing action enables it to come back to its normal position and hence provide stability to vehicle and comfort to rider. The suspension system reduces the amplitude of disturbance by absorbing and handling shock impulses and dissipating kinetic energy generated due to improper road conditions and bumps where the design of spring plays a crucial role. The project work is based on design and 3D modeling of helical compression spring used in suspension system of vehicle. The statistical structure analysis would be done by Finite Element Analysis method in Ansys for different spring material and varying wire diameter of spring. Spring is to be design in Creo. The result would be compared and discussed to conclude the better one.*

***Keywords*:** Helical suspension spring, mono suspension, Creo model, Ansys v15, Finite element analysis, changing material and wire diameter

## 1. INTRODUCTION

Spring is an elastic or resilient body, whose function is to deflect or deform when load is applied and recover its original shape when load is removed.[1]

Spring has a multiple area of application, with their different types. They are widely used for diff-diff purpose, their basic types are given below as follows,

1. Helical spring
2. Conical or volute spring
3. Disc or Belleville springs
4. Leaf or laminated spring

Among all these types of springs, leaf springs and helical springs are mostly used in automobile suspension system. Out of which helical spring is mostly used in motorcycle suspension because the coil spring are used to deliver more comfort as compared to leaf spring and the load on two wheelers or the motorcycle is less compare to the heavy vehicle. In the suspension system of two wheeler, damper is used along with the helical coil spring. When the load or shock vibrations are exerted on the spring it compresses and absorbs the vibration and reduces the amplitude of disturbances. As a result of absorption of shock vibration, the spring in turn starts to oscillate and here the damper is used for progressively diminishing these oscillation of the spring or else it will continuously oscillate. In this Project, the mono suspension system of unicorn bike is to be considered. A Creo model of the helical spring of the unicorn bike's mono suspension is been created while the analysis is done in Ansys.

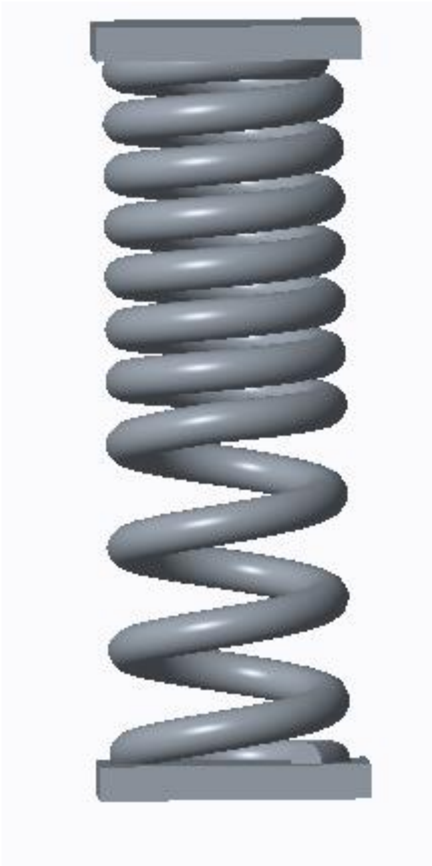


**Fig-1:** Creo model of helical spring

## 1.1 Material:-

To ensure that we are having a good result and doing things correctly we came across few materials and did analysis on them, by designing spring of the same. To carry on with the good one within them.

Following are few of them

1. 1095
2. 5160
3. Carbon steel
4. Cobalt chrome
5. Chrome vanadium
6. Beryllium copper

1095:-

**Table-1.1:** Composition of 1095[2]

| | |
|---|---|
| Iron (Fe) | 98.4 to 98.8 % |
| Carbon (C) | 0.9 to 1.0 % |
| Manganese (Mn) | 0.3 to 0.5 % |
| Sulfur (S) | 0 to 0.050 % |
| Phosphorus (P) | 0 to 0.040 % |

**Table-1.2:** Mechanical properties of 1095[2]

| | |
|---|---|
| Density | 7850 kg/m$^3$ |
| Elastic Modulus | $2.08 \times 10^{11}$ Pa |
| Poisson's Ratio | 0.3 |

5160:-

**Table-1.3:** Composition of 5160[3]

| | |
|---|---|
| Iron (Fe) | 97.1 to 97.8 % |
| Manganese (Mn) | 0.75 to 1.0 % |
| Chromium (Cr) | 0.7 to 0.9 % |
| Carbon (C) | 0.56 to 0.61 % |
| Silicon (Si) | 0.15 to 0.35 % |
| Sulfur (S) | 0 to 0.040 % |
| Phosphorus (P) | 0 to 0.035 % |

| | |
|---|---|
| Density | 7861.1 kg/m3 |
| Elastic Modulus | $2 \times 10^{11}$ Pa |
| Poisson's Ratio | 0.3 |

**Table-1.4:** Mechanical properties of 5160[3]

Carbon steel:-

**Table-1.5:** Composition of Low carbon steel[4]

| | |
|---|---|
| Carbon (C) | up to 0.3% approx. |
| Manganese (Mn) | up to 1.5% |

**Table-1.6:** Composition of Medium-carbon steels (Mild Steel)[4]

| | |
|---|---|
| Carbon (C) | 0.30 to 0.60% |
| Manganese (Mn) | 0.60 to 1.65%. |

**Table-1.7:** Composition of High-carbon steel[4]

| | |
|---|---|
| Carbon (C) | 0.60 to 1.00% |
| Manganese (Mn) | 0.30 to 0.90%. |

**Table-1.8:** Mechanical properties of High-carbon steel[4]

| | |
|---|---|
| Density | 7850 kg/m$^3$ |
| Elastic Modulus | $2.1 \times 10^{11}$ Pa |
| Poisson's ratio | 0.295 |

Cobalt chrome:-

**Table-1.9:** Mechanical properties of Cobalt chrome

| | |
|---|---|
| Density | 8400 kg/m$^3$ |
| Elastic Modulus | $2.5 \times 10^{11}$ Pa |
| Poisson's ratio | 0.29 |

Chrome vanadium:-

**Table-1.10:** Mechanical properties of Chrome vanadium[5]

| | |
|---|---|
| Density | 7860kg/m$^3$ |
| Elastic Modulus | $2.07\times10^{11}$ Pa |
| Poisson's ratio | 0.37 |

**Table-1.11:** Composition of Chrome vanadium[5]

| | |
|---|---|
| Chromium (Cr) | 0.80-1.10 % |
| Vanadium | 0.18% approx. |
| Manganese (Mn) | 0.70 to 0.90%. |
| Carbon (C) | 0.50% |
| Silicon (Si) | 0.30% |

Beryllium copper

**Table-1.12:** Mechanical properties of Beryllium copper[6]

| | |
|---|---|
| Density | 8250 kg/m$^3$ |
| Elastic Modulus | $1.25\times10^{11}$ Pa |
| Poisson's ratio | 0.3 |

**Table-1.13:** Chemical properties of wrought high strength alloys[6]

| | |
|---|---|
| Beryllium | 1.6 to 2.0% |
| Cobalt | 0.3% approx. |

.

**Table-1.14:** Chemical composition of Cast, high-strength alloys[6]

| | |
|---|---|
| Beryllium | 2.7%. |

**Table-1.15:** Chemical composition of High conductivity alloys[6]

| | |
|---|---|
| Beryllium | 0.2-0.7% |
| Higher amounts of nickel and cobalt. | |

## 2. Force calculation

For the purpose of force calculation we assume that our vehicle is in motion and then the base is considered to be excited by a sinusoidal motion of $y=Y\sin \omega t$, further the analysis is carried out by considering absolute amplitude of mass with respect to the support of chassis. The material that is being used in manufacturing of spring is carbon steel so we will find the forces and the stresses that is induced in carbon steel material which we will use to apply on other material springs.

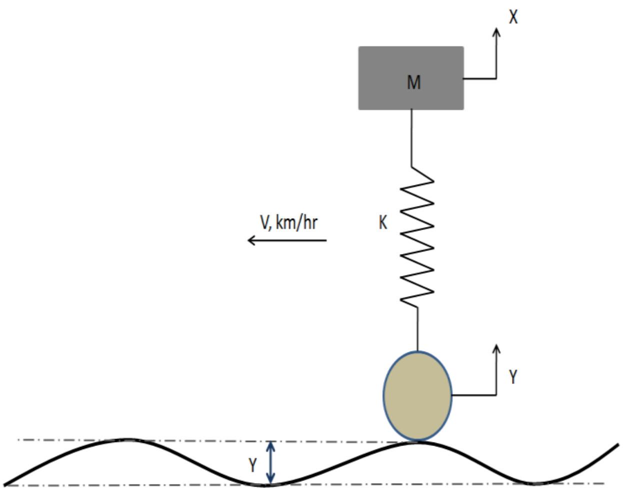



**Fig-2.1:** Schematic of suspension spring on sinusoidal curve[7]

This shows that in motion the vehicle can vibrate in vertical direction while travelling over a rough road.

Mass of vehicle = 145 kg

Sprung weight = 65 % of mass of vehicle

= 94.25

Supposing 2 passenger of each 80kg are riding on the bike than,

The total weight on the coil spring

= 94.25+80+80 = 254.25 kg

Considering damping ratio (ξ) = 0.5

Amplitude = 20mm

$$\text{Spring constant (K)} = \frac{Gd^4}{8nD^3}$$

$$= \frac{0.81\times10^5\times12^4}{8\times10\times58^3}$$

$$= 107.60 \text{ N-mm}^{-1}$$

1. For 5km/hr

The frequency ‘f’ of the base excitation can be found by dividing the vehicle speed ‘v’ km/hr by the length of one cycle of road roughness.

- ω= 2πf

$$f = \frac{v}{\lambda} = \frac{1.388}{1} = 1.388$$

$$\omega = 2 * 3.14 * 1.388 = 8.7266 \text{ rad/sec}$$

- The natural frequency of the vehicle is given by

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{107.6*1000}{254.25}} = 20.57 \text{ rad/sec}$$

- Frequency ratio (r) = $\frac{\omega}{\omega n} = \frac{8.7}{20.57}$ =0.422
- Amplitude ratio or Displacement transmissibility(X):

$$X = \frac{\sqrt{1+(2\xi\frac{\omega}{\omega n})^2}}{\sqrt{[1-\left(\frac{\omega}{(\omega n)}\right)^2]^2 + [2\xi\frac{\omega}{\omega n}]^2}} * Y$$

$$\frac{\sqrt{1+(2*0.5\frac{8.7}{20.57})^2}}{\sqrt{[1-\left(\frac{8.7}{(20.57)}\right)^2]^2 + [2*0.5\frac{8.7}{20.57}]^2}} * 0.2 = 0.0236 \text{ m}$$

Thus the displacement of vehicle at 5 km/hr is 0.0236 m. which shows that for excitation of 20mm the deflection in spring is 23.6mm.

- Force(F) exerted on the spring

| Sr. no. | Speed (km/h) | ω (rad/s) | $\omega_n$ (rad/s) | Force (N) |
|---|---|---|---|---|
| 1 | 5 | 8.72 | 20.57 | 2524.64 |
| 2 | 10 | 17.45 | 20.57 | 3157.80 |
| 3 | 25 | 43.63 | 20.57 | 1242.20 |
| 4 | 40 | 69.81 | 20.57 | 692.76 |

$$F = \frac{\delta G d^4}{8D^3 n} = \frac{0.0236*0.81*10^8*12^4}{8*58^3*10} = 2524.64 \text{ N}$$

Similarly the calculations have been carried out for different speeds like 10, 25 and 40 km/h.

**Table-2.1:** Forces at different speeds

### 2.2 Deformation and Stress in Materials:-

The analytical result for different speed and forces at the corresponding speed has been carried out on different materials like carbon steel, 1095, 5160, chrome vanadium, cobalt chrome and beryllium copper in Ansys and the result obtained is presented in below table.

**Table-2.2:** Ansys result at different speed.

| Speed (km/h) | Force (N) | Material | Deformation (cm) | Shear (MPa) |
|---|---|---|---|---|
| 5 | 2524.64 | Carbon steel | 2.4277 | 297.6 |
| | | 1095 | 2.4598 | 297.64 |
| | | 5160 | 2.5581 | 297.64 |
| | | Chrome vanadium | 2.5937 | 298.31 |
| | | Cobalt chrome | 2.0319 | 297.56 |
| | | Beryllium copper | 4.093 | 297.64 |
| 10 | 3157.80 | Carbon steel | 3.0365 | 372.24 |
| | | 1095 | 3.0766 | 372.29 |
| | | 5160 | 3.1997 | 372.29 |
| | | Chrome vanadium | 3.2441 | 373.13 |
| | | Cobalt chrome | 2.5415 | 372.19 |
| | | Beryllium copper | 5.1195 | 372.29 |
| 25 | 1242.20 | Carbon steel | 1.1945 | 146.43 |
| | | 1095 | 1.2103 | 146.45 |
| | | 5160 | 1.2587 | 146.45 |
| | | Chrome vanadium | 1.2762 | 146.78 |
| | | Cobalt chrome | 0.9997 | 146.41 |
| | | Beryllium copper | 2.0139 | 146.45 |
| 40 | 692.76 | Carbon steel | 0.6661 | 81.662 |
| | | 1095 | 0.6749 | 81.674 |
| | | 5160 | 0.7019 | 81.674 |
| | | Chrome vanadium | 0.7117 | 81.857 |
| | | Cobalt chrome | 0.5575 | 81.651 |
| | | Beryllium copper | 1.1231 | 81.674 |

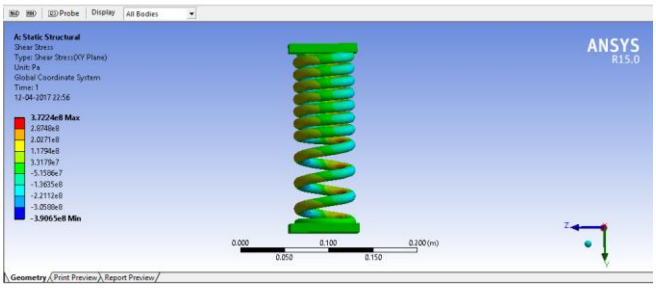



**Fig-2.2:** Carbon steel deformation at speed 10 km/h

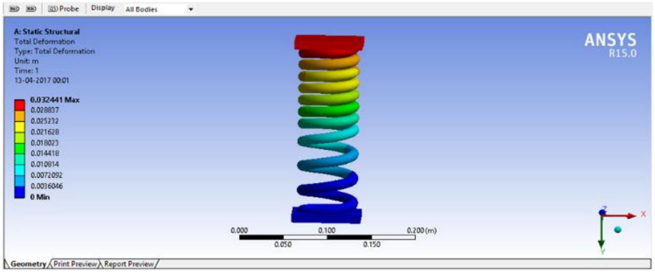



**Fig-2.3:** Carbon steel shear stress at speed 10 km/h

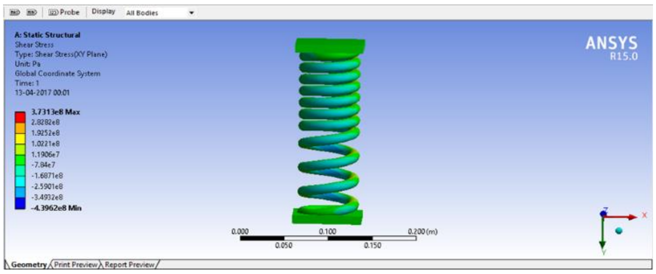



**Fig-2.4:** Chrome vanadium deformation at speed 10 km/h

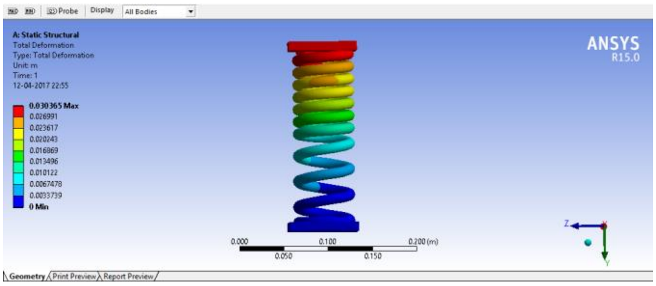



**Fig-2.5:** Chrome vanadium shear stress at speed 10 km/h

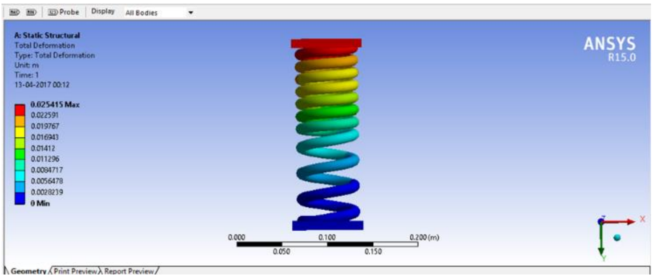



**Fig-2.6:** Cobalt chrome deformation at speed 10 km/h

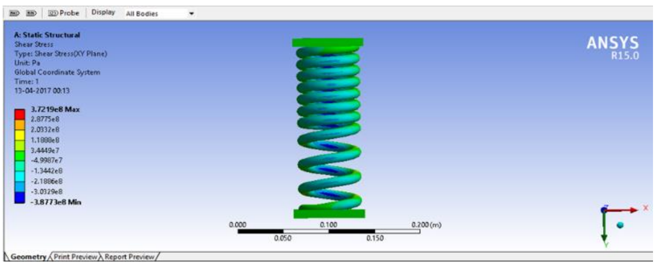



**Fig-2.7:** Cobalt chrome shear stress at speed 10 km/h

Based on the above results we'll choose two materials for further analysis by changing the wire diameter of the coil spring. The first one is Cobalt chrome as it shows the optimum results and the second one being the Chrome Vanadium because of its high corrosive resistance.

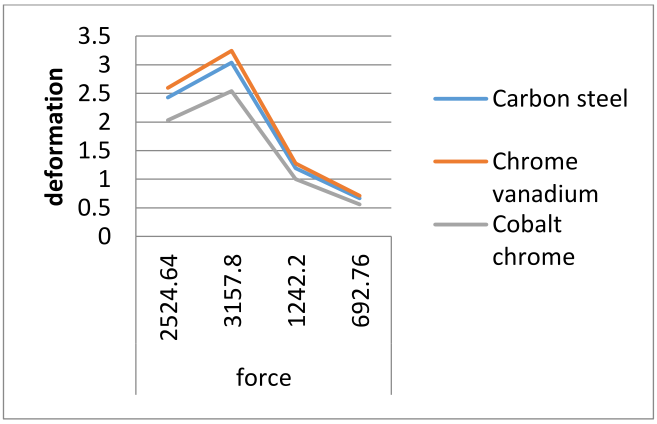



**Fig-2.8:** Deflection of spring at various loads at different speeds

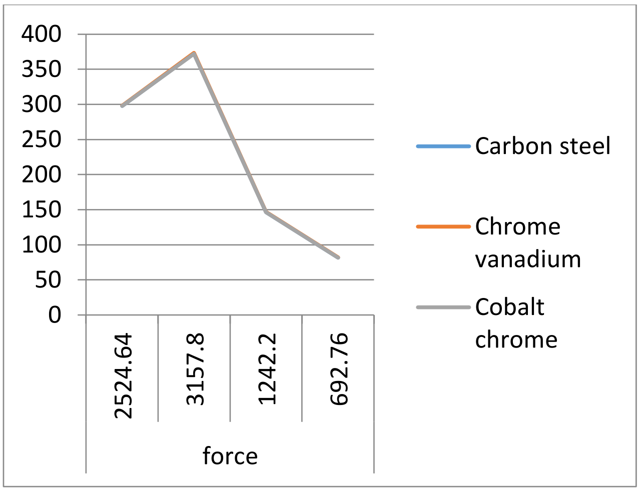



**Fig-2.9:** Shear stress at respective speeds

Theoretical Result:-

To validate the above result theoretical calculation is been carried out below for cobalt chrome, chrome vanadium and carbon steel.

Calculation for carbon steel:-

$$\text{Spring constant } (K) = \frac{Gd^4}{8nD^3}$$

$$= \frac{0.81\times10^5\times12^4}{8\times10\times58^3}$$

$$= 107.60 \text{ N-mm}^{-1}$$

For 5 km/h

Maximum deflection (δ) = F/k

$= 2524.64/\ 107.60$

$= 23.463$ mm

$= 2.3463$ cm

Similarly calculations have been carried out at 10, 25 and 40 km/h and for cobalt chrome and chrome vanadium at similar speed.

The spring's Index (C) $= D/d$

$= 58/12$

$= 4.833$

$$\text{Wahl correction factor (W)} = \frac{4C - 1}{4C - 4} + \frac{0.615}{C}$$

$$= 1.322$$

For 5 km/h

$$\text{Maximum shear stress } (\tau) = \frac{8WDF}{\Pi \times d^3}$$

$$= \frac{8 \times 1.322 \times 58 \times 2524.64}{\Pi \times 12^3}$$

$$= 285.26 \text{ MPa}$$

Similarly calculations have been carried out at 10, 25 and 40 km/h and for cobalt chrome and chrome vanadium at similar speed.

## 2.3 Comparison of Theoretical and Ansys values

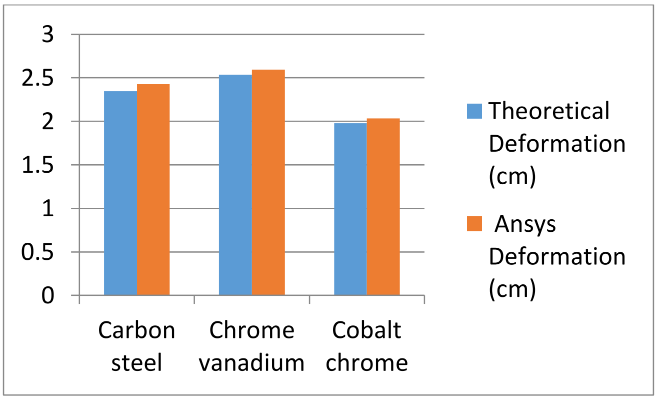



**Fig-2.10:** Comparison of theoretical and Ansys value of deformation at 5kmph

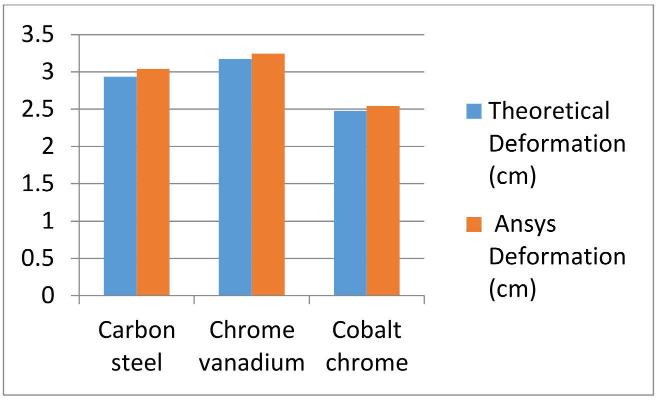



**Fig-2.11:** Comparison of theoretical and Ansys value of deformation at 10kmph

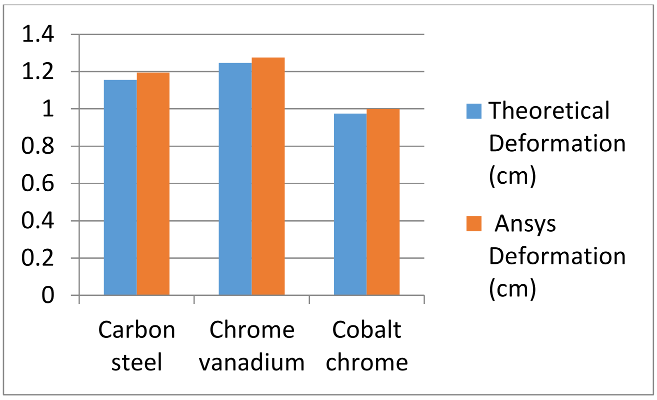



**Fig-2.12:** Comparison of theoretical and Ansys value of deformation at 25kmph

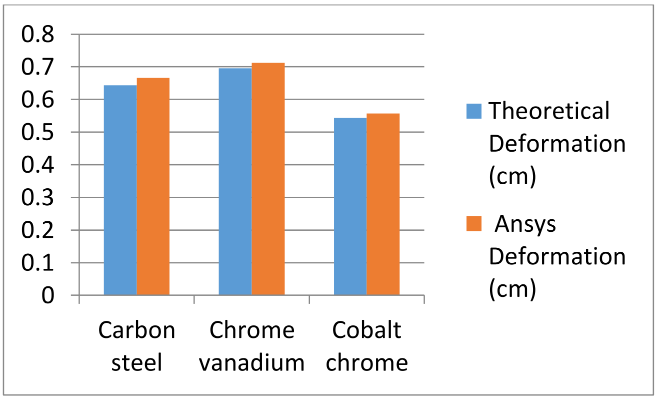



**Fig-2.13:** Comparison of theoretical and Ansys value of deformation at 40kmph

### 2.3 Change in Wire diameter:-

For reduction in stress, change in structure is to be carried out as stress is depend on structure. Change in wire diameter or mean diameter can reduce stress, here we are changing wire diameter as shear stress is inversely proportional to fourth power of wire diameter. Change in wire diameter means increase or decrease in wire diameter from its original size, here for reducing stress increase in wire diameter is required as shear stress is inversely proportional to fourth power of wire diameter.

As per standard dimension, the first preference is 14mm after 12mm which is been selected here for further analysis.

The new dimension of spring will be,

Free Length ($L_{free}$) = 210 mm

Mean diameter (D) = 58mm

Wire diameter (d) = 14mm

Pitch (p) = up to 100 mm of $L_{free}$ pitch is 30mm and then 17mm

Number of active turns (n) = 9

Solid length ($L_{solid}$) = 154mm

Spring index (c) = D/d = 4.14

Spring type – helical compression spring with closed and ground ends.

Based on the new dimension the analytical result for different speed and forces at the corresponding speeds is carried out on chrome vanadium and cobalt chrome in Ansys and result obtained is presented in below graph.

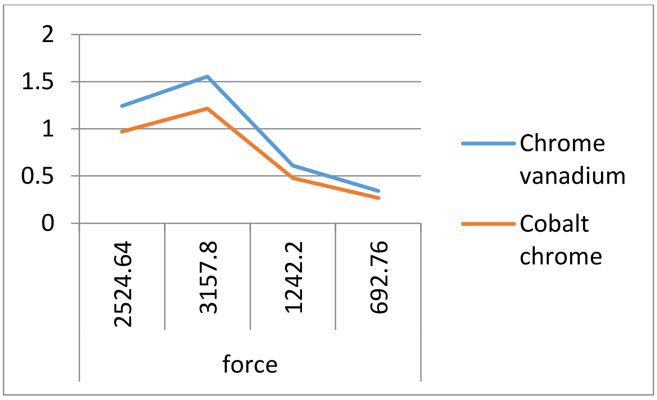



**Fig-2.14:** Ansys results of deformation at different speed for 14mm wire diameter.

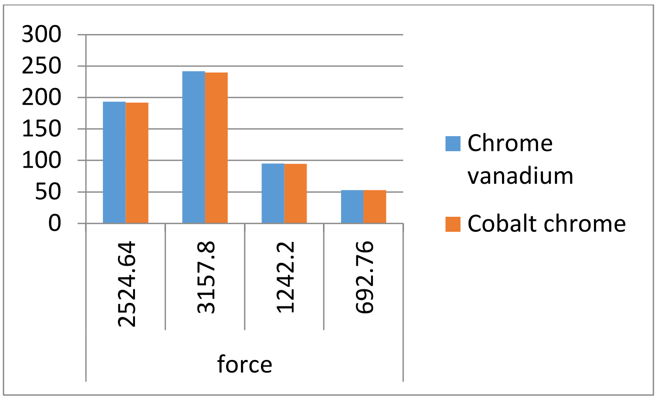
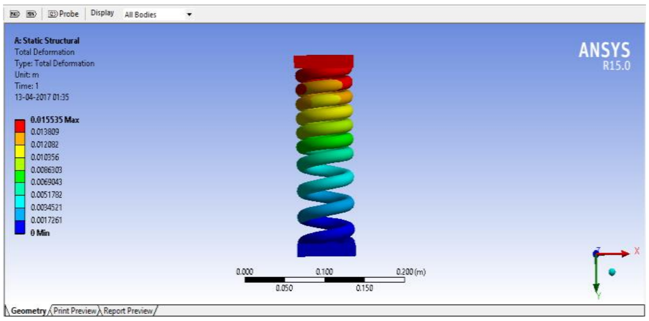



**Fig-2.15:** Ansys result of shear stress at different speed




for 14mm wire diameter.

**Fig-2.16:** Chrome vanadium deformation of 14 mm wire diameter at speed 10 km/h

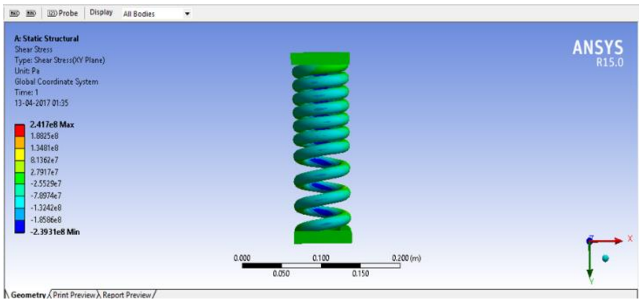



**Fig-2.17:** Chrome vanadium shear stress of 14 mm wire diameter at speed 10 km/h.

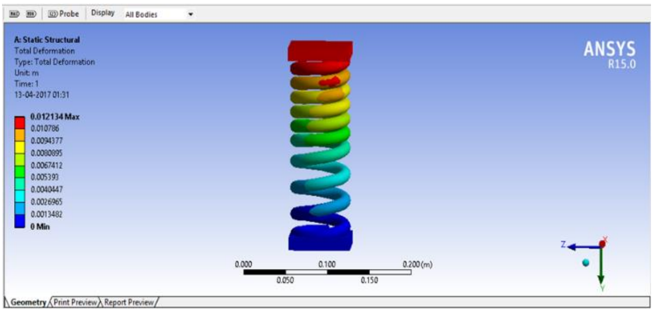



**Fig-2.18:** Cobalt chrome deformation of 14 mm wire diameter at speed 10 km/h

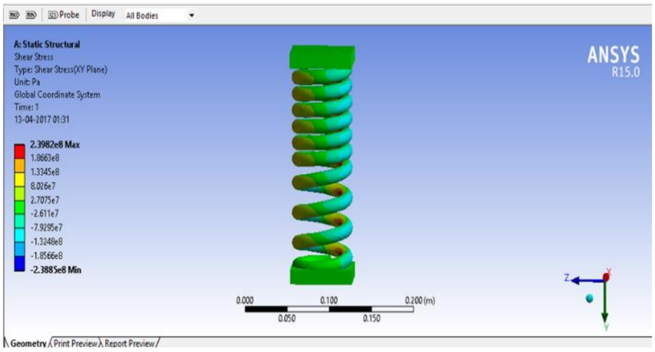



**Fig-2.19** Cobalt chrome shear stress of 14 mm wire diameter at speed 10 km/h.

Theoretical result:-

To validate the above result theoretical calculation is been carried out below for cobalt chrome and chrome vanadium.

Calculation for chrome vanadium:-

Spring constant (K) = $\frac{Gd^4}{8nD^3}$

$= \frac{0.75\times10^5 \times 14^4}{8\times9\times58^3}$

$= 205.09$ N-mm$^{-1}$

For 5 km/h

Maximum deflection (δ) = F/k

= 2524.64/205.09

= 12.309 mm

= 1.2309 cm

Similarly calculations have been carried out at 10, 25 and 40 km/h and for cobalt chrome at similar speed.

The spring's Index (C) = D/d

= 58/14 = 4.142

Wahl correction factor (W) = $\frac{4C-1}{4C-4} + \frac{0.615}{C}$

= 1.38

For 5 km/h

Maximum shear stress (τ) = $\frac{8WDF}{\Pi \times d^3}$

$= \frac{8\times1.38\times58\times2524.64}{\Pi \times 14^3}$

= 187.52 MPa

Similarly calculations have been carried out at 10, 25 and 40 km/h and for cobalt chrome at different speed.

### 2.4 Comparison of Theoretical and Ansys values of 14mm wire diameter

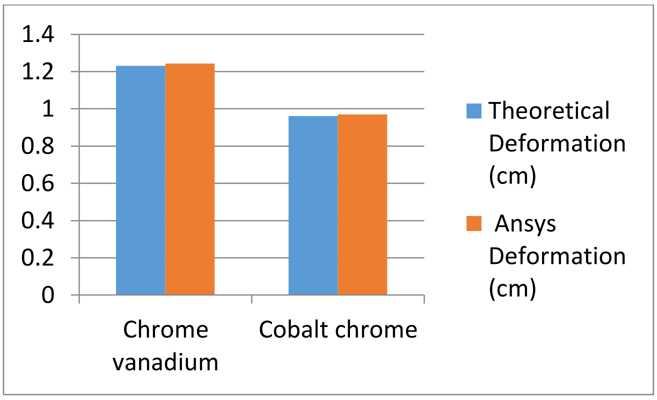



**Fig-2.20:** Comparison of theoretical and Ansys value of deformation at 5kmph

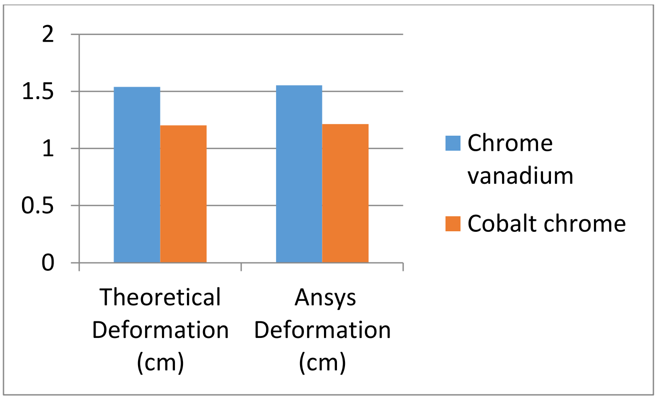



**Fig-2.21:** Comparison of theoretical and Ansys value of deformation at 10kmph

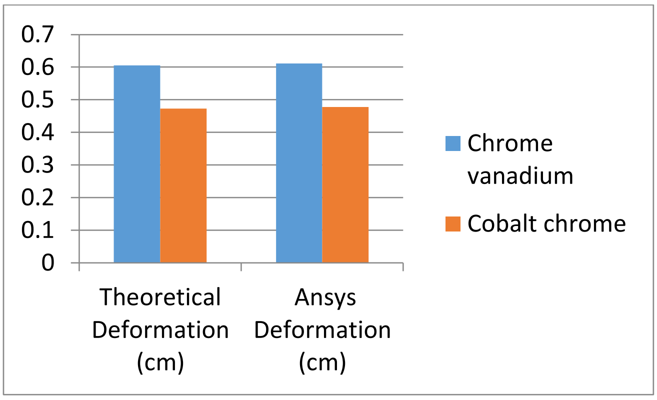



**Fig-2.22:** Comparison of theoretical and Ansys value of deformation at 25kmph

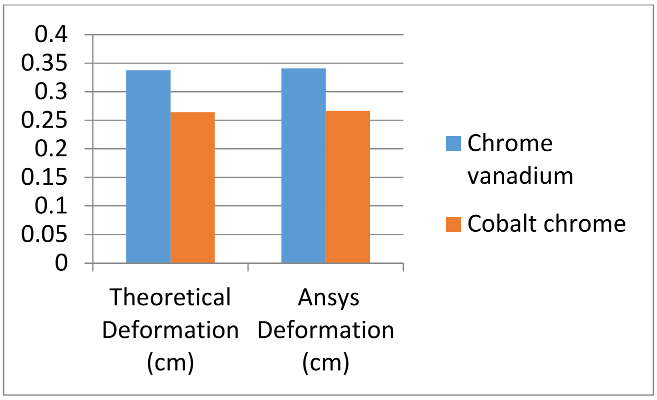



**Fig-2.23:** Comparison of theoretical and Ansys value of deformation at 40kmph

## 3. Result and Discussion

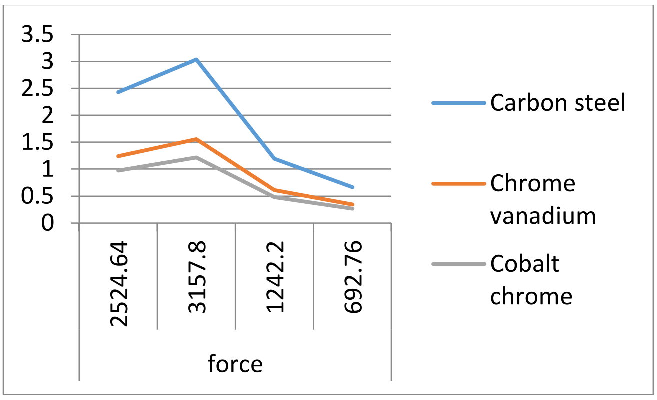



**Fig-3.1:** Comparison of original spring and modified spring deformation

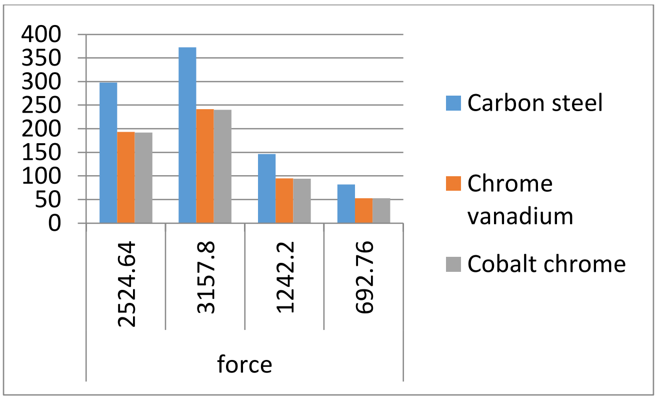



**Fig-3.2:** Comparison of original spring and modified spring shear stress

The above figure shows the comparison between carbon steel of 12mm wire diameter and 14mm wire diameter of chrome vanadium and cobalt chrome. The comparison is carried out at speed 5 km/h, 10km/h, 25 km/h and 40 km/h.

The stated problem of corrosion and the hydrogen embrittlement is sorted out by the use of chromium element in the steel grade and in cobalt chrome alloy. Chromium is highly corrosion resistive.

The increase in the ultimate tensile strength of the material helps the material to withstand the applied forces and to endure the stresses induced in them, so the material to be chosen should be such that it has high corrosion resisting properties and thus having greater strength to overcome hertzian contact stress.

## 4. Conclusion

From the obtained result of the analysis on Ansys we can conclude that for 14mm wire diameter coil spring cobalt chrome and chrome vanadium are better material than 12 mm wire diameter carbon steel which is currently used. Chrome vanadium and cobalt chrome both have high resistivity against corrosion, but cobalt chrome shows less deformation and also the induced stress is comparatively less than chrome vanadium. Thus cobalt chrome is the better one among the 6 material that were analyzed.

## 5. Acknowledgements

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