DESIGN AND DEVELOPMENT OF A SEMI-AUTOMATED COIL SPRING COMPRESSOR

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***Abstract**: The vehicle's suspension system has a substantial impact on passenger safety, offering a comfortable ride, stability, and handling. Thus, it's mandatory to keep it maintained and in good form. By incorporating this product into the market, we want to make sure that the maintenance process is carried out smoothly. The design, manufacturing, and performance study of a Semi-Automated Coil Spring Compressor is detailed in this report. The data for the various sections are presented in detail. The materials used for each part, the reasons for choosing that material, and the design of the Semi-Automated Coil Spring Compressor's several other parts are presented. The manufacturing methods that were involved are also discussed. The test result of the manufactured Semi-Automated Coil Spring compressor indicates that the tool was highly effective in removing the spring during the repair process without endangering the technician who was attending it.*

***Keywords**: Coil Spring Compressor, Semi-Automated.*

1. INTRODUCTION

Spring is a pliable object that can be used to store mechanical energy. Tension springs, compression or coil springs, helical springs, flat springs, torsion springs, and other types of springs can be classed based on how the load force is given to them. Spring steel is the most common material used to make springs. A coil spring, also known as a helical spring, is a mechanical device that is commonly used to store and release energy, absorb shock, or maintain a force between contacting surfaces.

In-car suspension, coil springs are often employed. These springs are compression springs, and their strength and size vary widely depending on the application. The stiffness or softness of a coil spring suspension depends on the vehicle. A coil spring can be used in conjunction with a shock absorber or on its own. Coil spring suspension is utilized in high-performance cars to absorb bumps and keep body roll to a minimum.

2. LITERATURE REVIEW

The functions of the automotive suspension system are as follows: it suspends the vehicle on its chassis, stabilizes thevehicle, absorbs road shock, provides comfort, and is an important part of the vehicle safety architecture.

Shock absorbers are enclosed by a coil spring in various suspension systems, such as strut suspension systems. Becausethe access space around the coil spring is frequently limited, especially on compact cars, a surrounding type spring compressing tool cannot be used. While previous inventions presented several types of spring compressors, these devices tend to shift laterally when in use, posing the risk of a disastrous discharge of the compressed spring.

When removing shock absorber springs or coil springs with ill-fitting equipment, most mechanics confront dangers, which have resulted in serious accidents. Time spent while removing the coil spring can also be tiresome because theequipment utilized is unreliable and cannot withstand the shock spring to its full capability.

3. MATERIAL SELECTION

Because of its qualities, mild steel is used to manufacture the Grippers, Safety net, and Base of the Semi-Automated Coil Spring Compressor. It has a low tensile strength, is malleable, and has a significant surface hardness which can be enhanced by carburizing. It is employed in situations where ductility or softness are crucial. The density of mild steel is 7850, the young modulus is 200GPa, and the Poisson ratio is 0.303. It is also cost-effective when compared to other metals. However, Carbon steel is employed to manufacture Power screws and nuts. The main reason is its ability to resist corrosion.

4. DESIGN OF THE COMPONENTS

Various components designed are, power screw, nut, clamps or grippers, safety net.

Due to the presence of Mild steel and Carbon Steel, the whole design is based on the Maximum shear stress theory(MSST). According to MSST, the material's maximum permitted stress is proportional to the material's yield strength and factor of safety.

4.1 Force applied on the spring

During static conditions, the force applied on the spring will be,

In a Hatchback model

Let's take the kerb weight of a hatchback car as 1000 kg. Now, the gravitational force acting on it will be $9.81 m/s^2$

Force on one tyre = 250kg

Therefore, according to Newton's second law of motion

F = ma (where a = Gravitational acceleration)

$F = 250\ \text{Kg} \times 9.81\ {}^{m}/_{s^2}$

F = 2452 N

Taking, x = 0.5m (length of a strut) In the formula,

F = kx

$$K = \frac{F}{x}$$

$$K = \frac{2452}{0.5}\frac{N}{m}$$

$$K = 4904\frac{N}{m}$$

$$F = kx$$

Now, force applied on the strut to unscrew the nut, x = maximum length to be

compressedTherefore, x = 0.1m

$$F = \frac{4904}{0.1} \frac{N/m}{m}$$

F = 4904 N

Thus, it indicates that a minimum compression force of 490N must be applied in order to deform the spring by 0.1m. In a SUV model

Let's take the kerb weight of an SUV car as 2200 kg. Now, the gravitational force acting on it will be

9.81m/s^2.Force on one tyre = 550kg

Therefore, according to Newton’s second law of motion

$$F = ma \text{ (}where\ a = Gravitatiokal\ acceleratiok\text{)}$$

$$F = 250\ kg \times 9.81\ m/s^2$$

$$F = 2452\ N$$

Taking, x = 0.5m (length of a strut)

In the formula,

$$F = kx$$

$$K = \frac{F}{x}$$

$$K = \frac{5395}{0.5} \frac{N}{m}$$

$$K = 10791\ \frac{N}{m}$$

Now, force applied on the strut to unscrew the nut, x = maximum length to be compressed

Therefore, x = 0.1m

$$F = kx$$

$$F = 10791\ {}^{N}/_{m} \times 0.1\ m$$

$$F = 1079\ N$$

Thus, it indicates that a minimum compression force of 1079N must be applied in order to deform the spring by 0.1m.

However, a Macpherson strut is not deployed in a car with weight above 2100 kg. But the above calculation gives us an overall idea of the minimum compression force required, in case a Macpherson strut is deployed in a car with weight near about 2100 kg.

4.2 Design of a Power screw

A Power screw is a threaded metallic screw bar made of Unalloyed medium Carbon Steel. In our design, it is in mesh with the nut welded with the grippers. So, the power is directly transferred from the power screw to the gripper and consequently to the spring. The bolt traverses a linear distance which is equivalent to the compressed spring's length difference. Bolts are made to endure shear force. The compressive stress imposed on the bolt as a result of the rotationalforce is calculated as follows:

Torque provided by the pneumatic gun = 350Nm at 7000rpm (given)

(1) By Hooke’s Law,

$$\mathrm{W} = kx\ (N)$$

$$K = \frac{\mathrm{W}}{x}$$

$$K = \frac{Gd^4}{8d^3}$$

Where G is the modulus of rigidity of the spring material made of high carbon steel **G** = 80×10^3 N/m^2. **D** is thediameter of the coil spring = 120mm = 0.111m. **d** is the diameter of the spring material = 13.4mm = 0.0134m

$$K = \frac{80 \times 10^3 \times (0.0134)^4}{8 \times (0.120)^3}$$

$$K = 0.1865\frac{N}{m}$$

$$\mathrm{W} = kx$$

$$\mathrm{W} = 0.1865\frac{N}{m} \times 0.1\ m$$

$$\mathrm{W} = 0.01865 \tag{1}$$

Input Torque on nut and gripper,

$$T = \mathrm{W} \times r$$

$$T = (0.01865 \times 0.8)\ Nm$$

$$T = 0.01492 \tag{2}$$

(2) Bolt or lead screw are designed on the basis of direct tensile stress or compressive stress acting on the bolt.

$$\sigma = \frac{W}{AC}$$

Where W is the weight and Ac is the core area of the bolt.

$$Ac = \frac{\pi}{4} Dc^2$$

Where Dc is the core diameter of the bolt, Dc = 27mm or 0.027m

$$Ac = \frac{\pi}{4}(0.027mm)^2$$

$$Ac = 5.72 \times 10^{-4}\ m^2$$

Therefore, tensile stress σ will be,

$$\sigma = \frac{0.01865\ \text{N}}{5.72\ \text{X}\ 10^{-4}\ \text{m}^2}$$

$$\sigma = 32.60\ \frac{\text{N}}{\text{m}^2}$$

(3) (3)

Torsional Stress,

$$\text{T} = \frac{16\text{T}}{\pi\ \text{Dc}^3}\frac{\text{N}}{\text{m}^2}$$

$$T = \frac{16 \times 0.01492}{\pi \times (0.027)^3}\ \frac{N}{m^2}$$

$$\text{T} = 3860.5\frac{\text{N}}{\text{m}^2}$$

(4) (4)

Since the screw is supplied to both axial and torsional shear stress,
Maximum shear stress will be,

$$T_{maS} = \frac{1}{2}\sqrt[2]{\sigma^2 + 4T^2}\ \frac{N}{m^2}$$

$$\text{T}_{\text{max}} = \frac{1}{2}\sqrt[2]{(32.60)^2 + 4(3860.5)^2}\ \frac{\text{N}}{\text{m}^2}$$

$$\text{T}_{\text{max}} = 3860.5\ \frac{\text{N}}{\text{m}^2}$$

(5) (5)

Maximum tensile stress σ max will be,

$$\sigma_{max}=(\frac{\sigma}{2}+\frac{1}{2}\sqrt[2]{\sigma_2+4T_2})\frac{N}{m^2}$$

$$\sigma_{max}=(\frac{32.60}{2}+\frac{1}{2}\sqrt[2]{(32.60)^2+4(3860.5)^2})\frac{N}{m^2}$$

$$\sigma_{max}=3876.5\frac{N}{m^2}$$

(6) (6)

Now,

$$\sigma_y = \sigma_{maS} \times k\frac{N}{m^2}$$

$$\sigma_{max}=\frac{\sigma_y}{n}\frac{N}{m^2}$$

Where, n is the factor of safety, n=4

$$\sigma_{max}=\frac{143\times10^6}{4}\frac{N}{m^2}$$

$$\sigma_{max}=35750\frac{N}{m^2}$$

(7) (7)

Therefore, comparing equations (6)&(7),

$3876.8 \ll 35750$

Also,

$T_y= T_{max}\times2n$

$$T_{max}=\frac{T_y}{2n}$$

$$T_{max}=\frac{250\times10^6}{2\times4}\frac{N}{m^2}$$

$T_{max}= 31250000\ Nm^2$

(8) (8)

Therefore, comparing equations (5) and (8),

$3860.5 \lll 31250000$

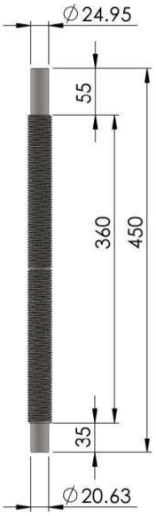

Figure 1: The Power screw

4.3 Design of a Screw Nut with Gripper

This element is constructed of carbon steel and slides along the screw bolt, holding and pushing the spring andcompressing it.

Average shear stress acting on the screw nut,

$$T_n = \frac{\mathrm{W}}{\pi Dbk}\frac{N}{m^2}$$

Where, W = weight of the mass, W = 0.01865 N
D = major diameter of power screw, D = 0.035m
n = number of threads in engagement, n= 8
b = width of bolt, b = 0.005 m

$$T_n = \frac{0.01865}{\pi \times 0.005 \times 0.035 \times 8}\frac{N}{m^2}$$

$$\mathrm{T_n} = 4.24\ \frac{\mathrm{N}}{\mathrm{m}^2} \qquad (1)$$

Maximum torsional stress,

$$\mathrm{T_y = T_{max} \times 2n}$$

$$\mathrm{T_{max} = \frac{T_y}{2n}}$$

Where, n is the factor of safety

$$\mathrm{T_{max} = \frac{250 \times 10^6}{2 \times 4}\ \frac{N}{m^2}}$$

$$T_{max} = 31250000\,\frac{N}{m^2} \tag{2}$$

Thus, comparing equations (1) and (2)

$4.24 \ll\ll 31250000$

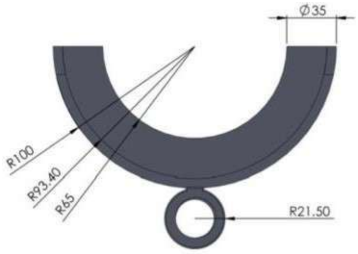

Figure 2: Top view of Nut-Gripper

Figure 3: Isometric view of Nut-Gripper

4.4 C-Channel with base Plate

The whole assembly is mounted on the C-channel. A C-channel provides rigid support to all the assembly parts. It isdesigned in such a way that it can sustain a maximum torque of 350Nm at 7000rpm. To avoid corrosion, firstly it is painted with red oxide, and over that, it is coated with grey paint. The base is welded with the C-channel and similar anti-corrosion processes are followed on it.

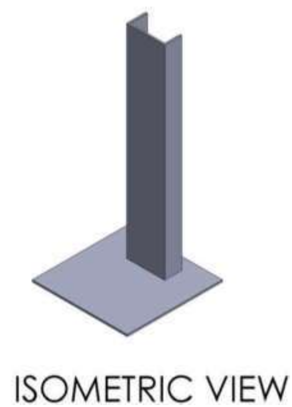

Figure 4: Isometric view of C-channel

4.5 Mountain Bearing

A UCB 205 mountain bearing is used to support the power screw, reduce friction and transfer the power from thepneumatic gun to the power screw and eventually to the grippers.

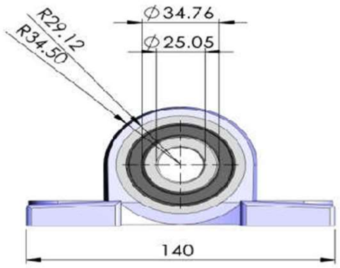

Figure 5: UCB-205 mountain bearing

4.6 Safety nets

Although it has been confirmed that grippers provide the maximum amount of safety, still to decrease the chance ofharm to the technician, we have incorporated safety nets in a hemispherical shape.

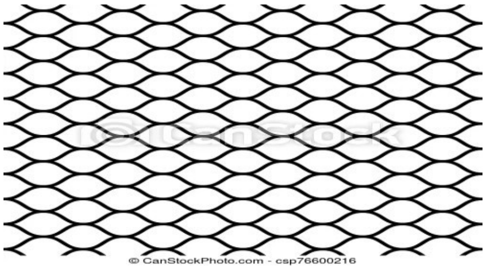
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Figure 6: Safety nets

4.7 Pnuematic gun

A Pneumatic gun is the best substitute for a gear motor assembly. Anyone can easily deploy and can use it safely. It requires almost zero maintenance as compared to a motor. Surprisingly, it provides a sufficient torque of 230Nm at 7000rpm. It just requires a compressor for an adequate supply of pressurized air till the time it runs.

Figure 7: Pneumatic gun

5 FABRICATION

The various components were constructed by the following methods;

1 Cutting operations
2 Bending operations
3 Threading operations
4 Machining
5 Assembly and welding
6 6 Finishing

Post fabrication of the various components, it can be observed as under,

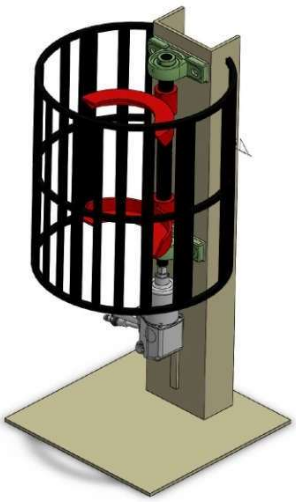

Figure 8: An isometric view of the Spring compressor

6 TESTING OF THE SPRING COMPRESSOR

To test the machine, three different shock absorber springs with various young modulus and diameter were utilized, yielding a narrative of force and change in length, in specific time. This test answers the reason for the downfall of the currently used, primitively engineered spring compressors.

Diameter (D) (m)	L1 (m)	L2 (m)	Force applied(N)	Time Required(s)
0.225	0.450	0.370	350	23
0.190	0.450	0.390	355	21
0.185	0.450	0.400	370	17

TABLE 1

7 RESULTS AND DISCUSSION

When the tensions applied to the spring are reduced, the deflection of the spring decreases. The number of spring revolutions has a negative impact on deflection and stress. Deflection reduces as the number of turns rises, and tensionsdecrease as well. This effect is impossible to achieve without a change in wire diameter because wire diameter affects deflection and stresses. As a result, as the wire diameter grows larger, the deflection and stresses decrease. This is owing to the improved spring index performance.

8 SUMMARY AND CONCLUSION

This design was made in response to the current problems that many vehicle owners and auto mechanic shops are experiencing as a result of the difficulty, accidents, and injuries that occur during the compression of shock absorber springs. The goal of this project was to provide a simple and safe method of removing shock absorber springs. In addition, the appropriate selection of materials was considered. The many methods required to complete this task were also highlighted, and this design is intended to alleviate the problem of coil spring compression.

We may simply conclude from this research that the spring compressor is a very useful instrument for some basic auto maintenance. When it comes to resolving problems with car suspension, the spring compressor is an essential tool. Most people are unaware of how dangerous working on a car's suspension without the use of a spring compressor canbe. During the repair operation, this tool is used to extract the coil spring. Learning how to use a spring compressor for typical auto repairs is a priceless skill for individuals who regularly perform routine maintenance on their cars athome.

9 REFERENCES

[1] *Auto Repair (2013), How to Use a Spring Compressor for Common Auto Repair, Retrieved 20 July 2019 fromhttps://www.Autos.com/html/How to use a spring compressor.*

[2] *Alkash, B. (2016), Analysis of spherical spring of suspension system, Engineering College Rejekota India. Giri, N. K. (2015), Automobile Technology, Nath market, Nai sarak Delhi, Khana publishers.*

[3] *Khurmi, R. S. (2005), Machine Design, Ram Nagar New Deihi, Eurasia publishing house.*

[4] *Kumhar V. (2016). Structure Analysis of Shock Absorber Spring using finite Element Analysis. Department of Mechanical Engineering Christian College of Engineering & Technology, Bhilai, Chhattisgarh, India, Vol. 6, Issue 1, 2-11*

[5] *Rajenda, S. (2006), Introduction to Manufacturing Processes, Bangalore, Cochin, Mumbai, New age international limited publishers*

[6] *William, H. (2017), how car suspension system works, Retrieved 20 July 2019*

[7] *Willie R. Hutchins, entitle 'Coil Spring Compressing Tool', Pat. No. 4,930,751 05 June 1990.*

[8] *K Pavan Kumar, S Praveen Kumar, and G Guru Mahesh, static analysis of a primary suspension spring used in locomotive"*
IJMERR, Vol. 2, No. 4, October 2013

[9] *V. B. Bhandari (1994), "Design of machine elements", New York, Tata McGraw-Hill.*