Design and Analysis of Shock Absorber for 150cc Bike

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Abstract - *Shock absorber is a mechanical device designed to damp shock impulses and dissipate kinetic energy. It reduces the effect of traveling over rough ground which leads to improved ride quality and increase in comfort because it substantially reduced amplitude of disturbances.*

In this project, a shock absorber is designed and a 3D model is created using Pro-E. Analysis is done by varying loads and materials at different conditions. Structural analysis is done to determine total deformation, stress and strain variations. Modal analysis is done to determine the displacements for different frequencies for different number of modes. In the end results are compared for two materials to verify the best one for the given suspension system.

***Key Words*: Shock absorber, Structural and Modal Analysis, Pro-E and Ansys**

1. INTRODUCTION

A shock absorber (shock "damper") is a mechanical or hydraulic device designed to absorb and damp shock impulses. It does this by converting the kinetic energy of the shock into heat which is later dissipated. Usually the shock absorbers are with fluid or air based heat dissipation system. Conventional shock absorbers consist of nested cylindrical tubes, an inner tube that is called the "working tube" or the "pressure tube", and an outer tube called the "reserve tube". At the bottom of the device, inside there is a compression valve or base valve. When the piston is forced up or down by bumps on the road, hydraulic fluid moves between different chambers via small holes or "orifices" in the piston and via the valve, converting the "shock" energy into heat which is dissipated into environment.

Earlier in motor vehicles leaf springs are used. One of the features of these springs was that the friction between the leaves offered a degree of damping. In 1912 review of vehicle suspension due to the lack of damping in helical springs. It was "impossible" to use them as main springs [2]. The amount of damping provided by leaf spring friction is limited, variable and depends upon their wet and dry conditions. C.L. Horock came up with a design in 1901 that had hydraulic damping; it worked in one direction only. These used a belt coiled inside a device such that it freely wound in under the action of a coiled spring, but met friction when drawn out. It does not seem to have gone into production right way.

First hydraulic damper to go into production was the Telesco Shock Absorber, exhibited at the 1912 Olympia Motor Show and marketed by Polyrhoe Carburettors Ltd. [3] This contained a spring inside the telescopic unit like the pure spring type 'shock absorbers', but also contain oil and an internal valve so that the oil damped in the rebound direction. The Telesco unit was fitted at the rear end of the leaf spring, in place of the rear spring to chassis mount, so that it formed part of the springing system, albeit a hydraulically damped part. [4]

1.1 Theoretical Approaches of Shock Absorber

The commonly used approaches towards shock absorption are Hysteresis, Dry friction, Fluid friction, Compression of gas, Magnetic effect and Composite hydro pneumatic. Hysteresis is the tendency for elastic materials to rebound with less force than was required to deform them. Simple vehicles with no separate shock absorbers are damped, to some extent, by the hysteresis of their springs and frames. Dry friction as used in wheel brakes, by using disks (classically made of leather) at the pivot of a lever, with friction forced by springs. In fluid friction the flow of fluid is through narrow orifice which constitutes the vast majority of automotive shock absorbers. Using a special internal valve the absorber may be made relatively soft to compression (allowing a soft response to a bump) and relatively stiff to extension, controlling "jounce", which is the vehicle response to energy stored in the springs, Similarly a series of valves controlled by springs can change the degree of stiffness according to the velocity of the impact or rebound. Pneumatic shock absorbers, which can act like springs as the air pressure is building to resist the force on it. Once the air pressure reaches the necessary maximum, air dashpots will act like hydraulic dashpots. In magnetic effects, Eddy current dampers are dashpots that are constructed out of a large magnet inside of a non-magnetic, electrically conductive tube. Conventional shock absorbers combined with composite pneumatic springs which allow ride on height adjustment or even ride height control. Ride height control is especially desirable in highway vehicles intended for occasional rough road use, as a means of improving handling and reducing aerodynamic drag by lowering the vehicle when operating on improved high speed roads. It is mostly seen in some large trucks and luxury sedans. The different methods of converting an impact /collision into relatively smooth are Cushioned contact, Elastomeric shock absorber, Hydraulic dashpot, Collapsing safety shock absorbers, Air (Pneumatic) springs and Self compensating hydraulics.

Failure of the hydraulic system will cause a drop in ride height and decrease in braking power. However, an acute failure will not lead to acute brake failure as the accumulator sphere holds enough reserve pressure to ensure safe braking far beyond that needed to bring a vehicle with a failed system to a standstill.

2. Design Consideration

We have considered a shock absorber made up of Structural steel and Beryllium copper. Different loading conditions are incorporated on the shock absorber and structural and modal analysis is performed on the shock absorber using Ansys.

2.1 Design Calculation

Modulus of Rigidity (Steel), G=78600 N/mm^2
Mean diameter of coil, D=33.3mm
Diameter of wire, d=6.7mm
Total number of coils, N_1 =17
Height, h=210mm
Outer diameter of spring coil, D_o=D+d=40mm
Number of active turns, N=15
Weight of bike=131Kg
Let the weight of one person=75Kg
Weight of two person=2×75=150Kg
Total Weight of Bike and Persons=263Kg
Rear Suspension=65% of weight=171Kg
Considering Dynamic loads, it weight will be double, w=342Kg=3355N
For single shock absorber weight, W=w/2=1677N
Compression of spring, $\delta=WD^3.n/G.d^4$
Structural Steel, δ=49.61 Beryllium Copper, δ=73
Spring Index, C=D/d=5
Solid Length, $L_s=N_1\times d=17\times 6.7=113.9$mm
Free length of the spring, L_f=Solid length + Maximum Compression + Clearance between adjustable coil=113.9+46.91+ (46.91×0.15)=167.8mm
Spring Rate, K=W/δ=35.74
Pitch of coil, P= $(L_f - L_s)/N_1+d$=10mm

2.2 Design of Shock Absorber using PRO-E

We have designed and assembled all the parts of shock absorber using Pro-E. Designing of every part is done by considering the dimensions calculated in design calculation section. Features like Extrude, Helical Sweep, Round and Draft are used to design the parts as shown below.

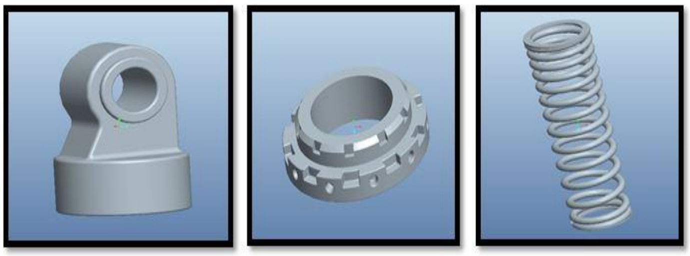


Fig -1: Bottom Parts of Shock Absorber

Fig -2: Exploded View and Inner Assembly

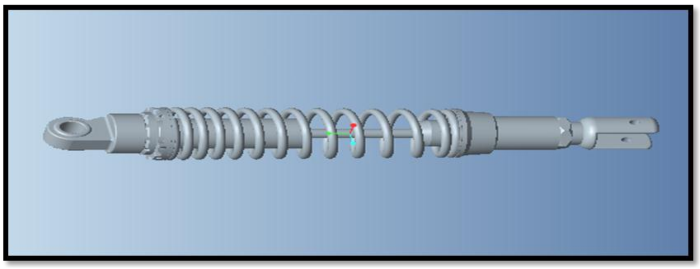


Fig -3: Assembly

3. Analysis Using Ansys

We have done structural and modal analysis on structural steel and Beryllium copper with different loading conditions. The model is meshed with an auto generated mesh model in Ansys. Stress, strain and deformation of both the materials are described in the section 3.1 and 3.2. The different load calculations for structural analysis are shown in the below table.

Table -1: Load Calculations

Load on Two Shocks	Load on Single shock	Load Conversion	Pressure (MPa)
113 Kg	56.5Kg	554.265N	0.144MPa
118 kg	94Kg	922.14N	0.239MPa
263Kg	131.5Kg	1290.015N	0.335Mpa

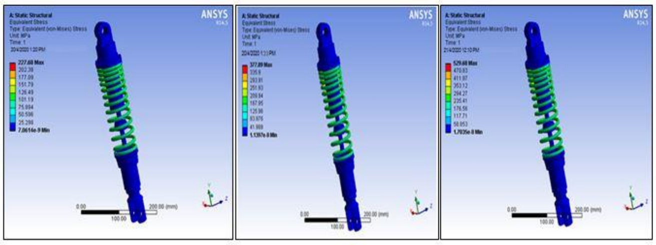
3.1 Structural Steel

3.1.1 Material Properties

Density: 7850kg/m^3
Ultimate Tensile Strength: 515-827Mpa
Yield Tensile Strength: 207-552Mpa
Young's Modulus: 190-210Gpa
Poisson's Ratio: 0.30
Percentage of elongation: 12-40
Shear Modulus: 78.6Gpa

3.1.2 Structural Analysis at Various Loads

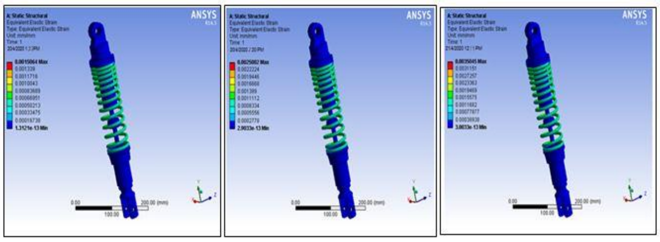
The stress induced at various loads are shown in the below figures.



Load 113 Load 188 Loads 263

Fig -4: Stress Induced at Different Loads

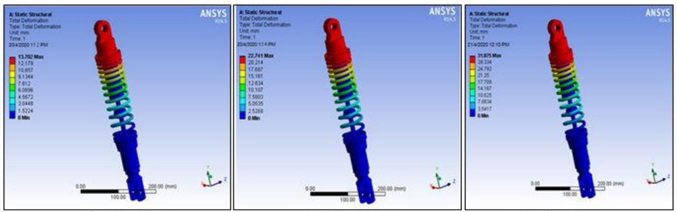
The change in the dimensions can be given by strain. Following figures represents the strain occurred at different loads.



Load 113 Load 188 Loads 263

Fig -5: Strain Induced at Different Loads

The total deformation at various load conditions is shown below.



Load 113 Load 188 Load 263

Fig -6: Total Deformation at Different Loads

The numerical values of stress, strain and total deformation are listed in the below table.

Table -2: Numerical Values of Structural Analysis

Von –Mises Stress (MPa)			Von-Mises Strain			Total Deformation (mm)		
113 Kg	188 Kg	263 Kg	113 Kg	188 Kg	263 Kg	113 Kg	188 Kg	263 Kg
227.68	377.89	529.68	0.0015	0.0025	0.0035	13.702	22.74	31.875

3.1.3 Modal Analysis

Modal analysis is a technique to study the dynamic characteristics of a structure under vibrational excitation. Natural frequencies, mode shapes and mode vectors of a structure can be determined using modal analysis. We have determined the natural frequencies and the total deformations using modal analysis.

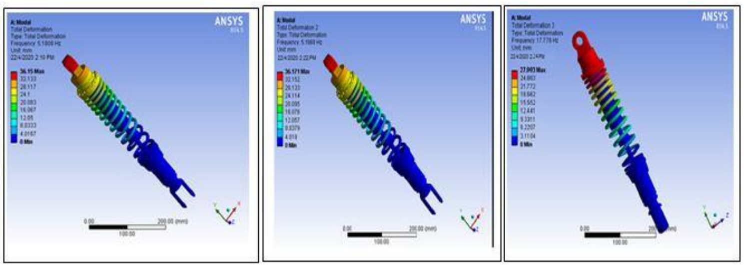


Fig -7: Total Deformation and Frequencies

Table -3: Numerical values of Modal Analysis

Mode Numbers	Frequency (Hz)	Total Deformation (mm)
Mode 1	5.1808	36.15
Mode 2	5.1969	36.171
Mode 3	17.776	27.993

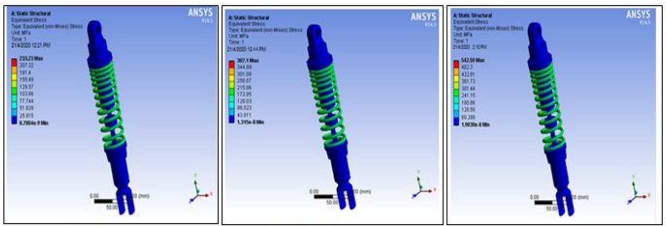
3.2 Beryllium Copper

3.2.1 Material Properties

Density: 8260 Kg/m^3
Ultimate Tensile Strength: 483-810Mpa
Yield Tensile Strength: 221-1172Mpa
Young's Modulus: 115Gpa
Poisson's Ratio: 0.30
Shear Modulus: 50Gpa

3.2.2 Structural Analysis at Various Loads

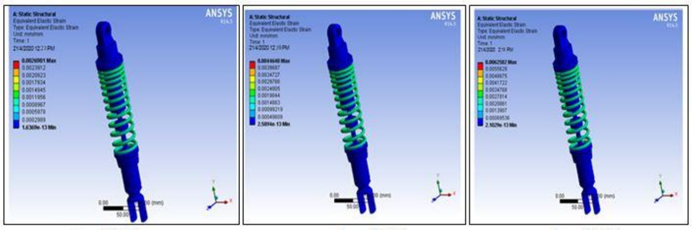
The stress induced in beryllium copper at various loading conditions is shown in figure.



Load 113 Load 188 Load 263

Fig -8: Stress Induced at Different Loads

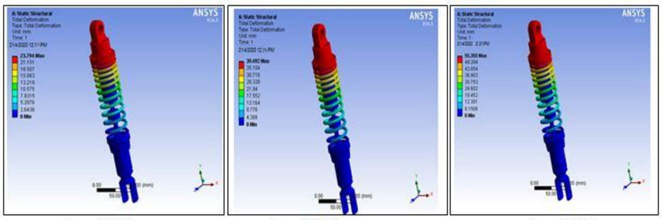
Following figures shows the strain at different loading conditions.



Load 113 Load 188 Load 263

Fig -9: Strain Induced at Different Loads

Total deformations are shown at various load are shown in below figures.



Load 113 Load 188 Load 263

Fig -10: Total Deformation at Different Loads

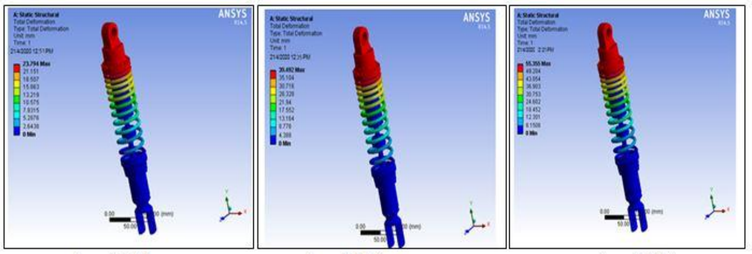
The numerical values of stress, strain and total deformation are listed in the below table.

Table -2: Numerical Values of Structural Analysis

Mode Numbers			Frequency (Hz)			Total Deformation (mm)		
113 Kg	188 Kg	263 Kg	113 Kg	188 Kg	263 Kg	113 Kg	188 Kg	263 Kg
233.23	387.1	542.59	0.0026	0.0044	0.0062	23.794	39.492	55.355

3.2.3 Modal Analysis

The total deformation and natural frequencies is shown in the figure.



Load 113 Load 188 Load 263

Fig -11: Total Deformation and Frequencies

Table -3: Numerical values of Modal Analysis

Mode Numbers	Frequency (Hz)	Total Deformation (mm)
Mode 1	3.8298	35.241
Mode 2	3.8417	35.261
Mode 3	13.14	27.29

4. CONCLUSIONS

The conclusions made after the structural and modal analysis on both the materials are listed here.

- The average stresses induced in structural steel and beryllium copper is 378.4166MPa and 387.64MPa. The percentage difference between both the materials is approximately 1.2%.
- The maximum total deformation in both the materials is 31.875mm and 55.355mm. At different loading conditions we have seen that beryllium copper has more total deformation than the structural steel.
- The (L_f-Ls) value from design calculation is 53.9mm but the deformation in beryllium copper is 55.35mm. Therefore, it can be concluded that Beryllium copper will not give Shock absorbing affect after 53.9mm of compression. Hence we can say structural steel is suitable to use here.
- From the modal analysis, the frequency at different deformation values of structural steel is more in comparison to beryllium copper, hence we can conclude that structural steel is more suitable on uneven roads.

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