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Characteristics of a Suspension Spring under Varying Thickness and Material

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Abstract: ***A suspension system or shock absorber is a mechanical device designed to smooth out or dampshock 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. The design of spring in suspension system is very important. In this project a shock absorber is designed and a 2D model is created using Pro/Engineer. The model is also changed by changing the thickness of the spring. Structural analysis and modal analysis are done on the shock absorber by varying material for spring, Spring Steel and Beryllium Copper. The analysis is done by considering loads, bike weight, single person and 2 persons. Structural analysis is done to validate the strength and modal analysis is done to determine the displacements for different frequencies for number of modes. Comparison is done for two materials to verify best material for spring in Shock absorber. Modeling is done in Pro/ENGINEER and analysis is done in ANSYS. Pro/ENGINEER is the standard in 2D product design, featuring industry-leading productivity tools that promote best practices in design. ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements.***

Keywords: amplitude, impulse, ride quality ,shock absorber

1. Introduction

A shock absorber ordamper is a mechanical device designed to smooth out or dampshock impulse, and dissipate kinetic energy.

A. Explanation

The shock absorbers duty is to absorb or dissipate energy. One design consideration, when designing or choosing a shock absorber, is where that energy will go. In most dashpots, energy is converted to heat inside the viscous fluid. In hydraulic cylinders, the hydraulic fluid will heat up, while in air cylinders, the hot air is usually exhausted to the atmosphere. In other types of dashpots, such as electromagnetic ones, the dissipated energy can be stored and used later. In general terms, shock absorbers help cushion cars on uneven roads.

B. Applications

Shock absorbers are an important part of automobile and motorcyclesuspensions, aircraftlanding gear, and the supports for many industrial machines. Large shock absorbers have also been used in structural engineering to reduce the susceptibility of structures to earthquake damage and resonance. A transverse mounted shock absorber, called a yaw damper, helps keep railcars from swaying excessively from side to side and are important in passenger railroads, commuter rail and rapid transit systems because they prevent railcars from damaging station platforms. The success of passive damping technologies in suppressing vibration amplitudes could be ascertained with the fact that it has a market size of around $ 4.5 billion.

Fig 1.1: Rear shock absorber and spring of a BMW R45/5 motorcycle

C. Types of shock absorbers

There are several commonly-used approaches to shock absorption:

- Hysteresis of structural material, for example the compression of rubber disks, stretching of rubber bands and cords, bending of steelsprings, or twisting of torsion bars. Hysteresis is the tendency for otherwise 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. Used in early automobiles such as the Ford Model T, up through some British cars of the 1940s. Although now considered obsolete, an advantage of this system is its mechanical simplicity; the degree of damping can be easily adjusted by tightening or loosening the screw clamping the disks, and it can be easily rebuilt with simple hand tools. A disadvantage is that the damping force tends not to increase with the speed of the vertical motion.

- Solid state, tapered chain shock absorbers, using one or more tapered, axial alignment(s) of granular spheres, typically made of metals such as nitinol, in a casing. [1],[2]

1.4 Shock Absorber types

There are a number of different methods of converting an impact /collision into relatively smooth cushioned contact..

- Metal Spring
- Rubber Buffer
- Hydraulic Dashpot
- Collapsing safety Shock Absorbers
- Pneumatic Cylinders
- Self compensating Hydraulic meal or elastomer based springs and the temperature range is restricted compared to metal springs.

1.5 Design Calculations for Helical springs for Shock absorbers

Material: Steel (modulus of rigidity) G = 41000
Mean diameter of a coil D=32mm
Diameter of wire d = 5mm
Total no of coils n^1= 15
Height h = 220mm
Outer diameter of spring coil D^0 = D +d =40mm
No of active turns n= 14
Weight of bike = 125kgs
Let weight of 1 person = 45Kgs
Weight of 2 persons = 45×2=150Kgs
Weight of bike + persons = 245Kgs
Rear suspension = 35%
35% of 245 = 135Kgs

Considering dynamic loads it will be double
W = 220Kgs = 2224N
For single shock absorber weight = w/2= 1314N = W

We Know that, compression of spring (δ) = $\frac{8W \times C^3 \times n}{G \times d}$

C = spring index = $\frac{D}{d} = \frac{62}{8} = 7.75 = 8$

(δ) = $\frac{8 \times 1617 \times 8^3 \times 14}{41000 \times 8} = 282.698m$

Solid length, $L_s = n^1 \times d = 15 \times 5 = 144$
Free length of spring,
L_f = solid length + maximum compression + clearance between adjustable coils

$= n^1 d + \delta_{max} + 0.15\delta_{max}$
= 439.102

Spring rate, K = $\frac{W}{\delta} = \frac{1617}{282.698} = 5.719$

Pitch of coil, P = $\frac{L_F + L_S}{n^1} = \frac{469.102 - 144}{18} = 26$

Stresses in helical springs: maximum shear stress induced in the wire

τ = K× $\frac{8WC}{\pi d^2}$

K = $\frac{4C-1}{4C-4} + \frac{0.615}{C} = \frac{4 \times 8 - 1}{4 \times 8 - 4} + \frac{0.615}{8} = 0.97$

τ=K $\times \frac{8WC}{\pi d^2} = 0.97 \times \frac{8 \times 1617 \times 8}{\pi \times 8^2} = 499.519 Mpa$

Buckling of compression springs, $W_{cr} = K \times K_B \times L_F$
spring rate or stiffness of spring K= $\frac{W}{\delta}$
Values of buckling factor $K_B = \frac{L_F}{D} = \frac{469.102}{62} = 7.5$
K = 0.05 (for hinged and spring)
The buckling factor for the hinged end and built-in end springs
W_{cr}=5.419×0.05×439.102=124.129N

2. Model of Shock Absorber

2.1 Parts of Shock Absorber

2.1.1 Bottom NOB

Figure 2.1: Bottom nob

2.1.2 TOP NOB

Figure 2.2: Top nob

2.1.2 Helical Spring

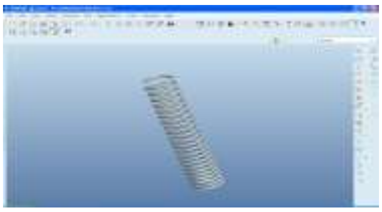


Figure 2.3: Helical Spring

2.2 Total Assembly

Figure 2.4: Total Assembly

2.2 Explode View

Figure 2.5: Explode view

2.4 2D Drawings of Shock Absorber

2.4.1 Bottom

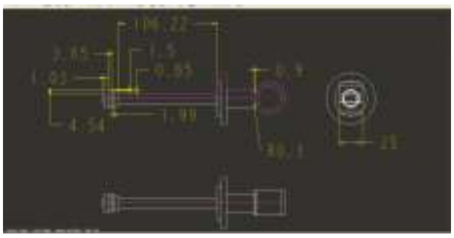


Figure 2.6: Bottom part

2.4.2 Top Part

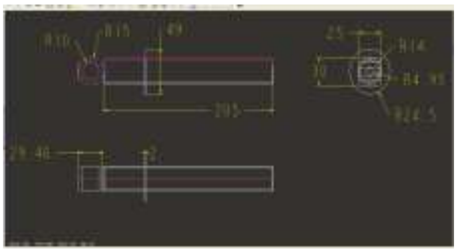


Figure 2.7: Top part

2.4.2 Helical Spring Part

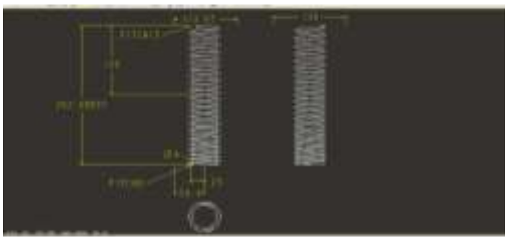


Figure 2.8: Helical Spring part

2.5 Assembly

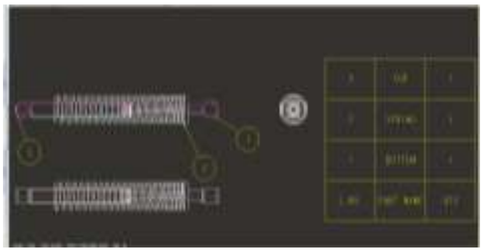


Figure 2.9: Assembly

2.3 Modified Spring of Shock Absorber

Figure 2.10: Modified spring of shock absorber

3. Present Design

3.1 Structural Analysis for bike weight (125kgs) using Spring Steel as spring material

Case 1: Load 125kgs

Element Type Solid 20 node 95
Material: Spring Steel
Material Properties: Youngs Modulus (EX) : 210000N/mm^2
Poissons Ratio (PRXY) : 0.29
Density : 0.000004550kg/mm^3

3.1.1 Imported Model from Pro/Engineer

Figure 3.1: Imported model from Pro/Engineer

3.1.2 Tetra Meshed Model

Figure 3.2: Tetra Meshed model

<u>Loads</u>
Pressure – 0.0045N/mm^2

Figure 3.3: Load applied on tetra mesh model

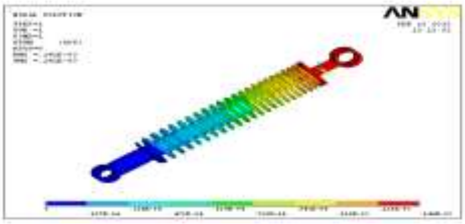


Figure 3.4: Displacement Vector Sum

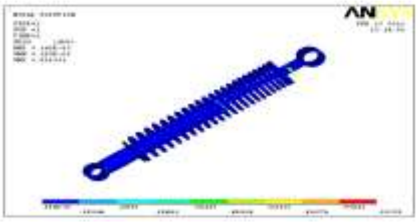


Figure 3.5: Vonmisses stress

3.1.3 Modal Analysis

3.1.4 Results

3.2 Structural Analysis for bike weight (125kgs) using Beryllium Copper as spring material

Case 2: Load 125kg

Element Type: Solid 20 node 95
Material: Beryllium Copper
Material Properties: Young’s Modulus (EX) : 250000N/mm^2
Poisson’s Ratio (PRXY) : 0.255
Density: 0.000001550kg/mm^3

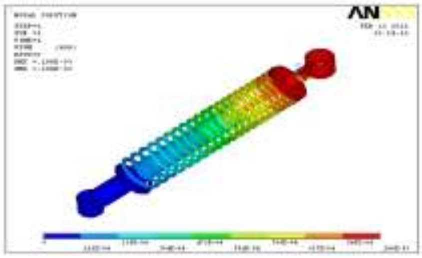


Figure 3.3: Displacement vector sum

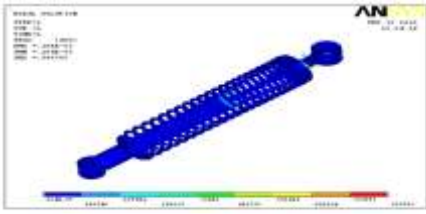


Figure 3.4: Von misses stress

3.2.1 Modal Analysis

3.2 Results

3.3 Structural Analysis for one person and bike weight (200kgs) using Spring Steel as spring material

Case 3: Load 200kg

Element Type Solid 20 node 95

Material: Spring Steel

Material Properties: Young's Modulus (EX) : 210000N/mm^2

Poisson's Ratio (PRXY) : 0.29

Density: 0.000004550kg/mm^3

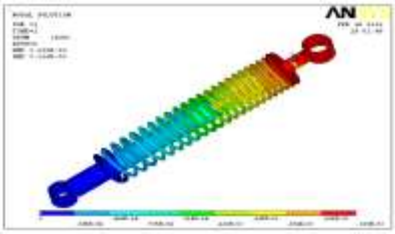


Figure 3.5: Displacement vector sum

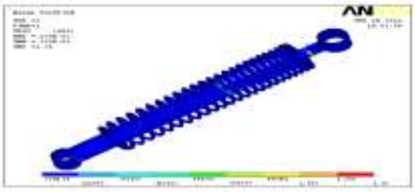


Figure 3.9: Van misses stress

3.3.1 Modal Analysis

3.3.2 Results

3.3 Structural Analysis for one person and bike weight(200kgs) using Beryllium Copper as spring material

Case 4: Load 200kgs

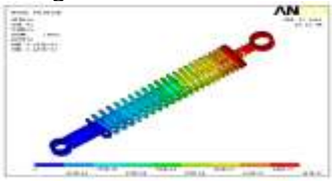


Figure 3.10: Displacement vector sum

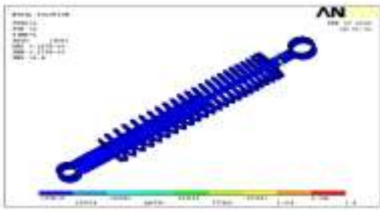


Figure 3.11: Von misses stress

3.3.1 Modal Analysis

3.3.2 Results

3.4 Structural Analysis for two persons and bike weight (245kgs) using Spring Steel as spring material
Case 5: Load 245kgs

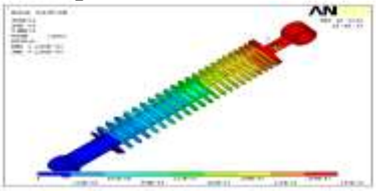


Figure 3.12: Displacement vector sum

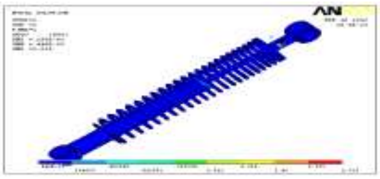


Figure 3.13: Von misses stress

3.4.1 Modal Analysis
3.4.2 Results

3.5 Structural Analysis for two persons and bike weight (245kgs) using Beryllium Copper as spring material
Case 3: Load 245kg
Post Processor

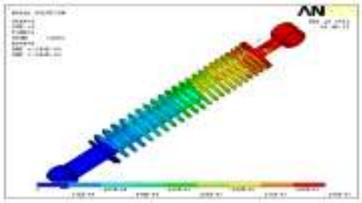


Figure 3.14: Displacement vector sum

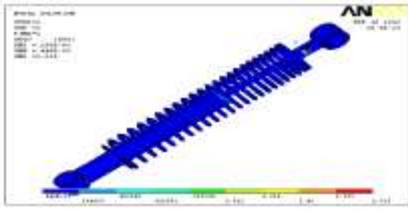


Figure 3.15: Von misses stress

3.5.1 Modal Analysis
3.5.2 Results

4. New Modified Design

4.1 Structural Analysis for bike weight (125kgs) using Spring Steel as spring material

Case 1: Load 125kgs

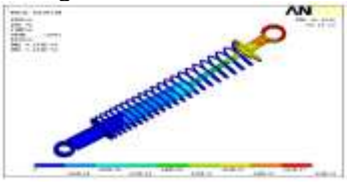


Figure 4.1: Displacement vector sum

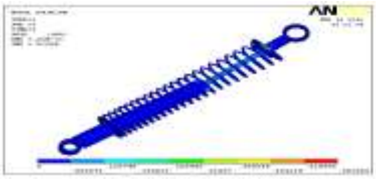


Figure 4.2: Von misses stress

4.1.1 Modal Analysis

4.1.2 Results

4.2 Structural Analysis for bike weight(125kgs) using Beryllium Copper as spring material

Case 2: Load 125kgs

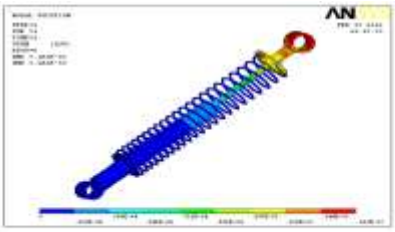


Figure 4.3: Displacement vector sum

Figure 4.4: Von misses stress

4.2.3 Modal Analysis

4.2.4 Results

4.3 Structural Analysis for one person and bike weight (200kgs) using Spring Steel as spring material

Case 3: Load 200kgs

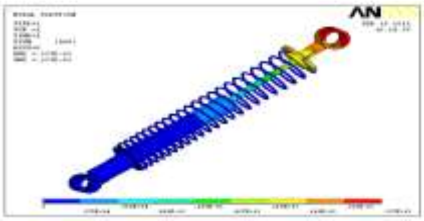


Figure 4.5: Displacement vector sum

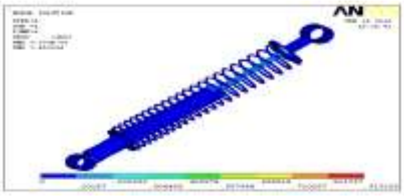
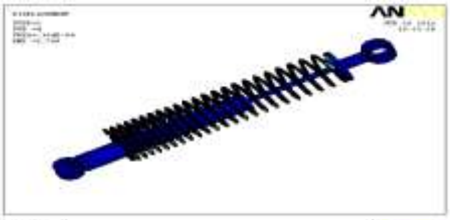


Figure 4.5: Von Misses Stress

4.5.1 MODAL ANALYSIS

4.5.2 Results



4.3 Structural Analysis for one person and bike weight (200kgs) using Beryllium Copper as spring material

Case 4: Load 200kgs

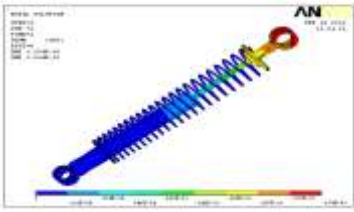


Figure 4.4: Displacement vector sum

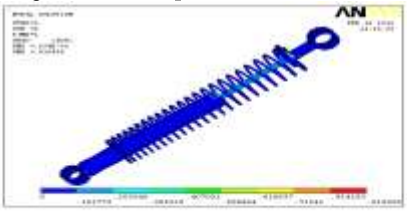
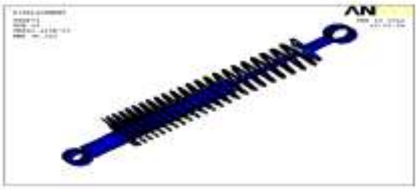


Figure 4.5: Von misses stress

4.3.1 MODAL ANALYSIS

4.3.2 Results



4.4 Structural Analysis for two person and bike weight (245kgs) using Spring Steel as spring material

Case 5: Load 245kgs

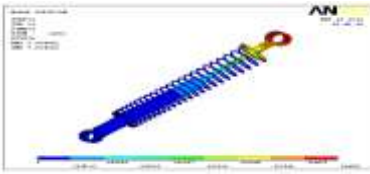


Figure 4.9: Displacement vector sum

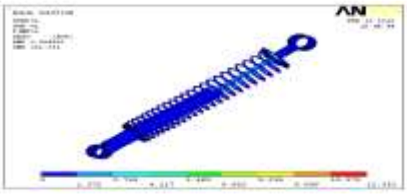


Figure 4.10: Von Misses Stress

4.4.1 Modal Analysis

4.4.2 Results

4.5 Structural Analysis for two persons and bike weigh (245kgs) using Beryllium Copper as spring material

Case 3: 245kgs

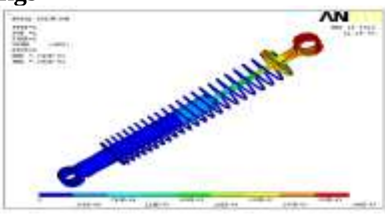


Figure 4.11: Displacement Vector Sum

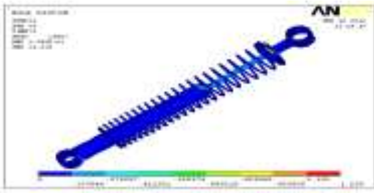


Figure 4.11: Von Misses Stress

4.5.1 Modal Analysis

4.5.2 Results

Results Table

5. Present Design

		SPRING STEEL			BERYLLIUM COPPER		
		BIKE	1P+BIKE	2P+BIKE	BIKE	1P+BIKE	2P+BIKE
	STRESS(N/mm²)	0.82351	1.36	1.839	0.888703	1.6	1.893
	DISPLACEMENT (mm)	$0.141e^{03}$	$0.220e^{03}$	$0.288e^{03}$	$0.106e^{03}$	$0.167e^{03}$	$0.225e^{03}$
MODE	FREQUENCY (HZ)	0.803459	0.80238	0.802388	1.912	1.914	1.914
	DISPLACEMENT (mm)	1.721	1.722	1.722	3.545	3.545	3.545
	FREQUENCY (HZ)	0.808263	0.80722	0.807224	1.924	1.921	1.925
	DISPLACEMENT (mm)	1.75	1.751	1.751	3.606	3.606	3.606
	FREQUENCY (HZ)	1.257	1.252	1.252	2.996	3.001	3.001
	DISPLACEMENT (mm)	1.85	1.85	1.85	3.4	3.4	3.4
	FREQUENCY (HZ)	1.424	1.424	[illegible].424	3.386	3.385	3.385
	DISPLACEMENT (mm)	1.818	1.818	1.818	3.745	3.745	3.745
	FREQUENCY (HZ)	1.611	1.612	1.612	3.831	3.829	3.829
	DISPLACEMENT (mm)	1.755	1.751	1.751	3.618	3.622	3.622

Modified Design

		SPRING STEEL			BERYLLIUM COPPER		
		BIKE	1P+BIKE	2P+BIKE	BIKE	1P+BIKE	2P+BIKE
	STRESS(N/mm²)	0.58388	0.91322	12.351	0.58361	0.915956	1.239
	DISPLACEMENT (mm)	$0.189e^{03}$	$0.184e^{04}$	0.004562	$0.162e^{03}$	$0.254e^{03}$	$0.343e^{03}$
MODE	FREQUENCY (HZ)						
	DISPLACEMENT (mm)	3.525	3.075	3.075	6.967	6.967	6.967
	FREQUENCY (HZ)						
	DISPLACEMENT (mm)	2.616	2.797	2.797	6.827	6.827	6.827
	FREQUENCY (HZ)						
	DISPLACEMENT (mm)	2.702	1.713	1.713	6.616	6.616	6.616
	FREQUENCY (HZ)	$0.364e^{-04}$	$0.184e^{-04}$	$0.184e^{-04}$	$0.606e^{-04}$	$0.606e^{-04}$	$0.606e^{-04}$
	DISPLACEMENT (mm)	1.997	2.706	2.706	3.66	3.66	3.66
	FREQUENCY (HZ)	2.797	$0.817e^{-04}$	$0.817e^{-04}$	$0.125e^{03}$	$0.125e^{03}$	$0.125e^{03}$
	DISPLACEMENT (mm)	3.38	3.364	3.[illegible]64	6.325	6.325	6.325

6. Conclusion

- In our project we have designed a shock absorber used in a 150cc bike. We have modeled the shock absorber by using 3D parametric software Pro/Engineer.
- To validate the strength of our design, we have done structural analysis and modal analysis on the shock absorber. We have done analysis by varying spring material Spring Steel and Beryllium Copper.
- By observing the analysis results, the analyzed stress values are less than their respective yield stress values. So our design is safe.
- By comparing the results for both materials, the stress value is less for Spring Steel than Beryllium Copper.
- Also the shock absorber design is modified by reducing the diameter of spring by 2mm and structural, modal analysis is done on the shock absorber. By reducing the diameter, the weight of the spring reduces. By comparing the results for both materials, the stress value is less for Spring Steel than Beryllium Copper.
- By comparing the results for present design and modified design, the stress and displacement values are less for modified design.
- So we can conclude that as per our analysis using material Spring steel for spring is best and also our modified design is safe.

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[6] Automotive Maintenance and Trouble Shooting by Ernest Venk & Edward D. Spicer