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Design Evaluation of a Two-Wheeler Suspension System for Variable Load Conditions

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ABSTRACT

A 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 travelling over rough ground, leading to improved ride quality, and increase in comfort due to substantially reduced amplitude of disturbances. The design of spring in suspension system is very important. In this project a shock absorber is designed and a 3D model is created using CATIA V5. 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.

KEYWORDS: *Introduction, applications, Types of Shock Absorber, Introduction to Catia V5,Introduction to Ansys, Generic Steps to Solving any Problem in ANSYS, Preparing the analysis part.*

I. Introduction

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

Description

Pneumatic and hydraulic shock absorbers commonly take the form of a cylinder with a sliding piston inside. The cylinder is filled with a fluid (such as hydraulic fluid) or air. This fluid-filled piston/cylinder combination is a dashpot. the dissipated energy can be stored and used later. In general terms, shock absorbers help cushion cars on uneven roads.

II. Applications

Shock absorbers are an important part of automobile and motorcycle suspensions, aircraft landing 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: REAR SHOCK ABSORBER AND SPRING OF A BMW R75/5 MOTORCYCLE

Vehicle suspension

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. Without shock absorbers, the vehicle would have a bouncing ride, as energy is stored in the spring and then released to the vehicle, possibly exceeding the allowed range of suspension movement. Control of excessive suspension movement without shock absorption requires stiffer (higher rate) springs, which would in turn give a harsh ride. Shock absorbers allow the use of soft (lower rate) springs while controlling the rate of suspension movement in response to bumps.

They also, along with hysteresis in the tire itself, damp the motion of the un sprung weight up and down on the springiness of the tire. Since the tire is not as soft as the springs, effective wheel bounce damping may require stiffer shocks than would be ideal for the vehicle motion alone. Spring-based shock absorbers commonly use coil springs or leaf springs, though torsion bars can be used in torsional shocks as well. Ideal springs alone, however, are not shock absorbers as springs only store and do not dissipate or absorb energy. Vehicles typically employ springs or torsion bars as well as hydraulic shock absorbers. In this combination, "shock absorber" is reserved specifically for the hydraulic piston that absorbs and dissipates vibration.

Structures

Applied to a structure such as a building or bridge it may be part of a seismic retrofit or as part of new, earthquake resistant construction. In this application it allows yet restrains motion and absorbs resonant energy, which can cause excessive motion and eventual structural failure.

III. Types of Shock Absorber

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

Metal springs

Simply locating metal springs to absorb the impact loads are a low cost method of reducing the collision speed and reducing the shock loading. They are able to operate in very arduous conditions under a wide range of temperatures. These devices have high stopping forces at end of stroke. Metal springs store energy rather than dissipating it. If metal sprint type shock absorbers are used then measures should be provided to limit Oscillations. Metal springs are often used with viscous dampers. There are a number of different types of metal springs including helical springs, bevel washers(cone-springs), leaf springs, ring springs, mesh springs etc. Each spring type has its own operating characteristics.

A **spring** is an elastic object that stores mechanical energy. Springs are typically made of spring steel. There are many spring designs. In everyday use, the term often refers to coil springs. When a conventional spring, without stiffness variability features, is compressed or stretched from its resting position, it exerts an opposing force approximately proportional to its change in length (this approximation breaks down for larger deflections). The rate or spring constant of a spring is the change in the force it exerts, divided by the change in deflection of the spring. That is, it is the gradient of the force versus deflection curve. An extension or compression spring's rate is expressed in units of force divided by distance, for example or N/m or lbf/in. A torsion spring is a spring that works by twisting; when it is twisted about its axis by an angle, it produces a torque proportional to the angle. A torsion spring's rate is in units of torque divided by angle, such as N-m/rad or ft-lbf/degree. The inverse of spring rate is compliance, that is: if a spring has a rate of 10 N/mm, it has a compliance of 0.1 mm/N. The stiffness (or rate) of springs in parallel is additive, as is the compliance of springs in series.

Elastomatic shock absorbers

These are low cost options for reducing the collision speed and reducing the shock loading and providing system damping. They are conveniently moulded to suitable shapes. These devices have high stopping forces at end of stroke with significant internal damping. Elastomeric dampers are very widely used because of the associated advantages of low cost and mouldability together with performance benefits. The inherent damping of elastomers is useful in preventing excessive vibration amplitude at resonance – much reduced compared to metal springs. However elastomeric based shock absorbers are limited in being affected by high and low temperatures. And are subject to chemical attack. Silicone rubber is able to provide reasonable mechanical properties between temperatures of -50O to +180O deg. C- most other elastomer has inferior temperature tolerance.

A **shock absorber** (in reality, a 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 another form of energy (typically heat) which is then dissipated. Most shock absorbers are a form of dashpot (a damper which resists motion via viscous frict

Hydraulic dashpot

This type of shock absorber is based on a simple hydraulic cylinder. As the piston rod is moved hydraulic fluid is forced through an orifice which restricts flow and consequently provides a controlled resistance to movement of the piston rod. With only one metering orifice the moving load is abruptly slowed down at the start of the stroke. The braking force rises to a very high peak at the start of the stroke and then falls away rapidly. On completion of the stroke the system is stable - the energy being dissipated in the hydraulic fluid as heat. This type of shock absorbers are provided with Springs sufficient to return the actuator to its initial position after the impacting load is removed.

Collapsing safety Shock absorbers

These are single use units which are generally specially designed for specific duties. They are designed such that at impact they collapse and the impact energy is absorbed as the materials distort in their inelastic/yield range. They therefore are more compact compared to devices based on deflections within their elastic range.

Air spring

These devices use air as the resilient medium. Air has a high energy storage capacity compared to metal or elastomer materials. For duties with high loads and deflections the air spring is generally far more compact that the equivalent metal or elastomer device. Due to the compressibility of air these have a sharply rising force characteristic towards the end of the stroke. The majority of the energy is absorbed near the end of the stroke. The force on an air cylinder buffer is determined by the relation PVn=constant. Air springs require more maintenance than meal or elastomer based springs and the temperature range is restricted compared to metal springs.

Air spring is a type of vehicle suspension powered by an electric or engine-driven air pump or compressor. This compressor pumps the air into a flexible bellows, usually made from textile-reinforced rubber. The air pressure inflates the bellows, and raises the chassis from the axle.

Self compensating hydraulic

These devices are similar to the hydraulic dashpot type except that a number of orifices are provided allowing different degrees of restriction throughout the stroke. These devices are engineered to bring the moving load is smoothly and gently to rest by a constant resisting force throughout the entire shock absorber stroke. The load is decelerated with the lowest possible force in the shortest possible time eliminating damaging force peaks and shock damage to machines and equipment. These type of shock absorbers are provided with springs sufficient to return the actuator to its initial position after the impacting load is removed.

A hydraulic positioner for seats includes a cylinder and piston structure with a piston rod secured to the piston and extending from the cylinder. A reservoir is provided in the cylinder by a gland jointly biased by a first spring located within the cylinder and a second spring which also urges the piston rod to an extended position. A sleeve is movable by the gland for visual indication of the hydraulic fluid in the cylinder.

Design Calculation For Helical Coil Spring Of The Shock Absorber

Material: Spring Steel (modulus of rigidity) G= 4100N/mm2

Mean diameter of a coil, D=62mm

Diameter of wire, d = 8mm

Total no of coils, n1= 18

Height, h = 220mm

Outer diameter of spring coil, D0 = D +d=70mm
No of active turns, n= 14
Weight of bike = 125 Kgs
Wight of 1person = 75Kgs
Weight of 2 persons
= 75×2=150Kgs
Weight of bike + persons = 275 Kgs
Rear Suspension = 65% 65% of 275

Considering dynamic loads it will be double W= 330Kgs = 3234N
For single shock absorber weight = w/2= 1617N = W
We Know that, compression of spring (δ) = WD3n G.d4
C = spring index = D/d = 62/8=7.75=8
(δ) = 282.698
Solid length, Ls =n1×d=18x8=144
Free length of spring,
Lf = solid length + maximum compression + clearance between adjustable coils=144+282.698+0.15x282.698=469.102

Spring rate, K = W =5.179
Pitch of coil, P = Lf – Ls + d n1=26
Stresses in helical spring: maximum shear stress induced in the wireτ = Ks × 8WD π.d3 Ks
Buckling of compression springs =499.519
Spring rate or Stiffness of spring k_B=7.5
Values of Buckling Factor(for hinged and spring) K=0.05
The buckling factor for the hinged end and built-in end springW_{cr} =1.719x0.05x469.102
=134.139 N

IV. INTRODUCTION TO CAD

Throughout the history of our industrial society, many inventions have been patented and Whole new technologies have evolved. Perhaps the single development that has impacted Manufacturing more quickly and significantly than any previous technology is the digital computer. Computers are being used increasingly for both design and detailing of engineering components in the drawing office. Computer-aided design (CAD) is defined as the application of computers and graphics Software to aid or enhance the product design from conceptualization to documentation. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system. Computer-aided design systems are powerful tools and in the Mechanical design and geometric modeling of products and components.

There are several good reasons for using a CAD system to support the engineering design function:

- To increase the productivity
- To improve the quality of the design
- To uniform design standards
- To create a manufacturing data base
- To eliminate inaccuracies caused by hand-copying of drawings and inconsistency between
- Drawings

CAD/CAM Software

Software allows the human user to turn a hardware configuration into a powerful design and Manufacturing system. CAD/CAM software falls into two broad categories, 2D and 3D,Based on the number of dimensions are called 2-D representations of 3-D objects is inherently confusing. Equally problem has been the inability of manufacturing personnel to properly read and interpret complicated 2-D representations of objects. 3-D software permits the parts to be viewed with the 3-D planes-height, width, and depth-visible. The trend in CAD/CAM is toward3-D representation of graphic images. Such representation approximate the actual shape and appearance of the object to be produced; therefore, they are easier to read and understand.

Applications of CAD/CAM

The emergence of CAD/CAM has had a major impact on manufacturing, by standardizing product development and by reducing design effort, tryout, and prototype work; it has made possible significantly reduced costs and improved productivity. AutoCAD is a computer-aided drafting and design system implemented on a personal computer. It supports a large number of devices. Device drivers come with the system and include most of the digitizers, printer/plotters, video display boards, and plotters available on the market.

AutoCAD supports 2-D drafting and 3-D wire-frame models. The system is designed as a single-user CAD package. The drawing elements are lines, poly lines of any width, arcs, circles, faces, and solids. There are many ways to define a drawing element. For example, a circle can be defined by center and its radius, three points, and two end points of its diameter. The system always prompts the user for all options.

Of course, the prompt can be turned off by advanced users. Annotation and dimensioning are also supported. Text and dimension symbols can be placed on anywhere on the drawing, at any angle, and at any size.

V. INTRODUCTION TO CATIA V5

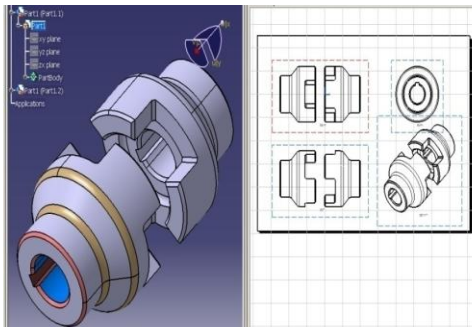
CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite.

Commonly referred to as a 3D Product Lifecycle Management software suite, CATIA supports multiple stages of product development, including conceptualization, design (CAD), manufacturing (CAM), and engineering (CAE). CATIA facilitates collaborative engineering across disciplines, including surfacing & shape design, mechanical engineering, and equipment and systems engineering. CATIA provides a suite of surfacing, reverse engineering, and visualization solutions to create, modify, and validate complex innovative shapes, from subdivision, styling, and Class A surfaces to mechanical functional surfaces.

CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, molded, forged or tooling parts up to the definition of mechanical assemblies. It provides tools to complete product definition, including functional tolerances as well as kinematics definition. CATIA facilitates the design of electronic, electrical, and distributed systems such as fluid and HVAC systems, all the way to the production of documentation for manufacturing.

Industries

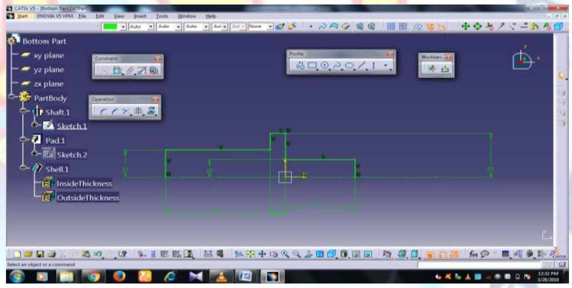
CATIA can be applied to a wide variety of industries, from aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services. CATIA V4, CATIA V5, Pro/ENGINEER, NX (formerly Unigraphics), and SolidWorks are the dominant systems.

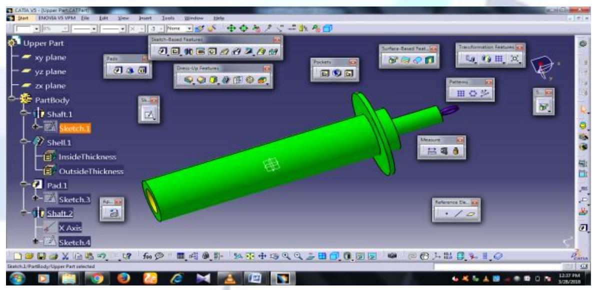


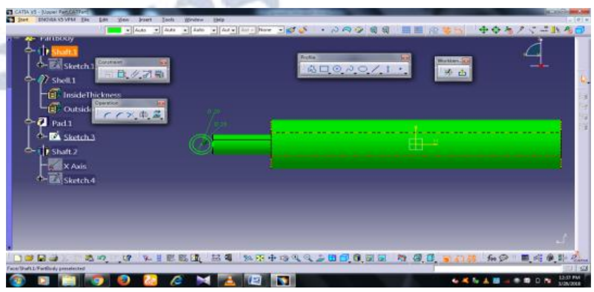
Aerospace

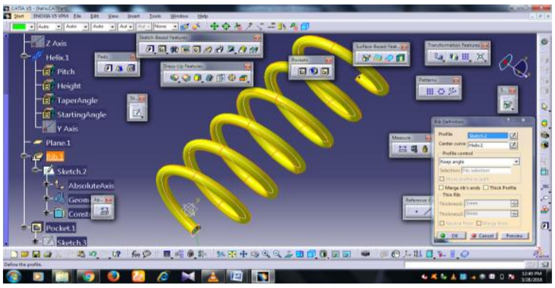
The Boeing Company used CATIA V4 to develop its 777 airlines and used CATIA V5 for the 787 series aircraft. They have employed the full range of Dassault Systems 3D PLM products – CATIA, DELMIA, and ENOVIA LCA – supplemented by Boeing-developed applications.

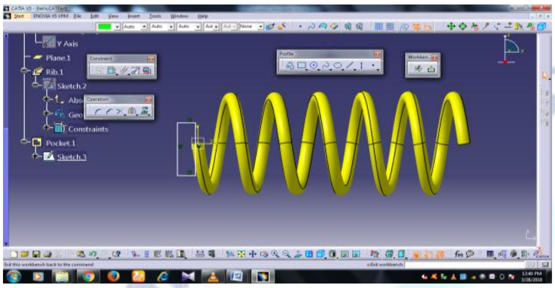
- ❖ The development of the Indian Light Combat Aircraft has used CATIA V5.
- ❖ European aerospace Airbus has used CATIA since 2001.
- ❖ The Anglo/Italian Helicopter Company AgustaWestland uses CATIA V4 and V5 to design their full range of aircraft.

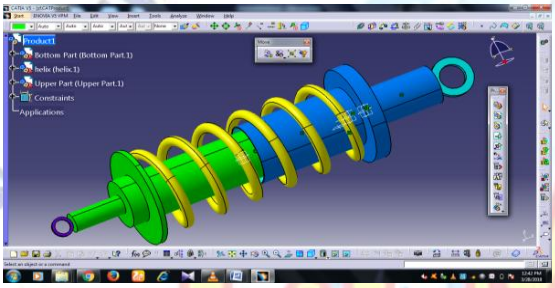


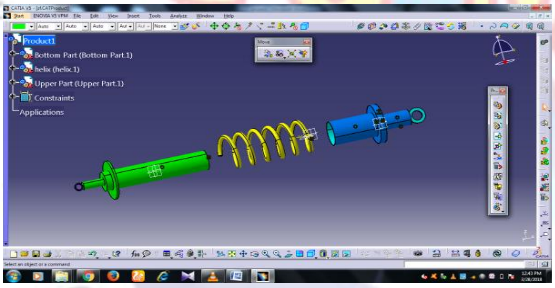












VI. INTRODUCTION TO ANSYS

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. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyse by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc.

Generic Steps to Solving any Problem in ANSYS

Like solving any problem analytically, you need to define (1) your solution domain, (2) the physical model, (3) boundary conditions and (4) the physical properties. You then solve the problem and present the results. In numerical methods, the main difference is an extra step called mesh generation. This is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Below describe the processes in terminology slightly more attune to the software.

Build Geometry

Construct a two or three-dimensional representation of the object to be modeled and tested using the work plane coordinate system within ANSYS.

Define Material Properties

Now that the part exists, define a library of the necessary materials that compose the object (or project) being modeled. This includes thermal and mechanical properties.

Generate Mesh

At this point ANSYS understands the makeup of the part. Now define how the modeled system should be broken down into finite pieces.

Apply Loads

Once the system is fully designed, the last task is to burden the system with constraints, such as physical loadings or boundary conditions.

Obtain Solution

This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved.

Present the Results

After the solution has been obtained, there are many ways to present ANSYS' results, choose from many options such as tables, graphs, and contour plots.

Specific Capabilities of ANSYS

Structural

Structural analysis is probably the most common application of the finite element method as it implies bridges and buildings, naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

Buckling Analysis – Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigenvalue) buckling and nonlinear buckling analyses are possible.In addition to the above analysis types, several special-purpose features are available such as **Fracture mechanics**, **Composite material analysis**, **Fatigue**, and both **p-Method and Beam analyses.**

Modal Analysis - A modal analysis is typically used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a harmonic response or full transient dynamic analysis. Modal analyses, while being one of the most basic dynamic analysis types available in ANSYS, can also be more computationally time consuming than a typical static analysis. A reduced solver, utilizing automatically or manually selected master degrees of freedom is used to drastically reduce the problem size and solution time.

Harmonic Analysis- Used extensively by companies who produce rotating machinery, ANSYS Harmonic analysis is used to predict the sustained dynamic behavior of structures to consistent cyclic loading. Examples of rotating machines which produced or are subjected to harmonic loading are:

- Turbines
  - Gas Turbines for Aircraft and Power Generation
  - Steam Turbines
  - Wind Turbine
  - Water Turbines
  - Turbopump
- Internal Combustion engines
- Electric motors and generators
- Gas and fluid pumps
- Disc drives

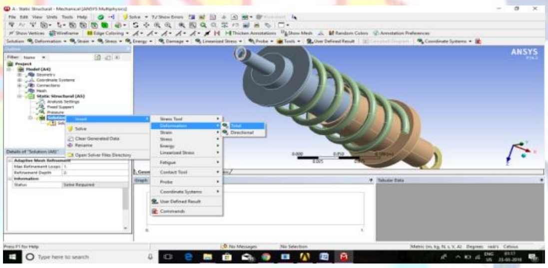
A harmonic analysis can be used to verify whether or not a machine design will successfully overcome resonance, fatigue, and other harmful effects of forced vibrations..

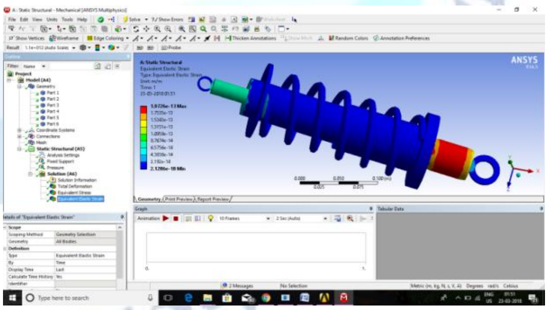
Fluid Flow

The ANSYS/FLOTRAN CFD (Computational Fluid Dynamics) offers comprehensive tools for analyzing two-dimensional and three-dimensional fluid flow fields. ANSYS is capable of modeling a vast range of analysis types such as: airfoils for pressure analysis of airplane wings (lift and drag), flow in supersonic nozzles, and complex, three-dimensional flow patterns in a pipe bend. In addition, ANSYS/FLOTRAN could be used to perform tasks including:

- ✓ Calculating the gas pressure and temperature distributions in an engine exhaust manifold
- ✓ Studying the thermal stratification and breakup in piping systems
- ✓ Using flow mixing studies to evaluate potential for thermal shock
- ✓ Doing natural convection analyses to evaluate the thermal performance of chips in electronic enclosures
- ✓ Conducting heat exchanger studies involving different fluids separated by solid regions

Preparing the analysis part





VII. 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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