DESIGN, MODELING AND PERFORMANCE ANALYSIS OF PSD SHOCK ABSORBER USING ANSYS

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Abstract

Shock absorbers are a critical part of a suspension system, connecting the vehicle to its wheels. The need for dampers arises because of the roll and pitches associated with vehicle manoeuvring, and from the roughness of roads. In the mid nineteenth century, road quality was generally very poor. The rapidly increasing power available from the internal combustion engine made higher speeds routine; this, plus the technical aptitude of the vehicle and component designers, coupled with a general commercial mood favoring development and change, provided an environment that led to invention and innovation of shock absorbers.

Shock absorbers are devices that smooth out an impulse experienced by a vehicle, and appropriately dissipate or absorb the kinetic energy. One of the problems is that the vehicle bounce continuously more than one times and it is called as bouncing problems. Shock absorbers have become such an essential component of an automobile. So that the objective of this project is to study the causes of the bouncing problem at the vehicle and to compare the failure parts performance in terms of its strength. In this work initially designing the Hero Honda bike PSD shock absorber with design data using Solid works and to test the performance of designed PSD shock absorber includes structural and model analysis using ANSYS tool at various loading conditions

Keywords: PSD Shock absorber, Solid works, Stress, Deformation, Strains, ANSYS, Damping.

1. Introduction

1.1 FUNCTIONS OF SHOCK ABSORBERS IN AUTOMOBILE

In common with carriages and railway locomotives, most early motor vehicles used leaf springs. One of the features of these springs was that the friction between the leaves offered a degree of damping and in a 1912 review of vehicle suspension the lack of this characteristic in helical springs was the reason it was "impossible" to use them as main springs. However the amount of damping provided by leaf spring friction was limited and variable according to the conditions of the springs, and whether wet or dry. It also operated in both directions. Motorcycle front suspension adopted coil sprung Druid forks from about 1906, and similar designs later added rotary friction dampers, which damped both ways - but they were adjustable (e.g. 1924 Webb forks).

These friction disk shock absorbers were also fitted to many cars. One of the problems with motor cars was the large variation in sprung weight between lightly loaded and fully loaded, especially for the rear springs. When heavily loaded the springs could bottom out, and apart from fitting rubber 'bump stops', there were attempts to use heavy main springs with auxiliary springs to smooth the ride when lightly loaded, which were often called 'shock absorbers'. Realising that the spring and vehicle combination bounced with a characteristic frequency, these auxiliary springs were designed with a different period, but were not a solution to the problem that the spring rebound after striking a bump could throw you out of your seat. What was called for was damping that operated on the rebound.

The purpose of a shock absorber, within any moving object, is to dissolve the kinetic energy evenly while eliminating any decelerating force that may be destructive to the object. 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. A transverse mounted shock absorber, helps keep railcars from swaying excessively from side to side and are important in passenger railroads systems because they prevent railcars from damaging station platforms. In a vehicle, it reduces the effect of travelling over rough ground, and leading to improved ride quality. 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. A prototype shock absorber capable of significantly reducing vibrations, such as those experienced while driving, has been developed by German researchers. The device can also convert vibrations into energy, meaning it has the potential to power inaccessible sensors. Shock absorbers are devices that dampen unwanted vibrations. Most are passive in nature and made of materials called elastomers that are yielding and malleable.

The main advantage over the friction disk dampers was that it would resist sudden movement but allow slow movement, whereas the rotary friction dampers tended to stick and then offer the same resistance regardless of speed of movement. There appears to have been little progress on commercialising the lever arm shock absorbers until after World War I, after which they came into widespread. A suspension system or shock absorber is a mechanical device designed to smooth out and dissipate kinetic energy. The shock absorbers function is to absorb or dissipate energy. In a vehicle, it reduces the effect of traveling over rough ground, leading to improve ride quality, and increase in comfort due to substantially reduced amplitude of disturbances.

Basic safety and also traveling ease and comfort to get a car's motorist are usually equally influenced by the particular vehicle's suspension method. Safety refers to the vehicle's handling and braking capabilities. Shock absorbers are a critical part of a suspension system, connecting the vehicle to its wheels. Basically shock absorbers tend to be products which lessen a good behavioral instinct skilled with an automobile, as well as properly absorb the actual kinetic power. Almost all suspension systems consist of springs and dampers, which tend to limit the performance of a system due to their physical constraints. Suspension systems, comprising of springs and dampers are usually.

1.2 TYPES OF VEHICLE SHOCK ABSORBERS

Diagram of the main components of a twin-tube and mono-tube shock absorber Most vehicular shock absorbers are either twin-tube or mono-tube types with some variations on these themes.

Figure1.1 Acceleration Sensitive Damping type shock absorber

a) Basic twin-tube

b) Twin-tube gas charged

c) **Position sensitive damping** Often abbreviated simply as "PSD", this design is another evolution of the twin-tube shock. In a PSD shock absorber, which still consists of two nested tubes and still contains nitrogen gas, a set of grooves has been added to the pressure tube. These grooves allow the piston to move relatively freely in the middle range of travel (i.e., the most common street or highway use, called by engineers the "comfort zone") and to move with significantly less freedom in response to shifts to more irregular surfaces when upward and downward movement of the piston starts to occur with greater intensity (i.e., on bumpy sections of roads— the stiffening gives the driver greater control of movement over the vehicle so its range on either side of the comfort zone is called the "control zone"). This advance allowed car designers to make a shock absorber tailored

to specific makes and models of vehicles and to take into account a given vehicle's size and weight, its maneuverability, its horsepower, etc. in creating a correspondingly effective shock.

d) Acceleration Sensitive Damping

e) Coil over

f) Mono-tube

g) Spool valve

2. LITERATURE REVIEW

Tongyi Xu et.al studied the two-terminal mass (TTM) based vibration absorber with variable moment of inertia (VMI) for passive vehicle suspension is proposed. The VMI of the system is achieved by the motion of sliders embedded in a hydraulic driven flywheel. The moment of inertia increases in reaction to strong vertical vehicle oscillations and decreases for weak vertical oscillations. The hydraulic mechanism of the system converts the relative linear motion between the two terminals of the suspension into rotating motion of the flywheel. In the case of stronger vehicle vertical oscillation, the sliders inside the flywheel move away from the center of the flywheel because of the centrifugal force, hence yielding higher moment of inertia. The opposite is true in the case of weaker vehicle oscillation. As such, the moment of inertia adjusts itself adaptively in response to the road conditions. The performance of the proposed TTM-VMI absorber has been analyzed via dynamics modeling and simulation and further examined by experiments. In comparison to its counterpart with constant moment of inertia, the proposed VMI system offers faster response, better road handling and safety, improved ride comfort, and reduced suspension deflection except in the case of sinusoidal excitations.

Ryabov et. al presents the analytical proof of the presence of two inefficient areas in vehicle suspension oscillation cycle in linear shock absorber work. It derived on the basis of analysis of the dynamics equations for the linear single-support single-mass vibrating system with fixed elastic and damping characteristics at harmonic kinematic disturbance. Expressions of the full, efficient and inefficient work of the linear damper in one oscillation cycle are derived. There under the equations for calculation of the effective shock absorber work ratio for various types of damping characteristics are determined. The graphs of the effective shock absorber work ratio on the relative frequency of

the disturbance and the relative damping factor are implemented. The evaluation of vehicle suspension efficiency based on the values of inefficient force pulse ratio for known efficient control algorithms of elastic-damping characteristic of pneumatic shock absorber.

Mr. Sudarshan Martande et.al Shock absorbers are a critical part of a suspension system, connecting the vehicle to its wheels. The need for dampers arises because of the roll and pitches associated with vehicle maneuvering, and from the roughness of roads. In the mid nineteenth century, road quality was generally very poor. The rapidly increasing power available from the internal combustion engine made higher speeds routine; this, plus the technical aptitude of the vehicle and component designers, coupled with a general commercial mood favoring development and change, provided an environment that led to invention and innovation of shock absorbers. Shock absorbers are devices that smooth out an impulse experienced by a vehicle, and appropriately dissipate or absorb the kinetic energy. shock absorbers have become such an essential component of an automobile even then there has been no particular method to test it using Finite Element Analysis technique and most of the testing is done using the physical tests. Thus this paper focuses on to develop new correlated methodologies that will allow engineers to design components of Shock Absorbers by using FEM based tools.

Pinjarla.Poornamohan et.al 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 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 3D 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 3D 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.

Prince Jerome Christopher J. et. al In vehicles problem happens while driving on bumping road condition. The objective of this project is to design and analyze the performance of Shock absorber by varying the wire diameter of the coil spring. The Shock absorber which is one of the Suspension systems is designed mechanically to handle shock impulse and dissipate kinetic energy. It reduces the amplitude of disturbances leading to increase in comfort and improved ride quality. The spring is compressed quickly when the wheel strikes the bump. The compressed spring rebound to its normal dimension or normal loaded length which causes the body to be lifted. The spring goes down below its normal height when the weight of the vehicle pushes the spring down. This, in turn, causes the spring to rebound again. The spring bouncing process occurs over and over every less each time, until the up-and-down movement finally stops. The vehicle handling becomes very difficult and leads to uncomfortable ride when bouncing is allowed uncontrolled. Hence, the designing of spring in a suspension system is very crucial. The analysis is done by considering bike mass, loads, and no of persons seated on bike. Comparison is done by

varying the wire diameter of the coil spring to verify the best dimension for the spring in shock absorber. Modeling and Analysis is done using Pro/ENGINEER and ANSYS respectively.

A.K. Samantaray Preloaded liquid spring/damper based shock isolation systems are suitable for heavy load military applications. In this paper, mathematical models are developed for passive liquid spring shock absorbers. The preloading is achieved by mounting the load between two liquid spring/dampers. Dynamics of such shock absorbers involve coupled hydrodynamic and thermodynamic phenomena. The energy dissipated through orifice due to hydrodynamic losses heats up the working fluid and consequently the heat is dissipated to environment. Such multienergy domain interaction is well represented in this paper by using bond graph models. Moreover, the developed model accounts for the strain-rate dependent damping offered by the compressible working fluid in the liquid spring. The results show that proper choice of preloading and geometric parameters (spring dimensions and orifice sizes) can, respectively, reduce the thermodynamic and strain-rat e dependent damping phenomena.

3. DESIGN AND MODELLING PSD SHOCK ABSORBER USING SOLIDWORKS DESIGN TOOL

To simulate and designing the PSD shock absorber with available hero Honda bike data and also it consists of top rod with stainless steel, piston rod with forged steel, spring with carbon steel and screw with stainless steel materials. For designing and modeling of PSD shock absorber using solidworks design tool and the designed PSD shock absorber is exported to IGES or .STEP file to analyze the performance of PSD shock absorber at various loading conditions. For evaluating the performance of PSD shock absorber using ANSYS workbench tool, by using this tool modal and static structural analysis are performing later stage.

3.1 PSD shock absorber parts design data

For designing and modeling of PSD shock absorber using solidsworks tool required design data which are represented in line diagrams. PSD shock absorber contains four parts those are

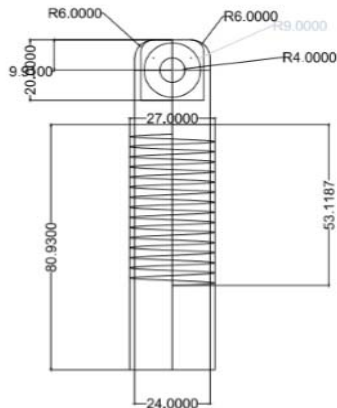i.   Top rod,   ii. Piston rod,   iii. Spring,
       iv.Screw

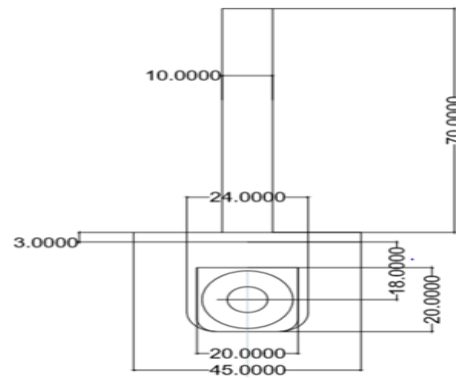Figure 3.1 line diagram of top rod with design data in mm
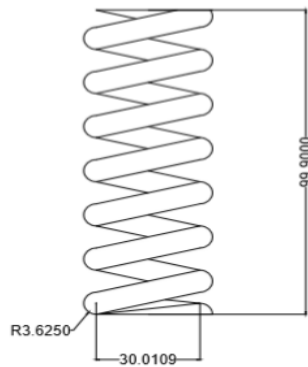
Figure 3.2: piston rod with design data in mm

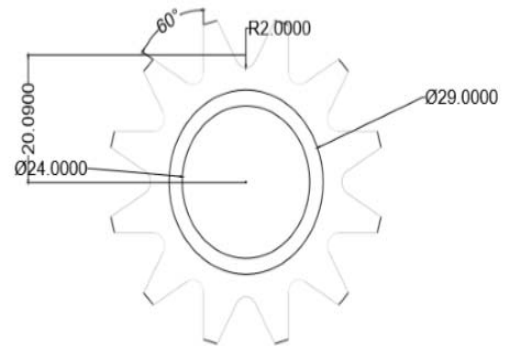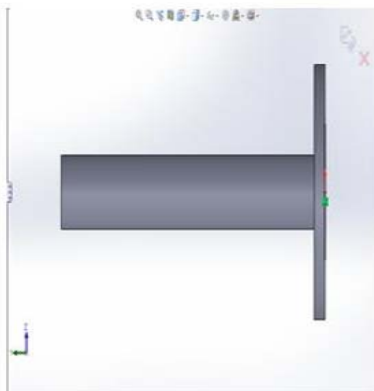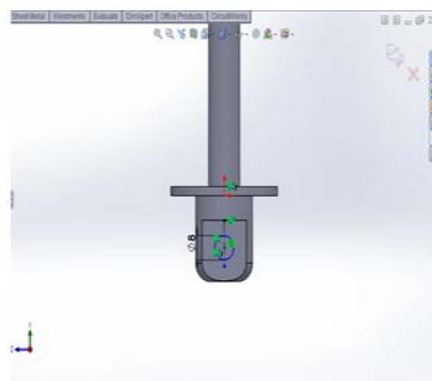Figure 3.3: line diagram of spring with design data in mm

Figure 3.4: line diagram of screw with design data in mm

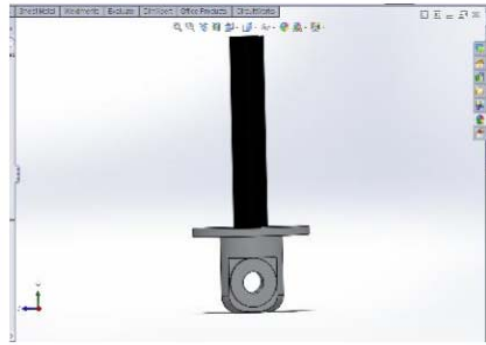## 3.2 Design and Modeling of PSD Shock Absorber Parts in Solids Works
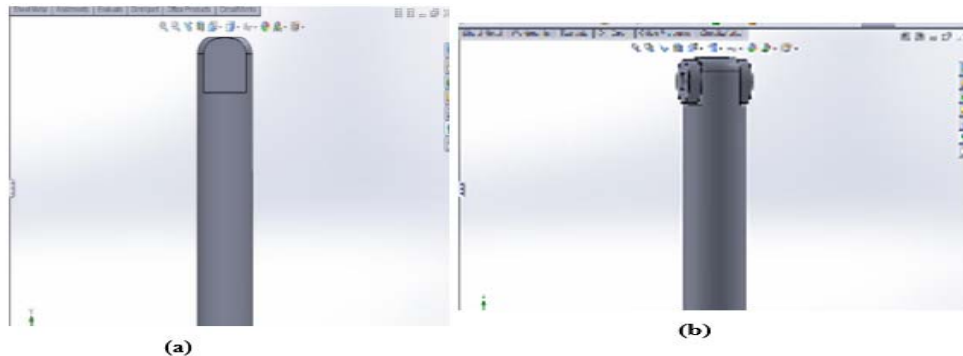### 3.2.1 Designing of Top Rod

(a)

(b)

(c)

Figure 3.5 (a–c): Designed Top rod

The above diagram represents the designing procedure of top rod using solidworks design tool. Making the first part of the design lets take top plane and draw the circle with required dimension then exit from the sketch and extrude it. Again select the top plane then draw the circle with 10mm diameter and then extrude it up to 70 mm. Now select the back face and draw a circle with diameter 24mm and extrude it 28mm.select the edge and apply fillet with 6mm radius. Cutting the sections by leaving the 15 mm gap. Take the cutting surface and draw circles with 8 and 18mm diameter and extrude by applying convert entities. The part is completed.

3.2.2 Designing of Piston Rod

(a)

(b)
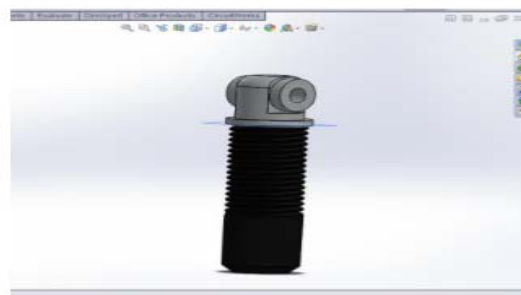
(c)

Figure 3.6 (a–c): Designed Piston rod

The above diagram represents the designing procedure of piston rod using solidworks design tool. Select a top plane, draw a circle with 24mm diameter and extrude it 108.93mm. Select a edge and fillet it to 3mm.Again cut the section as like in the first part. Take the another edge and draw a circle with 27mm diameter and extrude it up to 80.93mm.Again select the down surface and draw a circle then do a extruded cut up to 70mm length. Do the threading up to 50mm using helix command

.
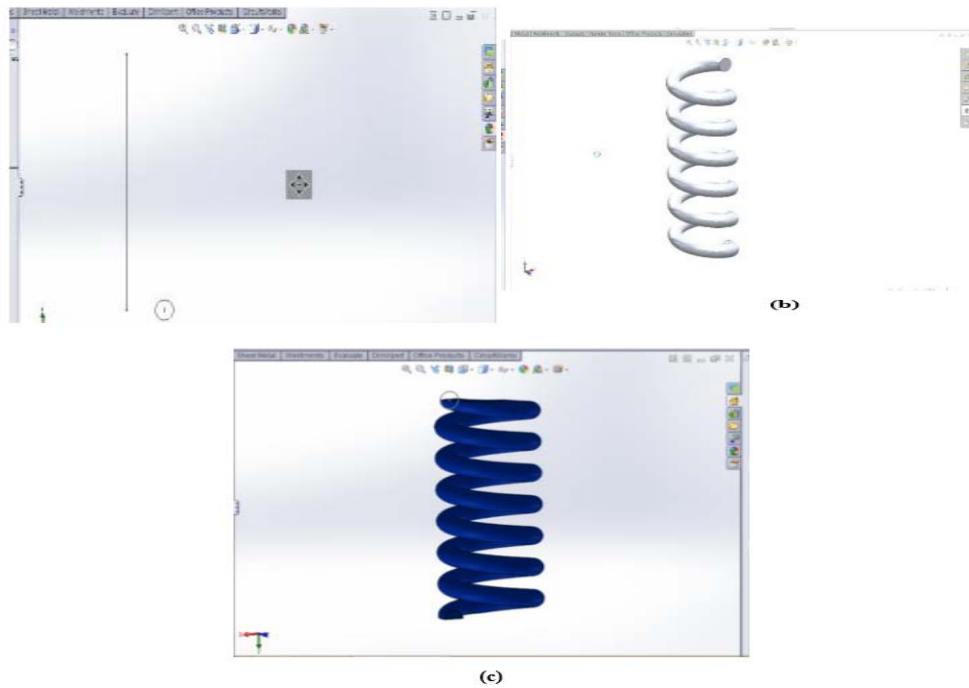### 2.2.3 Designing of spring

Figure Figure 3.7 (a–c): Designed Piston rod

The above diagram represents the designing procedure of spring using solidworks design tool. Select a front plane and draw a line in downward direction and then give dimension. Again select a front plane draw a circle with diameter 7.25mm and put 15mm distance from the line. Exit from the sketch go to feature and select swept boss. Then the required spring will be obtained.
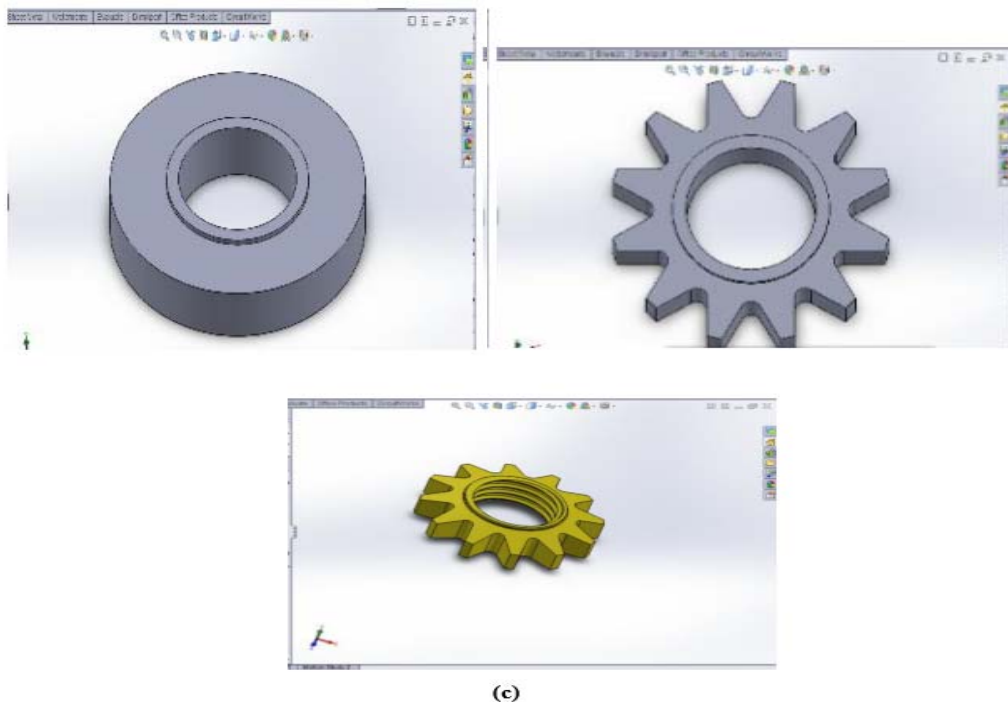
2.2.4 Designing of screw

Figure 3.8(a–c): Designed screw

The above diagram represents the designing procedure of screw using solidworks design tool. Select top plane sketch a circles with 52mm outer diameter and 24mm inner diameter. Extrude it with9mm.Draw a circle with 29mm diameter and again extrude it with 1mm.Select top face ,draw center lines and draw a circle with 2 mm radius. Draw the lines from circle to outer circle the angle between the lines is 60 degrees and then trim the circle. Now apply the polar array then apply extrude cut. Then the required screw is obtained.

2.2.5 Assembling of PSD shock absorber using solid works
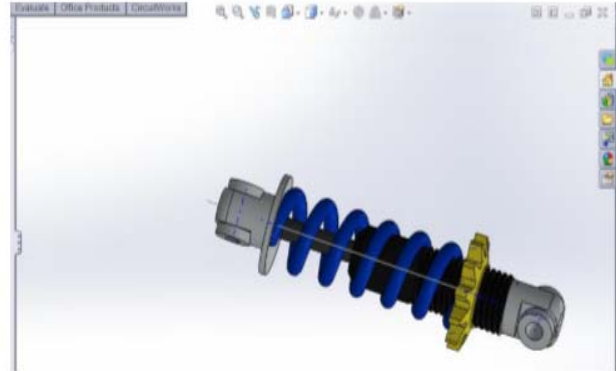

Figure 3.9 : assembled PSD shock absorber

The above diagram represents the designing procedure of assempbled PSD shock absorber using solidworks design tool. Select top plane sketch a circles with 52mm outer diameter and 24mm inner diameter. Extrude it with9mm.Draw a circle with 29mm diameter and again extrude it with 1mm.Select top face ,draw center lines and draw a circle with 2 mm radius. Draw the lines from circle to outer circle the angle between the lines is 60 degrees and then trim the circle. Now apply the polar array then apply extrude cut. Then the required screw is obtained.

4. PERFORMANCE ANALYSIS OF PSD SHOCK ABSOBER USING ANSYS

Once the modeling and assembly of PSD shock absorber completed using solidworks, the FEM analysis has been performed in workbench to identify the load carrying capacity of the PSD shock absorber at various loading conditions. The steps followed to perform analysis are listed below. Material dataof gear is tabulated in ta ble 4.1

Table 4.1 Mechanical properties of PSD shock absorber parts

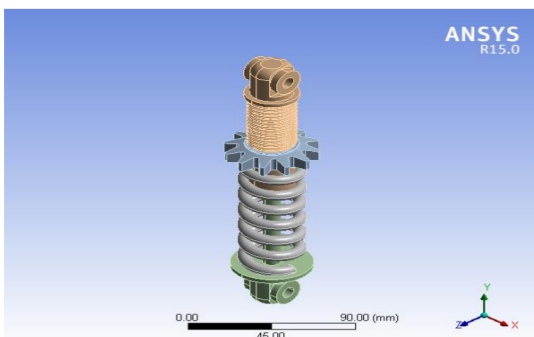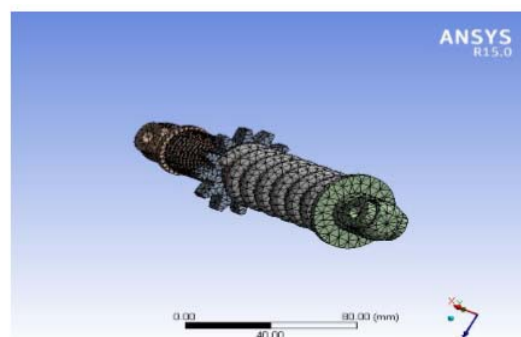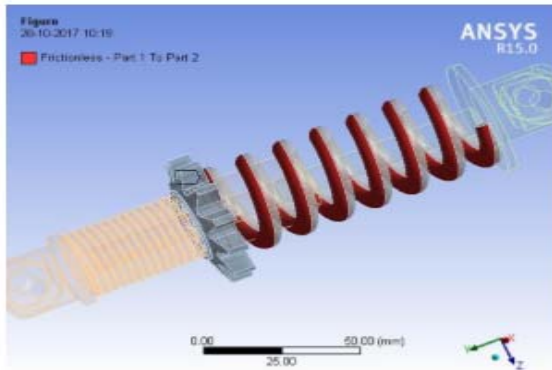| Material Property	Stainless steel	Forged steel	Carbon steel
Young's Modulus (MPa)	203	210	200
Poisson's ratio	0.3	0.33	0.28
Density (Kg/m^3)	7700	8,050	7850

Figure 4.1 Imported PSD shock absorber geometry
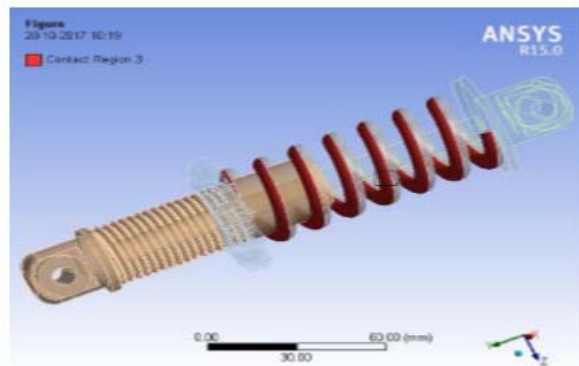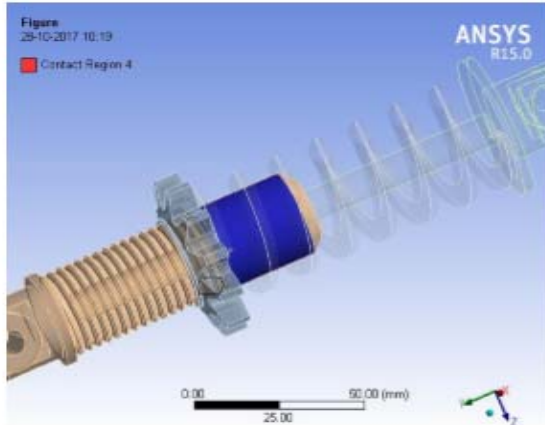

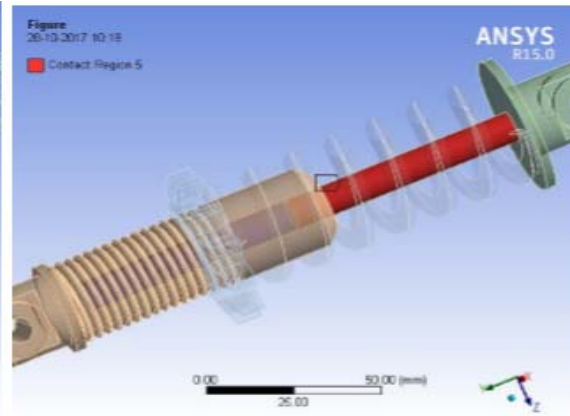**Fig 4.2 Meshed model of PSD shock absorber**

(a) Contact between top rod and piston rod

(b) Contact between piston rod, spring and screw

(c) Contact between top rod and screw

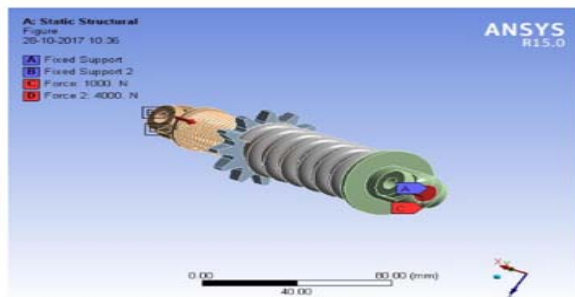(d) Contact between screw and spring

Fig 4.3 Support and forces

Creating contacts After the succsive completion of above step applying the contact reagions for PSD shock absorber. In this PSD shock absorber obtained a 5 contact. The acquired contact portions are shown in figure 4.3, and the no separation contact with automatic contact tool has been used to create contact surfaces.

Applying boundary conditions and loads Since the generated PSD shock absorber in contact and suspension nature, then force is applied to the both sides including one side passengers load and other side sudden damping load, And support were applied to both sides. Constrains are given according to FEA. Later a load of 1000 N to 2000N has been taken as a passengers load and 1000N to 20000N damping load to PSD shock absorber as boundary conditions. Conditions of loads are shown in figure 4.4.

5. RESULTS AND DISCUSSIONS
5.1 FEM analysis of Von- Mises strains for PSD shock absorbers

PSD shock absorber analyzed under the above conditions for the generation of von-Mises strains, total deformation and stress intensity at critical locations. The linear static finite element analysis was performed using FEM. The equivalent von Mises strains maximum occurred and thatload considered as critical load for PSD shock absorber performance with passenger load 1000 N and the critical load is 12000 N. The equivalent von Mises strains maximum occurred and that load considered as critical load for PSD shock absorber performance with passenger load

1000 N and the critical load is 11000 N critical locations for PSD shock absorber in below

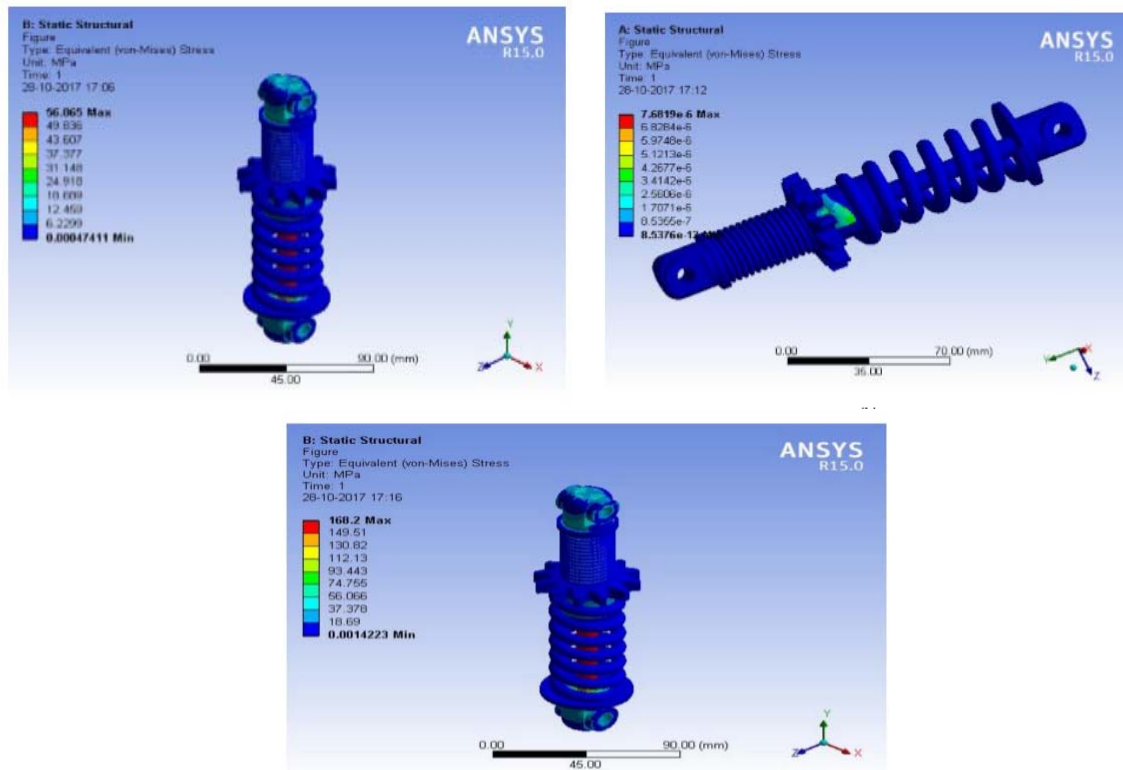figure from 5.2.The von mass stress at different load shown in tables 5.3-4.

Figure 5.1(a-c) von- mises stresses of PSD shock absorber at different passenger and damping load

Table 5.1 von- mises stresses (MPa) PSD shock absorber (MPa) PSD shock absorber at at passenger load 1000N

Passenger Load (N)	Damping load N	von- mises stresses (MPa)
1000	1000	40.25
	5000	69.2
	10000	72.8
	11000	81.8
	12000	Total failure

Table 5.2 von- mises stresses passenger load 2000N

Passenger Load (N)	Damping load N	von- mises stresses (MPa)
2000	1000	30.25
	5000	49.2
	10000	52.8
	11000	61.8
	12000	75.25
	13000	Total failure

5.2 FEM analysis of Von- Mises strains for PSD shock absorbers

PSD shock absorber analyzed under the above conditions for the generation of von-Mises strains, total deformation and stress intensity at critical locations. The linear static finite element analysis was performed using FEM. The equivalent von Mises strains maximum occurred and thatload considered as critical load for PSD shock absorber performance with passenger load 1000 N and the critical load is 12000 N. The equivalent von Mises strains maximum occurred and that load considered as critical load for PSD shock absorber performance with passenger load 1000 N and the critical load is 11000 N critical locations for PSD shock absorber in below figure from 5.2.The von mass stress at different load shown in tables 5.3-4.
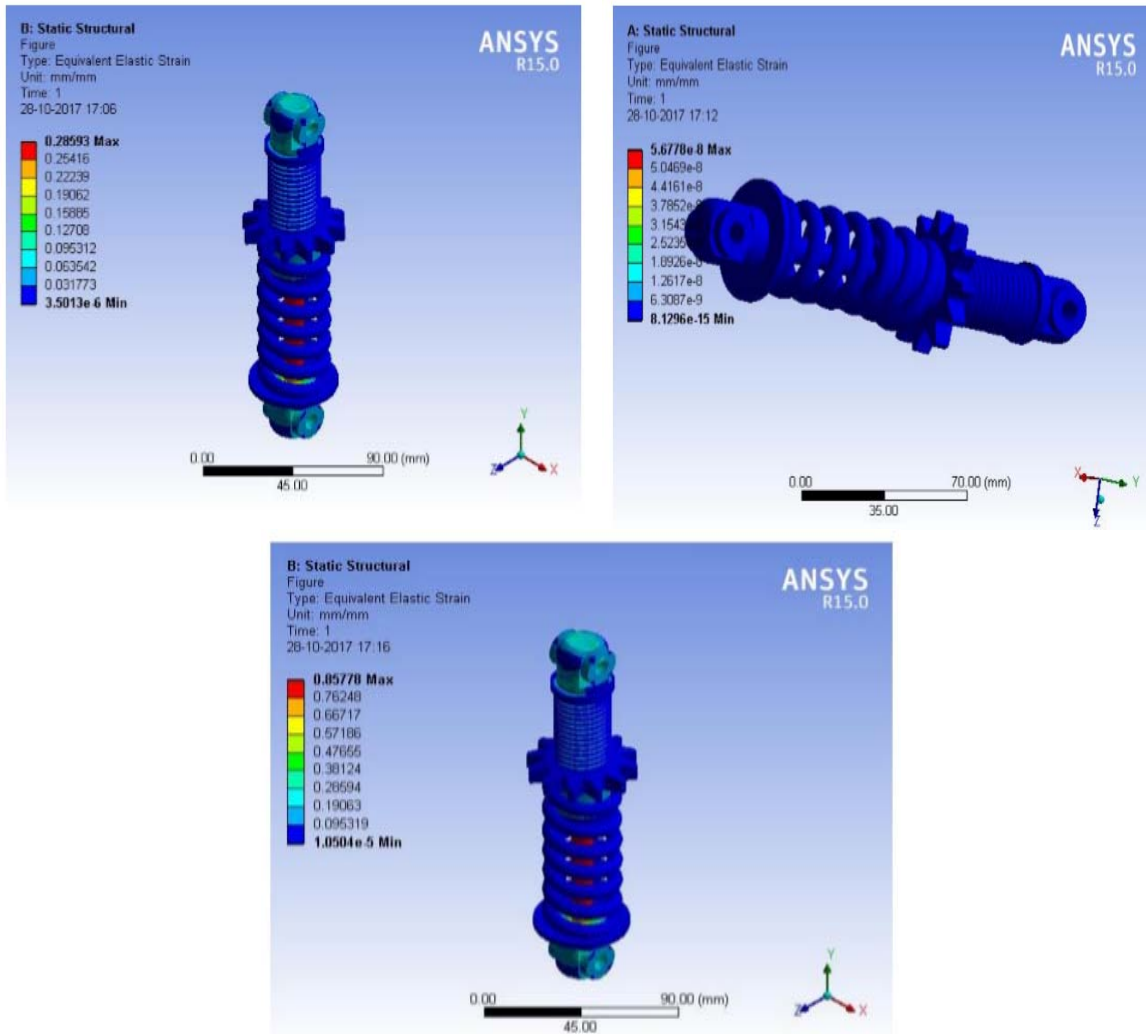
Figure 5.2(a-c) von- mises strains of PSD shock absorber at different passenger and damping load

Table 5.3 von- mises strains (MPa) PSD shock absorber shock absorber at passenger load 1000N Table

5.4 von- mises strains (MPa) PSD passenger at load 2000N

Passenger Load (N)	Damping load N	von- mises strain (MPa)
1000	1000	20.25
	5000	39.2
	10000	42.8
	11000	51.8
	12000	Total failure

Passenger Load (N)	Damping load N	von- mises strain (MPa)
2000	1000	28.25
	5000	39.2
	10000	51.8
	11000	63.8
	12000	Total failure

5.3 FEM analysis of total deformations for PSD shock absorbers

PSD shock absorber analyzed under the above conditions for the generation of von-Mises strains, total deformation and stress intensity at critical locations. The linear static finite element analysis was performed using FEM. The maximum deformation maximum occurred and that load considered as critical load for PSD shock absorber performance with passenger load 1000 N and the critical load is 12000 N. The equivalent maximum deformation maximum occurred and that load considered as critical load for PSD shock absorber performance with passenger load 1000 N and the critical load is 11000 N critical locations for PSD shock absorber in below figure from 5.3.The von mass stress at different load shown in tables 5.5-6.
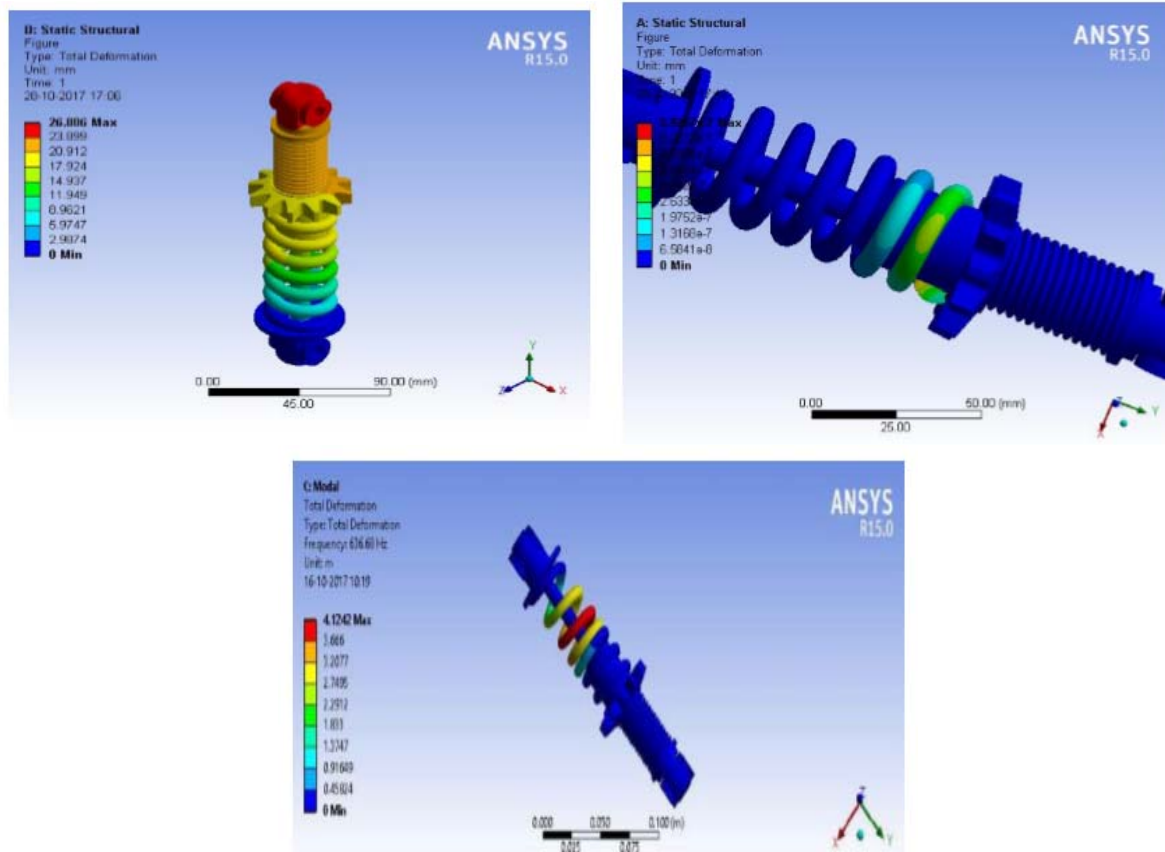
Figure 5.3 (a-c) Total deformations of PSD shock absorber at different Passenger and damping load

6. CONCLUSIONS

Based on the obtained results of fem analysis at different load conditions designed PSD shock absorber is safe at passenger load 1000N and damping load of 12000N. And also designed PSD shock absorber is safe to use up to passenger load 1000N and damping load of 12000N and damping loads.

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