1. Introduction

A suspension system or shock absorber is a mechanical device designed to smooth out or damp shock impulse, and dissipate 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 quality, and increase in comfort due to substantially reduced amplitude of disturbances. When a vehicle is travelling 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 lengthened, 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 Solidworks and analysis ids done using Ansys.

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. 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.

2. Shock absorber

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 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.

2.1 Function of Shock Absorber 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.

2.2 Type of vehicle Shock Absorber

Most vehicular shock absorbers are either twin-tube or mono-tube types with some variations on these themes.

Twin-tube

Basic twin-tube

Also known as a "two-tube" shock absorber, this device consists of two 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 on the inside is a compression valve or base valve. When the piston is forced up or down by bumps in 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 must then be dissipated.

Twin-tube gas charged

Variously known as a "gas cell two-tube" or similarly-named design, this variation represented a significant advancement over the basic twin-tube form. Its overall structure is very similar to the twin-tube, but a low-pressure charge of nitrogen gas is added to the reserve tube. The result of this alteration is a dramatic reduction in "foaming" or "aeration", the undesirable outcome of a twin-tube overheating and failing which presents as foaming hydraulic fluid dripping out of the assembly. Twin-tube gas charged shock absorbers represent the vast majority of original modern vehicle suspensions installations.

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.

Acceleration sensitive damping

The next phase in shock absorber evolution was the development of a shock absorber that could sense and respond to not just situational changes from "bumpy" to "smooth" but to individual bumps in the road in a near instantaneous reaction. This was achieved through a change in the design of the compression valve, and has been termed "acceleration sensitive damping" or "ASD". Not only does this result in a complete disappearance of the "comfort vs. control" tradeoff, it also reduced pitch during vehicle braking and roll during turns. However, ASD shocks are usually only available as aftermarket changes to a vehicle and are only available from a limited number of manufacturers.

Coilover

Coilover shock absorbers are usually a kind of twin-tube gas charged shock absorber inside the helical road spring. They are common on motorcycle and scooter rear suspensions, and widely used on front and rear suspensions in cars.

Mono-tube

The principal design alternative to the twin-tube form has been the mono-tube shock absorber which was considered a revolutionary advancement when it appeared in the 1950s. As its name implies, the mono-tube shock, which is also a gas-pressurized shock and also comes in a coilover format, consists of only one tube, the pressure tube, though it has two pistons. These pistons are called the working piston and the dividing or floating piston, and they move in relative synchrony inside the pressure tube in response to changes in road smoothness. The two pistons also completely separate the shock's fluid and gas components. The mono-tube shock absorber is consistently a much longer overall design than the twin-tubes, making it difficult to mount in passenger cars designed for twin-tube shocks. However, unlike the twin-tubes, the mono-tube shock can be mounted either way— it does not have any directionality. It also does not have a compression valve, whose role has been taken up by the dividing piston, and although it contains nitrogen gas, the gas in a mono-tube shock is under high pressure which can actually help it to support some of the vehicle's weight, something which no other shock absorber is designed to do.

3. <u>Design and Modeling of PSD Shock absorber using Solidworks design tool</u>

To simulate and designing the PSD shock absorber with available hero 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 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

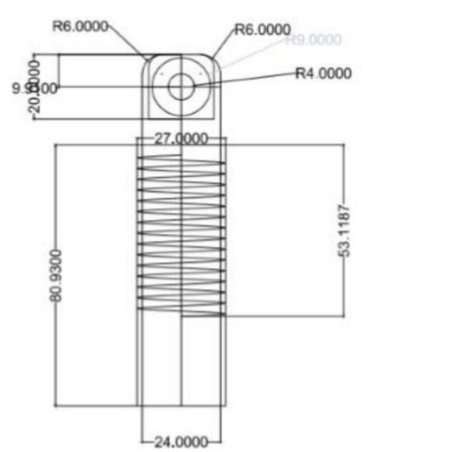


Fig 1: Line diagram of top rod with design data in mm

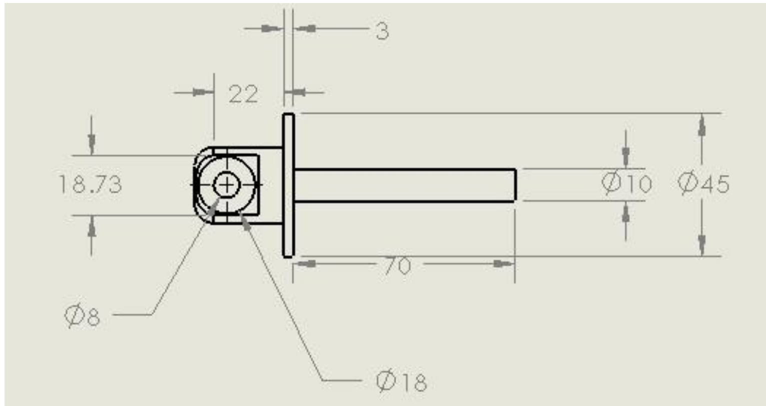


Fig 2: Front view of piston rod with design data in mm

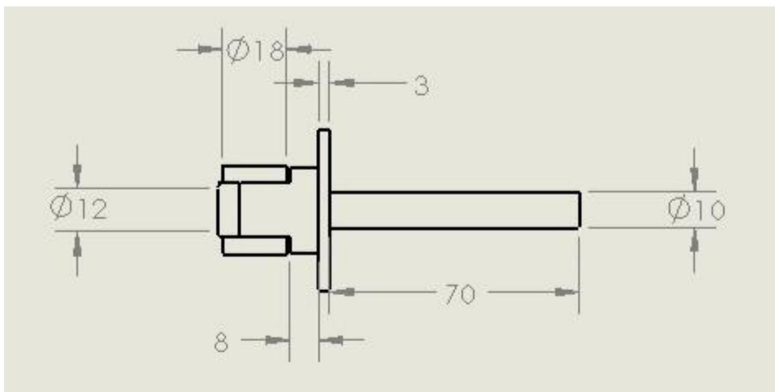


Fig 3: Side view of piston rod with design data in mm

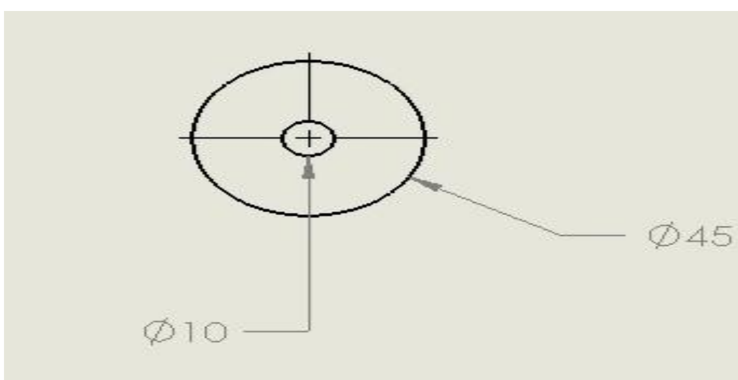


Fig 4: Top view of piston rod with design data in mm

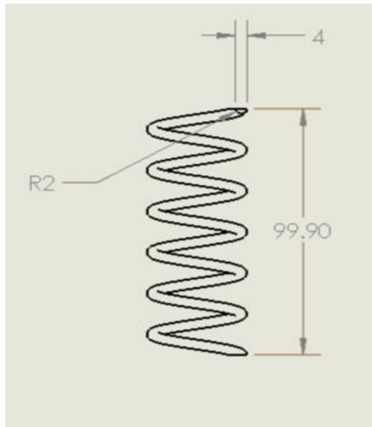


Fig 5: line diagram of spring with design data in mm

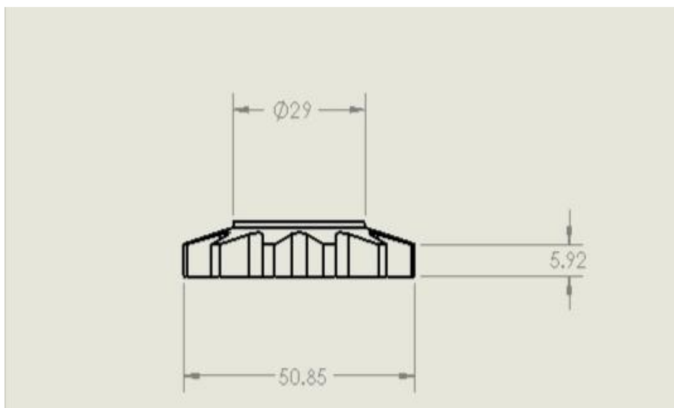


Fig 6: Side view of nut with design data in mm

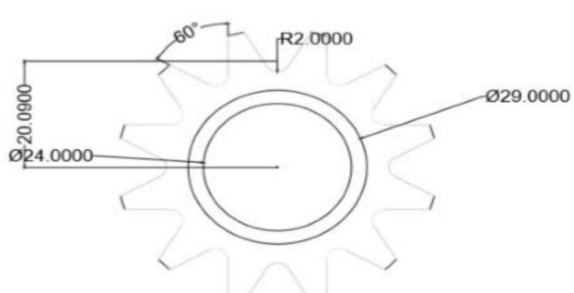
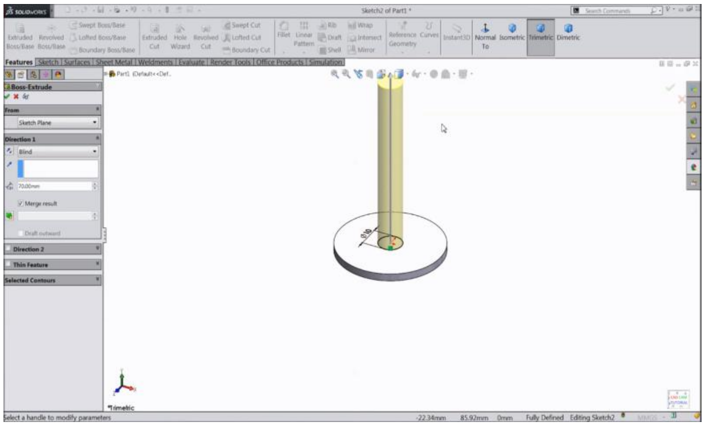


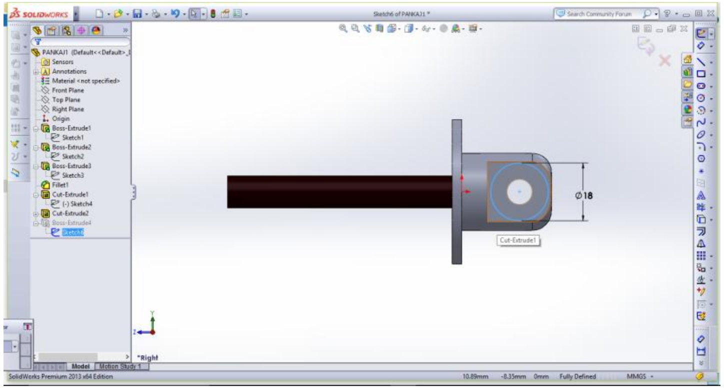
Fig 7: Top view of nut with design data in mm

3.2 Design and Modeling of PSD Shock Absorber Parts in Solidworks

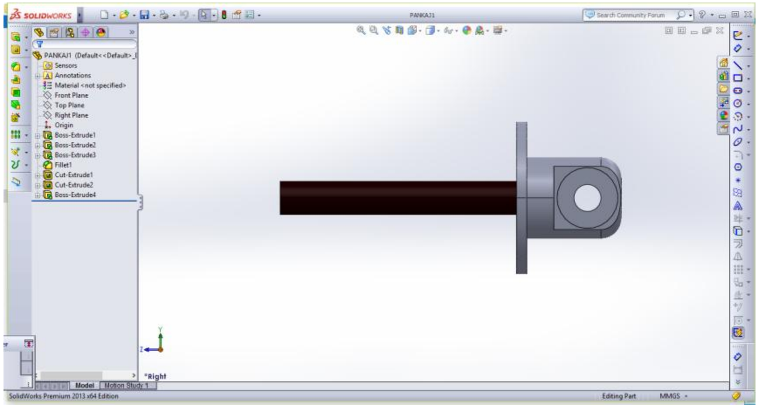
3.2.1 Design of top rod



(a)



(b)

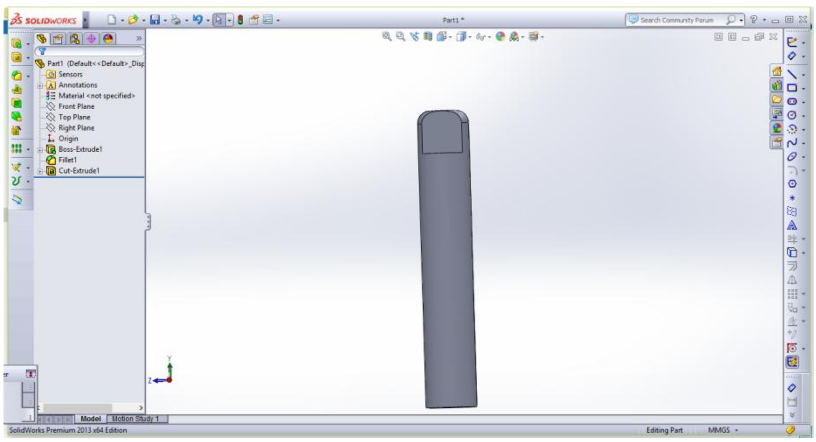


(c)

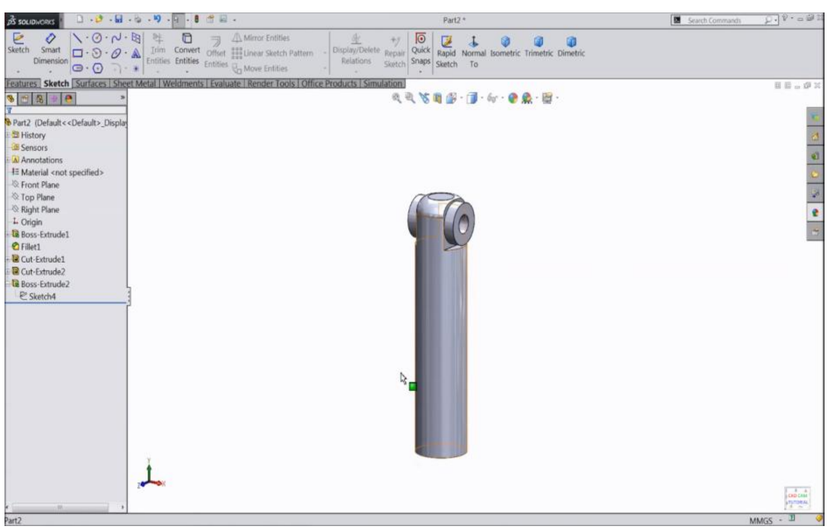
Fig 8:(a-c) Designed top rod

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.

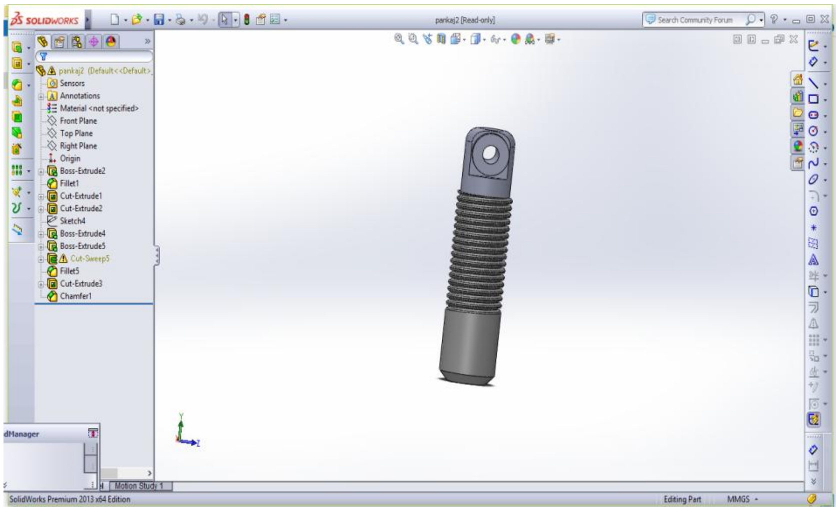
3.2.2 Designing of Piston Rod



(a)



(b)

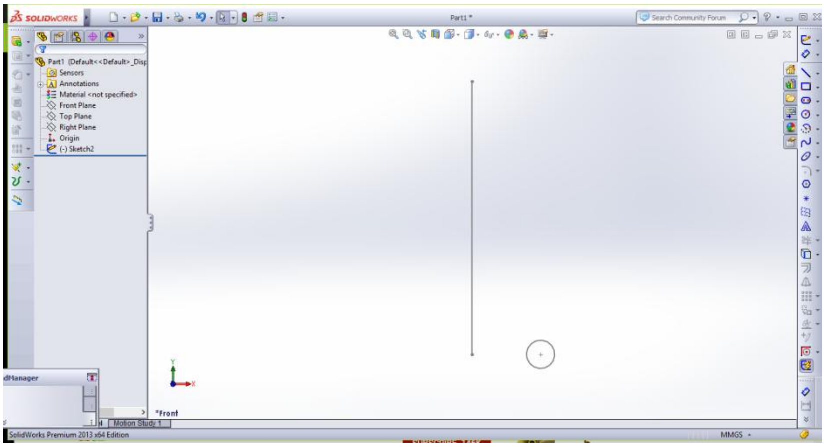


(c)

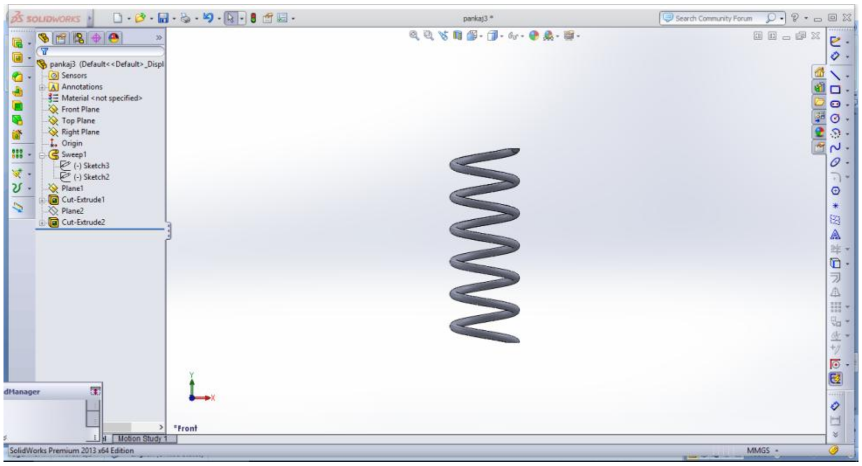
Fig 9: (a-c) Designed piston rod

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.

3.2.3 Designing of spring



(a)

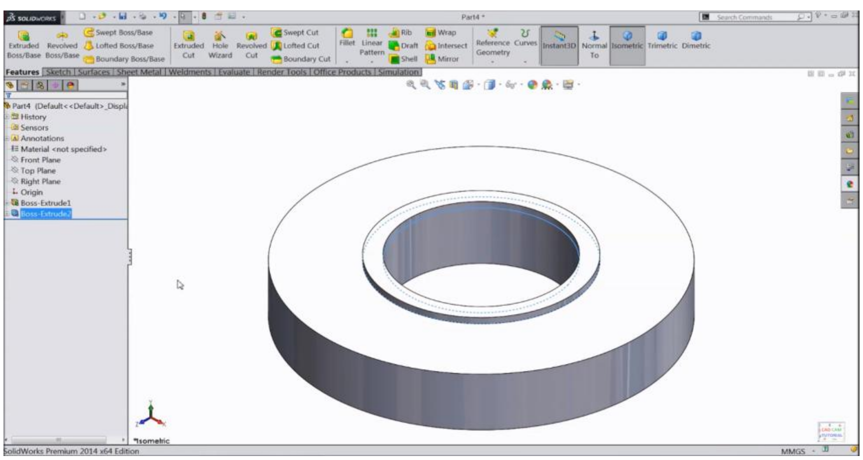


(b)

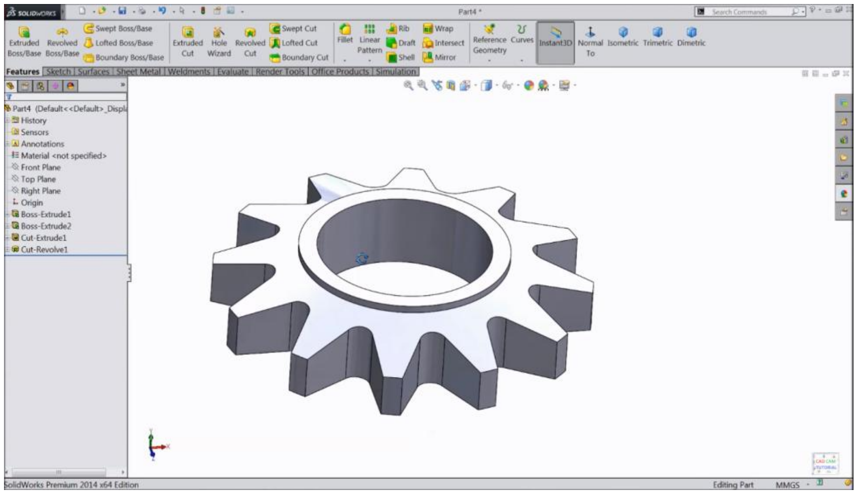
Fig 10: (a-b) Designed spring

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.

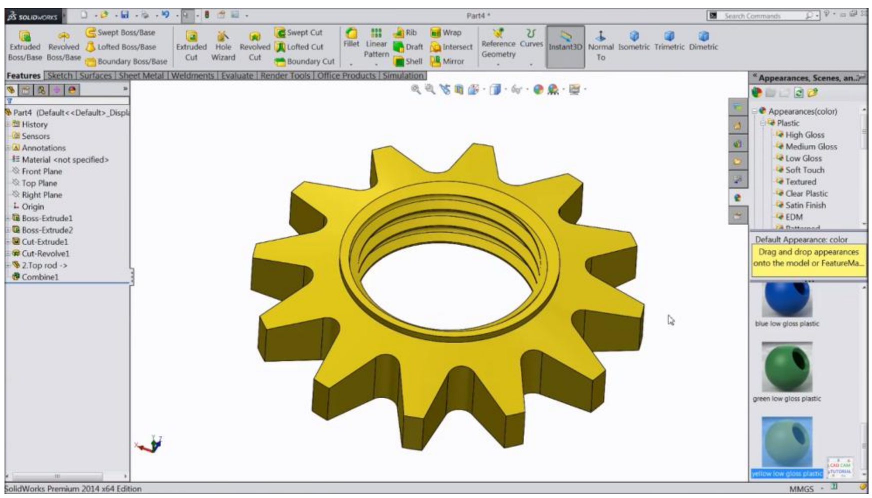
3.2.4 Designing of screw



(a)



(b)



(c)

Fig 11: (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.

3.2.5 Assembling of PSD shock absorber using solidworks

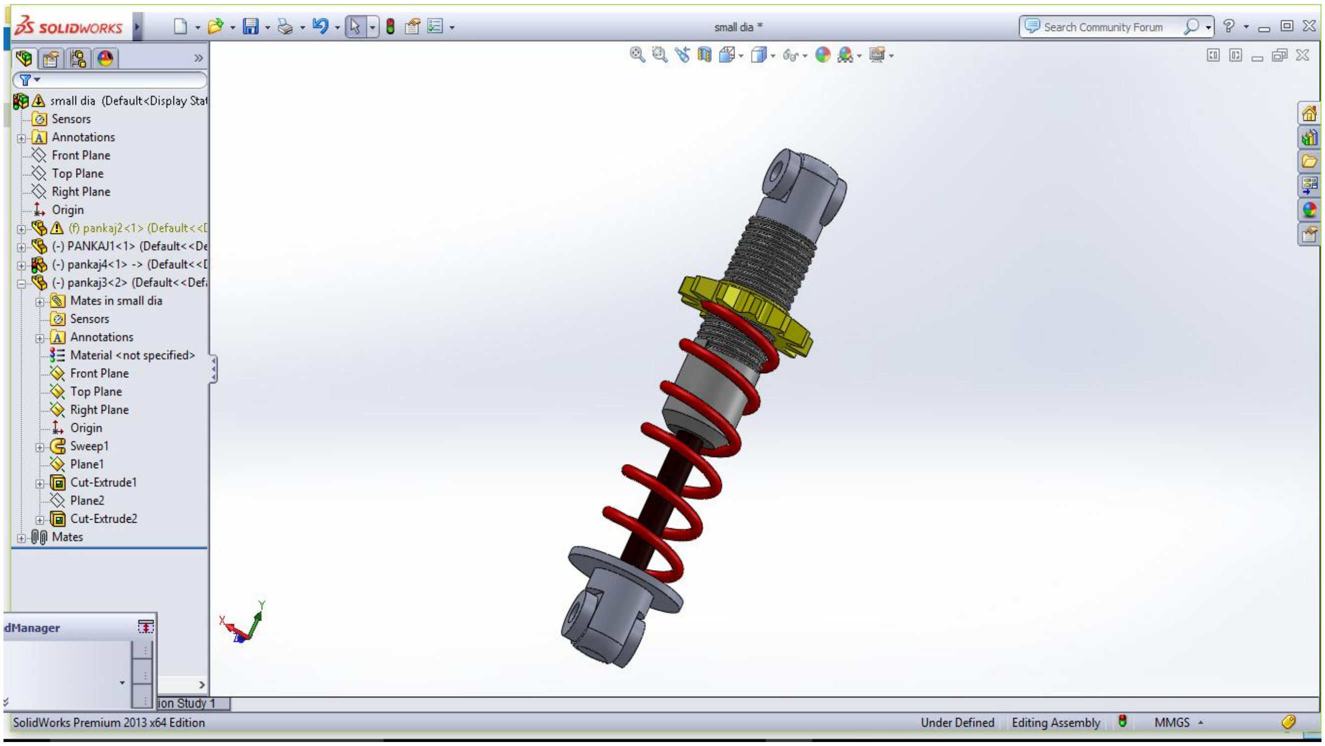


Fig 12: Assembled model of PSD shock absorber

4. Ansys workbench

In this section we are going to analyze the PSD shock absorber. We are going to do static structural on the Ansys workbench. 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.

4.1 Introduction to Ansys

Ansys develops and markets finite element analysis software used to simulate engineering problems. The software creates simulated computer models of structures, electronics, or machine components to simulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

Most Ansys simulations are performed using the Ansys Workbench software, which is one of the company's main products. Typically Ansys users break down larger structures into small components that are each modeled and tested individually. A user may start by defining the dimensions of an object,and then adding weight, pressure, temperature and other physical properties. Finally, the Ansys software simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic efficiency and other effects over time.

Ansys also develops software for data management and backup, academic research and teaching.Ansys software is sold on an annual subscription basis.

4.2 Static Structural Analysis

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. A static structural load can be performed using the ANSYS. The types of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)

In the static structural analysis first the model is imported or we can directly draw our model on the Ansys workbench . but here there is a problem in making of model using Ansys because it is best for the analysis purpose so we directly import our model which we make in solidworks. Solidworks is best suitable for making the 3-D model. Solidworks is mainly used for making three dimensional models in easiest way.

5. <u>Performance analysis of PSD shock absorber using Ansys</u>

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.

Step 1: at first we will open Ansys workbench. After opening we will directly go to the static structural analysis. There is another method of opening static structural analysis for this we directly drag the static structural analysis tab on the workbench.

Step 2: The second step is the naming of our project. This helps in finding our project easily when we want to work on our project.

Step 3: It include import of the designed model (designed in solidworks) and after import model must be edited to apply various load conditions.

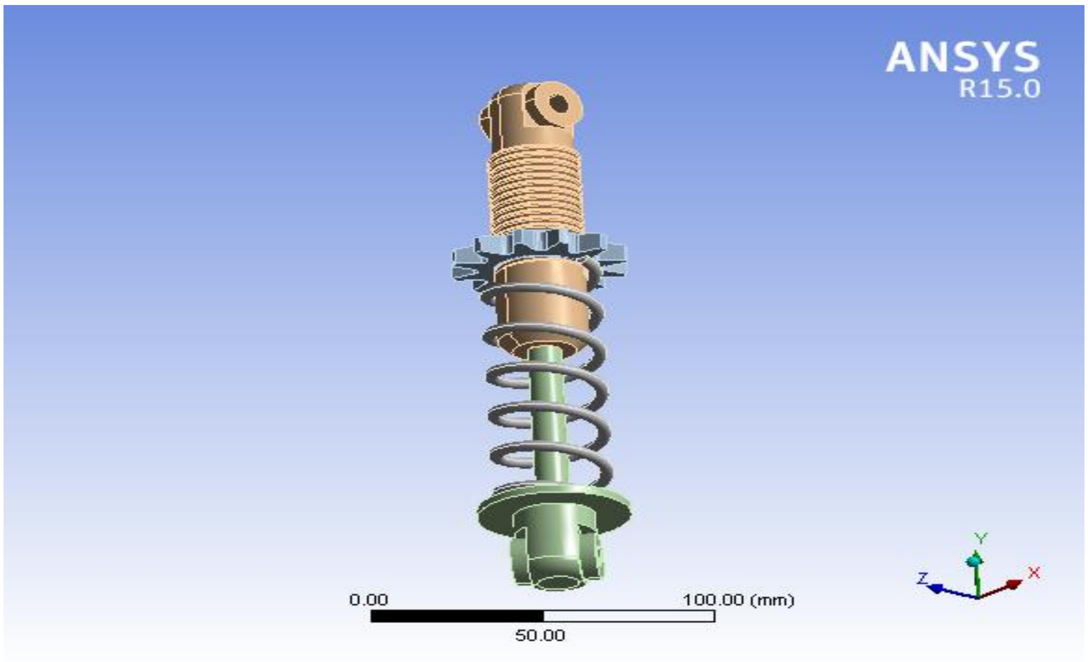


Fig 13: Imported model in Ansys workbench

5.1 Meshing of Model

Meshing is defined as the process of dividing the whole component into a number of elements so that whenever the load is applied on the component it distributes the load uniformly called as meshing.

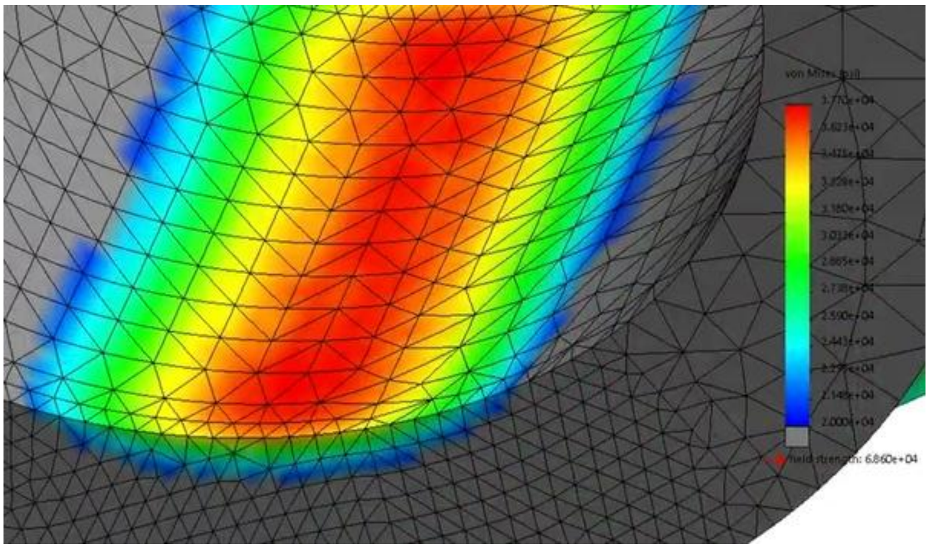


Fig 14: showing meshed component

A component is analyzed in two ways. One is with Meshing and the other is without meshing.

- **With Meshing:** If the load is applied on the structure or a body and the body is considered to have meshed, then the load is distributed uniformly on the entire structure.
- After Meshing, the entire structure is divided into a number of elements and each element having its own stiffness while loading.
- Adding all those elements stiffnesses, you can get the Global Stiffness Matrix with which you can calculate the stress developed in the structure, etc.
- If the Vonmises stress is less than the yield stress of the material, then the product analyzed is safe, else it is of failure type.
- **Without Meshing:** If you are applying the load on the body which does not mesh, then the load distribution is not uniform and you may get the irregular or faulty results.

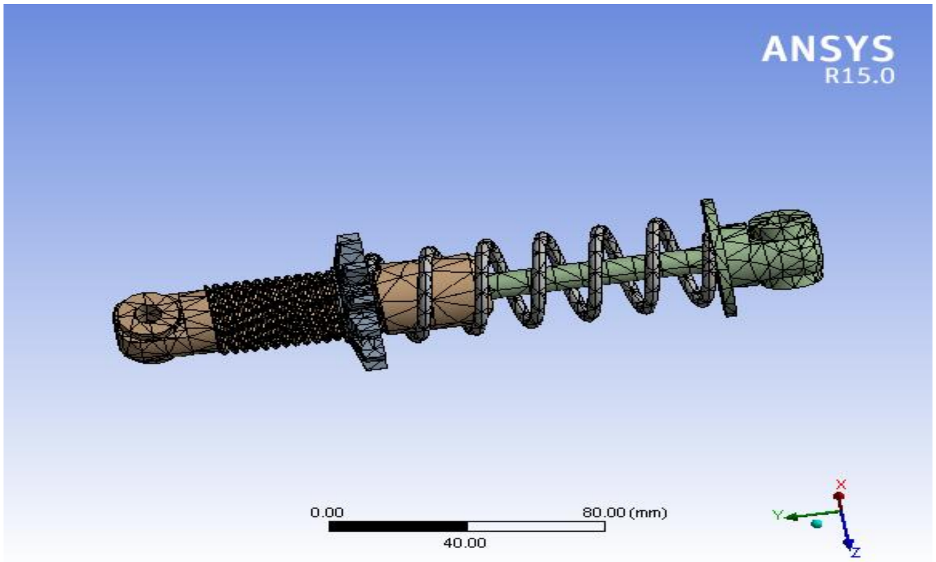


Fig 15: Meshed model of PSD Shock absorber

5.2 Creating contacts

The **Contact Tool** allows you to examine contact conditions on an assembly both before loading, and as part of the final solution to verify the transfer of loads (forces and moments) across the various contact regions. After the successive completion of above step applying the contact regions for PSD shock absorber. In this PSD shock absorber obtained a 5 contact. There are different colors which have different meaning in contact region

- Red: "The contact status is open but the type of contact is meant to be closed. This applies to bonded and no separation contact types."

  Workbench has detected an open contact Status condition, which is invalid based on the definitions of Bonded and No Separation contact types. It is very likely that the model will not be held together as expected. The geometry of the contact may be too far apart for the closed condition to be satisfied. Review of the Contact Region definition is strongly recommended.

- Yellow: "The contact status is open. This may be acceptable."

Workbench has detected an open contact Status condition on a nonlinear contact type, Frictionless, Rough, or Frictional, which is probably acceptable under certain conditions as stated in their descriptions.

- Orange: "The contact status is closed but has a large amount of gap or penetration. Check penetration and gap compared to pinball and depth."
- Gray: "Contact is inactive. This can occur for MPC and Normal Lagrange formulations. It can also occur for auto asymmetric behavior."

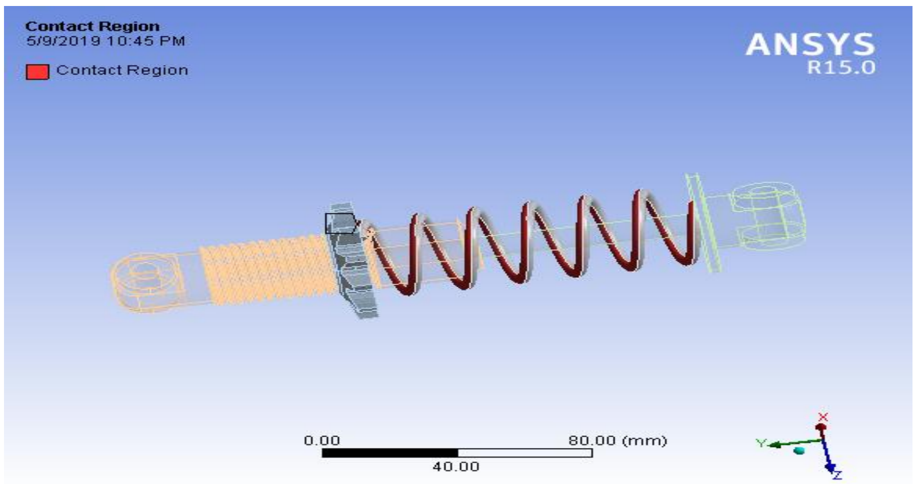


Fig 16: Contact between spring and screw

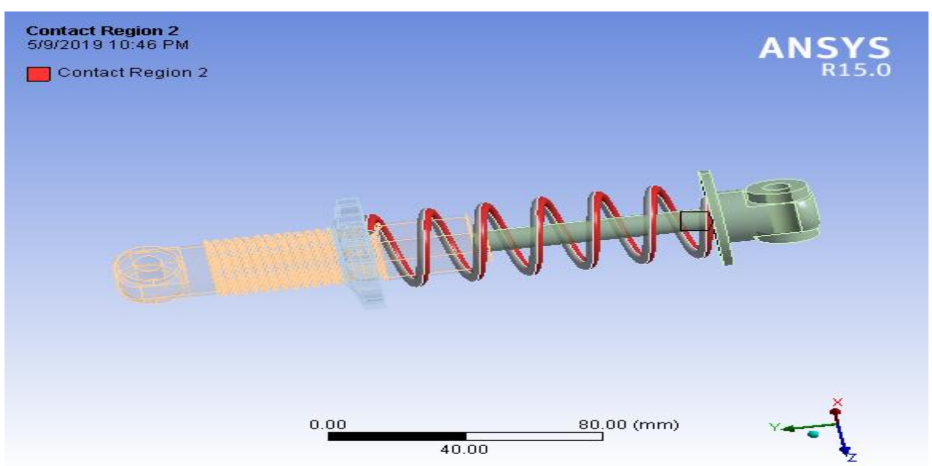


Fig 17: contact between spring and top rod

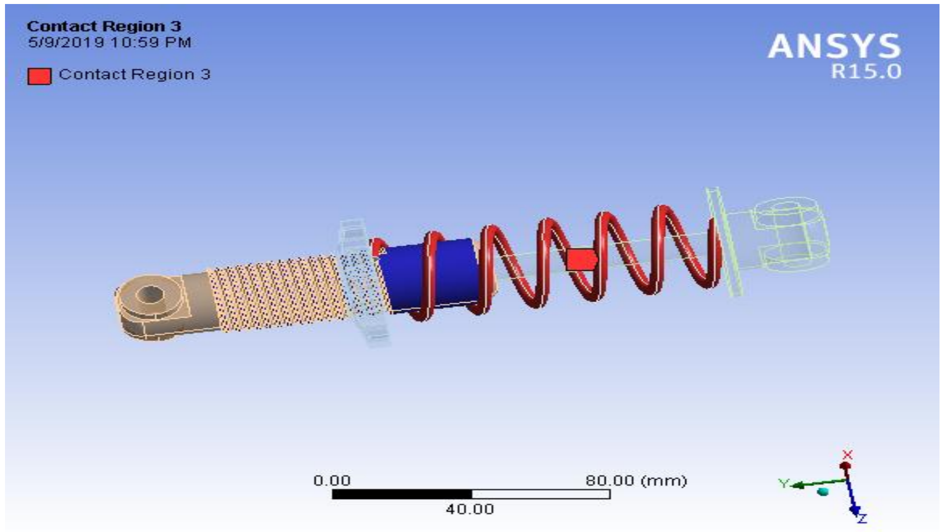


Fig 18: Contact between piston rod and spring

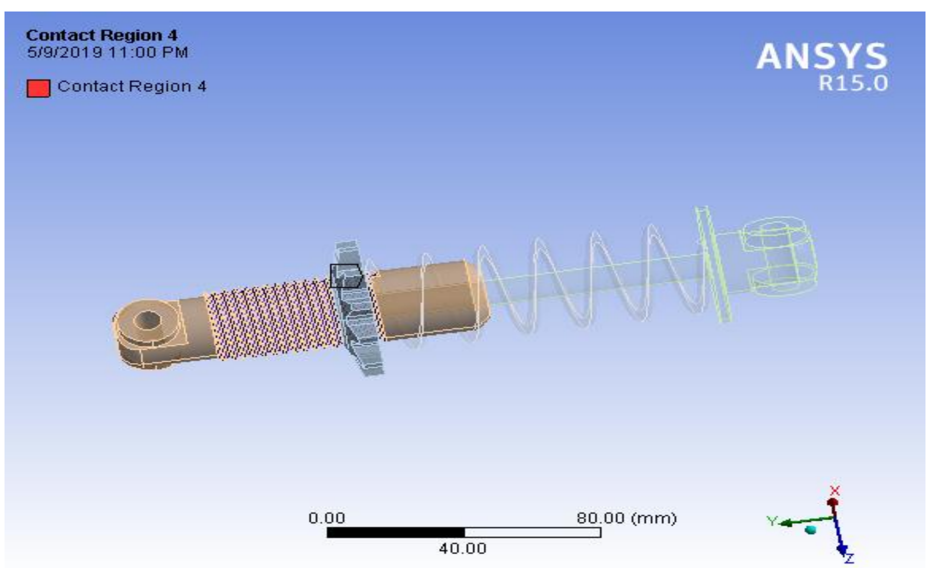


Fig 19: Contact between piston rod and screw

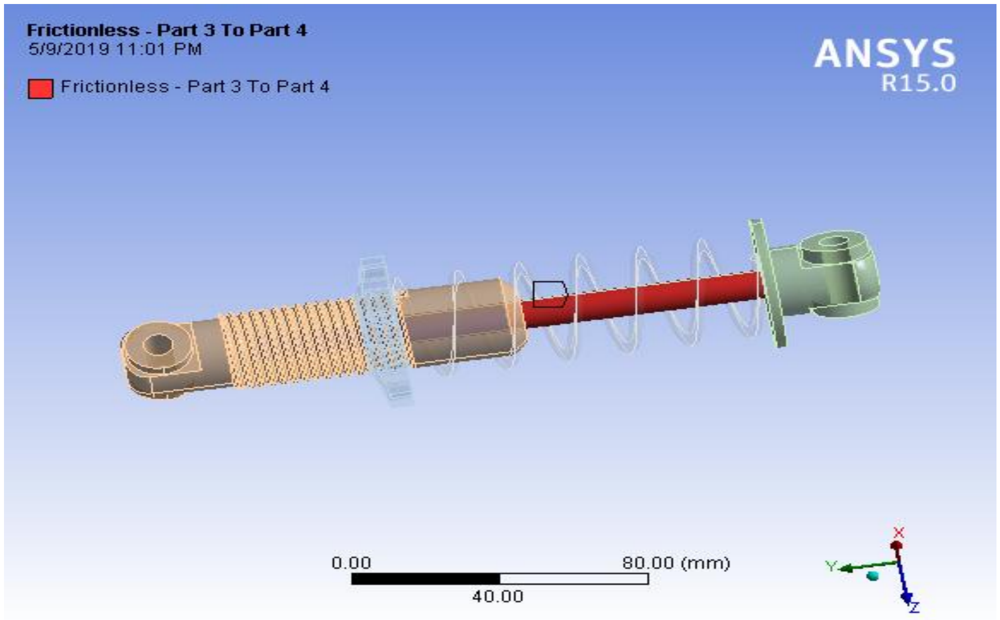


Fig 20: frictionless contact between piston rod and top rod

6. Results and Discussion

6.1 FEM analysis of Von- Mises stress for PSD shock absorbers

In this section we are going to discuss what the stress value is when we apply load of 1000N, 1500N, 2000N on the shock absorber using different material of spring. The spring materials that we are going to use are:

(i) Spring steel

(ii) Phosphor bronze

(iii) Carbon fiber

Material properties	Spring Steel	Phosphor Bronze	Carbon fibre
Young's modulus(MPa)	190000	110000	70000
Poisson's ratio	.29	.341	.1
Density (Kg/m^3)	7800	8800	1600

Table 1: Properties of material used in spring

- **Analysis using 1000N force on the shock absorber**

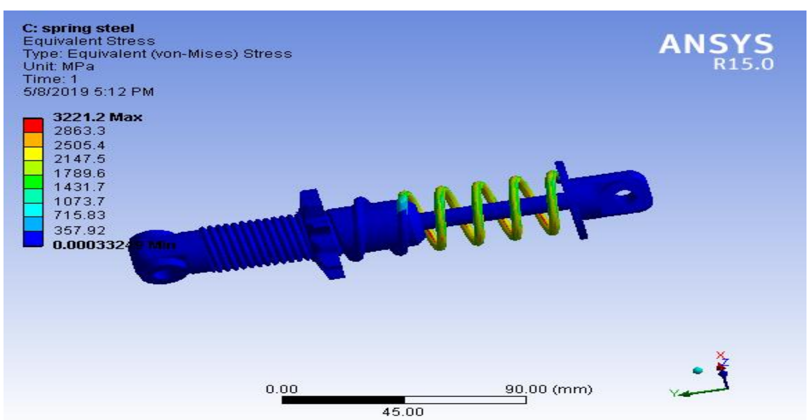


Fig 21: Spring Steel as a spring material(Von-Mises Stress)

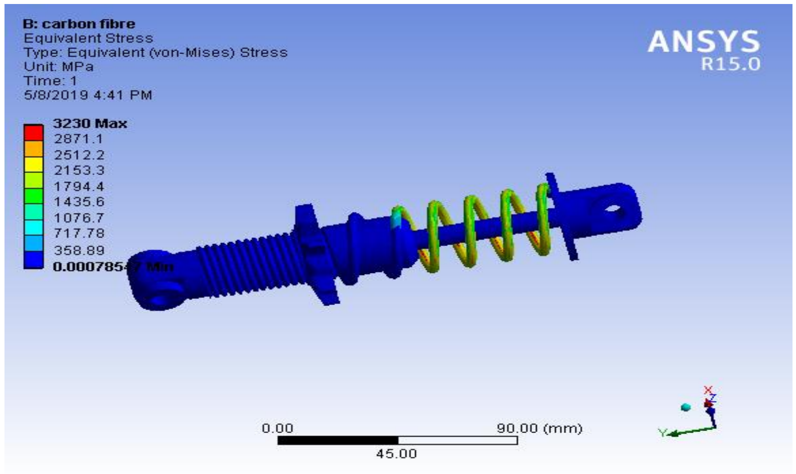


Fig 22: Carbon fiber as a spring material (Von-Mises Stress)

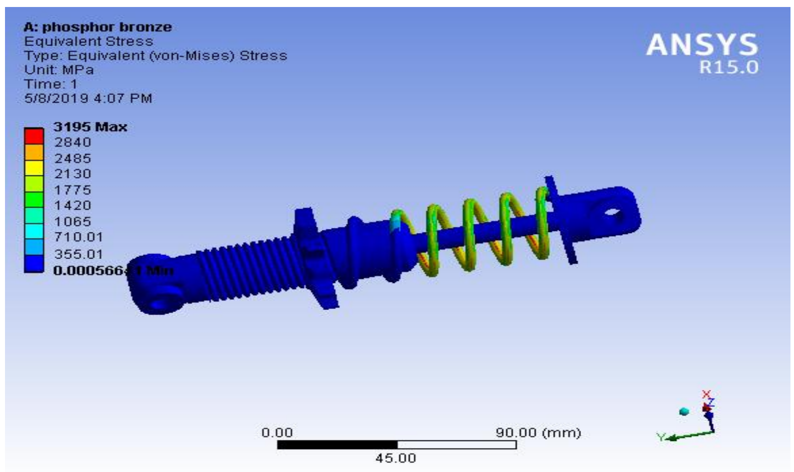


Fig 23: Phosphor Bronze as a spring material((Von-Mises Stress)

The result obtained from above analysis is that the stress generated in the carbon fiber is highest of the three materials that we are using.

Stress (MPa)	**Spring Steel**	**Carbon Fiber**	**Phosphor Bronze**
Maximum	3221.2	3230	3195
Minimum	0.000322	0.000785	0.000566

Table 2: Von-Mises Stress for force value of 1000N

- **Analysis using 1500N force on the shock absorber**

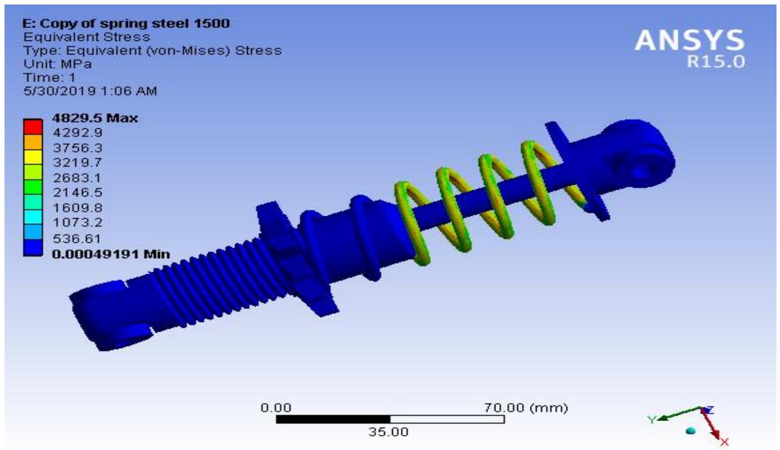


Fig 24: Von-Mises stress using spring steel as spring material

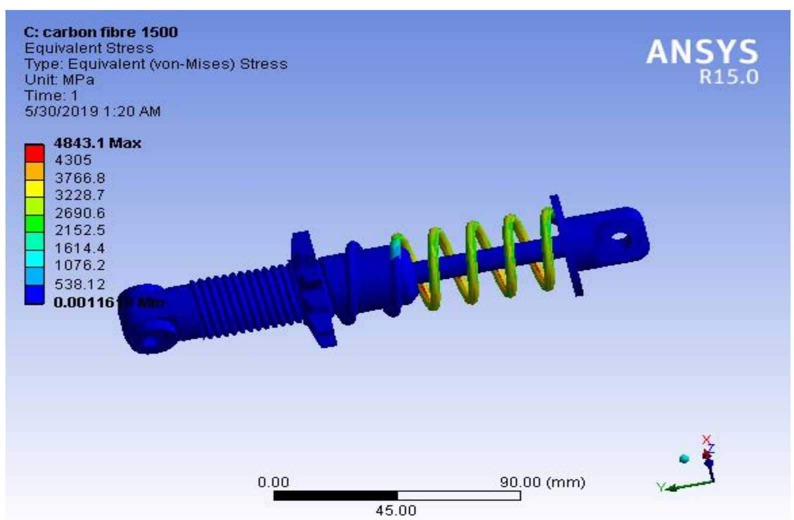


Fig 25: Von-Mises stress using carbon fiber as spring material

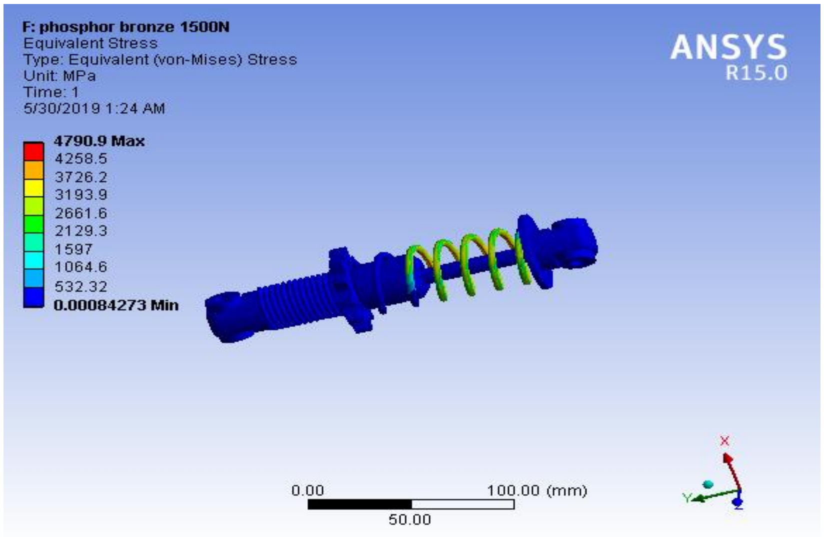


Fig 26: Von-Mises stress using Phosphor Bronze as spring material

Stress (MPa)	**Spring Steel**	**Carbon Fiber**	**Phosphor Bronze**
Maximum	4829.5	4843.1	4790.9
Minimum	4.9191e-004	1.1618e-003	8.4273e-004

Table 3: Von-Mises stress for the force value of 1500N

6.2 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. In this section total deformation of the assembly can be seen under the load 1000N.

6.2.1 Analysis using 1000N force on the shock absorber

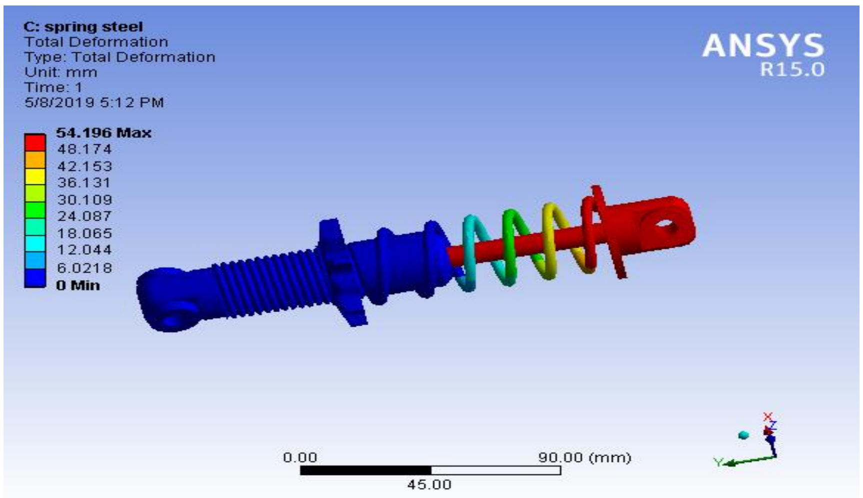


Fig 23: Total deformation using spring steel as a spring material

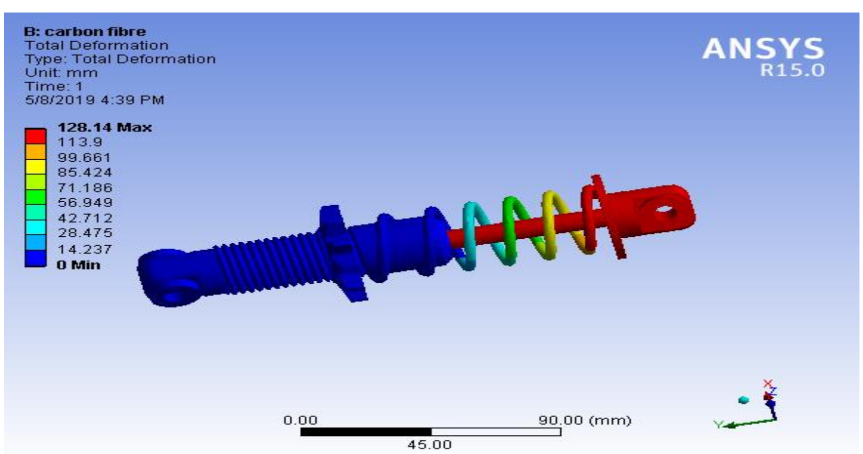


Fig 24: Total deformation using carbon fiber as a spring material

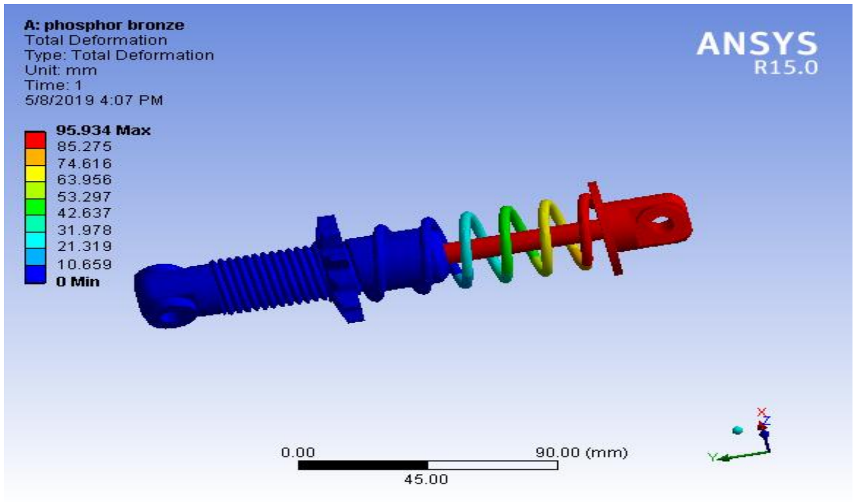


Fig 25: Total deformation using Phosphor Bronze as a spring material

Results obtained from above analysis are tabulated below:

Deformation(mm)	**Spring Steel**	**Carbon Fiber**	**Phosphor Bronze**
Maximum	54.196	128.14	95.934
Minimum	27.109	64.099	48

Table 4: Total deformation result for the force value of 1000N

6.2.2 Analysis using 1500N force on the shock absorber

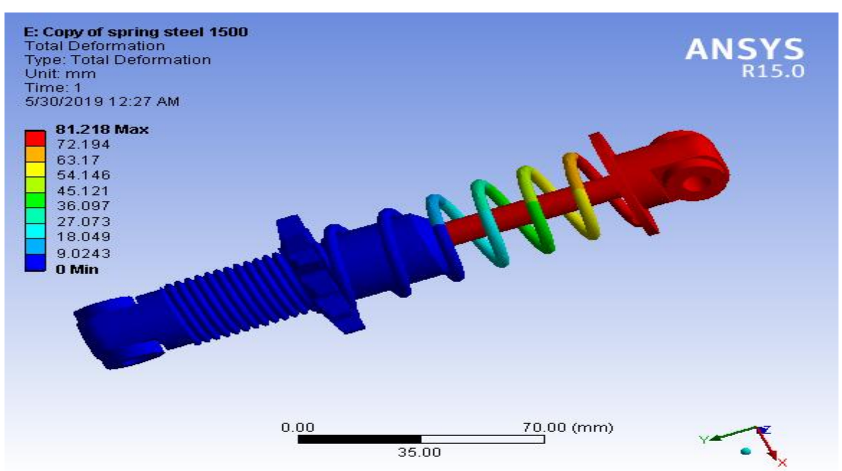


Fig 26: Total deformation using spring steel as a spring material with 1500N force

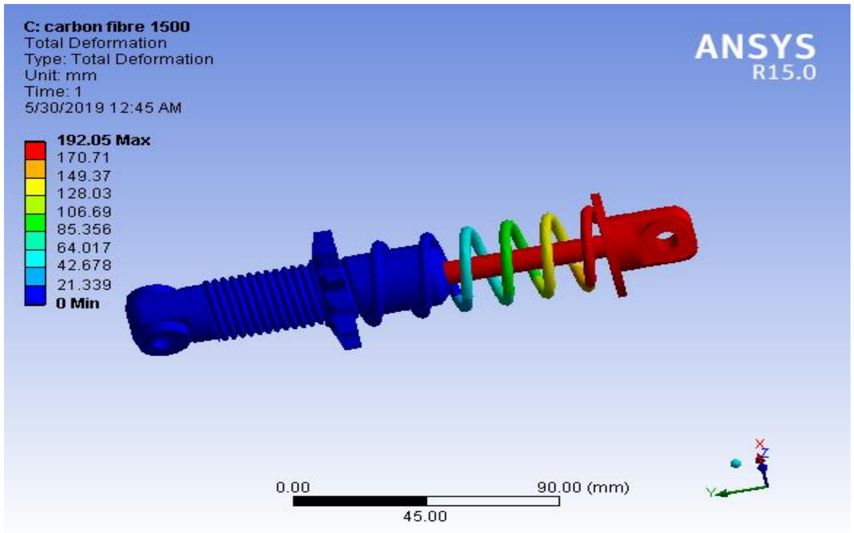


Fig 27: Total deformation using carbon fiber as a spring material with 1500N force

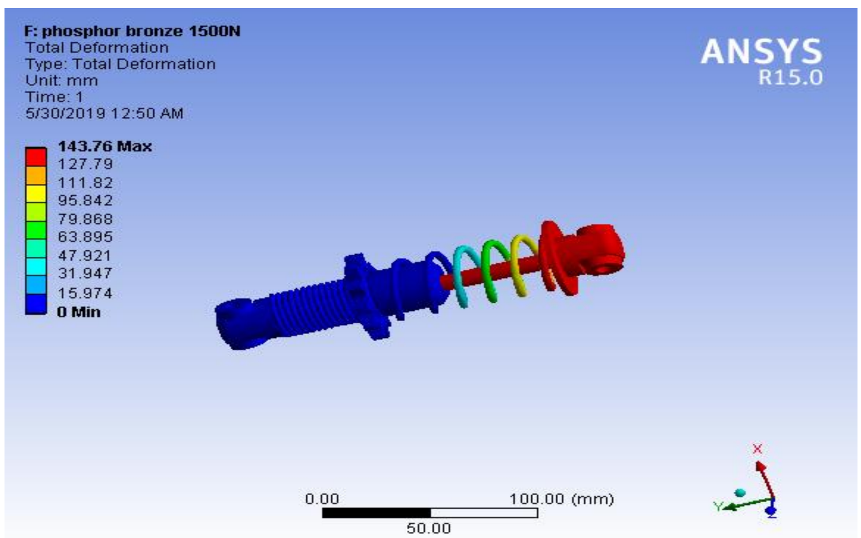


Fig 28: Total deformation using Phosphor fiber as a spring material with 1500N force

Deformation(mm)	**Spring Steel**	**Carbon Fiber**	**Phosphor Bronze**
Maximum	81.218	192.05	143.76
Minimum	40.634	96.051	71.911

Table 5: Total deformation result for the force value of 1500N

6.1.1 Stress induced when we are using spring steel as a spring material

- **Applying force of 1000N**