STRESS DISTRIBUTION AND DISPLACEMENT VECTOR PLOT OF A VEHICLE SHOCK ABSORBER SPRING BY USING FINITE ELEMENT ANALYSIS

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ABSTRACT

Shock absorber is a mechanical device designed to absorb or dissipate energy. The spring in the shock absorber compressed quickly, when a vehicle is traveling on a level road and the wheels strike a bump, the compressed spring will attempt to return to its normal loaded length when load is removed and doing so. Design of spring is a challenging criteria for selecting best material. This analysis is focus on the strength of spring material. A 3D model of shock absorber is created using SOLIDWORKS®. The model was imported and analysed in ANSYS®workbench as considering four different materials individually. The analysis is done by considering total load acting on the spring and neglecting hydraulic fluid part. Structural analysis was done to determine the stress, displacements using different material at same loading conditions. A detailed comparison has been done for verify the best material for spring. Determination of Critical spring coil diameter is also carried at the same loading condition.

Keywords: Shock Absorber, Spring Diameter, Material, Solid Works,Ansys

I INTRODUCTION

A shock absorber is a mechanical device which is used to give damp shock impulse, and it dissipate kinetic energy from the system. When the wheels of a vehiclestrike a bump on a level road the spring compressed quickly. The compressed spring will attempt to return to its original positionwhen the load is removed. The spring will rebound past its normal height, causing the body to be lifted. The spring will pushed down below its normal loaded height due to the dead weight of the vehicle. The springcauses to rebound again due to this.Movement finally stopsuntil the up-and-downprocess moves little less each time. It is very difficult to handle the vehicle if the bouncing motion get uncontrolled. In order to control this in a better way the design of spring in suspension system is very important.

While considering the material property of spring, the stiffer spring Control excessive suspension movement without shock absorption, also sometime user can feel a harsh ride. The rate of suspension movement in soft (lower rate) springs controls retort to bumps in Shock absorbers. To absorb the impact loads at a low cost,metal springs are widely usedfor reducing the shock loading. They are able to operate in very strenuous conditions under a wide range of temperatures. These material made shock absorber devices have high stopping forces evenat end of stroke and it store energy rather than dissipating it. The rate of Oscillations also taken into consideration, if we use these metal sprint type shock absorbers and hence viscous dampers are attached to that. There are variety of metal springs encompassing helical springs, bevel washers(cone-springs), leaf springs, ring springs, mesh springs etc. Each spring type has its own operating individualities.

Lang published a study regarding the behaviour of automotive dampers at high stroking frequencies [12]. Kim [10] also accomplished an analysis of a twin tube damper with focus on implementation into a vehicle suspension. 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. Achyut, recently conducted an investigation to find out the displacement at different frequencies on shock absorber spring by taking spring steel and phosper bronze as material [1]. Sidhant and team created a spring model on Creo® and analysed using ANSYS®15.0 by varying spring material to find out the displacement mode at different frequencies [2]. Durmus Ali Bircan conducted an analysis by considering hydraulic oil density and loads, executed and optimized using minitab program, point out the importance of thickness and resistance of spring [3]. Vidhyadhar analysed the double spring damper shock absorber and is mathematically modelled. And the vehicle dynamic characteristic of the double spring damper shock absorber is analysed using quarter car model [6]

Present work modelling is done in SolidWorks and analysis is done in ANSYS® workbench. SolidWorks® is one of the standard software in 3D product design, featuring industry-leading productivity tools that promote best practices in design system. The work included creation of the first parametric models of a Two wheeler shock absorber 3D model is created using SolidWorks®. The model is also changed by changing the spring coil diameter of the spring. Structural analysis and modal analysis are done on the shock absorber by varying material. The analysis is done by considering loads, bike weight, and single person. Structural analysis has been done to authenticate the strength and modal analysis also carried out to define the displacements at different frequencies. Comparison was done for different materials to verify best material for spring in Shock absorber.

II DESIGN OF HELICAL COMPRESSION SPRING

To begin designing compression springs, you must take into consideration all of the physical limitations around the spring. The compression spring dimensions must be taken into consideration are outer diameter, inner diameter, free length, solid height and material properties.

2.1 Load consideration

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The amount of load the spring is able to carry isbased on compression springs dimensions and material type. While designing Maximum load considering solid height is taken into account. If the maximum load considering solid height exceeded, the spring will either break or take a permanent set.

Parameters used for designing the model is mentioned below

- Material type: Spring Steel, Beryllium Copper , Zinc alloy
- Mean coil diameter of a spring D=60 mm
- Diameter of wire d = 8mm
- Total no of coils n= 15 Pitch=14mm
- Weight of one person be 75Kgs.
- Let weight of bike be 125kg
- Then total weight= weight of bike + weight of person =200Kgs
- *Considering Factor of Safety (FOS) = 1.5 Total weight = 200 × 1.5 = 300Kgs
- Therefore total load on Shock Absorber = 300 × 9.81 =2943N

III STRUCTURAL ANALYSIS

3.1MESHING

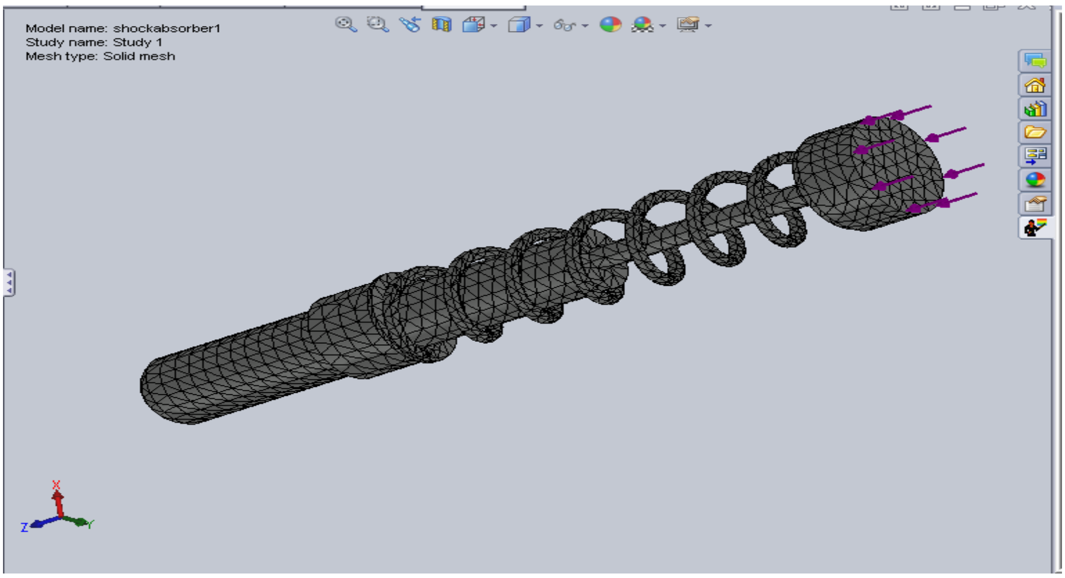

Fig 1. Meshed model of Shock absorber

Meshing divides the part into small elements. A finite element perfect meshing was carried out in the model. Based on this current design, two types of meshing were done in the same model. The accurate result is depend on the meshing of the model. In the corner areas stress concentration is more so there fine meshing is used and remaining all other areas coarse mesh was applied.

3.2 Stress analysis of the model using different material.

However the spring material we are commonly using is Alloy steel. Here our model is tested for four different spring materials and the hydraulic fluid cylinder material remains the same. Table.1,2,3,4 shows the material properties used for analysing the model.

Table.1, 1023 Carbon steel as spring material

Young’s Modulus (EX)	2.0499 E^{11} N/ m^2
Poisson’s Ratio (PRXY)	0.29
Ultimate Tensile strength	450Mpa

Table.2 ASTM A36 steel

Young’s Modulus (EX)	2.0E^{11} N/m^2
Poisson’s Ratio (PRXY)	0.26
Ultimate Tensile strength	4.0E^8 N/m^2

Table.3 Beryllium copper

Young’s Modulus (EX)	1.25 E^{11} N/m^2
Poisson’s Ratio (PRXY)	0.3
Ultimate Tensile strength	4.690 E^8 N/m^2

Table.4 Zinc alloy AC41A

Young’s Modulus (EX)	843Gpa
Poisson’s Ratio (PRXY)	0.3
Ultimate Tensile strength	283Mpa

3.3 Boundary conditions

The dead weight of the vehicle is acting on the top of the suspension and bottom portion is resisting that weight. During motion the dead weight compress the piston along with the spring, so here the overall weight is applied on the top (Vertically downwards in Y direction) and the bottom is fixed in X, Y and Z direction. A constant load of 2973 was applied for every material. All materials are assumed to be linear and isentropic.

IV RESULT AND DISCUSSION

4.1 Stress Plot

As a result of the load applied on the model, stress was developed inside the material. If the induced stress exceed the ultimate tensile strength of the material the material will break at that particular load.

Stress	Minimum	Maximum
Vonmisses stress(N/m$^{2)}$	37.6	2.79 E^5

Here the fig.2 shows the stress plot for the carbon steel material. From this fig.2 the maximum stress was obtained in the two corner of the compression spring and the piston rod was identified. From this table.5 it is clear that the maximum equivalent stress obtained in the material due to this load was lower than the ultimate tensile strength. Hence the design was safe in this model.

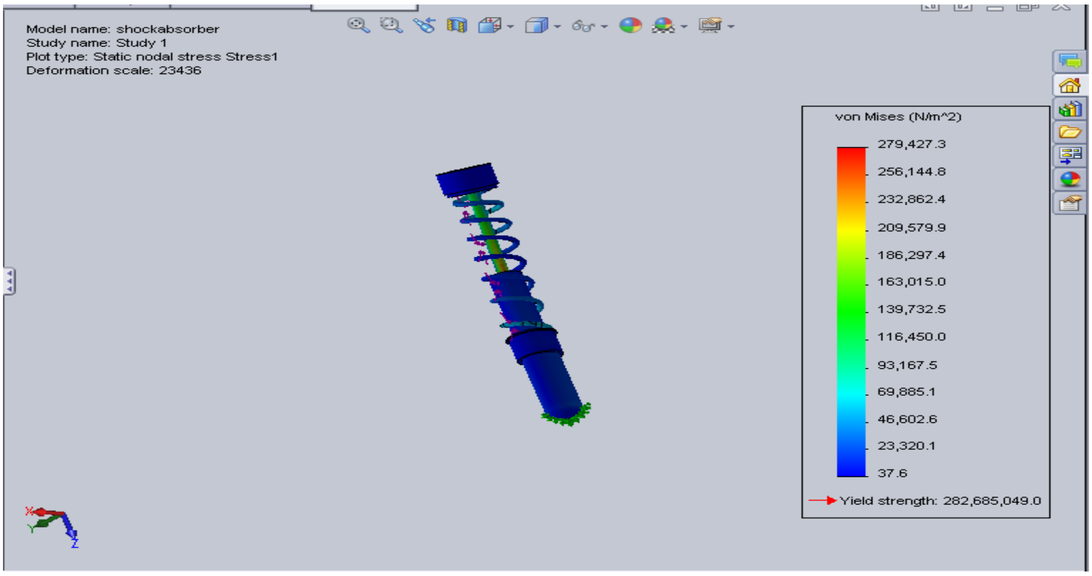

Table.5 Stress distribution for Carbon steel as spring material

Fig 2. Stress plot for the Carbon steel as spring material

The fig.3 shows the stress plot for the ASTM steel as spring material. From this fig.3 the maximum stress obtained in the spring region is less when compared to carbon steel. This is because the extra silicon condent present in the spring material, however the stress in the piston rod was almost equal when compared to ASTM steel. From this table.6 it is clear that the maximum equivalent stress obtained in the material due to this load was lower than the ultimate tensile strength. Hence the design was safe in this model.

Table.6 Stress distribution for ASTM steel as spring material

Stress	Minimum	Maximum
Vonmisses stress(N/m$^{2)}$	21.1	2.78 E^5

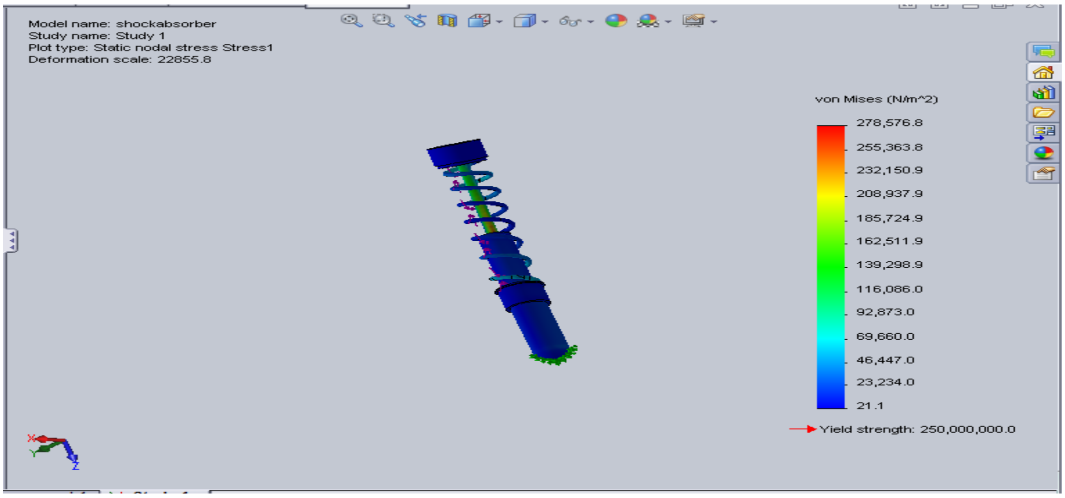

Fig 3. Stress Plot for the ASTM Steel s Spring Material

The fig.4 shows the stress plot for Beryllium copper as spring material. From this fig.4 the maximum stress obtained in the spring region is equal to carbon steel. From this table.7 it is clear that the maximum equivalent stress obtained in the material due to this load was lower than the ultimate tensile strength. Hence the design was safe in this model.

Table.7 Stress distribution for Beryllium copperas spring material

Stress	Minimum	Maximum
Vonmisses stress(N/m$^{2)}$	47	2.797 E^{5}

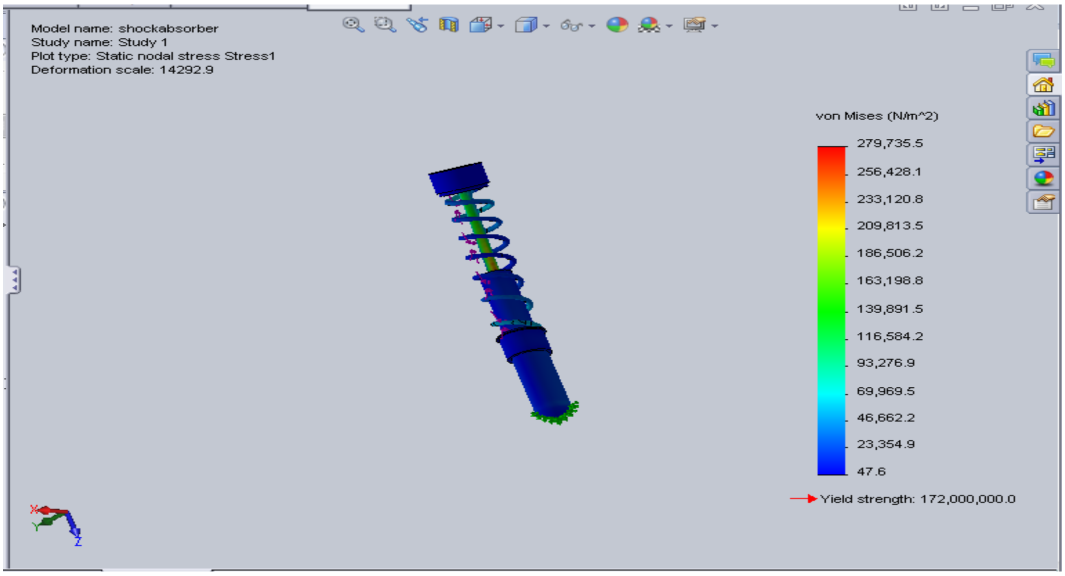

Fig 4. Stress plot for Beryllium copperas spring material

The fig.5 shows the stress plot for Zinc as spring material. From this fig.5 the maximum stress obtained in the spring region is very less when compared to other material. This is because the zinc alloy has high strength. The

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table.8 shows the maximum equivalent stress obtained in the material due to this load was lower than the ultimate tensile strength.

Table.8 Stress distribution for Zinc Alloyas spring material

Stress	Minimum	Maximum
Vonmisses stress(N/m$^{2)}$	37.6	2 .697 E^5

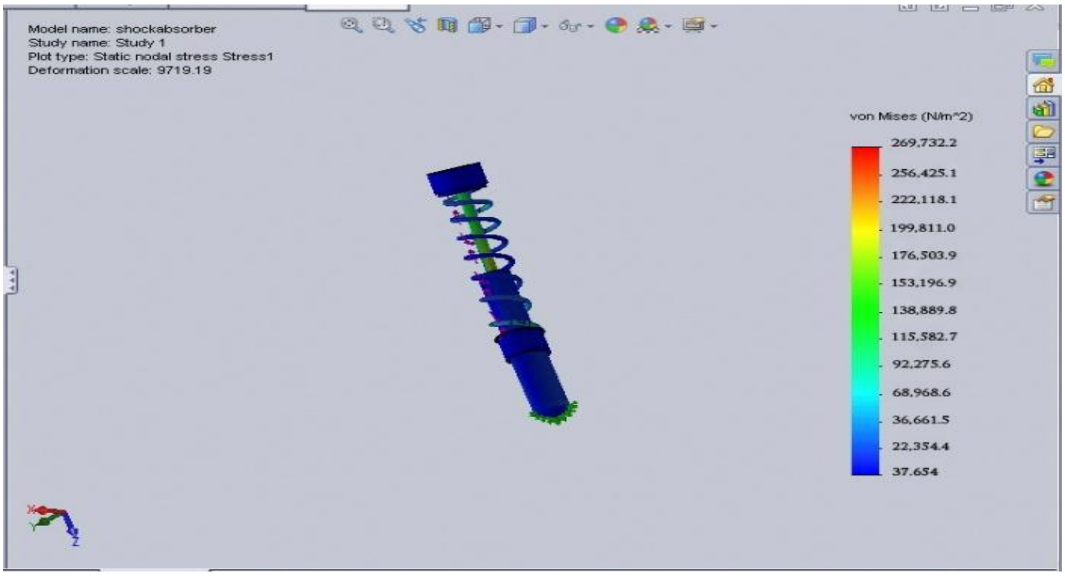

Fig 5. Stress plot for Zinc Alloyas spring material

4.2 Displacement Plot

For the applied load how much spring displaced is shown in the fig.6, 7, 8,9 for various material.

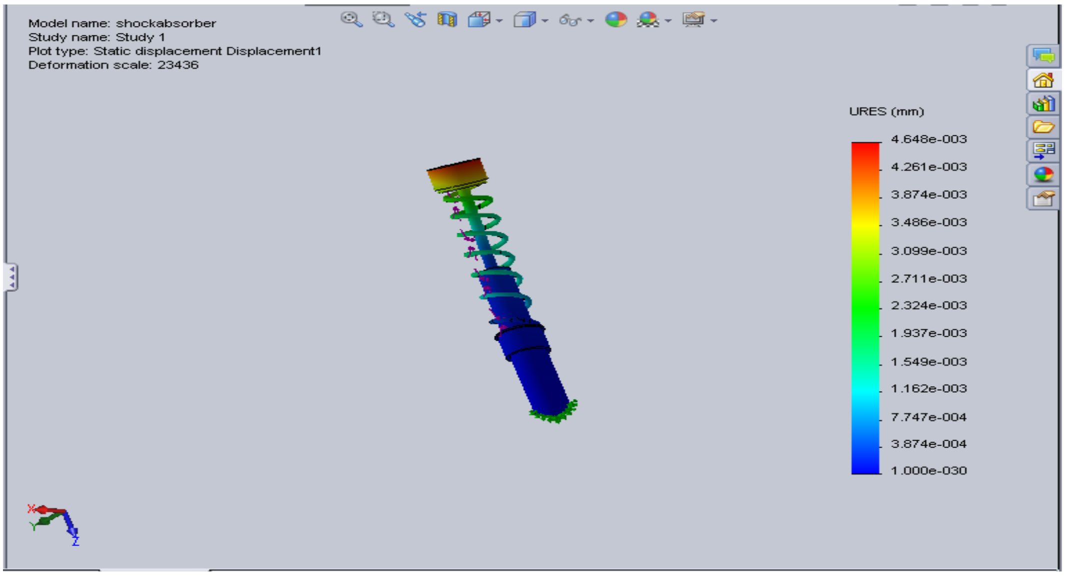

Fig.6 Displacement analysis for carbon steel

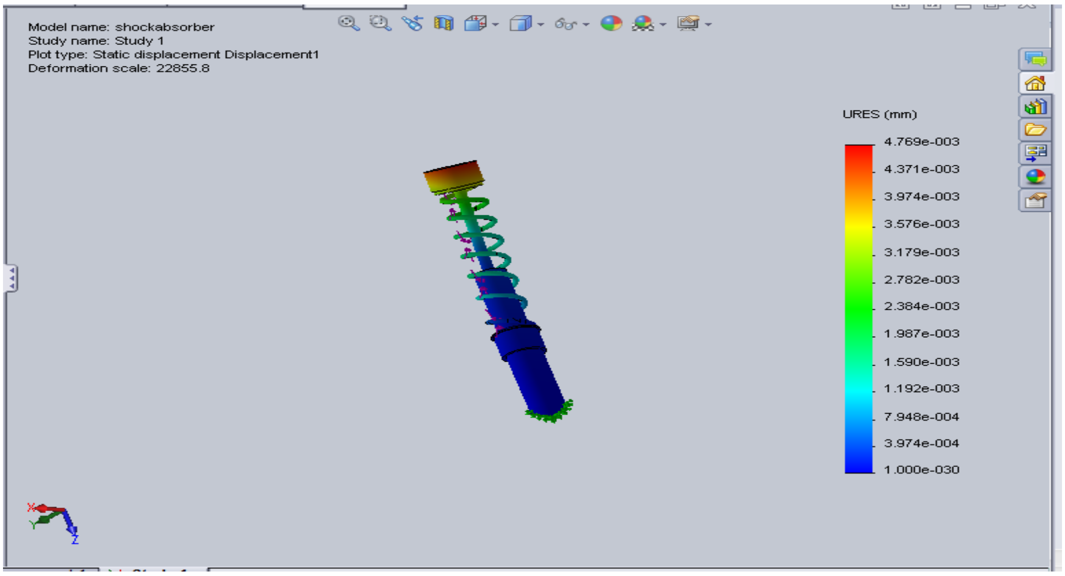

Fig.7 Displacement analysis for ASTM steel

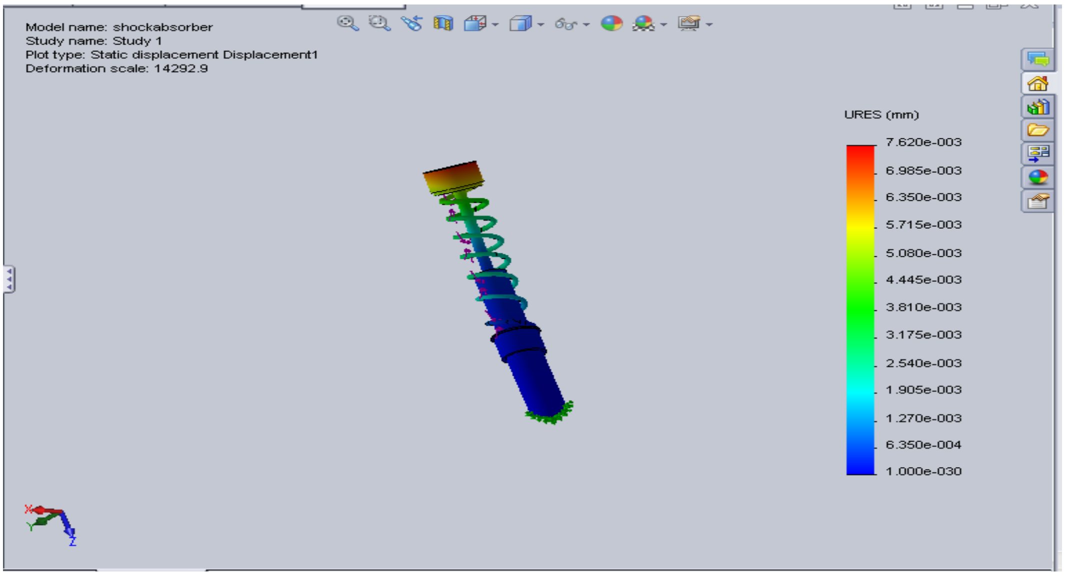

Fig.8 Displacement analysis for Beryllium copper

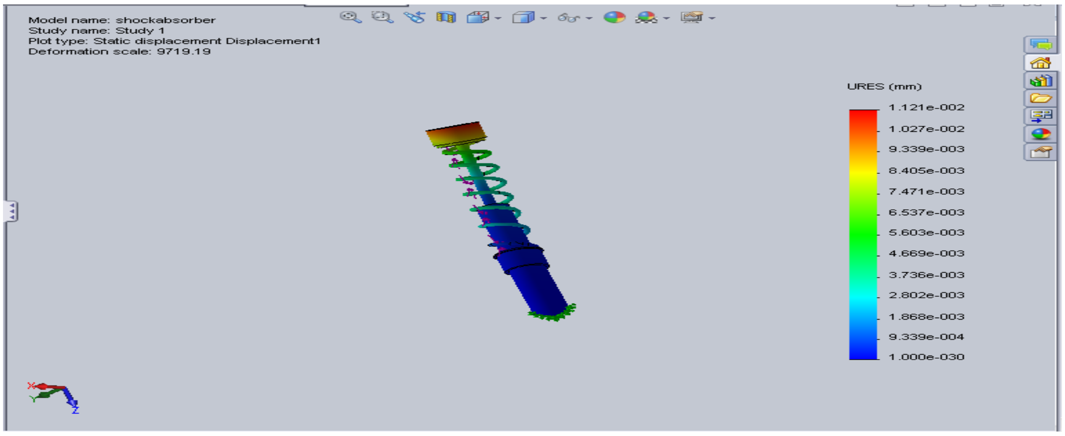

Fig.9 Displacement analysis for Zinc alloy

From the table.9 it is understood that the maximum displacement occurred in the carbon steel and the ASTM steel was almost same in the present design. In this maximum displacement was obtained in beryllium copper. The displacement is minimum in Zinc alloy, this is due to the excellent mechanical strength in the material.

Table.9 Comparison of Displacement for various materials

Description	Carbon steel		ASTM steel		Beryllium copper		Zinc alloy	
	Min 10^{-30}	Max. 10^{-3}	Min 10^{-30}	Max. 10^{-3}	Min 10^{-30}	Max. 10^{-3}	Min 10^{-30}	Max 10^{-2}
Displacement (mm)	1.003	4.648	1.003	4.76	1.003	7.620	1.003	1.121

4.3 Comparison of results of the four various materials

The shock absorber is analysed for two materials like structural steel and aluminium alloy with same boundary conditions and load for fine meshing using Ansys Workbench. The following results are shown in table.10

Table.10 comparison of results of various materials

Description	Carbon steel		ASTM steel		Beryllium copper		Zinc alloy	
	Min	Max.	min	Max.	min	Max.	min	Max.
Stress(N/m^2)	37.6	$2.79E^{5}$	21.1	$2.78\ E^{5}$	47	$2.797E^{5}$	37.6	$2.697E^{5}$
Displacement(mm)	$1.003E^{-30}$	$4.648E^{-3}$	$1.003E^{-30}$	$4.76E^{-3}$	$1.003E^{-30}$	$7.620E^{-3}$	$1.003E^{-30}$	$1.121E^{-2}$

The table.10 shows a compared result of various metals. From this table it is understood that the stress distribution in zinc alloy is very low when compared to the other three material. And also displacement due to this load is less in zinc alloy.

4.4 New Design

The same type of analysis is carried out in zinc alloy where the Spring mean coil diameter is increased from 60mm to 64 mm. Here we optimised the design with varying mean coil diameter. In this upto 64mm mean coil diameter we got the better result and above that stress induced in the material is gradually increasing. It gives better result upto 64mm diameter

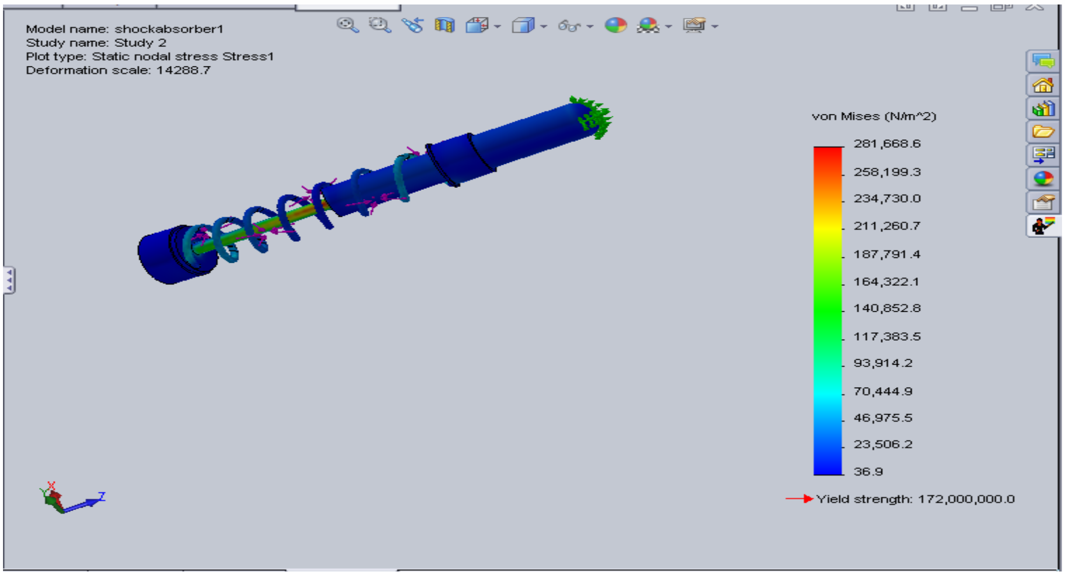

Fig.10 Stress analysis for new design, Zinc alloy as spring material

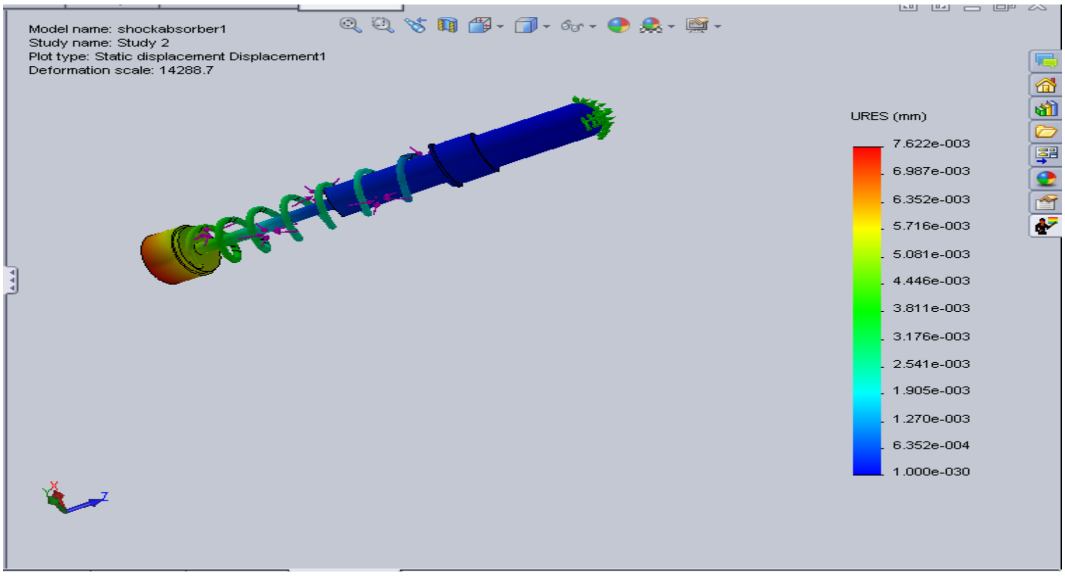

Fig.11 Displacement analysis for new design, Zinc alloy as spring material

The fig.10 shows the stress distribution of the modified model. From this we can see that the load is equally shared by the spring and the piston rod. The maximum stress obtained near the top of the piston rod area of the spring and the fig point out the displacement vector plot.

Table.11 comparison with existing design

Description	Existing design		New design		% Error	
	Min.	Max.	Min.	Max.	Min	Max
Stress(N/m2)	37.6	$2.697E^{5}$	34.9	$2.6153\ E^{5}$	25.7%	6.49
Displacement(mm)	$1.003E^{-30}$	$1.121E^{-2}$	$1.003E^{-30}$	$7.622\ E^{-3}$	0	37

The table.11 compare the stress distribution and the displacement of the modified model and the current model. The maximum stress obtained from the modified design is 6.67% low when compared to the previous one and also the material is 37% displaced less than the previous model. Here the outer diameter of the helical spring is fully constrained in the piston rod and make the load evenly distributed.

V. CONCLUSIONS

In this project we have modelled the shock absorber by using SOLIDWORKS® software and analysed using ANSYS®Workbench. The following results were obtained.

1. Identified the stress distribution on the shock absorber spring with respect to the applied load on different materials. It is found out that the Zinc alloy has less maximum stress when compared to other three materials and also the displacement is also lower than other.
2. From the above result we increased the spring coil diameter and repeated the analysis only for zinc alloy. In this up to 64mm we got improved result.

So we can conclude that as per our analysis zinc alloy for spring gives better result and also our modified design is safe up to 64mm spring coil diameter.

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