Design and Optimization of Two Wheeler Damper Spring and its Structural Components

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***Abstract* - The main functions of automobile suspension systems are to isolate the structure and the occupants from shocks and vibrations generated by the road surface. The suspension systems basically consist of all the elements that provide the connection between the tyres and the vehicle body. A spring is an elastic object used to store mechanical energy. It can be twisted, pulled, or stretched by some force. It can return to their original shape when the force is released. The force can be a linear push or pull, or it can be radial, acting similarly to a rubber band around a roll of drawings. 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 coil radius of the spring. Structural analysis and optimization are done in ANSYS 13.0 of the shock absorber by varying coil radius and spring radius. The analysis is done by considering loads, bike weight, and single person. Structural analysis is done to validate the strength and optimization is done to determine the better dimension of spring to carry applied load. Optimization is done for different dimensions to verify best size for spring in Shock absorber.**

Index Terms – Damper Spring, coil radius, Spring Radius, Strength, and Optimization.

I. INTRODUCTION

Suspension systems have been widely applied to vehicles, from the horse-drawn carriage with flexible leaf springs fixed in the four corners, to the modern automobile with complex control algorithms. The suspension of a road vehicle is usually designed with two objectives; to isolate the vehicle body from road irregularities and to maintain contact of the wheels with the roadway. Isolation is achieved by the use of springs and dampers and by rubber mountings at the connections of the individual suspension components. From a system design point of view, there are two main categories of disturbances on a vehicle, namely road and load disturbances. Road disturbances have the characteristics of large magnitude in low frequency such as hills and small magnitude in high frequency such as road roughness. Load disturbances include the variation of loads induced by accelerating, braking and cornering. Therefore, suspension design is an art of compromise between these two goals (Wang 2001).Today, nearly all passenger cars and light trucks use independent front suspensions, because of the better resistance to vibrations [1].The main functions of a vehicle’s suspension systems are to isolate the structure and the occupants from shocks and vibrations generated by the road surface. The suspension systems basically consist of all the elements that provide the connection between the tires and the vehicle body.

According to Gillespie (1992), the primary functions for suspension systems are;

- Provide vertical compliance so the wheels can follow the uneven road, isolating the chassis from roughness in the road.
- Maintain the wheels in the proper steer and camber attitudes to the road surface.
- React to the control forces produced by the tires-longitudinal (acceleration and braking) forces, lateral (cornering) forces, and braking and driving torques.
- Resist roll of the chassis.
- Keep the tires in contact with the road with Minimal load variations

To accomplish all functions, the suspension system requires an elastic resistance to absorb the road shocks and this job is fulfilled by the suspension springs. A spring is defined as an elastic machine element, which deflects under the action of the load & returns to its original shape when the load is removed [3]. Mechanical springs are used in machine designs to exert force, provide flexibility, and to store or absorb energy. Springs are manufactured for many different applications such as compression, extension, torsion, power, and constant force. Depending on the application, a spring may be in a static, cyclic or dynamic operating mode. A spring is usually considered to be static if a change in deflection or load occurs only a few times, such as less than 10,000 cycles during the expected life of the spring.

A. *Objectives of spring*

1) To apply force: A majority industrial, e.g. To provide the operating force in brakes and clutches, to provide a clamping force, to provide a return load, to keep rotational mechanisms in contact, make electrical contacts, counterbalance loading, etc.

2) To control motion: Typically storing energy, e.g. wind-up springs for motor, constant torque applications, torsion control, position control, etc.

3) To control vibration: used in essence for noise and vibration control, e.g. flexible couplings, isolation mounts, spring and dampers, etc.

4) To reduce impact: Used to reduce the magnitude of the transmitted force due to impact or shock loading, e.g. buffers, end stops, bump stops etc. In practical situations, springs are used to provide more than one of the above functions at the same time. Because of superior strength and endurance characteristics under load, most springs are metallic.

B. *Failure Modes of springs in Suspension*

- Raw materials defect
- Surface imperfections
- Improper heat treatment
- Sudden impact load created by the pit road
- Over load of rider
- Improper damper system
- Large pitch gap between the coil turn

C. *Materials used in Suspension Springs*

TABLE I
Material Properties of Suspension System

Material	Allowable shear stress (τ) MPa			Modulus of rigidity (G) kN/m²	Modulus of elasticity (E) kN/mm²
	Severe service	Average service	Light service		
1. Carbon steel					
(a) Upto to 2.125 mm dia.	420	525	651		
(b) 2.125 to 4.625 mm	385	483	595		
(c) 4.625 to 8.00 mm	336	420	525		
(d) 8.00 to 13.25 mm	294	364	455		
(e) 13.25 to 24.25 mm	252	315	392	80	210
(f) 24.25 to 38.00 mm	224	280	350		
2. Music wire	392	490	612		
3. Oil tempered wire	336	420	525		
4. Hard-drawn spring wire	280	350	437.5		
5. Stainless-steel wire	280	350	437.5	70	196
6. Monel metal	196	245	306	44	105
7. Phosphor bronze	196	245	306	44	105
8. Brass	140	175	219	35	100

II. PROBLEM DESCRIPTION

Fig. 1 Hero Honda Splendor Pro

In this problem damper spring of the Hero Honda Splendor Pro are taken. The shock absorber of the vehicle are going failure in many cases now we concentrate on a load which is acted maximum in the damper spring during the sudden impact of the vehicle in the un even roads. In that conditions load acting in the spring are damped load from the tire weight of the vehicle and person who riding the vehicle. A general specification of splendor bike is,

- Length=2000 mm
- Width=720 mm
- Height=1040 mm
- Saddle Height=785 mm
- Wheelbase=1230 mm
- Ground Clearance=159 mm
- Fuel Tank Capacity=11 Liter (Min)
- Weight=109 kg

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

A. *Model Diagram*

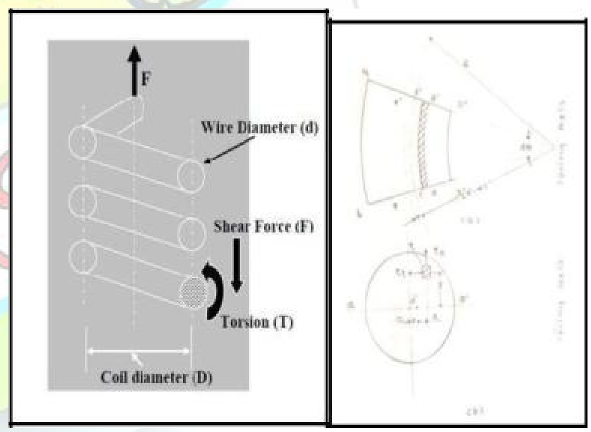


Fig. 2 Spring Details

B. *Introduction to CATIA V5*

CATIA V5 is a feature based, parametric solid modelling program. As such, its use is significantly different from conventional drafting programs. In conventional drafting (either manual or computer assisted), various views of a part are created in an attempt to describe the geometry. Each view incorporates aspects of various features (surfaces, cuts, radii, holes, protrusions) but the features are not individually defined. In feature based modelling, each feature is individually described then integrated into the part. However, other resilient materials, e.g. polymers, where special properties such as a low modulus and high internal damping capacity are required used later.

B. Part Design (Top Eye)

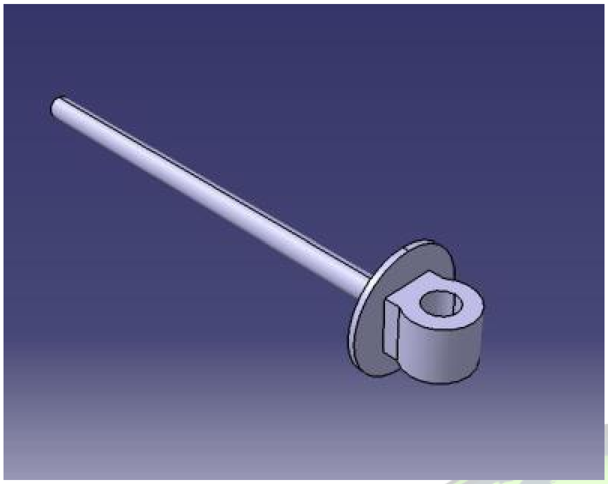


Fig. 3 Top Eye

B. Spring part

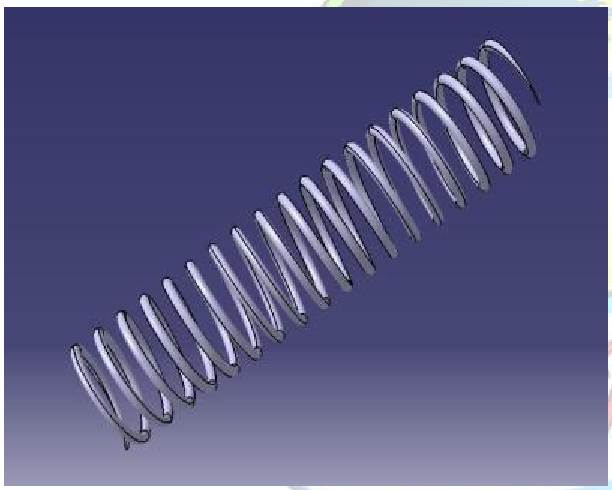


Fig. 4 spring

C. Bottom eye

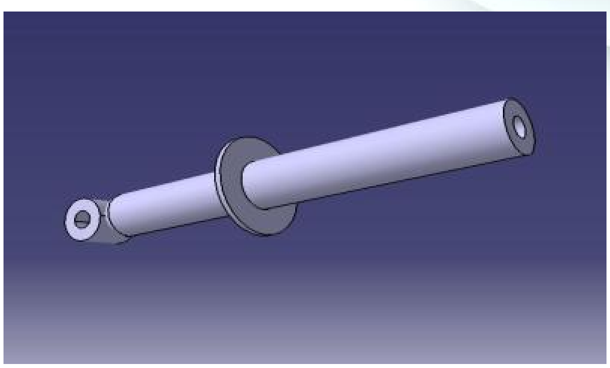


Fig. 5 Bottom eye

D. Assembly

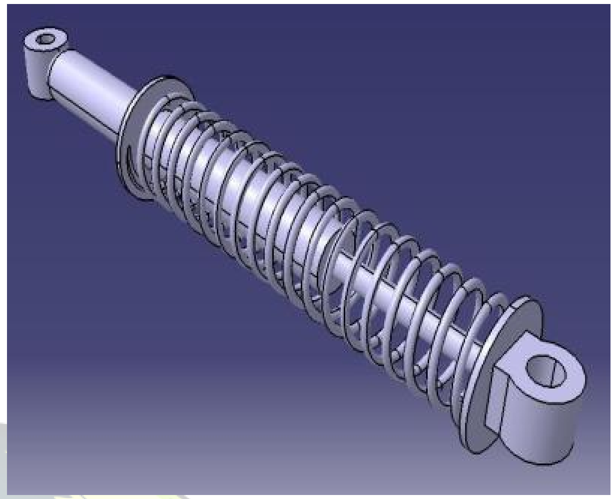


Fig. 6 Assembly model

E. Drawing Details

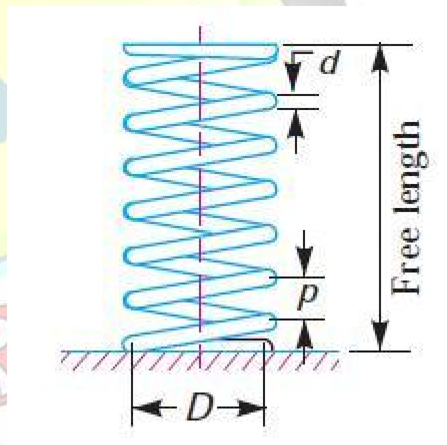


Fig. 7 spring detail

F. Design calculated variables for Helical Springs in Shock Absorbers

Material: Carbon Steel (Modulus of Rigidity) G = 80 KN/m² Mean radius of a coil R =40mm

Radius of wire r = 4.67mm
Total no of coils n1= 17
Height h = 223mm

Outer diameter of Spring $R_o = R + r = 46.67$mm
No of active turns n= 15
Weight of bike = 109kgs

Let weight of 2 person = 75+75=150kgs
Weight of bike + person = 150+109 = 259kgs Rear suspension = 65%
65% of 259 = 168Kgs

Considering dynamic loads it will be double W= 336Kgs =3296N

For single shock absorber weight = w/2= 1648N
Load Area = 3.14*((r+coil rad)*2)-((r-coil rad)*2)

Applied pressure per unit Area = 1648 N/mm
Spring stiffness = 0.5
Damping coefficient = 5.97
Modulus of elasticity = 2.1 E 5 N/mm^2
Poisson's Ratio = 0.3

III. DESIGN ANALYSIS

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

A. Build Geometry

Construct a three dimensional representation of the object to be modelled and tested using the work plane coordinates system within ANSYS.

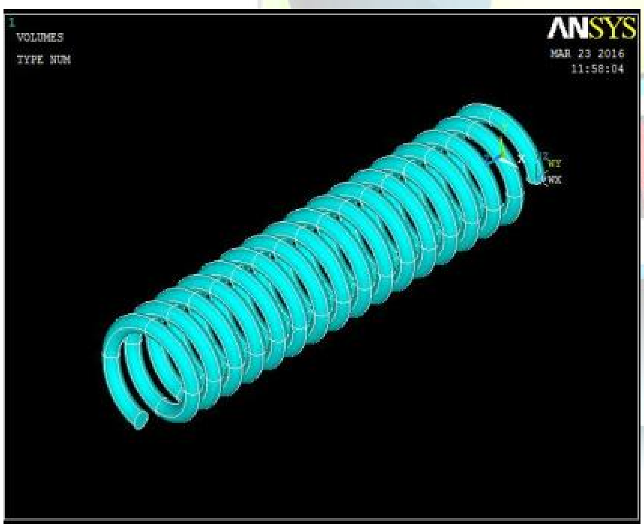


Fig. 8 Constructed model of spring

B. Define Material Properties

Now that the part exists, define a library of the necessary materials that compose the object (or project) being modelled. This includes thermal and mechanical properties. Here the material selected is steel so we take material properties values are,

Element type = SOLID 45
Young's modulus = 210 e 3 N/mm^2
Poisson's Ratio = 0.3
Density = 7850

C. Generate mesh

At this point ANSYS understands the makeup of the part. Now define how the Modelled system should be broken down into finite pieces. The spring design we done **vsweep** mesh to meshing model.

D. Selection of vsweep mesh

Fill an existing unmeshed volume with elements by sweeping the mesh from an adjacent area through the volume. However, those commands create the volume and the volume mesh simultaneously. In contrast, the VSWEEP command is intended for use in an existing unmeshed volume.

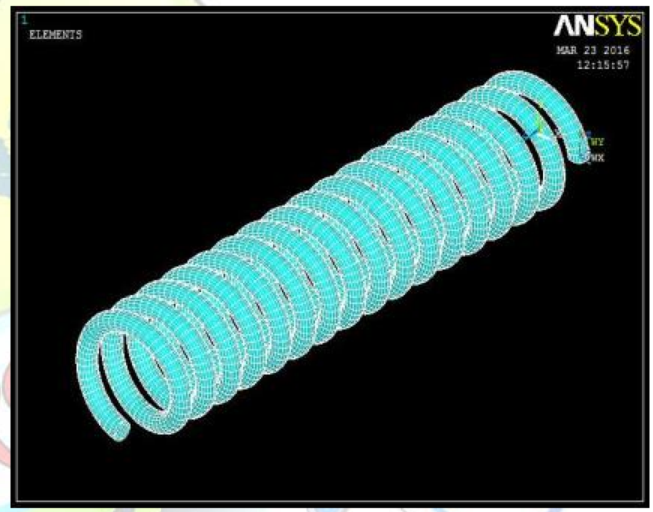


Fig. 9 Meshed model

E. 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. As this spring is used in the rear suspension it is necessary to find out the load acting on the spring in actual practice in static condition as well as in dynamic condition. Normally total weight of the vehicle with driver and one passenger is about 400 Kg, but for safer side it is taken as 505 Kg concentrated at the centre of gravity of the vehicle. It is assumed that this total weight is equally divided into two springs of rear suspension and one of front suspension. So the rear suspension spring is experiencing approximately 259 Kg load. This load is modelled in the analysis with the help of mass element. Then rigid body constraint equations are applied for giving contact between this element and the surface elements of the spring on upper side.

IV. DESIGN OF OPTIMIZATION

The optimization module (**/OPT**) is an integral part of the ANSYS program that can be employed to determine the optimum design. This optimum design is the best design in some predefined sense. While working towards an optimum design, the ANSYS optimization routines employ three types of variables that characterize the design process: design variables, state variables, and the objective function. These variables are represented by scalar parameters in ANSYS Parametric Design Language (APDL). The use of APDL is an essential step in the optimization process.

TABLE 2
Optimization detail

Fig. 10 Apply Load

F. Shear Stress Analysis

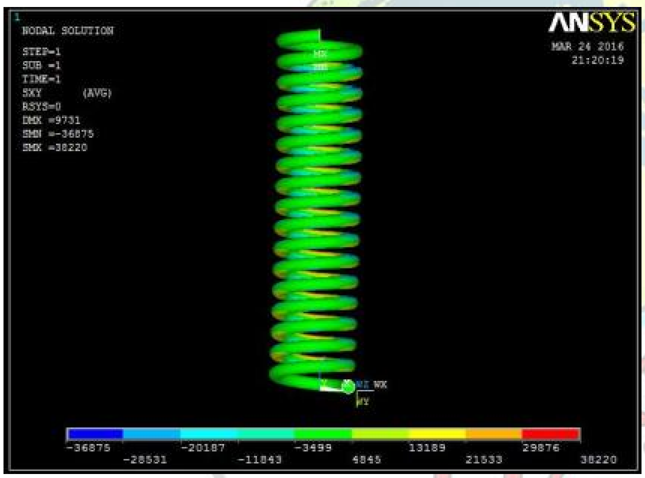
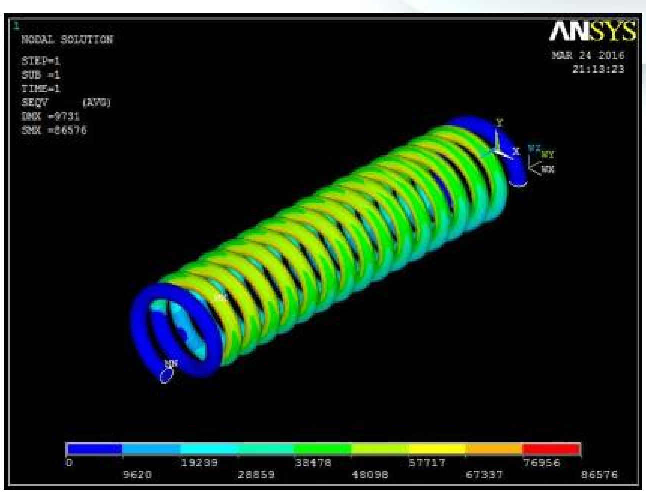
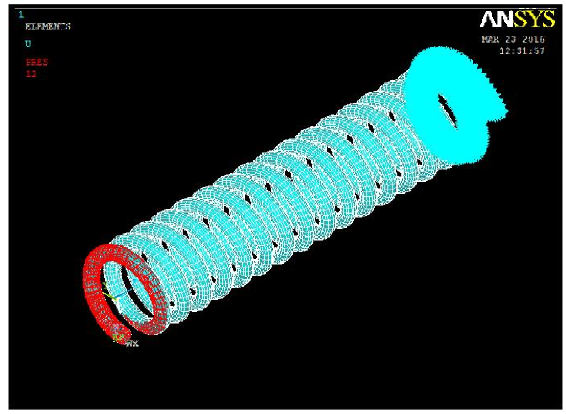


Fig. 11 Shear Stress Analysis

G. Von misses stress





Analysis Type(s):	Optimization (/OPT) Static Analysis (**ANTYPE** = 0)
Element Type(s):	3-D Structural Solid Elements (SOLID 45)
Input Listing:	Coil radius of spring Spring radius Spring stiffness Stress acting in the spring
Objective:	Analysis the spring parameter by constraining the stiffness value of spring material for a extreme load. By changing the coil radius and spring radius of spring to withstand the load applied and determine the best set of parameter values.

Fig. 12 Von misses Stress Analysis

Optimization ETABLE,Sp_stif,U,Z **conditions**
ESORT,ETAB,Sp_stif,0,1,,
*GET,max_dif,SORT,,MAX

A. Graph drawn from optimization result

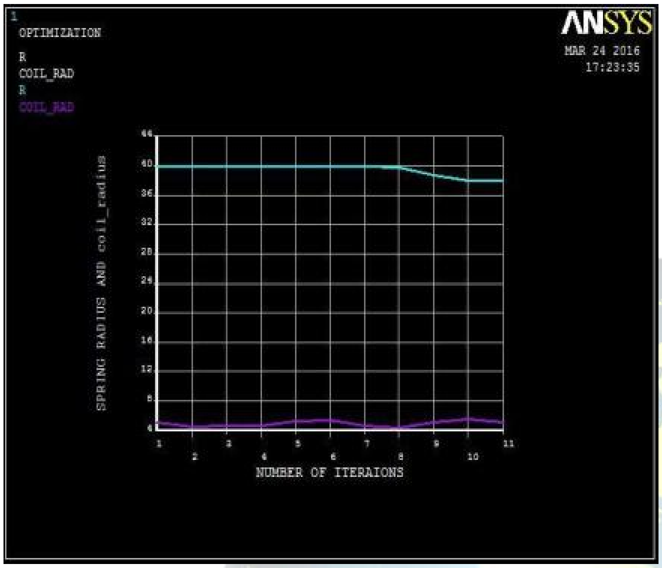
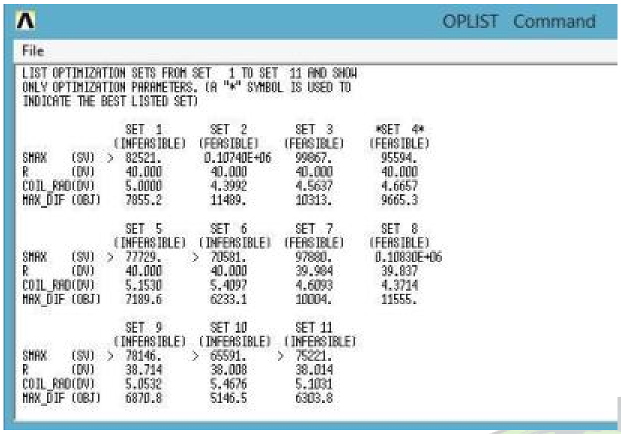


Fig. 13 optimization Graph

B. Optimization result table



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OPLIST Command
File
LIST OPTIMIZATION SETS FROM SET   1 TO SET  11 AND SHOW
ONLY OPTIMIZATION PARAMETERS. (A "*" SYMBOL IS USED TO
INDICATE THE BEST LISTED SET)

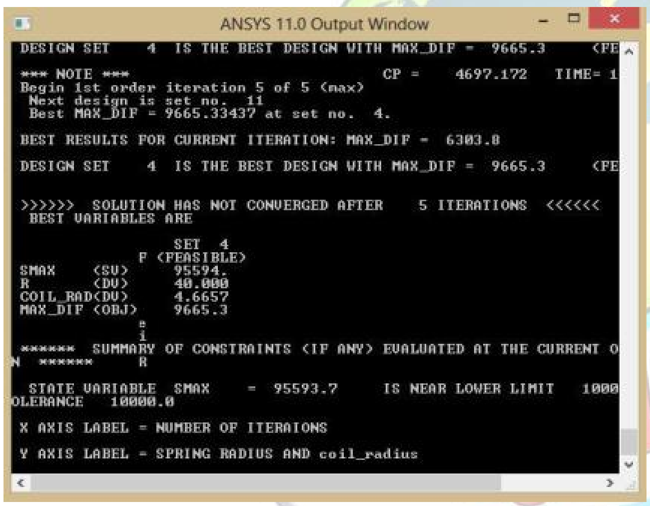
                     SET  1       SET  2       SET  3      *SET  4*
                  (INFEASIBLE)  (FEASIBLE)   (FEASIBLE)   (FEASIBLE)
SMAX     (SV)  >  82521.        0.10740E+06  99867.       95594.
R        (DV)     40.000        40.000       40.000       40.000
COIL_RAD(DV)      5.0000        4.3992       4.5637       4.6657
MAX_DIF (OBJ)     7855.2        11489.       10313.       9665.3

                     SET  5       SET  6       SET  7       SET  8
                  (INFEASIBLE)  (INFEASIBLE) (FEASIBLE)   (FEASIBLE)
SMAX     (SV)  >  77729.     >  70581.       97880.       0.10830E+06
R        (DV)     40.000        40.000       39.984       39.837
COIL_RAD(DV)      5.1530        5.4097       4.6093       4.3714
MAX_DIF (OBJ)     7189.6        6233.1       10004.       11555.

                     SET  9       SET 10       SET 11
                  (INFEASIBLE)  (INFEASIBLE) (INFEASIBLE)
SMAX     (SV)  >  78146.     >  65591.    >  75221.
R        (DV)     38.714        38.008       38.014
COIL_RAD(DV)      5.0532        5.4676       5.1031
MAX_DIF (OBJ)     6870.8        5146.5       6303.8
```

Fig. 14 result table

B. Ansys 11.0 Output Window



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ANSYS 11.0 Output Window
DESIGN SET    4  IS THE BEST DESIGN WITH MAX_DIF =  9665.3     (FE

*** NOTE ***                              CP =    4697.172   TIME= 1
Begin 1st order iteration 5 of 5 (max)
 Next design is set no.  11
 Best MAX_DIF = 9665.33437 at set no.  4.

BEST RESULTS FOR CURRENT ITERATION: MAX_DIF =  6303.8

DESIGN SET    4  IS THE BEST DESIGN WITH MAX_DIF =  9665.3     (FE

>>>>>>  SOLUTION HAS NOT CONVERGED AFTER    5 ITERATIONS  <<<<<<
 BEST VARIABLES ARE

                      SET  4
                  F (FEASIBLE)
SMAX     (SV)         95594.
R        (DV)         40.000
COIL_RAD(DV)          4.6657
MAX_DIF (OBJ)         9665.3
                  e
                  i
******  SUMMARY OF CONSTRAINTS (IF ANY) EVALUATED AT THE CURRENT O
N   ******        R

 STATE VARIABLE  SMAX     =  95593.7     IS NEAR LOWER LIMIT   1000
OLERANCE   10000.0

X AXIS LABEL = NUMBER OF ITERAIONS

Y AXIS LABEL = SPRING RADIUS AND coil_radius
```

Fig. 15 output table

V. CONCLUTION

Shock absorber 3D model is created using CATIA V5. The parameterized spring dimension was modelled in ANSYS APDL. Structural analysis and optimization are done on the shock absorber by varying coil radius and spring radius. The analysis is done by considering loads, bike weight and single person. Structural analysis is done to validate the strength and optimization is done to determine the better dimension of spring to carry applied load.

TABLE 3
Result

Initial range of spring parameters
Coil radius of the spring = 3.00 mm to 8.00 mm Spring radius of the system = 35.00 mm to 45.00 mm
We get the optimized value of the spring to carry a load of sudden impact are
Coil radius of the spring = 4.67 mm Spring radius of the system = 40.00 mm

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