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Modeling and Analysis of Two Wheeler Shock Absorber for Optimum Performance

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ABSTRACT
The suspension system plays a major role in every automobile to maintain comfort, vehicle position and ride quality. The commercial light vehicles nowadays use helical coil springs in two wheelers as suspension system. The current work is carried out on modeling and analysis of suspension modified spring provided axial taper (varying mean coil diameter along the axis) to replace the existed helical spring used in popular two wheeler vehicle. The modification applied to the existing model is to achieve higher stiffness and thereby to attain effective performance of the system. The modeling of spring is developed in *CATIA-V5* and structural analysis is carried in Ansys 14. Series of spring models, providing taper of 2^0, 4^0 and 6^0 are attempted, analyzed. Thus obtained results of stresses and deflections of all the considered models are compared with existing spring model (Zero taper) to verify best spring design of shock absorber.
Keywords:- Absorber

I. INTRODUCTION

The suspension system allows the wheels to bounce up and down on rough roads while the rest of the remains fairly steady. It also allows the vehicle to corner with minimum roll or tendency to loose traction between the tyres and the road surface. The basic elements of a suspension system are springs and shock absorbers. This paper is mainly based on spring. Springs are mechanical shock absorber system. A mechanical spring is defined as an elastic body which has the primary function to deflect or distort under load, and to return to its original shape when the load is removed. The main function of the suspension system is to reduce impacts. Over a period of time the methods on damping suspension systems have changed a lot.

Design in an important industrial activity which influences the quality of the product. The Shock absorber coil spring is designed by using the modeling software CATIA-V5. In modeling the time is spent in drawing the coil spring model and the risk involved in design and manufacturing process can be easily minimized. So the modeling of the coil spring is made by using CATIA-V5. Later this model is imported to ANSYS-14 for the analysis work. The ANSYS-14 software is used for analyzing the component by varying the taper and the results are observed. A solver mode in ANSYS-14 software calculates the stresses and their relation without manual interventions thereby reducing the time compared with the manual theoretical work.

II. GEOMETRIC DIMENSIONS & MATERIAL PROPERTIES OF CONSIDERED SHOCK ABSORBER SPRING

Material steel spring (rigidity modulus) G = 78600 N/mm^2
Mean diameter of coil D =40mm
Diameter of wire d =8mm
Total no coils, n1 =18
Height, h = 210mm
Outer diameter of spring coil, D_0 =D + d =48mm
No of active turns, n =16
Weight of the bike = 131kg
Weight of bike + person =250kg
W = 250kg = 2452.5 N

Using above dimensions the modeling of the shock absorber spring is carried using CATIA-V5, explained in the next section.

III. MODELING AND ANALYSIS

Start CATIA-V5, and select specific workbench (Part Design). The basic requirement for creating a solid model is a sketch (Fig:3.1). The sketch required is drawn using tools in the workbench. The tools in the part design workbench

are used to convert sketch into sketch-based feature. Thus model (Fig: 3.2) is saved in STP format.

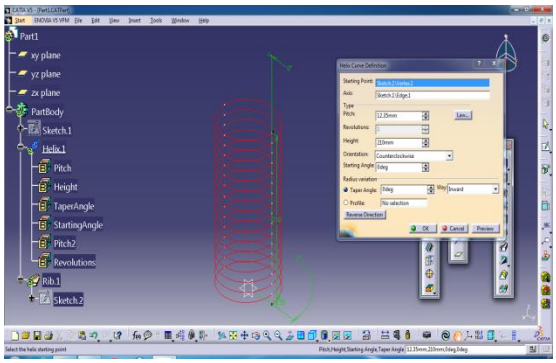

Fig 3.1: Sketcher of the shock absorber spring in CATIA-V5

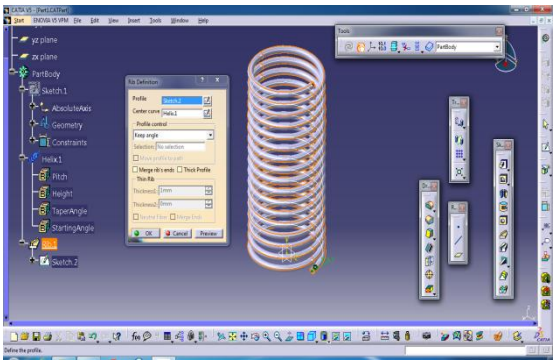

Fig 3.2: Model of shock absorber spring in CATIA-V5

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

Following the above mentioned procedure the deflection and stress developed in the shock absorber springs under test are explained here in detail.

After creating model using CATIA-V5 then model is saved in the form of STP file format.

Select CFX in the ANSYS-14. There after import created model into ANSYS-14, followed by meshing (select Body and apply). Then giving meshing element size and clicking on generate mesh results in meshing of our model as follows shown in Fig: 3.3.

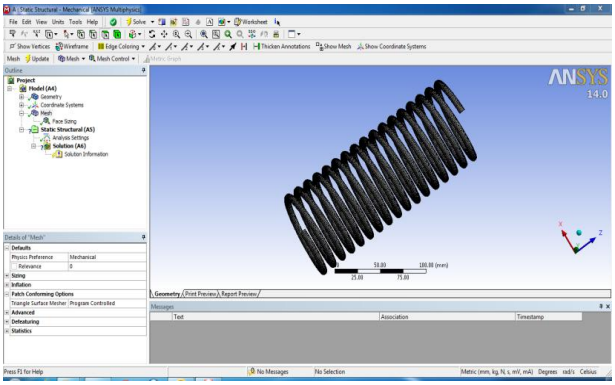

Fig 3.3: Meshed model of shock absorber spring in ANSYS 14.0.

Next entering "Setup" and choosing domain followed by entering boundary conditions of the spring is done. Fixed condition at one end of the spring and free at the other end with loading is considered. Then in solver control unit, numbers of iterations are selected and thereby to start run is selected. After completion of solution, it will be displayed that "program is completed" and then we just click on OK.

Repeating the procedure using series of springs (without and with different taper), the stress and deformation developed are observed, explained in the next section in detail.

IV. RESULTS AND DISCUSSION

Conducting series of numerical tests gives the deflection results are as follows. The analysis is carried for springs with different taper (gradually varying diameter along the length). The springs under test are represented as follows.

Spring-I	0^0 Taper
Spring-II	2^0 Taper
Spring-III	4^0 Taper
Spring-IV	6^0 Taper

4.1 Deflection in Shock Absorber Spring:

The deformation profile obtained using different springs through numerical analysis are shown in Fig 4.1 to Fig 4.4.

The deflection occurred in the shock absorber springs considered for tests are different as shown in fig. Also it is found that the deflection is higher at the inner diameter (surface) compared to the external surface, means the load though assumed to be uniformly distributed at all points theoretically but it is a eccentric load that twist the wire diameter

towards center. This is due to the twisting of the wire diameter towards the center from the point of load application towards the other end. Due to this the spring wire cross section of a coil gets in touch to its adjacent coil at the inner surface. Therefore the deflection is higher at the inner surface.

The deflection of the shock absorber spring with application of load at one end and keeping fixed at the other end for all considered springs with different taper (having gradually varying diameter) from one end to the other. The red colour shows the maximum deflection zone, which occurs at free end (loaded end) of the spring and decreases gradually to zero towards the fixed end.

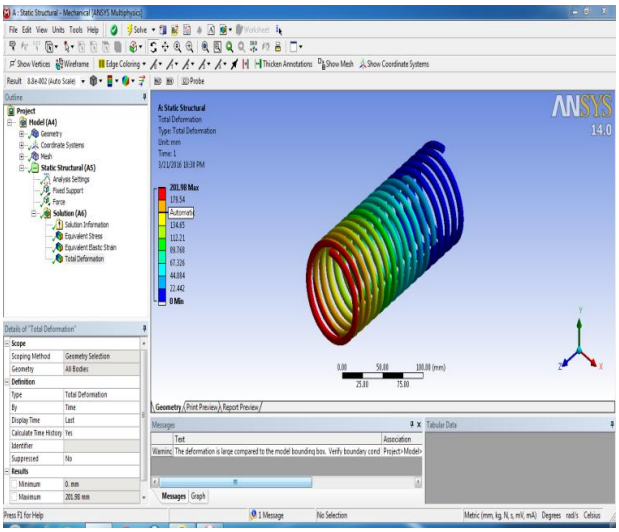

Fig 4.1: Deformation of spring-I shock absorber in ANSYS 14.0.

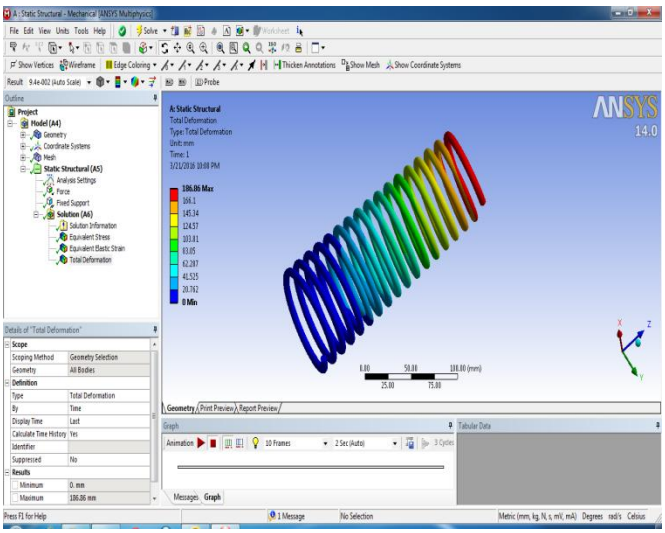

Fig 4.2: Deformation of spring-II shock absorber in ANSYS 14.0

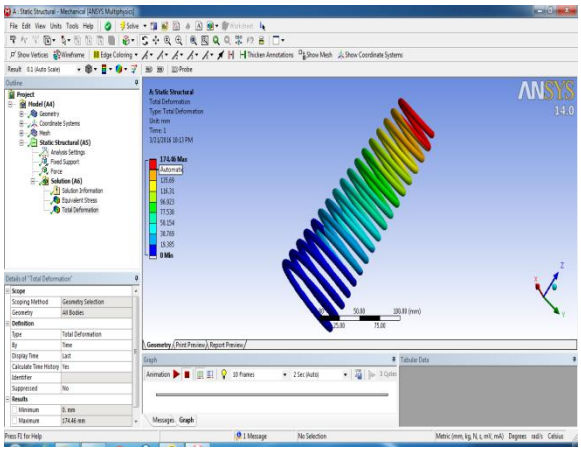

Fig 4.3: Deformation of Spring-III Shock absorber in ANSYS 14.0.

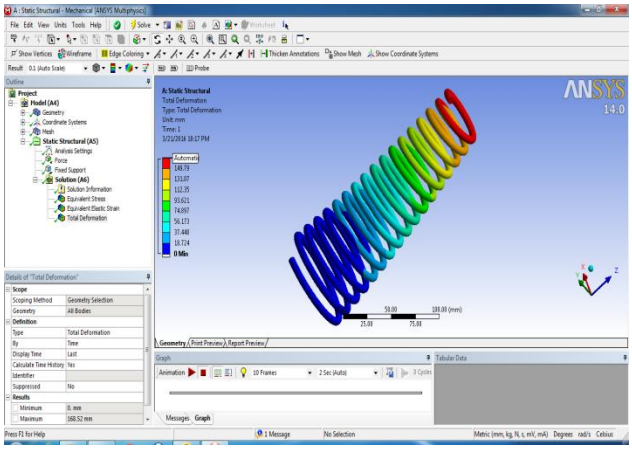

Fig 4.4: Deformation of spring-IV shock absorber in ANSYS 14.0

The effect of taper angle on deflection of the shock absorber spring is shown in Fig 4.5.The maximum deflection is observed to be decreasing with increase of taper. The maximum deflection is found to be 0.201, 0.186, 0.174 and 0.16mm for springs with corresponding taper angles of 0^0, 2^0, 4^0, and 6^0. Results show that there is reduction of deflection by 7.4% by proving 2^0 taper angles and it is 13.4% with 3 it is 20.3% with 6^0compared to the spring without taper (0^0). Finally these results shows that shock absorber with 6^0 is good in yielding lower deflection. But too much increase in taper is not preferred as it reduces the flexibility of providing the spindle assembly.

The obtained results show reduction in deflection which gives better performance of the shock absorber by providing taper and also the self weight of the spring reduces due to reduction in the material which in turn reduces the cost (economical).Even the reduction in self weight helps in increasing the vehicle mileage. Also due to irregularities on the road surface the load may not be pure compression which may leads to buckling of the spring that leads to dangerous for the shock absorber to the spring to bear the load (vehicle and persons together). Therefore providing taper supports in making the load to be compression as it tends to pointed to the centre of the spring.

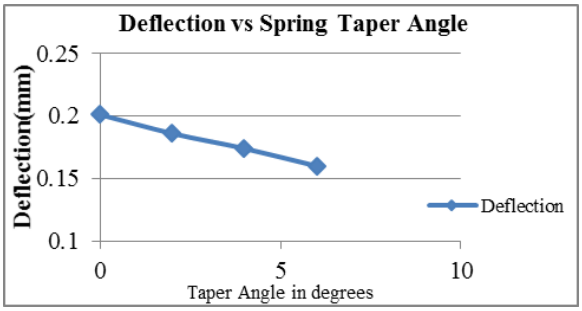

Fig 4.5: Graph between Deflection Vs Spring Taper Angle.

4.2 Stress Development in Shock Absorber Spring:

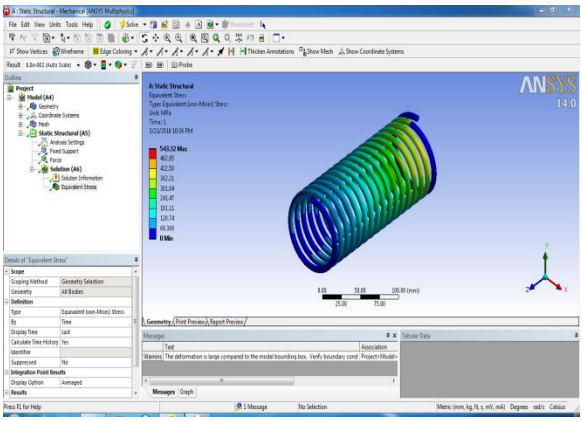

Fig 4.6: Stresses developed in shock absorber spring-I in ANSYS 14.0.

The stress development along the spring profile of the shock absorber without and with different level of taper is shown in Fig 4.6 to Fig 4.9. Both ends of the spring are under minimum stress development and middle part is under action of higher stress values. It is found that the heavily stressed coil is those which are adjacent to the fixed edge and decreases towards free end of the shock absorber spring profile. The maximum stress developed in the spring is found to be 543.32, 541.95, 540.32 and 531.44 N/mm^2 for the spring profile with corresponding taper angles of 0^0,2^0,4^0,6^0. From these it is found that the maximum stress is decreasing with increase of taper angle. The maximum stress developed is reduced by 2.1% by providing a taper of 6^0 compared to the spring without taper. Though the maximum stress developed is around 540N/mm^2, it is not clearly visible in the result diagrams because these heavily stressed points are occurred at the inner side of the spring. But the majority part of the spring profile at the external surface is developed by an amount of 393, 388, 384 and 376 N/mm^2. Even though the external surface is developed by stress lower than the stress at the inner surface for the same reason explained in the previous section. But in actual practice the external surface of the shock absorber is exposed to outside atmosphere which results in development of higher stress than expected theoretically (material properties changes). Therefore looking at these stress values developed at the outer surfaces it is found that 4.3% of reduction in stress development occurred by providing taper of 6^0.

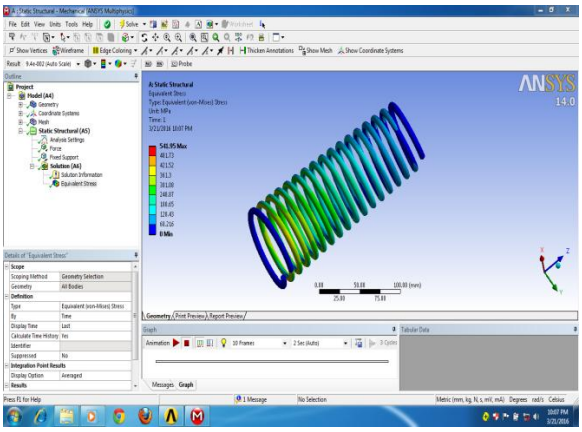

Fig 4.7: stresses developed in shock absorber spring-II in ANSYS 14.0

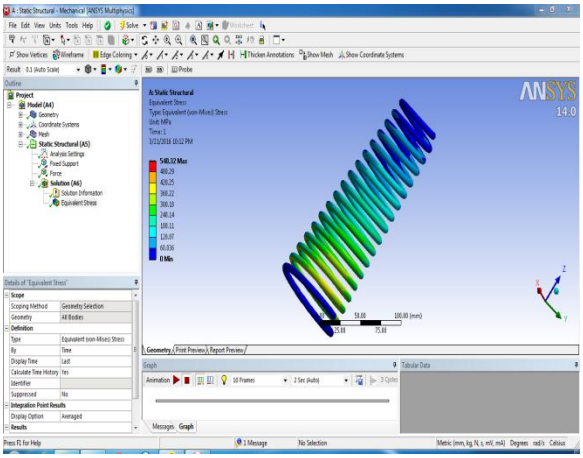

Fig 4.8: Stress developed in shock absorber spring-III in ANSYS 14.0.

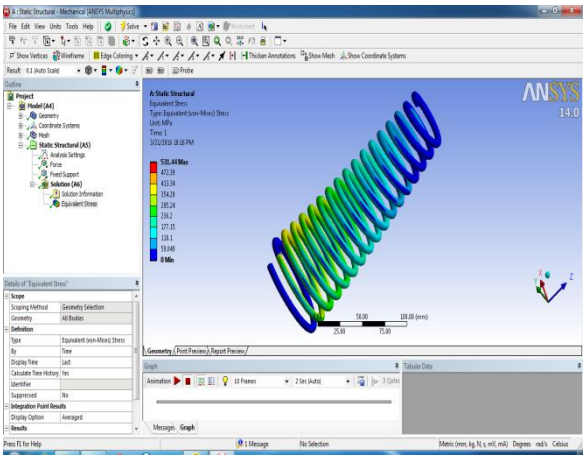

Fig 4.9: stresses developed in shock absorber spring-IV in ANSYS14.0

The effect of taper angle on the stress development is shown in Fig 4.10.The results show that the stress developed is decreasing with taper angle at slow rate up to 4^0 and thereafter falls at fast rate. Taper angle beyond 4^0 taper angle supports the probability of avoiding the eccentric action of the load and thus it gives higher strength.

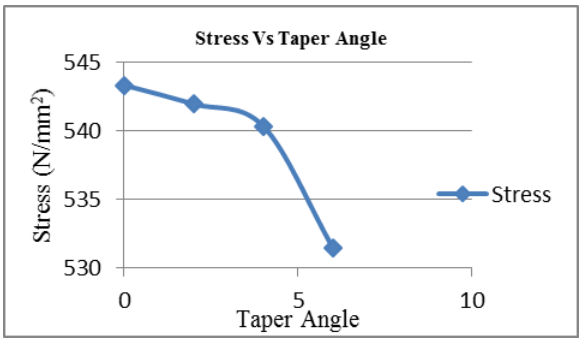

Fig 4.10: Stress Vs Taper angle.

4.3 Design Calculations of shock absorber:

We know that compression of spring (δ) $=WD^3n/G\,d^4$

$$=\frac{2452.5*40^3*16}{78600*8*8*8}$$

δ = 7.8 mm

Compression of spring (δ) = 7.8 mm

Spring index (c) = D/d = 40/8

= 5

Solid length (L_s) = n_1 * d = 18*8

L_s = 144 mm

Free length of spring (L_F) = Solid lengh + Maximum compression +Clearencebetween adjustable

$L_F = L_s + \delta + \delta*0.15$

$L_F = 144 + 7.8 + 7.8*0.15$

$L_F = 152.97$ mm

Spring rate (K)= W/δ = 2452.5/7.8

K = 314.40

Pitch of the coil $P = \frac{LF-LS}{n1} + d$

$$=\frac{152.97-144}{18} + 8$$

P = 8.49 mm

Stress in helical spring: maximum shear stress induced in the wire

$T = K_S*\frac{8WD}{\pi d^3}$

$K_S = \frac{4C-1}{4C-4} + \frac{0.615}{C}$

K_S =1.3105 N/mm^2

τ=639.40 N/mm^2

Buckling of compression spring :

Crippling load under which a spring may buckle

K_L = 0.1 (for hinged end spring)

The buckling factor for the hinged end and built –in end spring

$W_{cr} = K * K_L * L_F$ = 314.4*0.1*152.97

W_{cr} = 4809.37 N

4.4 Comparison of Analytical Results with Numerical Results:

Comparing the deflection results obtained through analytical and numerical methods is shown in Fig 4.11. It is found that deflection in the spring is higher calculated through analytical method compared to that of numerical process. The maximum deflection obtained is 3.618mm and 7.8mm for the shock absorber spring through numerical and analytical process. The difference in

these values is due to certain assumptions considered in analytical process.

Comparison of stress results of analytical and numerical methods is shown Fig 4.12. Through the comparison of the stress obtained through analytical and numerical process shows that the maximum stress developed is 639.4 N/mm^2 and 543.32 N/mm^2. There exists 15% of difference in the results obtained comparing analytical and numerical process. These results show that the numerical process is in good agreement to the analytical process.

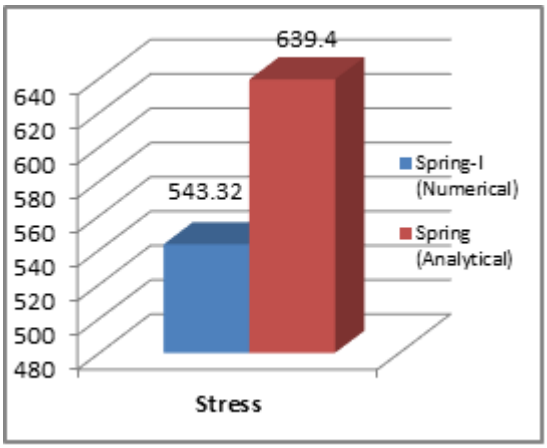

Fig 4.11: Deflection of spring-I (Numerical) and spring (Analytical).

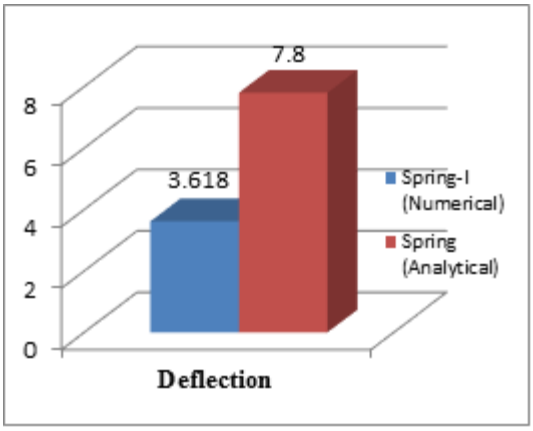

Fig 4.12: Comparison of Spring-I(Numerical) and Spring(Analytical)stresss

V. CONCLUSIONS

Carrying series of numerical analysis of the shock absorber spring providing different taper (gradually varying diameter from one end to the other) and also analytical analysis the following conclusions are drawn.

- The deflection in the shock absorber spring reduces with increase of taper angle of the spring. A maximum reduction of 20.3% in deflection is obtained by providing a taper angle of 6^0 to the shock absorber spring.
- The maximum deflection in the spring took place at the internal surface of helical profile of the spring of shock absorber.
- The maximum stress developed in the spring of the shock absorber also decreases with increase of taper angle. A maximum reduction of 4.3% in maximum stress is obtained by providing a taper angle of 6^0.
- The stress is maximum in the coils next to the fixed edge of the spring of shock absorber.
- The deflection and maximum stress developed in the spring through numerical analysis are valid compared to that of results obtained through the analytical calculations.
- The weight of the spring reduces with provision of taper sized coil for shock absorber that gives an economical product. Also weight reduction improves the vehicle performance in terms of mileage.
- Finally the modified shock absorber spring with 6^0 taper is decided to be optimum in occurring of lower deflection and stress values compared to the existing model without taper.

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