International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 9, September- 2014

Design and Analysis of Front Suspension of Three Wheeler Passenger Vehicle

[1] Sachin N. Lokhande
(ME Design),
Mechanical Department,SAE,Kondhwa,
Maharastra,India

[2]Dr. Dinesh N. Kamble,
Mechanical Depatmentt,
SAE,Kondhwa,
Maharastra,India

Abstract -A variety of models of Three Wheeled Passenger as well as Light Commercial Vehicles (LCV) have flooded the Indian market in the last four to five years which are equally beneficial to the today's transportation business as that of four wheeled vehicles. But in case of three wheeled vehicle it is always very tricky to design front suspension system as it takes care of steering system attached to the same front wheel. To balance the functionality of both suspension and steering system one need to have a very strong supporting structure which gives sufficient strength to the design. It is always economical to have strong design with less weight without compromising its required strength. The Dissertations deals with the optimization of front suspension system of three wheeler passenger vehicle and also suggests modifications to improve the directional stability of the vehicle. The front suspension it optimized in this in order to reduce its weight for the small version of three wheeler passenger vehicle. Another objective of The design of spring is to verify by using customize package of ANSYS, HYPERMESH to perform finite element analysis. The static stress analysis is Perform and the results are compare with theoretical calculations. The experimental investigation is to perform on verified design spring and the results are obtained to find its performance. By using hand calculations, best coil size was finalized for front suspension spring which will balance both ride comfort and handling characteristic of the vehicle.

Key Words: ANSYS, force, Stress, Deflection etc

1. INTRODUCTION

When people think of automobile performance, they normally think of horsepower, torque And 0-100kmph acceleration. But all of the power generated by a piston engine is useless if the driver can't control the car. That's why the suspension system in an automobile is Important and so much attention is given to it. The vehicle suspension system is responsible for the vehicle control, driving comfort and safety as the suspension carries the vehicle body and transmits all the forces between the road and the body.

The job of the suspension system is:

- To maximize the friction between the tires and the road surface
- Provide steering stability with good handling
- To ensure the comfort of the passengers

Rajkumar Roy has studied in Traditional engineering design optimization [1]
Vyankatesh Madane has studied Low Cost Durability Virtual Verification Methodology [2]
Caner Demirdogenhas studied in weight Optimized Design of a Front Suspension Component for Commercial Heavy Trucks. ,[3]
Koona Ramji has studied in Optimum design of suspension system of three—wheeled motor vehicles [4]
Manish Dakhore and Bhushan Bissa "Failure analysis of locomotive suspension coil spring using nite element analysis" [5]
Gajendra Singh Rathore1, Upendra Kumar Joshi2 "Fatigue stress analysis of helical compression spring[6] "

M. Satyanarayana, B. T. N. Charyulu, "Optimization Of Spring Weight Using Genetic Algorithm" [7]

2. PROBLEM STATEMENT

- The detailed assessment of the problem of three wheeler vehicle Suspension system is studied in this Literature .it is Observed that, the vehicle drifts towards one side due to high weight of suspension system. This weight causes the vehicle to drag. This problem can be solved by redesigning and optimizing front suspension spring.

- The design of spring is to verify by using customize package of ANSYS, HYPERMESH to perform finite element analysis. The static stress analysis is Perform and the results are compare with theoretical calculations.

- The experimental investigation is to perform on verified design spring and the results are obtained to find its performance.

- The calculated results are to compare on common scale and the prediction of the spring can be conclude.

3. DESIGN OF SUSPENSION SPRING

Table 3.1- Spring Calculations

Spring index (C)	6.25	
Wahl's stress factor (Kw)	1.24	
stiffness (K)	24.27	N/mm
	2.43	kg/mm
Spring Deflection (Y)	114.50	mm
load (F)	286.25	Kgf
shear Stress (τ)	88.36	Kg/mm^2
Shear strength	74.26	Kg/mm^3
Factor of Safety(F.O.S.)	1.4	
Solid Length (Ls)	120.00	mm
pitch (p)	16.96	17.00mm
Spring Length @max Def.	130.50	mm
Clearance	10.50	mm

Table 3.2 Spring Data

Spring material UTS	143	kgf/mm2
Wire dia. (d)	8.00	Mm
Mean Dia.(D)	50.00	
Free Length(Lf)	245.00	Mm
No. of active coils (Na)	13.50	
Modulus of Rigidity (G)	80000.00	N/mm^2

3.1. Calculation for Spring Stability

The equations for stability help to select the exact diameter, free length during designing of suspension spring .it is always necessary to check the design of the spring is safe or not i.e. the spring is designed will be stable or not. Therefore spring stability calculation is performed to prevent the spring from buckling when the load becomes too large.

a)Critical deflection(y_{cr}): $Lf < c`1\times[1-(\frac{c`2}{\lambda eff})^{\wedge L/2}]$

Where c’1 and c’2 are elastic constants

$c'1 = c`1 = (\frac{E}{2(E-G)})$

and $c'2 = c`2 = \frac{2\times\pi^2(E-G)}{(2G+E)}$

The critical deflection (y_{cr}) is the deflection corresponding to the onset of instability. During the calculation I got the critical deflection value as 212.6 where as the spring deflection value got during designing of the spring is 114.5 which mean that the spring will not become unstable on deflection.

a) $\lambda_{eff}$is the effective slenderness ratio and is given by

$\lambda_{eff} = \frac{\alpha\times Lf}{D}$

b) The above equation contain which is end-condition constant. This depends upon how the ends of the spring are supported. The table gives values of α for usual end conditions. In the equation of critical deflection, when C’2/ λeff2 is greater than unity the spring is absolutely stable. Thus by getting a value of 1.15, this proves that the spring is the spring is stable.

Therefore now the condition for spring stability is

$Lf < (\frac{\pi\times D}{\alpha})\times[\frac{2(E-G)}{2G+E}]^{\wedge 1/2}$

For steel it is, $Lf < 2.63(\frac{D}{\alpha})$ which round to 263mm.

This means that for a spring to be safe (stable) the free length of the spring should be less than 263mm. But our free length is 245mm. thus this mean that our design of the spring is safe.

4. VERIFICATION OF MODIFIED DIMENSIONS USING FEM

4.1. Background

Linear static analysis is carried out to get the desired results.

4.2.Pre-processing

An FEA-based design begins with the selection of the element type, how the model should be constructed, how accurate the results should be, and how fast the model should run. The most accurate FEA results can be obtained by creating 3-D parts of a coil spring and its seats, followed by meshing the parts with 3-D solid element. Finer meshing with higher-order elements will produce more accurate results.

- Save IGES
- Imported on IGES
- Check for model consistency
- Removal of Extra Points

4.2.3. Modelling

The 3-D model of suspension spring was modelled in Pro/ENGINEER software as shown in fig.1 and then imported in ANSYS software.

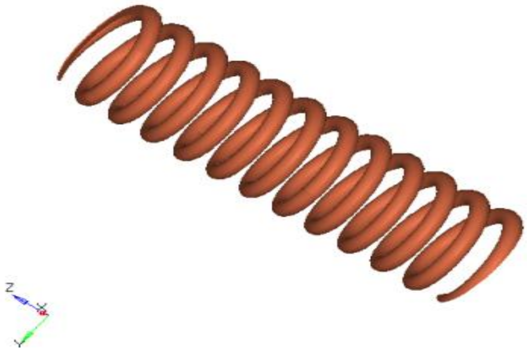


Fig 4.1. Suspension Spring Model

4.3. Meshing

Meshing is done in ANSYS. The suspension spring being a solid component, hence 3d meshing is required. To mesh this component the suspension spring is first meshed in 2d and then converted to 3d. For meshing the following steps are carried out.

4.3.1. Meshining in 2D

Suspension spring is imported in Hyper Mesh and 2D meshing is done. To create quality meshing surface of the spring is divided in to number of surfaces as shown in Fig.2. After dividing the surface component collector is created to apply 2D meshing. Then 2D meshing is created using quad4 shell elements and having an element size of 2 as shown in fig.3.

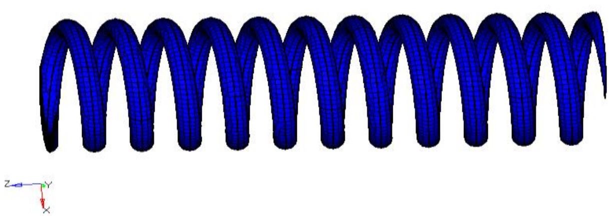


Fig 4.3. 2D Meshing of Suspension Spring

Fig 4.4.Meshed model of Suspension Spring

4.3.2. Convert to 3D mesh:

The suspension spring which is previously meshed by quad 2D elements then are meshed by tetra 10 elements as shown in fig.4. Then after quad meshing of 2D elements are deleted

4.3.3. Quality Check

The following quality checks are carried out in during to process of meshing.

Table 4.1-Element Quality check

Warpage	<10°
Aspect	<5
Skew	< 45°
interior angles	45°< Quad < 135°
	20°< Tri < 130°
Jacobian	> 0.6

4.3.4. Connections

The bolt connections were modelled by rigid elements as shown in fig. This gives same effect as that of the spring mounted in front suspension system.

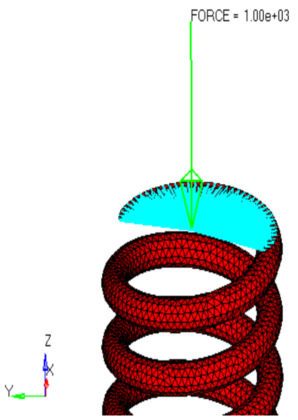


Fig 4.5.Connected by Rigid element

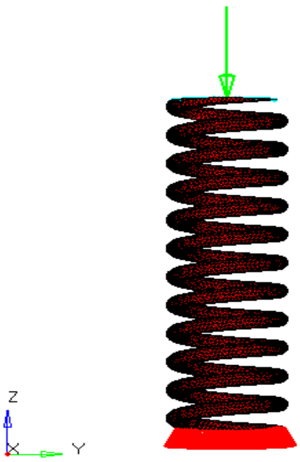


Fig 4.6.Boundary Conditions

4.4.1. Loading Static Calculations

Load case 1) Vertical Load = 1000N. The vertical loads are applied on the spring centre. Suspension spring is constraint as per above and 1000 N in Vertical is applied at spring centre as shown in fig6

4.2.2. Solutions

After performing above pre-processing steps analysis is started. The static analysis is done in radios solver.

4.5. Post Processing

After the solution is achieved the results and the stress plot and deflection plot are viewed and judged for the safety conditions. In the figure below the deflection plot of suspension spring shows spring deflection of 27.8mm under a vertical load of 1000N and a maximum stress of 642.6MPa is observed at the inner section of the spring.

5. EXPERIMENTAL ANALYSIS OF SUSPENSION SPRING

The experimental investigation is performed on closed coiled helical spring on spring compression test rig at Royal Technology Pvt Ltd Ahmednagar. The details of the investigation is reported in this chapter

5.1 Objective of Experimentation

The stress analysis of a helical coil compression spring, which is employed in three wheeler's auto-rickshaw belonging to the medium segment of the Indian automotive market. In the design of this kind of spring both the elastic characteristics and the fatigue strength have to be considered as significant aspects. The modified spring is manufactured as per the dimensions obtained at Royal Technology Pvt Ltd Ahmednagar. The spring stress and deflection is obtained and verified by software. This spring testing is Perform for finding its behavior in the practical application. The Spring testing is carried out under atmospheric conditions.

The parameter study is performed for the variation which is studied in software verification. The overall objective is to determine the stress and deflection with respect to the load variation

Fig 5.1.Experimental set up of suspension spring

6. RESULTS & DISCUSSION

The existing suspension spring having wire diameter 10.5mm, mean coil diameter 76mm and free length 305mm was modified to wire diameter of 8mm, mean coil diameter of 50mm and free length 245mm.

Table6.1.-Comparison between existing and modified dimensions

Parameter	Existing	Modified
Wire dia. (d)mm	10.5	8
Mean Dia.(D)mm	76	50
Free Length(Lf)mm	305	245
Weight (W) kg	2.4	1.7

6.1 Software Verification

The load variations are performed 7000N to 1300N.these load conditions are with reference to the vehicle specification specified by the manufacture various modes of spring deflection are studied along with determination maximum stress. The Different range of vertical loads is applied on the spring centre. As per mentioned constraint. The different coloured shades in the result image shows the overall deflection and stress distribution along the suspension spring under the load applications of 1100N. The red regions in shows the maximum stress value while blue indicate the minimum stress value. The deflection plot of suspension spring shows spring deflection of 31mm under a vertical load of 1100N and a maximum stress of 407MPa is observed at the inner section of the spring. The results are shown in Fig 6.1.

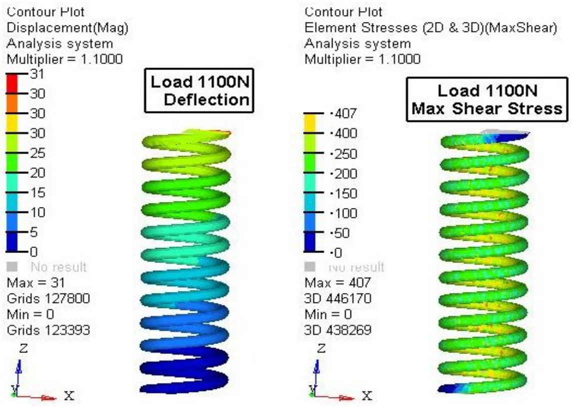


Fig 6.1.Deflection(mm) and Shear stress (Mpa) for 1100N

The Force is convenient parameter to know about deflection of the spring and stresses developed for different loading conditions. The maximum shear stress and deflection result increases as load on the suspension spring increases. Suspension spring shows spring deflection of 32mm under a vertical load of 1150N and a maximum stress of 425MPa is observed at the inner section of the spring. The ANSYS results are reported in Fig 6.2

The force is selected as an input parameter to select optimum design which gives required deflection without exceeding the stress level above yield strength of the spring material. The application of load increases under same constraints. The deflection plot of suspension spring shows spring deflection of 33mm under a vertical load of 1200N. The maximum stress for load 1200N is of 444MPa at the inner section of the spring. The results is shown in Fig 6.3

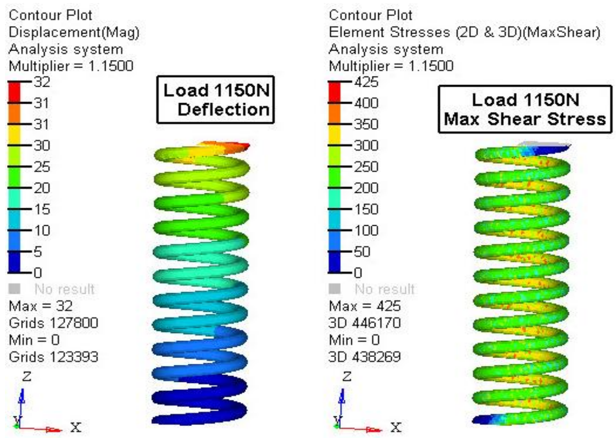
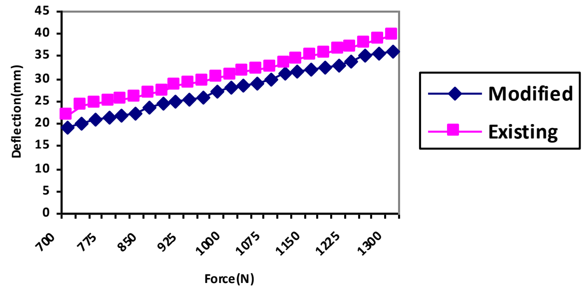


Fig 6.2. Deflection(mm) and Shear stress (Mpa) for 1150N

6.2 Software and Experimental Comparison

The verification by the software results and the experimental investigation is studied and compared..The software results show a good agreement with the experimental trend. The deviation for the deflection obtained against the load applied is obtained in the range of 5% to 10% as shown in Fig 6.6. The recommended deviation as per the literature is also in the same range of 5 to 10 %..The software prediction reports the trend line of Y=0.7046x+18.58 where as the experimental trend is reported as Y=0.7046x+16.58 .The further predictions beyond the scale values of the figure can be obtained by using the trend line equation.

The deviation is obtained in the range of 2% to 3% for development of Von Misses stress against force applied. The recommended deviation as per the literature is 6 to



10%. The software prediction reports the trend line of Y= 16.06x+433.14 where as the experimental trend is reported as Y=16.04x+419.18 as shown in Fig 6.7 .The verification by the software results and the experimental investigation is studied and compared. The software results show a good agreement with the experimental trend. The further predictions beyond the scale values of the figure can be obtained by using the trend line equation.

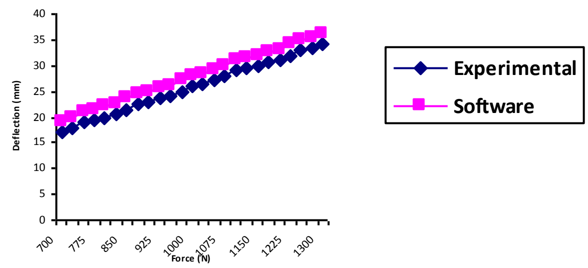


Fig.6.6.-Force (N) Vs Deflection (mm)

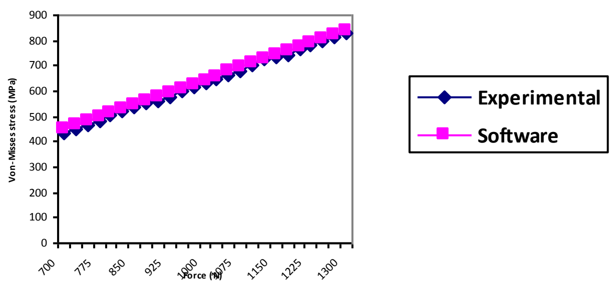


Fig 6.7.-Force (N) Vs Von-misses stress(Mpa)

6.3 Software comparison for Modified and Existing Spring

The verification by the Existing results and the Modified investigation is studied and compared. The Modified results show a good agreement with the existing trend. The deviation is obtained in the range of 8% to 10% .The recommended deviation as per the literature is 6% to 10%.The Existing prediction reports the trend line of Y=0.6867x+22.00 where as Modified the trend is reported as Y= 0.704x+18.58 . The further predictions beyond the scale values of the figure 6.9 can be obtained by using the trend line equation.

The verification by the Existing results and the modified investigation is studied and compared. The modified results show a good agreement with the existing trend. The deviation is obtained in the range of8.68% to.10%.The recommended deviation as per the literature is 6 %to 10%.The Existing prediction reports the trend line of Y=9.39x+300.2 where as the modified trend is reported as.

6.4 Theoretical and Experimental Comparison for modified suspension

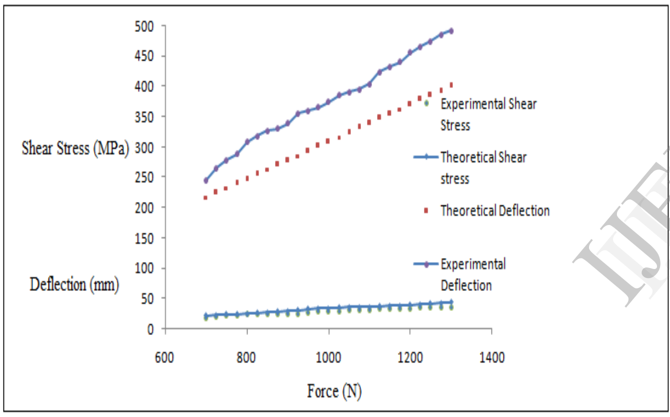


Fig 6.12.Force (N) Vs Shear stress (Mpa) And Deflection (mm)

The fig 6.12 shows the Force Vs shear stress and deflection results. The verification by the Theoretical results and the experimental investigation is studied and compared for shear stress and deflection. The Experimental results show a good agreement with the theoretical trend and are in the range of minimum 10% for shear stress and 2 % for Deflection. The further predictions beyond the scale values of the figure 6.12.are obtained by using the trend line equation.The conclusion remarks of the investigation is reported in the further chapter

7. CONCLUSION

1. The spring of the suspension system is redesigned with respect to stability equation. The dimensions changes from 10.5mm wire diameter and 76mm mean coil diameter to 8mm wire diameter and 50mm mean coil diameter.
2. The weight reduction is achieved to 29.16% to improve the ride comfort and handling characteristic of the vehicle.
3. The stress analysis of springs employed in the Three Wheeler Passenger front automotive suspension is presented and discussed. The static stress analysis using finite element method is done in order to find out the detailed stress distribution of the spring. It is observed that the shear stress calculation is more significant in the design of helical compression springs.
4. The obtained modified dimensions are studied and verified by using ANSYS
5. Comparison of the theoretical obtained result by the shear stress equation to the Finite Element Analysis result of helical compression springs is the mode of our present work. Suspension spring gives the various Optimum spring deflection and maximum stress readings under a load ranging from 7000N to 1300N.
6. In the experimental testing of suspension spring the load variations are performed 7000N to 1300N. These load conditions are with reference to the vehicle specification specified by the manufacture various modes of spring deflection are studied along with determination maximum stress.
7. The results are compared on common scale and the acceptance of modification shows good agreement in the range of 5 to 8 %.
8. The trend line equations are suggested in result comparison for the further prediction of the behavior

8. FUTURE SCOPE

The work may be extend to optimize and redesign the Steering column and suspension arm are by using topology optimization which results in considerable material saving without compromising its required strength. The change of material can be thought of to get better results.

9.REFERENCES

1 Rajkumar Roy a, ,Srichand Hinduja “Recent advances in engineering design optimization: Challenges and future trends”
2 Vyankatesh Madane “Low Cost Durability Virtual Verification Methodology ”7.2.4 2011-26-0015
3 Caner Demirdogen, Jim “Ridge Weight Optimized Design of a Front Suspension Component for Commercial Heavy Trucks” 2004-01-2709
4 Koona Ramji1, V. K. Goel “Optimum design of suspension system of three—wheeled motor vehicles” Vol. 3 (2007) No. 1, pp. 36-44
5 Manish Dakhore and Bhushan Bissa “Failure analysis of locomotive suspension coil spring using nite element analysis” Volume II, June’13 ISSN – 2320-0073.
6 Gajendra Singh Rathore1, Upendra Kumar Joshi2 “Fatigue stress analysis of helical compression spring “a review Issue 3, Vol.2 (May 2013).
7 M. Satyanarayana, B. T. N. Charyulu, “Optimization Of Spring Weight Using Genetic Algorithm” Vol. 1 Issue 9, November- 2 012