Static & Dynamic Analysis of Open Coil Helical Spring used in Two Wheeler Application

***Vikas Shakya*[1], *Dr. P.L.Verma*[2], *Dr. Pankaj Agarwal*[3], *Anil Chourasia*[4]**
M.E. Scholar[1], Professor[2], Professor[3], Professor[4]
[1,2,3,4]Department of Mechanical Engineering, [1,2,3]SATI Vidisha, [4]LNCT Bhopal
[1]shakyavikas1987@gmail.com, [2]vermapl@rediffmail.com, [3]dr_pankajagarwal@rediffmail.com,
[4]achourasia0112@gmail.com

Abstract: In this paper suspension spring of a 160cc 2-wheeler is analyzed and optimized for its performance. For this study the diameter and the material of the coil wire for suspension is changed and its effect is noted. In this study three materials were studied that is ASTM A227 hard drawn spring steel material, carbon fibre Material and titanium alloy. The results were obtained for all of these materials and based on the results it can be said that spring made of carbon fibre material gives the best results. The springs were tested under both static as well as dynamic loading, and in all of the tests Carbon fibre spring proved to be best.

ISSN 2454-308X
9 770024 543081

Keywords: Suspension, Open coil spring, Carbon fiber, Dynamic loading etc.

I. INTRODUCTION

When driving a car, the suspension spring bears the effect of load oscillations and high-frequency shock load and functions as a shock absorber and shock absorber. Therefore, the quality of the suspension plays a crucial role in the stationary and safety of the car. The helical spring has a good flexibility and can absorb a lot of mechanical energy. It is widely used as a car suspension, especially in the suspension of the light car and the central bus.

The springs are mechanical shock absorbers. A mechanical spring is defined as an elastic body whose main function is to bend or deform under the load and return to its original shape during load removal. The springs are used primarily in the industry to absorb the energy of the stick and bring the piece back to its original position of movement for a given function.

Finite element analysis tools have the enormous advantage of allowing design teams to consider virtually any molding option without the cost of production and machine time. The ability to test new concepts or concepts on the computer offers the possibility of eliminating problems before starting production. In addition, designers can quickly and easily determine the sensitivity of certain shape parameters to the quality and production of the finished part. The leaflet model is created by modeling software such as Pro-E, Catia and imported into the analysis software, and loading, the constraints are assigned to the imported model and the result is evaluated by the post-processor [1]. The different comparative results of the steel leaf spring and the compound leaf spring are obtained to predict the advantages of the leaf spring composed for a vehicle.

Suspension system of automobile

The suspension of the car is mounted on the axes, not coordinated, but rather a sort of springs. This is done to separate the vehicle body from obstacles in the road, which can be like Bob, Pitch, Roll or Influence. These slopes provide the climb to an uncomfortable ride and also cause further extension in vehicles. As part of the suspension, the vitality of the breathtaking road causes the influence of spring. These movements are limited to a reasonable value by a damper, commonly called a guard.

Automotive springs must be exposed to very high workloads. The structural reliability of the spring must therefore be guaranteed. For this purpose, the analysis of the static stress was performed using the finite element method to determine the detailed distribution of the stresses of the spring [2]. To extend life instead of today's spring, the coaxial spring (series) is analyzed. Factors influencing the fatigue life of this compression spring are also provided [3]. Alternatively, the project may include selecting a new material that has a better combination of properties for a specific application; The choice of material can not be carried out without taking into account the necessary production processes (eg molding, welding, etc.) which are also based on the properties of the material. Or, ultimately, the project could mean developing a process to make a material with better properties [4]. To predict the possible positions of the defects in the helical compression springs used in the fuel injection system for the entire length of the internal spring, finite element analyzes were performed using ABAQUS 6.10 [5]. Weight reduction is a necessity of the automotive industry. The springs must therefore be designed for higher loads with reduced dimensions. This requires a critical design of the coil springs. This leads to critical materials and production processes. Decarbonisation, which was not a major problem in the past, is now essential for better spring design [6]. Spring combination with steel and composite material, d. H. Fiberglass epoxy resin should be used instead of conventional spring steel [7] Over the years, researchers have provided various research methods such as theoretical, numerical, and experimental. Researchers use theoretical, numerical and FEM methods. The study concludes that the finite element method is the best way to solve numerically and calculate fatigue stress, the life cycle and the cutting force of the helical compression spring.

Design of composite helical spring.

The principle of conventional spring design is used for the design of composite springs. Stiffness and stress are the important parameter. The primary reaction force on the cross section of the coil is a twist that creates a shear stress in the coil. For homogeneous and isotropic materials, the "k" stiffness and the maximum cut resistance τ_{max} are approximate as [9]:

$$k = \frac{F}{y} \tag{1}$$

$$y = \frac{5.575 F D^3 \mathrm{Na}}{G b^4} \tag{2}$$

$$K_w = \frac{4C-1}{4C-4} + \frac{0.615}{C} \tag{3}$$

$$\tau_{max} = \frac{2.4\,FD}{b^3} K_w \tag{4}$$

$$C = \frac{D}{b} \tag{5}$$

Where F is the applied force, y is the deflection, D is mean coil diameter, G is shear modulus of the material, b is wire width, Kw is wahl factor. C is the spring index. The spring with square section is shown in Figure. 1.

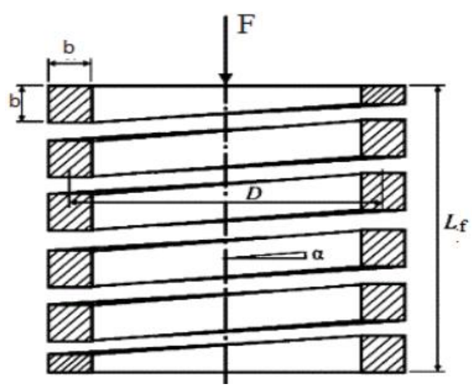

Fig1: Helical spring with square section

The spring rate should be between 15% and 85% of their total deflection [8]. The following research will be used to better understand the different aspects of the project:
In the research [1], the author highlights a point relating to the analysis of the fatigue stress of the spring used in the car suspension system. Its analysis is done theoretically, experimentally and numerically using various software, but the MEF is the best analytical tool.

Research [2] focuses on stress analysis of a helical compression spring, used in the three-wheeled self-thrust. This particular elastic property is a consequence of the research effort necessary to reduce the mass of typical components of the automotive industry, these springs must withstand very high efforts. The structural reliability of the spring must therefore be guaranteed. To do this, the analysis of static stress was performed using the finite element method.
In [3], the research focuses on the quantification of the analysis of the life of a spring. The experiments are performed using the fatigue fatigue testing machine (M08). Modeling is done with CATIA V5 and ANSYS. The analysis is performed with HYPERMESH as a NASTRAN preprocessor as solver and Hyperview as a postprocessor.
In [4] materials are sometimes selected by trial and error or simply for what has already been used. Although this approach works frequently, it does not always lead to optimization or innovation. The advent of computers has revolutionized the design process. Now you can make design changes and quickly create prototype components with very little effort.
In the research [5], the results of the simulation show a vibrational behavior of the stresses along the internal length. It was confirmed that the oscillation was due to the bending associated with the compression. It was also shown that the curvature was due to the geometry of the springs. The shear stresses along the entire length of the spring have proved to be asymmetrical with the local maxima at the beginning of each central winding. The asymmetry was less than 360 degrees due to the end coil.
The research report [6] is a review of the fundamental characteristics of the stress distribution of coil springs. A detailed discussion of the parameters influencing the quality of the coil springs is also presented. Factors affecting the helical spring resistance, F.E.A. The researchers' approaches to the analysis of helical springs are also being studied
In research [7], helical spring modeling was performed by software and simulations were performed with ANSYS to predict stress, to weaken the indicated loads. It has been found that the stresses developed in a conventional steel helical compression spring are more compared to the stresses developed in the composite helical compression spring.

II. METHODOLOGY

Steps of working

Step 1: Collecting information and data related to Suspension.
Step 2: A fully parametric model of the Suspension Spring is created in CATIA V5R20
Step 3: Model obtained in Step 2 is analyzed using ANSYS 15. (Static Structural & Explicit Dynamics) to obtain the deformation and maximum stress.

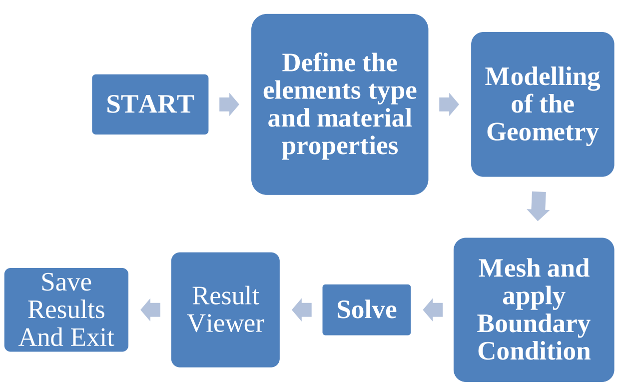

Fig 2: Setup of Working

Finite element analysis

Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. Finite element analysis shows whether a product will break, wear out, or work the way it was designed. For the present work ANSYS 15.0 software is used.

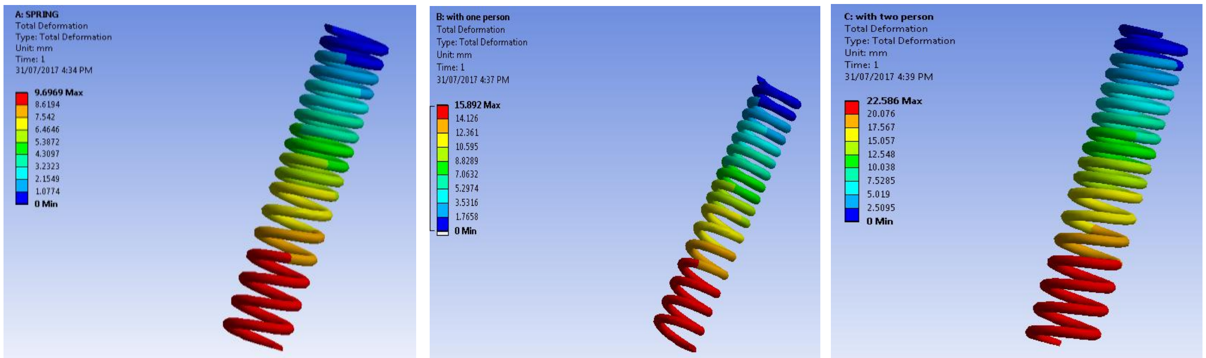

Fig 3:Total Deformation a) Bike only b)Bike +1 person c) Bike +2 person

The deformation occurring in the spring due to the static load of bike, bike with one person and bike with two person is found to be 9.69mm, 15.89 mm, and 22.58mm respectively while the von mises stress obtained for the same are 287.17Mpa, 470.64Mpa and 668.87Mpa respectively.

In order to test the behavior of the suspension spring under dynamic load of 838.5 N **EXPLICIT DYNAMIC analysis** is also performed for the spring shown in Fig:4 and 5.

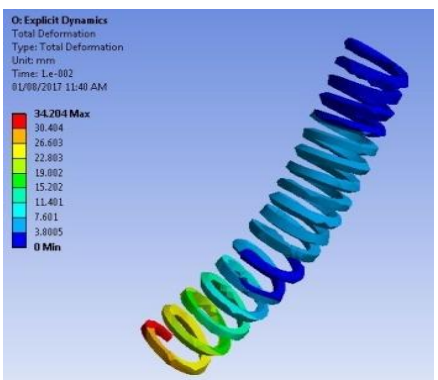

Fig:4 Deformation in original spring under dynamic load

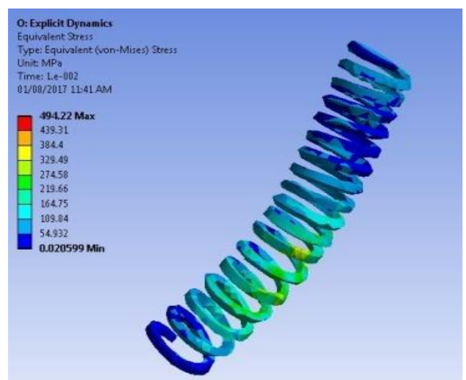

Fig: 5 Von-mises Stress in original spring under dynamic load

PROPOSED DESIGN 1:

FEM analysis for proposed design-1 with varying loads:

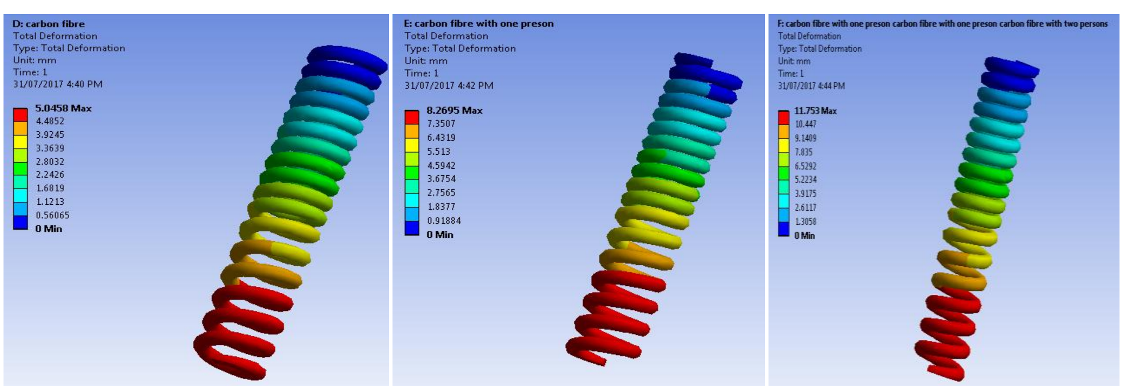

Fig 6:Total Deformation a) Bike only b)Bike +1 person c) Bike +2 person

The deformation occurring in the spring due to the static load of bike, bike with one person and bike with two person is found to be 5.04mm, 8.26 mm, and 11.75mm respectively while the von mises stress obtained for the same are 131.63Mpa, 215.73Mpa and 306.56Mpa respectively.

In order to test the behavior of the suspension spring under dynamic loading condition EXPLICIT DYNAMIC analysis is also performed for the spring for maximum load condition. The results of the analysis are presented below in Fig 7:

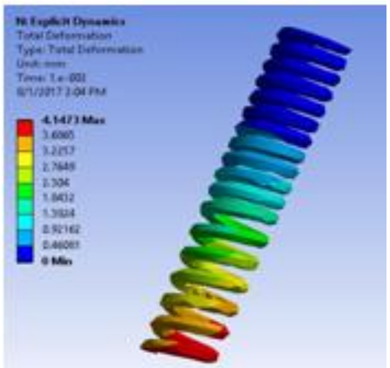

Fig 7: Deformation obtained in the Proposed design-1 spring under dynamic load of 838.5N

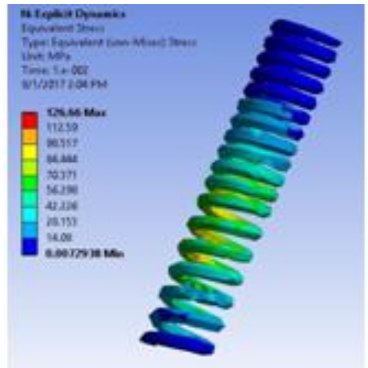

Fig 8: Von-mises Stress obtained in the Proposed design-1 spring under dynamic load of 838.5N

From the fig presented above it can be seen that the max deformation occurring in the spring at the end of the study is 4.14mm and max von-mises stress obtained are 126.66Mpa.

PROPOSED DESIGN-2

The FEM analysis is carried out for the Proposed Design-2 of the spring with Titanium Alloy material **with varying loads.**

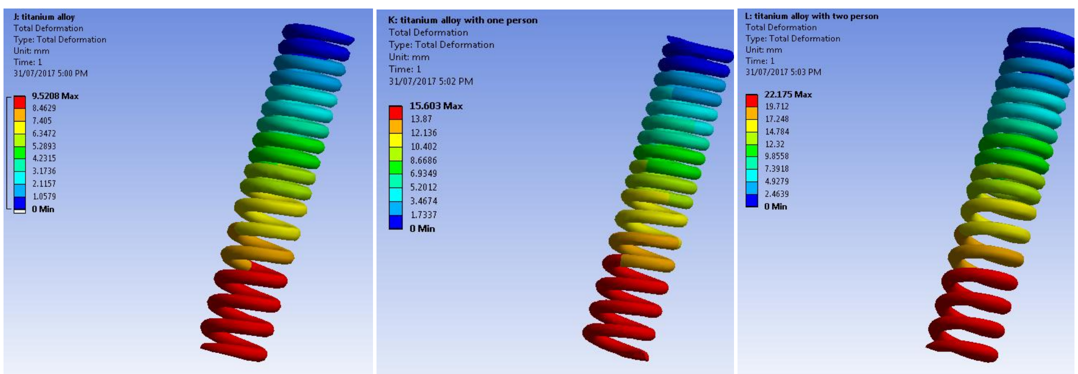

Fig 9:Total Deformation a) Bike only b)Bike +1 person c) Bike +2 person

The deformation occurring in the spring due to the static load of bike, bike with one person and bike with two person is found to be 9.52mm, 15.6mm, and 22.17mm respectively while the von mises stress obtained for the same are 249.58Mpa, 409.03Mpa and 581.31Mpa respectively.

In order to test the behavior of the suspension spring under dynamic loading condition EXPLICIT DYNAMIC analysis is also performed for the spring for maximum load condition. The results of the analysis are presented below in Fig 10.

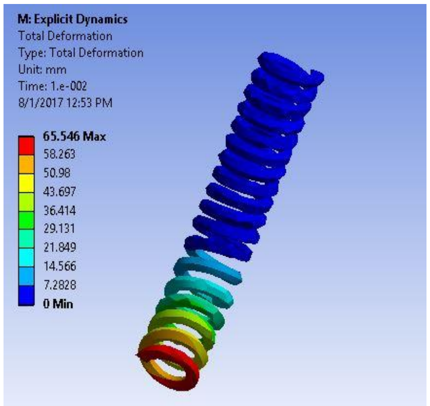

Fig 10: Deformation obtained in the Proposed Desgin-2 spring under dynamic load of 838.5N

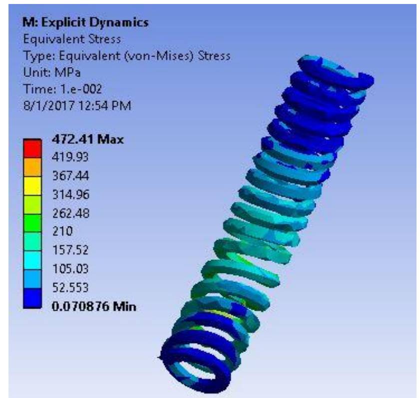

Fig 11: Von-mises Stress obtained in the Proposed Design-2 spring under dynamic load of 838.5N

Governing Equations

Spring Steel (Modulus of Rigidity)

$G = 78600 N/mm^2$

Mean diameter of a coil, D=33.3mm

Diameter of wire, d = 6.7mm

Total no of coils, n1= 17

Height, h = 210mm

Outer diameter of spring coil, D0 = D +d =40mm

No of active turns, n= 15

Weight of bike = 113kg

Let weight of 1person = 75Kg

Weight of 2 persons = 75×2=150Kg

Weight of bike + persons = 263Kg

Rear Suspension = 65%

65% of 263 = 171Kg

Considering dynamic loads it will be double

W = 342Kg = 3355N

For single shock absorber weight = w/2= 1677N = W

We Know that, compression of spring (δ) = (WD^3 n)/(Gd^4)

C = spring index = D/d = 5

(δ) = 46.91

Solid length, Ls =n1×d=17×6.7=113.9mm

Free length of spring,

Lf = solid length + maximum compression + clearance between adjustable coils

Spring rate, K = W/ δ = 35.74

Pitch of coil, P = (Lf – Ls)/ n1+ d

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

$\tau = (K_s \times 8WD) / \pi.d3$

$K_s = (4C-1)/(4C-4) + 0.615/C = 1.3105$

$\tau = 619.62$

Buckling of compression spring:

Crippling load under which a spring may buckle

KL = 0.1 (for hinged end spring)

The buckling factor for the hinged end and built -in end spring Wcr = q × KL × Lf = 35.74 × 0.1× 167.8 = 599.71N

ISSN : 2454 – 308X | Volume : 04 , Issue : 03 | January – March 2018

III. RESULTS AND DISCUSSION

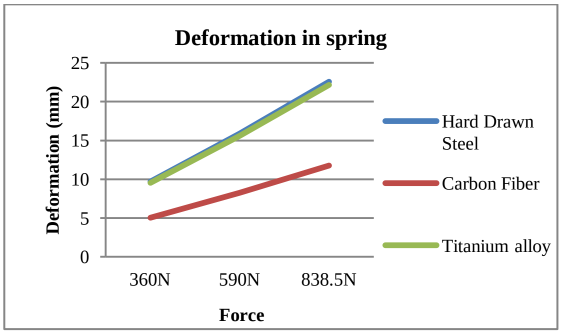

Figure 12: Deformation in springs

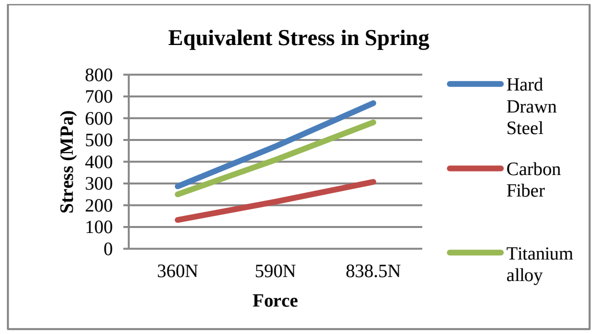

Figure 13: Equivalent Stress in Springs

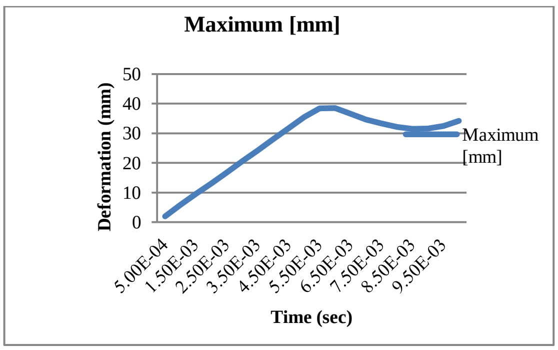

Figure 14: Deformation obtained in original Spring under Dynamic Loading

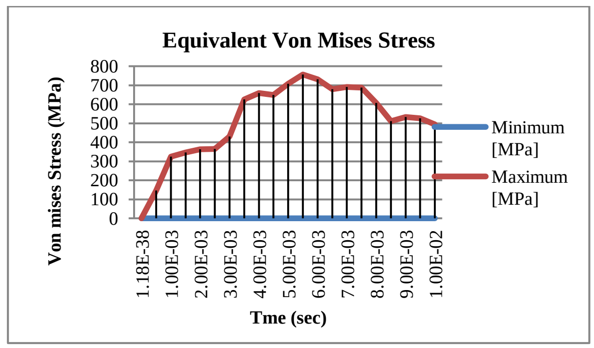

Figure 15: Von-Mises Stress obtained in original Spring Under Dynamic Loading

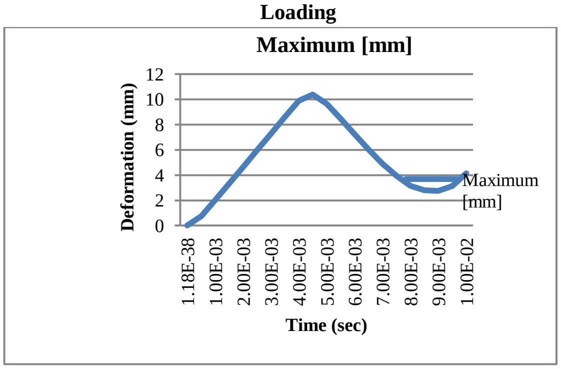

Figure 16: Deformation obtained in Proposed Design-1 Spring under Dynamic Loading

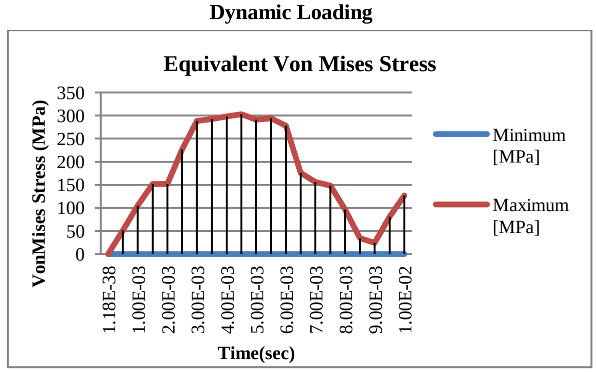

Figure 17: Von-Mises Stress obtained in Proposed design-1 Sprii Under Dynamic Loading

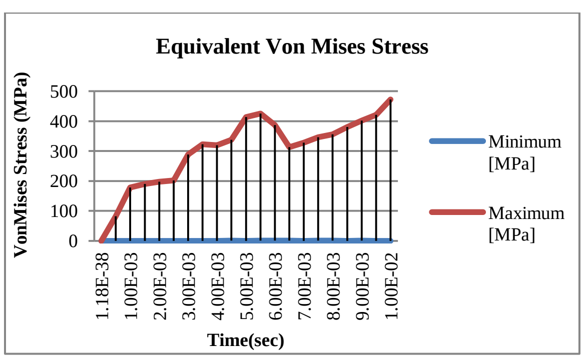

Figure 18: Von-Mises Stress obtained in Proposed design-2 Spring

Based on the results mentioned in the previous chapter following conclusion can be drawn from the research work.

IV. CONCLUSION

1. For the purpose of analysis 3 models of Suspension Spring were Successfully developed
2. Suspension spring with carbon fiber material showed the least deformation for all the load condition
3. The deformation in titanium alloy spring and ASTM a227 spring is same but equivalent stress in the titanium alloy spring is much lower than those of ASTM a227 spring
4. The results of the dynamic analysis showed that the Spring with ASTM a227 and Titanium alloy showed buckling at the center at the maximum load but that is not the case with Carbon fibre spring,
5. Also the deformation showed by the Carbon fibre spring under dynamic load is much less compared to other springs.
6. Though the diameter of the Carbon Fiber spring coil is greatest but it's weigh is lowest among all the three models followed by Titanium alloy spring and the heaviest being ASTM a227 spring
7. Based on the results it can be concluded that the suspension spring made of carbon fiber is the best suitable alternative to be used in the bike suspension system.

V. FUTURE SCOPE

Though the research is carried out with utmost accuracy, then also there is scope for some further improvement. Some of them are listed below:

- For this research work only the suspension spring was considered, research can be further extended by using the whole suspension assembly.
- Dynamic analysis on the spring were performed for maximum load condition in this study, the behavior of the spring under other loads can be studied further.

REFERENCES

[1] Dhiraj V. Shevale, Niranjan. D. Khaire., Review sson Failure Analysis of Helical Compression Spring, 2016.

[2] "Finite Element Analysis Of Helical Coil Compression Spring For Three Wheeler Automotive Front Suspension", Tausif M. Mulla1, Sunil J. Kadam2, Vaibhav S. Kengar3 (Ijmie) Issn No. 2231 –6477, Vol-2, Iss-3, 2012.

[3] Art of Fatigue Analysis Of Helical Compression Spring Used In Two-Wheeler Horn International Journal Of Mechanical Engineering And Technology (IJMET), ISSN 0976 – 6340(Print), ISSN 0976 – 6359(Online) Volume 4, Issue 2, March - April (2013) © IAEME.

[4] Chapter 22 / Materials Selection And Design Considerations.

[5] Investigation Of Probable Failure Position In Helical Compression Springs Used In Fuel Injection System Of Diesel Engines", Brita Pyttel,K K Ray, Isabell Brunner, Abhishek Tiwari, S. A. Kaoua.

[6] Design Of Helical Coil Compression Spring" A Review P.S.Valsange / International Journal Of Engineering Research And Applications (Ijera) Issn: 2248 -9622 Www.Ijera.Com Vol. 2, Issue 6, November - December 2012, Pp. 513 -522.

[7] "Review On Development And Analysis Of Helical Spring With Combination Of Conventional And Composite Materials ",International Journal Of Engineering Research And General Science Volume 3, Issue 2 , March - April, 2015 ISSN 2091-2730.

[8] Associated spring, Design Handbook: Engineering Guide to spring design. Associated spring, Bernes Group Inc., Bristol, Conn., 1987.

[9] P. C. Sharma and D. K Aggarwal. "Machine Design", S. K Kataria& sons – Delhi; Revised edition