Study of Static and Dynamic analysis of Composite Mono Leaf Spring

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Abstract- *The Automobile Industry has shown increased interest in replacement of steel spring with composite mono spring due to high strength to weight ratio. A leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. Leaf Springs are long and Narrow plates attached to the frame of a trailer that rest above or below the trailer's axle. There is single leaf springs and multi leaf spring used based on the application required. The objective of this paper is to analyze the leaf spring for the constraints such as material composition; it is subjected to millions of load cycles leading to fatigue failure. Static analysis determines the safe stress and corresponding pay load of the leaf spring and also to study the behavior of structures under practical conditions Vibrations developed in the springs. And finally for both, the analytical results are compared with experimental Results and verified. Vibration analysis is done and also how much damping will be required for the spring is Determined. Mode frequency for the spring is also determined using ANSYS software and FFT analyzer MCME2 software.*

Keywords- Glass fiber, Steel leaf spring, Composite leaf spring, stiffness, FFT analyzer, ANSYS software.

I. INTRODUCTION

Leaf spring is a simple form of a spring, commonly used for the suspension in wheeled vehicles. Recently automobile industries are focused on reducing the static weight of the vehicles to improve their fuel efficiency and reduce the cost. It is found that leaf springs add significant weight to the vehicles. Strain energy of the material becomes a major factor in designing the leaf springs. Composite materials have the higher strain energy capacity because of lower modulus and density. The low density and high elastic strain of glass fiber reinforced Composites (GFRC) provide them with high specific Strain energy capacity Therefore the composite materials become the strong candidate for fabricating the leaf springs to reduce their structural weight. [1] Other important characteristics of composites such as higher strength to weight ratio, fatigue strength, corrosion resistance, natural frequency and fail-safe capability made them excellent for leaf spring applications. The primary objective was to provide an understanding of the manufacture use capabilities of composite leaf springs and to reduce the vehicle weight. Leaf springs absorb the vehicle vibrations, shocks and bump loads (Induced deflections, so that the potential energy is stored in the leaf spring and then relieved slowly.

Vibration is the motion of a particle or a body or system of connected bodies displaced from a position of equilibrium. Most vibrations are undesirable in machines and structures because they produce increased stresses, energy losses, causes added wear, increase bearing loads, induce fatigue, create passenger discomfort in vehicles, and absorb energy from the system. Rotating machine Parts need careful balancing in order to prevent damage from vibrations. A static element is one whose output at any given time depends only on the input at that time while a dynamic element is one whose present output depends on past inputs. In the same way we also speak of static and dynamic systems. [2] A static system contains all elements while a dynamic system contains at least one dynamic element. Physical system undergoing a time-varying interchange or dissipation of energy among or within its elementary storage or dissipative devices is said to be in a dynamic state. Weight reduction has been the main focus of automobile manufacturers in the present scenario. The replacement of steel with optimally designed composite leaf spring can provide 92% weight reduction. Moreover the composite leaf spring has lower Stresses compared to steel spring. All these will result in fuel saving which will make countries energy independent because fuel Saved is fuel produced. The leaf spring should absorb the vertical Vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential Energy is stored in spring as strain energy and then released slowly. So, increasing the energy storage capability of a leaf spring ensures a more compliant suspension system. According to the studies made a material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf Spring. Fortunately, composites have these characteristics.

II. LITERATURE REVIEW

The automobile industry has shown increased interest in replacement of steel springs with fiberglass reinforced composite leaf spring. H.A.al-Qureshi (2001) in this paper present general study on the analysis, design and fabrication of composite springs. From this view point, the suspension spring of compact car, jeep selected as a prototype. A single leaf variable thickness spring of glass fiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multileaf steel spring, was designed, fabricated and tested. The testing was performed experimentally in the laboratory and was followed by the road test.Comparsion between the performance of the GFRP and the multileaf spring is presented. (Gaurav Saxena 2013)Present time the main issue of automobile industry are weight reduction. The automobile industry has looking for any implementation or modification to reduce the weight of the vehicle. The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for 10% to 20% of the unstrung weight. The introduction of composite leaf spring made of glass fiber rein forced plastic (GFRP) has made it to possible to reduce the weight of spring without any reduction on load carrying capacity and stiffness. (Stephan Krall 2015)The light weight engineering becomes more and more import. Especially rising energy cost and the international Growing request to save the environment with the help of optimized usage of resources and the reduction of Emissions are determining the constantly increasing demand of efficient or high performance products. The use of Fiber reinforced polymers is perhaps the most promising technology in this field.

LITERATURE SUMMARY

Composite leaf spring made up of different material (GFRC, CFRC, Kevlar) their work on analysis calculated dynamic behavior of CFRP,static analysis, mathematical medaling and optimizes using FEA ansys.In some paper cost weight ratio is high. Corrosion resistance is high so research calculated Reduce the weight of the steel leaf spring by introducing composite material.

Now this paper calculated the development of static and dynamic both combined analysis of composite mono leaf spring which made of glass fiber reinforced composite (GFRC) material design to which calculated maximum bending stress and maximum deformation by using Finite element analysis Ansys software. In dynamic condition check the vibration of mono leaf spring by using FFT analyzer and check modal frequency of mono leaf spring at different stage.

III. OBJECTIVES OF PAPER

The main objectives of this study are

1] Reduce the weight of the steel leaf spring by introducing composite material.
2] To increase the load carrying capacity.
3] To increase ride comfort for passengers.
4] Main Application of this paper is weight of the leaf spring without any reduction on the load Carrying capacity and stiffness.
5] To prevent the road shocks from being transmitted to the vehicle components.
6] To safeguard the occupants from road shocks.
7] To preserve the stability of the vehicle in pitting or rolling, while in motion.
8] Vibration analysis is done and also how much damping will be required for the spring is Determined.
9] Mode frequency for the spring is also determined

IV. DATA COLLECTION AND EXPERIMENTATIONS

A. SELECTION OF MATERIAL

Materials of the leaf spring should be consist of nearly 60%-70% of the vehicle cost and contribute to the quality and the performance of the vehicle. [3]Even a small amount in weight reduction of the vehicle, may have a wider economic impact. Composite materials are proved as suitable substitutes for steel in connection with weight reduction of the vehicle. Hence, the composite materials have been selected for leaf spring design.

B. FIBER SELECTION

The commonly used fibers are carbon, glass, Kevlar, etc. Among these, the glass fiber has been selected based on the cost factor and strength. The types of glass fibers are C-glass, S-glass and E-glass. The C-glass fiber is designed to give improved surface finish. S-glass fiber is design to give very high modular, which is used particularly in aeronautic industries. The E-glass fiber is a high quality glass, which is used as standard reinforcement fiber for all the present systems well complying with mechanical property requirements. Thus, E-glass fiber was found appropriate for this application.

V. MANUFACTURING OF COMPOSITE MONO LEAF SPRING

A. HAND LAY-UP TECHNIQUE

We used a hand-lay-up method to produce the prototype of a single composite leaf spring. Hand layup technique is suitable for manufacturing of composite leaf spring with suitable effective properties. In this process a mould cavity made up with the help of green sand mould, after manufacturing [5] cavity of suitable size optical gel coating of suitable thickness layer is made in the boundary of cavity then after this resin in liquid form is poured in that cavity and for getting require shape the consolidation roller rolls over the two layer of resin and dry reinforcement fabric layer of given thickness.

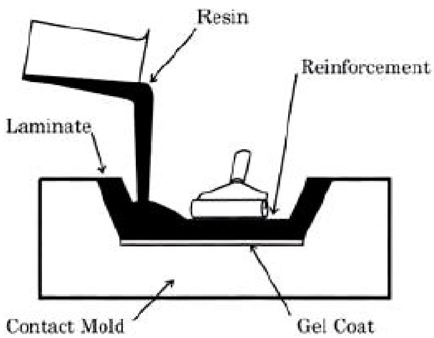

Fig 1.Hand Layup Technique [3]

A. COMPOSITE MONO LEAF SPRING

The constant cross section design is selected due to its capability for mass production, and to accommodate continuous reinforcement of fibers and also it is quite suitable for hand lay-up technique. The glass fibers were cut to the desired lengths, so that they can be deposited on the template layer by layer during fabrication. In the conventional hand lay-up technique, a releasing agent (gel/wax) was applied uniformly to the mould which had good surface finish. This is followed by the uniform application of epoxy resin over glass fiber. Another layer is layered and epoxy resin is applied and a roller was used to remove all the trapped air. This process continued till the required dimensions were obtained. Care must be taken during the individual lay-up of the layers to eliminate the fiber distortion, which could result in lowering the strength and rigidity of the spring as a whole. The duration of the process may take up to 30 min. The mould is allowed to cure about 4 – 5 days at room temperature.

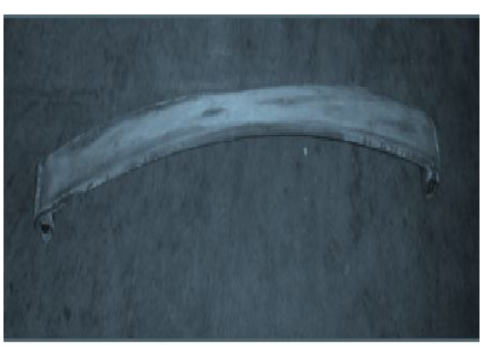

Fig 2 Complete composite mono leaf spring [2]

B. TESTING OF STEEL LEAF SPRING

The composite leaf springs are tested by using Hydraulic UTM. The experimental set up is shown in Figures the leaf springs to be tested are examined for defects. The spring is fixed at one end and one end is kept on slider for lateral movement of spring due to force. The load is applied from zero to the prescribed maximum load and back to zero. The spring is supported at center and hydraulic pressure is given from bottom to the spring.

C.STATIC DESIGN CALCULATION

1] Deflection $\delta = 4 \times W \times L3 / n \times E \times b \times t3$
2] Stress $\sigma = 6 \times W \times L / n \times b \times t2$
3] Bending Stress = 1.5WL/nbt2
4] Plotting Graph:
A] Theoretical Load v/s Deflection
B] FEA Load v/s Deflection

VI. VIBRATION ANALYSIS OF MONO LEAF SPRING

In general, a vibrating system consists of a spring as a means for storing potential energy, a mass or inertia as a means for storing kinetic energy, and a damper as a means by which energy is gradually lost as shown in Fig. An undamped vibrating system involves the transfer of its potential energy to kinetic energy and kinetic energy to potential energy, alternatively. In a damped vibrating system, some energy is dissipated in each cycle of vibration and should be replaced by and external source if a steady state of vibration is to be maintained.

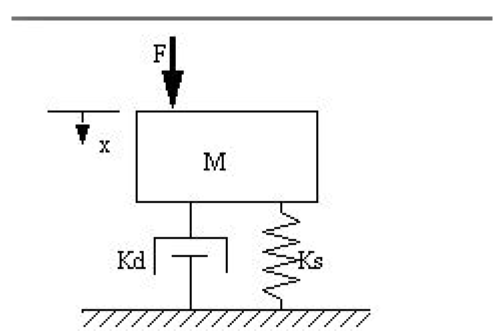

Fig 3. Elementary parts of vibrating system [4]

Vibrations can be classified in several ways.
1. Free vibrations 2. Forced vibrations 3. Self-excited.

Free vibration of a system is vibration that occurs in the absence of external force or sometimes an initial external force is given and then removed after which the system vibrates on its own. An external force that acts on the system causes forced vibrations. In this case, the exciting force continuously supplies energy to the system. Forced vibrations may be either deterministic or random.

Self-excited vibrations are periodic and deterministic oscillations. Under certain conditions, the equilibrium state in such a vibration system becomes unstable, and any disturbance causes the vibrations to grow until some effect limits any further growth. In contrast to forced vibrations, the exciting force is independent of the vibrations and can still persist even when the system is prevented from vibrating

A. FFT SPECTRUM ANALYSER

The FFT spectrum analyzer converts the input signal with time as an independent variable, into Frequency spectrum and displays it in the graphical form. [2]The spectrum analyzer measures the magnitude of an input signal versus frequency within the full frequency range of the instrument. The primary use is to measure the power of the spectrum of known and unknown signals. The input signal a spectrum analyzer measures is electrical, however, spectral compositions of other signals, such as acoustic pressure waves and optical light Waves can be considered through the use of an appropriate transducer. By analyzing the spectra of electrical signals, dominant frequency, power, distortion, harmonics and other spectral components of a signal can be observed that are not easily detectable in time domain waveforms. These parameters are useful in the characterization of electronic devices, such as wireless transmitters. The display of a spectrum Analyzer has frequency on the horizontal axis and the amplitude displayed on the vertical axis.

VII. EXPERIMENTAL SET UP FOR VIBRATION ANALYSIS USING FFT ANALYZER

After calculating the natural frequency of the composite leaf spring theoretically now we need to find the same by using FFT analyzer for different conditions. Also we need to show how the leaf spring would behave on different road conditions i.e. at different frequencies of the road. The increase in frequency of the Road surface causes what changes in the spring vibration also can be determined. For all the above purpose we need to design a set up on which the composite leaf spring should be mounted which give the expected results. The set up for mounting of the composite leaf spring is mounted in a way in which it is mounted in the vehicle.

One end of the composite leaf spring is fixed and the other end is movable. The end which is fixed is attached to a rigid heavy frame and the movable end is also attached to the rigid frame through the shackle. This shackle helps in accommodating the length of the leaf spring when large loads are applied on the spring.

Fig.4 Forced Vibration Setup FFT analyzer [2]

A. DETERMINATION NATURAL FREQUENCY

The natural frequency of any body or a system depends upon the geometrical parameters and mass properties of the body. It is independent of the forces acting on the body or a system. Consider a case when the frequency of External excitation force acting on the body is equal to the natural frequency of a vibrating body, the amplitude of vibration become excessively large. Such state is known as resonance. Resonance is dangerous condition and it may lead to failure of the part. Therefore to avoid the resonance condition, the natural frequency of the machine parts that are subjected to vibration or external excitation should be known. Hence it is of prime Importance to calculate the natural frequency.

There are various methods for calculating natural frequency of a given vibratory system.

1. Equilibrium method 2. Energy Method 3. Rayleigh's Method

   Standard simple harmonic motion given as,

   $\ddot{u} + \omega n^2 x = 0$

   We get,

   $\omega n^2 = k/m$

   $\omega n = (k/m)^{1/2}$

   Where k is the stiffness and m is the mass of the Leaf Spring.

   $Fn = \omega n / 2\pi$

   1] $Fn = 1/2\pi * (k/m)^{1/2}$

This is the equation for natural frequency of a composite leaf spring. Now, for calculating stiffness of the composite leaf spring we tested the spring for maximum deflection on the UTM and also we calculated the mass of the leaf spring

Stiffness of composite leaf spring (k) = F/∂max

Natural Frequency of leaf spring
(fn) = $1/2\pi * (k/m)^{1/2}$

This is the natural frequency of the composite leaf spring.

This natural frequency of vibration of composite leaf spring should not match the frequency of vibration or read Surface otherwise resonance will occur and spring will vibrate at maximum amplitude which is undesirable.

VIII. EXPECTED OUTCOMES

1] Strength and stiffness of composite leaf spring is more than steel spring.

2] Composite leaf spring gives more comfort, Test ride; noise and hardness are significantly reduced, more flexible than steel leaf spring High specific strength, rigidity.

3] Under the same static load conditions deflection and stresses of steel leaf spring and composite leaf spring are found with the great difference.

4] Deflection of composite leaf spring is less as compared to steel leaf spring with the same loading Condition.

5] Bending stress is also less in composite leaf spring as compared to steel leaf spring with the same loading condition.

6] Composite leaf spring can be used on smooth roads with very high performance expectations.

7] Under the dynamic load conditions natural frequency and stresses of steel leaf spring and composite leaf spring are found with the great difference. Here also the natural frequency of composite material is high than the steel leaf spring.

8] Natural frequency of composite leaf spring is determined and it is almost of the same value determined by various methods of calculation of natural frequency.

9] The frequency ratio is determined for both the springs and it is seen that the composite Leaf spring is more efficient than the steel leaf spring for every speed of vehicle and also the vibration Isolation is greater in the composite leaf spring than that of the steel leaf spring.

10] Increase in leaf width improves natural frequencies.

11] Springs with more number of longitudinal layers and when they are placed outer exhibit higher frequencies.

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