VIBRATION ANALYSIS OF E-GLASS FIBRE RESIN MONO LEAF SPRING USED IN LMV

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ABSTRACT

A leaf spring is a simple form of spring, commonly used for the suspension in vehicles. A leaf spring which is an automotive component is used to absorb vibrations induced during the motion of vehicle. Leaf Springs are long and narrow plates attached to the frame of a trailer that rest above or below the trailer's axle. There are single-leaf springs and multi leaf spring used based on the application required. It also acts as a structure to support vertical loading due to the weight of the vehicle and payload. Under operating conditions, the behavior of the leaf spring is complicated due to its clamping effects and interleafs contact, hence its analysis is essential to predict the displacement and mode frequency

The objective of this paper is to analyze the leaf spring for the constraints such as material composition, 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.

Key Words: Composite Mono Leaf Spring, Vibration Analysis, ANSYS, FFT Analyzer, MCME2 Software.

I. INTRODUCTION

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.

Vibration occurs when a system is displaced from a position of stable equilibrium. The system tends to return to this equilibrium position under the action of restoring forces (such as the elastic forces, as for a mass attached to a spring, or gravitational forces, as for a simple pendulum). The system keeps moving back and forth across its position of equilibrium. A system is a combination of elements intended to act together to accomplish an objective. For example, an automobile is a system whose elements are the wheels, suspension, car body, and so forth. 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. A static system contains all elements while a dynamic system contains at least one dynamic element.

A 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. All of the elements in general are called passive, i.e., they are incapable of generating net energy. A dynamic system composed of a finite number of storage elements is said to be lumped or discrete, while a system containing elements, which are dense in physical space, is called continuous.

II. ELEMENTS AND CLASSIFICATION OF A VIBRATING SYSTEM

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.1. 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.

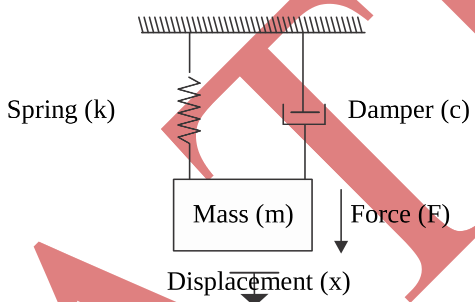

Fig.1 Elementary parts of vibrating system

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 (see Fig.2a).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. deterministic vibrations are the ones in which the magnitude of external excitation is known at a given time while for the random vibrations are the magnitude of force is not known at a given time period. The characteristic curves for deterministic and random vibrations are as shown above in fig 2 (a) and (b) respectively.

2.1 How vibration analysis is done?

The vibration analysis of a physical system may be summarised by the four steps:

1. Mathematical Modelling of a Physical System
2. Formulation of Governing Equations
3. Mathematical Solution of the Governing Equations
4. Physical interpretation of results.

III. FFT SPECTRUM ANALYSER

The FFT spectrum analyser converts the input signal with time as an independent variable, into frequency spectrum and displays it in the graphical form. 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.

3.1 Actual Vibration Analysis

For vibration analysis we have a composite leaf spring which is now-a-days being commonly used in automobile instead of a conventional leaf spring. This is because it has various advantages over the steel leaf spring such as low weight, less stress concentration, more fatigue life and etc.

The aim of this paper is to represent a general study on the design, analysis of leaf spring. The suspension system in a vehicle significantly affects the behaviour of vehicle, i.e. vibration characteristics including ride comfort, stability etc. Leaf springs are commonly used in the vehicle suspension system and are subjected to millions of varying stress cycles leading to fatigue failure. A lot of research has been done for improving the performance of leaf spring. The automobile industry has shown interest in the replacement of steel spring with composite leaf spring. In general, it is found that fiber glass material i.e. composite material has better strength characteristic and lighter in weight as compared to steel for leaf spring. The automobile manufacturers can reduce product development cost and time while improving the safety, comfort, and durability of the vehicles they produce with this analysis. Also during the analysis, the leaf spring is subjected to frequency with which the leaf spring has to operate most of the times in the vehicles. Hence for the suspension system i.e. the vibration system of our experiment the condition to be assumed are for forced vibration.

3.2 Determination of 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

All the above methods are reduced to a common and simple equation of motion which is compared with the standard simple harmonic motion given as,

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

We get,

$\omega_n^2 = k/m$

$\omega_n = \sqrt{(k/m)}$

where k is the stiffness and m is the mass of the leaf spring.

$f_n = \omega_n / 2\pi$

$\therefore f_n = 1/2\pi * \sqrt{(k/m)}$

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 which was 2.5 kg.

From UTM we obtain the result as, Load = 1800 & Deflection = 85.35 mm

Therefore, now for stiffness

$K = F/\partial_{max}$

$= 1800/(85.35*10^3)$

$= (1800*10^3)/85.35$

$\therefore K = 21089.63$ N/m

Now, $\omega_n = \sqrt{(k/m)}$

$= \sqrt{(\frac{21089.63}{2.5})}$,where m = 2.5 kg.

$\therefore \omega_n = 91.84$ rad/sec.

$f_n = 1/2\pi * \sqrt{k}/\sqrt{m}$

$= \omega_n / 2\pi$

$= 91.84/2\pi$

$\therefore \quad f_n = 14.61$ Hz

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.

IV 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.2 Experimental Vibration analysis setup

The load on the leaf spring acts on the centre and is then distributed all over the spring through its body. The spring thus vibrates and prevents the vibrations to pass over to the other parts. In our analysis load is given by using a cam jump which is placed right below the leaf spring and it gives the vibrations that will take place on the leaf spring. The frequency of the vibrations generated by the cam jump set up

Vibrations given to the spring are given on the basis of the different road conditions that the spring will encounter and how will it act during those conditions. Thus the vibration analysis is important and it is done by connecting the FFT analyzer with one end connected to a computer and the other end to the leaf spring having accelerometer which receives the vibrations the spring. The computer using MCME2 software after receiving the readings provides the necessary graphs required for the purpose. From the above set up we get the natural frequency of composite leaf spring.

4.1 Natural frequency by ANSYS & FFT

Various harmonics for natural frequency of composite leaf spring are obtained from ANSYS. The first harmonic will give the natural frequency of the leaf spring which is the required frequency.

Mode	Frequency [Hz]
1.	16.784
2.	158.64
3.	327.98
4.	495.17
5.	572.79
6.	858.52

Fig. 3 Amplitude spectrum graph By FFT Analyzer

Table1. Calculated value of natural frequency

Sr. No.	Method of calculation	Value of Natural frequency
1	Analytical method	14.61
2	Using FFT analyser	15
3	Using ANSYS	16.78

4.2 Comparison of composite and steel spring on vibrations transmissibility on road surface

Transmissibility is defined as the force or motion transmitted to the supporting structure or foundation, to the force impressed upon the system. Transmissibility measures the effectiveness of the vibration isolating material. Roughness is the parameter which is most important in consideration of road condition for the leaf springs. Roughness is the surface irregularities in 0.5 – 50 m wavelength. This corresponds to the frequency range which induces relative motion in road vehicle suspension system over a reasonable range of operating speeds.Consider general road conditions in India where the wavelength of normal road in city ranges from 1.5m- 1.7m Let, λ = 1.5m Now, $(2\pi/\omega) = (\lambda/v)$ $\therefore$ $\omega = (2\pi * v)/\lambda$ $\therefore$ $\omega = (2\pi * v)/1.5$ $\therefore$ $\omega = 4.18v$

This is the equation for frequency of vibration of road surface which varies with velocity 'v'.

4.2.1 For steel leaf spring.

Natural frequency of the system with composite leaf sprig is given as

$\omega_n = \sqrt{(k/m)}$ here k = 55000 N/m m = 500 + 4.533 = 504.533 kg $\therefore$ ω_n = 10.05 rad/sec.

Now (ω/ω_n) should be greater than $\sqrt{2}$. This is because the transmitted force should always be greater than the exciting force. Thus, better vibration isolation is possible in this region and hence, less vibrations are transmitted to the vehicle body as well as the passenger in the car.

Now, ω= 4.18v for wavelength λ = 1.5

Table2. Frequency ratio for steel leaf spring at various velocities

Sr. No.	ω_n	v (m/s)	ω	ω/ω_n
1.	10.05	5	20.9	2.079
2.	10.05	10	41.8	4.15
3.	10.05	15	62.7	6.238
4.	10.05	20	83.6	8.318

4.2.2 For composite leaf spring.

Natural frequency of the system with composite leaf sprig is given as $\omega_n = \sqrt{(k/m)}$

here k = 21089.63 N/m m = 500 +0.833=500.833

ω_n= 6.49 rad/sec

Now (ω/ω_n) should be greater than $\sqrt{2}$. This is because the transmitted force should always be greater than the exciting force. Thus, better vibration isolation is possible in this region and hence, less vibrations are transmitted to the vehicle body as well as the passenger in the car.

Now, ω= 4.18v For wavelength λ = 1.5

From the two tables 2 & 3 we see that the ratio of (ω/ω_n) is always greater than $\sqrt{2}$ which indicates the transmitted vibration is very less and also the frequency ratio goes on increasing proportionally with increase in speed which shows that the greater vibration isolation is possible at greater speeds.

Table3. Frequency ratio for composite leaf spring at various velocities

Sr. No.	ω_n	v (m/s)	ω	ω/ω_n
1.	6.49	5	20.9	3.17
2.	6.49	10	41.8	6.44
3.	6.49	15	62.7	9.66
4.	6.49	20	83.6	12.88

Now comparing the values for the steel and composite leaf spring we see that for same speed the value of frequency ratio for composite leaf spring is always greater than that of the steel leaf spring. This indicates that the composite leaf spring would give less transmissibility as compared with the steel leaf spring. Thus composite leaf spring would be more efficient than that of the steel leaf spring at the same speeds.

V. CONCLUSIONS & DISCUSSIONS

1. 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.
2. 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.
3. Comparison of composite leaf spring and steel spring is again done based on their working on actual road condition. 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.

REFERENCES

1. M.Senthil and S Vijayranjan "Static Analysis and Fatigue life pediction of steel and composite Leaf spring." Journal of scientific Steel and Industrial Research Vol66, Feb2007, pp128-134.
2. M. M. Patunkar, D. R. Dolas "Modelling and Analysis of Composite Leaf Spring under the Static Load Condition by using FEA"International Journal of Mechanical & Industrial Engineering, Volume 1 Issue 1-2011,pp1-4.
3. T.Rangaswamy, S. Vijayarangan "Optimal Design And Analysis Of Automotive Composite Drive Shaft" International Symposium of Research Students on Materials Science and Engineering December 2002-04, pp 1-9.
4. K. K. Jadhao "Experimental Investigation & Numerical Analysis Of Composite Leaf Spring" International Journal of Engineering Science and Technology. (IJEST) Vol. 3 No. 6 June 2011, pp4759-64.
5. Mahmood M. Shokrieh , Davood Rezaei "Analysis and optimization of a composite leaf spring." Composite Structures 60 (2003) pp 317–325.
6. Pro-E Wildfire 5.0 and ANSYS 10 help.
7. ASME standard specifications of handbook.