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ANALYSIS OF VIBRATION ON MULTI-LEAF SPRING IN AN AUTOMOBILE UNDER LOADING USING FEM TOOL ANSYS

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ABSTRACT

The leaf springs are widely used in suspension system of railway carriages and automobiles. But the form in which it is normally seen is laminated leaf spring.To assure proper spring life, the maintenance and inspection process must include the entire suspension system of springs and chassis parts.

The motoring public has learned that proper maintenance on their vehicles is essential to obtain longer life and economical service in this age of rising equipment and fuel costs. In most normal maintenance checks, the spring suspension system is sorely overlooked, but a minimum of attention to the spring suspension would yield a longer and more reliable suspension system service.

In this report,FEM approach has used for predicting the stress and deformation .A parametric study is also made by varying the load to investigate their effect on the stress of leaf spring .A frequency response graph is plotted to analyse the effect of Stress, Strain and Deformation.

KEYWORDS: Leaf Spring, Stress & deformation on leaf spring, Frequency Response, Laminated Spring FEM of Leaf Spring.

INTRODUCTION

Springs are an important and frequently used component in mechanical engineering. the most important requirement for a spring material is the ability to store a large amount of strain energy. This is usually best achieved by choosing Materials with a high Elastic Modulus, E, together with an ability to carry a high stress within the material's elastic range, that is, without permanent deflection. Depending on the application, it may also be important to be able either to recover the stored energy without excessive losses, or to absorb (or dissipate) as much of the stored energy as possible in order to prevent rebound. The objective of the research reported in the study to measure the force-producing characteristics of several different types of leaf springs while exciting them at various amplitudes and frequencies of oscillation about nominal loading conditions and develop a means for representing the force deflection characteristics of leaf springs in a form suitable for use in simulations of commercial vehicles. The test results showed that the leaf springs have rather unique force-deflection characteristics. Therefore, a model suitable for representing their characteristics over wide ranges of loading, deflection amplitudes, and random reversals of velocity is needed for use in vehicle dynamic simulations. Accordingly, they devised an equation to represent the characteristics of the leaf spring. They compare the predictions from this equation with test data and it shows that the model is indeed capable of representing the characteristics of the leaf spring, capturing the stiffness as well as the hysteresis loop.Often a combination of physical testing and analytical methods is used to obtain the load histories.

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MATERIALS AND METHODS

FINITE ELEMENT METHODS

Specification Of The Leaf Spring

The test steel leaf spring used for experiment is made up of Steel.
The composition of material is 0.91C%, 1.80 SI%, 0.70 Mn%, 0.045 P%, 0.045 S%.

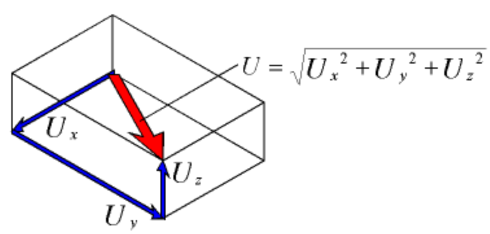
Parameter	Value
Total length of spring	1540 mm
No. of full length leaves (Master Leaf)	01
Thickness of leaf	13 mm
Width of leaf spring	60 mm
Ultimate tensile strength	1680-2200 Mpa
Tensile yield	1540-1750 Mpa
Number of graduated leaves	05

The following steps are used in the solution procedure using ANSYS

1. The geometry of the leaf spring to be analyzed is imported from solid modeler Pro/Engineer in IGES format this is compatible with the ANSYS.
2. The element type and materials properties such as Young's modulus and Poisson's ratio are specified
3. Meshing the three-dimensional leaf spring model.
4. The boundary conditions and external loads are applied
5. The solution is generated based on the previous input parameters.
6. Finally, the solution is viewed in a variety of displays.

Total and directional deformation analysis

Deformation in continuum mechanics is the transformation of a body from a reference configuration to a current configuration. A configuration is a set containing the positions of all particles of the body. Contrary to the common definition of deformation, which implies distortion or change in shape, the continuum mechanics definition includes rigid body motions where shape changes do not take place.Deformation is the change in the metric properties of a continuous body, meaning that a curve drawn in the initial body placement changes its length when displaced to a curve in the final placement. If none of the curves changes length, it is said that a rigid body displacement occurred.
It is convenient to identify a reference configuration or initial geometric state of the continuum body which all subsequent configurations are referenced from. The reference configuration need not be one the body actually will ever occupy. Often, the configuration at t = 0 is considered the reference configuration, $K_0(\mathbf{B})$. The configuration at the current time t is the current configuration.Physical deformations can be calculated on and inside a part or an assembly. Fixed supports prevent deformation; locations without a fixed support usually experience deformation relative to the original location. Deformations are calculated relative to the part or assembly world coordinate system.



Total and Directional Deformation Analysis

Component deformations (**Directional Deformation**)
Deformed shape (**Total Deformation** vector)
The three component deformations U_x, U_y, and U_z, and the deformed shape U are available as individual results
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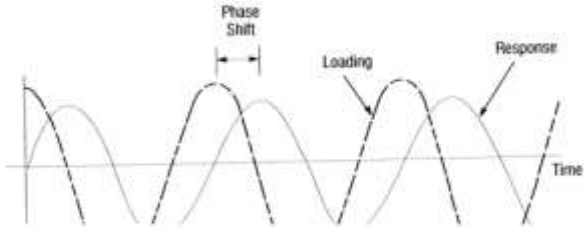
Frequency response analysis.

Frequency response analysis is a method used to compute structural response to steady-state oscillatory excitation. Examples of oscillatory excitation include rotation machinery unbalanced tires and helicopter blades. In frequency response analysis the excitation is explicitly defined in the frequency domain. All the applied forces are known at each forcing frequency. Force can be in the form of applied forces and / or enforced motion (displacement, velocities and accelerations)Oscillatory loading is sinusoidal in nature. In its simplest case, this loading is defined as having an amplitude at a specific frequence.The steady state oscillatory response occurs at the same frequency as the loading. The response may be shifted in time due to damping in the system .The shift in response is called a phase shift because the peak loading and peak response no longer occurs at the same time.



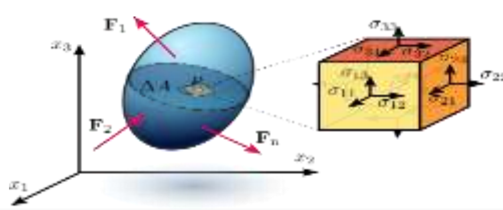
Frequency response analysis

Natural Frequency Analysis

Normally road natural frequency is 20 HZ. Therefore the natural frequency of leaf spring is more required. The used steel leaf spring frequency should be nearer to road frequency

Stress Analysis

In continuum mechanics, stress is a measure of the internal forces acting within a deformable body. Quantitatively, it is a measure of the average force per unit area of a surface within the body on which internal forces act. These internal forces arise as a reaction to external forces applied to the body. Because the loaded deformable body is assumed to behave as a continuum, these internal forces are distributed continuously within the volume of the material body, and result in deformation of the body's shape. Beyond certain limits of material strength, this can lead to a permanent shape change or structural failure.The stresses considered in continuum mechanics are only those produced during the application of external forces and the consequent deformation of the body; that is to say, relative changes in deformation are considered rather than absolute values. A body is considered stress-free if the only forces present are those inter-atomic forces (ionic, metallic, and van der Waals forces) required to hold the body together and to keep its shape in the absence of all external influences, including gravitational attraction. Stresses generated during manufacture of the body to a specific configuration are also excluded.The dimension of stress is that of pressure, and therefore the SI unit for stress is the Pascal (symbol Pa), which is equivalent to one Newton (force) per square meter (unit area), that is N/m2. In Imperial units, stress is measured in pound-force per square inch, which is abbreviated as psi."Stress" measures the average force per unit area of a surface within a deformable body on which internal forces act, specifically the intensity of the internal forces acting between particles of a deformable body across imaginary internal surfaces. These internal forces are produced between the particles in the body as a reaction to external forces. External forces are either surface forces or body forces. Because the loaded deformable body is assumed to behave as a continuum, these internal forces are distributed continuously within the volume of the material body, i.e. the stress distribution in the body is expressed as a piecewise continuous function of space and time



stress in a loaded deformable material body assumed as a continuum.

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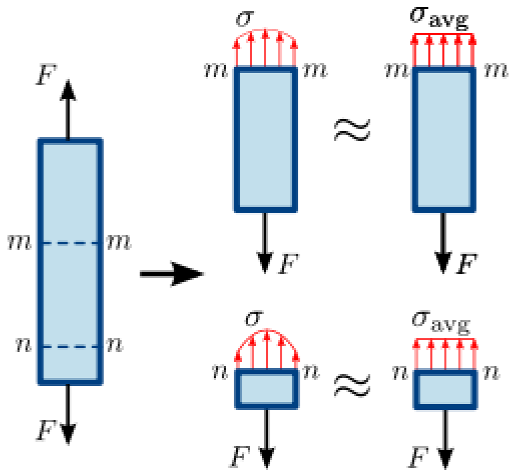
"Stress" measures the average force per unit area of a surface within a deformable body on which internal forces act, specifically the intensity of the internal forces acting between particles of a deformable body across imaginary internal surfaces.[3] These internal forces are produced between the particles in the body as a reaction to external forces. External forces are either surface forces or body forces. Because the loaded deformable body is assumed to behave as a continuum, these internal forces are distributed continuously within the volume of the material body, i.e. the stress distribution in the body is expressed as a piecewise continuous function of space and time.

Normal stress



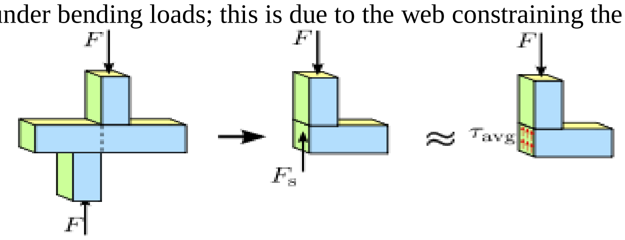
Normal Stress

Shear stress

A different type of stress occurs when the force occurs in shear, as shown in Figure 1.4. is called the shear force. Dividing the shear force by the cross-sectional area we obtain the shear stress (tau).

$$\tau_{\mathbf{avg}} = \frac{F_s}{A} \approx \tau$$

Shear stress can also be caused by various loading methods, including direct shear, torsion, and can be significant in bending. A shaft loaded in torsion experiences shear stress in the direction tangential to its axis. I-beams see significant shear in the web under bending loads; this is due to the web constraining the flanges.



Shear Stress

Stress analysis

Stress analysis is the determination of the internal distribution of stresses in a structure. It is needed in engineering for the study and design of structures such as tunnels, dams, mechanical parts, and structural frames, under prescribed or expected loads. To determine the distribution of stress in a structure, the engineer needs to solve a boundary-value problem by specifying the boundary conditions. These are displacements and forces on the boundary of the structure.Constitutive equations, such as Hooke's law for linear elastic materials, describe the stress-strain relationship in these calculations.When a structure is expected to deform elastically (and resume its original shape), a boundary-value problem based on the theory of elasticity is applied, with infinitesimal strains, under design loads.When the applied loads permanently deform the structure, the theory of plasticity applies.

Stress analysis is simplified when the physical dimensions and the distribution of loads allow the structure to be treated as one- or two-dimensional. For a two-dimensional analysis a plane stress or a plane strain condition can be assumed. Alternatively, stresses can be experimentally determined.Computer-based approximations for boundary-value problems can be obtained through numerical methods such as the finite element method, the finite difference

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method, and the boundary element method. Analytical or closed-form solutions can be obtained for simple geometries, constitutive relations, and boundary conditions

Maximum and minimum shear stresses

The maximum shear stress or maximum principal shear stress is equal to one-half the difference between the largest and smallest principal stresses, and acts on the plane that bisects the angle between the directions of the largest and smallest principal stresses, i.e. the plane of the maximum shear stress is oriented 45^0 from the principal stress planes. The maximum shear stress is expressed as

$$\tau_{\max} = \frac{1}{2} |\sigma_{\max} - \sigma_{\min}|$$

$$\sigma_1 \geq \sigma_2 \geq \sigma_3$$

$$\tau_{\max} = \frac{1}{2} |\sigma_1 - \sigma_3|$$

The normal stress component acting on the plane for the maximum shear stress is non-zero and it is equal to

$$\sigma_n = \frac{1}{2} (\sigma_1 + \sigma_3)$$

Equivalent and shear elastic strain and strain energy analysis

A strain is a normalized measure of deformation representing the displacement between particles in the body relative to a reference length.

A general deformation of a body can be expressed in the form $\mathbf{x} = \boldsymbol{F}(\mathbf{X})$ where $\mathbf{X}$ is the reference position of material points in the body. Such a measure does not distinguish between rigid body motions (translations and rotations) and changes in shape (and size) of the body. A deformation has units of length.

We could, for example, define strain to be

$$\varepsilon \doteq \frac{\partial}{\partial \mathbf{X}}(\mathbf{x} - \mathbf{X}) = \frac{\partial \boldsymbol{F}}{\partial \mathbf{X}} - \mathbf{1}$$

Hence strains are dimensionless and are usually expressed as a decimal fraction, a percentage or in parts-per notation. Strains measure how much a given deformation differs locally from a rigid-body deformation.A strain is in general a tensor quantity. Physical insight into strains can be gained by observing that a given strain can be decomposed into normal and shear components. The amount of stretch or compression along a material line elements or fibers is the normal strain, and the amount of distortion associated with the sliding of plane layers over each other is the shear strain, within a deforming body. This could be applied by elongation, shortening, or volume changes, or angular distortion.The state of strain at a material point of a continuum body is defined as the totality of all the changes in length of material lines or fibers, the normal strain, which pass through that point and also the totality of all the changes in the angle between pairs of lines initially perpendicular to each other, the shear strain, radiating from this point. However, it is sufficient to know the normal and shear components of strain on a set of three mutually perpendicular directions.If there is an increase in length of the material line, the normal strain is called tensile strain, otherwise, if there is reduction or compression in the length of the material line, it is called compressive strainElastic strain is a transitory dimensional change that exists only while the initiating stress is applied and disappears immediately upon removal of the stress. Elastic strain is also called elastic deformation. The applied stresses cause the atoms in a crystal to move from their equilibrium position. All the atoms are displaced the same amount and still maintain their relative geometry. When the stresses are removed, all the atoms return to their original positions and no permanent deformation occurs.Strain measures-Depending on the amount of strain, or local deformation, the analysis of deformation is subdivided into three deformation theories:Finite strain theory, also called large strain theory, large deformation theory, deals with deformations in which both rotations and strains are arbitrarily large. In this case, the undeformed and deformed configurations of the continuum are significantly different and a clear distinction has to be made between them. This is commonly the case with elastomers, plastically-deforming materials and other fluids and biological soft tissue.Infinitesimal strain theory, also called small strain theory, small deformation theory, small displacement theory, or small displacement-gradient theory where strains and rotations are both small. In this case, the undeformed and deformed configurations of the body can be assumed identical. The infinitesimal strain theory is used in the analysis of deformations of materials exhibiting elastic behavior, such as materials found in mechanical and civil engineering applications, e.g. concrete and steel.

which assumes small strains but large rotations and displacements.

In each of these theories the strain is then defined differently. The engineering strain is the most common definition applied to materials used in mechanical and structural engineering, which are subjected to very small deformations. On the other hand, for some materials, e.g. elastomers and polymers, subjected to large deformations, the engineering definition of strain is not applicable, e.g. typical engineering strains greater than 1%,[6] thus other more complex definitions of strain are required, such as stretch, logarithmic strain, Green strain, and Almansi strain.

Shear strain

The engineering shear strain is defined as (γ_{xy}) is the change in angle between lines $\overline{AC}$ and $\overline{AB}$. Therefore,

$$\gamma_{xy} = \alpha + \beta$$

From the geometry of the figure, we have

$$\tan\alpha = \frac{\frac{\partial u_y}{\partial x}dx}{dx + \frac{\partial u_x}{\partial x}dx} = \frac{\frac{\partial u_y}{\partial x}}{1 + \frac{\partial u_x}{\partial x}}$$

$$\tan\beta = \frac{\frac{\partial u_x}{\partial y}dy}{dy + \frac{\partial u_y}{\partial y}dy} = \frac{\frac{\partial u_x}{\partial y}}{1 + \frac{\partial u_y}{\partial y}}$$

For small displacement gradients we have

$$\frac{\partial u_x}{\partial x} \ll 1 \; ; \quad \frac{\partial u_y}{\partial y} \ll 1$$

For small rotations, i.e. α and β are $\ll 1$ we have $\tan\alpha \approx \alpha, \;\; \tan\beta \approx \beta$. Therefore,

$$\alpha \approx \frac{\partial u_y}{\partial x} \; ; \quad \beta \approx \frac{\partial u_x}{\partial y}$$

thus

$$\gamma_{xy} = \alpha + \beta = \frac{\partial u_y}{\partial x} + \frac{\partial u_x}{\partial y}$$

By interchanging x and y and u_x and u_y, it can be shown that $\gamma_{xy} = \gamma_{yx}$

Similarly, for the y-z and x-z planes, we have

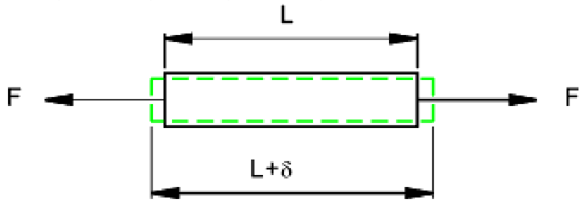
$$\gamma_{yz} = \gamma_{zy} = \frac{\partial u_y}{\partial z} + \frac{\partial u_z}{\partial y} \quad , \qquad \gamma_{zx} = \gamma_{xz} = \frac{\partial u_z}{\partial x} + \frac{\partial u_x}{\partial z}$$

The tensorial shear strain components of the infinitesimal strain tensor can then be expressed using the engineering strain definition, γ, as

$$\underline{\underline{\varepsilon}} = \begin{bmatrix} \varepsilon_{xx} & \varepsilon_{xy} & \varepsilon_{xz} \\ \varepsilon_{yx} & \varepsilon_{yy} & \varepsilon_{yz} \\ \varepsilon_{zx} & \varepsilon_{zy} & \varepsilon_{zz} \end{bmatrix} = \begin{bmatrix} \varepsilon_{xx} & \gamma_{xy}/2 & \gamma_{xz}/2 \\ \gamma_{yx}/2 & \varepsilon_{yy} & \gamma_{yz}/2 \\ \gamma_{zx}/2 & \gamma_{zy}/2 & \varepsilon_{zz} \end{bmatrix}$$

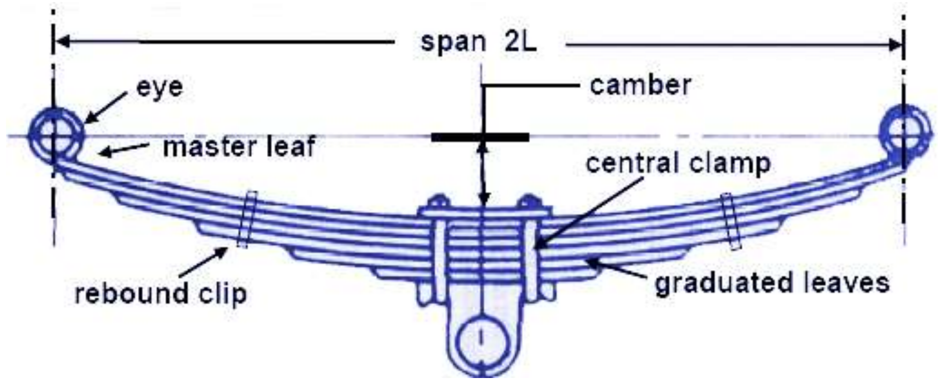
Elastic deformation is governed by Hooke's law which states:

Where σ is the applied stress, E is a material constant called Young's modulus, and ε is the resulting strain. This relationship only applies in the elastic range and indicates that the slope of the stress vs. strain curve can be used to find Young's modulus. Engineers often use this calculation in tensile tests. The elastic range ends when the material reaches its yield strength. At this point plastic deformation begins.When a sufficient load is applied to a metal or other structural material, it will cause the material to change shape. This change in shape is called deformation. A temporary shape change that is self-reversing after the force is removed, so that the object returns to its original shape, is called elastic deformation. In other words, elastic deformation is a change in shape of a material at low stress that is recoverable after the stress is removed. This type of deformation involves stretching of the bonds, but the atoms do not slip past each other.Any elastic material which is subject an applied force is deformed. There are clearly defined relationships between the applied forces and the resulting deformations. This page indentifies these relationships.The average normal strain experienced by a bar under tensile load is simply defined as the average change in length /original length

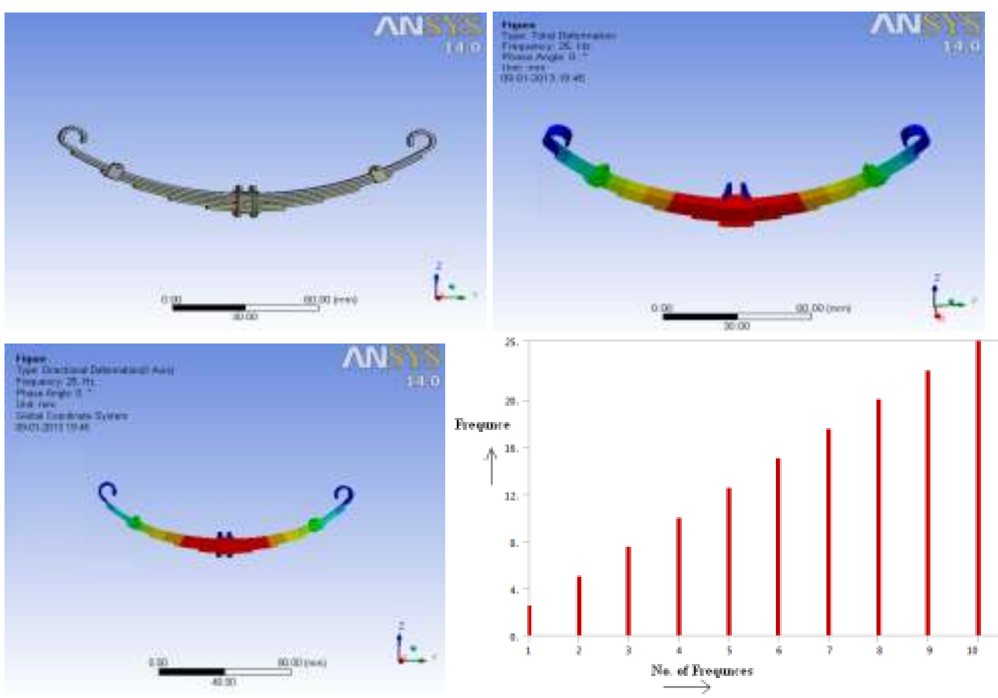


$\varepsilon_{avg} = \delta_{avg} / L$ $\varepsilon = \lim_{\Delta L \to 0} \Delta \delta / \Delta L = d\delta /$

Figure:



Laminated semi-elliptic spring



a) Leaf Spring Model In ANSYS b) Total Deformation Of Leaf Spring c) Directional Deformation Of Leaf Spring d) Graphical Repetition of Frequencies at Different set of Numbers for Total Deformation

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RESULTS AND DISCUSSION

Maximum And Minimum Values Of Leaf Spring

S.no.	Object Name	Result	
		Minimum	Maximum
1	Total Deformation	0. mm	1.7219 mm
2	Directional deformation	-0.0755 mm	1.7219 mm
3	Equivalent Stress	0. MPa	3711.2MPa
4	Equivalent Elastic Strain	0. mm/mm	0.021535 mm/mm
5	Shear Stress	0MPa	2129.4 MPa

Object Name	stress Frequency Response	Frequency Response strain	Frequency Response deformation	Phase Response stress	Phase Response strain
Maximum Amplitude	35.647 MPa	4.09e4 mm/mm	0.821mm	0.81837MPa	4.09e-0.004 mm/mm
Frequency	5 Hz	5 Hz			
Phase Angle	180 °	180. °		180°	
Real	-35.647 MPa	-4.09e.004mm/mm	0.8216 mm	-35.506 MPa	-
Imaginary	0 MPa	0 mm/mm	0mm	0 MPa	0 mm/mm
Reported Frequency	25 Hz			25 Hz	

CONCLUSION

At varying load the frequency response of stress shows that maximum amplitude of stress is developed in 5Hz and also maximum deformation is developed in 5Hz frequency and then graph decreases and gradually increased for further frequencies. Meanwhile, frequency response strain the value of strain is least at 5Hz and increased for further frequency.

The Stress, Deformation, Strain further not changes its value and gradually increased with the frequency there is no sudden change in the frequency spectrum. The stiffness of whole system does not decreases with the increase in frequency which guarantees the reliability of the selected material of leaf spring.

By using the frequency spectrum the stess, strain and other parameter which effect the structure are estimated. The combination of frequency and amplitude is found to be most efficient method for reducing or controlling applied force which generate stress.

The strength is a crucial parameter to prevent failure. Based on the result from the frequency response the values at 5 Hz should be improved. The stress in the full length leaves is 50% greater than stress in graduated leaves. In order to obtain best result all the leaves are equally stressed .this condition is obtained in two ways:

By making the full length leaves of smaller thickness than the graduated leaves. In this way, the full length leave will induce smaller bending stress due to small distance from the neutral axis to the edge of the leaf and improved the surface contact area of leaf in the same ratio as we reduce thickness.By giving a greater radius of curvature to the full length leaves than graduated leaves.A gap or clearance will be left between the leaves or a vibration absorber such as Thin Sponge sheet is to be placed between the contact surfaces of leaf.

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REFERENCES

[1] Sugiyama et al [2006] Fatigue of Composites – Fatigue Modulus Concept and Life Prediction Journal of Composite Materials,

[2] Fancher et al[1978] Composite Materials Design and Processes for Automotive Applications. The ASME Winter Annual Meeting, San Francisco.

[3] Cebon, D [1986] Simulation of the response of leaf springs to broad band random excitation. Vehicle System Dynamics, 15.

[4] Hoyle, [2004] "Evaluation of a Multi-Leaf Hybrid Springs for Automotive Suspensions" SAE paper series, 2004-01-0782

[5] Mouleeswaran Senthil Kumar, Sabapathy Vijayarangan, [2007] " Analytical And Experimental Studies On Fatigue Life Prediction Of Steel And Composite Multi-Leaf Spring For Light Passenger Vehicles Using Life Data Analysis" Materials Science . Vol.13.No.2.

[6] Erdogan Kilic [2006] "Analysis of composite leaf springs", http:// www.elsevier.com

[7] C.K. Clarke and G.E. Borowski [2012] " Evaluation of a leaf spring failure" ASM International 1547-7029

[8] Zhu Jianbao,Zhang Weibo [2008] (College of Mechanical Engineering and Automation,Fuzhou University,Fuzhou 350002,China);Optimized simulation design of taper leaf spring based on particle swarm optimization algorithms and ANSYS[J];Journal of Fujian University of Technology.

[9] Kumar Krishan and Aggarwal M.L[2011] A Finite Element Approach for Analysis of a Multi Leaf Spring using CAE Tools Research Journal of Recent Sciences ISSN 2277-2502 Vol. 1(2), 92-96, Feb. Res.J.Recent Sci.

[10] S G Harinath Gowd, E Venugopal Goud[2012] "Static Analysis Of Leaf Spring" Issn: 0975-5462 Vol. 4 No.08 August "International Journal Of Engineering Science And Technology (Ijest)"

[11] Ranjeet Mithari, Amar Patil, Prof. E. N. Aitavade [2012] "Analysis Of Composite Leaf Spring By Using Analytical & Fea" Issn: 0975-5462 Vol. 4 No.12 December 2012 "International Journal Of Engineering Science And Technology (Ijest)"

[12] V.Pozhilarasu, Dr. T.Parameshwaran Pillai [2012] "Performance Comparison Of Conventional And Composite Leaf Spring"Issn: 0975-5462 Vol. 4 No.12 December "International Journal Of Engineering Science And Technology (Ijest)"

[13] Thimmegowda Rangaswamy., Sabapathy Vijayarangan, [2005] Otimal Sizing And Stacking Sequence Of Composite Drive Shafts Materials Science Vol. 11, No. 2.

[14] Tirupathi R. Chandrupatla & Ashok D.Belegundu, [2005] "Introduction to Finite Elements in Engineering". Third Edition- Pearson Education Pvt. Ltd.

[15] S.S.Rao, [2001] "The Finite Element Method in Engineering". Third Edition- Butterworth Heinemann Publications.

[16] T.V.S.Sundarajamoorthy, N.Shanmugam [2000] "Machine Design"- Eighth Edition- Published by M.Sethuraaman, Anuradha Agencies.

[17] O.P.Khanna, [1999] "Material science and metallurgy"-First edition Dhanapati Rai Publications.

[18] Autar. K.Kaw, [1999]" Mechanics of Composite materials" CRC Press.

[19] Gummadi Sanjay, Akula Jagadeesh Kumar[2009] "Optimum design and analysis of a composite drive shaft for an automobile" Masters Degree Thesis.