Design and Modal Analysis of Composite Leaf Spring Suspension System for Light Weight Vehicles

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Abstract— The aim of this present work is to estimate the natural frequency or self-excitation frequency induced in the Composite leaf spring of transport vehicle. This project is on the application of computer aided analysis using finite element method. The component chosen for analysis is a leaf spring which is an automotive component used to absorb vibrations induced during the motion of vehicle. 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 complicated due to its clamping effects and interleaf contact, hence its analysis is essential to predict the displacement, mode frequency and stresses. The leaf spring, which we are analyzing, is a custom designed leaf spring with different eyes like as, Berlin and upturned eyes with different materials at different sections. This spring is intended to bear heavy jerks and vibrations reduced during real operating conditions in military operations. In analysis part the finite element of leaf spring is modeled using solid works and analysis is done using ansysworkbench. Appropriate boundary conditions, material properties and loads are applied selected as per intended performance. The mode frequencies obtained are analyzed.

Key words: Leaf spring, Composite, FEA, Modal Analysis, Solid Works, ANSYS WORKBENCH

I. Introduction

A spring is defined as an elastic body, whose function is to distort when loaded and to recovers its original shape when the load is removed. Semi- elliptic leaf springs are almost universally used for suspension in light and heavy commercial vehicles. For cars also, these are widely used in rear suspension. The spring consists of a number of leaves called blades. The blades are varying in length. The blades are us usually given an initial curvature or cambered so that they will tend to straighten under the load. The leaf spring is based upon the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called main or master leaf, the remaining blades are called graduated leaves. All the blades are bound together by means of steel straps.

II. Literature review

ZliahuZahavithe leaf spring works is very complicated from the point of view of mechanics and numerical computations. The magnitude of loading is high as well as spring deformations. Multi-surfaces 3D contact between subsequent leafs also takes place. The main advantage of leaf springs is that the ends of the spring are guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. Practically, a leaf spring is subjected to millions of load cycles leading to fatigue failure. Free vibration analysis determines the frequencies and mode shapes of leaf spring.

A.strzat and T.Paszek performed a three-dimensional contact analysis of the car leaf spring. They considered static three-dimensional contact problem of the leaf car spring. Different types of mathematical models were considered. The static characteristics of the car spring was obtained for different models and later on, it is compared with one obtained from experimental investigations.

Fu-chinwag performed a detailed study on leaf spring. His work mainly discusses the active suspension control of vehicle models. The employing active suspension through the analysis of the mechanical networks is discussed. He derived a parameterization of the set of all stabilizing controllers for a given plant.He considered practical parameters and applications of a leaf spring model through his work, thus supporting both the situations, that is active and passive suspension cases, individually.

I.Rajendran and S. Vijayarangan performed a finite element analysis on a typical leaf spring of a passenger car. Finite element analysis has been carried out to determine natural frequencies and mode shapes of the leaf spring. A simple road surface model was considered.

Further literatures are available on concepts and design of leaf springs. Some of the springs manufacturing companies publish catalog on leaf spring giving dimension details. Some of the passenger manufacturers also publish manuals, which give important dimensions of leaf spring.

III. Components used for test

For the present study, 3 models are used for analysis. Al6061/silicon nitride with increasing the percentage of silicon nitride is used for modal analysis.

IV. Finite element analysis of component

The component is modeled using solid works. Manufacture of the component and geometric dimensions there on are used to model the component. Using the cross sectional area, the part is extruded. Displacement boundary conditions on the model with all degree of freedom constrained on the surfaces. Also the evaluated engineering properties of the three composite compositions are given in Table 1.

Property	Unit	0% of Si_3N_4	6% of Si_3N_4	10% of Si_3N_4
Density	Kg/m^3	2700	2860	2964.8
Modulus of Elasticity	GPa	70.8	85.699	95.209
Poisson's ratio		0.33	0.3408	0.34771

Table 1: Engineering Properties of theAl6061 Si3N4 composite Material

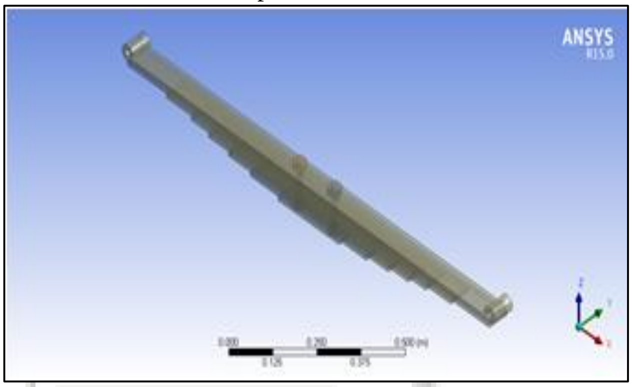

Fig. 1: ANSYS Imported CAD Model

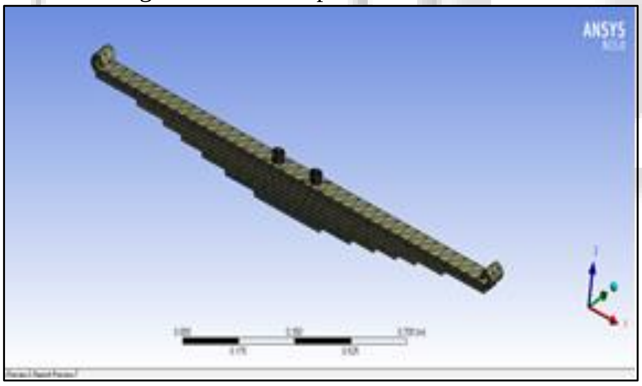

Fig. 2: Meshed model

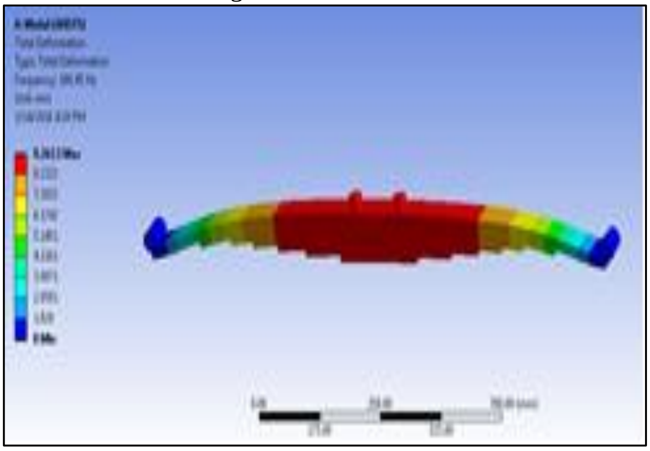

Fig. 3: Mode1 natural frequency of component with 0% of silicon nitride.

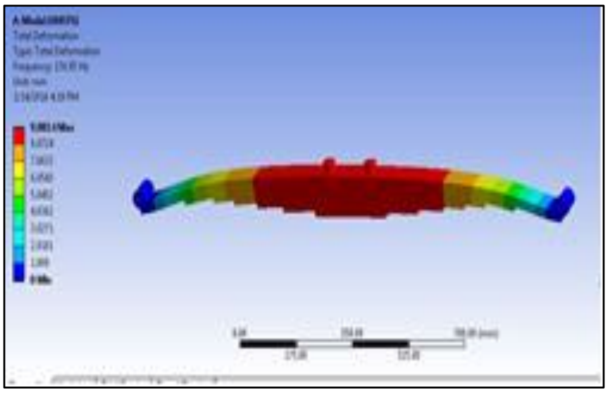

Fig. 4: Mode1 natural frequency of component with 6% of silicon nitride.

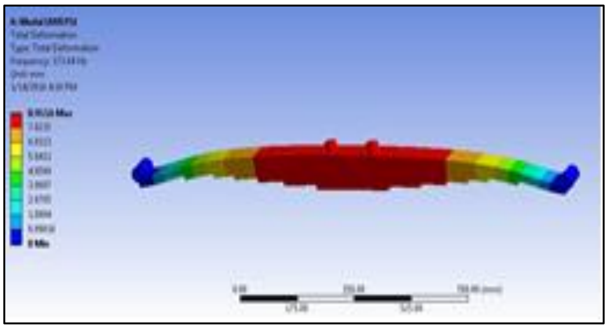

Fig. 5: Mode1 natural frequency of component with 10% of silicon nitride.

Tabular Data

	Mode	Frequency [Hz]
1	1.	180.45
2	2.	205.12
3	3.	402.22
4	4.	669.87
5	5.	746.78
6	6.	1024.

Fig. 6: Mode 1-6 natural frequency of component with 0% of silicon nitride.

Tabular Data

	Mode	Frequency [Hz]
1	1.	176.95
2	2.	201.14
3	3.	394.41
4	4.	656.86
5	5.	732.27
6	6.	1004.1

Fig. 7: Mode 1-6 natural frequency of component with 0% of silicon nitride.

Tabular Data

	Mode	Frequency [Hz]
1	1.	173.64
2	2.	197.38
3	3.	387.04
4	4.	644.58
5	5.	718.59
6	6.	985.31

Fig. 8: Mode 1-6 natural frequency of component with 0% of silicon nitride.

Above figures shows first six mode results for the Leaf spring with 0%, 6% and 10% wt. of Si3N4.

V. Results and Discussions

The prepared CAD models are imported to ANSYS workbench and are meshed. Engineering properties of material like young's modulus, poisson's ratio and density are inputted. Modal analysis is performed to determine the natural frequency of the component.

	0% SI_3N_4	6% SI_3N_4	10% SI_3N_4
Mode	Frequency [Hz]	Frequency [Hz]	Frequency [Hz]
1.	180.45	176.95	173.64
2.	205.12	201.14	197.38
3.	402.22	394.41	387.04
4.	669.87	656.86	644.58
5.	746.78	732.27	718.59
6.	1024	1004.1	985.31

Table 2: Natural frequencies of components with different weight percentage of Si3N4.

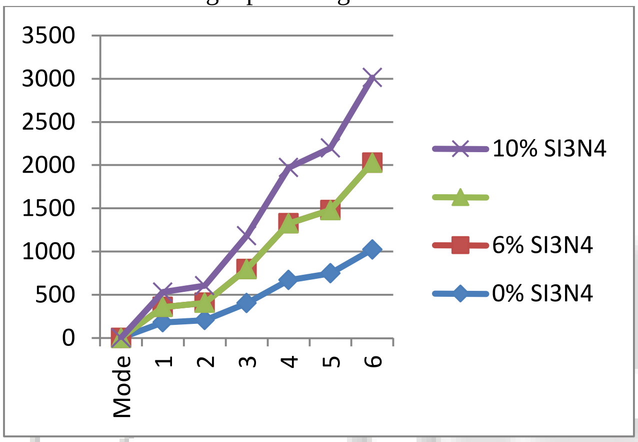

Fig. 9: Plot of natural frequencies.

The damping ratio, coefficient and other parameters are calculated using the values obtained from the free vibration test and a table containing the results of the test is made. From Table.1 we can see that the damping coefficient increases in each successive composition.

The graphical representation in variation of damping coefficient for all three compositions clearly indicates that the value of damping coefficient increases with each composition. This is because in each successive composition of the percentage of silicon nitride is increased

VI. Conclusions

Above analysis observation shows that Natural frequency or self-excitation of the component decreases with increasing the silicon nitride percentage. The highest percentage of silicon nitride component having less natural frequency high damping capacity can be used as high damping leaf spring Manufacturing for light weight vehicles.

References

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