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Dynamic Analysis of Steel Leaf Spring

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***Abstract*— This work proposes modal analysis i.e. Natural Frequency Analysis of steel mono leaf spring. Natural frequency of selected leaf spring is determined experimentally by FFT analyzer. Finite Element Analysis will be carried out considering existing conventional steel leaf spring of a light commercial vehicle with a proper material properties and element types, to get Natural Frequency and Mode Shapes of the mono leaf spring using Ansys Software. Comparison of the natural frequency by FFT analyzer with FEA will also be done.**

***keywords*—Modal anlysis, Natural frequency, Mode shapes, Solid works,Ansys workbench.**

I. INTRODUCTION

Leaf spring is main component of automobile suspension system. It consists of a number of flat plates, which are stacked together. The longest leaf, called the master leaf, is bend at both ends to form spring eyes. Through the eyes, spring is attached to the body of the vehicle.

One or two more full length leaves are provided between main or master leaf and other type of leaves known as graduated leaves. These extra full length leaves are provided to support the transverse shear force, in addition to bending load.[11]

The leaves are given an initial curvature known as camber. This initial curvature is provided so that the leaves will tend to straighten under the load. The leaves are held together by means of U-bolts and the central bolt or band shrunk around them at centre. Rebound clips are located at intermediate positions along the length of the spring. So that the graduated leaves share the rebound load with main or master leaf. The rebound clips also help to keep to keep leaves in alignment and prevent lateral shifting of leaves during the operation.

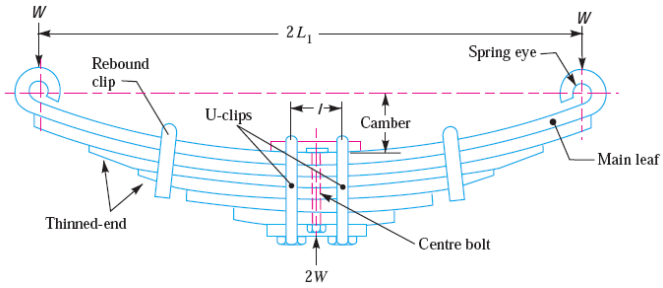

Fig.1.Construction of leaf spring

Suspension system prevents the road shocks from being transmitted to the vehicle components also safeguard the occupants, it preserves the stability of the vehicle in rolling, while in motion.Leaf spring selected for this study is steel leaf spring of Armada vehicle.

II. LITERATURE REVIEW

G Harinath Gowd and E Venugopal Goud has carried out static analysis of steel leaf spring & determined the maximum pay load of the vehicle experimentally and analystically[1]. Pankaj saini and Ashish Goel designed and proposed a method of fabrication of composite mono leaf spring with better ride quality and carried out its static analysis using Ansys 9.0[2]. B.Vijaya Lakshmi1and I. Satyanarayana has compared load carrying capacity and weight saving of composite leaf spring with that of steel leaf spring[3]. Zoman Digamber, Jadhav Mahesh, P R Kharde and V R Kharde has carried out static analysis of two conventional steel leaf spring made up of SUP 10 & EN 45. Leaf spring was modelled in CATIA V5R17 and analyzed using ANSYS 14.0. Analytical results were compared with FEA results[4]. Shishay Amare Gebremeskel has designed, simulated and analyzed composite leaf spring of three wheeler vehicle. He has prepared prototype of that leaf spring and carried out static analysis[5]. He has considered static conditions only.

COMMENTS

Review of papers concludes that dynamic analysis of steel leaf spring is not studied yet. So, The aim of present work is to carry out Dynamic Analysis (Modal Analysis) using ANSYS software and obtained results will be compared with the experimental results(FFT Analyser).

III. PROBLEM DEFINITION

Objective of present work is to consider an existing automobile leaf spring model and to carry out its dynamic analysis (Modal Analysis).

Modal Analysis is the basic dynamic analysis to calculate the natural frequencies of the structures. Output of the modal analysis is Natural Frequency and Mode Shapes. It helps to understand the structural behavior in actual loading conditions.

In present work Modal Analysis will be carried out using Ansys Software and results will be compared with experimental (FFT Analyzer) results and theoretical results.

IV. METHODOLOGY

1) Experimental modal analysis using FFT analyzer

Experimental set up is prepared to simulate actual working conditions. One end of steel leaf spring is connected to fixed element which is welded to long metal strip, providing zero degrees of freedom. Another end of that spring is connected to shackle i.e flexible link which in turn provides one directional displacent i.e. in X-direction only. Experimental setup is shown in fig below.

Fig.2.Experimental arrangement

Fig.3.Modal analysis on FFT analyzer

Experimental procedure for modal analysis on FFT analyzer:

1)Start the FFT analyzer.

2)Go to Run-up mode-set-New set(Rename)-OK.

3)Set the ranges of force amplitude, frequency and scale for graphs.

4)A force of very small amplitude is applied on a steel leaf spring by a hammer which is provided with FFT analyzer and corresponding results(Natural frequencies) are obtained on FFT analyzer. These results are shown below:

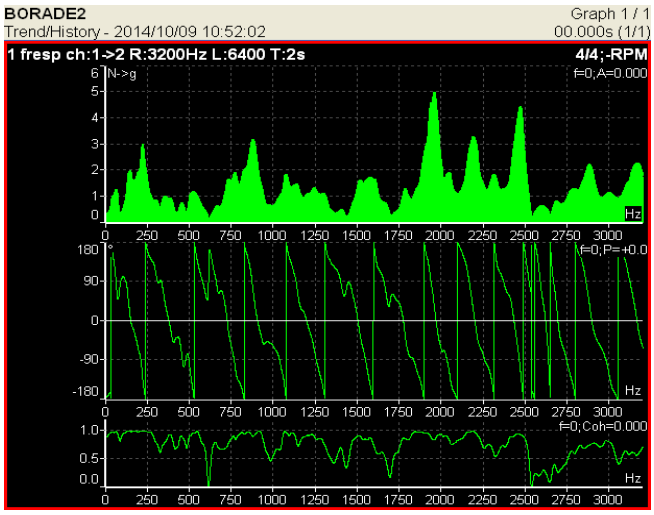

Fig.4.Results on FFT analyzer

This graph shows magnitude of input force, phase difference and coherence on Y-axis and natural frequency on X-axis.

Procedure for determination of natural frequencies is as follows:

1)Select a pick value.

2)Check phase difference for that pick value, it is expected to be 180°. If this condition is satisfied then go for 3rd step and if not then select next pick and follow steps 1 and 2.

3)Check coherence for that corresponding pick, it is expected to be one ideally(0.75 to 1 can also be choosen). If this condition is satisfied then corresponding pick will give first natural frequency and if not then select next pick and follow steps 1,2 and 3 again. In this way we can get First, second, third,…..etc. natural frequencies by using FFT analyzer.

Results(First six natural frequencies) obtained by this experiment are given below. [10]

Sr.No	Natural Frequencies(Hz)
1	225
2	525
3	1075
4	1300
5	1575
6	2475

Table.1.Natural frequencies obtained on FFT

2)Modal analysis by FEA(Ansys).

Modal analysis in ansys has been carried out with following steps:

1. Material testing using spectrometer to determine material of selected leaf spring. According to material configuration obtained on spectrometer, name of the material is determined.
2. According to the material, material properties are selected from design data book. [13]
3. Dimensions of selected leaf spring are obtained and its model is drawn in Solid works.
4. That model is imported in Ansys.
5. Material properties of that material are entered in the Ansys.
6. Boundary conditions are given i.e. one end is fixed having zero degrees of freedom and another end is having only one degree of freedom i.e. in X-direction.
7. Natural frequencies and mode shapes are obtained.
8. Experimental results are compared with FEA results.

Above steps are explained in detail in further sections:

1)Material testing using spectrometer to determine material of selected leaf spring:

Material of selected leaf spring is determined by spectrometer. Experimental arrangement is shown below.

Fig.5.Material testing on Spectrometer

Results obtained by this testing are shown in the table below.

Sr. No.	Elements	Observed Readings %	Specified Value of 55Si2Mn90	Remark
1	C	0.58	0.5-0.6	Material Confirms to steel 55Si2Mn90 Grade
2	Mn	0.97	0.8-1	
3	Si	1.68	1.5-2	
4	P	0.04	---	
5	S	0.05	---	
6	Cr	0.1	---	
7	Mo	0.03	---	

Table.2.Material configurations obtained by testing of leaf spring on Spectrometer

Where,C-Carbon, Mn-Mangenese, Si-Silicon, P-Phosphorous, S-Sulphur,Cr-Chromium,Mo-Molybdenum.

Hence, material of selected leaf spring is Silicon Magnesium Steel.

2)Material of selected leaf spring is of grade 55Si2Mn90. i.e.Silicon Mangesium steel. From P.S.G. Design Data Book[9] Material properties of Silicon Magnesium Steel are selected which are as follows:

Youngs modulus=2.1*e5 N/mm^2

Density=7.860*e-6 kg/mm^3

Poissions ratio= 0.3

Tensile strength=1962 N/mm^2

3) Dimensions of selected leaf spring are obtained and its model is drawn in Solid works in following steps.

Dimensions:

Span= 875 mm(center to center),

Camber= 130 mm,

Width at end = 62 mm,

Width at center = 62 mm,

Thickness = 5mm,

Inner dia = 35 mm,

Outer dia = 45 mm.

Steps of modeling of leaf spring in solid works with above dimensions:

i. Draw a rectangle of dimensions 875*130.
ii. Draw circles at both top most corners of dia 35 mm.
iii. Draw a centerline at 875/2 distance.
iv. Draw a 3 point arc passing through two topmost corner of rectangle and third point as a intersection of centerline with bottom side of rectangle.
v. Make it tangent with both the circle drawn at the upper side of rectangle.
vi. Trim the extra part of the circle.
vii. Add the thickness by offset command by 5 mm.
viii. Extrude this sketch by 62 mm to provide required width.

4)Import this model in Ansys workbench:

5)Enter the material properties I the Ansys which are obtained from design data book.

6)Apply boundary conditions:

One end of the leaf spring is fix i.e.zero degree of freedom and other end connected to shackle is having one degree of freedom i.e. in X-direction.

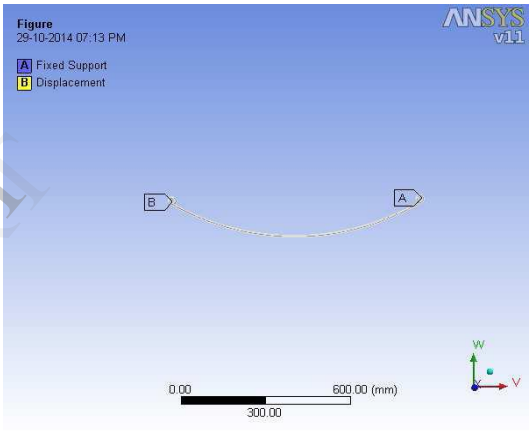

Fig.6.Boundary conditions for FEA testing of leaf spring

7) Natural frequencies and mode shapes are obtained after FEA analysis in Ansys are as follows[12].

Sr.No	Natural Frequencies(Hz)
1	207.75
2	517.3
3	1158.1
4	1277.8
5	1589.
6	2455.5

Table.3.Natural frequencies obtained by FEA analysis of leaf spring

Mode shapes are given below:

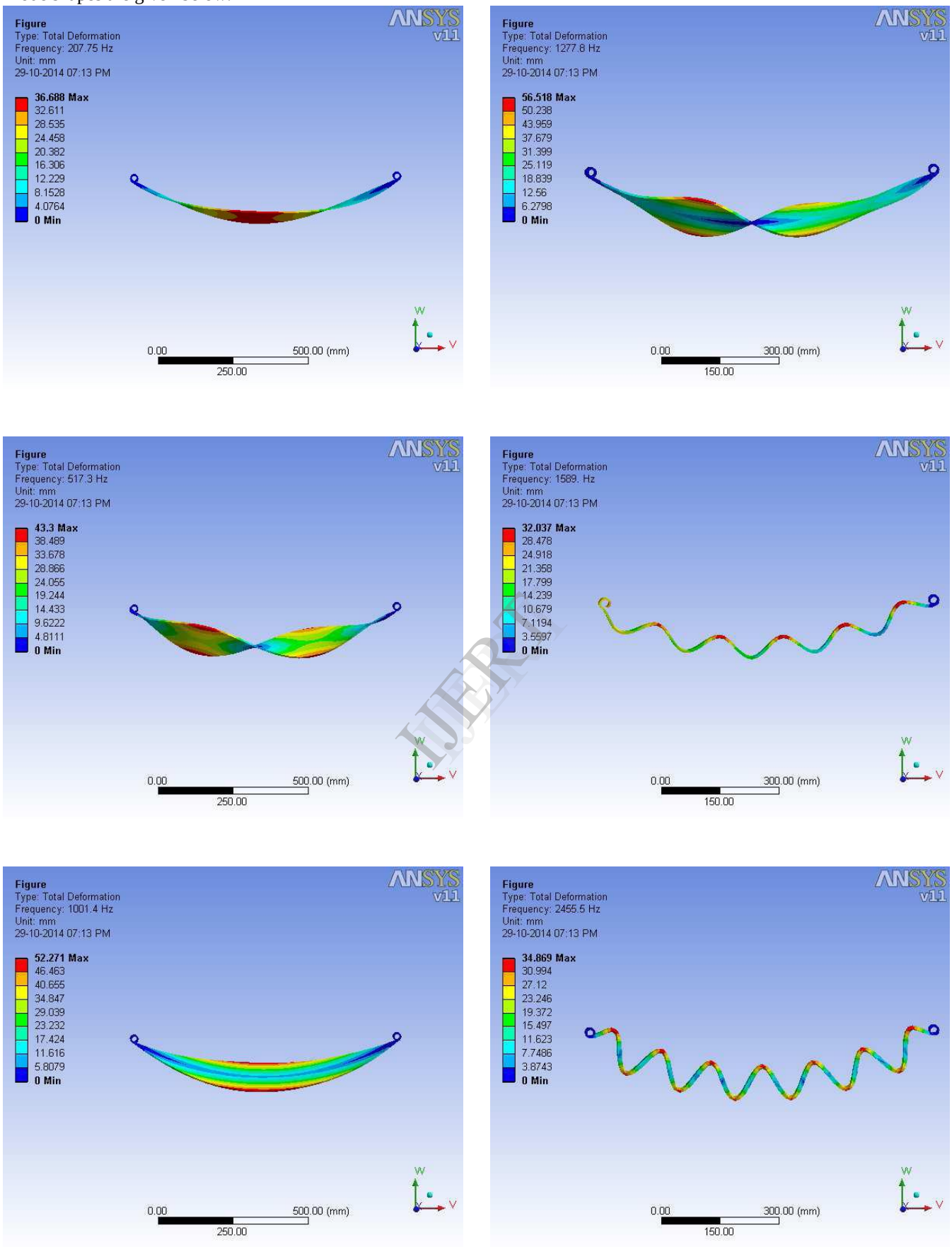

Fig.7.Mode shapes obtained for first six natural frequencies

V. RESULTS AND DISCUSSION

Natural frequencies of steel leaf spring is determined by Experimental modal analysis and by FEA analysis and the results are comparable. These results are shown in the table below.

Sr.No	Natural Frequency(Hz) Experimental	Natural Frequency(Hz) FEA
1	225	207.75
2	525	517.3
3	1075	1158.1
4	1300	1277.8
5	1575	1589
6	2475	2455.5

Table.4.Comparison of Experimental and FEA results

From above table, it is seen that natural frequencies of steel leaf spring obtained experimentally are quite comparable with the natural frequencies obtained by FEA analysis. Hence we can say that these frequencies are closer to the actual values of frequencies of that particular steel leaf spring.

VI. CONCLUSION

Results obtained by experimental modal analysis and by FEA analysis are nearly same. So, one can say that these are quite correct values of frequencies of selected steel leaf spring. So, if material of this steel leaf spring is changed keeping its dimensions same as initial dimensions and if the change in natural frequencies of that spring is studied with respect to change in material of that spring, this study will be useful for material optimization of leaf spring.

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