DETECTION OF CRACK LOCATION AND CRACK DEPTH IN LEAF SPRING BY USING FUZZY LOGIC TECHNIQUE.

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ABSTRACT

The objective of this work is to find the crack location and crack depth in leaf spring of an army jeep. The spring is subjected to heavy jerks and vibration during the military operation. Therefore it is necessary to find the crack in a leaf spring. Crack in a leaf spring introduces local flexibility that would affect the vibration response of the leaf spring. Main problem is to detect existence of a crack together with its location and depth in the leaf spring .We used a natural frequency a basic criteria for crack detection. Analytical calculations are done to find out natural frequency of leaf spring by using Euler's beam theory.Ansys 16.0 is used to find out natural frequency along with experimentation on FFT analyzer. Now, We propose a method based on some set of fuzzy rules obtained from the information supplemented by Numerical Analysis. Fuzzy controller use comprises of three input variables (first, second and third natural frequency) and two output variables (relative crack length and relative crack depth) are generated with Triangular MF.

KEYWORDS *– Leaf Spring; Free vibration; Crack; Natural frequency; Fuzzy Logic etc*

1. INTRODUCTION

Mechanical element in real service life are subjected to combined or separate result of the dynamic load, temperature, corrosive medium and other kind of damages. Cracks in a element could also be hazardous because of static or dynamic loadings, so that crack detection plays most important role for structural health monitoring application. Crack detection is important because fatigue cracks are advantage supply of catastrophic failure .It is required that leaf spring must safely work for the duration of its service life. Damages initiate a breakdown period on the element. One technique for reducing inspection associated shutdown time and related cost is to provide a mechanism with an early warning failure device. Such a device monitors, online, crack-associated irregularity in the behavior of a system. If the device gives a sound signal that a crack is present, a message is given out to the operator to shut down the machine and have got to be checked. For the development of such early warning devices, knowledge of the dynamics of cracked structures is required. A crack in a structure is also realized from the local divergence in structure stiffness affecting the global dynamic behavior of the structure. Also, a crack may just occur its presence in a beam-like structure by way of the trade in change in natural frequency and mode shape of the system. These indicators will also be used to measure the extent of the damage and to determine its location. Several researchers confirmed interest in developing algorithms to detect cracks in beams. The inducement for this curiosity is that the identification of cracks in a spring furnishes foremost factor of reference to test the precision of identification approaches; additionally, many mechanical programs have dynamic habits just like a single beam, like shafts and blades. To decrease the weight of vehicles in recent years is the basic needs of industry. The suspension spring is one of most important system in automobile which reduces the vibration and absorb jerk during riding. Steel leaf spring have been vigorously developed for many applications. Other advantages steel are: (a) the possibility of reducing noise, vibrations and ride harshness due to their high damping factors, which means lower maintenance costs; and (c) lower tooling costs, which has favorable impact on the manufacturing costs. Springs are crucial suspension elements in cars; need to reduce the vertical vibrations due to road regularities. Where the function of the springs for an automobile industry are to maintain good control and passenger comfort. Behavior of leaf spring is nonlinear; whose weight is high, and change in solid axle angle due to weight transfer. This lead to over steer and directional instability under such condition it is very difficult for driver to control vehicle. Like this some defect of metallic leaf spring observe so considering automobile development and importance of relative aspects. Where graphite and carbon fiber demonstrate better performance over steel material, however due to cost and availability limits usage on wide scale. The present work is restricted to leaf spring. Many papers were devoted to find spring geometry. In this work, stress-strain study and modal analysis of Leaf spring is being done with and without Crack.

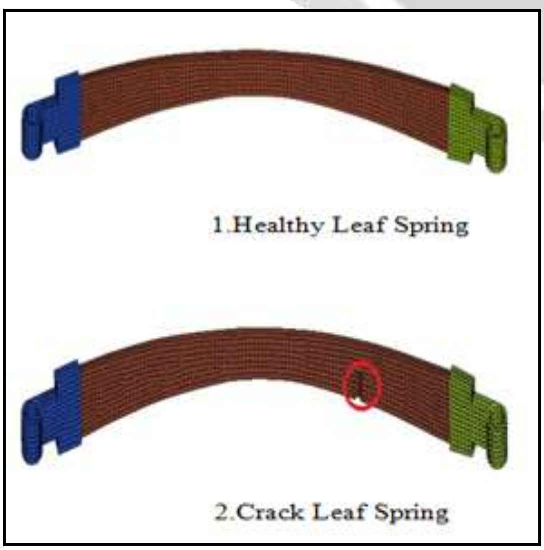
2. LITERATURE REVIEW

[1]Pankaj Charan Jena, Dayal R. Parhi, Goutam Pohit (2012) concluded on his paper on faults detection of a single cracked beam by theoretical and experimental analysis using vibration signatures that approach evolved in this paper intimate location, size and depth of the open crack in beam of different end conditions i.e. cantilever beam, clamped-clamped beam and simply supported beam with rectangular cross section. The comparisons of result in both methodologies written above are performed. The results of theoretical analysis and experimental analysis are compared and are found to be good correlation in between them.
[2] M Taghi V Baghmisheh, M Peimani, M H Sadeghi and M M Ettefagh (2008)

investigated for modeling the cracked-beam structure an analytical model of a cracked cantilever beam is utilized and natural frequencies are obtained through numerical methods. The identification of the crack location and depth in the cantilever beam is formulated as an optimization problem, and binary and continuous genetic algorithms (BGA, CGA) are used to find the optimal location and depth by minimizing the cost function.
[3] FLeonard, J Lanteigne, S Lalonde and Y Turcotte (2001) proposed a study on spectrograms of the free-decay responses showed a time drift of the frequency and damping: the usual hypothesis of constant modal parameters is no longer appropriate, since the latter are revealed to be a function of the amplitude.
[4] M. Karthikeyan and R. Tiwari (2008) studied and establish an identification procedure for the detection, localization, and sizing of a flaw in a beam based on forced response measurements. The experimental setup consisted of a circular beam, which was supported by rolling bearings at both ends.
[5]H. Nahvi and M. Jabbari (2005) finds results that the finite element model of the cracked beam is constructed and used to determine its natural frequencies and mode shapes. From the theoretical analysis and experimental measurements, it is found that the crack location, as well as crack size, has noticeable effects in the first and second natural frequencies of the cantilever beam.

3. MATERIAL AND DIMENSION OF LEAF SPRING

Steel leaf spring of army jeep is considered for the analysis. One leaf spring is considered as uncracked and other two leaf springs are cracked. Cracks of 2 mm are produced by using grinding machine. Modulus of elasticity and density of a leaf spring have been measured to be 210GPa and 7850 Kg/m^3 respectively.



Sr. No.	Parameters	Value
1	Total Length of Spring(Eye to Eye)	920mm
2	Camber	120mm
3	Thickness	6mm
4	Width	45mm
5	Weight	4kg

Fig-1: Dimension of leaf spring

4. METHODOLOGY

In this case, for a given problem, it is necessary to measure or compute the first three transverse natural frequencies of the leaf spring with a crack and the corresponding uncracked spring. As stated earlier, both the crack location and the crack depth influence the changes in the natural frequencies of a cracked spring. Consequently, a particular frequency could correspond to different crack locations and crack depths. The point of intersection, common to all the three modes, indicates the crack location, and crack depth. The steps adopted to carry out research methodology are as follows:

i. Theoretical calculations for first three natural frequencies of all spring models.
ii. Finite Element Analysis using ANSYS.
iii. To experimentally validate the three natural frequencies of cracked and uncracked spring, experimental modal analysis will be done using FFT analyzer.
iv. With the help of above mentioned three methods,the three natural frequencies for cracked & uncracked leaf spring will be compared with each other.
v. Frequencies are provided as input to Fuzzy logic to obtained relative crack location and depth.
vi. Outputs are compared with theoretical ones.
vii. Conclusion

4.1 ASSUMPTIONS

For the purposes of crack identification the following assumptions are made:

i. The crack is open. This assumption is expected to be realistic because the crack is usually found in areas which are exposed to heavy weights, which naturally leads to an open crack.
ii. The crack is a transverse crack.

5. ANALYTICAL CALCULATIONS

Theoretical analysis is done by Euler’s beam theory. First three mode of natural frequencies are calculated by this theory. FNF, SNF, TNF are first three natural frequencies in hertz and RCD, RCL are relative crack depth and relative crack location respectively.

Table-1: Different leaf spring models with dimension and natural frequencies

Model no.	RCD	RCL	First Natural Frequency	Second Natural Frequency	Third Natural Frequency
1	0	0	16.618	66.51	149.021
2	0.33	0.25	16.305	65.25	146.204
3	0.33	0.50	16.305	65.25	146.204

6. FINITE ELEMENT ANALYSIS OF LEAF SPRING

Finite Element Analysis of cantilever beam is done by using ANSYS workbench 16.0 software. Following steps show the guidelines for carrying out Modal analysis.

i. Generation of model in Designing software.
ii. Start ANSYS workbench 16.0.
iii. Select Modal Analysis System.
iv. Enter material specifications in Engineering Data.
v. Import geometry which is already made in CATIA.
vi. Open Model which has geometry of beam.

vii. Mesh the model with fine.
viii. Update analysis setting.
ix. Insert boundary conditions.
x. Give free vibration on beam.
xi. Evaluate all the results.
xii. Result summary.
xiii. Generate a report of the analysis results.

Some of the Results obtained by the finite element analysis are presented here which will represent the natural frequency of respective mode in the left side. First three natural frequencies are calculated by this method. This also represents how every specimen behaves after the presence of crack with different crack location and crack depth. All frequencies are in hertz.

Result of Finite Element Analysis

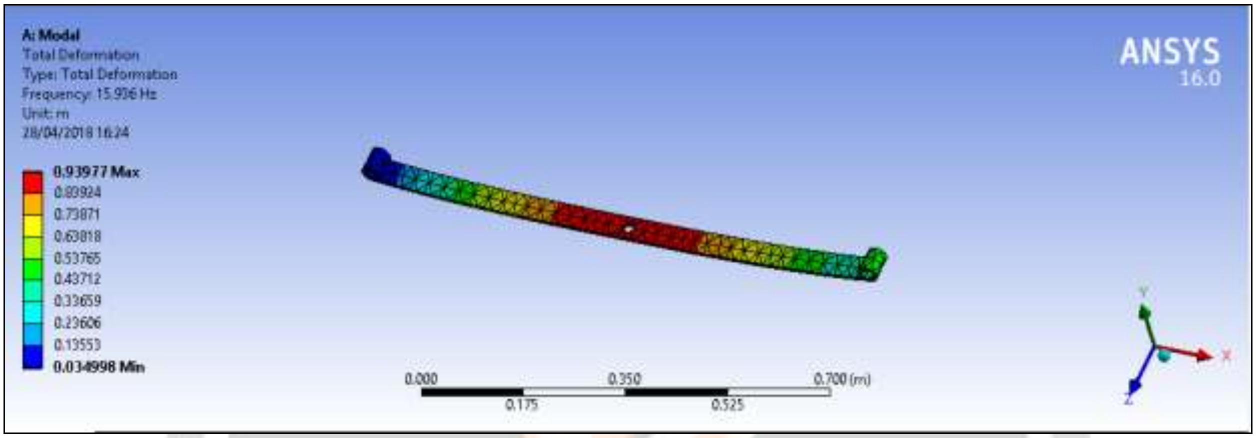


Fig-2 First Mode Vibration of Uncracked Leaf Spring

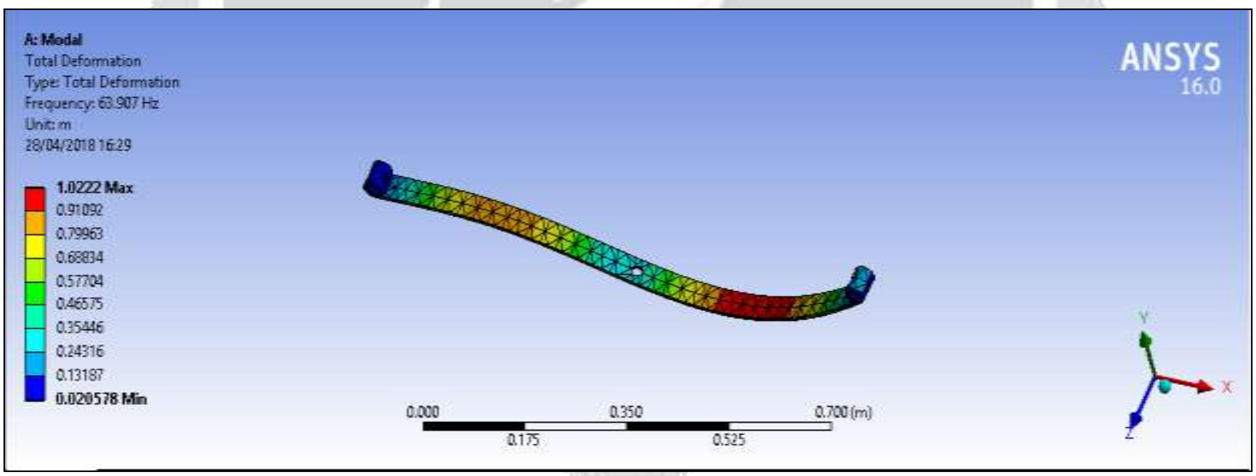


Fig-3 Second Mode Vibration of Uncracked Leaf Spring

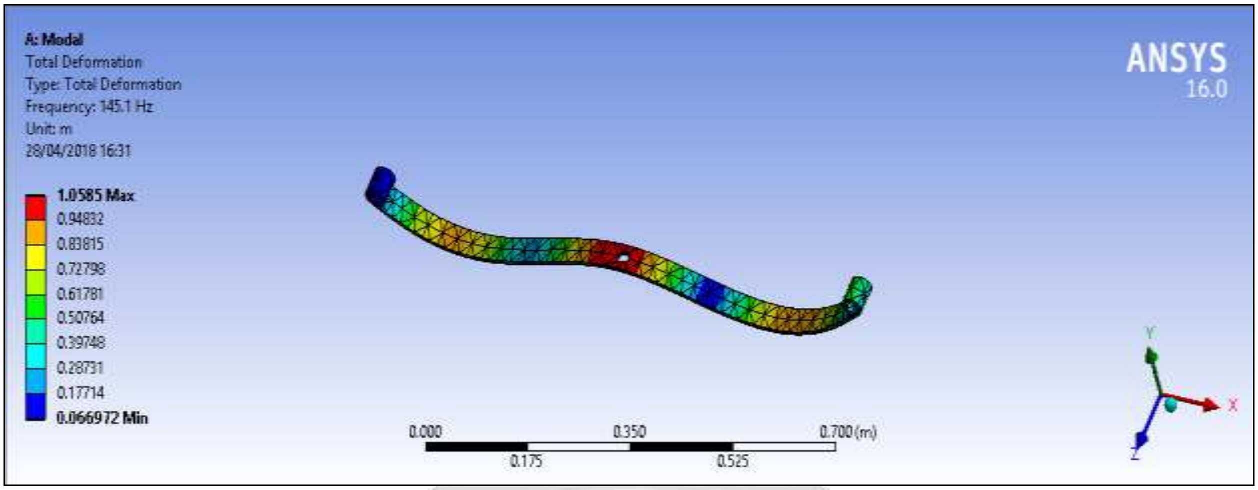


Fig-4 Third Mode Vibration of Uncracked Leaf Spring

Table-2 Natural frequencies of Leaf spring model in Hz by using Finite Element Method

Model no.	RCD	RCL	First Natural Frequency	Second Natural Frequency	Third Natural Frequency
1	0	0	15.936	63.907	145.1
2	0.33	0.25	15.886	63.569	144.78
3	0.33	0.50	15.73	63.10	143.55

7. EXPERIMENTAL SETUP

Experimental analysis is carried out on the FFT analyzer. The experimental setup is as follows.

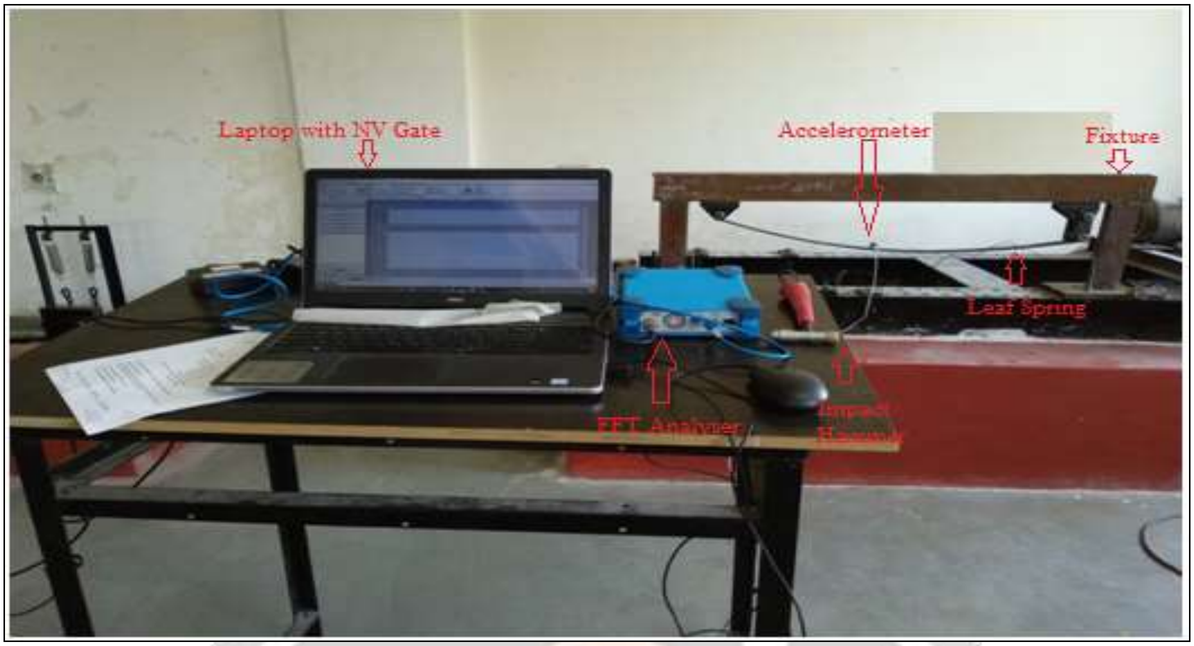


Fig-5 Experimental Setup

Signals from the impact hammer and the accelerometer will be received by the vibration analyzer for each impact. The curve known as Frequency Response Function (FRF) will be generated by the software that is used to find the natural frequencies of the cantilever beam. Observe the curve and read frequencies that correspond to peaks of the FRF. Change the frequency view as amplitude and phase. We get the frequency response function (FRF), a magnitude and phase plot with coherent plot. The peaks observed in FRF are the natural frequencies of the beam. All the components as explained above are connected neatly having a laptop loaded with software for modal analysis.

Table-3 Natural frequencies of leaf spring model in Hz by using FFT Analyzer

Model no.	RCD	RCL	First Natural Frequency	Second Natural Frequency	Third Natural Frequency
1	0	0	16.20	64.15	146.50
2	0.33	0.25	15.95	63.88	145.25
3	0.33	0.50	15.409	62.97	144.88

8. CONCLUSION

In this study the Euler's equation, Finite Element Analysis of a leaf spring and experimentation on FFT analyzer with single transverse crack to find out first three natural frequencies. Comparison of all frequencies of healthy and cracked leaf spring was done. Fuzzy logic has to use for the detection of crack with its location and depth. Considering all the investigations, following conclusion are drawn:

i. Natural frequencies calculated by the theoretical method are only considering the crack depth without crack location.

ii. Natural frequencies calculated by the theoretical method, finite element method and experimentation are close to each other.
iii. For the same crack location as the crack depth increases, first three natural frequencies are gradually decreases.
iv. For the same crack depth as the crack location shift towards the fixed end, natural frequencies are gradually decreases.
v. The effect of the crack near the fixed end is more than the crack away from the fixed end.
vi. Small change in first three natural frequencies represents the existence of the crack.