

Investigation of Natural Frequency by FEA Modal Analysis and Experimental Modal Analysis of Connecting Rod

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ABSTRACT: The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This study incorporates FEA modal analysis and experimental modal analysis of connecting rod. A parametric model of Connecting rod is modelled using CATIA V5 R19 software and finite element analysis is carried out by using ANSYS Software. Finite element method is used to determine natural frequencies of a connecting rod and compare results with FFT analyzer. FFT analysis is done by hanging the connecting rod at small end and experimental results were compared with FEM.

KEYWORDS: Connecting rod, FEA, FFT Analysis.

I. INTRODUCTION

A Connecting rod is the link between the reciprocating piston and rotating crank shaft. Small end of the connecting rod is connected to the piston by means of gudgeon pin. The big end of the connecting rod is connected to the crankshaft. The function of the connecting rod is to convert the reciprocating motion of the piston into the rotary motion of the crankshaft.

A combination of axial and bending stresses act on the rod in operation. The axial stresses are product due to cylinder gas pressure and the inertia force arising on account of reciprocating motion. Whereas bending stresses are caused due to the centrifugal effects. To provide the maximum rigidity with minimum weight, the cross section of the connecting rod is made as I – section. Small end of the rod is a solid eye or a split eye, this end holds the piston pin. The big end rest on the crank pin and is always split for heavy engines. In some connecting rods, a hole is drilled between two ends for carrying lubricating oil from the big end to the small end for lubrication of piston and the piston pin.

Pravardhan S. Shenoy and Ali Fatemi [1] studied “Connecting rod optimization for weight and cost reduction”. Authors performed optimization to reduce weight and manufacturing cost of a forged steel connecting rod. The main objective of this study was to explore weight and cost reduction opportunities for a production forged steel connecting rod. A forged steel connecting rod subjected to cyclic load comprising the peak compressive gas load and the peak dynamic tensile load at 5700 rev/min, corresponding to 360° crank angle. The structural factors considered for weight reduction during the optimization process included fatigue strength, static strength, buckling resistance, bending stiffness, and axial stiffness. Additional constraints imposed during the optimization process included maintaining the forgeability as well as interchangeability of the optimized connecting rod with the existing one. Cost was reduced by changing the material of the existing forged steel connecting rod to crackable forged steel (C-70). The fracture splitting process eliminates the need to separately forge the cap and the body of the connecting rod or the need to saw or machine a one-piece forged connecting rod into two. Heat treatment, machining of the mating faces of the crank end, and drilling for the sleeve are also eliminated.

S.A. Sajjadi, H.R. Ezatpour, M. Torabi Parizi [2] studied “Comparison of microstructure and mechanical properties of A356 aluminum alloy/Al₂O₃ composites fabricated by stir and compo-casting processes”. Metal–matrix composites

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(MMCs) are most promising in achieving enhanced mechanical properties such as: hardness, Young's modulus, 0.2% yield strength and ultimate tensile strength due to the presence of nano and micro-sized reinforcement particles into the matrix. Generally, regards to the mechanical properties, the reinforcements result in higher strength and hardness, often at the expense of some ductility. Aluminum-matrix composites (AMCs) reinforced with particles and whiskers are widely used for high performance applications such as in automotive, military, aerospace and electricity industries because of their improved physical and mechanical properties.

Salah Eldin Mohammed, Masri Baharom, Abdul Rashid Abdul Aziz [3] studied "Comparative analysis of two proposed models of connecting rods for crank-rocker engines using finite element method". Author's modeled two connecting rods for a crank-rocker engine in CATIA V5, and the Finite Element Analysis of the two models have been conducted using FEA tool (ANSYS Workbench). The two connecting rods were modeled to have the same volume for apple-to-apple comparisons. First model was created for conventional connecting rod and second model for Y-shape connecting rod. In case I (Compressive load) - The load was applied at the small end of connecting rods as compressive load and the big end side was fixed. In case II (Tensile load) - The load was applied at the small end of connecting rods as compressive load and the big end side was fixed. The results for the von-misses stress was obtained from the ANSYS Work bench.

B. Anusha, Dr. C.Vijaya Bhaskar Reddy [4] studied "Comparision of materials for two-wheeler connecting rod using Ansys". The dimensions of the selected connecting rod are found using vernier calipers, screw gauge and are tabulated and presented in the table. According to the dimensions the model of the connecting rod is developed using PRO/E (creo-parametric). In this analysis two materials are used Cast Iron & Structural Steel.

Ramanpreet Singh [5] studied "Stress analysis of orthotropic and isotropic connecting rod using finite element method". One analysis was done for the conventional steel and the other was performed on the E-Glass/Epoxy connecting rod keeping all the parameters same for both the analysis.

II. METHOD

A 3D model of a connecting rod was developed in CAD software. The connecting rod was examined considering the free-free boundary conditions as it allows the component to vibrate freely without interference of the other parts. It also facilitates better visualization of mode shapes associated with natural frequency. For validation of FE model one must recognise the dynamic properties as modulus of elasticity, density and Poisson's ratio of the component. Only linear behaviour is viewed in a modal analysis while non-linear properties are neglected.

III. FEA MODAL ANALYSIS

FEA modal analysis of connecting rod is carried out for two different materials. First modal analysis is carried out with existing material Carbon Steel 16MnCr5 and then with alternate material Aluminium LM9.

Solid model created in CATIA V5R19 is imported in ANSYS 14. After importing, meshing is to be done in ANSYS by selecting SOLID45 element. Then apply the constraint and run the modal analysis for Carbon Steel 16MnCr5 material.

Solid model created in CATIA V5R19 is imported in ANSYS 14. After importing, meshing is to be done in ANSYS by selecting SOLID45 element. Then apply the constraint and run the modal analysis for Aluminium LM9 material.

IV. EXPERIMENTAL MODAL ANALYSIS

The connecting rod was tested through the EMA with free – free boundary conditions. The observational approach to investigate the way patterns and natural frequencies of the structure through impact hammer test consists of the next steps.

1. Generation of model.
2. Model test setting
3. Divide the structure inadequate number of points with the appropriate special distribution.
4. Shake up the structure with impact hammer.

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5. Taking the measurements
6. Analysis of measured output data.
7. Establishment with the FEM data.

The test equipment used for the experimentation is the Fast Fourier Transform (FFT) with sixteen channels along with data acquisition system made of Scadas Front End. The structure was excited using impact hammer (Dytran Make 5800B3) at all predefined locations as indicated in fig. 1 and the response was collected using tri-axial accelerometer (PCB T356A02 & 356B21) at an identified driving point transfer function (DPTF) location. The type of EMA is known as the Frequency Response Function (FRF) method which evaluates the input excitation and output response simultaneously. The essence of all frequency response functions (FRF's) was resolved to extract natural frequencies and mode shapes. Fig.1 shows the experimental modal analysis set up for connecting rod.

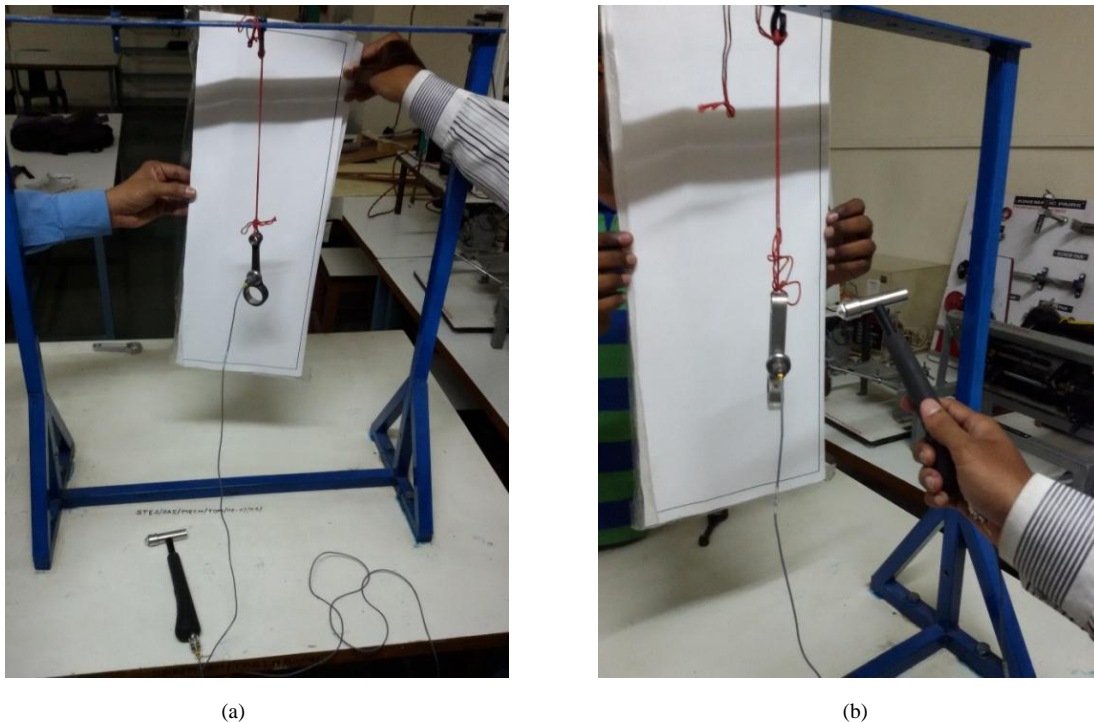


Fig. 1. Set up of Experimental Modal Analysis of connecting rod (a) Carbon steel 16MnCr5 (b) Aluminium LM9

Figure 1 show the set up of experimental modal analysis of Carbon steel Aluminium LM9 connecting rod. For this set up connecting rod is suspended at small end vertically down word. An accelerometer is attached to the connecting to measure the frequency response when excitation given by the impact hammer.

Experimental modal analysis, also known as modal analysis or modal testing, deals with the determination of natural frequencies, damping ratios, and mode shapes through vibration testing. Two basic ideas are involved:

- When a structure, machine, or any system is excited, its response exhibits a sharp peak at resonance when the forcing frequency is equal to its natural frequency when damping is not large.
- The phase of the response changes by 180° as the forcing frequency crosses the natural frequency of the structure or machine, and the phase will be 90° at resonance.

Experimental modal analysis is done by hanging the connecting rod at small end and experimental results were compared for Carbon steel & Aluminium LM9. From the experimental modal analysis the natural frequencies were determined.

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V. RESULTS AND DISCUSSION

Natural frequencies obtained for connecting rod of carbon steel and aluminium LM9 material by FEA & EMA are given in table 1.

Table. 1. Natural frequencies for Connecting rod of Carbon steel 16MnCr5 & Aluminium LM9 material by FEA & EMA

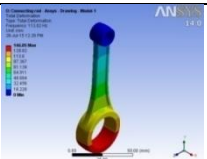
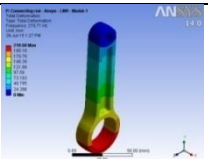
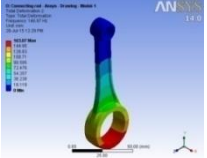
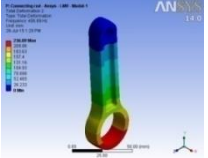
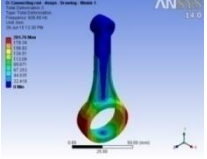
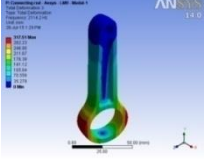
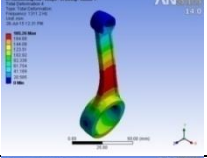
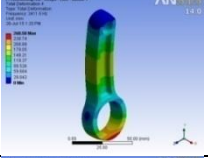
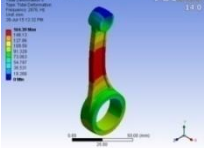
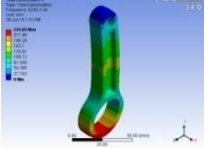
Mode No.	Carbon steel (16MnCr5)			Aluminium LM9		
	EMA	FEA		EMA	FEA	
	Natural frequency (Hz)	Natural frequency (Hz)	Mode shapes	Natural frequency (Hz)	Natural frequency (Hz)	Mode shapes
1	127	113		256	279	
2	163	147		441	487	
3	629	607		2045	2114	
4	1363	1311		3384	3411	
5	2816	2876		4207	4249	

Table 1 show the natural frequencies found from experimental modal analysis and finite element analysis of Carbon steel & Aluminium LM9 connecting rod. Natural frequencies for first five modes are noted by both the methods.

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The graph of comparison of natural frequencies for different materials is shown in Fig. 2 & 3.

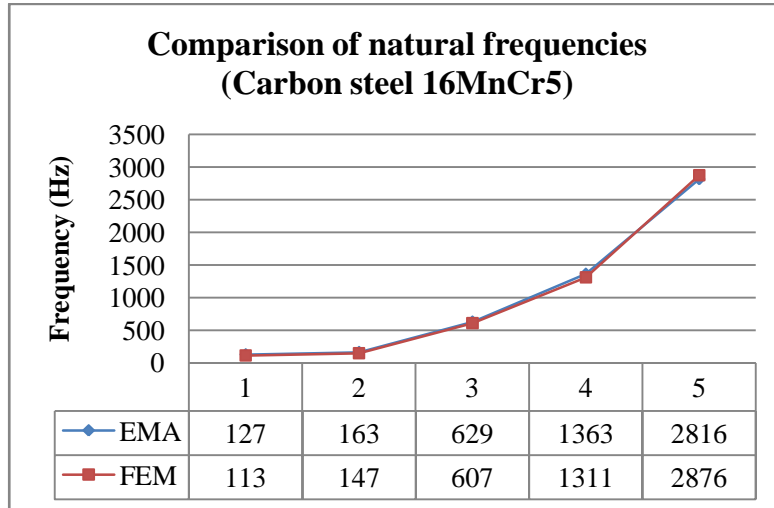


Fig. 2. Comparison of natural frequencies (Carbon steel 16MnCr5)

Figure 2 show the graph of comparison of natural frequencies found from experimental modal analysis and finite element analysis of Carbon steel connecting rod. Natural frequencies for first five modes are compared by both the methods and the variation found is within the limit.

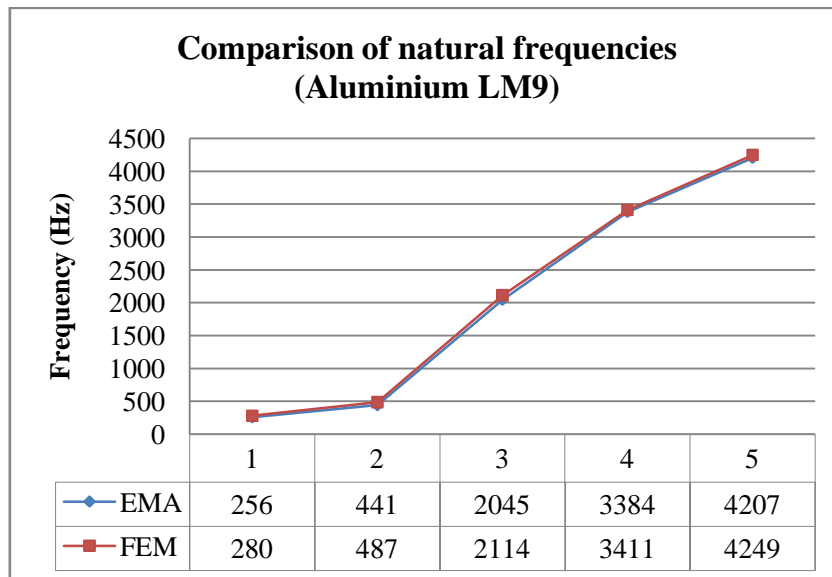


Fig. 3. Comparison of natural frequencies (Aluminium LM9)

Figure 3 show the graph of comparison of natural frequencies found from experimental modal analysis and finite element analysis of Aluminium LM9 connecting rod. Natural frequencies for first five modes are compared by both the methods and the variation found is within the limit.

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VI. CONCLUSION

This work investigated suitable better material for connecting rod. Modal analysis was performed to the connecting rod with computer based FEA simulation tools. EMA was then performed using FFT analyser to find natural frequencies of connecting rod. The following conclusions can be drawn from this study.

The natural frequencies determined by using FEA method are nearly similar to the natural frequencies determined by using EMA method for existing carbon steel (16MnCr5) connecting rod.

The natural frequencies determined by using FEA method are nearly similar to the natural frequencies determined by using EMA method for Aluminium LM9 connecting rod.

It is observed that, natural frequency of Aluminium LM9 connecting rod is higher than existing carbon steel (16MnCr5) connecting rod.

It is also found that the Aluminium LM9 connecting rod is light in weight than existing carbon steel (16MnCr5) connecting rod.

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