

Review of Intermediate Shaft for Automobile Gear Box Using FE Modal Analysis

Hemant Shinde¹, Neha Dhiman², Swati Patil³

Assistant Professor¹, Student^{2,3}

Department of Mechanical Engineering

Lord Krishna College of Technology Pithampur Rd, Rau, Indore, Madhya Pradesh 452003

Corresponding Author's Email: - nehadhiman1994@gmail.com²

ABSTRACT

The experimental and FE modal analysis of an intermediate shaft utilised in an automotive gear box are presented in this work. The natural frequencies are calculated using an FFT analyzer throughout the experiment. PRO-E is used to create the three-dimensional finite element model. ANSYS workbench is used to mesh the model. The three fundamental bending modes are recovered throughout the study. The findings indicate that the intermediate shaft is not running at critical speed. The finite element model correlates well with the FFT results and may be used as the intermediate shaft's baseline model.

KEYWORDS: *Finite Element Analysis, FFT analyzer, ANSYS workbench*

INTRODUCTION

The intermediate shaft is the most crucial component of an automobile's gear box. Different gears are fitted on the intermediate shaft to transmit power from the input shaft to the output shaft with varying speed ratios. According to the study, every material system with a variable mass and stiffness distribution is subject to vibration. To establish the

inherent frequencies of a material system, free vibration analysis is required. These are in charge of the resonance phenomena. The resonance occurs when the load frequency matches one of the natural frequencies. It results in a high amplitude of vibration.

Bending vibrations and critical speeds of rotating shafts are among the most

prevalent problems highlighted by a vibration engineer, since they are a frustrating day-to-day challenge in equipment design and maintenance. Some rotors weigh up to 100 tons, as in the case of large steam turbines, and they clearly demand special attention in this respect. The rotors will always have some residual imbalance, no matter how perfectly balanced they are, and will enter resonance when rotated at speeds equivalent to the bending natural frequency. Rankin refers to these speeds as crucial speeds, and they should be avoided as much as possible. Special care should be used when transitioning the rotor from a critical speed

to an operating speed. Because the system must spin at different speeds, fault detection of bearing, detection of misalignment, and condition monitoring of bearing or gearing system are required. If a given r.p.m. meets a crucial speed that is closer to the initial bending, the inherent frequency of the shaft will produce excessive vibrations owing to resonance.

Intermediate Shaft Details

The intermediate shaft of an indica automobile was chosen as a case study. Figure 1 depicts the intermediate shaft mode



Fig.1 Model of intermediate shaft

The table 1 shows the details of intermediate shaft.

Table 1 intermediate shaft details

Overall length of shaft	417 mm
Maximum operating speed	5000 rpm
Maximum forcing frequency	83.34 Hz

Experimental Modal Analysis

A system's experimental modal analysis deals with the identification of natural frequencies, damping ratios, and mode shapes through vibration testing. In the case of forced vibration, the analysis comprises the investigation of the systems' acceleration, velocity, and displacement responses. When a structure, machine, or system is aroused, its response presents a high peak at resonance when the driving frequency is equal to its natural frequency, if damping is not present in substantial amounts. As the forcing frequency passes the natural frequency of the structure or machine, the phase of the response changes by 180°, and the phase at resonance is 90°.

Experimental Setup

Fig .2 shows the experimental setup for modal analysis.

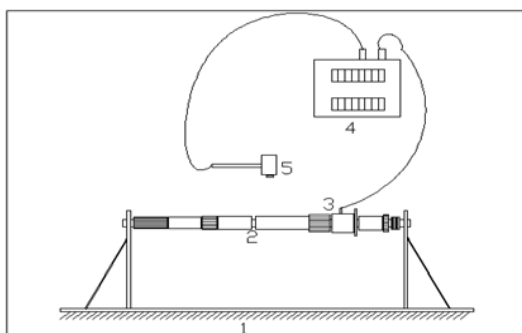


Fig.2 Experimental Setup

1. Fixed frame
2. Intermediate shaft

3. Accelerometer
4. Exciter
5. Impact hammer

Following are the instruments used for the modal analysis

- FFT Analyzer
- Accelerometer
- Exciter
- Impact hammer

Procedure of Experimentation

- 1) Attach the accelerometer and impact hammer to the proper FFT channels via cables.
- 2) Prepare the Modal analysis and In-pulse software setup.
- 3) Using a magnetic base, secure the accelerometer to the shaft.
- 4) Excite the shaft by using an impact hammer to deliver an in-pulse.
- 5) Record the accelerometer response in the frequency and time domains.
- 6) Use FFT software to identify and record the natural frequencies and phases.

- 7) Repeat the method for different shaft vibration types.
accelerometer locations to record all

Experimental Results

The FFT produces a FRF graph with cursor values of frequencies for the relevant mode shape.

The FFT findings are given in table 2.

Table 2 FFT results

modes	Frequency in Hz
1	709.87
2	2087.04

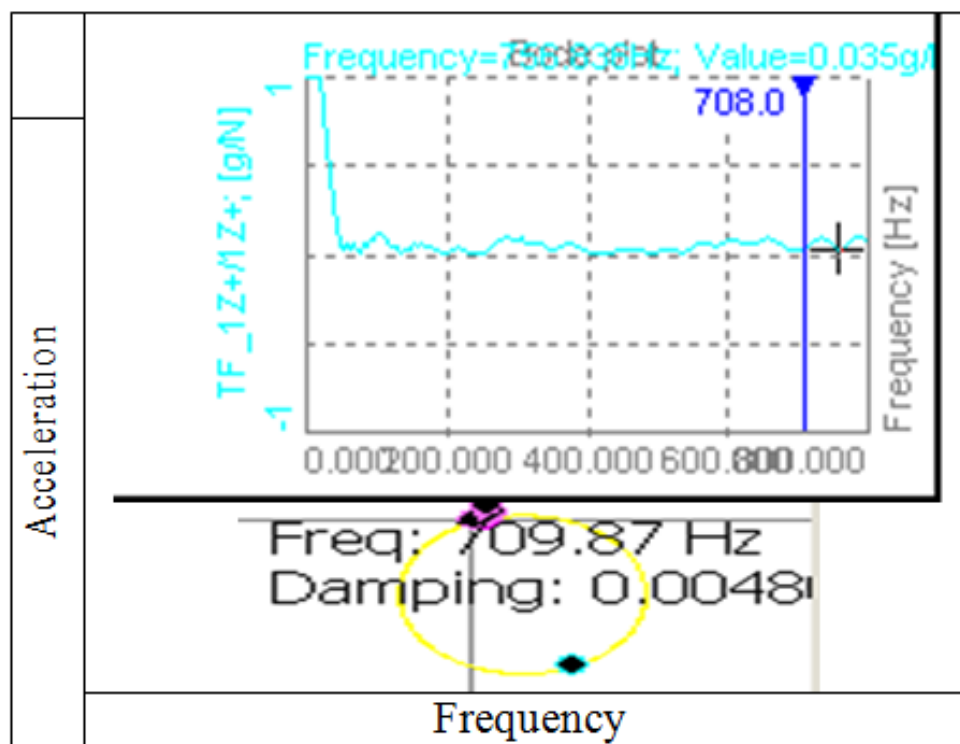


Fig.3 Frequency Response Function (FRF) for first mode

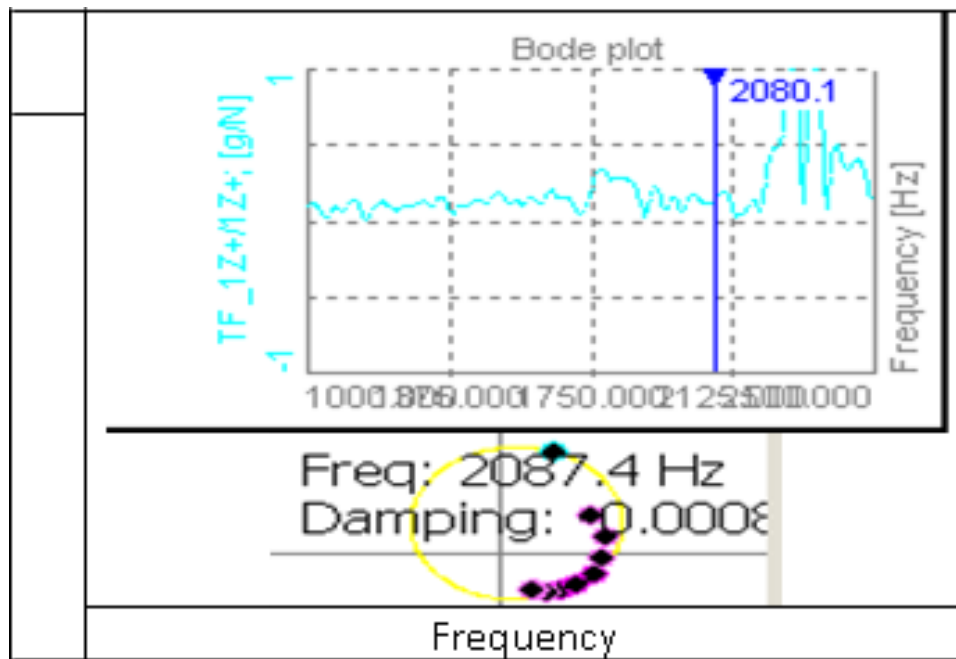


Fig.4 Frequency Response Function (FRF) for second mode

Finite Element Analysis

This section discusses intermediate shaft modelling and finite element analysis of intermediate shafts using FEA. The Finite Element Method (FEM) replicates the behaviour of physical parts by splitting the geometry into a number of typical form elements and imposing restrictions. The use of correct boundary conditions is critical since it has a large impact on the outcomes of the finite element analysis. Pro-E is used to create the intermediate shaft. The model's step file is loaded into ANSYS workbench. The primary goal of this study is to conduct a Finite Element Analysis of an intermediate shaft using CAE Tools in order to estimate the natural frequency of the shaft. CAE need material characteristics in order to execute analysis.

The intermediate shaft is made of steel En19, and the material parameters are presented in table 3.

Table 3 Material properties

Density	7800 kg/mm ³
Poisson Ratio	.3
Young's modulus	210000 Mpa

Finite Element Modelling

The definition of FEM is concealed throughout the world. Finite - every continuous object has a finite degree of freedom and cannot be solved in this format. Using discretization, the Finite Element Method decreases the degree of freedom from infinite to finite. Element - all computations are performed at a small number of nodes. Element is a node-

joining entity that forms a specified shape, such as a quadrilateral or triangular shape. The interpolation function is used to obtain the value of a variable at any moment between the computation points.

Any engineering problem may be solved using one of three ways. Finite Element Analysis is a type of numerical approach. Any solid component's finite element modelling consists of generating geometry, applying material characteristics, meshing the component, specifying boundary constraints, and applying the appropriate load type.

Geometry of intermediate shaft

The dimensions of the intermediate shaft are acquired from a case study of a selected model of the intermediate shaft. The solid model of the intermediate shaft is built by Pro-E software utilising correct dimensions. Figure 5 depicts the created solid model of the intermediate shaft.



***Fig.5 Geometry of intermediate shaft
Mesh Generation***

The geometry is meshed in an ANSYS 14 mechanical model window. For the geometry, the hex dominating approach is used. Maximum hexahedron elements are applied to difficult geometry using this approach. The body sizing is applied to the entire geometry, and the element size is specified as 5 mm. The intermediate shaft geometry FE model is meshed with hexahedral elements with global element lengths of 5 mm and local element lengths of mm. Figure 6 depicts the meshed intermediate shaft.

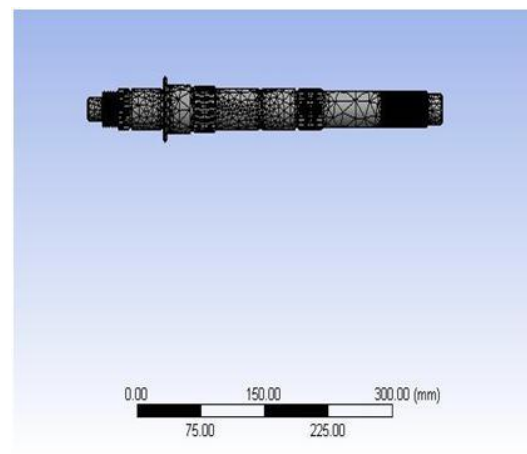


Fig. 6 Meshed Geometry

FEA SOLUTION

Three modes are derived from the intermediate shaft analysis. Table 4 is a summary of the findings. Figures 7 to 9 depict the three forms of intermediate shaft.

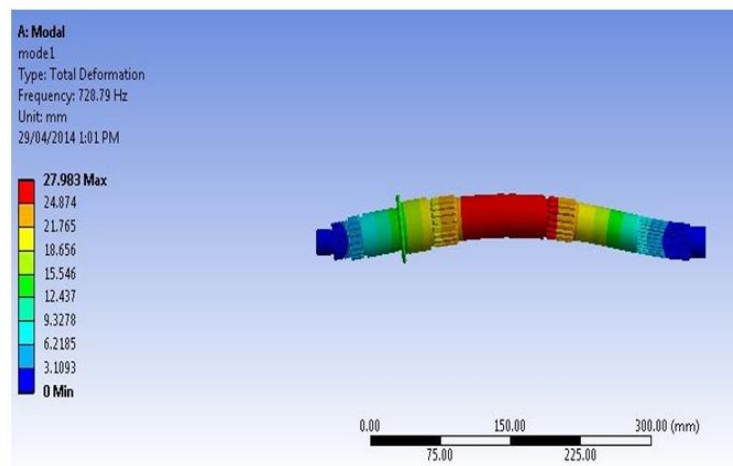


Fig. 7 First vibration mode of intermediate shaft

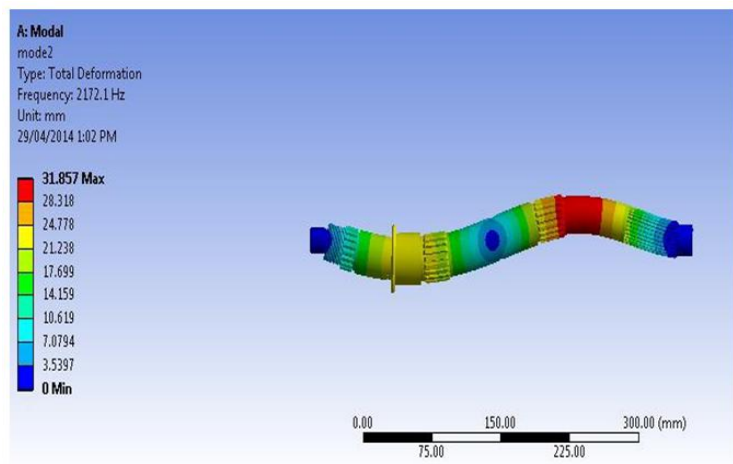


Fig. 8 second vibration mode of intermediate shaft

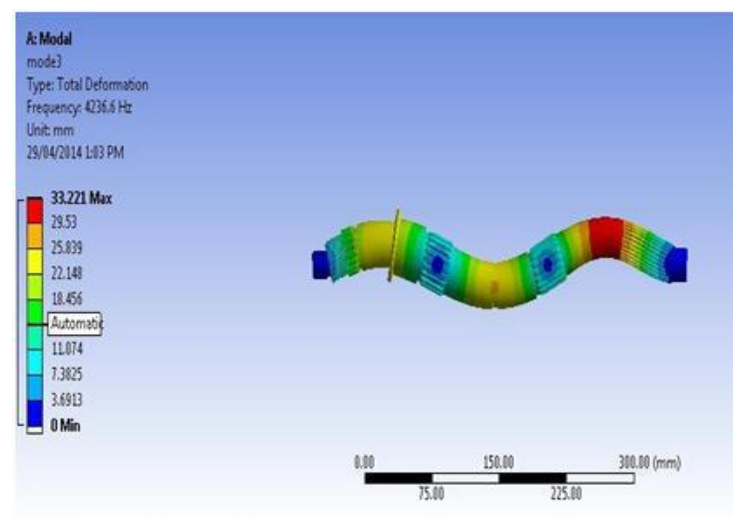


Fig. 9 third vibration mode of intermediate shaft

Table 4 FEA Results

Mode	Frequency in Hz
1	728.79
2	2172.1
3	4236.6

COMPARISON BETWEEN EXPERIMENTAL AND SOFTWARE RESULTS AND DISCUSSION

Table 5 Comparison between Experimental and Software Results

Natural Frequency Hz	Experimental (FFT)	FEM	% Difference
f ₁	709.87	728.79	2.6
f ₂	2087.04	2172.1	3.91

The comparison between experimental and (FEM) software results is shown in Table 6.3 above.

Figure 10 also depicts a graph comparing FEM or software results to experimental data.

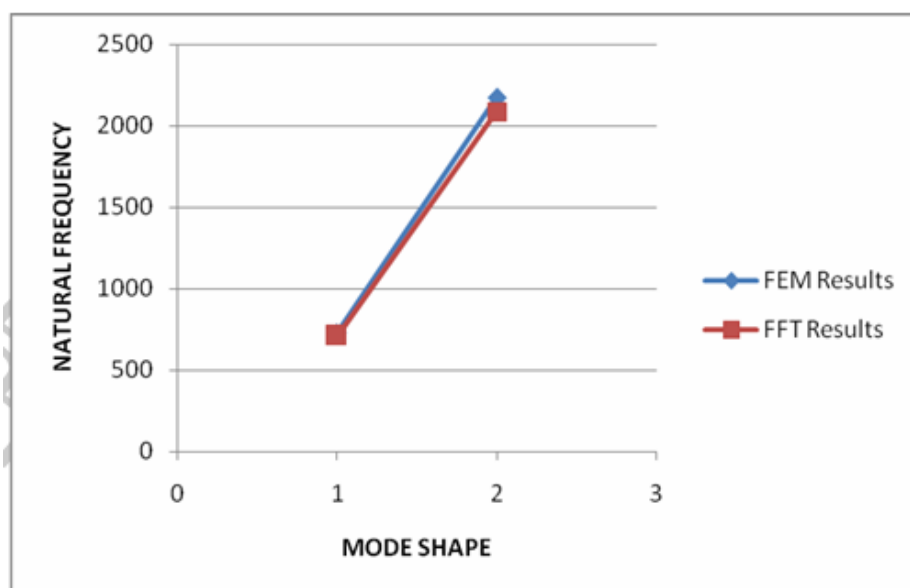


Fig.10 comparison between FEM or Software Result and Experimental results

The difference in initial frequency between FEM and FFT is around 2.6 percent.

The intermediate shaft can be vibrated in a variety of orientations. The initial vibration mode is the most essential.

Resonance occurs when the forcing frequency of any harmonic component is near to the natural frequency of the first mode of vibration. The component is considered to be running at critical speed in this state.

CONCLUSION

The experimental and FEM techniques for calculating the natural frequencies of intermediate shafts are given in this work. The first natural frequency is established by testing. This is the lowest natural frequency of the intermediate shaft. The intermediate shaft is simulated in PRO-E and its natural frequency is calculated in ANSYS. During modal analysis, three modes are retrieved. The variation in initial frequency between FFT and ANSYS is around 2.6 percent. The forcing frequency of the intermediate shaft is 83.34 Hz, which is much lower than the natural frequency of the intermediate shaft. As a result, the situation of resonance is avoided, and the intermediate shaft does not operate at critical speed.

REFERENCES

1. C. Azoury, A. Kallassy, B. Combes, I. Moukarzel, R. Boudet (2012). "Experimental and Analytical Modal Analysis of a Crankshaft." IOSR Journal of Engineering, 2(4), 674-684.
2. Shrikant K Yadav, Prof. Dr. S. B. Wadkar and Mr. S. J. Patil, "Modal Analysis of Compressor Crankshaft"
3. S. M. Ghoneam , A. A. Hamada and M. I. EL-Elamy , "Dynamic Analysis of A Rotating Composite Shaft"
4. R. Sino , T. N. Baranger , E. Chatelet and G. Jacquet , "Dynamic Analysis of a Rotating Composite Shaft"
5. Dr.Oliver A. Bauchau, "Optimal Design Of High Speed Rotating Graphite /Epoxy Shafts"
6. E.Chatelet , D. Loranage , And G. Jacquet –Richardet, "A Three Dimensional Modeling Of The Dynamic Behavior Of Composite Rotors"