Optimisation of Connecting Rod Material through Finite Element Analysis (Modal Analysis)

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Abstract— Connecting rod is an important component of the automobile engine dynamic system, it is not only a transmission component but also moving part, at the same time it must withstand variable load such as tensile, compressive force and bending in the working process. Therefore, dynamic characteristics study on the connecting rod has become an important part of design. Modal analysis is an effective method to determine vibration mode shapes and weak parts of the complex mechanical system. In this study, a modal analysis was applied to a connecting rod by ANSYS software at critical working conditions, the main purpose of analysis is to identify the model parameters of connecting rod such as natural frequency, vibration mode shapes and provide a basis for selecting connecting rod material. In this study, modal analysis applied for three different materials of the connecting rod. In this study, modal analysis was performed to calculate natural frequencies and mode shapes. By comparing the natural frequency, select optimum connecting rod material to avoid resonance. To avoid resonance, natural frequency high.

Key words: Connecting Rod, CATIA, ANSYS, Modal

I. INTRODUCTION

In short - modal analysis provides an overview of the limits of the response of a system. Every object has an internal frequency (or resonant frequency) at which the object can naturally vibrate. It is also the frequency where the object will allow transfer of energy from one form to the other with minimal loss – here vibrational to kinetic. It is important to know these frequencies at which the structure can behave erratically.

The automobile engine connecting rod is a high-volume production, critical component. It connects reciprocating piston to rotating crankshaft, transmitting the thrust of the piston to the crankshaft. Every vehicle that uses an internal combustion engine requires at least one connecting rod depending upon the number of cylinders in the engine.

Modes (or resonances) are inherent properties of a structure. Modes are determined by the material properties (mass, stiffness, and damping properties), and boundary conditions of the structure. Each mode is defined by a natural (modal or resonant) frequency, modal damping, and a mode shape. If either the material properties or the boundary conditions of a structure change, its modes will change. If mass is added to a structure, it will vibrate differently. Each mode is entirely independent of all other modes. Thus, all modes have different frequencies and different mode shapes. Since the lower modes vibrate with greater amplitude, they cause the most displacement and stress in a structure. Thus, they are called fundamental modes.

A. Problem Definition

The connecting rod has been taken under the performance investigation in that we have planned to change connecting rod material. Analyse the connecting with material i.e. stainless steel, Aluminium alloy, Titanium alloy. Compare natural frequency, mode shapes and total deformations of various connecting rod materials.

B. Objectives

The main objective of the present work is to find out and suggest optimize connecting rod material based on dynamic analysis considering natural frequency, mode shape and deformation. After generating an accurate finite element model, a strategy for the optimization of material workflow was defined. Target is to optimizing connecting rod material.

II. ANALYSIS PROCEDURE

A. Solid Modelling

In present work, CATIA V5 is used. From the obtained values of dimensions from initial calculations, a two-dimensional sketch of one half in total vertical cross section is made along with a central axis. The sketch is now three dimensionally modelled using the SWEEP function along the central axis. The model is now saved as STL or IGS file. The file is now ready to be exported to any other compatible analysis software with minimal disruption in data and surface profiles. Heading to the phase of two-dimensional model, various sketches changing the shapes of dome and dimensional values will result in different models and for each of it further analysis can be made separately.

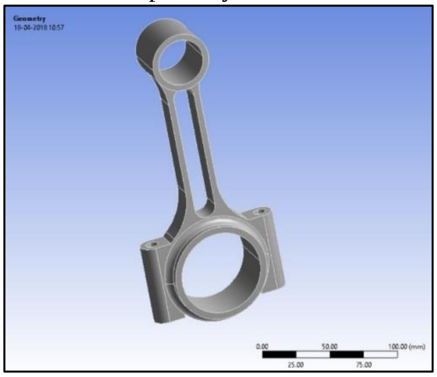


Fig. 1: 3D Model of Connecting Rod

B. Material

The material chosen for the connecting rod is Stainless steel, Aluminium Alloy, Titanium alloy. All the materials are used simultaneously and get required result individually.

C. Meshing

A coarse type relevance centre is chosen and keeping the element size as default by the software, minimum edge length observed is 2.e-003 m. The mesh size is 5 mm.

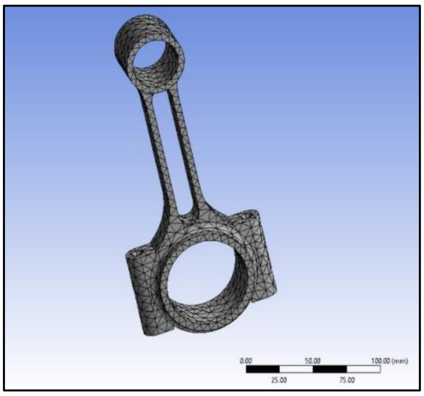


Fig. 2: Meshing of Connecting Rod

D. *Structural Boundary Condition*

1) *Fixed support at small end*

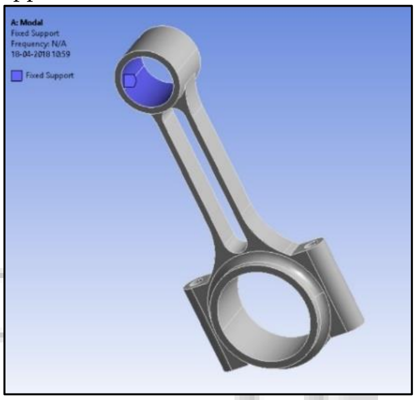


Fig. 3: Fixed Support at Small End

2) *Cylindrical Support at Big End*

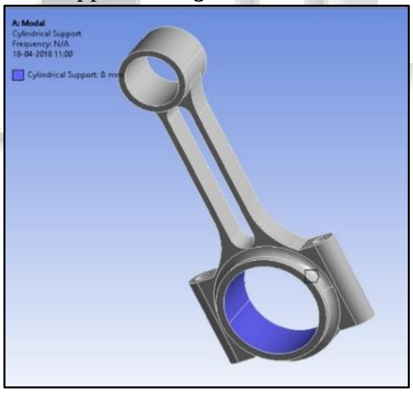


Fig. 4: Cylindrical Support at Big End

E. *Thermal Boundary Condition*

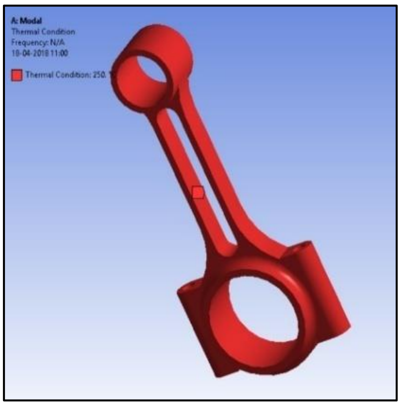


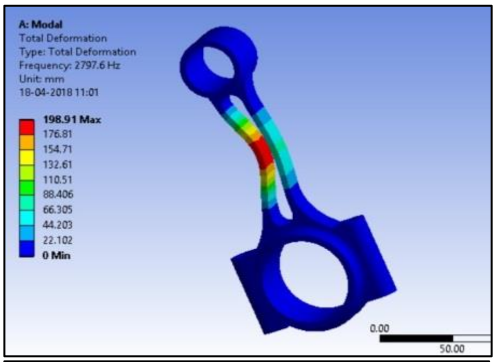
Fig. 5: Thermal Boundary Condition

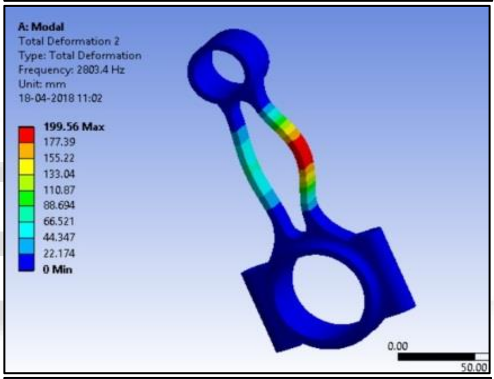
III. Results & Discussion

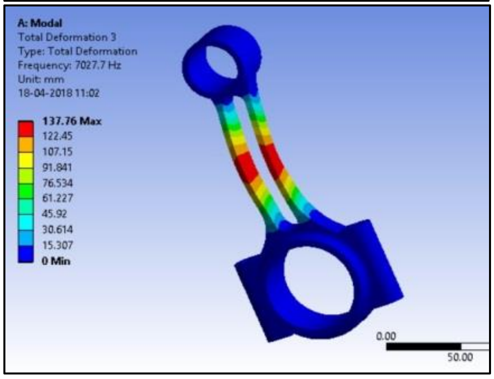
After processing solution, the contours of natural frequency and mode shapes in dynamic structural analysis are plotted. These results as part of dynamic analysis are obtained for connecting rod with material Stainless steel, Aluminium alloy and Titanium alloy. We are getting results of each material.

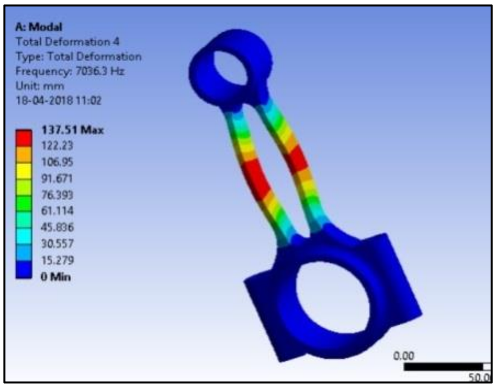
A. *Result of Connecting Rod for Stainless Steel Material*

A maximum natural frequency for stainless steel material for mode 1 is 2797.6 Hz, mode 2 is 2803.4 Hz, mode 3 is 7027.7 Hz, mode 4 is 7036.3 Hz and mode 5 is 7325.2 Hz are observed.









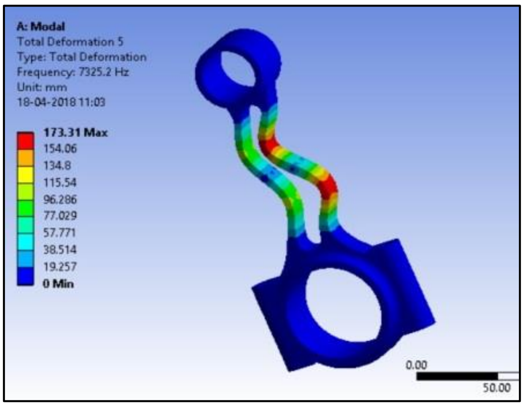
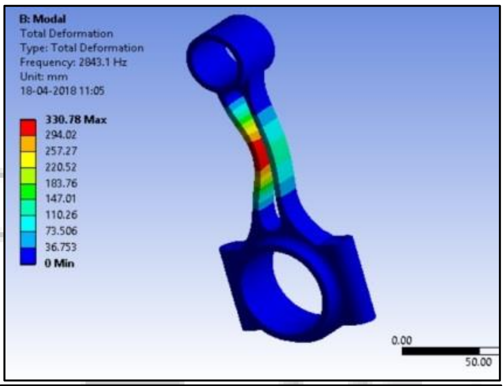
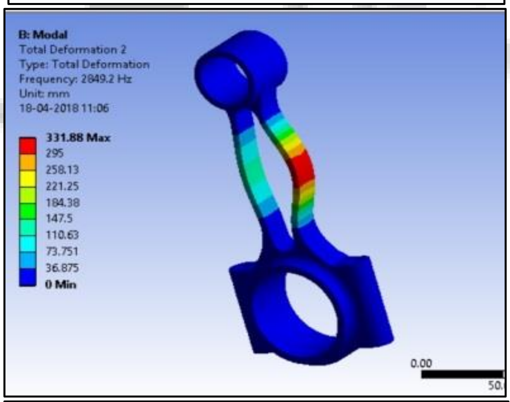


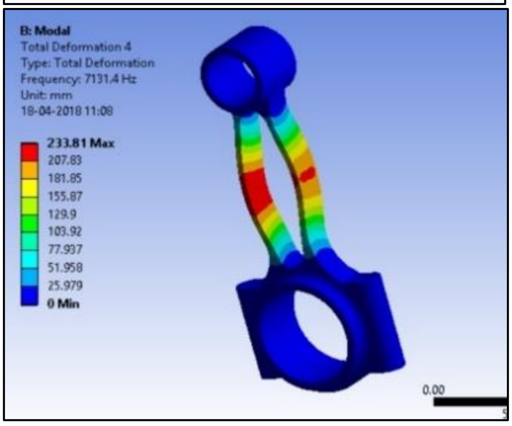
Fig. 6: Mode Shapes for Stainless Steel Material

B. Result of Connecting Rod for Aluminium Alloy Material

A maximum natural frequency for stainless steel material for mode 1 is 2843.1 Hz, mode 2 is 2849.2 Hz, mode 3 is 7125.5 Hz, mode 4 is7131.3 Hz and mode 5 is 7444.6 Hzare observed.







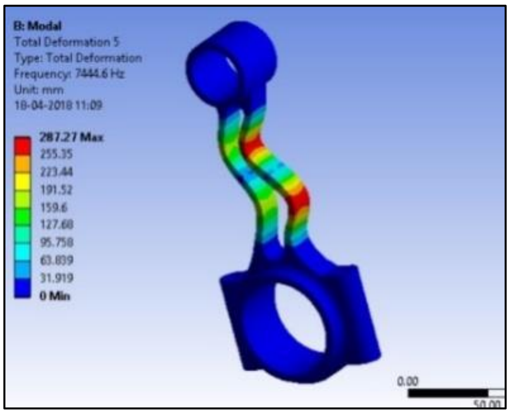
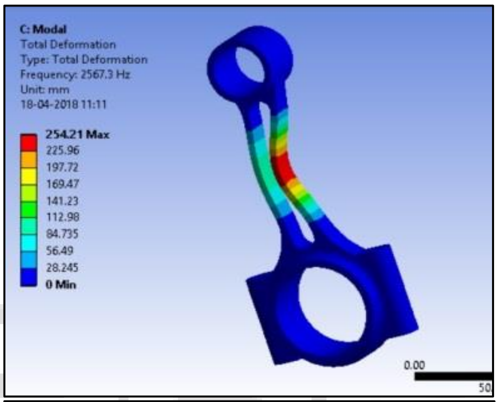
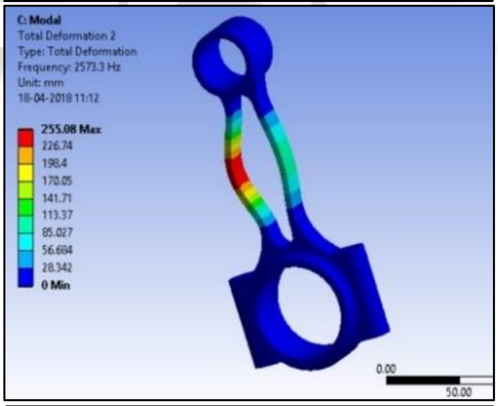


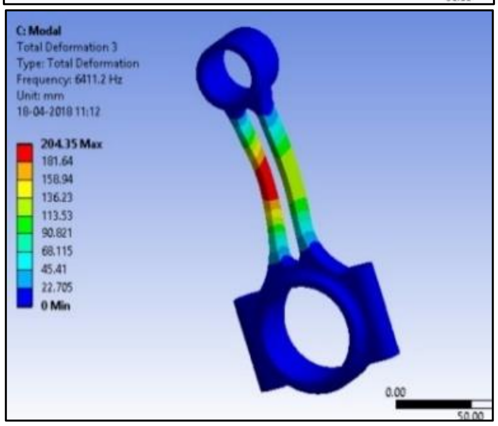
Fig. 7: Mode Shapes for Aluminium Alloy Material

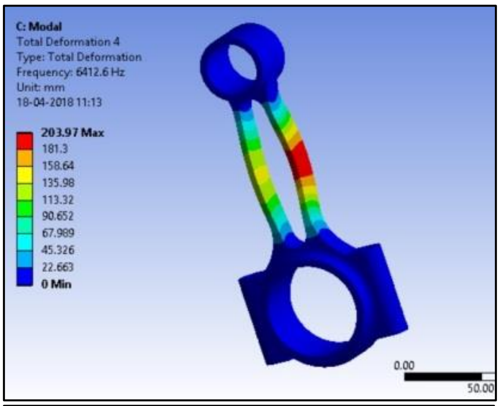
C. Result of Connecting Rod for Titanium Alloy Material

A maximum natural frequency for stainless steel material for mode 1 is 2567.3 Hz, mode 2 is 2573.3 Hz, mode 3 is 6411.2 Hz, mode 4 is 6412.6 Hz and mode 5 is 6723 Hz are observed.









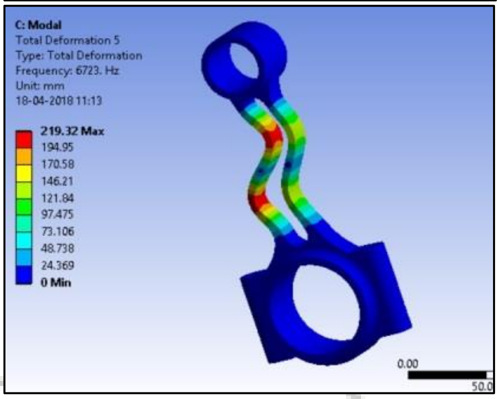


Fig. 8: Mode Shapes for Titanium Alloy Material

D. Result Table

Types of material	Natural frequency(Hz) for mode shape 1	Natural frequency(Hz) for mode shape 2	Natural frequency(Hz) for mode shape 3	Natural frequency(Hz) for mode shape 4	Natural frequency(Hz) for mode shape 5
Stainless steel	2797.6	2806.4	7027.7	7036.3	7325.2
Aluminium alloy	2843.1	2849.2	7125.5	7131.3	7444.6
Titanium alloy	2567.3	2573.3	6411.2	6412.6	6723

Table 1: Result Table

IV. CONCLUSIONS

Modal analysis provides an overview of the limits of the response of a system. Every object has an internal frequency (or resonant frequency) at which the object can naturally vibrate. It is also the frequency where the object will allow transfer of energy from one form to the other with minimal loss – here vibration to kinetic. It is important to know these frequencies at which the structure can behave erratically.

There are several examples where a prior accurate modal analysis could have prevented loss to lives and property, for instance in case of an earthquake.

To avoid the resonance, we increase the natural frequency of the system**.** In this mini project, select titanium alloy as a material for connecting rod because compare to other material aluminium alloy having highest natural frequency**.**

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