Modal & Harmonic Response Analysis of Two Stage Gearbox-Using ANSYS

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***Abstract*: Gearing is a very important term in many power transmission system. Natural frequency is the inherent property of the system. Natural frequencies and mode shapes are the two important design parameters to characterize the system. Modal analysis technique is used to find the natural frequency and mode shapes of the system on the finite element software Ansys.**

Due to the torque transmitted and any defects in the gear sets or shaft, gear box undergoes loading of varying magnitude. So it is necessary to conduct the harmonic analysis. In this paper, behaviour of the two stage gear train for a frequency range (0-8500 Hz) is analysed. The system behaviour changes determined near its natural frequencies .After that a safe working range is determined.

***Keywords*: 3D modelling: two stage gear train, natural frequency, and harmonic response, FEA**

Introduction

Gear is a very important component to transmit the power from one shaft to another shaft, in many power transmission systems like, automobiles, marine drive and many such industries. Any failure in the gearing system, there are lot of wastage in of time and money. Before the design, we have to know the cause of failure, remove them and prevent the failure of the system. So, to avoid failure, the design should be perfect, within operating range.

Vibration is a major problem in many mechanical systems. Natural frequency is the inherent property of any structure. Modal Analysis is a technique to study the dynamic characteristics of the system. Natural frequency and mode shape of the system can be determine by modal analysis.

In actual working conditions, to prevent the resonant condition, it is important to study the model and Harmonic analysis of the two stage geared system. The modal is analysed with the help of Finite Element Analysis (Ansys) technique. It allows the design to prevent resonant and gives the information about proper design. Two stage gear train is modelled and analyses to predict the dynamic characteristics.

The objective of this study is to determine the natural frequency and mode shape of a two stage gearbox. Harmonic analysis has been done to predict the response in terms of amplitude and stress.

Geometric modal was developed and assembled in Creo 2.0 and analysed in finite element package Ansys 16.0 (workbench) .The Analysis benefit is that the mode shapes could be accurately visualized and simulated.

LITREATURE REVIEW

Extensive work has been done by many researcher in the field of modal analysis in past studies. Finite analysis method is a useful tool that can analyse modal characteristics because it’s quick and very informative.

Rishav Ranjan, Sindhu Srinath and Shanmukha Nagraj, (2017) has been analysed the harmonic response of a gearbox,The analysis has been done to find the stress and safe operating frequencies for different materials to avoid resonance

Dr. C.M. Ramesha, Abhijit K G, Abhinav Sing, Abhishek Raj, Chetan S Naik,(2015) has been studied the modal analysis of a single cylinder engine crankshaft. The natural frequencies of two, free-free and constrained boundary conditions were found out and analysed. Harmonic response of the crankshaft for the excitation has been studied. These characteristics help in better understanding of vibration response of a component to dynamic loading.

FU Shengping, LUO Ning and LI Shengbo [2017], in this paper, dynamic characteristics under multi boundary conditions and excitation source which are responsible for vibration is analysed. The study provides the guidance for gearbox design and optimization.

Ankur Saxena, Anand parey and Manoj Chouksey [2016] studied the dynamic characteristics of geared system to find the natural frequencies and mode shapes using the modal analysis. The modal analysis has been done using finite element software Ansys workbench. The effect of bearing stiffness on natural frequencies also find out.

Edward J. Dielhl and J. Tang [2016] proposed the approach to modelling and analysis of two stage gear box to predict the fault.

Ankur Saxena, Anand Parey and Manoj Chouksey [2016] described the dynamic behaviour of the multi mesh geared-rotor system. Finite element analysis technique is used to find the natural frequencies and force harmonic response of the system. It has been found that the position of the gear and coupling, affect the gear dynamic behaviour.

Kadam G. N. and Prof. Bajaj D.S. [2015], aim of this paper is to reduce the weight of the gear system, they studied the effect of design parameters on natural frequencies and vibration modes. To optimize the alternative design choice and to reduce the weight, modal parameters are often altered during the design process.

Shoyab Hussin [2015] studied the torsional vibration characteristic of multi rotor using finite element method. Natural frequencies can help to avoid the failure of any system. The results are compared with Holzer and Ansys 14 to establish the effectiveness of finite element method.

WANG Tao, XIE Chen, WANG Feng, HU XIAO-Rui and HU Li-ming [2014], aiming of this paper is that for actual working conditions, the linear modal analysis methods fail at high and frequent variable speeds. This paper provides the guidance and reference data for design, use and maintenance.

Jairo Alberto Ruiz-Botero, Juan Fernando Lopez and Hector Fabia Quentero- Riaza [2014], studied the failure in two stage gear box and shows the variation on gear mesh stiffness for different amount of damage.

James Kuria and John Kithiu [2008], described the effect of gear mesh stiffness, frictional torque on vibration and stress level of multi stage geared system. It helps to optimum gear design parameters for any spur gear train.

METHODOLOGY

I. Model development

Model is developed in Creo 2.0 which contains three shafts and two pairs of the gear. The essential elements of the gear train model is Shown in fig. Model contains two pairs of gear meshes each with a shaft stiffness, moment of inertia of gears, Moment of inertia of the input and output masses.

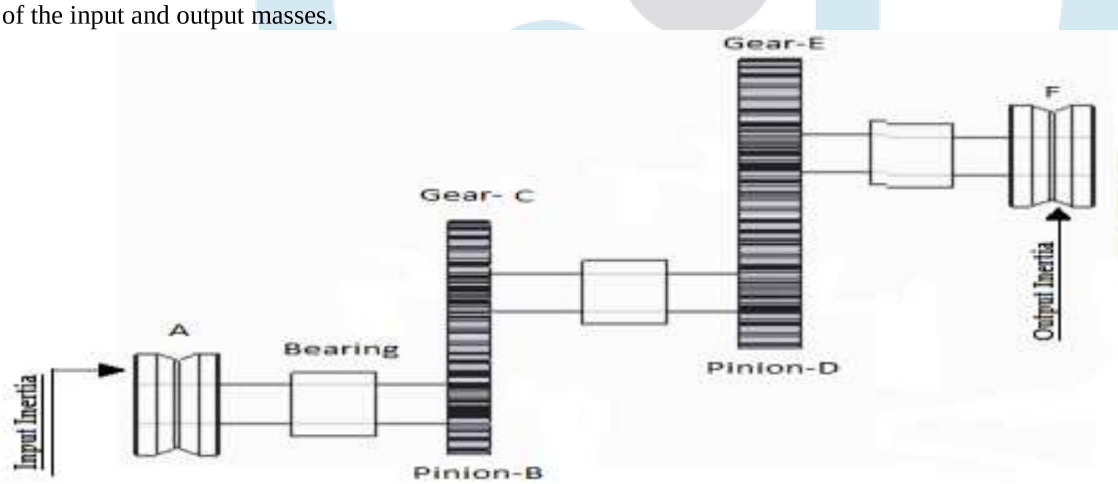

Fig-1 Schematic Diagram of Gear box set up

Gear parameters Used-

Parameters	I stage		II stage	
	Pinion-A	Gear-B	Pinion-C	Gear-B
Press. angle	20^0	20^0	20^0	20^0
module	2.5	2.5	2	2
No. of teeth	18	26	20	35
Width (mm)	10	10	15	15
Moment of inertia(Kg-m²)	30.5×10^{-6}	135×10^{-6}	29×10^{-6}	272×10^{-6}
Pitch circle dia.(mm)	45	65	40	70
Gear ratio	G1 = 1.445		G2=1.75	
Moment of Inertia of Input-output pulley(kg-m²)	35×10^{-6}			

II. Finite element analysis

The spur gears of two stage are sketched, modelled and assembled in Creo-2.0 and saved as an IGES file. The IGES assembly file is imported to the finite element software (Ansys 16.0) for model analysis. By define contacts, meshing and applying proper boundary conditions and solve, we get the natural frequencies and mode shapes of the two stage geared system.

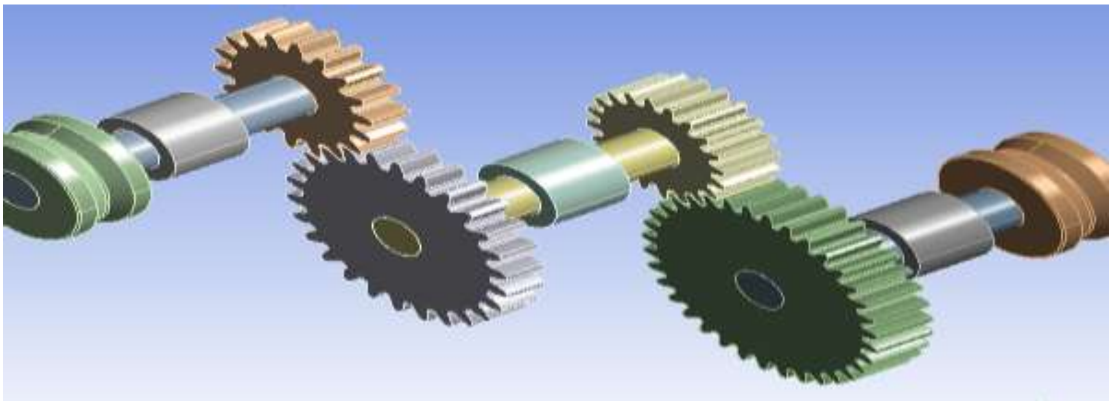

FIG-2 Modal Generated on Creo-II

Material properties (Structural steel)

Material property	unit	value
Density	Kg/m^3	8500
Young's modulus	Gpa	200
poison's Ratio	-	3
Ultimate tensile strength	Mpa	460
Hardness	HB	210
Shear modulus	Gpa	76.9

Harmonic response Analysis

This analysis was done on ANSYS 16.0 software. The Analysis was done for a frequency range of 0-8500 Hz. This range was obtained after the calculation of natural frequencies. Different boundary conditions were applied.

RESULTS:

Modal Analysis: Harmonic Analysis were linked with modal analysis. Through model analysis we got different natural frequencies of the system**.**

Mode	Frequency	Total deformation(mm)	Type of mode
1	818.23	57.3	Torsional
2	1352.5	49.8	Torsional
3	2383.6	94.1	Torsional
4	2579.7	65.7	Torsional +Translation
5	2711.7	85.33	Torsional
6	4630.2	59.7	Torsional +Bending
7	5301.6	63.4	Torsional +Bending
8	5414	54.9	Torsional +Bending
9	6855.7	89.0	Torsional +Bending +Translation
10	6969.6	68.2	Torsional +Bending

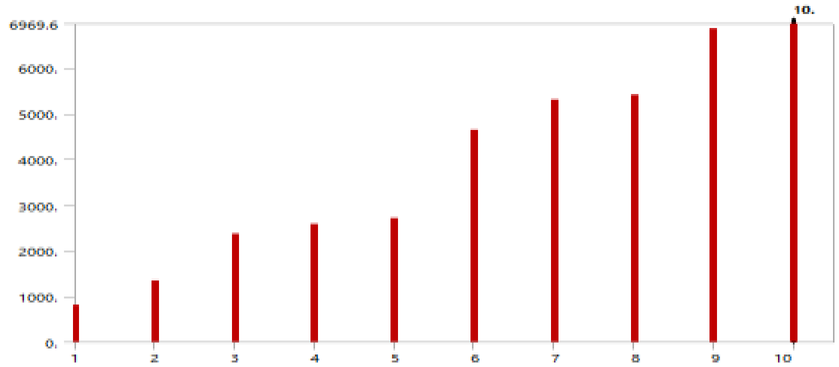

FIG 3: Modes Shape Variation

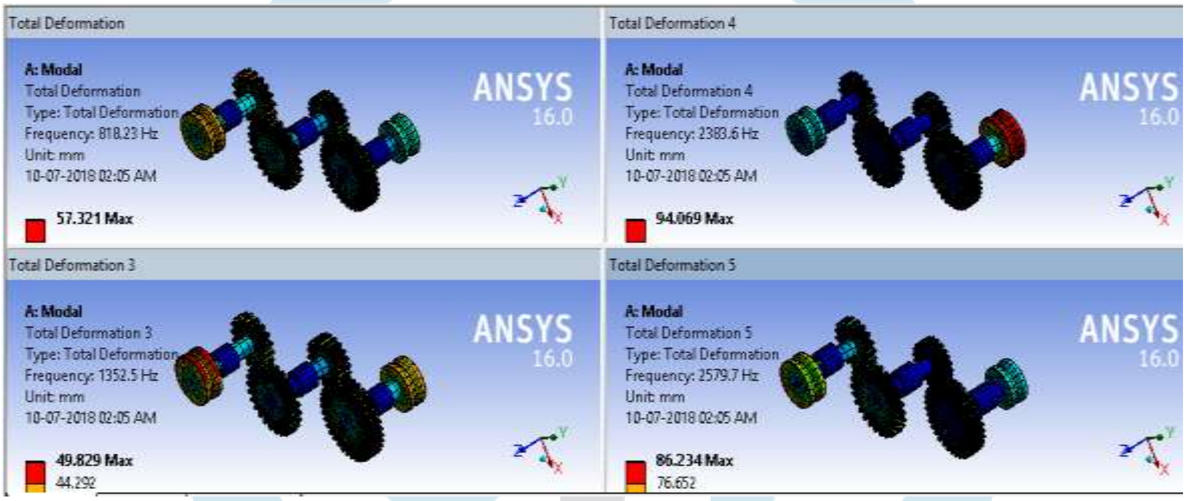

Figure-4: Behaviour of system at some natural frequencies.

- HARMONIC RESPONSE ANALYSIS

The Ahrmonic Response analysis was done on Ansys Harmonic Analysis module. The Analysis were done in all three directions. The results are shown below in figure 5, 6 and 7

I. FREQUENCY Vs. AMPLITUDE RESPONSE

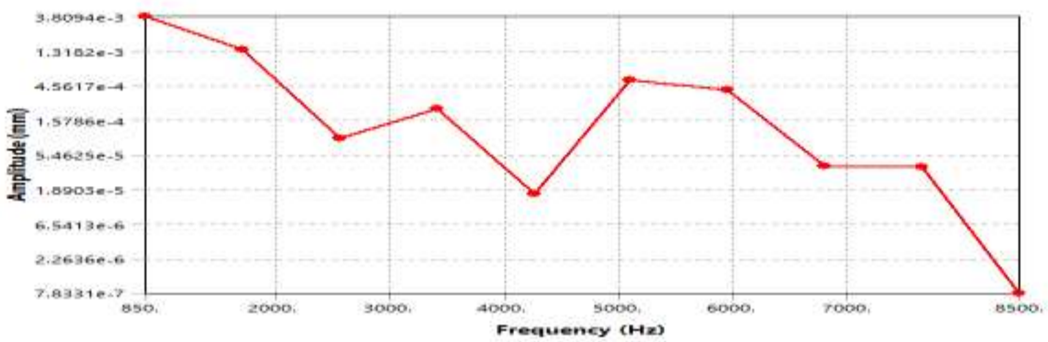

Fig-5 Variation of displacement amplitude with different exciting frequencies(**x-direction**)

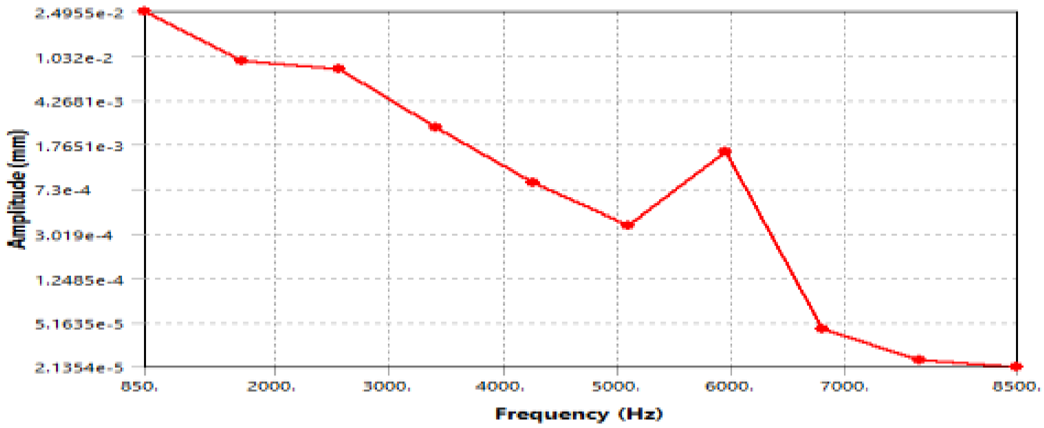

Fig-6 Variation of displacement amplitude with different exciting frequencies(**y-direction**)

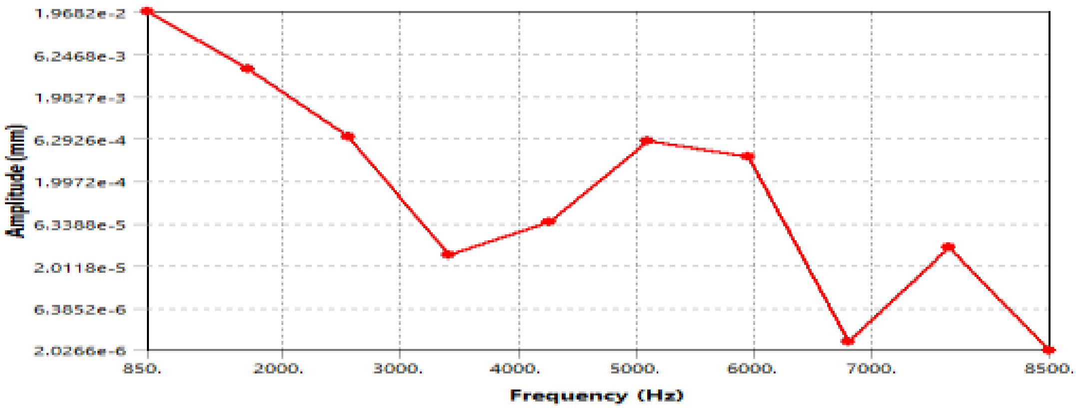

Fig-7 Variation of displacement amplitude with different exciting frequencies **(z-direction**)

II. FREQUENCY Vs. STRESS RESPONSE

Again Variation of stress with frequency were recorded in all three directions at different natural frequencies as shown in figure 8, 9 and 10.

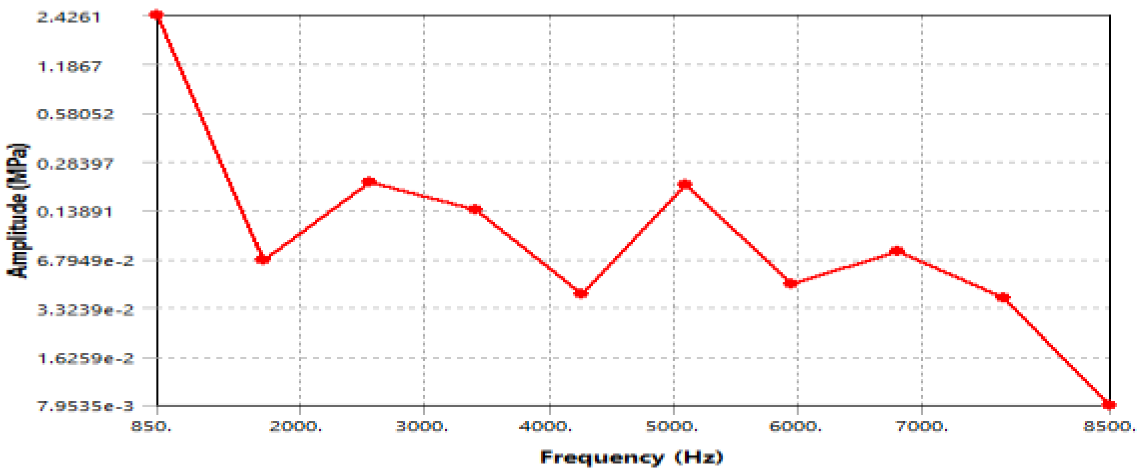

Fig-8 Variation of Stress with different exciting frequencies (x-direction)

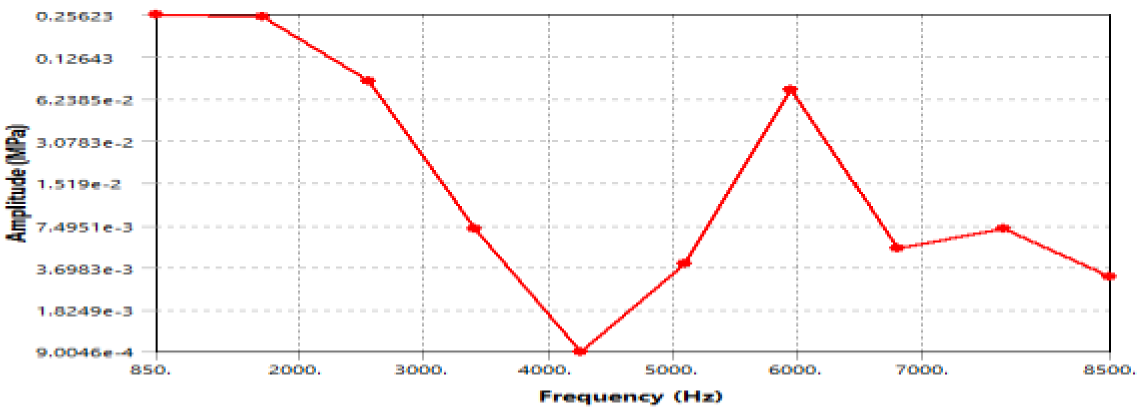

Fig-9 Variation of Stress with different exciting frequencies (y-direction)

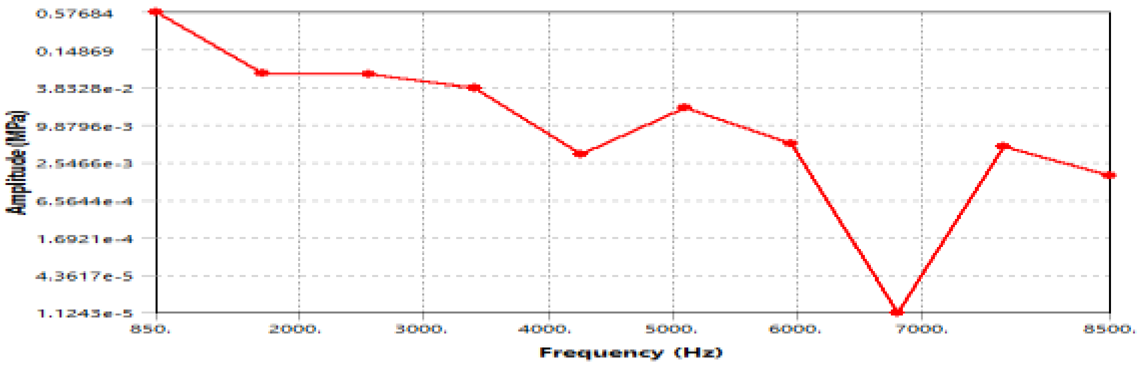

Fig-10 Variation of Stress with different exciting frequencies (z-direction)

In this study, frequency ratio can set to 0.25 from the first modal natural frequency analysis in order to prevent resonance.
Forced frequency = 0.25× natural frequency
= 0.25×813.23 = 203.31 Hz

Conclusion

Modal analysis was carried out for a two stage gearbox. The natural frequencies under boundary conditions were found out and analysed. The variation of number of modes vs frequency has been plotted graphically. These characteristics help in design of the two stage gearbox for dynamic conditions.

Harmonic response of the two stage gearbox for the excitation in the range of 0-8500 Hz has been studied. The maximum amplitude (3.809e-003 mm) and maximum stress (2.4261MPa) occurs in X-direction, at the frequency of 850 Hz. At the initial frequency 850 Hz, the amplitude and stress are maximum, as the frequency increases the amplitude and stress decreases. To avoid the resonant condition, the safe working frequency range is 0-203.31Hz. These characteristics are helpful for proper design of the system.

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