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SIMULATION AND VIBRATION ANALYSIS OF GEAR BOX USED IN COOLING TOWER FAN

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ABSTRACT

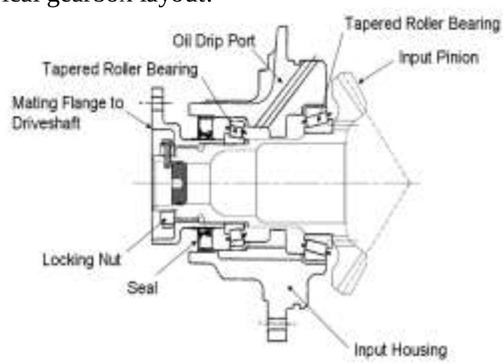
Vibration and cross wind pressure are suspected as the major reason for the failure of the gear box of the cooling tower fan. Also, Vibration suppression of rotating machinery is an important engineering problem. In the present thesis work, I have done a study of the mathematical modeling of gear box of cooling tower fan, target setting for vibration & noise refinement in a system, and investigated various modes of active & passive vibration control techniques. This thesis presents a novel approach to determine the noise and vibration characteristics by predicting the vibration response of a rotating mechanism through data obtained by vibration simulation of a CAD model. Vibration analysis is widely used in industry for condition monitoring of a variety of machines and components. The simulation is then compared to a real-life testing & the 2 results are compared. The experiments are performed for pre-determined loading conditions.

INTRODUCTION

Cooling towers are a very important part of many chemical plants.The primary task of a cooling tower is to reject heat into the atmosphere. They represent a relatively inexpensive and dependable means of removing low-grade heat from cooling water. The make-up water source is used to replenish water lost to evaporation. Hot water from heat exchangers is sent to the cooling tower. The water exits the cooling tower and is sent back to the exchangers or to other units for further cooling.

The cooling tower fan gearbox is located inside the cooling tower cell, the vertical output shaft below the fan. A typical fan has 7 blades each of 3m radius. A horizontally mounted 3-phase induction motor, located on the top level of the cooling tower drives the gearbox via an input coupling, which extends outside the cell. In some examples, the motor and gearbox have a common mounting frame.

The typical speed reduction is from 1490rpm - 990rpm (from a 4-pole or 6-polemotor) down to 100rpm - 50rpm. The input gear mesh is a 90˚ bevel and there are either 2 or 3 single helical reduction gear meshes on vertically mounted shafts. An integral oil pump, driven from an intermediate shaft circulates lubricating oil. Rolling element bearings are used throughout the gear box. Some designs have an axial cooling fan on the input shaft to force air over the casing of the gearbox. Another design feature on some gearboxes is a device to stop reverse rotation of the fan when not being driven, which may occur when the upward airflow from operational fans then returns down through the“idle cell. Figure 1 shows a typical gearbox layout.



Input assembly of intermediate gearbox

OBJECTIVES

To predict the response of a rotating machinery system when acted upon by an external load (moment) such as Gear Box used in various motion and torque transmission applications. This can be achieved by the following actions:

1. Proper designing & modeling of a gear box with a Spur gear mechanism using a CAD Modeling Software like CATIA
2. Simulating the same in a CAE software package like ANSYS. For this project, a study of the scope of vibration & noise refinement as well as the active & passive vibration control techniques also hold considerable importance.

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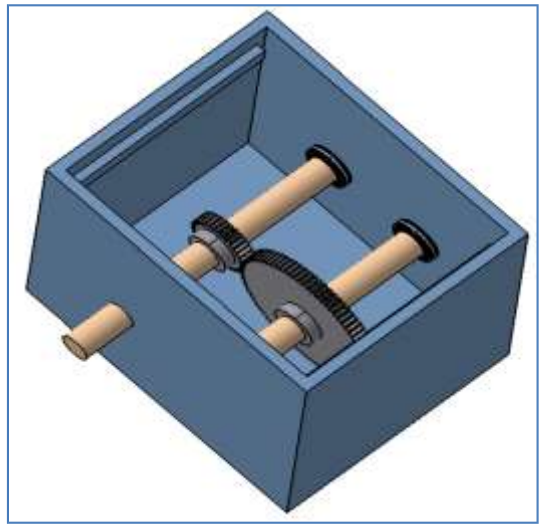
3. The results obtained from the CAE Analysis are then compared with the real-life testing results & a comparison of the results is carried out.
4. Based on the comparison, suggestions are made as to bridging the differences between the 2 results to ensure more efficient prediction techniques and mathematical modeling of more complicated systems.

DESIGN & SIMULATION OF A GEARBOX

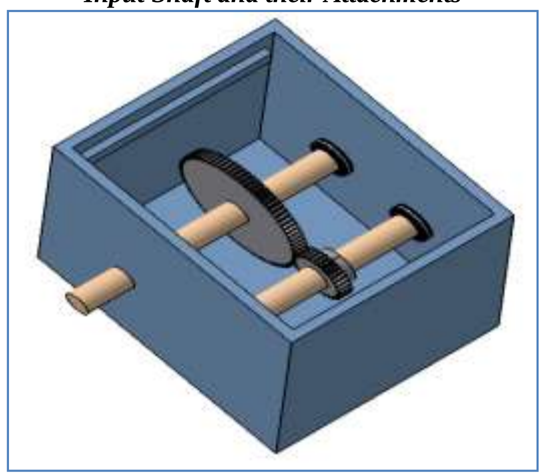
The design of the Gearbox model comprises the following components:2 Spur Gears with the following design data:

Parameter	**Healthy Input Gear**	**Output Gear**
Type	Spur (Pinion)	Spur
No. of teeth	32	80
Pressure Angle	14.5	14.5
Diametral Pitch	16/Inch	16/inch
Module	1.5875mm	1.5875mm
Module	1.5875mm	1.5875mm
Material	Steel	Steel

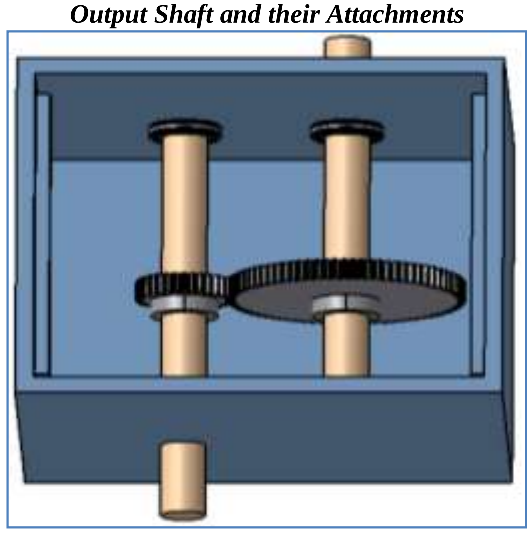
2Shafts each of Diameter = 1 inch
4 Spherical Roller Bearings (ID = 1inch)
The Gear Box encompassing all the above components.
All the components were designed using CATIA (V5) software.



Input Shaft and their Attachments



Output Shaft and their Attachments



Complete Gearbox Assembly

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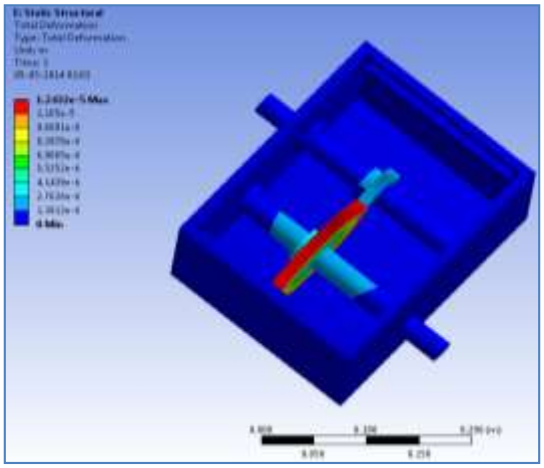

Fig.: (a)

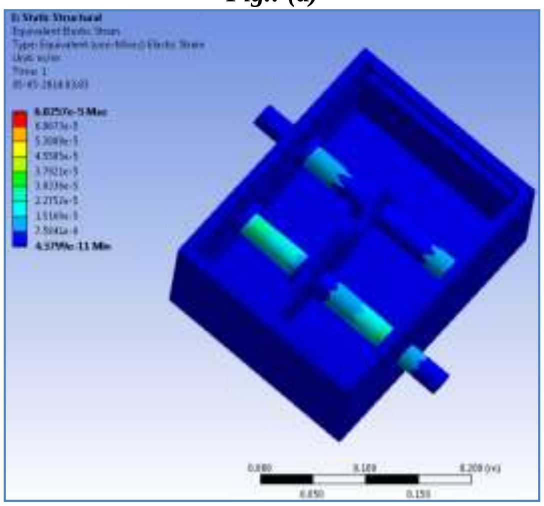

Fig.: (b)

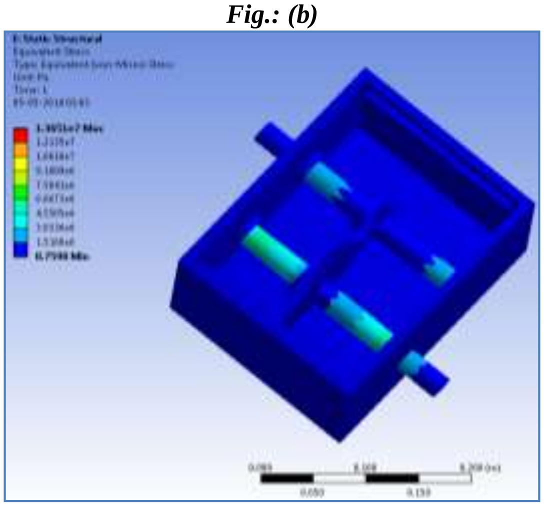

Fig.: (c)

Above Figure (a) to (c) Static Structural Analysis Results : Clockwise from left – Equivalent Stress, Total Deformation and Equivalent Strain.

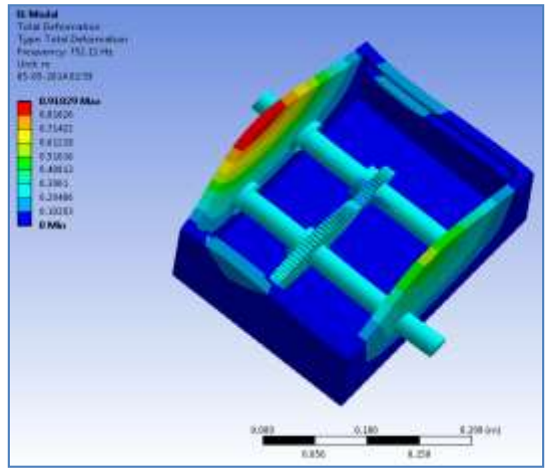

Fig.: (d)

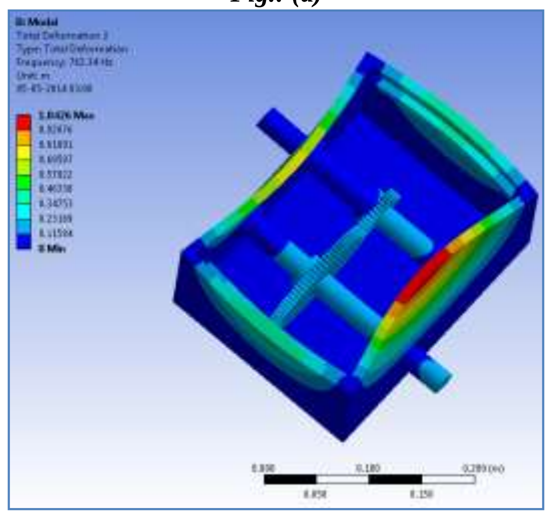

Fig.: (e)

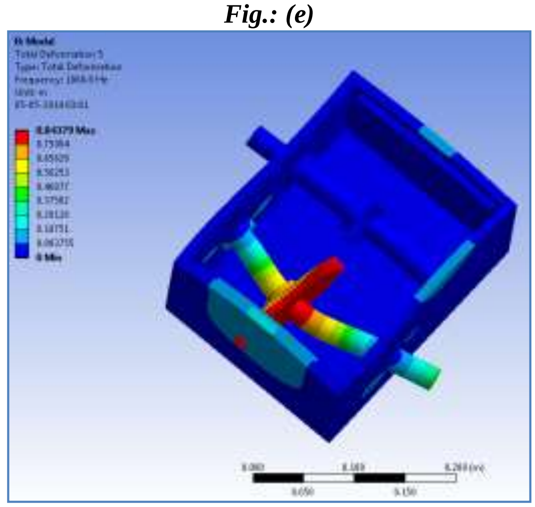

Fig.: (f)

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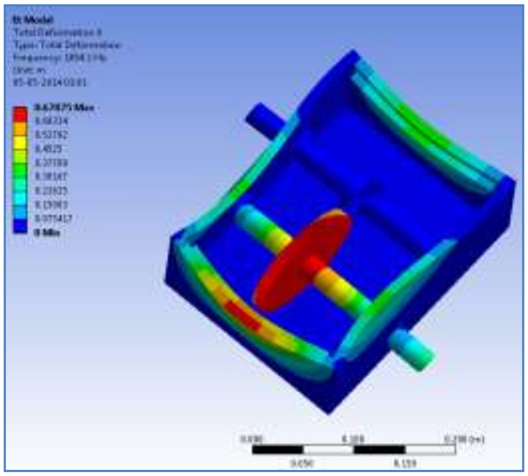

Fig.: (g)

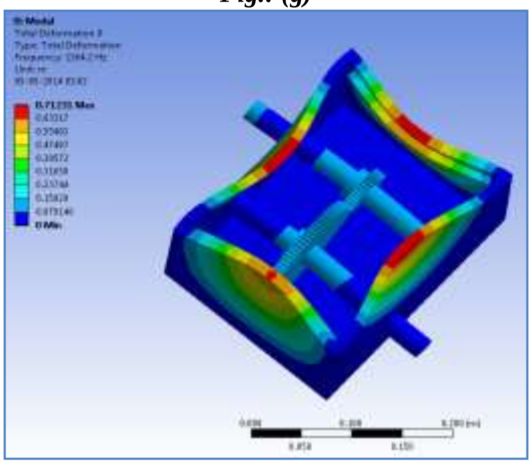

Fig.: (h)

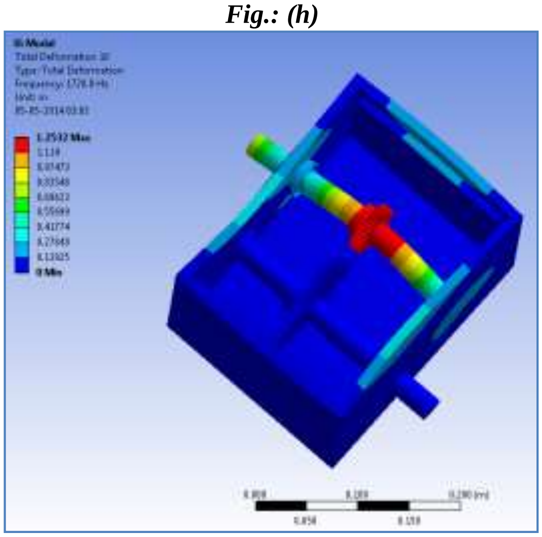

Fig.: (i)

Above Figure (d) to (i) Modal Analysis Results : Total Deformation from Mode 1 to Mode 6

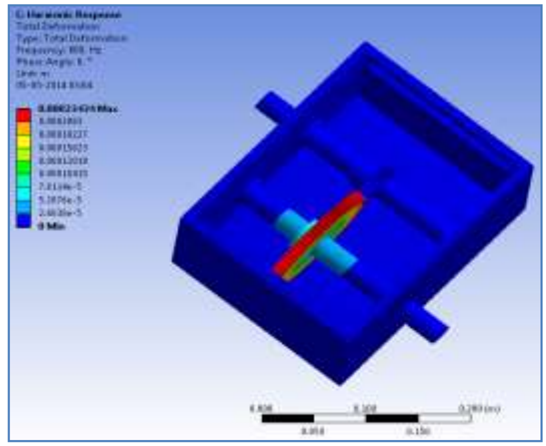

Fig.: (j)

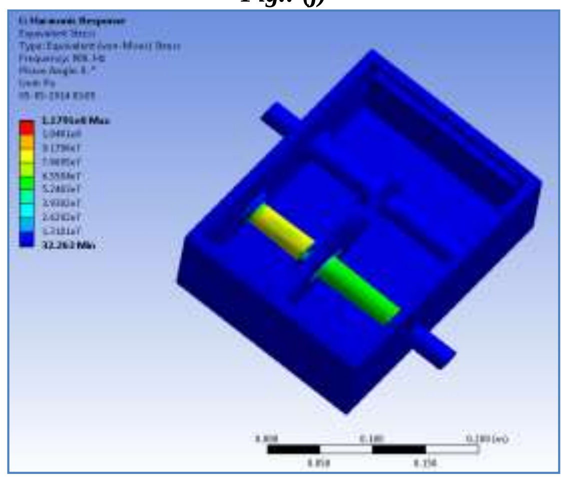

Fig.: (k)

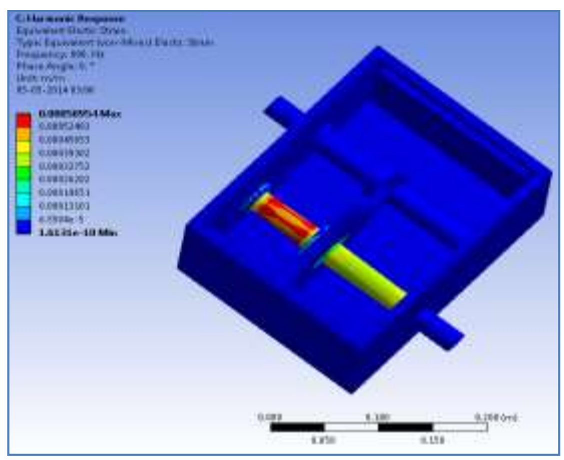

Fig.: (l)

Above Figure (j) to (l) shows Harmonic Response on Modal Analysis Results: Clockwise from left – Equivalent Strain, Total Deformation and Equivalent Stress.

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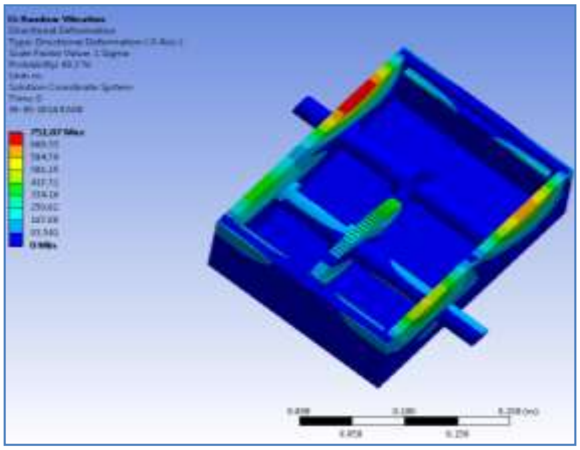


Fig.: (m)

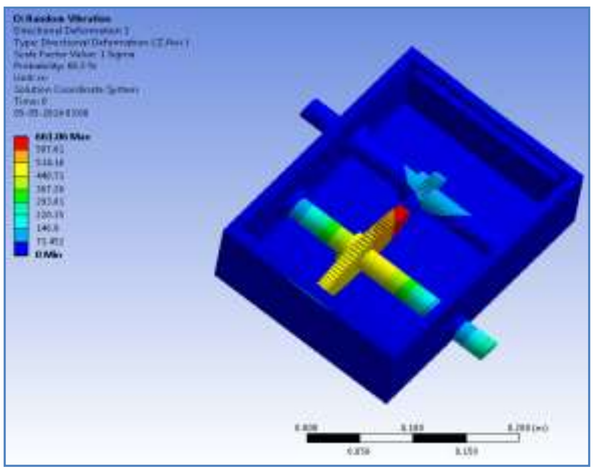


Fig.: (n)

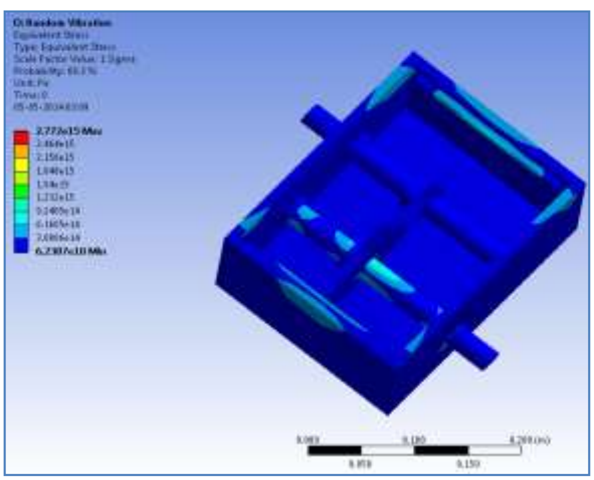
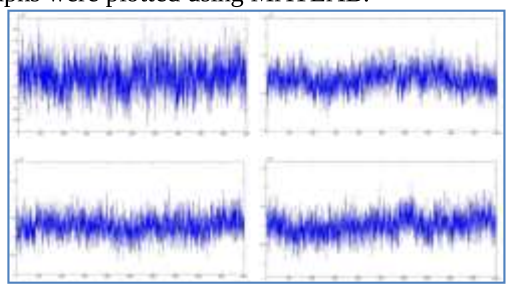


Fig.: (o)

Above Figure (m) to (o) shows Random Vibrations on Modal Analysis Results : Directional Deformations (along X, Y & Z) and Equivalent Stress.

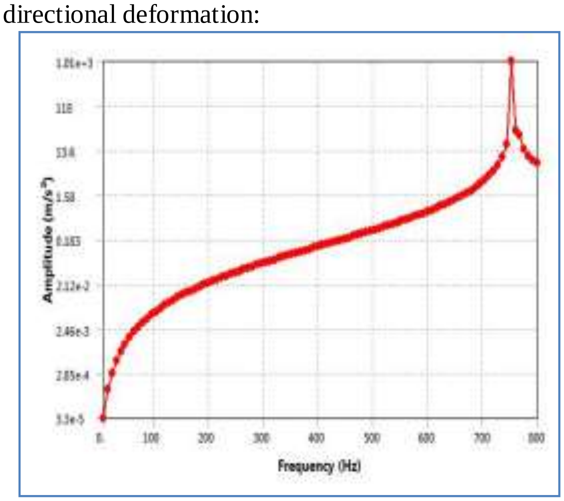
RESULT & ANALYSIS

Time domain signals were captured from Drive train Diagnostics Simulator for this analysis. The two stage gear setup was utilized in which the gear in consideration was a 32-teeth pinion (healthy gear) meshed with an 80-teeth gear. The rotating speed at which the readings were taken was 50Hz. The load was also varied from 0% to 90% for each speed. The sampling rate of the signal was kept at 6.4 kHz. The signals acquired from the sensor for healthy gear are shown in fig. 7.1. The speed was kept at 20Hz and the load varied as 0%, 30%, 60% and 90%. These graphs were plotted using MATLAB.



Time domain signal for healthy gear at 20 Hz speed and at 0%, 30%, 60%, and 90% load

The results from the Harmonic Response (in a frequency range of 0 – 800Hz) to the Modal analysis of the CAD Model in ANSYS generated the following graphs related to acceleration and directional deformation:



ANSYS Acceleration Response (along X axis) in Frequency Domain

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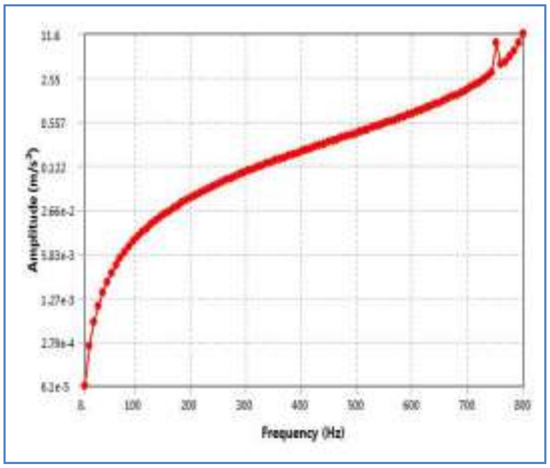

ANSYS Acceleration Response (along Y axis) in Frequency Domain

CONCLUSION

According to the experimental data obtained from the DDS, the gear meshing frequency of the setup was found out to be approximately 650Hz at 20Hz rotating speed and 60% loading conditions.

The results from the Harmonic Response (in a frequency range of 0 – 800Hz) to the Modal analysis of the CAD Model in ANSYS generated 752Hz as the approximate resonance frequency under similar loading conditions as in the experimental setup in DDS. Although the acceleration response showed considerable deviation from the real-life test values. A reason for this deviation could be due to the presence of additional components like the driving motor, the additional planetary gear box, the magnetic braking system & also the presence of splash lubrication in the DDS Experimental Setup.

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