Vibration Signature Analysis of Spherical Roller Bearing Using CAE Software

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Abstract— Roller bearings are important machine elements and are widely used. If the healthy bearing is loaded with load of 300 N and run at 1000, 1200 and 1400 RPM respectively, its behavior is found out with the help of CAE software ANSYS. First the CAD model of the bearing is modeled in CATIA V5, and is imported in ANSYS, after the pre-processing, it is sent to the solver and the results are acquired. The results at various frequencies are found so that the maximum for each RPM is found out. This pave way to predict the signature of vibration in defective roller bearing. This will also help further to predict the behavior of various types of bearings.

Keywords: Finite Element Analysis, Vibration Signature Analysis, Spherical Roller Bearing, CATIA V5, ANSYS

I. INTRODUCTION

This paper presents Vibration Signature Analysis of Defective Spherical Roller Bearing. Modeling of the setup is done on CATIA V5 software. It is then imported in Ansys Workbench which is preprocessor software and simulated. Its finite element modeling is done. Finite element analysis is also done using Ansys Workbench as post processor. Optimization is carried out by using trial and error method. Two cases are analyzed for the different rpm. RPM are taken 1000 rpm, 1200 rpm, and 1400 rpm for optimization. Graph of Acceleration and displacement are obtained for each case. Modal analysis is also done in Ansys Workbench for three excitation frequencies. Life of any bearing depends upon some important parameters such as operating conditions, quality of lubrication, contamination of bearing and presence of surface irregularities if any. These parameters are major source of vibration in rotor bearing system. These vibrations affect the endurance strength of bearing leading to failure of machinery. Presence of surface irregularity (local defects like pits, cracks and distributed defects like waviness, roughness, etc) in bearings is one of the most commonly observed parameters in failure analysis. These defects in turn lead to vibrations of bearing during its working. This could be heard in the form of noise. Some of the important diagnostic techniques such as vibration measurement, sound intensity, shock pulse method, stator current method and acoustic emission technique are reviewed by few researchers [1]. Accordingly, it was noted that vibration measurement is one of the most effective and widely used techniques for bearing failure analysis. When vibration features of component are obtained, its health condition can be determined by comparing these patterns with those corresponding to its normal and failure condition. It is established that the failure in any machine part result in the change in the vibration signature [2], predominantly with a negative effect. Various studies conducted earlier on other types of rolling contact bearing suggest that the failure increases the vibration in the bearing [3], which can ultimately result in the failure of the system.

Dr. Abhay Utpat [7], attempted the vibration analysis of the defective bearings making a physical defect of on inner race and outer race. The similar kind of vibration investigation is conducted by Mr. Deshpande Hrishikesh et.al [6] on a cylindrical roller bearing.

Various researchers have used different vibration measurement techniques like the use of FFT or the fuzzy entropy technique [4], as well as different FEA techniques have been used.

Many researchers have created a defect on the bearing and have studied the vibration signatures of healthy and defective bearing at various speeds and load and based on that conclusions were drawn.

Kumbhar S.G et al [9], did theoretical and experimental studies on vibrations produced by defects in taper roller bearing using vibration signature analysis. For this study an artificial defect was created on roller and outer race. Then vibration response for defected taper roller bearing was tested under different speed and loading conditions. The resulting vibration signals were processed using considerable vibration-based techniques in frequency domain. These results were then compared with healthy bearing

In order to do the finite element analysis, this paper presents a combination of CAD (Computer Aided Design) software, FEA (finite element analysis) software and graphical method is used.

II. SYSTEM UNDER INVESTIGATION

The 3D view of the mechanism to be investigated is shown in figure 1 which is modeled in CATIA V5software. As the figure indicates, the system is assembly of many components.

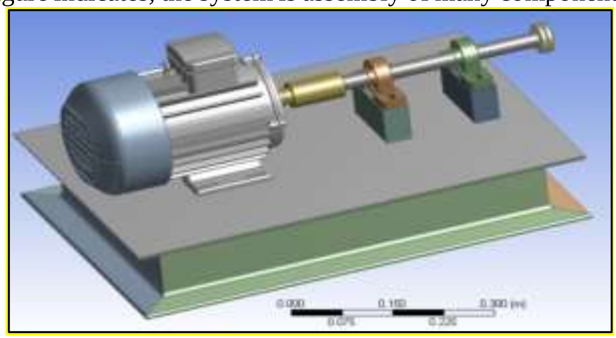

Fig. 1: CAD Model of the Whole Set-Up

III. FINITE ELEMENT MODELING

Cad model exported from CATIA V5 is imported in ANSYS for further procedure. Once the geometry cleanup operation is completed the mesh parameters are set so as to achieve best quality mesh. The meshing in ANSYS is carried out by two approaches. “Assembly meshing” refers to meshing an entire model as a single mesh process, as compared to part- or body-based meshing, in which meshing occurs at the part or body level respectively. In part-based meshing, parts are meshed individually and have no connections (other than mesh connections). Assembly meshing performs Boolean operations that you would otherwise have to perform manually in the ANSYS Design Modeler application or a CAD system. These operations include a mixture of volume filling, volume intersection, and volume combination operations that create a conformal mesh between all solids, fluids, and virtual bodies in the analysis. Assemblies can also be meshed using part-based meshing methods, but in such cases the mesher operates one part at a time, and therefore cannot mesh virtual bodies or evaluate parts that occupy the same space.

If we want more control over the mesh, we can get it by using mesh control tools. Both global mesh controls and local mesh controls are available. Global mesh controls are located in the Details View when the Mesh object is selected in the Tree Outline. To access the local mesh control tools, highlight the Mesh object, then either click the right mouse button and choose Insert or choose a mesh control from the Mesh Control context toolbar.

In general, in cases where a numeric value can be specified for an option but a value of 0 would not make sense within the context of the option, specifying 0 resets the option to its default. For example, the Curvature Normal Angle option accepts a value from 0 to 180, but since 0 does not make sense within its context, specifying 0 resets Curvature Normal Angle to its default. On the other hand, setting Number to -1 resets the option to its default because 0 is a valid value for Number of Retries.

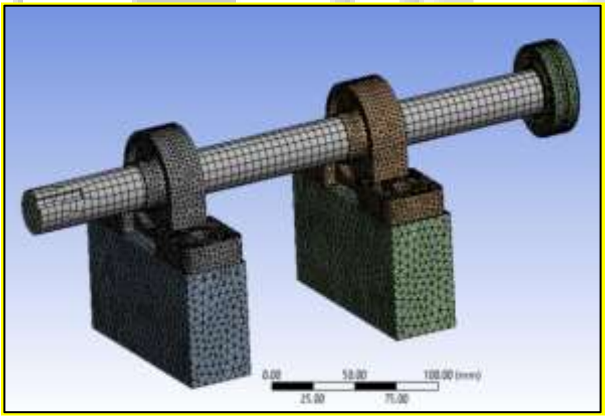

Fig. 2: Mesh Model

The Roller Bearing model consists of inner race, outer race and rollers in between. Tetrahexal and Hexahedral (SOLID65) are chosen for the analysis which is having ten numbers of nodes.

The refinement technique of meshing is used to mesh the model. The finite element model is shown in figure having 1,25,913 elements and 2,10,712 nodes.

The finite element model of the Roller Bearing is shown in the figure. The model shown here is in horizontal position to fit the view.

A. Material Modeling and Load Conditions

Material properties have to be determined for the computer simulation. The loading may be in the form of a point load, a pressure load or a displacement in a stress (displacement) analysis, a temperature or a heat flux in a thermal analysis and a fluid pressure or velocity in a fluid analysis. The loads may be applied to a point, an edge a surface or an even a complete body.

Material	Youngs Modulus (GPa)	Poissons Ratio	Density kg/m^3
Structural Steel	200	0.3	6850
Bearing Steel (Crome steel)	205	0.29	7320

Table 1: Mechanical Properties

B. Boundary Condition

The force boundary conditions are imposed during the evaluation of the element matrices itself while the prescribed displacement boundary conditions are imposed after the assembly of the element matrices. Then the global system of linear equations is solved by any numerical technique to get the displacements at global nodes.

Then boundary conditions and loading conditions are applied to the model. In this model, bases of the two bearing housings are boundary conditions. Remote load is applied to the bearing which is fixed at the end of the shaft. This bearing is under observation and this bearing has been loaded with the load of 30kg i.e. approximately 300N. For next iterations, same boundary conditions and loading conditions are applied but only bearing is replaced.

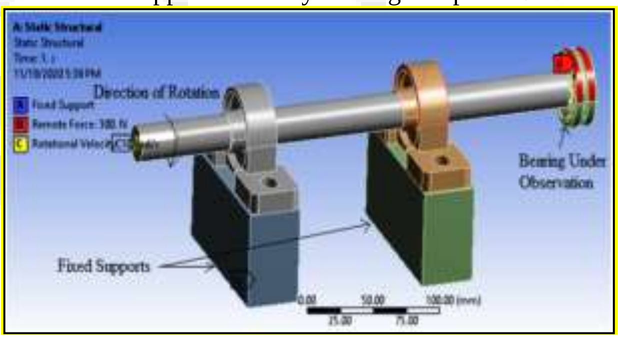

Fig. 3: Loading & Boundary Conditions of the Set-Up

C. Post Processing

After completion of the analysis the result files are generated as per the preparation of the deck. The .RES file is generated which contains all the binary plots of the solution. This file containing all the results is opened in the same window by clicking on the desired option for analyzing and plotting the results in graphical form. Displacement results can be displayed as a plot of the deformed element mesh superimposed over a plot of the not deformed model. Displacements can be scaled such that the deformed shape is exaggerated for clarity. For two-dimensional solid models, stress components can be displayed as contour plots. The stress components available from the solution are the normal, shear, and Von Mises stress components for plane stress and plane strain, and the radial, axial, shear, and hoop stress components for axisymmetric models. For models using truss or beam elements, stress components are plotted as bar charts. Acceleration plots for three different RPM for healthy bearing are as follows

IV. ACCELERATION AT 1000 RPM

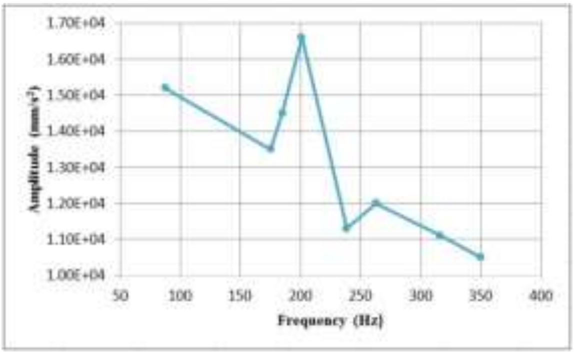

Fig. 4: Healthy Bearing Results at 1000 RPM (Frequency Vs Acceleration)

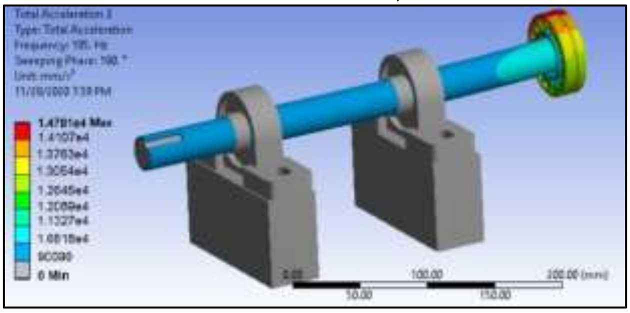

Fig. 5: Acceleration at 185 Hz

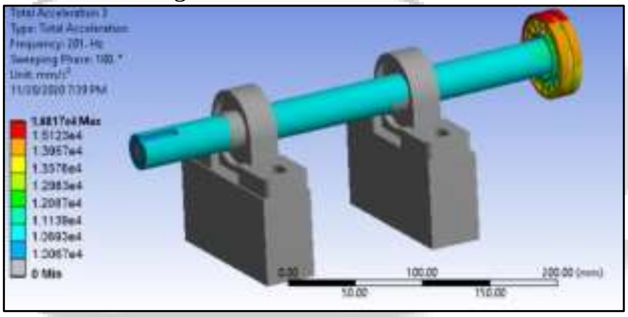

Fig. 6: Acceleration at 201 Hz

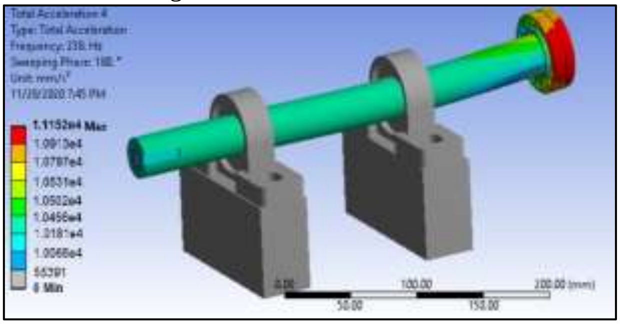

Fig. 7: Acceleration at 238 Hz

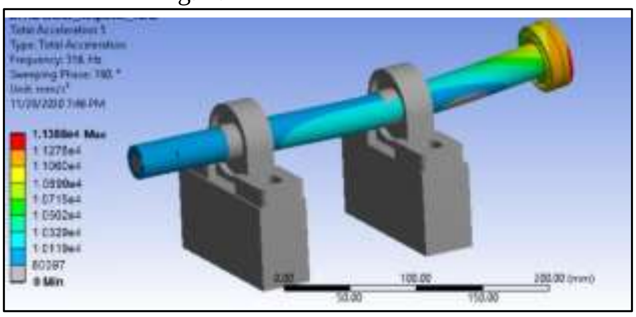

Fig. 8: Acceleration at 316 Hz

V. ACCELERATION AT 1200 RPM

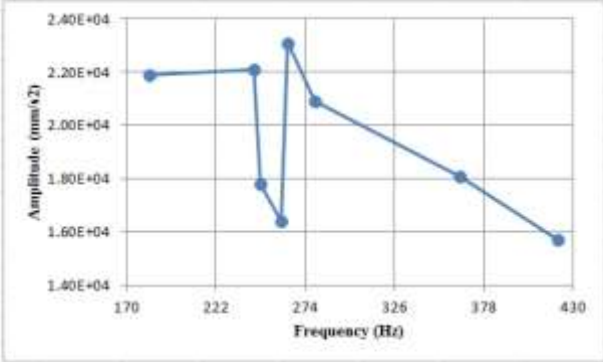

Fig. 9: Healthy Bearing Results at 1200 RPM (Frequency Vs Acceleration)

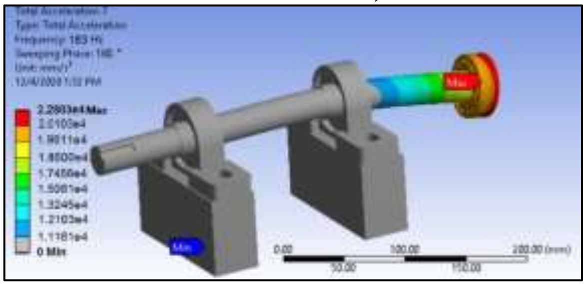

Fig. 10: Acceleration at 183 Hz

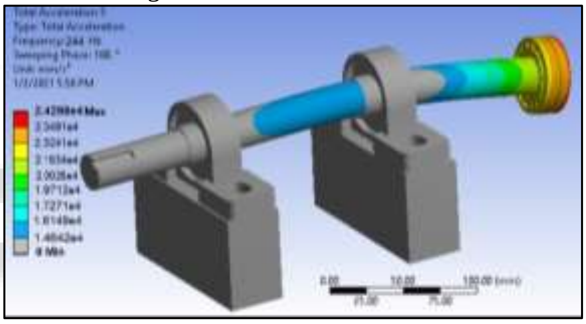

Fig. 11: Acceleration at 244 Hz

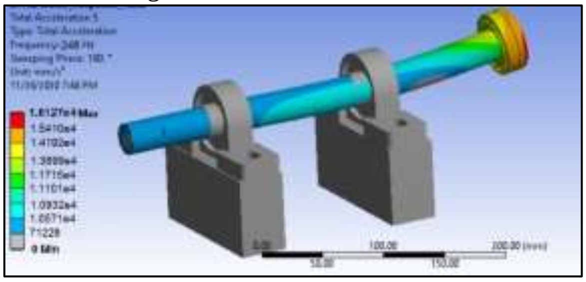

Fig. 12: Acceleration at 248 Hz

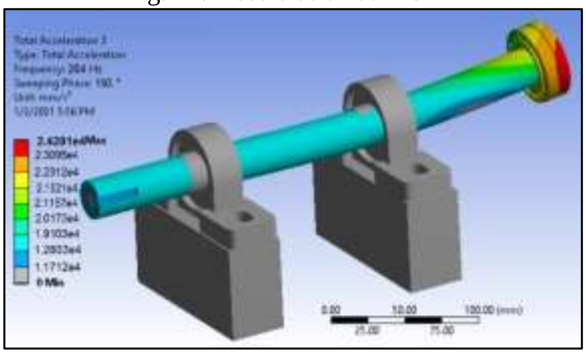

Fig. 13: Acceleration at 264 Hz

VI. ACCELERATION AT 1400 RPM

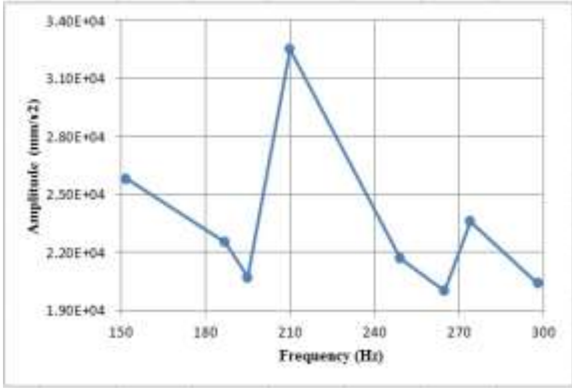

Fig. 14: Healthy Bearing Results at 1400 RPM (Frequency Vs Acceleration)

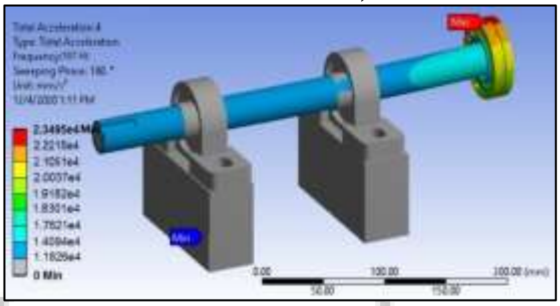

Fig. 15: Acceleration at 187 Hz

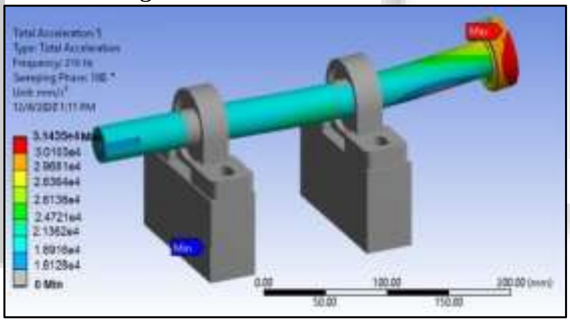

Fig. 16: Acceleration at 210 Hz

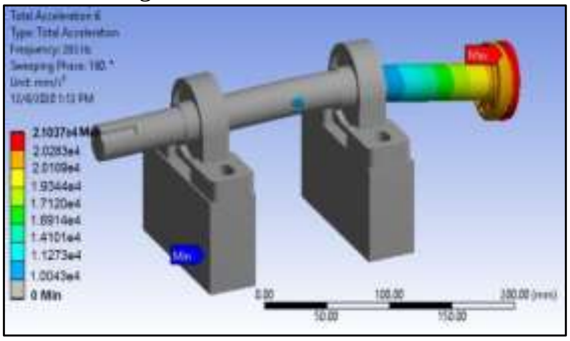

Fig. 17: Acceleration at 265 Hz

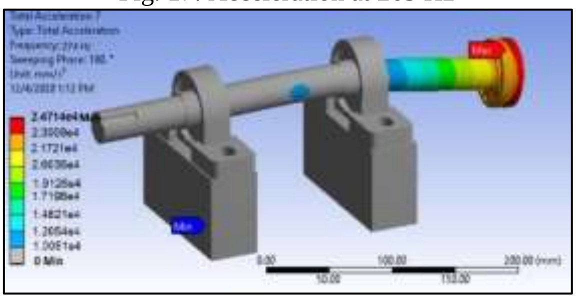

Fig. 18: Acceleration at 274 Hz

VII. RESULTS DISCUSSION

1) Maximum Acceleration for 1000 RPM is 1.6817E4 mm/s^2
2) Max Acceleration for 1200 RPM is 2.4281E4 mm/s^2
3) Max Acceleration for 1400 RPM is 3.1435 E4 mm/s^2

VIII. CONCLUSION

1) It can be seen from results that, as RPM is increasing, acceleration is also increasing.
2) As the results are logical, displacements for the given frequency can be found out.
3) Ansys can be used to find and optimize the vibration in the Roller bearing.
4) By increasing RPM further, one can predict behviour and life of the bearing for given RPM.
5) As the results of the spherical bearings are logical in the same way analysis can be done for defective spherical roller bearings.

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