MODAL ANALYSIS OF BEARING USING FINITE ELEMENT METHOD

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Abstract : Bearing are the machine element which are extensively used in rotating machine parts and are subjected to dynamic conditions and so they are more liable to failure. The close monitoring of bearing is very necessary to minimize the downtime and failure of machine. In the current study, single row ball bearing 6205 of SKF make has been used. Finite Element Method (FEM analysis) i.e. Static analysis, Modal analysis and Dynamic analysis are done to study the effect of shaft speeds and loadings conditions on bearing. By modal analysis natural frequencies and mode shapes are obtained for healthy and defective bearings. Stress and Displacement analysis has been done under the effect of shaft speeds and loading conditions on bearing.

***IndexTerms* – Ball bearing, Dynamic Analysis, Mode shapes, Finite Element Methods.**

I. INTRODUCTION

Rotating machines runs under high service loads during operation. Ball bearings are ideally suited to wheel bearing applications. Nowadays industry improves the operating conditions, which means that failure of a bearing will result into unplanned maintenance cost and break-down. So the industry has focused on the improvement of maintenance and improvement in components. Ball bearings are ideally suited to radial load applications. High stress levels are imposed on the bearing because of the weight of the components, impact loads torque change, gear or belt change or poor working conditions. Irregularities, design defect, faulty installation or damage of the ball bearing can also results in vibration and noise. Abrupt changes occurred due to this faulty installation or defect will results into contact stresses occur. Hence structural excitation because of these changes results into excitation and the generation of vibrations.

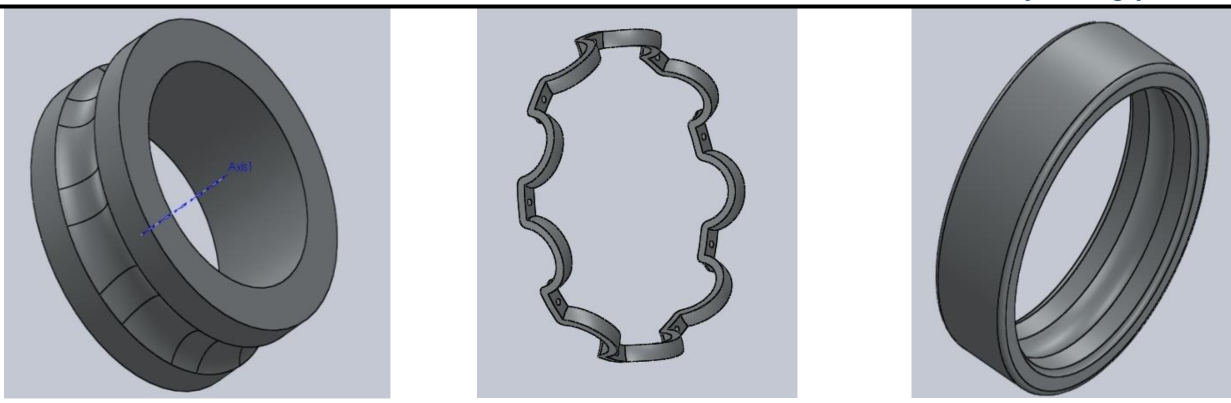
Auweraer [1] established the physical interpretation of modal analysis in mechanical structures and its validity in design improvements. Guo et al [2] used finite element analysis and mode shapes to understand human spine injury. Structural analysis under dynamic behavior of the railway vehicle has been done using F.E.M by Harak et al [3]. The structural analysis of the freight wagon shows that if any external exciting frequency occurred due to system inaccuracy, coincide with the modal frequency of system, then whole system will be highly unstable. Gerdun et al [4] provided two case studies related to railway bearing failure and suggested the bearing damage mechanism. Singh et al [5] presented an explicit dynamic model for analysis of defective roller bearing. The modeling results shows that much larger contact forces and accelerations are generated when rolling elements exits from the defect compared to when roller strike the defective surface. Shukla and Harsha [6] used modal analysis for dynamic analysis of turbine blades in healthy and cracked condition. Results obtained from model were verified by experiments. It was established that the mode shapes are suitable tool for preliminary analysis of body under dynamic loading subjected to external excitation. Harak et al [7] studied the effect of geometric nonlinearity on rail draft pad in pre stressed condition with the help of modal analysis and to study fatigue behavior of draft pad. Modal analysis of tapered roller bearing used in railway wagons has been carried out by Singh and Harsha [8] using finite element method to analyze the system under dynamic conditions.

II. DETAILS OF SOLID AND FE MODEL

The modal of SKF 6205 ball bearing is created in Solidworks. Dimensions and solid model of the bearing are as given below-

Table 1.1- Dimension and other details of SKF 6205 ball bearing

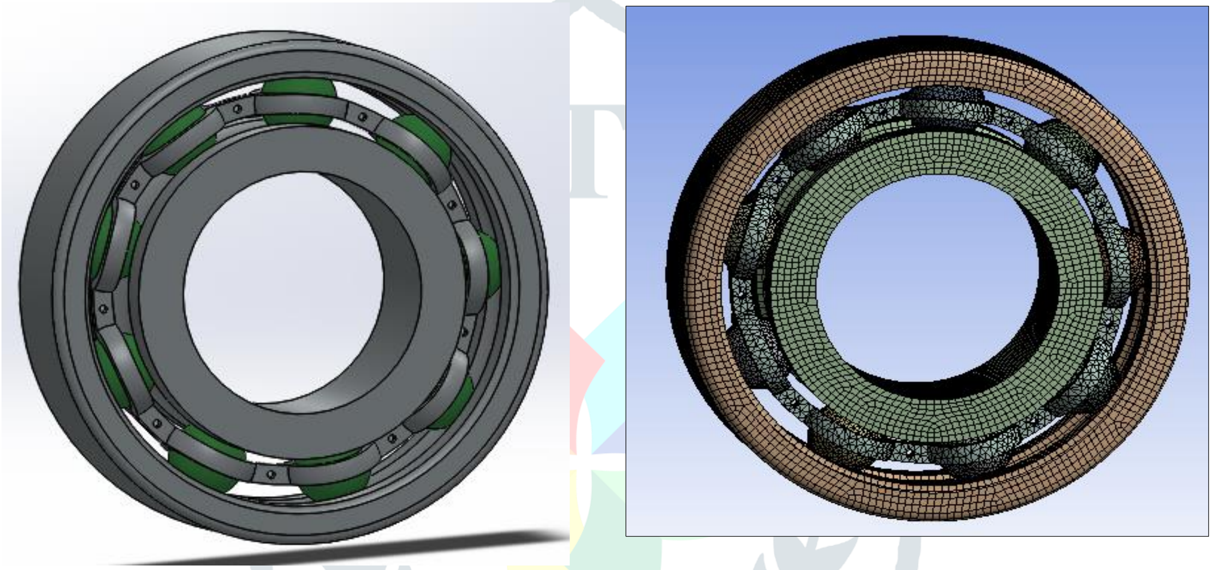
Outer dia D	52 mm
Bore dia d	25 mm
Pitch dia d_m	38.5mm
Ball dia d_b	7.9mm
Raceway width w	15mm
Contact angle α	0^o
Number of balls Z	9



(a) Inner Race (b) Cage (c) Outer Race

Fig. 2.1. Various components of SKF 6205 ball bearing

The material employed for this model is Chrome steel. The model designed is then imported to ANSYS. Engineering data manager is used for storing and defining the specifications of component materials. The contact faces between various bearing elements have been identified and defined as per the suitable contact definition between these parts. Imported solid model is then discretized in ANSYS and meshing in this model of bearing is done using the quad element. Total numbers of nodes are 232965 and elements are 74607.



(a) Solid model (b) Meshing of model

Fig. 2.2. Model of ball bearing

Following are the boundary conditions for analysis-

<u>FOR MODE SHAPE ANALYSIS-</u>

- No load
- Fixed support on outer race

<u>FOR STATIC ANALYSIS-</u>

- Fixed support on outer race
- Vertical load of 2 kg shaft

<u>FOR DYNAMIC ANALYSIS-</u>

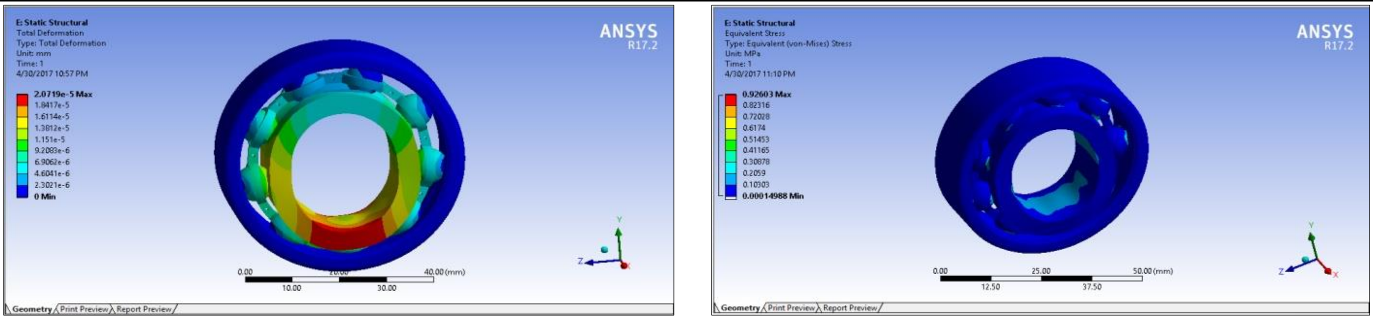
- Fixed support on outer race
- Vertical load of 2 kg

Rotational velocity on inner race of 3000 rpm

III. RESULTS

A. <u>Static Analysis</u>

This analysis was run with outer race as fixed support and inner race with 19.6 N load on inner race downward. The displacement in this analysis ranges from 0 to maximum of 20.72 µm. The maximum displacement caused in this is on the edge of the inner race. So this deformation we can conclude that the most probable area for damage and deformation is the inner race of bearing. The maximum stress is found out to be 0.9260MPa. The maximum stress is generated on the groove of the inner race and on ball it is under constant load.

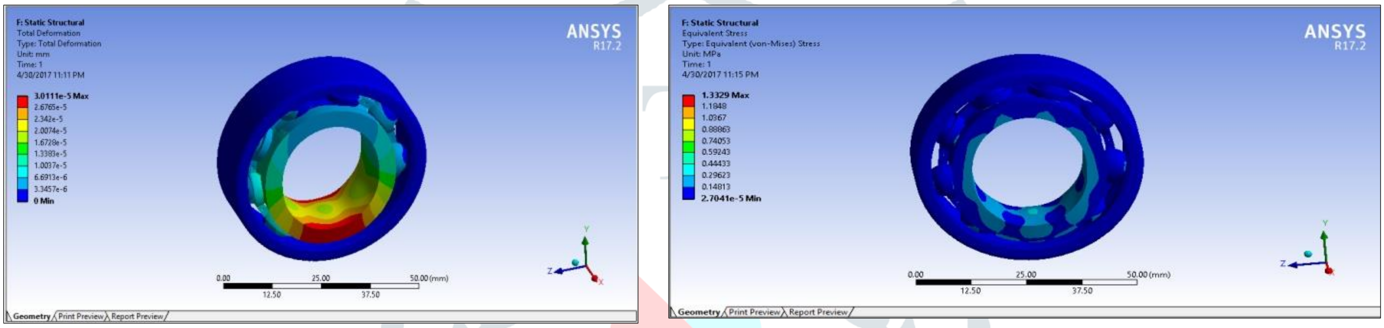


(a) Displacement (b) Equivalent stress

Fig. 3.1. Static analysis results

B. Dynamic Analysis

This analysis was run with outer race as fixed support and inner race with 19.6 N load on inner race downward. The displacement in this analysis ranges from 0 to maximum of 30.11µm. The maximum displacement caused in this is on the inner race and cage. So this deformation we can conclude that the most probable area for damage and deformation is the inner race of bearing. The maximum stress is found out to be 1.33MPa. The maximum stress is generated on the edge and corner of the inner race ad it is under constant load and rotational velocity.



(a) Displacement (b) Equivalent stress

Fig. 3.2. Dynamic analysis results

C. Mode Shape Analysis

Mode shapes are inherent characteristics of any structure, and these mode shapes are dependent and determined by the material properties of structure (mass, damping, and stiffness), as well as by boundary conditions [1] . Modes will change if material property or boundary conditions changes. Mode shapes of SKF 6205 ball bearing are calculated, for both healthy and defectives (defect on inner race and outer race) at same boundary conditions.

Table 4.1. Modal frequencies at various conditions

Modes	Healthy		Inner race defective		Outer race defective	
	Frequency in Hz	Max Total deformation mm	Frequency in Hz	Max Total deformation mm	Frequency in Hz	Max Total deformation mm
Mode-1	223.05	0.00779	265.21	0.00736	253.59	0.00728
Mode-2	508.11	0.00638	451.57	0.00565	422.54	0.00616
Mode-3	554.82	0.00722	639.00	0.00685	651.67	0.00643
Mode-4	643.71	0.00680	827.08	0.00678	826.88	0.00788
Mode-5	750.35	0.00700	1406.4	0.00677	886.25	0.00724

Similar like the static and dynamic analysis, inner race is all cases show maximum deformation in most of the mode shapes. Similarly modal frequencies in case of defective inner race are higher comparative to other cases.

Healthy Bearing

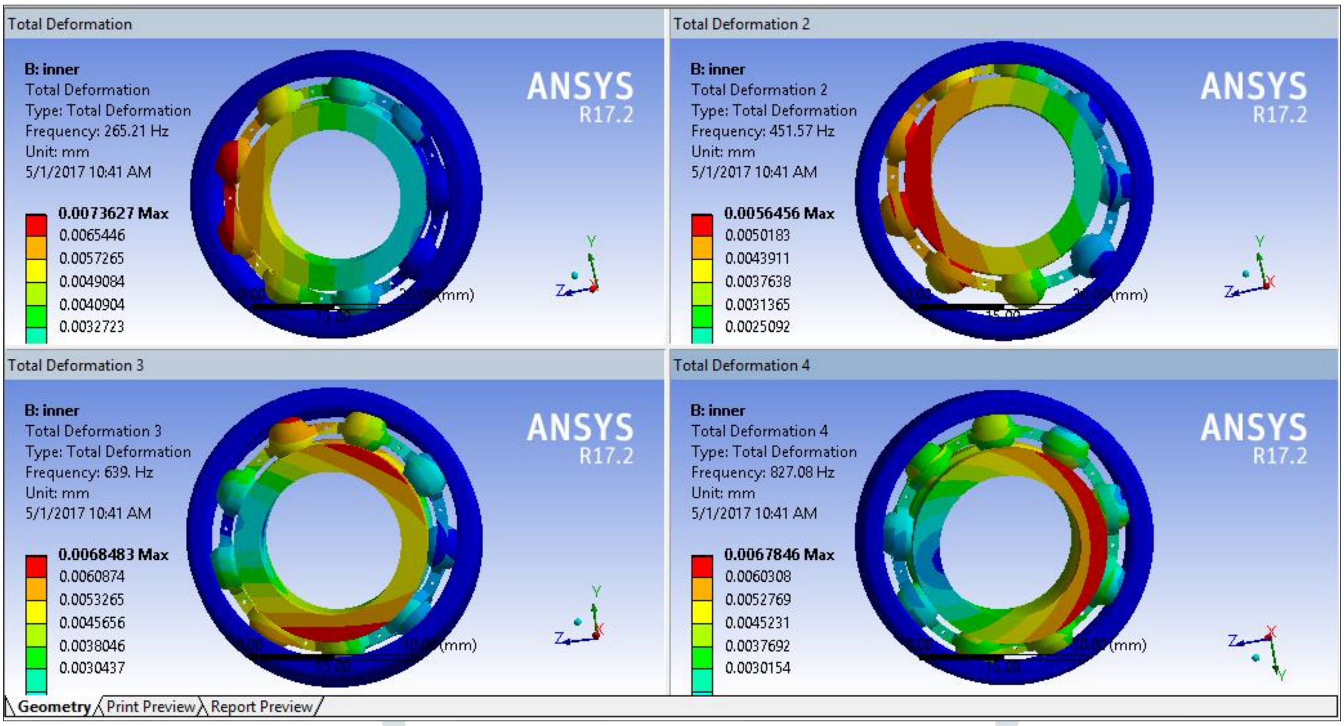


Fig. 4.1. Mode shapes of healthy bearing

Defect on Inner race

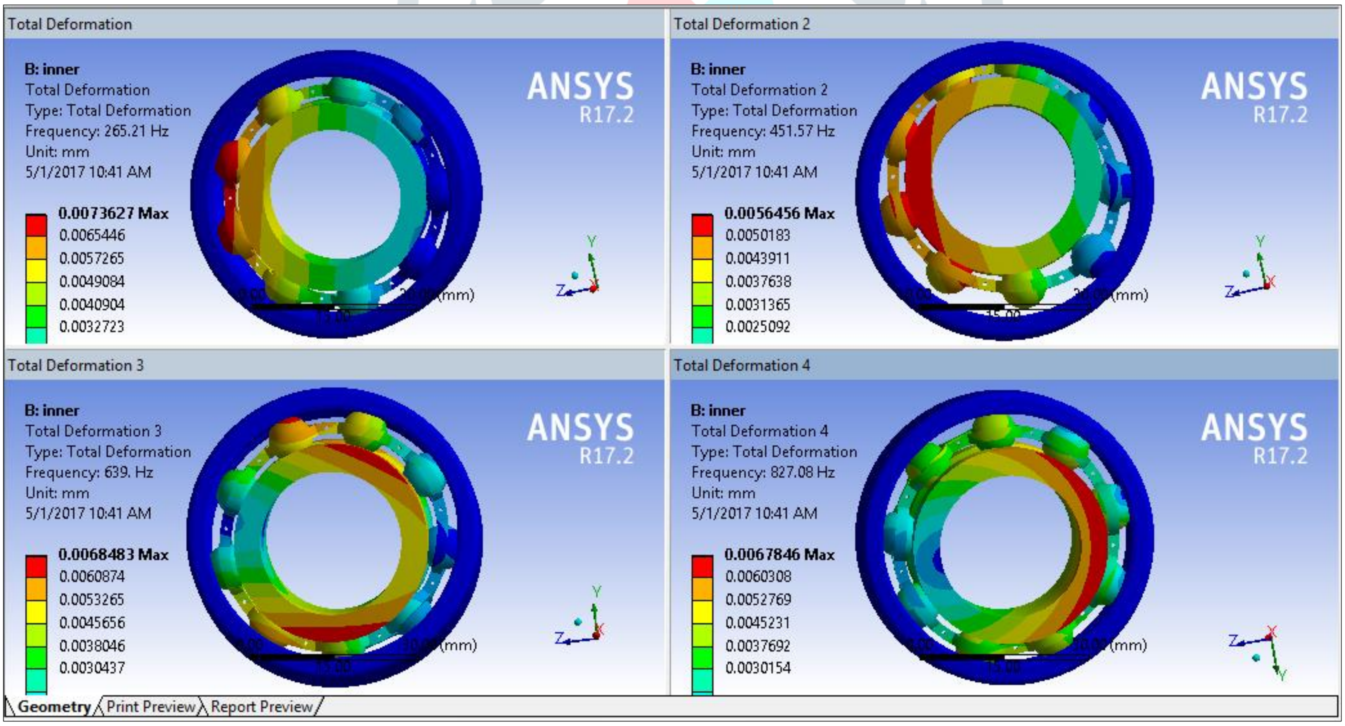


Fig. 4.2: Mode shapes of inner race defect bearing

Defect on Outer race

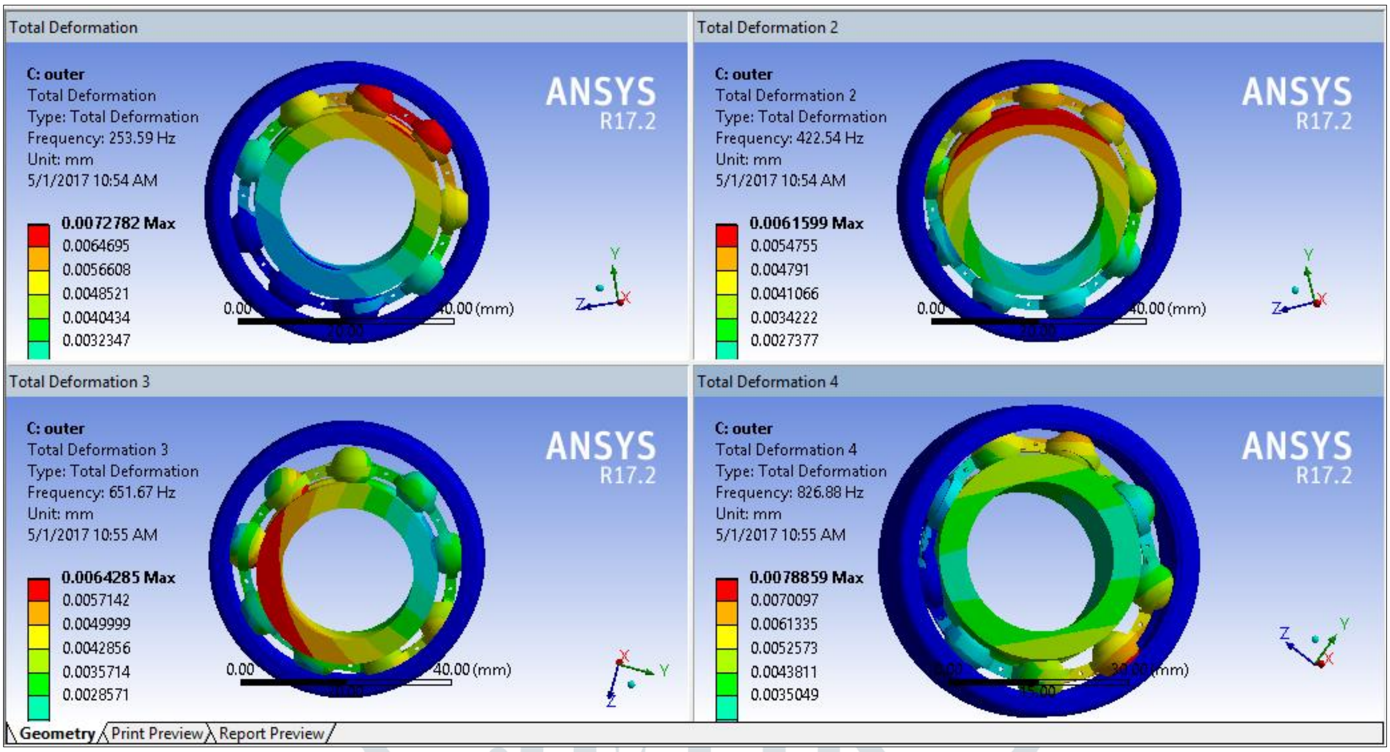


Fig. 4.3: Mode shapes of outer race defect bearing

IV. CONCLUSION

Vibration and Dynamics Analysis are done using finite element method. FEM has been used to evaluate the natural frequencies and corresponding mode shapes, which shows the critical deforming feature of bearing components at resonance. Stress and Displacement analysis has been done under the effect of shaft speeds and loading conditions on bearing. The dynamic behavior of the bearing shows if external excitation frequencies due to rotor excitation match with modal frequencies, particularly in defected bearing condition, instability of the structure will drastically increase.

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