Study & Analysis of Ball Bearing by using CFD

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Abstract - Bearing is an important part of a moving machine which is used for relative motion between the contact surfaces. Wear and tear of bearing is a common problem due to friction between the moving parts. A lot of researchers have done work for improving the life of the bearing. In the present work, traditionally used ball bearing has been modeled and analysed using FEM. Parameters such as Equivalent (Von-Misses) Stress, Maximum Principal Stress, Equivalent Elastic Strain, Maximum Shear Stress and Total Deformation have been found out. Analysis has also been carried for finding out the effect of material of bearing: steel, Structural Steel, Si3N4 and SiC on its performance along with elastic strain, stiffness and total deformation for various materials. It can be concluded that the Deformation and Elastic Strain induced in the SiC is less than the steel, structural steel and Si3N4 for the present investigation and the Stiffness of SiC is maximum as compared to steel, structural steel and Si3N4 hence SiC is the best material for ball bearing.

Keywords – FEA, Ball bearing, materials, Structural Steel, Friction Factor, Lubrication, Load.

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I. INTRODUCTION

Bearings are an important part of any moving machine which is used for relative motion. Due to friction between the moving parts, their wear and tear is a common problem. A lot of researchers have done work for improving the life of the bearing. Factors such as friction coefficients and side load have been worked upon. Various correlations have also been developed by many researchers which would be helpful for new design and life of bearing. Numerical analysis of bearings has also been suggested by the researchers for life prediction of bearings. In the present work, the work done by various researchers have been discussed in brief. It can be concluded that FEA can help in proper designing of bearings.

A. Classification of Bearings

- Sliding Contact Bearing: The sliding takes place along the surfaces of contact between the moving element and the fixed element. The sliding contact bearings are also known as plain bearings.
- Rolling Contact Bearing: The steel balls or rollers are interposed between the moving and fixed elements. The balls offer rolling friction at two points for each ball or roller.

B. Types of Sliding Contact Bearings

The sliding contact bearings in which the sliding action is guided in a straight line and carrying radial loads may be called slipper or guide bearings. Such types of bearings are usually found in cross-head of steam engines.

Full Journal Bearing

The sliding contact bearings in which the sliding action is along the circumference of a circle or an arc of a circle and carrying radial loads are known as journal or sleeve bearings. When the angle of contact of the bearing with the journal is 360° then the bearing is called a full journal bearing. This type of bearing is commonly used in industrial machinery to accommodate bearing loads in any radial direction.

Partial Journal Bearing

When the angle of contact of the bearing with the journal is 120° then the bearing is said to be partial journal bearing. This type of bearing has less friction than full journal bearing, but it can be used only where the load is always in one direction. The most common application of the partial journal bearings is found in rail road car axles. The full and partial journal bearings may be called as clearance bearings because the diameter of the journal is less than that of bearing.

C. Fitted Journal Bearing

When a partial journal bearing has no clearance *i.e.* the diameters of the journal and bearing are equal, then the bearing is called a fitted journal bearing.

Figure 1: Ball Bearings, Roller Bearings, Mounted Units Bearings

D. Life of a Bearing

The life of an individual ball (or roller) bearing may be defined as the number of revolutions (or hours at some given constant speed) which the bearing runs before the first evidence of fatigue develops in the material of one of the rings or any of the rolling elements. The rating life of a group of apparently identical ball or roller bearings is defined as the number of revolutions (or hours at some given constant speed) that 90 per cent of a group of bearings will complete or exceed before the first evidence of fatigue develops (i.e. only 10 per cent of a group of bearings fail due to fatigue). The term minimum life is also used to denote the rating life.

It has been found that the life which 50 percent of a group of bearings will complete or exceed is approximately 5 times the life which 90 per cent of the bearings will complete or exceed. In other words, we may say that the average life of a bearing is 5 times the rating life (or minimum life). It may be noted that the longest life of a single bearing is seldom longer than the 4 times the average life and the maximum life of a single bearing is about 30 to 50 times the minimum life.

II. LITERATURE REVIEW

Bruno R. Mose et al 2023 A 3-dimensional Abaqus model of the angular contact ball bearing (ACBB) was modeled to investigate the innocence of race thickness on the bearing performance. It was found that the ability to support higher contact stress increased with race thickness. However, large deformations were found to occur on outer race with thickness t = T1 and only small deformations were observed on outer race with t = T3. The large deformations induce higher shear stresses on thin races than on thick races. These stresses cause spall growth in bearings and propagates into a network of cracks. As a result of these ndings, thin races are prone to failure compared with thick races

S. Belabend et al2020 FEM analysis is a very efficient method for achieving results of stresses at different loading conditions according to forces and boundary conditions applied to the component the static analysis. The purpose of the study is to collect data's using two different softwares and then to compare them with analytical results. This work aims at analysing the behaviour of the ball bearings under a static load, using Solidworks, ANSYS and MESYS software. The comparison is done between the analytical results using the Hertzian theory, ANSYS and MESYS, for two different cases of loading.

Priya Tiwari et al 2019 Angular contact ball bearing can take both radial and axial loads and thus are widely used in high speed applications. Therefore, it is important to analyse the various factors that affect the bearing life and its performance. This research mainly focuses on the design and analysis of angular contact ball bearing and aims for determining the parameters affecting the performance of the angular contact ball bearing. This paper represents the literature review of the ball bearing. The bearings subjected to various working conditions are analysed using analytical and FEA stimulation method. The different parameters that affect the bearing performance and its fatigue life are investigated and discussed in this paper. This will help in optimizing the bearing performance which will give high load carrying capacity, reduce weight, improves wear resistance as well as fatigue life of the bearing.

R. Pandiyarajan et al. 2016 The large diameter bearings (diameter >400mm) are of great importance in complex engineering mechanisms such as Aircraft gas turbines, Rolling Mills and Nuclear Reactor etc, in which varying load and critical environmental conditions leads to the failure of such bearings. Majorly spalling failure occurs due to contact mechanism. The contact mechanism of ball and raceway of bearing behaves highly non-linear and it reduces the service life of component considerably. This paper presents to determine the contact stress of large diameter ball bearings using analytical and numerical methods. In analytical method the contact stress is found out using the Hertzian Elliptical Contact Theory. The calculation procedure consists of calculation of the maximum contact pressure on the rolling element, which is done by the in-house developed program, and detailed finite element analysis of the contact between the ball and the raceway. The finite element analysis also performed to predict contact pressure in ball and raceway. Comparison of the results is made at the end

Hui Xing, Qili Wu,et al. 2014 FE models for crankshaft and main bearings of a two-stroke low-speed marine diesel engine, intermediate shaft, tail shaft, intermediate bearings and sterntube bearings of a chemical carrier were established, and the results files generated from reduced FE models by employing substructure methods were entered into MBD model. Sterntube bearing forces, load distribution, orbital path, minimum oil film thickness (MOFT) and total friction power loss on for stern tube bearing and aft sterntube bearing in one working cycle under rated working conditions were investigated. Simulation results show that the sterntube bearings were safe enough for normal operation, the vertical load and the total friction power loss on aft stern tube bearing were significantly higher than that of fore sterntube bearing

Ayao E. Azianou et al. 2012 A deep groove ball bearing model is pro-posed basing on geometry specific measurement. Two approaches (finite element method and semi-analytical) have been used to determine the distribution of an external radial force applied. These two approaches have been compared in terms of computation time and precision. At the second point, a deformable complex bearing housing has been inte-grated in the FEM ball bearing model to assess the influence of its deformation on load distribution

Y.S. WANG, Q.Q. YUAN 2011, A computational model in which the clearance of bearing is first included is presented for determining the contact force distribution and static load-carrying capacity of a double row four-point contact ball bearing which is subjected to the combined radial, axial and overturning moment loadings. The relation between the negative axial clearance and the contact force distribution is analyzed. The static load-carrying capacity curves are established. The clearance values in the range of _0.2 mme0 mm have little effect on the static load-carrying capacity of bearing. With the increase in the curvature radius coefficient of raceway groove and the decrease in the initial contact angle, the static load capacity of bearing decreases

Teruie Takemasu et al. 2008 Surface rolling experiments and surface durability tests were carried out using Cr-Mo and Ni-Mo pre-alloyed sintered steels purpnin gears with different densities fabricated by powder metallurgy (P/M). The P/M gear specimens were machined from sintered packs made from the single-press single-sinter route and some were surface-rolled using a high-precision CNC form-rolling machine of two roller-dies transverse-type. A fully identified surface layer less than 2% porosity was obtained on the tooth flank approximately 0.5 mm thick when P/M pinions with a density of 7.4 Mg/m3 or more were surface-rolled using the amount of stock rolled at 0.15 mm.

Michele Cerullo 2007 Sub-surface fatigue crack growth at nonmetallic inclusions is studied in AISI 52100 bearing steel under typical rolling contact loads. A first 2D plane strain finite element analysis is carried out to compute the stress history in the inner race at a characteristic depth, where the Dang Van damage factor is highest. Subsequently the stress history is imposed as boundary conditions in a periodic unit cell model, where an alumina inclusion is embedded in a AISI 52100 matrix. Cracks are assumed to grow radially from the inclusion under cyclic loading. The growth is predicted by means of irreversible fatigue cohesive elements. Different orientations of the cracks and different matrix-inclusion bonding conditions are analyzed and compared

III. METHODLOGY

The steps involved in creating a model of the ball bearing. A model of the ball bearing is first created using UNIGRAPHICS (NX8.5) software. Then the model is imported to ANSYS 14.5 to complete static structural analysis; the finite element analysis and mechanical properties of four materials has been compared. The entire section deals with the methodology adopted for the analysis of ball bearing for comparison of stresses, elastic strain and total deformation.

The basic objective of design here is to determine the stress, strain and deformation and comparison of FEA results. In the present thesis work the design of ball bearing has been done taking dimensions from the journals and analytical method has been adopted. The results obtained from analytical method gives very close results as obtained from FEA. The model of the ball bearing has been analyzed using finite element static analysis under the boundary and loading condition. The FE analysis has been done to obtain the safe design for static loading condition.

Dimension and Modeling of Ball Bearing

In this thesis work the dimensions were taken for modeling the ball bearing from journal. Modeling of the ball bearing is done by UNIGRAPHICS (NX8.5), and analysis has been done using ANSYS 14.5. For analysis static structural solver is used in ANSYS 14.5. Modeling of ball bearing in UNIGRAPHICS (NX8.5), whose dimension is as given below, in Table.

Table 1: Dimensions of ball bearing

SN	Parameters	Values
1.	Bearing outside diameter	80mm
2.	Bearing bore diameter	40mm
3.	Ball diameter	12.3mm
4.	Raceway diameter of inner ring	53mm
5.	Raceway groove radius of outer ring	1.1mm

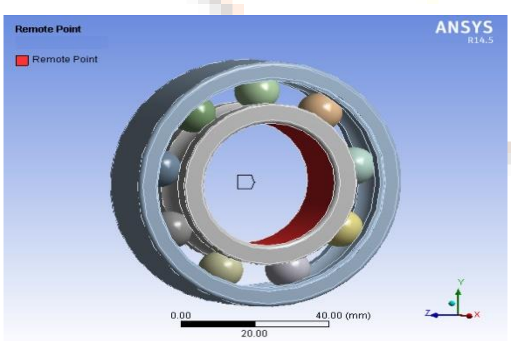

Figure 2: Model of ball bearing.

IV. RESULTS

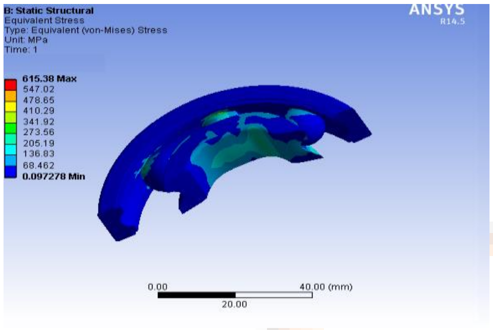

Figure 3: Von-misses stress of steel ball bearing.

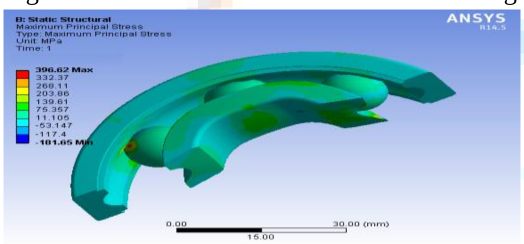

Figure 4: Principal stress of steel ball bearing.

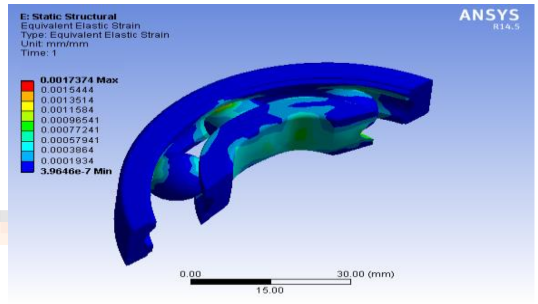

Figure 5: Elastic strain of SiCball bearing.

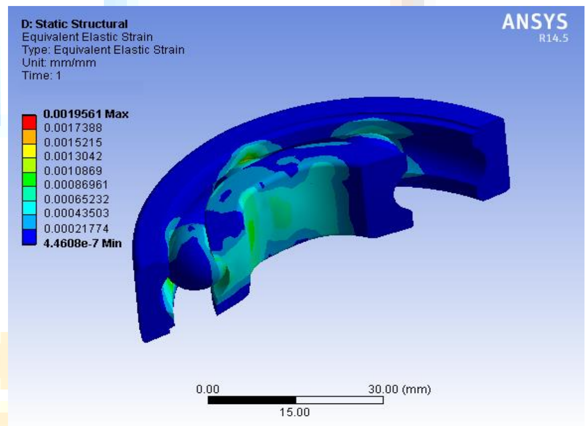

Figure 6: Elastic strain of Si_3N_4ball bearing.

Table 2: Comparison Results

Serial No.	Type	Steel	Structural steel	Si3N4
1.	Deformation	0.0246mm	0.02646mm	0.026086mm
2.	Strain	3.3989×10^{-3}	2.27297×10^{-3}	1.9561×10^{-3}
3.	Stiffness	3.792 KN/mm	36.792 KN/mm	38.734 KN/mm
4.	Weight	0.33729 kg	0.34422 kg	0.12507 kg

V. CONCLUSIONS

In this thesis work we compared the Finite element analysis of four different materials like Bearing Steel, Structural Steel, Si_3N_4 and SiC with mechanical properties results of ball bearing. In the present work, ball bearing is 3D solid modeled with UNIGRAPHICS (NX8.5) and static analysis is carried out by using ANSYS software to understand the Structural response of the ball bearing. Finite element analysis of the ball bearing has been done using FEA tool ANSYS Workbench and are tabulated in Table 2. The results from the present work are summarized as follows:

- Static analysis of materials is carried out by ANSYS and the maximum Von-misses stress is 615.38MPa, Principal stress is 396.62MPa, Shear stress is 149.08MPa and the minimum Von-misses stress is 97.278×10^{-3} MPa, Principal stress is -181.65 MPa, Shear stress is -224.7 MPa respectively for steel.
- Deformation occurs in steel (23.26%), structural steel (14.58%) and Si_3N_4 (13.36%)

ball bearing are higher as compared to the SiC ball bearing.

- Elastic Strain occurs in steel (48.58%), structural steel (23.56%) and Si_3N_4 (11.18%) ball bearing are higher as compared to the SiC ball bearing.

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