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Stress Analysis of Ball Bearings with Aluminum Alloy Based Materials using CATIA and ANSYS Software

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ABSTRACT

Rolling paper bearings are generally used to reduce friction in the rolling motion. Components include rings, folding elements and cage. A spherical bearing consists of spherical solid balls that rotate between two surfaces and reduce friction. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. Bearing design based on parameters such as bore diameter, depth, and load ratings for dynamic and static loads were considered in this work. A 3D model of the ball bearing was generated using CATIA. High pressure areas have been identified and design changes have been suggested if necessary. Bearing life is also calculated based on the rotational speed and load characteristics.

KEYWORDS- Ball bearings; CATIA software; ANSYS software:

1 INTRODUCTION

Ball bearing is a very important component of a mechanical gearbox. It supports rotating parts by hanging from the rotor and contacting the roller with the inner and outer ring. In this way the transition between force and motion can be achieved. The performance structure of the ball bearing is directly related to the reliability and safety of the entire mechanical system. Moreover, the ball bearing is also an easily damaged part. Statistical data indicates that nearly 30% of mechanical failures are caused by failure of ball bearings. As a result, the hardness, contact stress, and deformation of the spherical bearing have been the biggest problem in the study of geometry.

The difficulty in studying spherical bearings lies in the connection between rotation and the internal or external call. It is a contact point when the load is zero, while the contact point is extended to the tray to an elliptical contact surface. The paper takes an example of deep groove ball bearings and builds its 3D finite element model using commercial ANSYS Workbench software FEM (Finite Element Analysis). Based on this, the contact stress and deformation are analyzed and calculated, which provides the basis for the design and optimization of deep groove ball bearings.

The Finite Components Strategy is a useful asset for obtaining numerical rankings for a wide range of design issues. This technique is common enough to handle any amazing shape or geometry, for any material under various constraints and stacking conditions. A comprehensive interpretation of finite component technology suits the pre-screening requirements of today's complex building frameworks and structures where closed structural arrangements are usually not accessible to manage equilibrium conditions. It is also an effective planning device by which fashion enthusiasts can implement modular structures by looking at the states of different plans (different shapes, materials, loads, etc.) and analyzing them to choose the ideal plan.

The strategy began in the aviation industry as a tool for examining concerns in a complex airframe. This comes from the so-called mesh scanning technology used in the airframe. This technology has increased its wide presence among analysts and professionals. The main idea of the finite component technique is that an object or structure can be isolated into small components of finite measurements called "finite components". The first body or structure is then seen as a collection of these components linked by a limited number of joints called axes or nodes.

Hertz's theory is generally used to calculate the contact pressure and radial stiffness of spherical roller bearings. The limitations of Hertz's theory are reproduced in the fact that it can only consider a small part of the contact surface of spherical bearings and cannot include the total structural deformation of the ball, the outer ring and the inner ring also as housing, this limits the engineering calculations when considering the overall structure of the aforementioned deformation. The finite element method remains very practical for structural analysis and gives convincing results in many types of engineering calculations. The contact condition between rollers and rings is complex and using FEM analysis is a sensitive task. These connection problems are very difficult. First, before solving the problem, the specific contact area is not recognized. With change in load, material, boundary condition, or other external factors, contact or separation of surfaces occurs. When the load is 0, the contact area is reduced to a point, that is, the contact point. With the increase of the load during operation, the inner ring of the bearing, the outer ring and the rolling elements will cause deformation in the contact area so that the contact point becomes a surface contact. Besides, the contact area gradually becomes elliptical and generates residual stress.

They thought about the static behavior and life of the metal balls. The default cause of deformation, hardness, material edge change, and head life appeared with soft material. In light of this, a nonlinear numerical model was established to investigate the static behavior of metal rollers. Ensuring the lifetime of the metal roller determined by intersecting the area intersecting the static behavior from the results, it is assumed that the scientific model palatably depicts the static behavior of the metal spheres from the purpose of deformation and hardening.

The researchers investigated the moving contact hypothesis to establish an unambiguous connection between movements and cooperation within metal spheres. The wet blanket lifetime and turn ratio were detailed to characterize the relative non-twisting motion between the bell and the inner/outer race track. A quasi-case survey model was developed to report the movement of the balls and the races of the metal roller which also gave them the characteristic of depicting the rotation of the slide and the foot within the contact area.

2 THEORETICAL ANALYSIS OF BALL BEARING STATIC BEHAVIOUR

In the elastic region, it is possible to calculate the contact stress and the resulting deformation at the contact points of the rolling elements and orbitals by means of Hertz's theory, with respect to the contact of elastic bodies of size.

3 LITERATURE REVIEW

Nabhan et al. (2016), The main objective of this article is to determine the effect of external race factor for ball bearings (SKF 6004) using experimental and numerical methods. The 3D finite element model of the shell and outer vein was simulated using the commercial ABAQUS/CAE package. Experimental results are obtained using rail cars to verify the simulated results. A good agreement was found between the results of the finite element model and the experimental results. **Vimal Kumar Pal et.al, (2017),** The parallel shaft is the main part of the machine and it carries a specific capacity for a given load, which prevents misalignment errors in the compaction of any other asset. A parallel shaft reduces friction and supports rotational, axial and radial loads that cause friction, increase temperature and vibration in the bearings. If the generated heat and vibration cannot be properly removed from the indoor ventilation, the temperature may exceed a certain limit. I designed and analyzed the system using the popular finite element tool ANSYS Workbench 14.0. **Maro et al. (2017)** In an elastic lubrication system that occurs in toroidal bearings, very high contact pressures deform the surface, resulting in small elliptical contact areas. The frequent formation of broken connections eventually leads to local fatigue. It is known that spalling is a common failure mode that occurs in oil bath lubricated roller bearings. The development of elastic wear zones is susceptible to the presence of material defects near the surface surface, and the presence of solid particles at the interface, among other factors.

Navdeep minhas et.al (2018), Rolling element bearings are important parts of a shaft system. Failure to do so can lead to dire consequences. To reduce the possibility of vulnerability, the researchers studied the trans-dynamic behavior of the mating bodies for structural and vibrational analysis. Various techniques have been used and appropriate literature is available for different situations. In this review, several conveyor rotary structures with different load and failure conditions are summarized. In addition, different methods and techniques have increased the prediction of early failure. These appear to be promising tools for realizing the uniform dynamic behavior of the spindle shaft system. **Mohsen Mosleh et al. (2018)** the rolling contact stress (RCF) life of rolling materials can be determined through full-scale stress tests. These tests performed on health testing machines are expensive and time consuming. Over the past few decades, simple and quick life test devices such as drum-on-roll or ring testers, three-ball-on-rod setup, reel-on-flat apparatus, V-groove ball testers, four. One ball tester, and five ball testers were used in the RCF study of different parts of rolling bearings. However, none of the RCF testers could reproduce the complex kinetics and contact conditions encountered in a full-scale device. Moreover, the lifetime performance of the RCF obtained from these testers at the lifetime of the real symptomatic application needs further validation. Four ball testers are widely used in two types of tribological tests using ball elements. In the first type, the lower three balls are fixed and the movement is a sliding motion between the upper ball resting on the three fixed balls.

Makoto Nishimura (2020), lubricated solid ball bearings have been successfully used in space drive systems such as solar array drive assemblies or antenna drive systems. Undoubtedly, proper lubrication techniques have been developed without heavy bearings such as those found, for example, in the shoulder joint of the space station's rigging arm. Their business area has now expanded to the vacuum industry, including large-scale integrated circuit (IC) and integrated circuit (LSI) production. Rock Potoknik et al. (2021), the exception is the rotational speed, which is usually low and does not cause a high centrifugal force. However, the operating conditions of these bearings are very different from those of standard thrust or radial rolling bearings, which means that their load capacity cannot be determined with sufficient accuracy using the above criteria. Therefore, more advanced methods need to be developed for such systems, which is becoming more evident with the recent increase in research and production of wind turbines. In the professional literature, there are not many books that specifically address the load distribution and/or capacity of slewing bearings.

4 FINITE ELEMENT METHOD

The finite element method is a useful asset for obtaining the numerical order of a wide range of design problem. This technique is general enough to handle any mind-boggling shape or geometry, of any material under various stacking conditions and constraints. The comprehensive statement of finite component technology fits the pre-screening requirements of today's complex building frameworks and structures where closed structure arrangements are not accessible to manage equilibrium conditions. Likewise, it is an effective plan device with which designers can perform parametric structure visualizations by looking at different plan states (different shapes, materials, loads, etc.) and dissecting them to choose the optimal plan.

The strategy began in the aircraft industry as a device for studying anxiety in complex airframe structures. It becomes what is known as the mesh probe technology used in the airframe. This technology has increased its popularity among analysts and professionals. The basic idea of finite component technology is that an object or structure can be isolated into small components of finite measurements called "finite components". The first body, or structure, is then seen as a collection of these components linked by a limited number of joints called axes or nodal points.

5 MODELLING

Table 1 Concrete parameters of deep groove ball bearing (61915)

External diameter	**Inner diameter**	**Roller diameter**	**Roller number**	**Rotational speed**	**Poisson ratio**
(mm)	**(mm)**	**(mm)**	**(mm)**	**(rad/s)**	
105	**75**	**8.734**	**18**	**1440**	**0.3**

6 CONSTRAINTS AND LOAD APPLIED

The motor body is subjected to axial and tangential stresses. And only radial elastic deformation is allowed to prevent the use of the body in mechanical studies. Heavy objects including inertia and inertial weight Inertia weight includes gravity and the speed of rotation. Inertial load is radial load. Therefore, both low gravity and the inner ring are used, and current is used to rotate the inner ring and the steel at the same speed. Now use the lower half of the bottom inner ring to measure the weight of the shaft coming off the shaft.

Finite Element Simulation

By modeling the elements, the coordinate and distribution of contact stresses and strains are determined. The shape and size of the inner and outer races are as well as the contact area.

Model

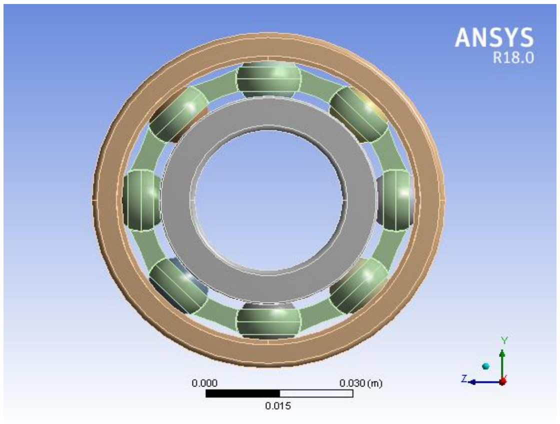

Figure 1 Model

Meshing

The mesh structure is the subdivision of the mathematical model that has a simple geometric shape, and does not overlap, called a finite element. The response for each finite element simulation is expressed in a finite number of degrees of freedom that represent the values of the unknown function (motion function) at various crucial points. Thus, the mathematical model will result in an approximation of the answer obtained by assembling a discrete model with all the other elements of the model. Mesh optimization was performed in order to obtain a continuous mesh and a correlation between the number of finite elements and the number of associated nodes. Choosing a simple type, here we use “Tetrahedrons”, will result in a top quality mesh with 29716 nodes and 85422 elements in view of the structure and complexity,

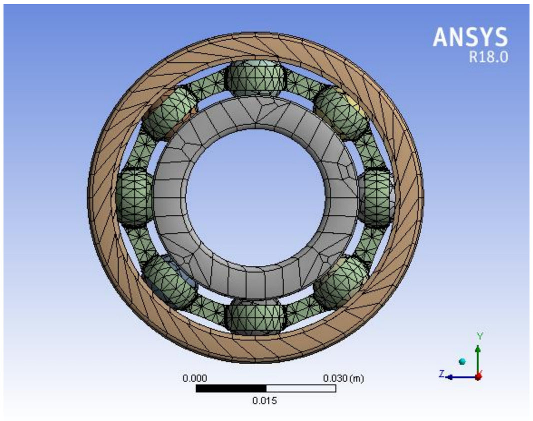

Figure 2 Mesh

7 RESULTS AND DISCUSSION

Force

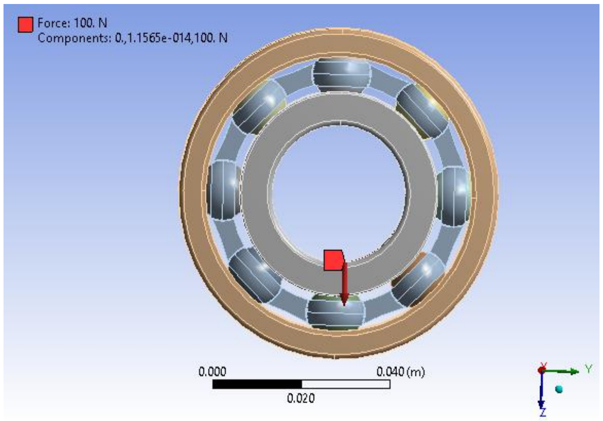

Figure 3 Bearing with applied Load of 100 N

Force 2

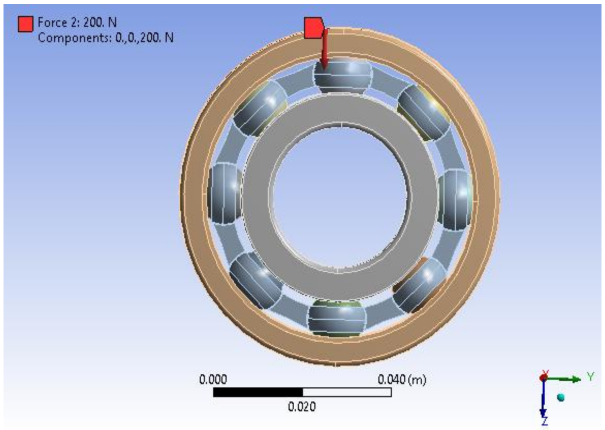

Figure 4 Bearing with applied Load of 200 N

Transient

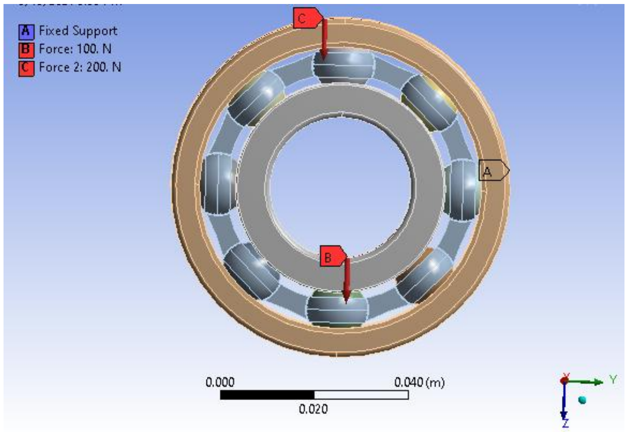

Figure 5 Bearing with applied Load of 100N and 200 N

Aluminum Alloy

Total Deformation

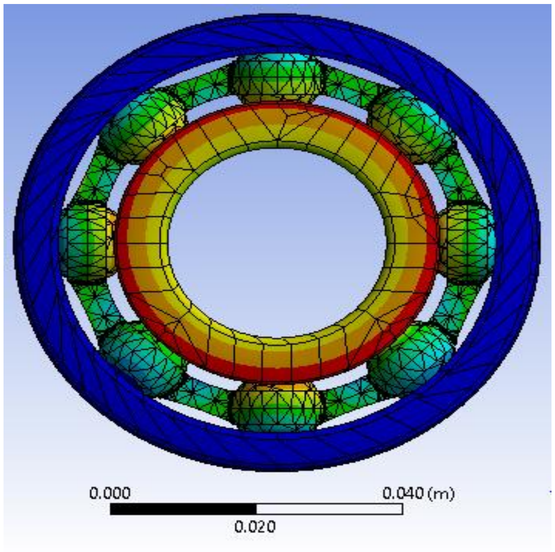

Figure 6 Total Deformation

Maximum Principal Elastic Strain

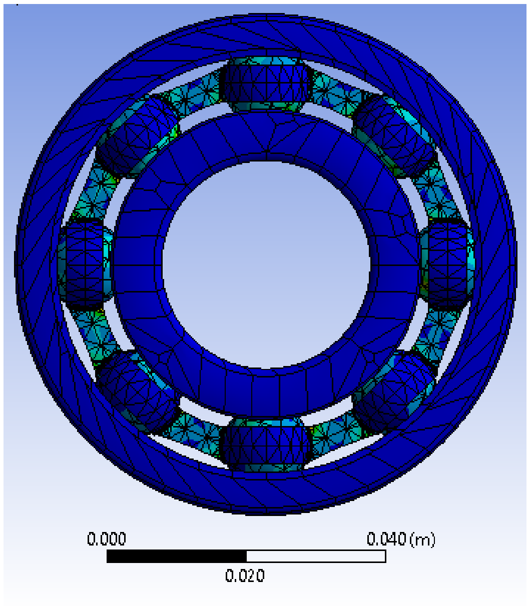

Figure 7 Maximum Principal Elastic Strain

Maximum Principal Stress

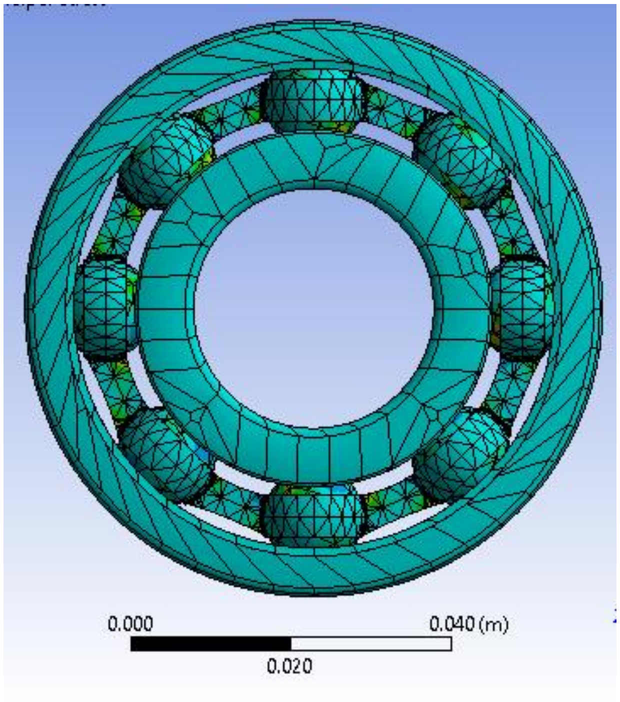

Figure 8 Maximum Principal Stress

Maximum Shear Elastic Strain

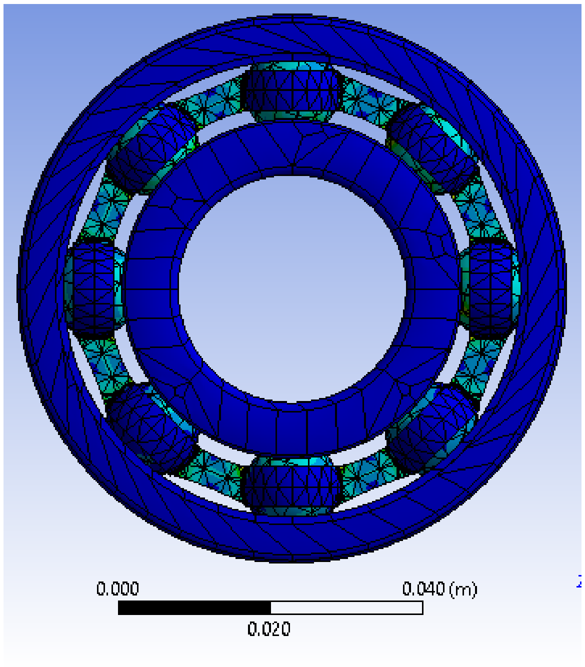

Figure 9 Maximum Shear Elastic Strain

Maximum Shear Stress

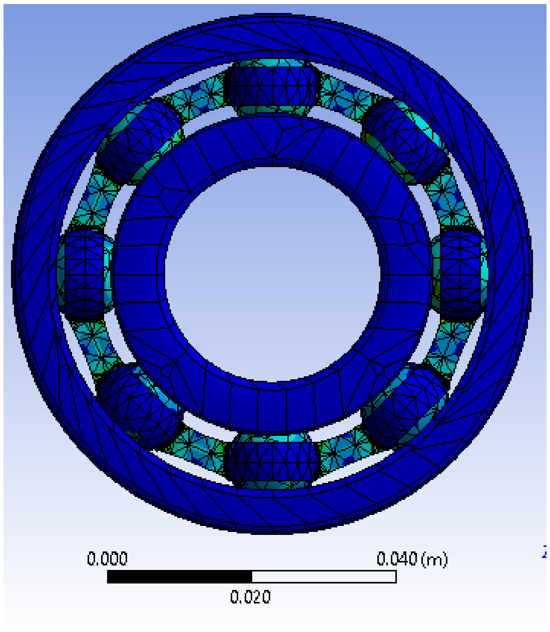

Figure 10 Maximum Shear Stress

Maximum Principal Elastic Strain

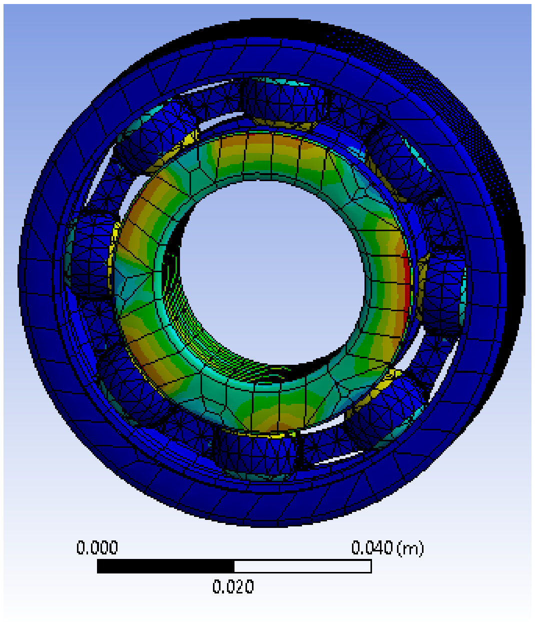

Figure 11 Maximum Principal Elastic Strain

8 CONCLUSIONS

This work aims to analyze the behavior of ball bearings under static load using CATIA and ANSYS software. Displacement is higher in the inner ring for radial and axial load application and stresses are higher in the outer ring for radial loads within limits. Compared to the radial load, the axial load causes more stress. Bearing life is also calculated on the basis of axial and radial load. The results and data obtained from this study can be used to improve the properties and geometry of bearings for next-generation products. The contact stress and deformation of the 61951 deep groove ball bearing are calculated and analyzed using the applied load by a simulation approach using aluminum alloy material, where the work focuses on the size, location and distribution of the maximum contact stress.

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