Int. J. Mech. Eng. & Rob. Res. 2013

International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 2, No. 3, July 2013

Research Paper

DEFECT ANALYSIS OF BEARING OF WAGON TIPPLER BY VIBRATION USING CAE BASED METHODOLOGY

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This study examines the dynamic behavior of the roller bearing used in wagon tippler. In this work various mode shapes and their frequencies accordingly has been investigated for the bearing without any wear, i.e., notch, scratch, cut, roughness. Then after, bearing with a definite defect of particular geometry has been created and various modes and frequency of that bearing has been calculated. A comparative study is also presented between both of the cases. A bearing is the most important element of any machine or equipment and various types of failures may be occurring in the same and wear and tear is one of them. Hence, this study will be useful to investigate the behaviour of bearing after locating a defect and this study also provide the safety features against the catastrophic failures of bearings. This work has been accomplished with FEM methodology and Ansys tool.

Keywords: Bearing, Dynamic analysis, Finite element model, Natural frequency, Mode shapes

INTRODUCTION

The Wagon tippler designed for unloading broad-gauge open railway by inverting the wagon by inverting on its own center of gravity through an angle of 140° to 160°, thereby discharging its contents into hopper below rail. The tippler is designed to handle wagons having a gross load up to 32 tons. The tippler ensures handling of wagons, without any damage.

The tippler consists of following components such as cradle, end rings, side beam, top clamp assembly, bearing, gearbox and drive unit. The tippler is driven by a drive unit located on one side of the tippler. The drive unit consists motor – with flexible coupling, thruster operated brake, bearing, helical gear box, pinion a toothed rings (Figure 1).

A rolling-element bearing, also known as a rolling bearing is a bearing which carries a load

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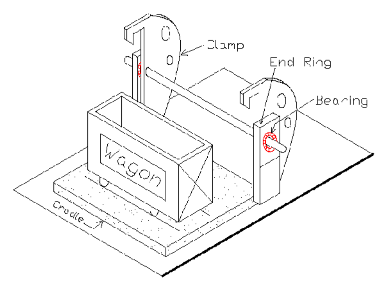
Figure 1: Schematic of Wagon Tippler



by placing round elements between two bearing rings. The relative motion of the pieces causes the round elements to roll with very little rolling resistance and with little sliding.

A rolling element rotary bearing uses a shaft in a much larger hole, and cylinders called “rollers” tightly fill the space between the shaft and hole. As the shaft turns, each roller acts as the logs. However, since the bearing is round, the rollers never fall out from under the load.

Rolling-element bearings have the advantage of a good trade-off between cost, size, weight, carrying capacity, durability, accuracy, friction, and so on.

A particularly common kind of rolling-element bearing is the ball bearing. The bearing has inner and outer races between which balls roll. Each race features a groove usually shaped so the ball fits slightly loose. Thus, in principle, the ball contacts each race across a very narrow area. However, a load on an infinitely small point would cause infinitely high contact pressure. In practice, the ball deforms (flattens) slightly where it contacts each race much as a tire flattens where it contacts the road. The race also yields slightly where each ball presses against it. Thus, the contact between ball and race is of finite size and has finite pressure. Note also that the deformed ball and race do not roll entirely smoothly because different parts of the ball are moving at different speeds as it rolls. Thus, there are opposing forces and sliding motions at each ball/race contact. Overall, these cause bearing drag.

Most rolling-element bearings feature cages. The cages reduce friction, wear, and bind by preventing the elements from rubbing against each other.

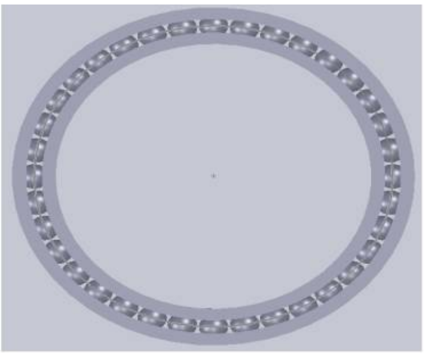
A prematurely failed rear bearing cone from a mountain bicycle, caused by a combination of pitting due to wet conditions, improper lubrication and fatigue from frequent shock loading. Rolling-element bearings often work well in non-ideal conditions, but sometimes minor problems cause bearings to fail quickly and mysteriously. For example, with a stationary (non-rotating) load, small vibrations can gradually press out the lubricant between the races and rollers or balls (false brinelling). Without lubricant the bearing fails, even though it is not rotating and thus is apparently not being used. For these sorts of reasons, much of bearing design is about failure analysis. Vibration based analysis can be used for fault identification of bearings.

Although there are many other apparent causes of bearing failure, most can be reduced to these three. For example, a bearing which is run dry of lubricant fails not because it is “without lubricant”, but because lack of lubrication leads to fatigue and welding, and the resulting wear debris can cause abrasion.

In rolling contact bearings, the contact between the bearing surfaces is rolling instead of sliding as in sliding contact bearings. The ordinary sliding bearing starts from rest with practically metal-to-metal contact and has a high coefficient of friction. It is an outstanding advantage of a rolling contact bearing over a sliding bearing that it has a low starting friction. Due to this low friction offered by rolling contact bearings, these are called antifriction bearings.

The main and foremost part of the engine is a roller bearing which is used to propel the tippler ahead which must be able to accomplish all the design requirements whether structural or vibration. The roller bearing which we are going to accommodate here is situated in the shaft of wagon tippler as shown in Figure 2.

Figure 2: Geometric Model of Roller bearing



This model is being modelled in considering all the designing parameters of the roller bearing.

Presently, the rotor-bearing systems utilized for modelling rotating machinery and their mounting structures, for example, electric motors, turbo machinery, transmission shafts, propellers, etc., are commonly analyzed by the finite element method. Computations of natural frequencies, mode shapes, critical speeds, steady state responses, and transient responses play important roles in the design, identification, diagnosis, control of rotor-bearing systems. Thus, an accurate prediction for the dynamic characteristics of a rotor-bearing system using FEM is essential for modern equipment.

LITERATURE REVIEW

Rolling element bearing faults are among the main causes of breakdown in rotating machines. In this paper, a rolling bearing fault model is proposed based on the dynamic load analysis of a rotor-bearing system. The rotor impact factor is taken into consideration in the rolling bearing fault signal model. The defect load on the surface of the bearing is divided into two parts, the alternate load and the determinate load. The vibration response of the proposed fault signal model is investigated and the fault signal calculating equation is derived through dynamic and kinematic analysis. Outer race and inner race fault simulations are realized in the paper. The simulation process includes consideration of several parameters, such as the gravity of the rotor-bearing system, the imbalance of the rotor, and the location of the defect on the surface. The simulation results show that different amplitude contributions of the alternate load and determinate load will cause different envelope spectrum expressions. The rotating frequency sidebands will occur in the envelope spectrum in addition to the fault characteristic frequency. This appearance of sidebands will increase the difficulty of fault recognition in intelligent fault diagnosis. The experiments given in the paper have successfully verified the proposed signal model simulation results. The test rig design of the rotor bearing system simulated several operating conditions: (1) rotor bearing only; (2) rotor bearing with loader added; (3) rotor bearing with loader and rotor disk; and (4) bearing fault simulation without rotor influence. The results of the experiments have verified that the proposed rolling bearing signal model is important to the rolling bearing fault diagnosis of rotor-bearing systems (Cong F *et al.,* 2013).

Rolling element bearings are the key components in many rotating machinery. For efficient performance of the machine it is necessary to accurately predict the effect of various parameters and operating conditions on the machine's behavior. This paper deals with the development of a nonlinear model of the rotor-bearing system on rolling element bearings with clearance. Clearance is an important nonlinearity which can cause bifurcations and chaos as has been shown in this paper. In this paper a detailed model for clearance is developed. In this model the inner race centre and the outer race center are not assumed to be collinear when relations for deflections in the rolling element are developed. The model is non-dimensionalized and then analyzed to reveal rich nonlinear phenomena. Further, for better performance of any machine it is necessary to identify and stay out of chaotic regimes of operation. Hence, Lyapunov exponents and Poincare mappings are used to analyze the system and determine the regions of chaotic response. (Kappaganthu K and Nataraj, 2011).

An analytical model to predict non-linear dynamic responses in a rotor bearing system due to surface waviness has been developed. In the analytical formulation the contacts between the rolling elements and the races are considered as non-linear springs, whose stiffness are obtained by using Hertzian elastic contact deformation theory. The governing differential equations of motion are obtained by using Lagrange's equations. The implicit type numerical integration technique Newmark-β with Newton-Raphson method is used to solve the non-linear differential equations iteratively. A computer program is developed to simulate surface waviness of the components. Results presented in the form of fast Fourier transformation with agreement of various author's experimental researches. (Harsha *et al.,* 2004).

This article presents an overview of fundamentals of rolling element bearing designs and technologies. The aim is to outline the complex interrelation of all fundamentals with the rolling contact fatigue and the attainable bearing life. Such fundamentals include, amongst others, bearing stressing and life capability. The article shows the different types of rolling bearing stressing and the analysis of the stress distribution (principal stresses and equivalent stresses) in the material under the rolling contact area. It becomes obvious that the contamination of the bearing with foreign particles leads to a drastic reduction in bearing life. Furthermore, it demonstrates the impact of the bearing lubrication and coating as well as the effect of additives on the attainable life and wear. Further fundamentals of rolling element bearing design are the materials, the material cleanliness and the heat treatment. The article reveals the importance of the cleanliness of bearing steels as well as different types of inclusions and their effect on rolling contact fatigue. Additionally the article describes how to optimize the material properties (strength, toughness and residual stress) by the heat treatment processes. The outcome of these investigations is that endurance life of a rolling element bearing can be achieved if specific operating conditions, an adequate lubrication, good system cleanliness and specific bearing stressing are met. The article provides a guideline for bearing engineers on how designs and technologies can be applied to optimizing a bearing for a particular industry. (Ebert, 2007)

METHODOLOGY

The complex spatial nature of roller bearing makes the solid element approach an attractive one for determining their coupled flexural, torsional and longitudinal vibration modes. This study models bearing by using a tetrahedron elements for dynamic testing (Figure 3). For preparing the results of dynamic analysis, a rolling element bearing is used. The model of the roller bearing has been modelled in Solidworks 10.0 with suitable dimensions then after dynamic analysis has been performed at the platform of ANSYS 14.0. The result has been drawn from various modes of roller bearing under dynamic analysis.

COMPUTATIONAL DYNAMIC ANALYSIS AND RESULTS

Here we have carried out the dynamic analysis for the natural frequency of the roller bearing using the block lanczos method in Ansys workbench platform. The mode shapes and respective values of deformation of bearing are represented in below mentioned figure and value of the natural frequency of respective mode shapes and max displacement of roller

Figure 3: Meshed Model of Bearing

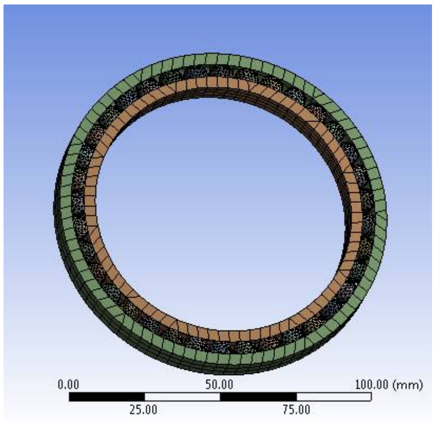


Figure 4: First Mode Shape of Bearing

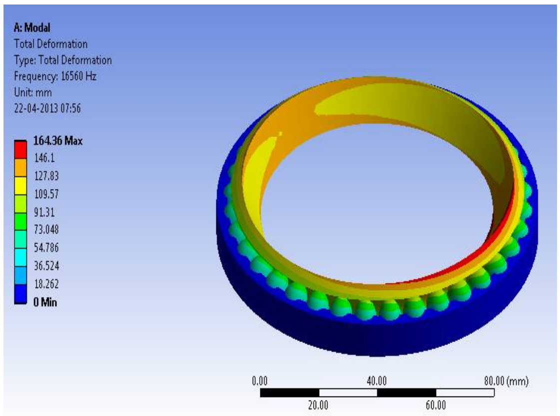


Figure 5: Second Mode Shape of Bearing

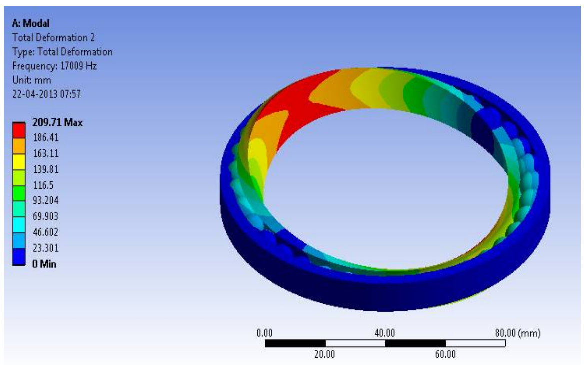


Figure 6: Third Mode Shape of Bearing

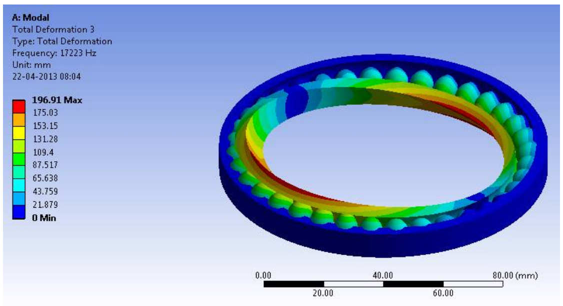


Figure 7: Fourth Mode Shape of Bearing

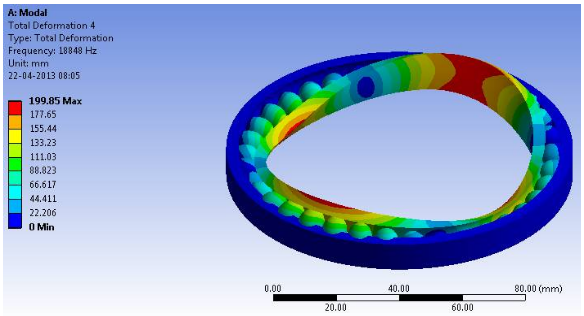


Figure 8: Fifth Mode Shape of Bearing

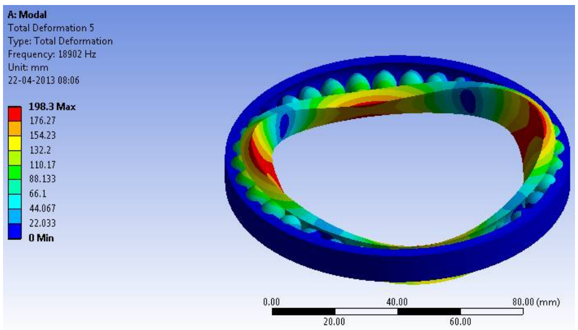


Table 1: Results for Bearing

Mode	Frequency	Displacement (max)
1	16560	164.36
2	17009	209.71
3	17223	196.91
4	18848	199.85
5	18902	198.3

bearing without defect and with defect (notch) have been tabulated as Table 1 as follows:

CONCLUSION

This study entails the dynamic behaviour of the roller bearing under the different respective mode shapes. The first case is of about the dynamic analysis of bearing without any defect for the modal analysis and the frequencies of various mode shapes are 16560, 17009, 17223, 18848, and 18902, respectively.

The study clearly shows as conclusion that if any defect occurs in the bearing, the range of frequencies is increased so that dynamic behavior of roller bearing has been quite different in respect of vibration.

Hence, with the help of this work, investigation of the behaviour of bearing after locating a defect is analyzed as vibration so that we can put the attention for the safety features as well as design features of the bearing and selection of material of bearing. Finally, this study is also useful to provide the safety features against the catastrophic failures of bearings as comparison with the size of defect of bearing in practical real ground because by comparison of defect size and nature with real defect of bearing, we can analysis the vibration parameter of bearing for the real practical ground and safety features may be considered for the bearing accordingly.

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