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Analysis of Rolling Contact Bearing Using FEM

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ABSTRACT

The rolling bearings dynamically behavioural analysis is a critical condition to determine the machine vibration response .The rolling bearing, with outer ring fixed, is a multi body mechanical system with rolling elements that transmit motion and load from the inner raceway to the outer raceway. In rolling bearing analytical formulation, the contact between rolling element and raceways is considered as nonlinear springs and their stiffing are obtained using hertzian elastic contact deformation theory .The contact model among the rolling element and raceways will be determined due to the great important in the vibration pattern analysis. To evaluate the suitability and compatibility among analytical and simulation models, the results from simulation will be applied to inner motion equation of analytical model to obtain a valuable error signal. In this, the simulation of kinematics, dynamic and behaviours of rolling bearings and their vibration response without faults will be presented, a analytical model using finite element model.

Keywords— Rolling bearings, vibration response, elements of mechanical system, simulation, finite element model.

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I. INTRODUCTION

Ball and Roller bearings, generally called rolling bearings, are commonly used machine elements. Even the geometry might look simple the physical effects to be regarded in a nonlinear Finite Element analysis are quite complex. Modeling the complete geometry would lead into impractical model sizes. Different ideas to idealize roller bearings with analogous models exist. The term “rolling bearing” includes all forms of roller and ball bearing which permit rotary motion of a shaft. Normally a whole unit of bearing is sold in the market, which includes inner ring, outer ring, rolling element (balls or rollers) and the cage which separates the rolling element from each other. Rolling bearings are high precision, low cost but commonly used in all kinds of rotary machine.

Bearing is used is that first it can transfer moment or force. Secondly and may be more important is that it can be interchanged easily and conveniently when it’s broken. It is also possible to amount the shaft directly with housing. However, when this mechanism has some problem, the only possibility to recover the function of this system is to replace the housing or the shaft. From the mechanical engineer point of view, both of them are not only very expensive but also time consuming to manufacture a new housing or shaft with the same parameters.Most rolling bearings consist of rings with raceway (inner ring and outer ring), rolling elements (either balls or rollers) and cage. The cage separates the rolling elements at regular intervals, holds them in place within the inner and outer raceways, and allows them to rotate freely. Rolling elements classify in two types: balls and rollers. Rollers come in four types:

cylindrical, needle, tapered, and spherical. Balls geometrically contact with the raceway surfaces of the inner and outer rings at "points", while the contact surface of rollers is a "line" contact. Theoretically, rolling bearings are so constructed as to allow the rolling elements to rotate while also rotating on their own axes at the same time.

A Bearing failures modes:-When a bearing is properly designed, manufactured, installed, and maintained, then the natural cause of bearing failure is typically the fatigue life of its rolling elements and races. The environment within which the bearing operates also determines the bearing life. The contact stresses developed in the rolling elements and races of a typical bearing is cyclic in nature. This in turn will result in a potential fatigue failure for these elements. The fatigue life a bearing is influenced by the operating speed, load conditions, bearing material, clearance of the mating parts, contact surface geometry, and the environment in which the bearing operates.

The fatigue failure modes, mentioned above, could be categorized according the following list:

1. Rolling element surface fatigue
2. Common wears of the interacting surfaces (races and rollers) 3. Cross-sectional cracking and fretting. The cross-sectional cracking and fretting could be caused by unusual and/or abnormal operating conditions that were not considered during the bearing design. Excessive “hoop-stresses”, caused by centrifugal forces, could lead to race-way fractures.

Differential gears in an automobile's drive-train allow the driving wheels to transmit torque, or twisting force, at different turning rates. Thus one wheel can follow the longer arc around the outside of a turn while the other wheel tracks the shorter inside arc without skidding on the road surface. In a front-engine, rear-drive car, engine torque flows through the transmission and drive shaft to turn the ring-and-pinion gears inside the rear-axle assembly, powering the rear driving wheels. In a front-engine, front-drive car, the differential and final drive gears are in the same housing with the transmission, mounted directly on the engine. In both design, the drive gears work through differential gears to turn the axle and the driving wheels.The drive shaft ends in a pinion gear inside the differential. When the drive shaft turns, the pinion drives a ring gear that is part of the differential housing, so that both housing and ring gear rotate together. Inside the housing are two pinion gears and two side gears; each side gear is connected, via an axle, to a drive wheel. When the car drives straight ahead and the axle shafts turn at the same speed, the differential housing rotates, but no differential action occurs. When the car negotiates a turn, however, the differential must compensate for the difference in distance traveled by the drive wheels. The opinions roll around the side gears, allowing the inside wheel to turn more slowly and the outside wheel to turn more slowly and the outside wheel to turn faster.Free-turning gears divide torque equally between the driven wheels. If one drive wheel is on dry pavement and the other on ice, the gears roll around inside the housing to spin the slipping wheel at twice the ring gear's speed. Each drive wheel gets the same slight amount of torque required to spin the slipping wheel; the car does not move at all. Some cars have locking, or limited-slip, differentials to reduce wheel spin by transferring some torque to the wheel with better traction.

B Objectives:

1. System design and analytical calculation of contact stresses.
2. To determine the strains developed in bearings.
3. Comparison between hertzian theory and ansys simulations.
   The following features of the bearing system will lead to application of bearing in variety of field applications:

To provide a relatively uniform contact stress distribution along the length of a roller by reducing the contact stiffness of the roller in the radial direction of the rollers transverse cross-section. Reduced roller stiffness at its ends in the radial direction. Reduce the mass of a bearing, reducing the inertia effects acting on the outer raceway, which directly improves overall bearing life span.

C. Software:

CATIA V5R20

CATIA provides a suite of surfacing, reverse engineering, and visualization solutions to create, modify, and validate complex innovative shapes, from subdivision, styling, and Class A surfaces to mechanical functional surfaces.

CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and molded, forged or tooling parts up to the definition of mechanical assemblies. It provides tools to complete product definition, including functional tolerances as well as kinematics definition

ANSYS 14.5

ANSYS Workbench

ANSYS Work bench can be thought of as a software platform or framework where you perform your analysis (Finite Element Analysis) activities. In other words, workbench allows you to organize all your related analysis files and databases under same frame work. Among other things, this means that you can use the same material property set for all your analyses. Some of the applications that fit into the workbench framework are:

1. Design modeler
2. Mechanical (simulation)
3. Design Explorer
4. AUTODYN
5. CFX Mesh
6. FE Modeler

The ANSYS Workbench platform allows users to create new, faster processes and to efficiently interact with other tools like CAD systems. In this platform working on Multiphysics simulation is easy. Those performing a structural simulation use a graphical interface (called the ANSYS Workbench Mechanical application) that employs a tree-like navigation structure to define all parts of their simulation: geometry, connections, mesh, loads, boundary conditions and results. By using ANSYS workbench the user can save time in many of the tasks performed during simulation. The bidirectional links with all major CAD systems offer a very efficient way to update CAD geometries along with the design parameters.

II. LITERATURE REVIEW:

A. Dynamic analysis of rolling bearing system using Lagrangian model Vs. FEM code.H Rubio, university Carlos iii Madrid Spain.

It has been a common practice for many decades to utilize roller bearing elements in machinery in order to evenly distribute the bearing load across the line contact between the rollers and race-ways. However, designing a bearing such that a uniform contact stress distribution is resulted along the contact lines of a roller bearing is highly unrealistic. This difficulty stems from the fact that the two ends of a typical roller act as stress-concentration zones, causing the contact stresses to have spikes at the roller end points. The conventional method of rectifying this undesirable condition is to modify the geometric configuration of the ends of the roller in a way that a sharp or abrupt transition from the contact line to the cross-section of the roller is avoided. This geometric modification is called "crowning" of the roller. Contrasts between an unmodified and a crowned roller respectively, with their corresponding contact stress distributions.A substantial amount of research work has been done to study structural integrity and behavior of cylindrical rolling elements, which have been crucial parts of a typical bearing from contact stress point of view. Many researchers and designers have developed various analytical, numerical, and experimental techniques in order to predict and improve contact stress distributions along the contact line of rolling element bearings. For, example Dareing and Zimovsly proposed analytical techniques in order to computationally predict the contact stress distribution along the contact line of a rolling element that is not crowed. Hardnett, Kannel, and Heydave and Goohar included nonlinear behavior of the contacting surfaces under stress and came up with an analytical solution to better predict the stress distribution at the contact line. With the advent of various advanced FEA codes, and fast computational hardware, the inherent difficulties of solving nonlinear FEA problem have been addressed and resolve to a great extent.The rolling bearing dynamic behavior analysis is critical condition to determine the machine vibration response. The rolling bearing with outer ring fixed is multibody mechanical system with the rolling elements that transmits motion and load from the inner raceway to the outer raceway.

B. **Contact analysis of deep groove ball bearing based on Ansys.**

Deep groove ball bearing is simply and is widely used. Its main failure mode is contact fatigue spalling of elements. The contact finite elements analysis can show bearings information under contact such as contact stresses, strains penetration and sliding distance, and so on, which play a significant role in optimum design of complicated rolling bearings.Contact is a complex nonlinear phenomenon, which involves not only change in state, but also accompanies with heat or electricity. Contact problem mainly includes two considerable difficulties at present. Firstly, before solving problems the specific contact area isn't usually been known. With the change of load, material, boundary conditions or the other factors, touch or separation will take place between surfaces. That is hard to predict even in an abrupt change. Secondly most frictional effects on contact problems are needed to be considered, they may be disordered or nonlinear.After this calculation, ansys simulation is done. Ansys gives good blue print for contact analysis which can take friction heat and electrical contact in account.it also has special contact guide which is conveniently for creating contact pairs.When ball bearing works, it is usually that more than one rolling ball bears the load. The condition is complex between rollers and rings. When the load is 0 the contact area is a point, i.e. Point-contact. When load increases in running, the bearing inner ring and rolling elements bring forth plastic deformation in contact area,so the point-contact becomes face-contact. Furthermore, the contact area gradually becomes ellipse, and generates residual stress. The contact parameters, such as the place, size, shape of contact area as well as the contact pressure and friction force distribution, will be variable with loads change. These are typical boundary nonlinear problems.In contact problem involved two boundaries, it is natural that take one boundary as target surface and take the other one as contact surface. Surface-surface contact is Very suitable for those problems. ANSYS support surface contact elements of rigid-flexible contact. The elements form contact pairs by using target and contact surface. For rigid flexible contact it can be chosen as contact surface such as convex surface, dense meshing or little size surface.

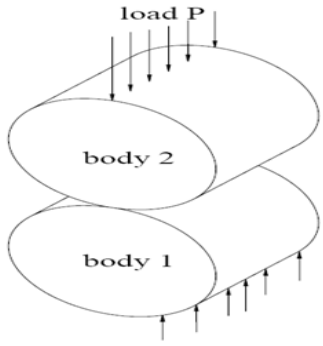
III. METHODOLOGY

1. Literature review. Study of various bearing handbooks, United State Patent documents, Technical papers, etc. 2. Development of theory.

A) System Design : This part includes the design and development for bearing system as per the theoretical derivations to produce the desired output
B) Simulation Design: This part includes the design and development of bearing system , selection of material of bearing , strength analysis of various components under the given system of forces.

A. Hertz Formulation for Line-Contact Conformity:

Figure shows two cylindrical bodies with their longitudinal axes parallel. The cylinders are pressed by a force of p per unit length as shown in Figure. The contact area between the two bodies is a rectangle of width 2a having a length equal to that of the cylinders.



B. Contact stress behavior at the boundaries of cylinders pressed together:

The contact stress at the end points of two cylinders pressed together exhibits stress concentration

behavior. In order to avoid these stress concentration points in a typical roller bearing, the axial profile of the roller is modified from a straight cylindrical shape to a barrel shape configuration. This geometric modification will results in eliminating or minimizing the stress concentration at the ends of the rollers.

1) **The two contacting surfaces of same length:**

Both roller and race-way are of the same length and come to end at the same cross-sectional plane. On cross-sections away from the ends, an axial compressive stress exists to maintain the condition of plane strain. At the free ends this compressive stress reduces in value, allowing the solids to expand slightly in the axial direction and thereby reducing the contact pressure at the end. An estimate of the reduction in the pressure at the end of the roller may be obtained by assuming that the end of cylinder is under a state of plane stress.Linear contact modelling between roll situations of this problem, without any aspect of friction. The global rigidity of roller of roller bearing is influenced by contact profile. When the problems of the rolling bearings crown are profoundly studied, Hertz solution doesn't see enough precise because of this lack of permission from the point of view of the examination of an important part from the rolls heads. The contact problem analysis in this work refers to a roller bearing with cylindrical rolls on a row. Because this problem present a double symmetry the study must be reduce at system. The surface of contact are perfectly clean, dry and without friction.

IV. CONCLUSION

- By using ANSYS to numerically simulate and analyze on stress and strain during rolling contact bearing.
- Solutions with the help of finite element method should be good consistent than the hertzian theory solutions.
- With the help of finite element method we can understand the running parts information.

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