Spherical Roller Bearing

Amitkumar S. Jain
Magna Automotive India Pvt Ltd, India

Abstract— Rolling element bearings are essential for rotating machinery. The spherical roller bearing (SRB) is one variant seeing increasing use, because it is self-aligning and can support high loads. It is becoming increasingly important to understand how the SRB responds dynamically under a variety of conditions. This doctoral dissertation introduces a computationally efficient, three-degree-of-freedom, SRB model that was developed to Predict the transient dynamic behaviors of a rotor-SRB system. In the model, bearing forces and deflections were calculated as a function of contact deformation and bearing geometry parameters according to nonlinear Hertzian contact theory. The results reveal how some of the more important parameters; such as diametral clearance, the number of rollers, and osculation number; influence ultimate bearing performance. Distributed defects, such as the waviness of the inner and outer ring, and localized defects, such as inner and outer ring defects, are taken into consideration in the proposed model. Following model verification, a numerical simulation was carried out successfully for a full rotor-bearing system to demonstrate the application of this newly developed SRB model in a typical real world analysis. Accuracy of the model was verified by comparing measured to predicted behaviors for equivalent systems.

Keywords: Spherical roller bearing, dynamic analysis, defect

I. Introduction

Bearings are one of the most important components in mechanical systems, and their reliable operation is necessary to ensure the safe and efficient operation of rotating machinery. For this reason, a multipurpose dynamic roller bearing model capable of predicting the dynamic vibration responses of rotor-bearing systems is important. However, bearings introduce nonlinearities, often leading to unexpected behaviors, and these behaviors are sensitive to initial conditions. For rolling element bearings, the significant sources of nonlinearity are radial clearance between the rolling elements and raceways and the nonlinear restoring forces between the various curved surfaces in contact. A special type of nonlinearity is introduced to the system if the contact surfaces have distributed defects, such as waviness, or localized defects, such as inner or outer ring defects.

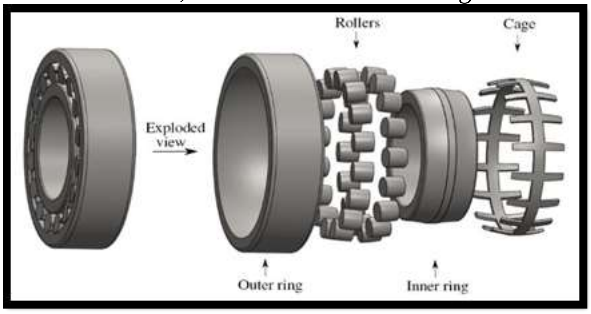

Fig. 1: components of SRB

II. Why Spherical Roller Bearing Used?

SKF bearings are developed for customer satisfaction. The best confirmation of the total quality of SKF spherical roller bearings is their success on the market. There are twice as many SKF spherical roller bearings in service as those of any other bearing manufacturer. This is not just by chance: SKF spherical roller bearings are well-proven in the field and undergo continuous development to provide improved performance. The latest examples include the introduction of SKF Explorer bearings, which opened up new application horizons, and sealed bearings. The use of SKF spherical roller bearings implies several benefits.
Spherical roller bearings offer an attractive combination of design features, which are making them irreplaceable in many demanding applications.

A. Self-aligning

Spherical roller bearings accommodate misalignment between the shaft and housing without increasing friction or reducing bearing service life.

B. Very high load carrying capacity

Optimized internal geometry within the available cross section provides maximum radial and axial load carrying capacity.

C. Robust

Insensitive to misalignment caused by shaft or housing deflections as a result of heavy loads.

D. Easily fitted for loads in all directions

The bearings are non-separable and ready to install, having a choice of mounting methods.

E. Simplify the application

The favorable design characteristics combined with simplified mounting procedures enable more efficient and compact machine designs. Spherical roller bearings with integral seals offer additional benefits.

F. Protect against contaminants

Sealed spherical roller bearings are especially suited for bearing positions where space or cost considerations make external seals impractical.

G. Grease retention

A contact seal on both sides of the bearing retains the factory grease fill where it is required: inside the bearing.

H. Minimized maintenance requirements

Under normal operating conditions, sealed spherical roller bearings are maintenance free, keeping service costs and grease consumption low.

III. Dynamic Model of the Spherical Roller Bearing

A spherical roller bearing consists of a number of parts, including a series of rollers, a cage, and the inner and outer raceways. Describing each component in detail can result in a simulation model with a large number of degrees-of freedom. Additionally, as with all radial rolling bearings, spherical roller bearings are designed with clearance. This clearance also increases the computational complexity of the system. However, bearing analysis computation should be efficient so it can be used to simulate the dynamics of complete machine systems. To improve the computational efficiency of the proposed spherical roller bearing model the following simplifications have been introduced.

- Cage movement is based on the geometric dimensions of the bearing; therefore, it is assumed that no slipping or sliding occurs between the components of the bearing and that all rollers move around the raceways with equal velocity.
- The inner raceway is assumed to be fixed rigidly to the shaft.
- There is no bending deformation of the raceways. Only nonlinear Hertzian contact deformations are considered in the area of contact between the roller sand raceways.
- The bearings are assumed to operate under isothermal conditions.
- Rollers are equally distributed around the inner race and there is no interaction between them.
- The centrifugal forces acting on the rollers are neglected. The bearings tiffness matrix and bearing force calculation routines are implemented according to the block diagrams shown in Figure 1.

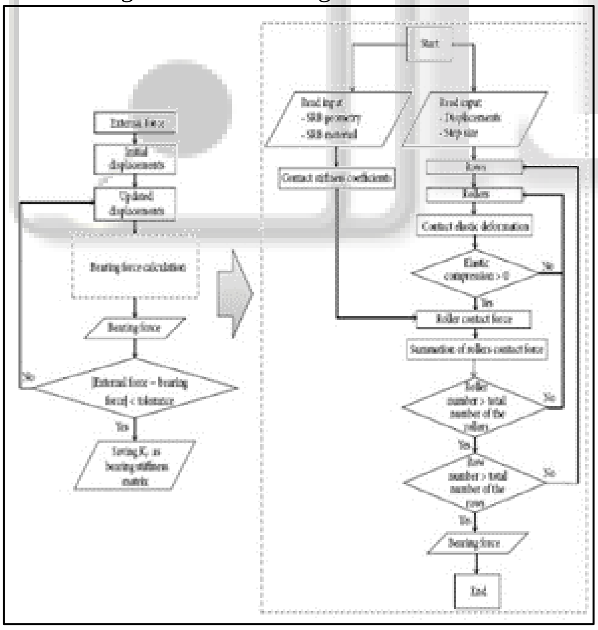

Fig. 2: Block diagram for the bearing stiffness matrix and bearing force calculation

The bearing geometries, material properties and the displacements between the bearing rings are defined as inputs. For the stiffness matrix calculation routine, the external force on the bearing is given as an input. The bearing force calculation routine can be used as a stand-alone program or as part of a bearing stiffness matrix calculation routine in a multibody or rotor dynamic analysis code.

IV. SELECTION OF BEARING SIZE

The life-extending improvements embodied in SKF Explorer spherical roller bearings can best be understood using the SKF rating life equation. This calculation method constitutes an extension of the fatigue life theory developed by Lundberg and Palmgren and is better able to predict bearing life. The SKF rating life equation was presented in the SKF General Catalogue 6000 and is in accordance with ISO 281:1990/Amd 2:2000. The equation to be used for roller bearings is

$$L_{nm} = a1 * aSKF * L_{10}$$

Or,

$$L_{nm} = a1 * aSKF * \left(\frac{C}{P}\right)^{\frac{10}{3}}$$

If the speed is constant, it is often preferable to calculate the life expressed in operating hours using,

$$L_{nmh} = a_1 * aSKF * \left(\frac{1000000}{60n}\right) * \left(\frac{C}{P}\right)^{\frac{10}{3}}$$

Where,

Lnm = SKF rating life (at 100 – n1) % reliability), millions of revolutions Lnmh = SKF rating life (at 100 – n1) % reliability), operating hours

L10 = basic rating life (at 90 % reliability), million revolutions a1 = life adjustment factor for reliability

aSKF = SKF life modification factor C = basic dynamic load rating, kN

P = equivalent dynamic bearing load, kN n = rotational speed, r/min

A. *The aSKF factor*

The aSKF factor represents a very complex relationship between various influencing factors: the fatigue load limit ratio (Pu/P), contamination and lubrication. Values of the fatigue load limit (Pu) are provided in the tables. Lubrication conditions are expressed by

$$k = \frac{n}{n_1}$$

Where,

k = viscosity ratio

n = actual operating viscosity of the lubricant, mm²/s

n1 = rated viscosity, depending on the bearing mean diameter and rotational speed, mm²/s

Values of aSKF can be obtained from different values of hc (Pu/P) and k, where hc=factor for the contamination level of the lubricating the bearing. For standard spherical roller bearings, the values in black on the x axis should be used and for SKF Explorer bearings the values in blue on the x axis should be used. In fact, for SKF Explorer spherical roller bearings it has been found appropriate to multiply hc (Pu/P)by a factor of 1,4 as an expression of the life extending refinements of these bearings, and the blue values correspond to this. Has been drawn up for a safety factor commonly used in fatigue life considerations and is valid for lubricants without EP additives. If a lubricant containing such additives is used, reference should be made to the SKF General Catalogue or to the SKF Interactive Engineering Catalogue, available online at www.skf.com.

Values for life adjustment factor a_1			
Reliability %	Failure probability n %	SKF rating life L_{nm}	Factor a_1
90	10	L_{10m}	1
95	5	L_{5m}	0,62
96	4	L_{4m}	0,53
97	3	L_{3m}	0,44
98	2	L_{2m}	0,33
99	1	L_{1m}	0,21

Table 1: values for life adjustment factor

B. *Equivalent dynamic bearing load*

The equivalent dynamic bearing load for spherical roller bearings can be obtained from

$$P = F_r + Y_1 * F_a \text{ When } \frac{F_a}{F_r} \leq e$$

$$P = 0.67 * F_r + Y_2 * F_a \text{ When } \frac{F_a}{F_r} > e \text{ Where,}$$

P = equivalent dynamic bearing load, kN
Fr = actual radial bearing load, kN
Fa = actual axial bearing load, kN
Y1, Y2 = axial load factors for the bearings e = calculation factor.
Appropriate values for the factors e, Y1 and Y2 can be found in the bearing tables for each individual bearing.

V. MANUFACTURERS

Some manufacturers of spherical roller bearings are

- SKF,
- Schaeffler,
- Timken Company,
- NSK Ltd.,
- NTN Corporation and
- JTEKT.

Since SKF introduced the spherical roller bearing in 1919, spherical roller bearing manufacturers have purposefully been refined through the decades to improve carrying capacity and to reduce operational friction. This has been possible by playing with a palette of parameters such as materials, internal geometry, tolerance and lubricant. Nowadays, spherical roller bearing manufacturers are striving to refine the bearing knowledge towards more environmentally-friendly and energy-efficient solution.

VI. APPLICATIONS

Spherical bearings are used in countless industrial applications, where there are heavy loads, moderate speeds and possibly misalignment. Some common application areas are

- Gearboxes
- Wind turbines
- Continuous casting machines
- Material handling
- Pumps
- Mechanical fans and blowers
- Mining and construction equipment
- Pulp and paper processing equipment
- Marine propulsion and offshore drilling
- Off highway vehicle

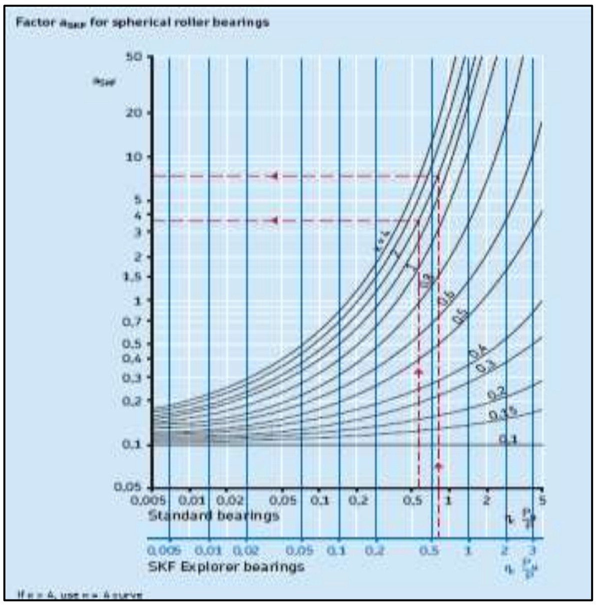

Table 2: factor a SKF for SRB

VII. CONCLUSION

This study introduces a comprehensive and computationally efficient, three-degree-of- freedom, SRB model that was developed to predict the transient dynamic behaviors of a rotor-SRB system. The new SRB model can be used as an interface element between a rotor and its supporting structure in an analysis of rotor dynamics. The model is simple and useable for either steady-state or transient analyses. It takes into account the influences of roller angular position on bearing contact forces. To verify the new bearing model, a series of verifying numerical calculations were carried out for a single SRB subjected to a simple radial load. Physical parameters such as contact force, bearing displacement, elastic deformation, diametric clearance, osculation number, and the number and arrangement of bearing rollers were examined to verify the model.

VIII. FUTURE STUDIES

- Future studies: Study about spherical roller bearing and rotor-bearing systems can be improved by the following suggestions
- Performance of spherical roller bearing can be considers in non-axial rotation due to shaft tilting and misalignment.
- Improve the contact theory for internal components connections
- Considering the effect of lubricant film damping in rolling contacts and centrifugal force of rollers in dynamic behavior of bearing, might make the model more realistic

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