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12FTM02

AGMA Technical Paper

Power Loss and Axial Load Carrying Capacity of Radial Cylindrical Roller Bearings

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

The application of cylindrical roller bearings (CRB) is widespread in mechanical engineering. CRB can carry comparatively high loads and are usable in high speed ranges. These bearings have been proven to be variably applicable and economic. With lipped inner and outer rings CRB permit the transmission of axial loads in addition to radial loads. The axial load is induced on the lip of the inner or the outer ring and transferred by the roller end face contacts to the opposing lip. In comparison to an only radially loaded bearing, there are additional friction losses in the contact between the lip and the roller ends as a result of sliding.

The limiting factors for the permissible axial load are high temperatures, which can cause smearing and seizing, lip fracture, fatigue failure and wear. In consequence of the axial loading, the stresses in the contact between the roller and the raceway rise and the fatigue durability of the bearing is reduced.

At high speeds the permissible thrust load is dominantly limited by high temperatures. At low speeds the limiting factors are lip fracture and wear.

Within the examination an extensive test program with different bearing geometries is carried out. Thereby the decisive measure is the friction torque of the bearings.

The friction torque of a thrust loaded radial cylindrical roller bearing is mainly dependent on the parameters speed, load, size and design of the bearing.

An analytical simulation model, which has been developed at the institute, allows calculating the lubrication conditions, the stresses within the lip - roller contact and the axial load dependent friction torque.

The intention of the study is to enlarge the application range of radial cylindrical roller bearings by means of a more precise determination of the thrust load capacity and to allow more economic designs.

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American Gear Manufacturers Association
1001 N. Fairfax Street, Suite 500
Alexandria, Virginia 22314

October 2012

ISBN: 978-1-61481-033-9

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Introduction

CRB have a wide application range and high significance in drive engineering. Due to the line contact CRB have a greater radial load capacity than other rolling bearings of the same size. The possible application at high speed and an advantageous friction behavior are additional benefits of radial CRB [1]. Several designs, which vary regarding the quantity and arrangement of the lips can be distinguished. The lips allow the application of axial loads in one (supporting bearing) or two directions (locating bearing). When axial forces are applied, they are transferred from the lip of the inner ring to the roller end faces of the roller and from there to the lip of the outer ring for example. Alternating axial loads can be supported by a bearing of the NJ-type in combination with an angle ring HJ or by a bearing of the NUP-type with a loose lip [2].

Despite the fact that combined loaded CRB are employed for more than 100 years, there is no standard for the calculation of the axial load dependent friction torque and of the axial load capacity until now [3]. There are equations given in the relevant literature and in the bearing catalogues which allow the calculation of the axial load dependent friction torque. These equations are mostly based on empiric approaches and the results of the different equations vary significantly.

Lubenow [4] performed extensive measurements on combined loaded CRB. Figure 1 shows the results from the equations of Schaeffler [5], SKF [6], Braendlein [7] and the simulation according to Lubenow as well as the measurement results according to [4]. The illustrated results are valid for a run in bearing of the type NJ 210 at an operation temperature of 70°C and lubrication with a mineral oil of the viscosity class ISO VG 220.

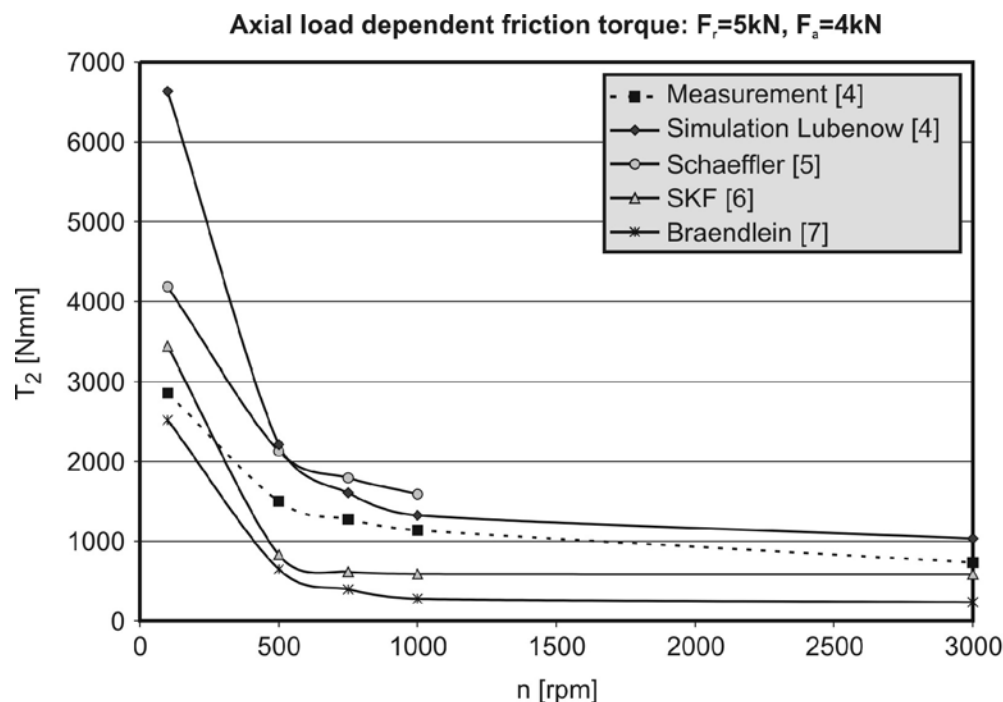


Figure 1. Axial load dependent friction torque T_2 according to different calculations methods and measurement results

The radial load amounts to $F_r = 5 \text{ kN}$ whereas the axial load $F_a = 4 \text{ kN}$ is chosen. The axial load dependent friction torque T_2 is illustrated in dependency of the inner ring speed n .

Figure 1 shows significant deviations between the different determined axial load dependent friction torques. Particularly at low speeds not only the results from the equations of the bearing manufacturers and of Braendlein vary from the measurement results, but also the simulation results according to [4].

The friction torque of thrust loaded radial cylindrical roller bearings is an important parameter for the determination of the axial load carrying capacity at medium to high speeds. The permissible thrust load can be determined by means of a heat balance [4]. At low speeds the frictional losses decrease and therefore the theoretically permissible thrust load strongly increases. The bearing manufacturers therefore additionally give a limiting ratio of axial to radial load and a limiting axial load in dependency of the size and the design of the bearing.

However, these details are only valid for the bearings of one manufacturer and considerable safety margins are included.

Testing program

For this investigation [10] five different designs of CRB in three sizes are considered. For the evaluation of the size effect, bearings with the bearing diameters $d = 30, 50$ and 80 mm are chosen. Rolling bearings are produced in different series. These series feature varying load ratings in dependence of the outer diameter, quantity of rolling elements and the bearing width. Besides the bearing series 22, the series 23 is examined. Bearings of the NJ-design normally provide friction optimized lip geometries. The lip is not orthographic to the raceway but inclined with the lip angle φ . Furthermore the lip can be crowned. The loose lip of a NUP-design and an angle ring in contradiction do not feature a friction optimized geometry. The evaluation of these shall show the influence of the lip geometry on the friction behavior of axial loaded CRB. Full complement bearings employ the maximum possible number of rolling elements, whereby the radial load is shared by a greater number of contacts which leads to greater load rating. These bearings can be used as a supporting bearing like a NJ-design because they also feature three lips.

The lubricant has a large influence on the friction behavior and therefore on the permissible thrust load of radial cylindrical roller bearings. Within this study a mineral oil and a polyglycol of the viscosity class ISO VG 220 are tested. Table 1 gives a summary test program.

Table 1. Examined bearings and lubricants

Bore reference number	06	10	16
Bore diameter	$d = 30 \text{ mm}$	$d = 50 \text{ mm}$	$d = 80 \text{ mm}$
Variant	NJ2206 E.TVP2	NJ2210 E.TVP2	NJ2216 E.TVP2
	N2306 E.TVP2	NJ2310 E.TVP2	--
	NUP2206 E.TVP2	NUP2210 E.TVP2	--
	NJ2206 E.TVP2 + HJ206	NJ2210 E.TVP2 + HJ210	NJ2216 E.TVP2 + HJ216
	SL182206	SL182210	--
Mineral oil	Aral Degol BG 220		
Polyglycol	Tribol 800/220		