Performance Analysis on Taper Roller Bearing System Based on Romax

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***Abstract*—Tapered Roller Bearing System is widely used in rotating machinery system, the dynamic performance has a significant impact on rotating machinery. In this paper, 30207 Tapered roller bearings as an object, used Romax software to build the dynamic model of tapered roller bearing system, we studied the contact stress distribution and the roller contact stress distribution between the bearing rollers and roller path; based on tapered roller bearing structure and working conditions, we conducted a tapered roller bearing fatigue life calculation of the load distribution, stress level and so on, to verify the reasonableness of bearing design parameters. In addition, we studied the affect of stress distribution on the number of rollers between the bearing rollers and roller path. The optimized design while shortening design cycles, improve the success rate of new product development.**

Keywords-Romax; modelling; bearing; virtual

I. INTRODUCTION

With the development of industrial technology, performance requirements for tapered roller bearings are also increasing; good stability, low vibration and high running accuracy and longevity, reliability, those makes tapered roller bearings dynamic performance research has increasingly become the focus of attention. According to the relevant literature [1-4] shows, because of tapered roller bearings' structural parameters and lubrication conditions, the roller end and the bearing cone keeping up the side contact load at the same time, with each other with the slide, so it's larger than the friction torque of ball bearings. Along the rolling direction of the slide and spin causing the local sliding, roller skew caused by alternating spins, the bearing cone keeping up the side and roller end faces severe wear heat and energy loss inside the bearing retainer cracking occurs, contributing to a strong bearing vibration, eventually leading to early failure. Based on pseudo static calculation analysis theory for bearing, researchers [5] get more accurate hydrodynamic pressure computation module, and predict the retainer slide-roll ratio and bearing drag coefficient. Subsequently, researchers [6] established a dynamic model of rolling bearings, researchers in domestic and foreign has developed the computing program such as CYBEAN, ADORE, BRAIN, BEAST and so on. Research of bearings tapered roller in China, using a variety of statistical or empirical data derived the stiffness characteristics that will lead to large deviation in dynamic characteristics analysis [7-10]. Model the tapered roller bearings are too simple lead to simulation modeling of data obtained from the actual data, there is a certain deviation, the software is imprecise and inefficient computing, but has not been widely used. Among them, the study is less on influence of bearing structural parameters on bearing rotor system dynamic performance. Romax software to establish the tapered roller bearing and rotor-based systems, you can consider the five-dimensional stiffness of the bearing and is capable of bearing rotor system dynamic characteristics analyzed, it is provided a method for tapered roller bearings bearing system performance analysis.

II. CALCULATION OF TAPERED ROLLER BEARINGS LOAD DISTRIBUTION

A. Structural Analysis of Tapered Roller Bearings

In this paper, we study on line contact tapered roller bearings 30207; its structural features are presented. In the Fig. 1, you can see the analysis of the internal dimensions of tapered roller bearing performance, among them, dm represents the pitch diameter of the bearing, the average diameter of the roller is D_w=1/2(D_{min}+D_{max}), included angle between rolling element and inner orbital is α_i , included angle between rolling element and outer lane is α_o , included angle between rolling element center line and x-axis is α_m , inclination angle between base cone lage flange and x-axis is α_m . Set the angular position of the roller bearing from the bottom of the recall to ϕ_i represents the angular position of the roller.

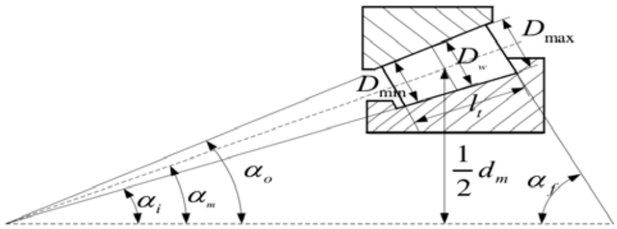


Figure 1. Inside dimension of tapered roller bearings

B. Curvature Calculation of Tapered Roller Bearings

Principal curvatures and function of tapered roller bearings:

$$\sum \rho = \rho_{1I} \rho_{1II} + \rho_{2I} + \rho_{2II}$$

Curvature and function of contact between roller and inner raceway:

$$\sum \rho_i = \rho_{1II} + \rho_{2II} = \frac{2\cos\beta}{D_w} + \frac{2\gamma_i}{D_w(1-\gamma_i)}$$

Principal curvatures and function of contact between roller and outer raceway:

$$\sum \rho_o = \rho_{1\text{II}} + \rho_{2\text{II}} = \frac{2\cos\beta}{D_w} - \frac{2\gamma_o}{D_w\left(1+\gamma_o\right)}$$

In the formula, D_w is center diameter of the tapered roller bearing, β is half cone angle of the tapered roller bearing, γ is dimensionless geometric parameter, definition is:

$$\gamma_j = \frac{D_w \cos\alpha_j}{d_m}\left(j = i, o\right)$$

Among them, α_i is contact angle between rolling element and inner raceway, α_o is contact angle between rolling element and outer raceway, d_m is diameter pitch of bearing.

C. Load Distribution Calculation of Tapered Rolling Bearing

In the Fig. 2, roller A get the maximum load, Q_A normal load is bearing inner ring act to roller A, radial component is P_A, so $Q_A = P_A / \cos\alpha_i$. Along clockwise is negative, along counterclockwise is positive. Radial load is f_r, the formula of bearing in equilibrium state is:

$$F_r = \cos\alpha_i\left(Q_A + 2\sum_{m=1}^{K} Q_i \cos\varphi_m\right) = \cos\alpha_i \cdot Q_A\left[1 + 2\sum_{m=1}^{K}\cos^{1/t}\varphi_m \cdot \cos\varphi_m\right]$$

So maximum load act on roller A:

$$Q_A = \frac{F_r}{\cos\alpha_i \cdot Z \cdot J_r}$$

In the formula, J_r is the radial load distribution point, magnitude is:

$$J_r = \frac{1}{Z}\left(1 + \sum_{m=1}^{K}\cos^{1+1/t}\varphi_m\right)$$

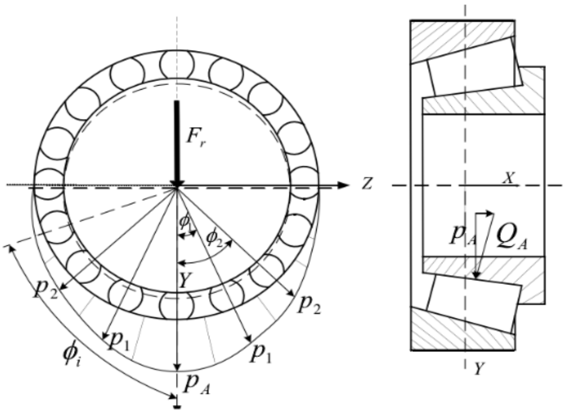


Figure 2. Load distribution of tapered rolling bearing

III. BEARING SYSTEM ANALYSIS BASED ON ROMAX

A. Construction of Bearing Model

Steps of model and analysis (show in Fig. 3) of bearing 30206 based on Romax is: model → working conditions → analysis → optimization. Bearing model is established based on the actual parameters. Available modified parameters include: position of bearings, inner and outer diameter, contact angle, coefficient of curvature of inner and outer ring, quantity of roller, the way of lubricate, the choice of materials, and so on. Romax can add the force, moment and unbalance force on the roller. After the solving, we can get the force, displacement, lifetime of bearing, five-dimensional rigidity, contact angle of rolling element and so on. Dynamic analysis of roller system in Romax also cans analysis the balanced response, critical speed, and modal analysis and so on.

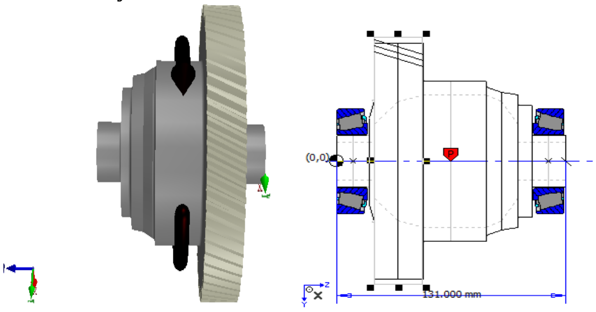


Figure 3. Modal of loading

B. Analysis of Inner Load

After the model and data loading is complete, we can use the software to analyze the bearing capacity. In this case, we mainly study on theoretical bearing life, load distribution (show in Fig. 4 (a) and (b)) and the stress level of analysis of bearings 4 and bearing 5, the results in the bearing 5 as an example in Table 1, Table 2.

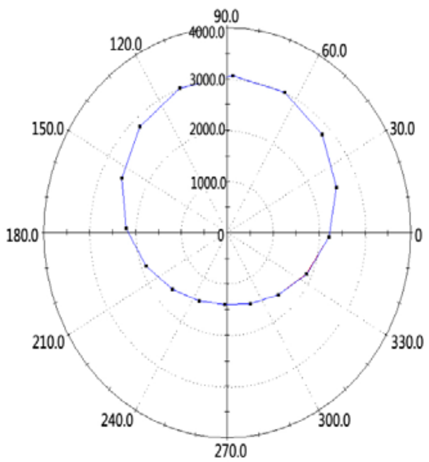
TABLE I. BEARING 4, 5 BEARING LIFE ANALYSIS

	Bearing 4	***Bearing 5***
ISO Damage (%)	1.5	5.1
ISO TS 16281 Damaged (%)	0.8359	1.2
ISO Life (hrs)	654.6362	194.4450
ISO TS 16281 Life	1196.2563	841.3348

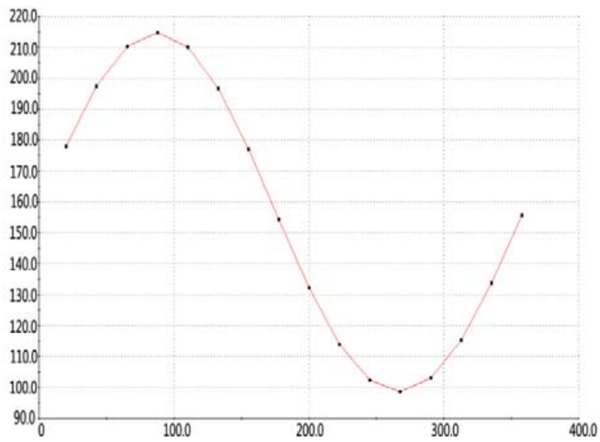
TABLE II. BEARING INNER RING STRESS SIZE DISTRIBUTION

Roller No.	***Angle (deg)***	***Outer contact stress (Mpa)***	***Within the contact stress (Mpa)***
1	20.254	1401.043469	1637.281991

2	42.754	1452.822115	1702.569058
3	65.254	1484.380477	1747.810405
4	87.754	1494.963199	1768.763424
5	110.254	1483.039702	1760.829904
6	132.754	1447.821336	1721.554192
7	155.254	1390705366	1653.731412
8	177.754	1318.855901	1566.134615
9	200.254	1240740471	1470.803674
10	222.754	1171.837285	1383.228081
11	245.254	1126.080387	1324.529642
12	267.754	1113.769020	1305.259671
13	290.254	1137.693561	1328.846650
14	312.754	1190.907275	1388.952692
15	335.254	1261.810329	1470.191741
16	357.754	1335.160471	1556.520409



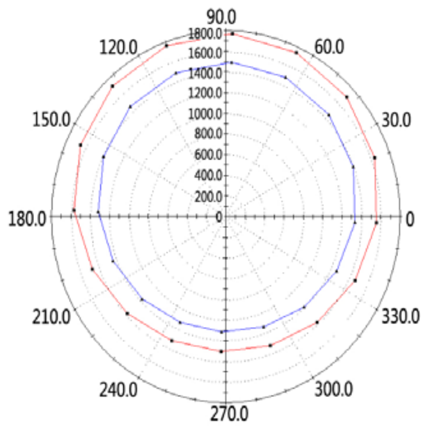
(a)



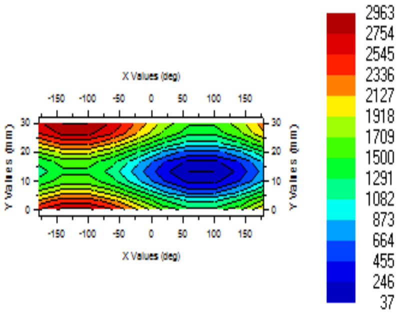
(b)

Figure 4. Bearing load distribution

From the data analysis above, we know that 2963 MPa is the maximum contact stress that the biggest roller bearing loaded, that 1769 MPa is the maximum stress that the inner ring raceway bore, that 1495 MPa (show in Fig. 5 (a) and (b)) is the maximum stress that the outer ring raceway endured, and usually 4000 MPa is the maximum contact stress between the rolling elements of all roller bearings which bore most and the raceways connected contact center, so we can say the bearing stress level meets the design requirements.



(a)



(b)

Figure 5. Bearing stress distribution

IV. CONCLUSIONS

This paper analyzes the calculation of the structure and load distribution of the tapered roller bearing, the structure and correlation dimensions of tapered roller bearing are given, the formulas for calculating the contact stiffness of the roller bearing and the roller in the tapered roller bearing are respectively analyzed, the influence of load and structure parameters on the distribution of bearing load is studied. The main conclusions are as follows:

The increase of the radial load will increase the maximum normal load under the same roller number condition; the position angle of the roller is 0 degrees with the increase of radial load, the he load of the roller which the position angle of 0 degrees is gradually increasing.

The designer can quickly guide the bearing life, load distribution, stress level with the analysis through software calculation, clears the rationality of the design parameters of the bearing, finally realize the product optimization design, reduces the probability of the long period and the error caused by the analysis of the artificial computation. Thereby shortening the design cycle, improves the research and development efficiency of new products.

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