

Design and Analysis of a proposed Cylindrical Roller use in Bearing

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ABSTRACT

Cylindrical roller bearings are designed to carry heavy radial loads, but due to misalignment and edge loading it is affecting the life of the bearing. So in the design of cylindrical roller bearings the profile of the roller plays important roll. The use of this approach for profile modifications resulted in to sustain uniform contact stress distribution across the roller contact length. In addition to these benefits, this design concept reduces the mass of a bearing and inertia effects acting on the outer raceway, which directly improves overall bearing life span. Taking a cylindrical roller bearing NU2206E as a research object, the stresses develop on roller of the bearing is studied by means of ANSYS in order to determine new profile of cylindrical roller.

Index Term— Cylindrical roller, Crown, Groove, FEA, FOS, Contact stresses, Radial load

1. INTRODUCTION

A bearing is a machine element that constrains relative motion between moving parts to only the desired motion. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts.

In cylindrical roller bearing there is line contact. Due to the line contact in between rolling elements and raceways, cylindrical roller bearings have higher radial load capacity and they are suited to high-speed applications. The roller plays an important role in the cylindrical roller bearing performance. Hence in the design of roller, the study of roller profile, contact stresses, stress distribution is important. In CRB, the roller is subjected to only radial load. The circular crowning of roller is made to increase the load carrying capacity of roller without edge stress formation, to uniformly distribute the contact pressure uniformly over roller length. Bearing design calculations require a good understanding

of the Hertzian contact stress due to which high stress concentration is produced which greatly influence the fatigue life and dominate the upper speed limits as in the case of solid rolling elements. Since being originally introduced, cylindrical rolling element bearings have been significantly improved, in terms of their performance and working life.



fig.1.1 NU2206E Roller bearing

A major objective has been to decrease the Hertz contact stresses at the roller–raceway interfaces, because these are the most heavily stressed areas in a bearing. Whereas making the proposed rollers design which is flexible enough reduces

stress concentration, uniformly distribute pressure and finally increase the life and performance of bearing.

If cylindrical roller profile is circular crowned, the stress concentration can be eliminated in low and moderate loads.

1.1. Contact stress behavior at the boundaries of cylinders roller 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.

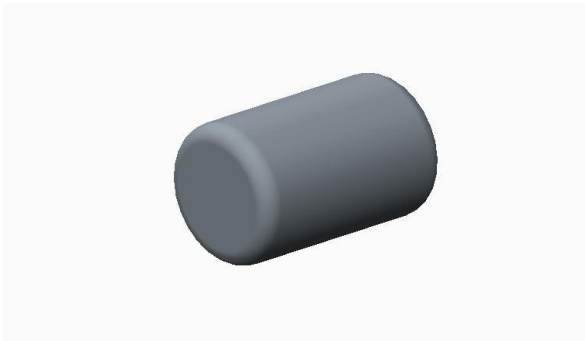


Fig.1.2 Barrel Shape Roller

The half-width b of the rectangular contact area of two parallel cylinders is found as:

$$b = \frac{4F \left[\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right]}{\pi L \left(\frac{1}{R_1} + \frac{1}{R_2} \right)} \quad (1)$$

Where E_1 and E_2 are the moduli of elasticity for cylinders 1 and 2 and ν_1 and ν_2 are the Poisson's ratios, respectively. L is the length of contact. The maximum contact pressure along the center line of the rectangular contact area is:

$$P_{\max} = \frac{2F}{\pi b L} \quad (2)$$

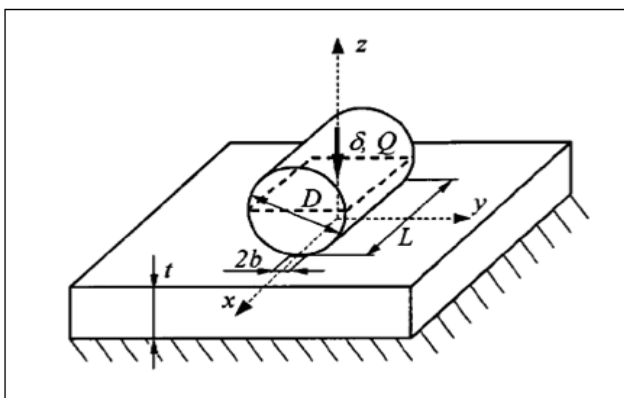


Fig.1.3: 3D contact model of roller and flat raceways with coordinates

This limits the contact to only one continuous, rectangular area. The defining equations of surfaces must also have continuous second derivatives, meaning that there are no discontinuities and no sharp transitions between regions of the contacting surfaces.

2. ANALYTICAL SOLUTIONS

A solution based on the theory of elasticity can be applied to the case of a roller bearing.

Roller bearing	NU 2206E
Material for bearing	Bearing steel
Material density	7.85 g/cm ³
Dimensions	d=30mm, D=62mm, B=20mm
Radius of roller	10 mm
length of roller	15 mm
Young's modulus	208 GPa
Poisons ratio	0.30
Static Radial load	49KN
Dynamic radial load	50KN
Tensile Yield Strength	710.16 Mpa

Table no-01: cylindrical roller bearing specification.

By using the equations (1), (2) and table no 01 for numerical calculation, the maximum contact stress for the cylindrical roller under application of 3500N radial load, the analytical result is given in table no 02.

Load(F)N	Half-width(b) mm	$P_{\max}$ N/mm ²	Deformation (δ_c)mm	Max stress (MPa)
3500	0.09873	1504.5	0.00805	358.4

Table no-02: Analytical results from hertz's theory.

The maximum contact stress value obtained from analytical solution is used for the reference value for further work.

3. PROPOSED CYLINDRICAL ROLLER DESIGN

During the past few decades the design of cylindrical roller bearings has been significantly improved. These improvements are mainly achieved by advancement in bearing steel materials and geometric design improvements. The design enchantments are mostly focused on contact stress reduction at the bearing rolling contact regions.

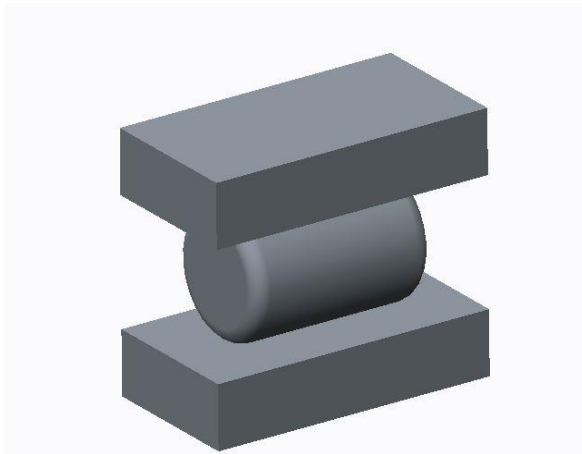


Fig.3.1; Graphical model of proposed cylindrical roller (with crown)

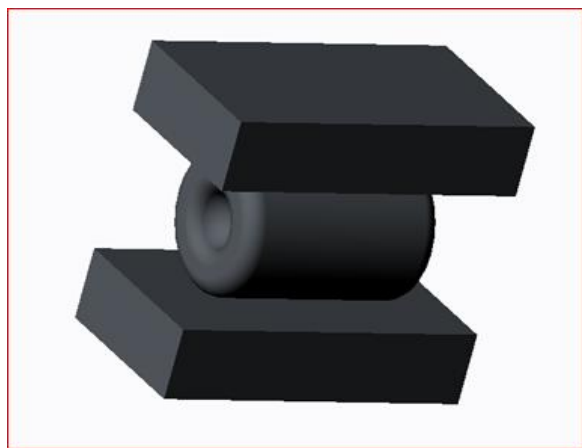


Fig.3.2; Graphical model of proposed cylindrical roller (with crown and groove)

The crown with groove shape end-cavity shaped roller has the characteristic of deflecting at two ends of the roller in response to radial loading. This results in a reduction of the contact stress at the rollers ends. In other words, crown with groove shape cavity on the both end of roller design establishes an elastic behavior of roller ends and allows deflection of the roller ends in the radial direction which is along the direction of the applied contact load. Use of these methods of profile modifications resulted in considerable progress to identify relative accuracy of edge profiles necessary to sustain uniform

contact stress distribution across the roller length. In addition to these benefits, this design concept reduces the mass of a bearing and inertia effects acting on the outer raceway, which directly improves overall bearing life span.

4. FEA OF PROPOSED CYLINDRICAL ROLLER DESIGN

Finite Element analysis of proposed as well as typical roller is performed with the ANSYS 14.0 to study the internal and contact stresses developed in a both proposed roller. This FEA work examines difference between the structural changes for both rollers

4.1. Structural analysis of proposed (with crown) cylindrical roller

For the flat circular crown cylindrical roller (maximum circular crowning radius), the circular crowning radius for the roller is $r = 1.23\text{mm}$, the length and diameter of roller is 15mm and 10 mm respectively. Refer the table 01 for the properties and specification for roller. The roller is places between two flat raceways of thickness 5mm which is equal to raceways thickness. The material for roller and raceways is bearing steel material. The load is 3500N in compressive nature.

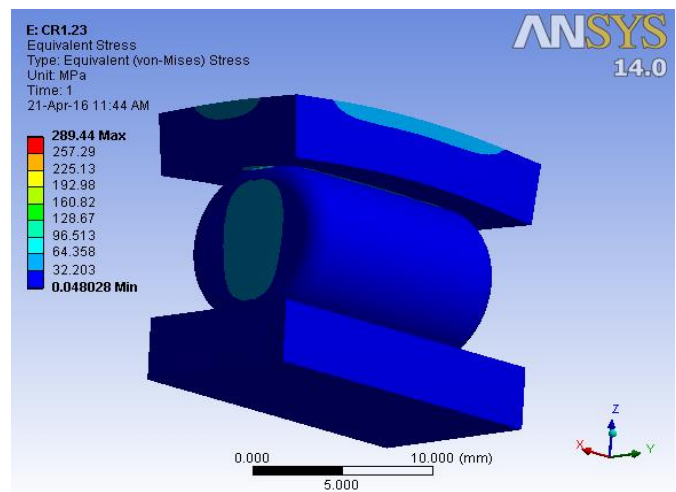


Fig.4.1 FEA model of proposed cylindrical roller (with crown)

Load(F)N	Factor of safety	Deformation (δ_c)mm	Max stress (MPa)
3500	2.4536	0.0095686	289.44

Table no-03: FEA results for the structure analysis of proposed cylindrical roller (with crown).

The FEA results of typical roller are given in table 03 for deformation, strain, stress and FOS. These results are used as reference and comparison with new proposed roller design.

4.2 Structural analysis of proposed (crown and groove) cylindrical roller

In the proposed design consist of circular crowning radius = 1.23mm and concentric circular shape cavity on both end faces of the roller as in fig-06. The dimension of circular cavity are as (diameter of cavity) = 4; (depth of cavity) = 2 mm. material properties and loading conditions are same as considered in above model.

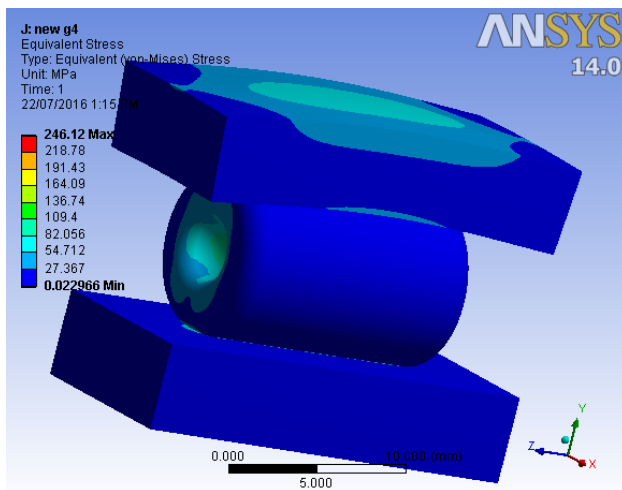


Fig.4.2 FEA model of proposed cylindrical roller(crown and groove)

Load(F)N	Factor of safety	Deformation (δ_c)mm	Max stress (MPa)
3500	2.8854	0.010208	246.12

Table no-04: FEA results for the structure analysis of proposed cylindrical roller (crown and groove)

4.3 EXPERIMENTATION RESULTS

Force applied on roller
= total load ÷ No. of rollers in bearing
= 49000 ÷ 14
= 3500N

Roller Design	Load(F)N	Factor of safety	Deformation (δ_c)mm	Max stress (MPa)
Crown	3500	2.4536	0.0095686	289.44
Crown and Groove	3500	2.8854	0.010208	246.12

Table no-05: FEA results for the structure analysis of proposed cylindrical rollers.

From the experimental results given in table 05, the proposed cylindrical roller with crown and groove is the best design than the only crown. It saves the material hence cost is less. Edge stress concentration is less as compared to typical roller. The stresses induced in it under the load are much less than Crown roller.

5. CONCLUSIONS

The design of proposed cylindrical roller is relies on the uniform pressure distribution according to H. Hertz theory, reducing the edge stress concentration and it is achieved successfully. The internal stresses induced in the cylindrical roller are also reduced. The proposed roller design is superior as compared to Lundberg crown profile. In the proposed design, there is no sharp corner hence the friction will be less. So the application CAE in mechanical designing component is efficient, reliable. With the proposed design following goals are achieved.

The loading capacity of proposed design of roller is more than the other roller of same material property as less stresses are developed in the roller under load. Edge stress concentration is less as compared with other and uncrowned cylindrical roller. In proposed design, the contact stresses is uniformly distributed. The material is saved in proposed design and hence less cost is required for manufacturing process. Fatigue and dentations failure of roller get minimized as the proposed design is more stable than other roller design.

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