# Design Optimization Based on Analytical and Data Interpretation Synergy Technique of Rib Roller Contact in Tapered Roller Bearing

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**Abstract:** The present paper deals with design optimization of rib roller contact in tapered Roller Bearing. The analytical formulation in synergy with data interpretation approach has been used to study and resolve the optimum rib roller contact. To be more precise in present analysis, the three different tapered roller bearings have been used. The obtained results suggest the efficient point of contact for all the sizes by varying the spherical head radius of roller. Also it has been found that the percentage of range available for spherical head radius is more bearing having high outer diameter as well as cup angle.
**Keywords:** Design optimization; Rib Roller Contact; Tapered Roller Bearing.

## 1 INTRODUCTION

The tapered roller bearings have always been a great deal of interest for researchers since 1898 when Henry Timken and Reginald heinzelman was first awarded the patent for the same [1]. Tapered roller bearings highly appreciable ability to take axial forces as well as radial forces make them unique from various points of applications such as wheel and axle transmission, gear box ,differential etc. They are extremely excellent thrust bearings. Initially tapered roller bearings have been used mostly in low speed applications but in recent years their usages in high speed applications and critical design characteristics have been explored by many researchers. The original design proposed in 1898 has come long way through continuous improvement to presently manufactured bearing globally. Fig. 1 Shows the present tapered roller bearing used globally. Low Speed quasi-static model neglecting the centrifugal force and gyroscopic torque for low speed applications was first proposed in 1973 [2, 3]. In 1976 this effect was included and improved model was proposed [4]. Later extension of these models was used to study load distribution and internal dissipation shared between the rows [5-8]. Another aspect related to roller skew movement such as dimensional discrepancy and effect on pressure distribution was studied by many researchers and finally optimized solution was obtained in some years after [9-12]. Till now an important area that has been neglected by most of researchers is related to optimization of rib roller contact in tapered roller bearing.

The constraint of speed limitation in real life application is contributed by fact that rib roller contact plays significant role in stress generated at point of contact during dynamic conditions arising from centrifugal loading.

The present paper took into consideration the found gap and proposed the analytical formulation in combination with data interpretation approach

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to optimize the rib roller contact in tapered roller bearing. The feasibility of roller spherical head radius on rib contact has been explored considering the varying roller spherical head radius on changing pressure point.

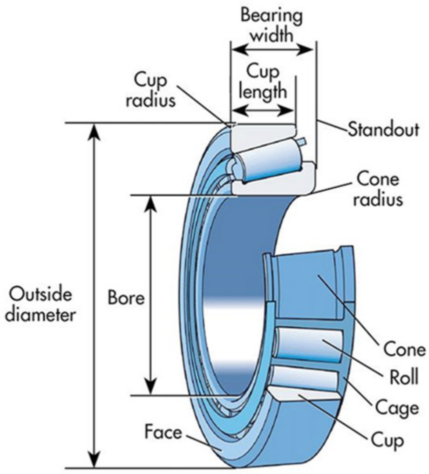


Fig 1: Recent Single row Tapered Roller Bearing manufactured globally.

The mentioned approach has been used to analyze the behavior of three bearings namely 32010, 33111 and 30313. Again based on fact that bearings outer commonly known as cup angle plays significant role in defining the macro geometrical features of bearing as well reducing the stress at rib roller contact ,the three mentioned sizes with varying cup angle were chosen to optimize the rib roller contact by given approach.

## 2 ANALYTICAL APPROACH

$R_{aa}$=Roller Spherical Head Radius
$R_{bb}$=∞(*i.e* Flat surface)
$D_{max}$=Maximum Roller Large End Diameter
$\theta$=Angle from Cone Raceway to $Rib_{Face}$
$a_f$=Flange Angle
$a_i$=Cone Angle
$a_r$=Roller Angle
$h$=Height of Rib Roller End Contact Point from Cone Raceway
(Pressure Point)

$$\phi = a\sin\left(\frac{D_{\max}}{2R_{aa}}\right) - \frac{a_r}{2} \tag{1}$$

$$\theta = 90 - (a_f - a_i) \tag{2}$$

$$h = R_{aa}(\sin(\phi) + \cos(\theta)) \tag{3}$$

## 3. DETAILS OF BEARING USED

Tab. 1. Details of Bearing Used

| Bearing No. | Inner Diameter (mm) | Outer Diameter (mm) | Width (mm) | Cup Angle (Degrees) |
|---|---|---|---|---|
| 32010 | 50 | 80 | 20 | 31.67° |
| 33111 | 55 | 95 | 30 | 28° |
| 30313 | 65 | 140 | 36 | 57.62° |

As mentioned earlier the importance of cup angle in optimization of Rib Roller Contact the three bearings used 32010, 33111 and 30313 are chosen with varying cup angle i.e. 31.67°, 28° and 57.62° respectively to study the effect of varying spherical radius at point of contact. The details of bearings can be seen in Tab. 1. While choosing the bearings it has also been taken into consideration that bearings have different inner diameter i.e. 50 mm, 55 mm and 65 mm; outer diameter 80 mm, 95 mm, 145 mm; width 20 mm, 30 mm, 36 mm respectively for bearings 32010, 33111 and 30313 respectively.

## 4 RESULTS AND DISCUSSIONS

The Figs. 2-4 Shows the variation of pressure point with varying roller spherical head radius for bearing 32010, 33111, and 30313 respectively. Similarly, Tab. 2 Shows the Details of Varying Spherical Head Radius and Pressure Point for Bearing 32010, 33111 and 30313.For all the mentioned sizes it has been seen that pressure point decreasing linearly with increasing the roller spherical head radius. For bearing 30313 pressure point varies from 2.781 mm to 2.046 mm while varying roller spherical head radius from 122 mm to 135mm. For bearing 33111 pressure point varies from 1.404 mm to 1.139 mm while varying roller spherical radius from 174 mm to 186 mm. Similarly for bearing 32010 pressure point varies from 1.191 mm to 1.006 mm.

The roller spherical head radius range for all three bearing i.e. 122 mm to 135 mm; 174 mm to 186 mm and 131 mm to 140 mm reflects the optimum spherical head radius allowable for bearing 30313, 33111 and 32010 respectively. Beyond these ranges the roller spherical head radius will increase beyond the available area available when loaded statically as well as dynamically. In dynamic condition it will impact overall smooth running of bearings and will produce hazardous results related to desired bearing life.

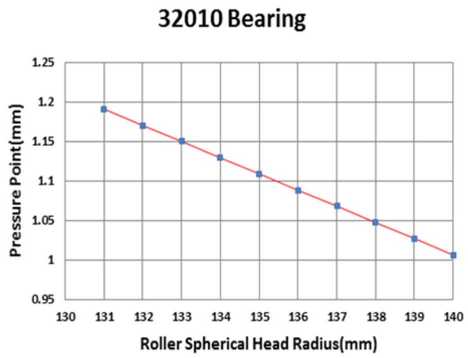


Fig. 2: Variation of Pressure Point with Increasing Roller Spherical Head Radius for Bearing 32010

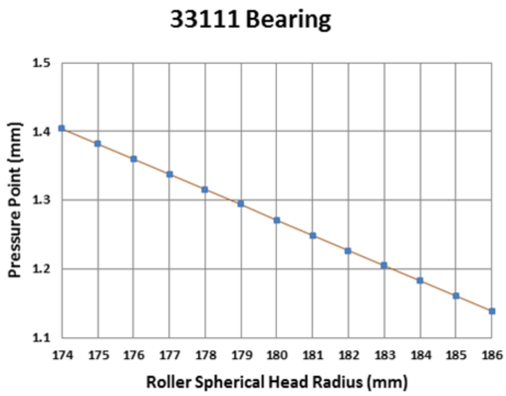


Fig. 3: Variation of Pressure Point with Increasing Roller Spherical Head Radius for Bearing 33111

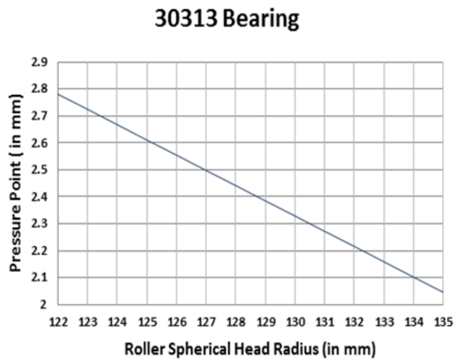


Fig. 4: Variation of Pressure Point with Increasing Roller Spherical Head Radius for Bearing 30313

Tab. 2: Details Varying Spherical Head Radius and Pressure Point for Bearing 32010, 33111 and 30313

| 30313 Bearing | | 33111 Bearing | | 32010 Bearing | |
|---|---|---|---|---|---|
| SHR* (mm) | PP** (mm) | SHR* (mm) | PP** (mm) | SHR* (mm) | PP** (mm) |
| 122 | 2.781 | 174 | 1.404 | 131 | 1.191 |
| 123 | 2.725 | 175 | 1.382 | 132 | 1.170 |
| 124 | 2.668 | 176 | 1.360 | 133 | 1.150 |
| 125 | 2.611 | 177 | 1.338 | 134 | 1.129 |
| 126 | 2.555 | 178 | 1.316 | 135 | 1.109 |
| 127 | 2.498 | 179 | 1.294 | 136 | 1.088 |
| 128 | 2.442 | 180 | 1.271 | 137 | 1.068 |
| 129 | 2.385 | 181 | 1.249 | 138 | 1.047 |
| 130 | 2.329 | 182 | 1.227 | 139 | 1.027 |
| 131 | 2.272 | 183 | 1.205 | 140 | 1.006 |
| 132 | 2.216 | 184 | 1.183 | - | - |
| 133 | 2.159 | 185 | 1.161 | - | - |
| 134 | 2.102 | 186 | 1.139 | - | - |
| 135 | 2.046 | - | - | - | - |

SHR* means Roller Spherical Head Radius
PP** means Pressure Point

Tab. 3: Percentage of Range Available for SHR

| Bearing | Percentage of Range available for SHR* |
|---|---|
| 30313 | 9.630 |
| 33111 | 6.452 |
| 32010 | 6.429 |

SHR* means Roller Spherical Head Radius

Interestingly it can also been seen that roller spherical radius available range is more for 30313, and least for 32010. The same fact can be depicted in Tab. 3. The percentage of range available for spherical head radius for three bearing. The bearing 30313 has highest range available at 9.630 % and for bearing 32010 having the least at 6.429 %

## 5 CONCLUSION

The present paper suggests the design optimization of rib roller contact in tapered roller bearing. Major conclusions drawn from work are as follows,

- Pressure point decreases linearly with increasing the roller spherical head radius.
- The percentage of range available for spherical head radius is more bearing having high outer diameter as well as cup angle.
- The height of pressure is more for roller with less roller spherical head radius.
- While designing a bearing the analytical approach must be combined with proper data interpretation to define optimized spherical head radius for manufacturing of bearing considering their dynamic applications for more bearing life.

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