



GUJARAT TECHNOLOGICAL UNIVERSITY

(Established by Government of Gujarat under Gujarat Act No. : 20 of 2007)

ગુજરાત ટેકનોલોજીકલ યુનિવર્સિટી

(ગુજરાત સરકારના ગુજરાત અધિનિયમ ક્રમાંક : ૨૦/૨૦૦૭ દ્વારા સ્થાપિત)

Accredited with A++ Grade by NAAC

Abstract of the Thesis



Name: KHANT AMISHABEN BABUBHAI

Enrollment No.: 219999919002

Faculty: DR. JAYDEEP K. DADHANIYA

Discipline/Branch: MECHANICAL ENGINEERING

Title of the Thesis: EXPERIMENTAL INVESTIGATION AND ANALYSIS OF
FRICTION TORQUE IN TAPERED ROLLER BEARINGS

Abstract

Tapered roller bearings (TRBs) are widely employed in automotive, railway, heavy machinery, and industrial transmission systems due to their capability of carrying both radial and axial loads. However, under high axial loading conditions, the friction torque generated at the roller raceway and roller end rib contacts increase considerably, resulting in excessive heat generation, elevated bearing temperature, increased power loss, lubricant degradation, and reduced bearing service life. Although numerous studies have investigated the influence of operating conditions on bearing performance, the effect of inner race rib convexity on the frictional and thermal behaviour of TRBs has received limited attention. Therefore, the present research aims to experimentally investigate the influence of inner race rib convexity, axial load, and operating speed on friction torque and bearing temperature, and to determine their optimum combination for improving bearing performance.

To accomplish the research objectives, a dedicated friction torque test rig was used for conducting controlled experiments on single row TRBs 33118. The test rig consists of a drive unit, customized bearing hub, hydraulic loading system, flexible coupling arrangement, torque sensor, and a SCADA based data acquisition system capable of continuously monitoring friction torque, bearing temperature, axial load and rotational speed. The performance of the developed test rig was validated by comparing the experimentally obtained bearing temperature characteristics with the standard SKF bearing temperature profile, and a close agreement between the two confirmed the accuracy and reliability of the experimental setup.

Prior to the main experimentation, pilot experiments were conducted over a wide range of axial loads, operating speeds, and rib convexity values to establish the safe operating limits of the bearing and test rig. The pilot study indicated that operation beyond 6000 kgf axial load and 600 rpm resulted in excessive friction torque, rapid temperature rise, severe vibration, and noticeable surface damage on the bearing components. Post-test inspection confirmed that operation up to 6000 kgf maintained satisfactory bearing condition with only slight thermal discoloration. In addition, Hertzian contact stress analysis using MESYS AG software verified that rib convexity values up to 6 μm maintained the maximum contact



GUJARAT TECHNOLOGICAL UNIVERSITY

(Established by Government of Gujarat under Gujarat Act No. : 20 of 2007)

ગુજરાત ટેકનોલોજીકલ યુનિવર્સિટી

(ગુજરાત સરકારના ગુજરાત અધિનિયમ ક્રમાંક : ૨૦/૨૦૦૭ દ્વારા સ્થાપિત)

Accredited with A++ Grade by NAAC

stress below approximately 2400 MPa, thereby ensuring safe operating conditions. Based on these investigations, three process parameters, namely rib convexity (0, 3, and 6 μm), axial load (2000, 4000, and 6000 kgf), and operating speed (400, 500, and 600 rpm), were selected for the detailed experimental study.

Initially, a three factors, three levels, L27 Full Factorial Design (FFD) was employed to investigate the combined influence of the selected parameters on friction torque and bearing temperature. The experimental data were analysed using MINITAB 19 to develop second order regression models and perform Analysis of Variance (ANOVA). The developed regression models exhibited excellent predictive capability with coefficients of determination (R^2) of 98.87% for friction torque and 99.36% for bearing temperature. Statistical analysis confirmed that rib convexity, axial load, and operating speed significantly influence both responses. The experimental results revealed that friction torque increases with increasing axial load and operating speed, whereas it decreases with increasing rib convexity. However, bearing temperature attained its minimum value at approximately 3 μm rib convexity, indicating an optimum rib geometry that balances friction reduction and contact stress distribution.

To improve modelling efficiency and reduce the number of experimental runs, the Design of Response Surface Methodology based Box Behnken (RSM BBD) was subsequently adopted. The developed RSM BBD models showed high predictive capability, with R^2 values of 99.74% for friction torque and 99.21% for bearing temperature. Contour plots and three dimensional response surface plots were used to investigate the interaction effects among rib convexity, axial load, and operating speed, providing a clear understanding of their combined influence on friction torque and bearing temperature. A comparative assessment between the Full Factorial Design and the RSM BBD indicated that both techniques generated statistically reliable models however, the Box–Behnken Design required 15 experimental runs as compared to 27 runs of Full Factorial Design, while maintaining comparable modelling accuracy, making it more suitable for optimization studies involving tapered roller bearings.

Multi response optimization was carried out using four different approaches, namely Full Factorial optimization using MINITAB 19, Desirability Function Approach (DFA), RSM based BBD, and Grey Relational Analysis (GRA). The optimum operating conditions predicted by all four optimization techniques were found to be in close agreement. The RSM based optimization yielded the highest desirability and predicted the optimum combination at approximately 3.21 μm rib convexity, 2000 kgf axial load and 400 rpm, yielding a predicted minimum friction torque of 7.96 Nm and a bearing temperature of 54.57 $^{\circ}\text{C}$. Confirmation experiments conducted at the optimum condition demonstrated good agreement with the predicted results, thereby validating the developed regression models and optimization methodologies.

Overall, A novel experimental and predictive framework integrating Full Factorial Design, Response Surface Methodology based Box–Behnken Design (RSM-BBD), Desirability Function Analysis (DFA), and Grey Relational Analysis (GRA) was developed for multi-response optimization of TRB performance. The developed RSM-BBD models demonstrated predictive capability, with R^2 values of 99.74% for friction torque and 99.21% for bearing temperature. The optimized condition was identified as a rib convexity of 3.21 μm , axial load of 2000 kgf (19.61 kN),

Page 2 | 3

Ph.D. Programme

Winners of: "Most Promising University of India 2020" ❖ "1st rank Among All Universities in Gujarat 2020 by Uni Rank"
❖ "1st Rank in Gujarat State Institutional Ratings Framework (GSIRF) 2019" ❖ "National Leadership Excellence Award 2019 in Technical Education" ❖ "India's Most Trusted State University 2019" ❖ "Outstanding University in West India 2019"

Head office : GTU Campus, Nr. Visat Three Road , Visat-Gandhinagar Road , Chandkheda, Ahmedabad - 382 424. Gujarat, India.

Phone :- +91 079-23267521/570

e-mail : info@gtu.ac.in

Website : www.gtu.ac.in



GUJARAT TECHNOLOGICAL UNIVERSITY

(Established by Government of Gujarat under Gujarat Act No. : 20 of 2007)

ગુજરાત ટેકનોલોજીકલ યુનિવર્સિટી

(ગુજરાત સરકારના ગુજરાત અધિનિયમ ક્રમાંક : ૨૦/૨૦૦૭ દ્વારા સ્થાપિત)

Accredited with A++ Grade by NAAC

and rotational speed of 400 rpm, resulting in predicted friction torque of 7.96 Nm and bearing temperature of 54.57 °C with a composite desirability of 1.000. Confirmation experiments showed prediction deviations within 5%, demonstrating the applicability of the developed models and optimization methodology. The findings of this research offer practical guidelines for minimizing frictional losses, reducing operating temperature results in improving lubrication performance, enhancing the efficiency, reliability, and service life of TRBs used in automotive and industrial applications.

This PhD Thesis would be useful for bearing manufacturers, automotive and industrial machinery industries for analysis, testing, and performance evaluation of Tapered Roller Bearings. The application of Design of Experiments, Response Surface Methodology based Box Behnken, Desirability Function Approach, and Grey Relational Analysis can be useful for systematic modelling and multi-response optimization of bearing performance. The findings also provide a basis for future investigations involving different bearing sizes, geometries and operating ranges.

List of Publication(s):

1. A. B. Khant, J. K. Dadhaniya, "Influence of Operating Parameters and Rib Convexity on Friction Torque of Taper Roller Bearings," International Journal of Mechanical Engineering, vol. 11, no. 11, pp. 34-46, 2024. DOI: <https://doi.org/10.14445/23488360/IJME-V11I11P104>
2. A. B. Khant and J. K. Dadhaniya, "A Review on Friction Torque of Tapered Roller Bearings," International Journal of Engineering Research & Technology., vol. 14, no. 05, 2025, DOI: 10.5281/zenodo.18106655
3. A. B. Khant, J. K. Dadhaniya, and H. G. Chothani, "Parametric Optimization of Friction Torque and Bearing Temperature in Tapered Roller Bearings Using Response Surface Methodology," Journal of Engineering and Technology for Industrial Applications., vol. 11, no. 54, pp. 120–130, 2025, DOI: <https://doi.org/10.5935/jetia.v11i54.1775>