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# Improvement of Rolling Element Bearing Torque Predictions Using Lubricant Rheological Measurements

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Rolling element bearing torque and power losses arise because of rolling and sliding friction. Sliding losses due to lubricant shear occur at several interfaces in a rolling bearing. This work applies the WLF-Yasutomi and the Carreau-Yasuda lubricant rheological models to the prediction of these shear losses. Lubricant property measurements are obtained using a falling body viscometer and a pressurized Couette high shear viscometer. Friction results are presented using a ball on disk arrangement. Results demonstrate the use of measured rheological data and viscosity models to improve the accuracy of bearing torque predictions.

**Keywords:** rheology, rolling element bearings, torque, viscosity

## 1. Introduction

Reducing torque power losses in rolling element bearings (REB) to improve efficiency is increasingly critical to equipment designers. Torque predictions for REB are difficult to calculate, so several simplifying approaches have gained popularity over time. As the science and experimental apparatus used in fluid rheological measurements have improved, more accurate models are being adopted [1]. This presentation walks through a modern REB torque calculation process, applying fluid rheological measurement data to improve accuracy over standard methods.

## 2. Methods

### 2.1. Approach

Lubricant viscosity is measured at temperature and pressure using falling body viscometers. Viscosity under high shear is measured using a specialty annular gap viscometer. Limiting shear stress under load is measured using a ball-on-disk tribometer. Modern models are employed to use the experimental data and predict sliding friction in rolling element bearings as summarized in Table 1. Calculated sliding friction results are used in bearing models to predict full bearing torque for comparison to measured data. A single-bearing torque assessment was performed on a Timken vertical torque rig using a premium performance fuel economy automatic transmission fluid as a case study.

Table 1: Summary of rheological models

| **Rheological Models** | **Common Approach** | **Modern Models Used** |
|---|---|---|
| Viscosity | Roelands | WLF-Yasutomi |
| P.V.C. | Generic function of temperature | Lubricant specific Vogel-type model |
| Traction Law | Lee-Hamrock | Carreau-Yasuda |
| Limiting Shear Stress | Constant | f(T,P) |
| Sliding Friction | Integration of nominal shear stress | Integration of domain-dependent shear stress |

### 2.2. Results

Thirty-four operating condition sets were evaluated on the vertical torque rig, varying speed, load, and lubricant temperature. These same conditions were simulated using experimental viscometer data and the modern models as indicated in Table 1. Figure 1 shows that the agreement between simulated torque and experimental results, expressed as percent error, is much less variable when the modern rheology models are employed vs. common legacy models.

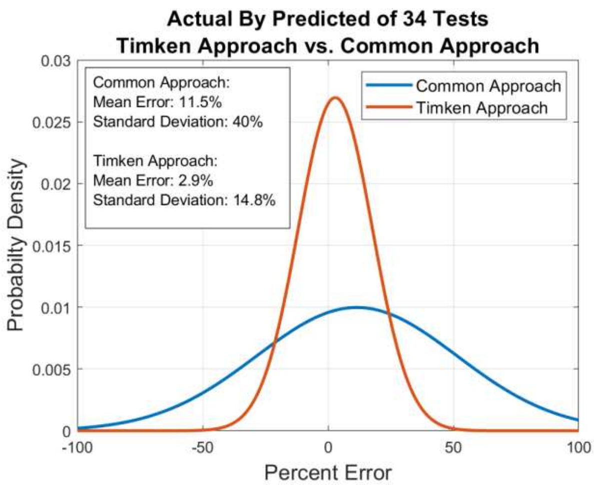


Figure 1: Comparison of error between predicted vs. experimental single bearing torque results for common and modern friction simulation approaches.

## 3. Discussion

As low-viscosity lubrication trends continue, an accurate understanding of rheological properties becomes more critical for efficient design. Measured rheological data fit with modern models show a reduction in mean error for power loss predictions compared with experiments. Such improvements in REB torque prediction model fidelity can give equipment designers confidence to design the next generation's high efficiency machines.

## 4. References

[1] Bair, S., High pressure rheology for quantitative elastohydrodynamics, Second Edition, Elsevier, 2019, ISBN: 9780444641564.