

The Effect of Outer Ring Distortion on Wheel Bearing Friction Torque

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ABSTRACT

Wheel bearing friction torque ("drag") directly contributes to vehicle fuel economy and CO₂ emissions. At the same time, one of the most important factors for long-term durability of wheel bearings is effective seal performance. Since these two factors are often in conflict, it is important to balance the desire for low friction with the need for optimal sealing. One factor that affects wheel bearing sealing performance is the distortion of the outer ring that occurs when the bearing is mounted to the steering knuckle with fasteners. Minimizing this distortion is not just important for sealing, however. This paper explores the relationship between the outer ring distortion and the resulting friction torque. A design of experiments (DOE) approach was used in order to study the effects of the fastening bolt torque, constant velocity joint (CVJ) fastening torque, and outer ring distortion on component-level drag. The correlation shows the importance of maintaining raceway roundness in order to both improve sealing effectiveness and reduce friction within the wheel bearing.

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INTRODUCTION

Wheel Bearing Drag

Vehicle fuel economy is comprised of many factors, such as driving behavior, environmental influences, and physical component-level features. One such component-level factor that contributes to fuel economy is wheel bearing friction torque ("drag"). Total wheel bearing drag consists of multiple aspects, including ball or roller bearing friction, preload, seal friction, and internal lubrication characteristics. During the design phase, wheel bearing manufacturers strive to optimize these key features. However, external interactions are also present which affect the wheel bearing drag and thus the contribution to the overall vehicle fuel economy.

The importance of the relationship between wheel bearing drag and fuel economy can be quantified by considering the value of brake drag reduction to vehicle manufacturers. The value of a 1 Nm drag reduction for an average vehicle can range from \$20.74 to \$30.98 [1]. Since wheel bearing drag is contained within this value, and four bearings are used per vehicle, even small improvements can have a large effect on overall fuel economy.

It should be noted that though wheel bearings are produced in a number of different forms, for the purpose of this study, Generation 3 ball bearings were analyzed. Additionally, since the torque of the CVJ nut could potentially have an effect on drag, this factor needs to be considered during any drag comparison study. Therefore, driven bearings were used during the study in order to include CVJ shafts and nuts.

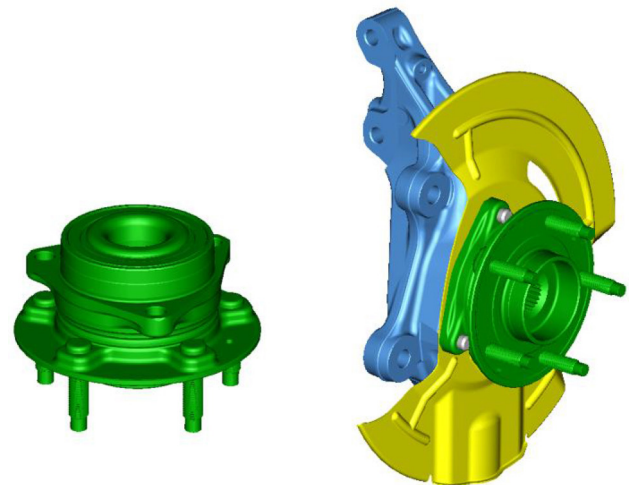


Figure 1. Wheel bearing and typical vehicle mounting environment.

Interaction of Drag and Durability Performance

The desire to improve fuel economy through lower wheel bearing drag must be balanced with the requirement for wheel bearings to maintain long-term durability performance. These two constraints are often in conflict with each other. For example, one key factor in wheel bearing design is seal lip pressure. Higher lip pressure will improve seal performance for durability, but may have a negative effect on drag. Therefore, it is important to recognize those design factors which can have a positive effect on both drag and durability.

Outer Ring Raceway Roundness Effect on Durability

The wheel bearing outer ring raceway roundness has a direct influence on durability, from both a sealing and a raceway integrity standpoint [2]. Raceway distortion occurs when wheel bearings are assembled to knuckles and secured with fasteners. Raceways that have a highly distorted shape such as the one shown in [figure 2](#) are more susceptible to spalling failure modes and reduced sealing performance.

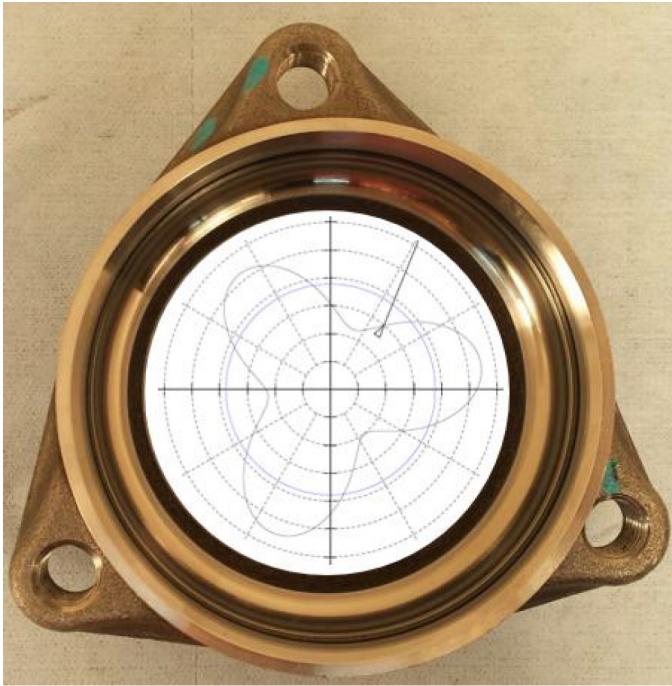


Figure 2. Depiction of the distortion of an outer ring when mounted to a knuckle, as measured with a roundness trace machine.

In order to counteract these effects, the mounting flange design must be optimized in order to minimize raceway distortion. This is often achieved through concavity of the flange, as shown in [figure 3](#).

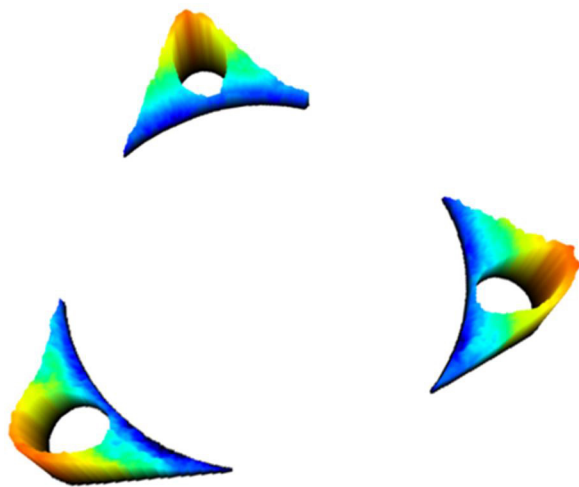


Figure 3. Concavity of outer ring mounting flange.

One case study in particular demonstrates the effectiveness of the mounting flange design optimization. [Figure 4](#) shows the warranty performance of front wheel bearings on a particular vehicle, represented by cumulative IPTV (incidents per thousand vehicles) over 36 months in service. An improvement of approximately 33% was achieved by reducing the raceway distortion through the optimization of the flange design.

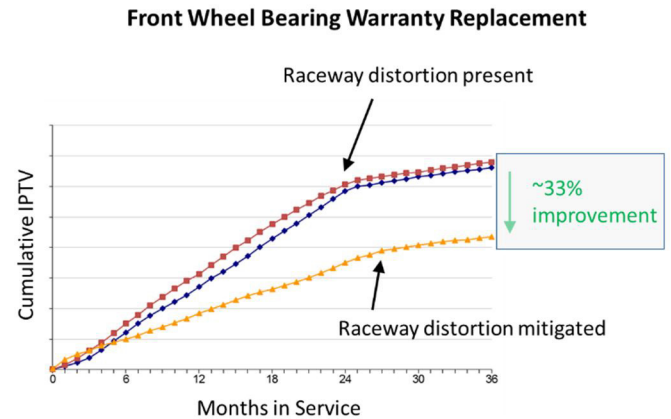


Figure 4. Warranty comparison before and after raceway distortion improvement.

OUTER RING DISTORTION EFFECT ON DRAG

In addition to outer ring raceway roundness being a key factor for durability performance, it also has a significant effect on wheel bearing drag. When the raceway is distorted, the localized stress is increased and the balls must expend more energy to travel around the raceway, thus leading to a higher drag value.

One way to influence the roundness of the raceway is through the torque value of the fasteners used for mounting the bearing. [Figure 5](#) shows the difference in measured drag values when using the proper specified mounting bolt torque versus using a very low mounting bolt torque.

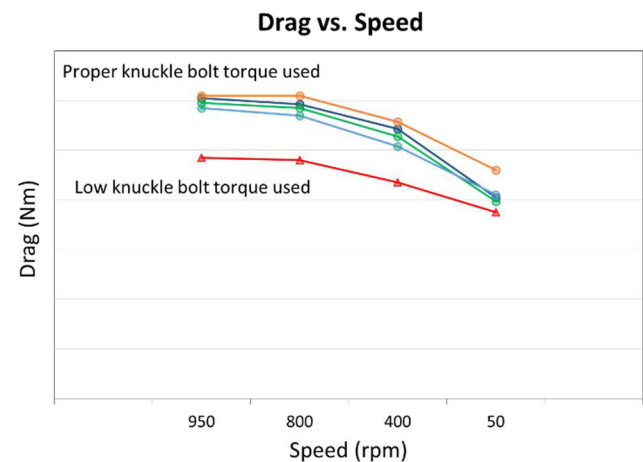


Figure 5. Typical effect of mounting bolt torque on wheel bearing drag.