

Wheel Bearing Brinelling and a Vehicle Curb Impact DOE to Understand Factors Affecting Bearing Loads

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ABSTRACT

As material cleanliness and bearing lubrication have improved, wheel bearings are experiencing less raceway spalling failures from rotating fatigue. Warranty part reviews have shown that two of the larger failure modes for wheel bearings are contaminant ingress and Brinell damage from curb and pothole impacts. Warranty has also shown that larger wheels have higher rates of Brinell warranty. This paper discusses the Brinell failure mode for bearings. It reviews a vehicle test used to evaluate Brinell performance for wheel bearings. The paper also discusses a design of experiments to study the effects of factors such as wheel size, vehicle loading and vehicle position versus the bearing load from a vehicle side impact to the wheel. As the trend in vehicle styling is moving to larger wheels and low profile tires, understanding the impact load can help properly size wheel bearings.

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INTRODUCTION

Wheel Bearing Failure Modes

Wheel bearings allow the wheels of a vehicle to rotate relative to the chassis. In addition to supporting the loads of the vehicle and providing lateral stiffness, a key design requirement for bearings is to avoid noticeable noise or vibration to the passengers. While contaminant ingress is one of the larger failure modes at higher mileage, another significant failure mode is Brinell damage to the raceways [1,2]. Brinell marks are dents in the bearing raceways caused by excessive stress of the raceway material. If the Brinell marks are large enough, the bearing can generate noise that is audible to passengers in the vehicle [3, 4].

Figure 1 shows a bearing outer ring raceway with Brinell damage on the raceway. The dents are at ball spaced internals. For this particular bearing, the dents are deeper near the contact angle rather than the shoulder. This is a sign of a vehicle hitting a pothole instead of bumping into a curb. The Brinell dents for bearings from vehicles with lateral curb impacts have more damage near the raceway shoulder.

Figure 2 shows a roundness trace of a bearing raceway with Brinell damage. The multiple raceway dents are at ball spaced internals. The size of the dent corresponds to the amount of stress from each ball into the raceway during the impact load.

Warranty bearing reviews of some vehicles have shown that over 40% of the warranty was caused by Brinell damage. This warranty review focused on bearings with 12 or less months of field exposure. The warranty pareto is shown in figure 3.

Lateral versus Radial Impact Brinell Damage

High impact loads to the wheel bearing cause the Brinell damage to the raceways. To damage most wheel bearings, typically the load needs to be a moment load rather than a pure radial load. The moment load can come from a lateral impact into a curb or a moment load, with a stronger radial vector, caused by a vehicle running through a pothole. If multiple raceway roundness traces are taken between the contact angle and the raceway shoulders, it is possible to determine if the damage was caused by a curb impact or from a pothole.

Bearings that have more damage near the raceway contact angle are generally caused by vehicles hitting potholes. The contact angle is the angle made by a plane perpendicular to the axis of rotation and the line of contact between the ball and the raceways [5]. Bench testing shows that a high radial load and small lateral load correlate better with vehicle results than bearings that experienced pure radial loads.

Lateral curb impacts, however, move the maximum dent depths away from the contact angle and closer to the raceway shoulders. The comments above apply to ball bearings, but similar analysis can be performed with tapered roller bearings.

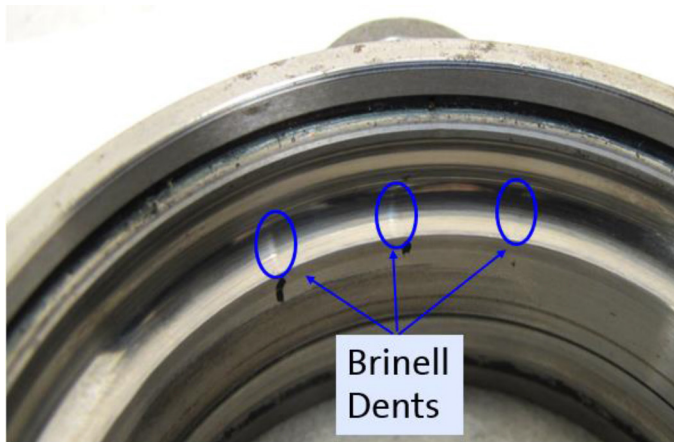


Figure 1. Wheel bearing outer ring showing Brinell damage on the raceway.

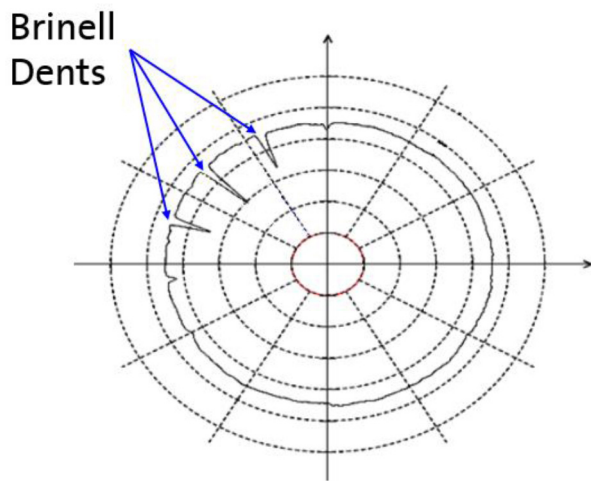


Figure 2. Wheel bearing raceway roundness trace showing Brinell dents.

Noise Root Cause Warranty Pareto 12 Months in Service

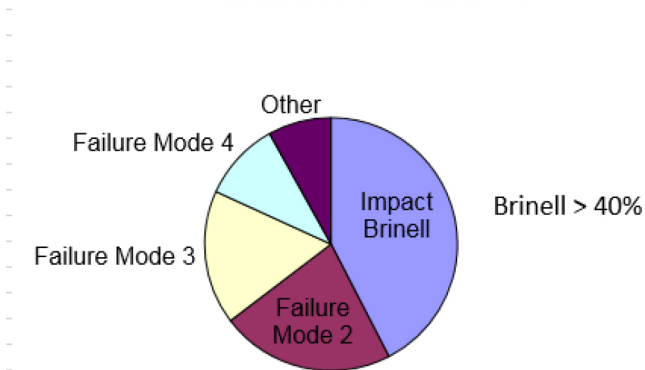


Figure 3. Warranty Pareto of wheel bearings returned within the first 12 months of service.

Relationship between Impact Loads and Bearing Noise

Even if a wheel bearing experiences enough stress from an impact to create Brinell damage on the raceways, the bearing may or may not create noise that is heard by a customer.

To understand the relationship between impact load and bearing noise, a vehicle lateral curb impact test was performed. The test was run at different speeds with different bearing designs to evaluate the bearings for noise. Additional information on the vehicle test is discussed later in this paper.

After performing the vehicle curb bump hits, objective vibration measurements and subjective noise evaluations were performed. At the lowest impact speed, noise from the wheel bearings was not heard in the vehicle. At the higher speed impacts, the bearings had audible noise. The vibration levels were measured in g-RMS, the root mean squared acceleration in g's [6]. These results, shown in figure 4, were used to develop a vibration threshold for the tested vehicles.

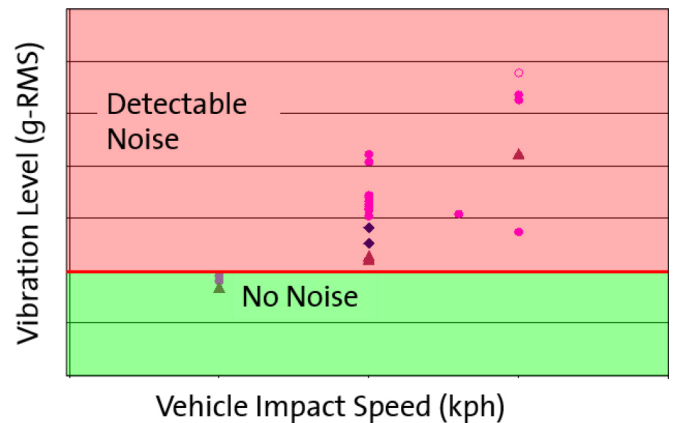


Figure 4. Graph showing the vibration level for wheel bearings after vehicles were impacted at different speeds. The x-axis is the side impact speed in kph. The y-axis is the vibration level of the bearings after test, measured in g-RMS.

The wheel bearing raceways were measured to confirm the raceway Brinell depths. For the tested vehicles, bearings with dents smaller than three microns did not make noise. Bearings with Brinell dents larger than three microns made noise.

Since Brinell impact damage can be a warranty issue for wheel bearings, it should be considered as part of the wheel bearing design process. Car manufacturers are looking for wheel bearing designs with low cost, low mass, low drag, and low warranty. Understanding the vehicle factors that affect the bearing load from an impact can help engineers develop optimum bearing designs. If the impact loads are not considered, the bearing could be undersized for this failure mode and the parts could have high warranty.

Warranty Comparison of Different Wheel Sizes

Vehicle wheels are getting larger. Styling and increased profit are key drivers for this change [7]. Unfortunately, for the wheel bearings, larger wheels also increase the load into the bearings from impacts.

A warranty analysis for one vehicle showed that the warranty rate for bearings increases as wheel sizes get larger. The warranty rate for vehicles with 20-inch wheels was over double the warranty of 17-inch wheels. Figure 5 shows relative warranty levels for different size wheels.