

The Effect of Outer Ring Flange Concavity on Automotive Wheel Bearings Performance

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ABSTRACT

Through transmitting power and carrying vehicle weight, automotive wheel bearings play an important role. Counterbalancing the bearing responsibilities, they also are designed to last the life of a vehicle without servicing. When mounted to the vehicle steering knuckle by bolts, distortion occurs to the outer ring. Performance is affected when distortion takes place at the seal mounting location and raceways. Finite element analysis using commercial software was performed to analyze the outer ring distortion. Elasto-plastic and contact analyses were carried out to compute the clamping behavior of the outer ring, bolts and the knuckle under various conditions. To verify the reliability of this study, the distortion of the outer ring was measured. The experimental results proved to be comparative with the analysis results.

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INTRODUCTION

Within the automotive industry, there have been increased demands for compact, lightweight and maintenance-free wheel bearings. This has driven progression within wheel bearing research and development, specifically the Generation 3 bearing. Generation 3 bearings incorporate flanges into the bearing inner and outer rings for mounting directly to the vehicle knuckle and wheel. [Figure 1](#) displays a Generation 3 wheel bearing and the mating and surrounding components. The flanges are subject to deformation as a consequence of fastening to the adjoining components. Deformation must be considered during design and testing. [1], [2]

The outer ring of the Generation 3 wheel bearing is fastened to the vehicle knuckle through a bolt-induced clamping force which causes distortion of the outer ring, specifically, at the seal mounting location and raceways. If, by design and in the manufacturing process, the outer ring flange forms a concave shape, it will influence the distortion generated during the tightening process between the outer ring and knuckle. Distortion of the outer ring raceways may increase the probability of spalling or flaking caused by non-uniform roundness of the bearing as shown in [Figure 2](#). Distortion may also affect the seal mounting location which can lead to decreased seal performance. Seal performance is vital as it protects the bearing from contaminants and water ingress. Preventing these failure modes by reducing the possibility of distortion during assembly by designing an optimized flange design is the subject of this paper.

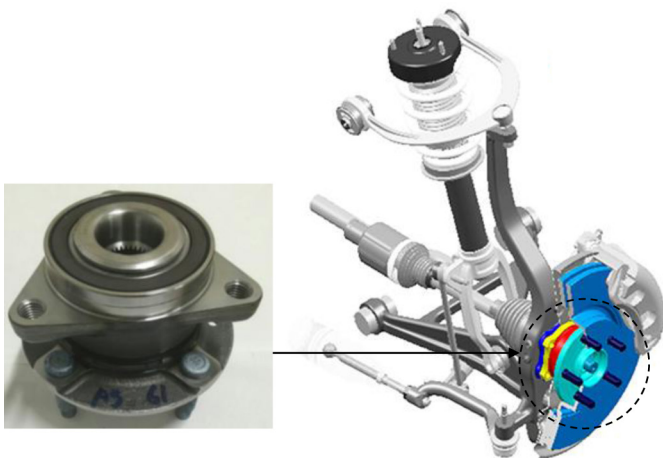


Figure 1. Automotive wheel bearing.

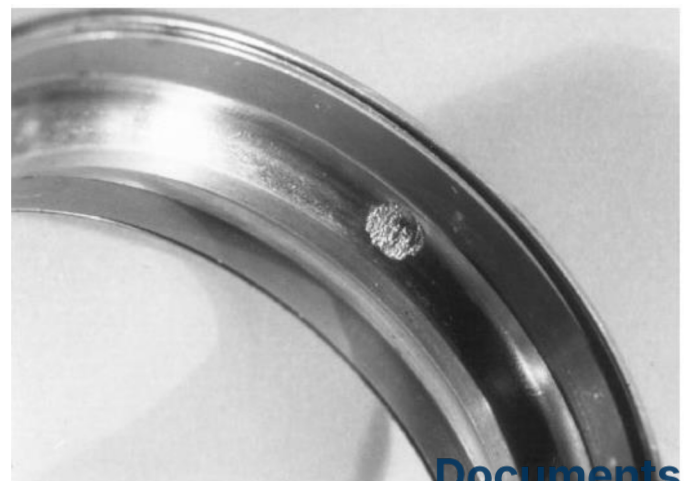


Figure 2. Fatigue spall in ball raceway surface [4]

This paper investigates the effect of outer ring flange distortion through numerical analysis. The objective is to maintain the roundness of the seal mounting location and raceways. The commercial, finite element software, MSC.MARC [3], was used for the analysis. Elasto-plastic and contact analyses were carried out to compute the clamping behavior of the outer ring, bolts, shield and knuckle. To verify the analysis results, an experiment was performed for comparison purposes and compared analysis results with test results.

DISTORTION ANALYSIS

A distortion analysis was performed to investigate the effects of outer ring flange concavity from $0\text{ }\mu\text{m}$ to $50\text{ }\mu\text{m}$ in $10\text{ }\mu\text{m}$ increments.

Figure 3 depicts this outer ring concavity.

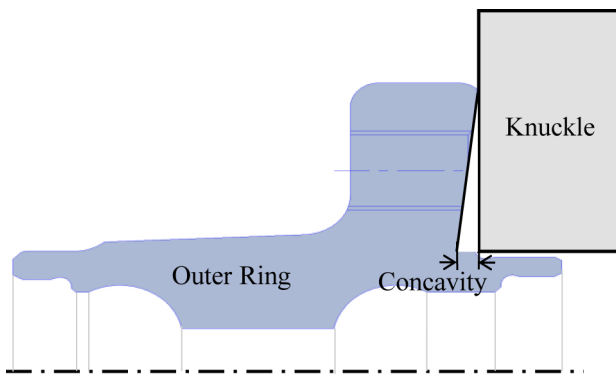
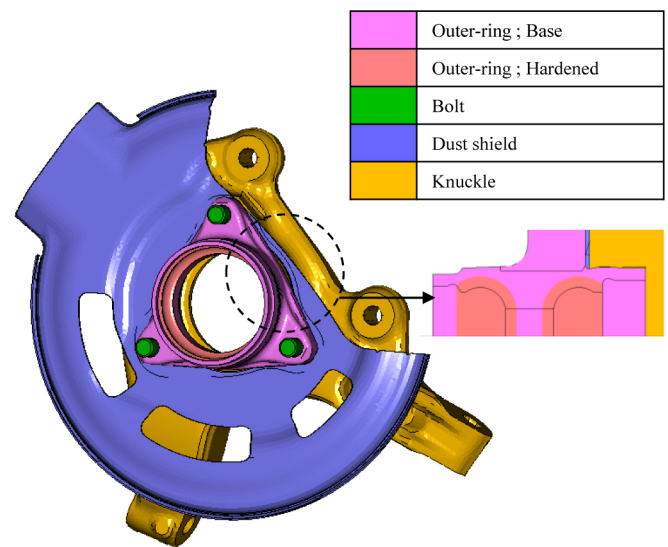


Figure 3. Concavity of outer ring flange

The outer ring was modeled in MSC.MARC using two types of elements: Element 7, an eight-node hexagonal element (three-dimensional arbitrarily distorted brick), and Element 134, a four-node tetrahedron element (three-dimensional four-node tetrahedron). Both Element 7 and Element 134 have 3 degrees-of-freedom, u_x , u_y , u_z per node. The commercial software, CATIA [5], was used to design the outer ring, bolt, shield and knuckle. Because the hub and inner ring of the wheel bearing have no significant effect, they were not considered in this study.

Due to high contact stresses between the rolling elements and raceways, the raceways are heat treated, and more specifically, induction hardened, a common process performed to improve strength and hardness selectively at the contact surfaces. The geometrical model and generated mesh are displayed in Figure 4. Figure 4(a) identifies the induction heat treated (hardened) area and the non-heat treated (base) area. These were modeled separately. Figure 4(b) shows the mesh which was generated using the commercial software, Hypermesh. [6] The total number of nodes and elements used were 103,000 and 255,000, respectively. The number of eight-node hexagonal elements used was 43,000. For the four-node tetrahedron elements, 212,000.



a. Geometric model



b. Generated mesh

Figure 4. Geometric model and generated mesh of outer ring, bolt, dust shield and knuckle

The outer ring was modeled using SAE1055 material properties. Different material properties were applied to the heat treated area in comparison to the non-heat treated area. Elasto-plastic analysis was performed to compute the distortion behavior of the outer ring, bolts and knuckle. Figure 5 shows stress-strain curves which were obtained from uniaxial tensile testing. To consider the material property effect, a distortion analysis was performed with aluminum and a cast iron knuckles.

As shown in Figure 6(a), fixed boundary conditions were applied to the bolt holes of the knuckle. The three degrees-of-freedom were fixed. To improve the reliability of the analysis, contact boundary conditions for the outer ring shield and knuckle were applied. Bolt-induced clamping torque, 180 Nm, was applied to the all three bolts shown in Figure 6(b).