

Seal Failure Analysis Method of Wheel Bearing

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ABSTRACT

The seal structure and key parameters of wheel bearing were introduced. Research on sealing failure diagnosis, abrasive scratch analysis, residual interference, and abrasion reconstruction was carried out for a typical seal structure. Based on these methods of scientific failure analysis, eight causes of seal failure were summarized systematically, which were important for the guidance of seal design and failure analysis of wheel bearings.

CITATION: Huang, D., Zhou, X., Qian, P., Wen, C. et al., "Seal Failure Analysis Method of Wheel Bearing," *SAE Int. J. Passeng. Cars - Mech. Syst.* 10(3):2017, doi:10.4271/2017-01-2527.

INTRODUCTION

Many factors have to be considered for the development of wheel bearing seals, such as seal structure, texture of rubber, the characteristics of the contacting surface between rubber and metal, and the type of grease used. These factors result in the difficulties in the precise simulation (e.g. Finite Element Analysis, (FEA)) of elastohydrodynamic lubrication behaviour [1-2]. Hutchinson (France), UMC (Japan), NOK (Japan) and other seal manufacturers evaluate the design of seal by sealing test. The sealing failure analysis after the sealing test is as important as the sealing test. The current sealing tests, including the sealing failure analysis of the wheel bearing in real vehicle, only assess whether the test is "passed" or "failed", which is not a systematic methodology. This results in a lack of clear direction and low efficiency in the improvement after sealing failure [3-4]. The aim of this study is to develop a precise and efficient method of sealing failure analysis, which may guide and optimize the design of sealing and make the development of the sealing efficient and more focused.

1. TYPICAL SEAL STRUCTURES OF WHEEL BEARINGS

The seal of a wheel bearing normally consists of two parts: the stationary part and rotary part, which compose a friction pair. The friction pair is the sliding friction between rubber surface and metal

surface of a seal. The filled lubricant reduces the friction coefficient between the sliding surfaces. Five structures of the seals in the wheel bearing are displayed in [figure 1, 2, 3, 4, 5](#) [5].

For the 1st generation of wheel bearing, the inboard and outboard seals normally employ the seals of type I, II and III. For the 2nd generation of wheel bearing, the inboard seal also normally employs the seals of type I, II and III, while the outboard seal employs end cap seal. For the 3rd generation of wheel bearing, the inboard seal normally employs type I, II and III seals and the outboard seal employs type IV or V. [Figure 6, 7, 8](#) show the examples of 1st, 2nd and 3rd generation wheel bearing with typical structure of seals respectively. Seals of type II, III, V tend to replace seal type I and IV and have become the main seals used due to the increase in seal performance requirements from vehicle manufacturers.

2. INFORMATION COLLECTIONS FOR FAILURE ANALYSIS

To analyse the causes of sealing failure, it is vital to understand the operating conditions and structure of seals clearly.

2.1. Operating Condition Analysis

The operating condition is the surrounding environment where the seals are applied and it is the external cause of the failure. Normally, it includes two aspects: the installing condition and usage condition.

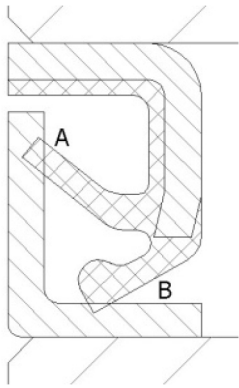


Figure 1. Seal type I

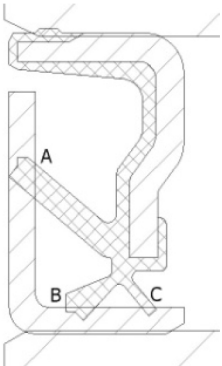


Figure 2. Seal type II

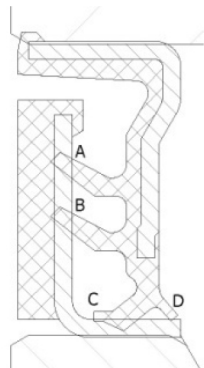


Figure 3. Seal type III

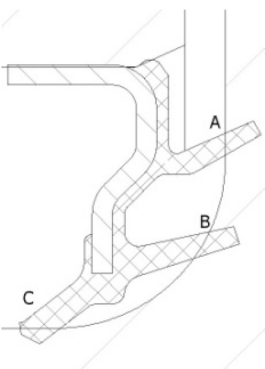


Figure 4. Seal type IV

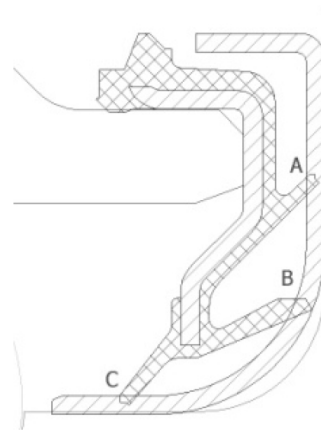
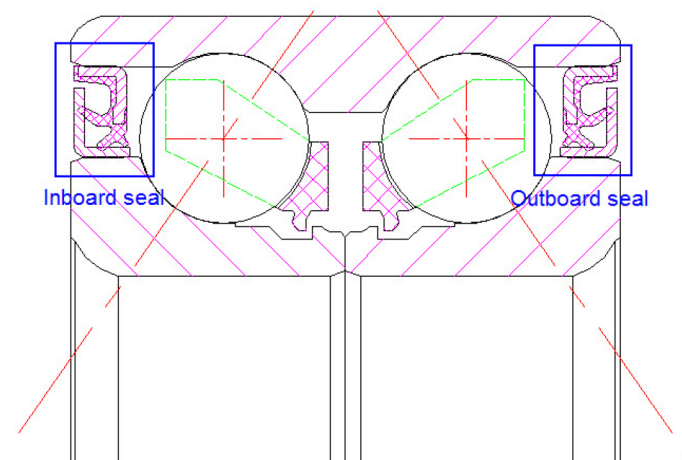
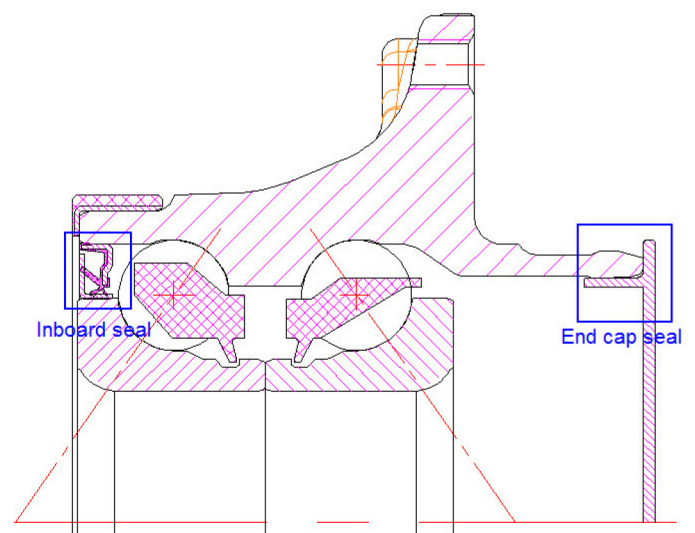
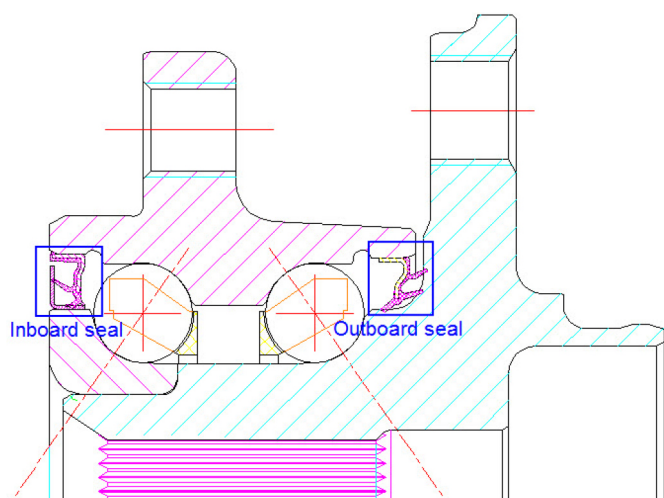


Figure 5. Seal type V

Figure 6. 1st Generation of wheel bearing with sealsFigure 7. 2nd Generation of wheel bearing with seals

Figure 8. 3rd Generation of wheel bearing with seals

The installing condition of seals includes two key points: the fitting interference and the parallel deviation of press fitting. The fitting interference and the minor roundness deviation provide the uniform fitting between the seal framework and bearing components. The actual fitting interference and the fitting uniformity are monitored by reviewing the curve of the pressing force of the seal. A high precision guiding mechanism is used to press the seal for ensuring a good parallel deviation and preventing the seal lean which causes abrasion.

The usage condition of seal concludes into two points: the preload of bearing and the operating environment. Usually, failure analysis is carried out on the bearing with seals on the test bench or on the roads. The insufficient preload normally causes bearing looseness and results in a reduction in the lip interference, and thus decreased sealing performance. The operating environment is the slurry environment on the road or simulated on the test bench.

The 3rd generation of wheel bearing (inboard seal is seal type II, outboard seal is type IV) is taken as an example to demonstrate the operating condition. As shown in figure 9 and Table 1, where A1~A5 are the seal installing conditions, B1~B3 are the preload conditions, B4 is the environment condition.

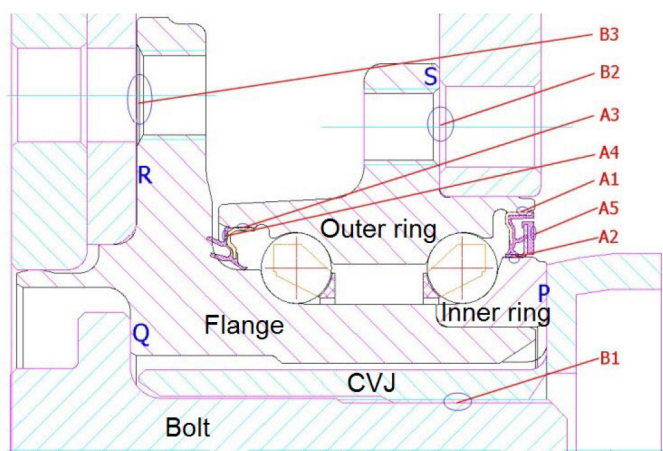


Figure 9. Operating condition of seal

Table 1. List of application conditions

Symbol	Designation
A1	Fitting of inboard seal and outer ring (interference, roundness)
A2	Fitting of inboard seal and inner ring (interference, roundness)
A3	Fitting of outboard seal and outer ring (interference, roundness)
A4	Parallel deviation of outboard seal and end face S of outer ring
A5	Parallel deviation of inboard seal and end face R of inner flange
B1	Fasten method of CVJ spindle and centre bolts (centre bolts specification+ torque)
B2	Fasten method of outer ring (Knuckle bolts specification+ torque)
B3	Fasten method of flange (Wheel stud specification+ torque)
B4	(a) testing environment: formula of mud, semi-immersed or splash; (b) road environment

2.2. Parameters of Seal Structure

It is necessary to understand the seal structure before the failure analysis is carried out, which provides better assessment of whether the seal meets the application requirements. Figure 10, Figure 11, Figure 12, Figure 13 display the key parameters of the inboard and the outboard seals of wheel bearing, which are lip edge diameter, axial elongation, thickness, opening angle, position angle, thickness of waist of rubber, etc.

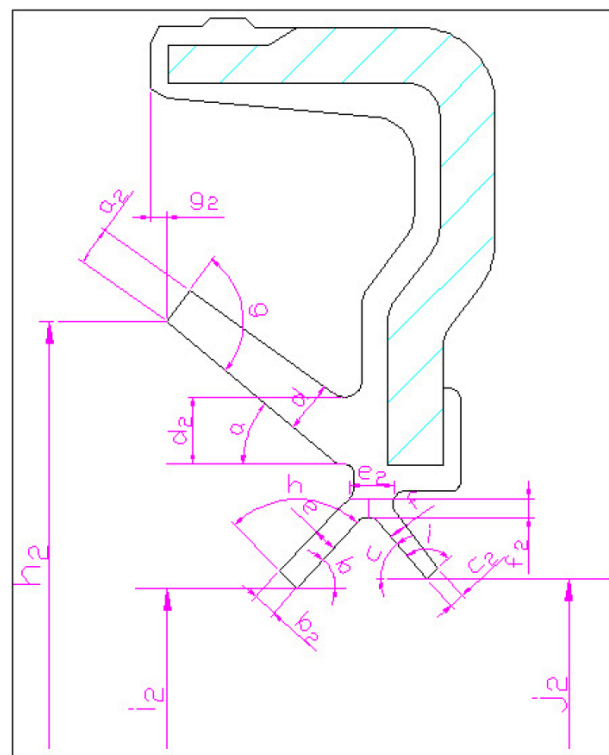


Figure 10. Key parameters for seal rubber of inboard seal pairs