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Failure analysis of the balance ball pin in the car steering system

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ABSTRACT

A balance ball pin used in the car steering system was found broken into two pieces. An evaluation of the failed part was investigated to determine the cause of failure and assess its integrity. Mechanical properties tests of the material are conducted first. Macroscopic examinations, scanning electronic microscopy(SEM) examination, metallographic examination,hardness measurement and chemical composition analysis were all conducted. The results indicated that fatigue fracture is the main fracture mode, and the uneven quench treatment led to the inhomogeneous thickness of quench-hardened case. As a result, in the fluctuations load, microcracks along the circumferential direction emerged on the subsurface of the quench-hardened case. Moreover, due to poor assembly, the stabilizer bar didn't turn smoothly in the working and fitting surface was worn badly, where produced the large resistance, which is the main torque to the ball pin.

1. Introduction

With the wider application of steering system in cars, the reliability and stability of it make a difference in the driving safety. The steering equilibrium units, including balance ball pin, transverse stabilizer bar and link rod and so on, play a key role in the process of driving. The balance ball pin, which is widely used in the steering system, is the most important connector among the transverse stabilizer bar constituting the link rod [1]. The balance ball pin transmits force from the transverse stabilizer bar to link rod. In the processing of working, balance ball pin bounce up and down or turns, and its angle has a larger swing. Therefore, the balance ball pin is subjected to great shear stress and easy to damage, which occurs frequently in driving.

The processing technology of the balance ball pin is already mature. However, failure occurs particularly due to the manufacturing errors and misuse in working. The general types of car steering system failure include fatigue failure, impact fracture, wear and stress rupture [2]. In addition, there are several other factors that influence failure which include poor assembly, material defects, processing technology, improper heat treatment and subsurface defects in critical areas. Fatigue is one of the most commons automotive components failures [3]. Due to rubbing and wearing, a large torque is generated in the process of working. If the balance ball rubbing and wearing is serious, it is necessary to replace it. The failed balance ball pin prevents the steering system from functioning properly and causes the critical issues in driving safety [4]. The manufacturer received nearly 10 reports about the balance ball pin early fracture in one year, in order to prevent the similar case, investigate the early fracture cause in the automobile steering system is very important.

Seung K. Koh [5] investigated a fatigue failure analysis of an automotive link. The analysis indicated the steering link rod occurred low-cycle fatigue failure at the middle region and the fracture crack is initiated at the highly stressed region. The fracture is taken place after a fatigue procedure under a combined bending and torsional stresses. Wassim Maktouf et al. [6] presented a fracture

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Fig. 1. Fractured balance ball pin.

analysis of automobile anti-roll bar. They found that the fractured of anti-roll bar in a ductile manner, caused a combined bending and torsional stress. The above analysis and investigations provide the probable root failure causes of different parts of the steering system. This will provide guidance for the study of this article.

The cracked balance ball pin is shown in Fig. 1. The global assembly relation of the transverse stabilizer bar, the link rod and the balance ball pin is shown in Fig. 2(a) and (b). A ball pin consists of a threaded part and a fitting part. The balance ball pin is mainly subject to fluctuations load. Failure took place in the middle part which is made of 40Cr steel with a diameter of 18 mm. And this material is a mature material, which is widely used in automotive connectors. After quenching on the ball pin surface, the surface has higher hardness [7].

This paper presents a failure analysis case on a balance ball pin in the car steering system. Based on the factors influencing the failure of a ball pin, some suggestions for preventing these kinds of failures are proposed for subsequent production of this kind of balance ball pin.

2. Equipment and procedures

The chemical composition of balance ball pin was determined by Energy Dispersive Spectrometer(EDS) chemical analysis. The mechanical properties were conducted. Micro-hardness profiles from surface to interior in various regions were made. The fracture surface was observed by visual examination and scanning electronic microscopy (SEM). The microstructure was observed by optical metallography.

3. Results

3.1. Visual inspection

Failed balance ball pin is shown in Fig. 3. Multiple parallel scratches existing on the outer surface indicated the balance ball pin was worn. The fracture surface character is shown in Fig. 4, which is covered with corrosion. Three different feature zones of the fracture surface are designated as initial zone, expansion zone and final fracture zone, respectively. The extend zone shows the fine fatigue striation, which is a typical characteristic of fatigue failure. The final fracture zone which is near the fracture edge appears the shear lips.

3.2. Micro-fracture examination

The examination around the ball pin surface revealed that there are a lot of parallel cracks, shown in Fig. 5(a). A lot of debris can be seen under high magnification, shown in Fig. 5(b). EDS result of the cracks is shown in Fig. 6,which indicates that crack surface is covered with the principal elements O and Fe. With the above analysis, it can be identified that the parallel cracks belong to fatigue cracks, and the debris on the cracks is mainly composed of iron oxides.

The micromorphology of initial area, which indicates that there is no obvious crack source, lots of cracks propagating along the circumference and the river pattern, shown in Fig. 7(a) and (b). The outer surface exists the dense and uneven quench-hardened case, shown in Fig.7(c). There are lots of irregular cracks on the subsurface where the fatigue source is located and the cracks initiate,

Fig. 2. Macroscopic assembly: (a) Global assembly; (b) Local assembly.