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FRACTURES ANALYSIS IN HIGH-PRESSURE PUMPS

BY

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Abstract. The wear is a very common physical phenomenon in the mechanical area. It can be observed in different mechanisms in different forms. Depending of the role of the mechanism in the assembly or subassembly of which it is part of, wear can happen. Thus, after a short analysis in the automotive area, it can be observed that in the fuel high pressure pumps, several forms of wear are encountered. Various levels of the wear can be studied. Depending of the working period and the operating conditions of the pump, various types of wear can occur, such as adhesion, corrosion, abrasion, fatigue or erosion. The purpose of this paper is to experimental study a type of wear often encountered in high pressure pumps, whose early identification can be useful in damages prevention in order to assure the pump performance. Some wear examples due to material fractures are described.

Keywords: wear; high pressure pump; diesel engine; fracture.

1. Introduction

Regardless of the constructive solution, high pressure pumps play the same role for the vehicles. Over time, there have been different constructive solutions, with similar operating principles. The high pressure pumps have been

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gradually improved in order to increase the performance and durability. Their operating mode depends on the vehicle engine. In order to have an extensive view on the wear types which may occur in high pressure pumps, we must first know their interface with diesel engine, their role in the engine operations, the operating mode of the pump, the area where there is a functional impact or the influence of the external factors. In order to analyse the working conditions of the high pressure pump, first it is necessary to know the operating mode of the diesel engine. A part of diesel engine consists in the fuel injection system and the pump is part of this system that is the main focus of the study. The pumps are connected to the engine via gear wheels, belts or other similar mechanisms (Ricco and Borrione, 2002**)**. The common rail system, which also includes the high pressure pump, is well known due to performance attributed to the internal combustion engine. Low pollutant emissions, reduced fuel consumption, low noise level are some of the advantages of using this system (Schommers *et al*., 2000). The high pressure pump is a mechanical system, with subassemblies and electronically controlled with an electric valve. The role of this valve is to receive the information from the Electronic Control Unit in order to be able to deliver the necessary quantity of fuel that reaches in the common rail. The high pressure pump can have multiple iterations based on the engine manufacturer requirements. Nowadays the latest used types of pumps are the ones with roller-shoe transmission mechanism. Another type is the cam-tappet transmission mechanism. The mechanical subassemblies are most likely to encounter wear. Although initially diesel engines were used, car manufacturers have also adapted the system for gasoline engines (Baur *et al*., 2014). Even if the trend is favourable for other fuel types, diesel engines will remain the basis of commercial vehicle propulsion systems. The development of the system consists on its ability to create high-pressure fuel and distribute it to the injectors. The injectors must spray it into the engine cylinders. As mentioned above, one of the main advantages of this system is that it helps to reduce the pollutant emissions. This is based on the fuel spraying features developed of the injectors (Chen *et al*., 2013). Although constructive points of views are different from generation to generation, high pressure pumps are based on similar operating principles. The manufacturers of these systems work for continuous development, so that they can offer to their customers a variety of products, at different prices, different qualities, but similar performances. Various tests and studies have been carried out in order to improve the fuel delivery capabilities and its control (Botwinska *et al*., 2016). Durability is an important factor underlying the functioning of an engine equipped with a common rail system. This is approximated by different tests performed on the offered products, and also can be established an approximate running period under safe conditions (Petrea *et al*., 2019). In a narrow sense, the durability of a common rail system is closely linked to the high-pressure pump and injectors. These are two of the main components that help to determine the engine performance. In close connection with the workability there is the wear of the components. This is a complex and often occurring phenomenon for components in contact. Considering the constructive complexity of a high pressure pump, the occurring of different types of wear is inevitable. Thus abrasion, corrosion, adhesion or fatigue wear can be encountered (Wilczkowski *et al*., 2001). The aim of this paper is to give some realistic examples of complex wear types that can contribute to pump malfunction.

2. Main Pump Subassemblies

The most prone to wear areas are those where we have direct contact elements and where is present the action of high-pressure fuel. Regardless of the constructive solution chosen by the manufacturer, the high-pressure pump has one or more hydraulic heads (Fig. 1). This is the subassembly inside which the low pressure is carried out in high pressure. Also, another common component found in all high pressure pumps is the drive shaft. It takes the rotational motion from the vehicle engine and transform this in translation one. Thus, it is subjected to different mechanical stresses and also to different wear types due to contact with the other components (Iordache *et al*., 2019).

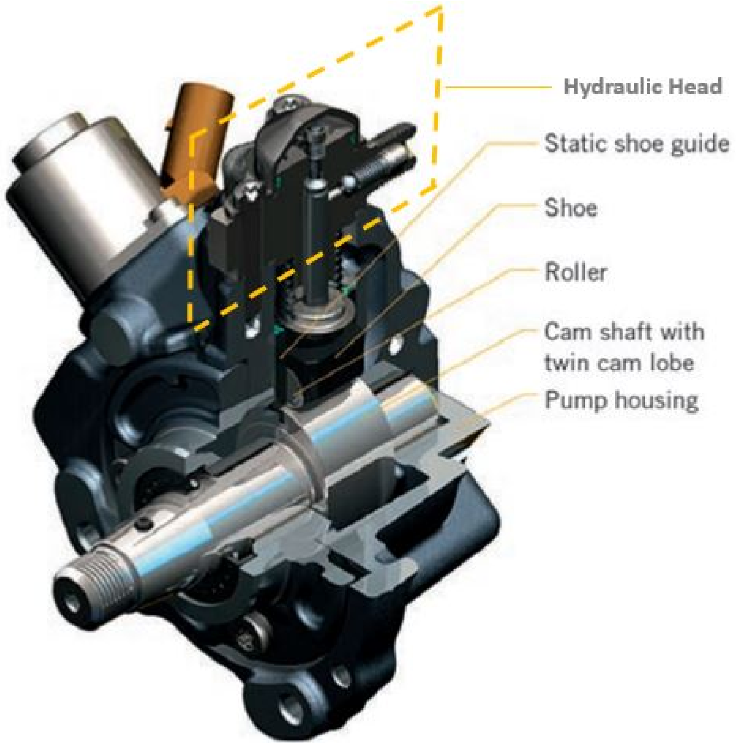

Fig. 1 – High pressure pump (Jorach *et al*., 2009).

Fractures and fatigue wear are two complex deterioration processes. They are met in components from internal subassemblies, which are in direct contact or on the surfaces of the components where various pressures are exerted.

3. Fractures and Fatigue

Although the hydraulic heads have different designs, the wear can have a similar appearance and a similar effect. Often, at the base of the wear occurrence are manufacturing defects, which in contact with the high-pressure fluid can degenerate and create dysfunctions of the subassemblies. For the penetration and evacuation of the fuel, various types of valves are integrated in the construction of the hydraulic heads. Considering the repeated action of opening and closing of the valves, fatigue wear can be inevitable. In this situation, the most stressed are the mechanisms in motion. In most cases, fractures are common defects. These occur due to deviations from the normal manufacturing process. Thus, during the technological processes of elaboration and casting processes, non-metallic particles can appear. So, the inclusions can be created and later leading to the fractures occurring. Fractures can be influenced by various factors such as temperature or pressure. Their analysis is most often performed on high quality and precision performance equipment. Therefore, the using of SEM (Scanning Electronic Microscope) is necessary in case of advanced investigation (Campilho and da Silva, 2015). A very important role in fracture analysis is constituted by the type of material, which can easily indicate the starting point. The materials used in the construction of the assemblies are often fragile (Fig. 2). This feature appears from the tendency of increasing their hardness by different heat treatments.

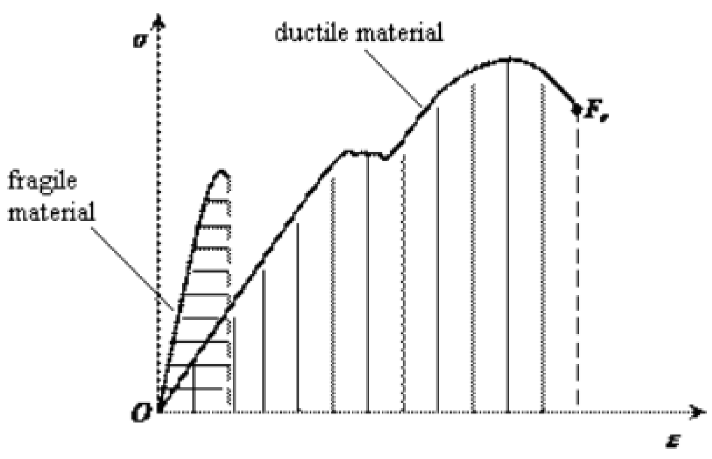

Fig. 2 – Tensile test curve (Pasare and Mihut, 2014).

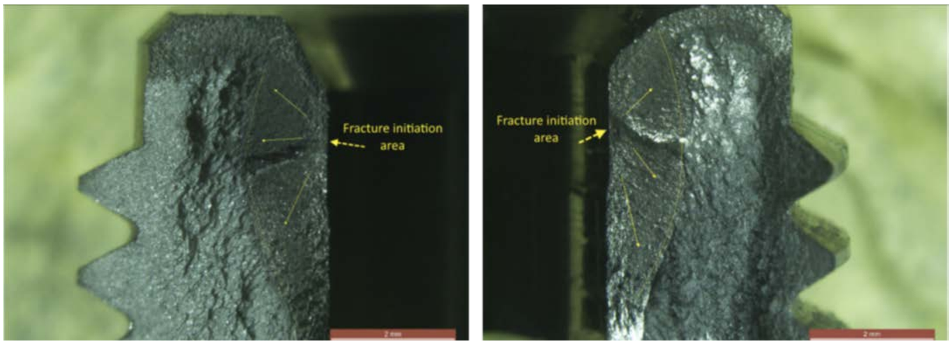

Fig. 3 – Fracture. Normal microscope view.

The fracture initiation area is easily visible due to the material-appearance catch with the help of a normal microscope (Fig. 3).

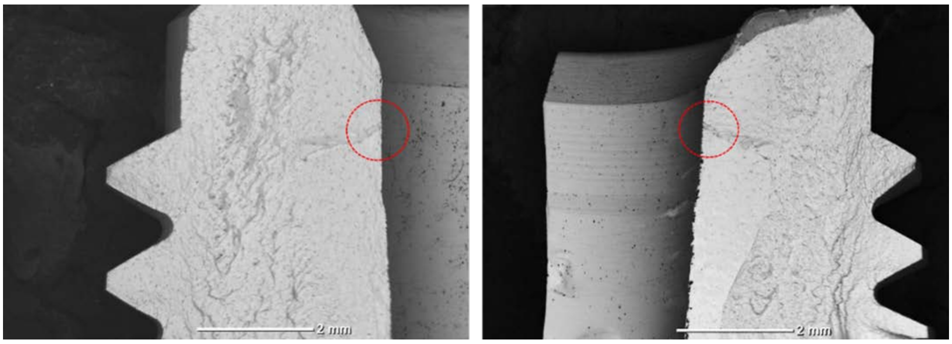

Fig. 4 – Fracture. SEM view.

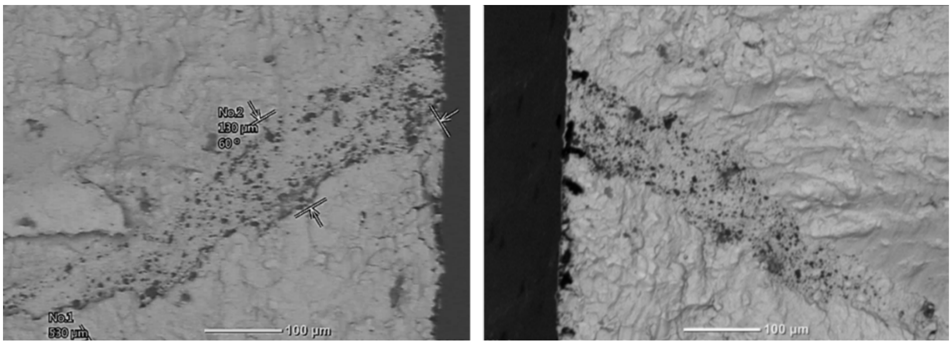

Fig. 5 – Zoom view. Inclusion.

Following a short analysis under the SEM microscope, an inclusion of particles of oxygen, magnesium and aluminium was observed (Figs. 4, 5). This can be considered the cause of the fracture.

As mentioned above, in the case of valves, the component most affected by fatigue wear is the one in motion. Often, in the construction of valves, a ball constitutes the sealing element. Due to its repeated movement and the harsh contact with the valve seat, plastic deformations can be meet and even fractures may occur.

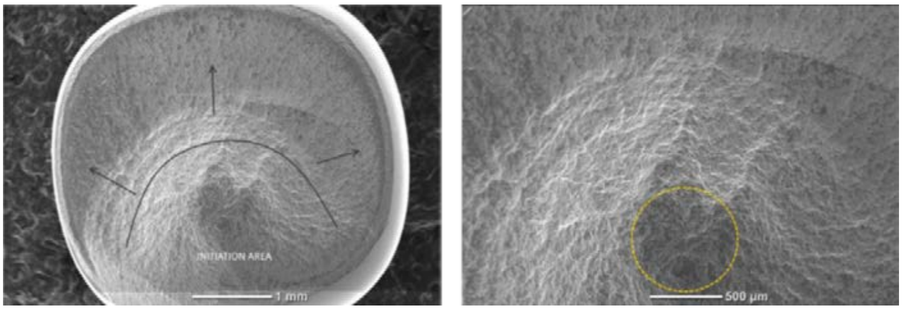

Fig. 6 – Opened fracture in a ball. Fatigue propagation.

In Fig. 6, fatigue propagation marking is present and it pointing to an area placed underneath surface. A distinct feature was discovered at the initiation area. The discontinuity of the material is visible and is similar with a recess where an inclusion was present before.

4. Conclusions

The pump behaviour and its performance is clear influenced by wear level of internal components. There is various form of components deterioration. Thus, some wear types cannot cause total malfunction of the pump, and this can continuous running, but with minimum performance. Fractures occurrence signals a deterioration type which can lead to serious issues, as internal and also external leakage. Also, considering the direct contact of components, the fractures can lead to fatigue wear. The most common root causes are the inclusions. The inclusions occurring are due to deviations during elaborating and casting process. The defect analysis is complex and it is needed to use professional tools and equipment. The defects above described are some light examples which show us the process analysis of the fractures. The material visual appearance when the fracture is opened is very important because with its help it can be identified the initiation point. Scanning Electronic Microscope is very useful because it is able to identify all suspected areas and also to check the chemical composition. The fractures can be encountered in all mechanisms whose components are based on casting processes. The effects of their occurrence are always visible and also the functional role of the affected component cannot be correctly realized.

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ANALIZA FRACTURILOR ÎN POMPELE DE ÎNALTĂ PRESIUNE

(Rezumat)

Uzura este un fenomen fizic des întalnit în domeniul mecanic. Acesta poate fi observat în diverse mecanisme sub diferite forme, în funcţie de rolul pe care mecanismul îl are în ansamblul sau subansamblul din care face parte. Astfel, după o scurtă analiză în zona automotive, am observat că în pompele de înaltă presiune sunt întalnite mai multe forme ale uzurii, ce pot fi studiate în diverse faze ale evoluţiei lor.

Pentru a avea o viziune mai largă asupra tipurilor de uzură care pot apărea în pompele de înaltă presiune, trebuie să cunoaştem mai întâi legătura acestora cu motorul diesel, importanţa lor în funcţionarea motorului, modul de funcţionare al pompei, zona în care acestea îşi exercită rolul funcţional şi influenţa factorilor externi.

De asemenea, pentru a analiza condiţiile în care lucrează o pompă de înaltă presiune, este necesar să cunoaştem mai întâi funcţionarea motorului diesel şi necesitatea utilizării sistemului cu rampă comună în componenţa sa.

Articolul prezentat face referire la apariția fracturilor în diverse componente. Sunt expuse câteva exemple clare de fracturi, metode de analiză şi metode de identificare a acestora.