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EXPERIMENTAL ANALYSIS ON HIGH PRESSURE PUMP SEALING GASKET

BY

DIANA PETRONELA BISTRICEANU[*] and CARMEN BUJOREANU

“Gheorghe Asachi” Technical University of Iaşi, Romania,
Faculty of Mechanical Engineering

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Abstract. A gasket is classified as a mechanical seal, filling the space between two or more mating surfaces. Usually, this is done to prevent leakage between the combined surfaces during compression. Sealing by compression fittings is provided by screws; therefore their strength must be large enough to fill any irregularity of the joint surfaces. The gasket is the sealing element between the pump body and the front end, fixing it by screws. Gaskets are subject to environmental factors such as temperature, pressure differences, relative movements. The material and geometry of a gasket is adapted to the pump on which it is mounted and to the parameters to which it must withstand. With this material construction and elastomer, very narrow ribs can also be sealed. Our paper presents a series of macroscopic and microscopic analysis that have been performed to identify the underlying causes of unexpected deformations of these high pressure pump seals.

Keywords: gasket; Leica optical microscope; distortion; Taylor Hobson system; fatigue; pump.

[*]Corresponding author; *e-mail*: bistriceanu.dianna@yahoo.com

1. Introduction

Car manufactures have replaced on engine the classic system with direct and indirect injection with some new injection systems with a common rail. As a benefit of the new injection system, significant reductions in pollutant emissions, increased engine performance and noise reduction were observed (Alamgir *et al*., 2017; Fiebig *et al*., 2014; Ghaffarpour *et al*., 2006).

To meet the new increasingly pollution regulation standards, car builders have been forced to improve continuously the injection system and engine design for weight reduction (Chen *et al*., 2004).

The pump is the most affected part of the injection system (Fig. 1). The diesel pump has as main assemblies: the front plate, housing, driveshaft, gasket and hydraulic head. In Fig. 2 is depicted the typical shape of a gasket.

Fig. 1 – The diesel pump.

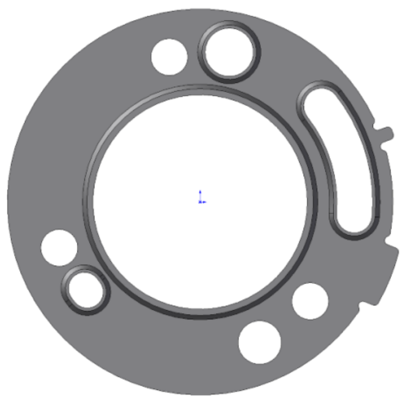

Fig. 2 – Current production gasket.

The gasket is a mechanical seal, a combination/ mixture of materials used for a perfect joint between two components in order to prevent leakage during compression but also to withstand different temperatures (https://www.theprocesspiping.com; http://vrittiassociates.com/Gaskets-India.html). In the literature we find a lot of analyzes on the design seals and their properties (Jinzhu *et al*., 2011; Kwang *et al.*, 1992; Hoyes and Bond, 2007).

This gasket manufacturing technology is mainly used in high-power motor vehicles, supercharged turbine vans and air-cooling system. The sealing by compression fittings is provided by screws, therefore their force must be large enough to prevent the gasket from flowing and filling any irregularity in the joint surfaces by making the sealing (Aibada *et al.*, 2017).

Sealing is the process of closing or securing a piece or assembly with a fluid-tight or waterproof adhesive. Seals are used in fixed or mobile assemblies or in machine and machine assemblies to function in optimal conditions (Gonzalez, 2017).

Factors influencing sealing gaskets are pressure, vibration and temperature. The literature presents numerous analyses on designing, sealing, how the different materials change under these conditions, but also how they deal with low load conditions (Drago, 2008).

The objective of our work is to analyse the sealing gasket with different systems to observe how they deform and how they resist after a certain number of kilometres.

2. Methodology and Materials

Progressive weakening of the gasket itself can be caused by 'ageing', *i.e.*, detrimental changes to the physical properties of the gasket material, and by 'fatigue', *i.e.*, deterioration due to the repetition or continuous application of stress. The performance of the gaskets is dependent on the correct assembly of the fittings with the appropriate gasket, the proper fitting of the gasket and the proper preloading of the bolts of a joint. The performance of the sealing gaskets at the pumps must be very high, which is prone to external leakage and to the penetration of foreign bodies into the interior (Mueller, 2006; Atlas Copco 2017-2019; Abid and Hussain, 2008; Klan *et al*., 2009).

For a sealed flange joint, the two main concerns are joint force and sealing capability (Dauphinais, 2011). The uneven distribution of bolt torque is caused by deformation of the sealing gasket, which is also studied in the literature (Nijgh, 2006; Hwan *et al*., 2010; Gasket Handbook, 2017).

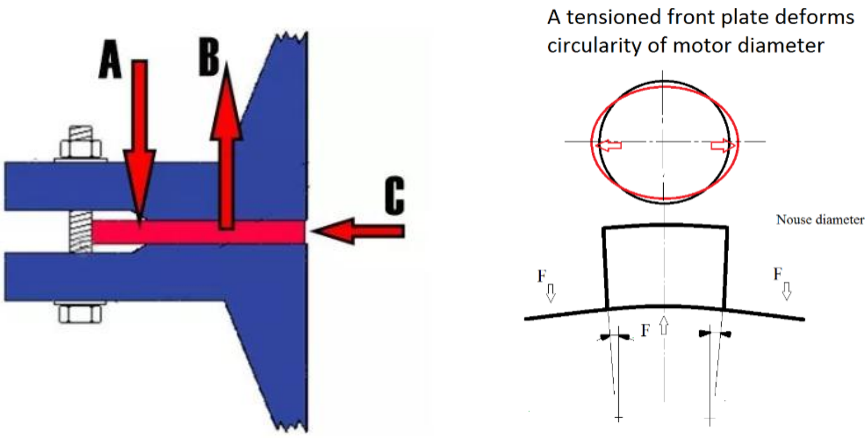

Fig. 3 – Forces on the front plate and the gasket.

Fig. 3 suggests that the force exerted by the screws is not uniformly distributed over the entire surface of the gasket. The force of tightening is A, the hydrostatic force is B and C is the internal pressure.

The flanges sealed with a gasket using the screws to keep them together are prone to leakage during operating conditions. Therefore, the performance of sealed flanges is directly influenced by certain parameters: correct assembly of the fittings with the appropriate gasket, proper fitting of the gasket and proper pre-loading of the bolts of a joint (Abid and Khan, 2017; Zhang *et al.*, 2016).

The injection pump has different sealing gaskets that are divided into metallic and non-metallic types. Metallic seals use materials such as stainless steel, aluminium, titanium, monel, copper, gold, rhenium and Inconel. Table 1 presents a summary of their features and applications (Chang-Chun *et al.*, 2005).

Table 1
Metallic Gaskets, their Characteristics and Applications

No.	Material	Characteristics	Heading
1	Stainless Steel	Decent corrosion resistance	High temperature applications
		Decent tensile strength	
		Can withstand elevated temperatures	
2	Rhenium	Less hole deformation	High pressure applications
		Higher sample stability	
3	Gold	High corrosion resistance	Small c/s area application
4	Copper	Good sealing capacity	High temperature application
5	Inconel	Good corrosion resistance	High temperature applications
		High creep strength	
6	Aluminium	Good corrosion resistance	Corrosion prone environments
7	Monel	Good chemical resistance	High pressure applications
		Good corrosion resistance	
8	Titanium	Good corrosion resistance	High temperature applications

The gaskets are used for large loads, pressures in different shapes depending on the area where it is necessary to seal the components.

The studied gasket is made of stainless steel (nickel-chromium), which gives it a higher resistance to traction and corrosion. The gasket realizes the sealing between housing and front plate.

The seal was studied with the Mahr measuring system to evaluate its roundness and Zeiss system to determine its position and diameter. The measurement system allows to be used in various fields because it has optical systems and sensors that can accurately determine the diameters.

It has been adopted in various industries: mechanical engineering, medicine, plastics, industrial automotive. Further, the studied seals were analysed using EvoCam optical microscope and Olympus microscope; this allowed the study of the gaskets in detail and the measurement of the offshore surfaces. This has enabled the components to be studied in detail.

3. Gasket Analysis Using a EvoCam Optical Microscope

Fig. 5 shows how the seal after a certain number of kilometres loses its properties and the progressive weakening of the gasket itself occurs. Sealing gasket wear is not noticeable with the naked eye because it is not so pronounced.

The EvoCam Microscope (Fig. 4) allowed the gasket (Fig. 5) to be studied as much as possible.

Fig. 4 – The optical EvoCam microscope.

Fig. 5 – Gasket studied at EvoCam optical microscope.

These gaskets have to withstand the main features for which it was thought:

a) Resistance characteristics

1. Resistance to deformation - the ability of the gasket material to adapt to the sealing surfaces;

2. Fatigue resistance- very important quality, especially when vibrations occur;

3. Hardness;

4. Wear resistance - is a very important property, depending on this, it is appreciated the durability of the sealing gasket;

5. The flow limit.

As well, they must have thermal stability: each material has a range of temperatures in which it retains its properties unaltered.

b) Tribological characteristics

The gasket characteristics from the tribological point of view, the coefficient of friction and especially its behaviour at different speeds, temperatures and conditions of lubrication are very important.

Fig. 6 and Fig. 7 present the defects of the gasket after a certain number of travelled kilometres.

Fig. 6 – The upper part of the gasket.

Fig. 7 – The lower part of the gasket.

4. Gasket Analysis Using the Olympus Microscope

The study of the gasket was done on its surface, first using the Olympus microscope (Fig. 8).

Fig. 8 – The Olympus microscope.

Fig. 9 – Gasket studied at Olympus microscope.

Using the Olympus microscope, we were able to capture the wear and deformation of the gasket (Fig. 10).

Using the Zeiss Contura measuring system, we managed to achieve the gasket profile after dismantling the pump (Fig. 11).

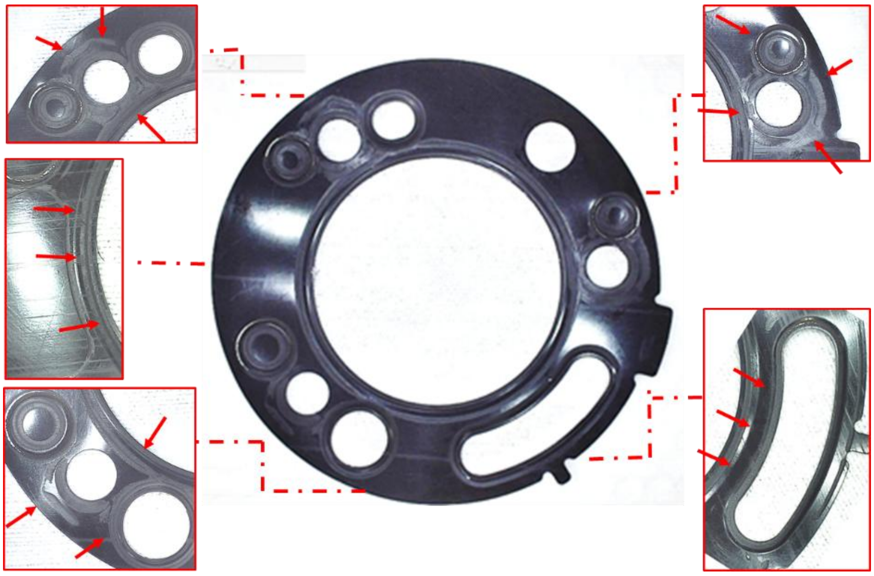

Fig. 10 – The analysed of sealing gasket using the Olympus microscope.

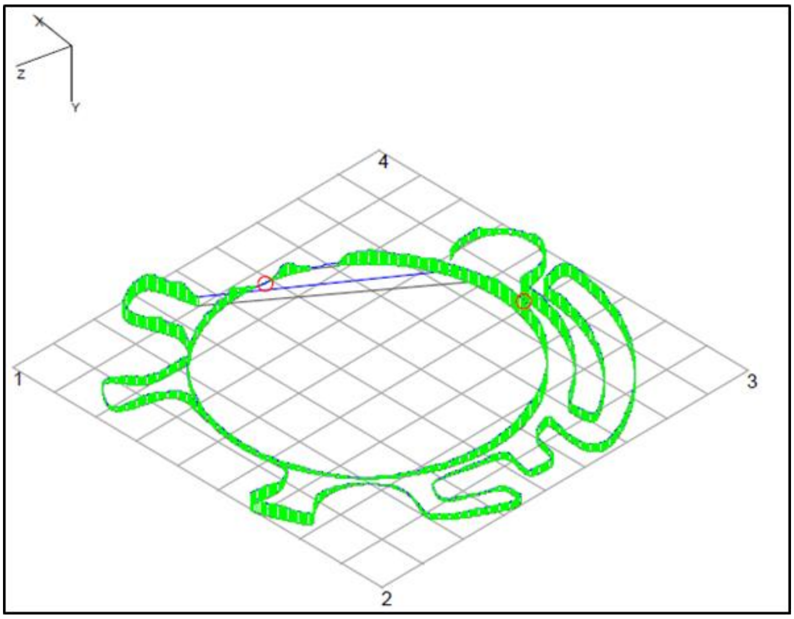

Fig. 11 – Gasket sealing profile.

The area most commonly worn is shown in Fig. 12.

Fig. 12 – The most used area of the gasket.

The surface was measured using the Zeiss measuring system and it is shown in Fig. 13. Also, Fig. 13 highlights the worn from sealing areas and how the wear affects the surface of gasket.

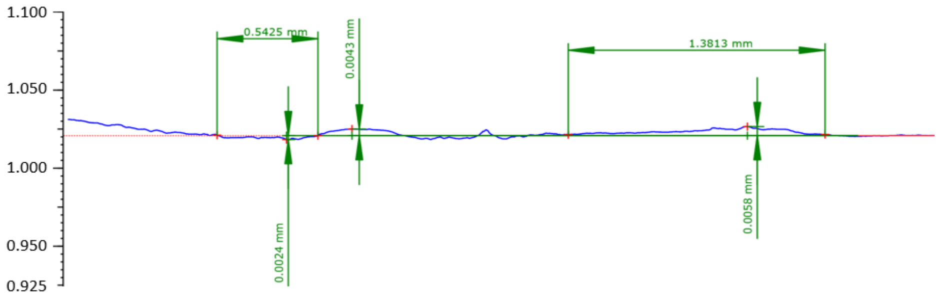

Fig. 13 – Measurements made on Zeiss for the waste area.

5. Conclusions

The paper presents an overview to the sealing possibilities in high pressure pumps and emphasizes that their performance is directly influenced by certain parameters as: correct assembly of the fittings with the appropriate gasket, proper fitting of the gasket and proper pre-loading of the bolts of a joint. The experimental analysis allows evaluating the wear and deformation of the gasket, achieving the gasket profile after dismantling the pump. A future paper will focus on the analyze and influence of the coating layers on the gasket surfaces.

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ANALIZA EXPERIMENTALĂ PRIVIND GARNITURA DE ETANŞARE A UNEI POMPE DE ÎNALTĂ PRESIUNE

(Rezumat)

În lucrare este prezentată analiza experimentală a unei garnituri utilizată la etanșarea componentelor unei pompe de injecție.

S-a demonstrat că cea mai afectată componentă a unui sistem de injecție *common rail* este pompa.

Cele mai importante componente ale pompei de injecție sunt: placa frontală, garnitura, carcasa, arborele de antrenare, șuruburile, capurile hidraulice.

Posibilitățile de etanșare ale pompelor de înaltă presiune și performanțele acestora sunt direct influențate de anumiți parametri, cum ar fi: asamblarea corectă a armăturilor cu garnitura adecvată, montarea corespunzătoare a garniturii și preîncărcarea corespunzătoare a bolțurilor.

Garnitura de etanșare, o combinație de crom și nichel, este analizată utilizând diferite sisteme de măsurare (Mahr, Olympus, Zeiss Contura, Evo Cam, Microscop optic Olympus).

Acestea au ajutat la determinarea suprafețelor de uzură ale garniturii și a diferențelor dintre suprafețe.