Research on the injectors remanufacturing

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Abstract. During the remanufacturing process, the injector body - after disassembling and cleaning process - should be subjected to some strict control processes, both visually and by an electronic microscope, for evidencing any defects that may occur on the sealing surface of the injector body and the atomizer. In this paper we present the path followed by an injector body in the process of remanufacturing, exemplifying the verification method of roughness and hardness of the sealing surfaces, as well as the microscopic analysis of the sealing surface areas around the inlet. These checks can indicate which path the injector body has to follow during the remanufacturing. The control methodology of the injector body, that is established on the basis of this research, helps preventing some defective injector bodies to enter into the remanufacturing process, thus reducing to a minimum the number of remanufactured injectors to be declared non-conforming after final verification process.

1. Introduction

Remanufacturing is an industrial activity, where a product, which is in some state of physical or moral wear or complete disrepair, it is transformed into a product having at least the performance of a similar new one, whether or not having the same use, reusing as many components and giving it a new period of operation, identical to a newly manufactured product.

Remanufacturing eliminates, to a large extent, the possibility of bringing a product to its primary value, given by the value of raw materials, a situation encountered in case of the primary and secondary recycling processes [1].

Remanufacturing is often mixed up with refurbishing or even repair of a product, in the technological equipment manufacturing industries. Remanufacturing, refurbishing and repair of a product are distinguished by the amount of the required work, but especially by the quality of the resulted products. It can be said that remanufacturing, which is using the greatest amount and the most qualified work, develops the highest quality, followed by refurbishing and repair [1], [2].

In the process of remanufacturing injector that are fitted in the internal combustion engines, particular attention is paid to the injector body, as it is the component that meets all the requirements of the remanufacturing process.

2. Work assumptions

Once in the workshop, the injector has to be cleaned, checked on the test bench and completely dismantled. The internal components are analyzed to determine their wear degree. The remanufacturing process seeks complete removal of wear, compensation of the allowances to the

original tolerances as well as restoring the free movements of the moving parts. The worn-out parts and those that could not be remanufactured have to be replaced with new ones.

The studied subject of this paper resulted from the analysis of the problems arisen during the process of injectors refurbishing, from various specialized units.

Thus, some injectors did not pass the final check on the test bench after refurbishing, later finding that the malfunctioning according to parameters was caused by loss of leak tightness in connection of the injector body and atomizer, resulting in too much fuel on return, in the case of most injectors [3]. In the process of the injector remanufacturing, the atomizer and the atomizer needle are to be replaced with new ones. Between the injector body and atomizer there is a metal-to-metal seal on a flat surface, into which more holes are made [3], [4].

Since the injector body is subjected to outstanding stress, operating under high pressure and temperatures, a series of shape defects and surface quality (lack of flatness, high roughness caused by the emergence of erosion, camber holes etc.) on its sealing surface with the atomizer. In this paper, the authors' aim is to study the root causes of these sealing problems, and they propose a technology to eliminate them.

3. Research stages
One batch of four injector bodies that are shown in Figure 1 was used for the research purposes. These are the stages proposed for the research: checking the roughness of the sealing surface of the injector body and atomizer; checking the hardness of the injector body in the sealing area and the microscopic analysis of the sealing surface.

Figure 1. The batch of the studied injector bodies

3.1. Checking the roughness
In order to check the roughness of the four injector bodies in the studied batch, an Innovatest type TR 200 electronic roughness tester was used [5]. The roughness measurement process of (Ra) is shown in the Figure 2.

Figure 2. Measuring the roughness of the injector body

The roughness checking areas are shown in the Figure 3, in which (1) and (4) are the holes for the positioning pins, (2) is the return hole, and (3) is the intake hole.
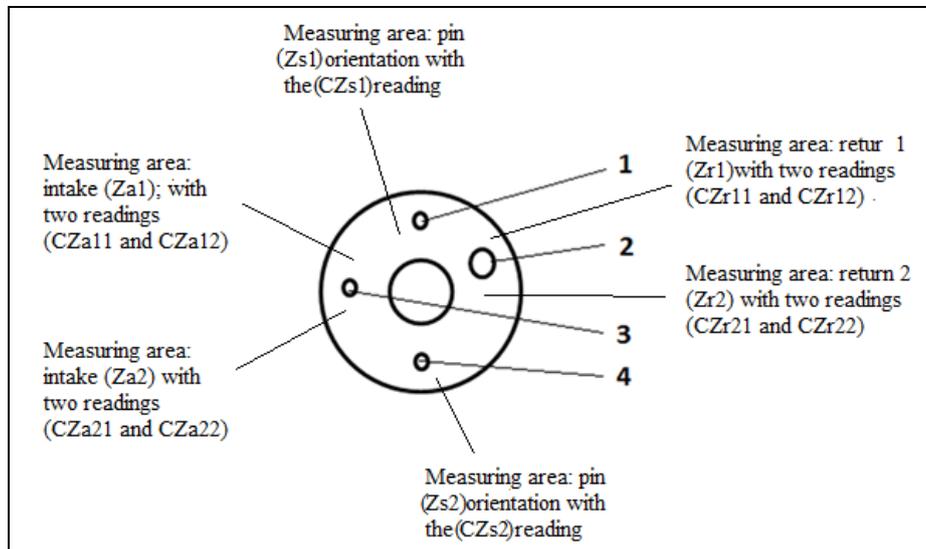

Figure 3. The areas on the sealing surface in which the roughness is measured

The results of the measuring are shown in the Table 1.

Table 1. The results of the roughness measuring

	Measuring area									
	Pin				Return				Intake	
	Za1		Za2		Zr1		Zr2		Zs1	Zs2
Injector	CZa11	CZa12	CZa21	CZa22	CZr11	CZr12	CZr21	CZr22	CZs1	CZs2
Injector 1	0.015	0.013	0.030	0.022	0.016	0.027	0.014	0.040	0.014	0.020
Injector 2	0.048	0.052	0.032	0.054	0.032	0.086	0.028	0.043	0.033	0.028
Injector 3	0.021	0.058	0.019	0.022	0.025	0.106	0.086	0.044	0.056	0.036
Injector 4	0.066	0.029	0.010	0.013	0.018	0.022	0.019	0.055	0.027	0.020

The roughness variation is shown in the Figure 4.
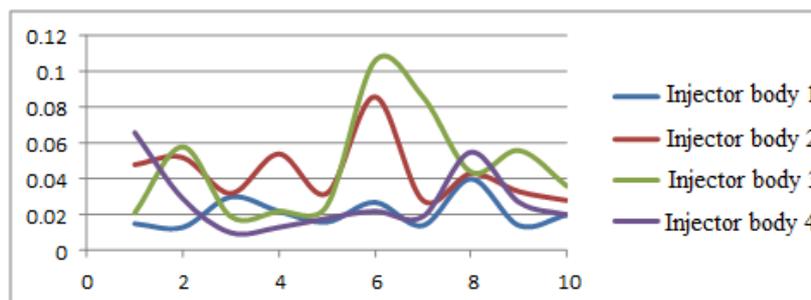
Figure 4. Roughness variation

3.2. Checking the roughness

Checking the injector body hardness aims to identify possible changes in hardness in certain areas of the body, a phenomenon which requires a different approach to remanufacturing.

The hardness was measured using a CV-450 AAT type Vikers Hardness Tester, manufactured by CV-Instruments [6]. The hardness measuring is shown in the Figure 5.

Figure 5. Hardness measuring

The results are shown in the Table 2.

Table 2. The results of the roughness measuring

Injector 1	Injector 2	Injector 3	Injector 4
112.2 HRB	107.8 HRB	109.3 HRB	108.8 HRB

Analyzing the results, it follows that no change of hardness of the studied injectors bodies appeared. The body hardness was obtained by a thermochemical nitriding treatment.

3.3. Microscopic analysis of the sealing surface

The purpose of the analysis is to identify certain physical defects appeared on the studied sealing surface and/or the total or possibly partial structural modifications of the material structure, that were caused by the thermal cycles.

The appearance of possible structural changes that would remove the injector body from the cycle remanufacture is checked.

The emergence of possible structural changes of the material of the injector body can be caused by heating and keeping at a high temperature in conjunction with possible hidden material defects [7].

The heating of the extremity of the injector is made by heat exchange between the space in the combustion chamber and the extremity of the atomizer, where there are exhaust gases containing oxygen, carbon dioxide, nitrogen oxides, water vapors and other corrosive gases favoring the phenomena of oxidation and decarburization.

Carbon oxides can detach from the contact surface between the injector and atomizer, especially from the area of the intake hole and entering into the injection circuit, causing the destruction of the piston.

The metallographic analysis was performed with a Neophot 21 type metallographic microscope shown in the Figure 6.

The surface preparation of the injector body that is to be studied is performed using a laboratory grinding equipment shown in Figure 7.

Figure 6. Metallografic microscope

Figure 7. Equipment for preparing metallographic samples

A microscopic analysis of the sealing surface, at a magnification of 1575x, without attacking the surface, in order to identify any cracks, tear or other defects that can not be seen with the naked eye was conducted in the first phase. The results of this analysis are shown in Figure 8. This stage of the study could not reveal any defects in any of the four injector bodies.
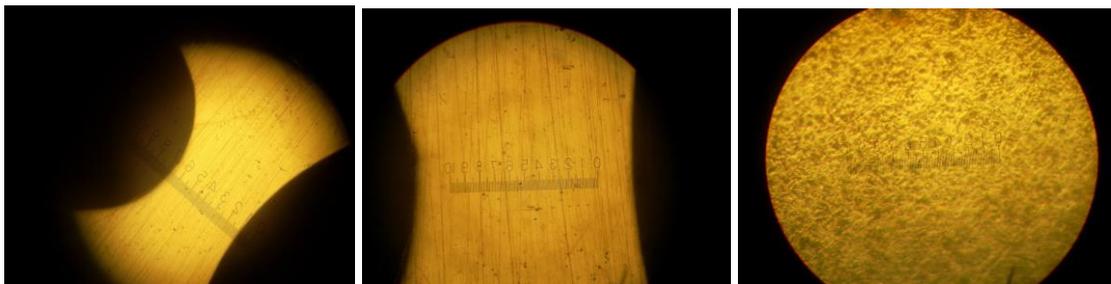
Figure 8. The structure of the material without attacking the analyzed surface

The microscopic structure was evidenced by attacking the analyzed surface with Nital reagent in the area of the intake holes, in the next stage of the research. We chose the intake holes whereas the highest stress appears there during the operation of the injector, due to the high pressure and the cavitation phenomenon which may occur. The results of this phase of the research are presented in the images in Figure 9.
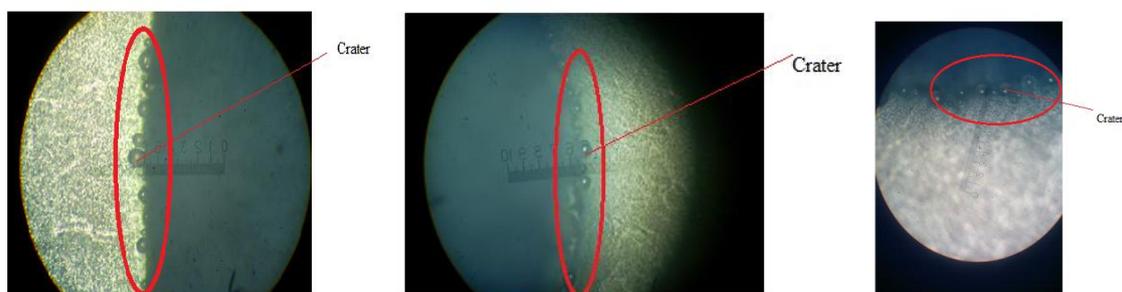

Figure 9. Highlighting the craters appeared around the intake holes

The presence of craters in the area of the intake hole was revealed by metallographic analysis. Therefore, a simple microscopic analysis which is usually done in the event of repair / refurbishing of the injectors is not sufficient.

4. Interpretation of the results

It was found that, the roughness obtained in the manufacturing process was maintained after one operation cycle (injector body 1 and 4). The restoration of the flatness of the sealing surface was attempted using sandpaper placed on a flat surface, in this way affecting the roughness of that surface, at the injection bodies 2 and 3. The hardness of the sealing surface between the injector body and the atomizer does not change after one operation cycle; therefore, based on this criterion, the body of the injector can be used in the remanufacturing process of the injector. The appearance of some craters in the area of the intake holes leads to loss of tightness between the body of the injector and the atomizer.

The sealing surface of the injector body should be brought back to the initial parameters, for the remanufacturing purposes. In this regard, it is recommended that the remanufacturing technology of the injector to provide the lapping operation of the sealing surface of the body. Lapping is a metal cutting operation for obtaining a flat, low roughness surface, using a process of removal of metal particles from a surface by mechanical or mechanical-chemical methods, using free, abrasive, very fine grains mixed into a viscous mass.

5. Conclusions

An appropriate technology should be outlined, depending on the type of the injector and the type of defects that occur during the exploitation process, before starting the process of the injector remanufacturing.

The stage of checking the injector parts under the remanufacturing process is essential, and the metallographic checking of the sealing surface should not miss

In this research we did not measure the dimensions of the craters highlighted by metallographic analysis.

Corroborating the research results with data from the companies which are carrying out injectors repair or refurbishing activities, we can say that during exploitation, due to the aggressive operating conditions (high temperature and pressure) and the cavitation phenomenon, a erosion process takes place at the intake hole area, which leads to the appearance of those craters that affect the sealing between the injector body and atomizer.

Based on the presented research results, we may conclude that the processing of the front surface of the injector body is required, so that to obtain an injector having the same operation characteristics of an injector manufactured as new, through the remanufacturing process.

The mentioned surface processing would be performed on a depth that would lead to the elimination of any craters. This requirement imposes a metallographic study by the means of an electronic microscope that allows measuring the depth of the appeared craters.

References

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