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DESTRUCTION OF A CAST IRON CYLINDER HEAD IN OPERATION AND AFTER WELDING RECOVERY

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Abstract: The subject of this study is cast iron cylinder head of a diesel engine with about 240,000 kilometers run. Results indicated a decrease of the tensile strength in the areas of combustion chambers as compared to the sections away from them. After recovery by welding with an iron-nickel electrodes, the decrease in strength in the field of combustion was noticeable - 20-30%. During operation there was evidence of cracks and corrosion in depth, which further impeded the recovery process. Finally, the formation of numerous pores on the bottom of the weld pool in the area of the combustion chamber was found.

Keywords: cylinder head, welding, corrosion, destruction

INTRODUCTION

The recovery is one of the main components of the process of reproduction which determines the full life cycle of machines. The efficiency of product manufacturing depends largely on this process and it is therefore necessary to choose an appropriate details recovery technology.

Cast iron is widely used as a construction material, featuring a good casting properties and low coefficient of linear expansion, high durability and workability.

The widespread use of cast iron parts in the automotive, agricultural and lifting transport equipment and damaging them during the operation process creates the need for their recovery, in order to reduce the cost of replacement of the parts with new ones. The recovery through welding and hard-facing of worn and damaged cast iron parts, due to the construction and physical-chemical properties of iron, is still difficult.

Rapid cooling of the molten metal in the surfacing zone, as well as combustion of silicon contributes to the bleaching of the cast iron, which hampers its processing with cutting tools.

Consequently, the low plasticity of the cast iron in uneven heating and cooling may form cracks in the welding seam itself and in area around the seam. The low melting temperature and the rapid transfer of cast iron from solid to liquid state and back hinders the complete exit of the gases from the seam, resulting in pore formation.

There are many methods and technologies for the recovery of cast iron parts of the automotive transport equipment, which give sufficient reliability for the operation of the renovated details [2,5,8]. The possibilities for modifying the surface allow to increase wear resistance by introducing alloying elements in the deposited zone. Yet much difficulty represents the restoration of cast iron cylinder heads due to the need to obtain hermetic compound with sufficiently high strength and at the same time workability by cutting.

This study presents the results of the tests on samples of cast iron cylinder head of a car Opel Omega 2.3 TD with around 240,000 *km* run.

METHODOLOGY OF THE EXPERIMENT

Samples taken from the combustion chamber (Figure 1) and from the place with the least heat load (a side wall of the first cylinder) were tested. The thickness of the walls, where the samples were taken from, was identical, in order to avoid the influence of the scale factor on the structure and casting properties.

Hard facing and welding of samples were carried out with electrodes ENiFe produced by Elektrodi JSC, Ihtiman. The electrodes have the following chemical composition: C - 1%, Ni - 53%, Fe – 46%. Before hard facing and welding of the samples, the electrodes were heated to 150o C for 1 hour to remove hydration water.

Metallographic and fracture graphic studies were implemented using microscope Neophot 32. Microhardness was measured using the method of Vickers on a PMT-3 setting with a 50-gram load.

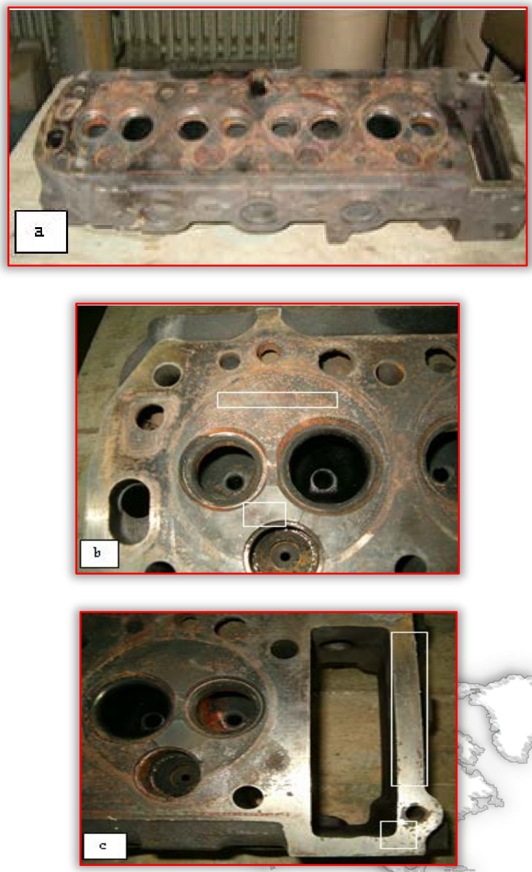

Figure 1. Cast iron cylinder head of a car Opel Omega 2.3 TD with the place of the samples

Samples for the tensile test had rectangular cross section with dimensions 6.8 x 7.1 mm. The welded samples were prepared for welding in X shape. During welding they were clamped to avoid distortions. The final dimensions were received by grinding. The tensile test was conducted on a universal testing machine until samples' destruction. Hardness was measured by Brinell's method under standard test conditions.

RESULTS AND DISCUSSION

During details repair determining the chemical composition of the details is not always economically feasible. That is why determining the cast iron type was performed by examining its microstructure and mechanical characteristics. Microstructural base material of the cylinder head was cast iron with lamellar graphite Fig. 2 with Brinell hardness 195-200 HB.

The tensile strength of the samples taken from the combustion chamber was Rm = 185 ÷ 200 MPa and those on the outside wall - Rm = 220 MPa. The metal ferrite-pearlite matrix had predominantly pearlite structural component. Modification of the structure was observed in the combustion chamber due to the beginnings of graphitization of carbon from the cementite. It was a consequence of the increased diffusion capacity of the carbon at high temperatures, the combustion chamber material was subjected Fig. 3.

Figure 2. Microstructure of the base material of the cylinder head

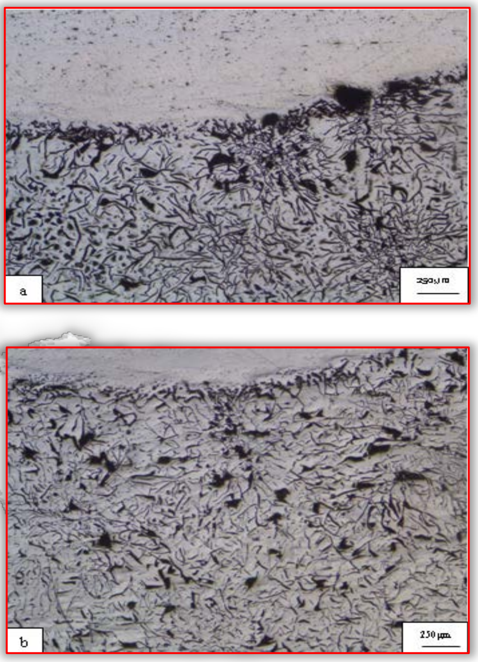

Figure 3. Microstructure after welding of cylinder head in the combustion chamber – a) and the base material – b)

As it is known, graphite inclusions in the cast iron reduce tensile strength and ductility. In this case, the increase in their number and their effect as stress concentrators, lead to reduced tensile strength of the cast iron after the impact of high temperatures and aggressive environments. The presence of defects (corrosion of the material in depth and cracks) further decreased the strength - Fig. 4 and Fig. 5. The reasons for the occurrence of corrosion of the combustion chamber material were the high temperatures of the combustion gases and the oxidizing environment in the combustion process.

Corrosion processes occurred at grain boundaries and at the most intensive border between the graphite and metal matrix. Due to the cyclicality of engine operation and the continuous change of the gas phase temperature - from 360 to 2200 ° C, the material was subjected to prolonged heat fatigue [3,4,7]. It caused the appearance of microcracks and their development in depth until the connection of the fuel space with the water space in the cylinder head. From the continuous observations of details with similar defectiveness it was found their predominant generation and development in two main areas: first, at places where the combustion process was most intensive (pre-chamber - inlet valve); and second, at places with sharp edges, smallest section and relatively low cooling (between the valve seats)[1,3,9].

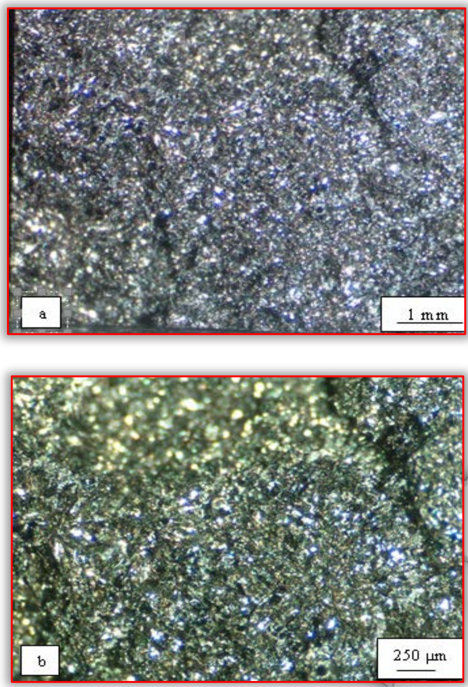

Figure 4. Fracture surface of cylinder head in the combustion chamber after tensile testing

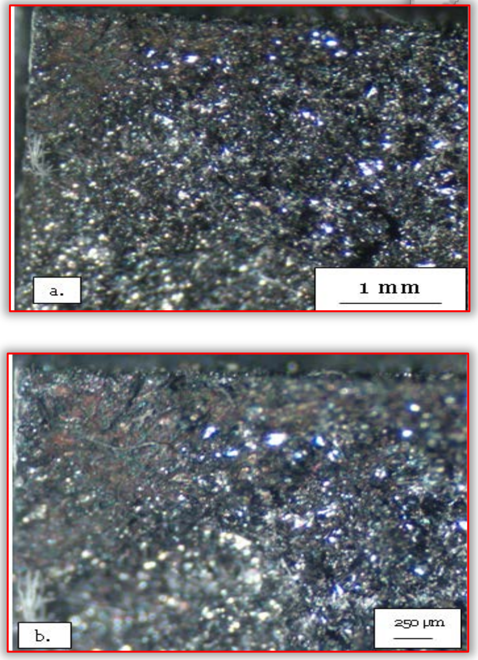

Figure 5. Fracture surface and corrosion of cylinder head in the combustion chamber after tensile testing

During operation the main cause of damage to the details was the stress of tension arising from the non-free change of the workpiece size in the presence of a temperature gradient between its parts. As a result of the heat significant local extensions of the detail took place, and this happened at a time when the volume of the cold detail remained constant due to the low thermal conductivity of cast iron. This lead to the formation of internal stresses. Their accumulation lead to the formation of cracks during detail operation. Some major differences between the samples were identified during the analysis of tensile testing fractures. Microcracks had been created during operation in the cast iron that was subjected to prolonged thermal and oxidative stress. With time the microcracks had developed into macrocracks with growth direction from the surface of the material into its depth Fig. 4a and b. The reasons for the cracks' occurrence and growth were the above-mentioned corrosive processes, thermal fatigue, low silicate fatigue, as well as the high pressures which, under extreme conditions, reaches 0.8-0.9 MPa.

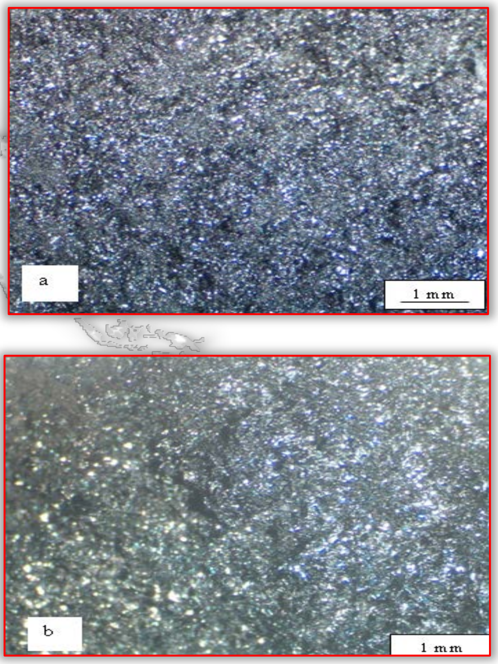

Figure 6. Fracture surface of cylinder head from the wall a) and the combustion chamber b) after tensile testing

Probably the spread of the cracks affects the vibrations in the engine. The material on the cleft surface was highly oxidized and the characteristic yellow-brown colour is observed in fig. 5 a) and b). The destruction of the material during the tensile testing continued along these microcracks. The fractures of the samples of the material, which was not subjected to thermal and oxidative stress, lack cracks and oxidation in depth - Fig. 6a.

After the welding of the samples, the differences in the tensile strength increased. In all specimens the destruction in tensile testing occurred in the heat affected zone. The decreased strength of the welded samples may be explained by the presence of many defects and the occurrence of brittle phases in the transition zone and the heat affected zone. Furthermore, the presence of oxides in depth creates prerequisites for cavities of the welded joint as depicted on Fig. 7 c.

Comparing the stresses at which the destruction of the welded samples of the wall and the combustion chamber occurred, a difference of 20-30% was observed. This was mainly due to increased porosity on the bottom of the weld pool compared with the samples from the wall.

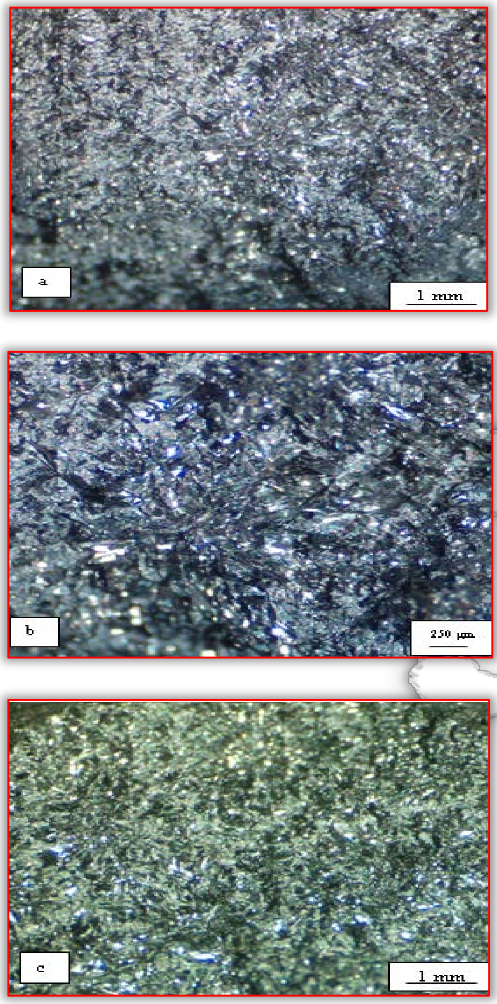

Figure 7. Fracture surface of cylinder head from the combustion chamber after tensile testing

CONCLUSION

As a result of the combustion process, irreversible changes occur in the structure and strength of the material of the cast iron subjected to thermal and oxidative deterioration. These changes have a negative influence on subsequent recovery by welding, strength and density of the welded joint cannot be ensured. For these reasons, it is difficult to ensure long-term operation recovered by welding with an iron-nickel electrodes, cast iron cylinder heads.

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