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COMPREHENSIVE IMPROVEMENT OF THE SURFACE QUALITY OF THE DIESEL ENGINE PISTON

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Preliminary Note – Prethodno priopćenje

An important requirement for the material for pistons concerns its parameters at different temperatures of piston operation at different ambient temperatures. The study uses penetration tests in quality control of diesel engine pistons used in passenger cars. The purpose of the tests was to determine, with the use of traditional quality management tools, the sources of incompatibility of castings detected in eddy current testing. The aim of the analysis was to reduce the number of non-compliant products or to eliminate them altogether.

Key words: diesel engine piston, eddy current tests, metallographic tests, quality control, quality management tools

INTRODUCTION

Ensuring proper quality of manufactured products determines the necessity of eliminating elements with non-conformity of both surface and sub-surface [1, 2, 3, 4, 5, 6]. An effective method of detecting defects and imperfections in structural materials or in the finished product and preventing it from being put into service may be the use of non-destructive testing in production quality control systems. Such tests are a set of methods allowing to determine the physical condition - the quality of the tested products - without causing any changes in their functional properties.

The type of non-destructive testing particularly suitable for diagnostics in the production process or during the operation of the product are tests classified in the category of electromagnetic tests [7-9].

Eddy current tests (ET)

Electromagnetic induction, which is the induction of current in a closed electrical circuit due to the action of an alternating magnetic field, is the basic phenomenon that is used in eddy current testing. The eddy currents induced in the material under investigation induce their own magnetic field, which, according to the Lenz rule, is directed in the opposite direction to the exciting field. The magnetic field strength generated by eddy currents depends on the electromagnetic properties of the product area to be tested (relative permeability and electrical conductivity). All changes in the analyzed material, such as: change of structure, change of hardness, discontinuities, affect the value of electromagnetic parameters, and thus the value of eddy current intensity and induced magnetic field. Diagnostics of electromagnetic field and amplitude changes as well as phase shift of voltage and current makes it possible to assess the condition of the tested product area [10-14].

ANALYSIS

Alloy B2 characteristics

The research was conducted on pistons made of B2 alloy (AlSiCuMgNi alloy), which is an eutectic aluminum alloy with silicon designed for pistons for diesel and petrol engines used in light vehicles [15]. Chemical composition of the alloy B2, as well as physical and mechanical properties can be found in the literature, e. g. [16-19].

Purpose of the study

The purpose of the tests is to diagnose, using the eddy current method, the condition of the combustion chamber surface in the diesel engine piston. Identification of the sources of non-conformity of castings and, ultimately, by means of quality management techniques, the reduction of the presence of non-conforming products or their complete elimination.

Subject of the tests

In order to assess the possibility of detecting internal inconsistencies in the material of the product, experimental tests have been carried out. The subject of the research was a piston intended for diesel engine, used in passenger cars, manufactured by Toyota. Drawing of the diesel engine piston is shown in Figure 1. The pis-

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tons are produced in one of the plants in the south of Poland.

Methods of the tests

Detection of incompatibilities in the combustion chamber is carried out using the Foerster Statograph Ds 6. 440 with built-in manipulation systems.

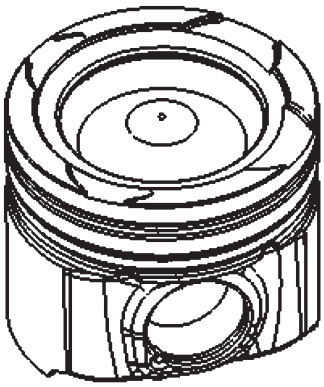

Figure 1 Subject of the tests - diesel engine piston model [20]

These systems control the Kukka Kr 16 manipulator arm, equipped with Siemens Sinumerick D640/i software, positioning and rotating the test piston and positioning and rotating the surface testing probe. Thanks to the use of a rotary sensing system, the probe spins at high speed right next to the surface of the piston combustion chamber. A new track is scanned every time the probe is rotated. During the test, the results are visualized in real time.

The device is equipped with eddy current control system according to EN 12084 using digital techniques [21].

RESULTS OF ANALYSIS

The obtained results of eddy current testing of the diesel piston combustion chamber are shown in Figure 2.

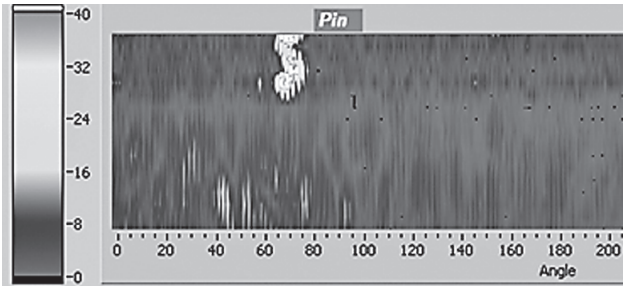

Figure 2 Diesel piston combustion chamber eddy current test result

The results indicated the presence of material discontinuities in the piston combustion chamber. As a result, samples were taken from discontinuities and metallographic surveys were carried out. The results of observations of metallographic deposits are presented in Figure 3.

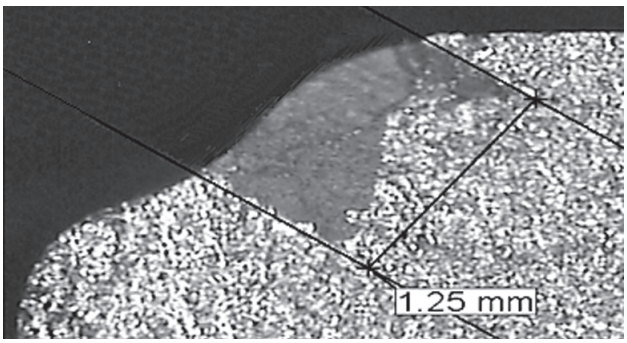

Figure 3 Result of metallographic examination of the discontinuity area

Metallographic tests showed the presence of discontinuities in the combustion chamber in the form of 1,25 mm oxide. The localized discontinuity exceeds the maximum permissible size according to TS1E-010-011-0000, which disqualifies the piston. The eddy current testing method is an effective tool for assessing the quality of non-destructive testing, which can be used to assess the quality of pistons.

PROPOSAL FOR IMPROVEMENT

Data for testing came from batches of products ending in 2018 and were collected for a period of 5 months.

The proposed instrument for testing the defectiveness of the product is the analysis of the causes of non-compliance with the help of the Ishikawa diagram. Figure 4 shows the factors influencing the formation of one of the most important piston incompatibilities for the company - the presence of oxides in the piston casting. The most important factor influencing the formation of oxides in the piston casting was singled out in the case of the casting method. In this group the most important was the low temperature of alloy B2 during mould pouring.

Due to the frequent presence of incompatibilities in castings and the desire to further analyse the problem, actions have been taken in order to identify the reasons for the problem. The 5WHY method was used for this purpose (Figure 5).

The analysis (Figure 5) shows that the main reason for flooding the mould with an alloy of inappropriate temperature is a new, inexperienced employee. The machine was operated by a newly hired employee who incorrectly read the instruction manual. His too little experience and lack of training was the main cause of the incompatibility.

CONCLUSION

In this work an analysis was carried out together with a diagnostic test of the diesel engine piston by eddy current testing. The purpose of the test was to control the quality of the product and to verify the usefulness of the control and diagnostic test in the production process.

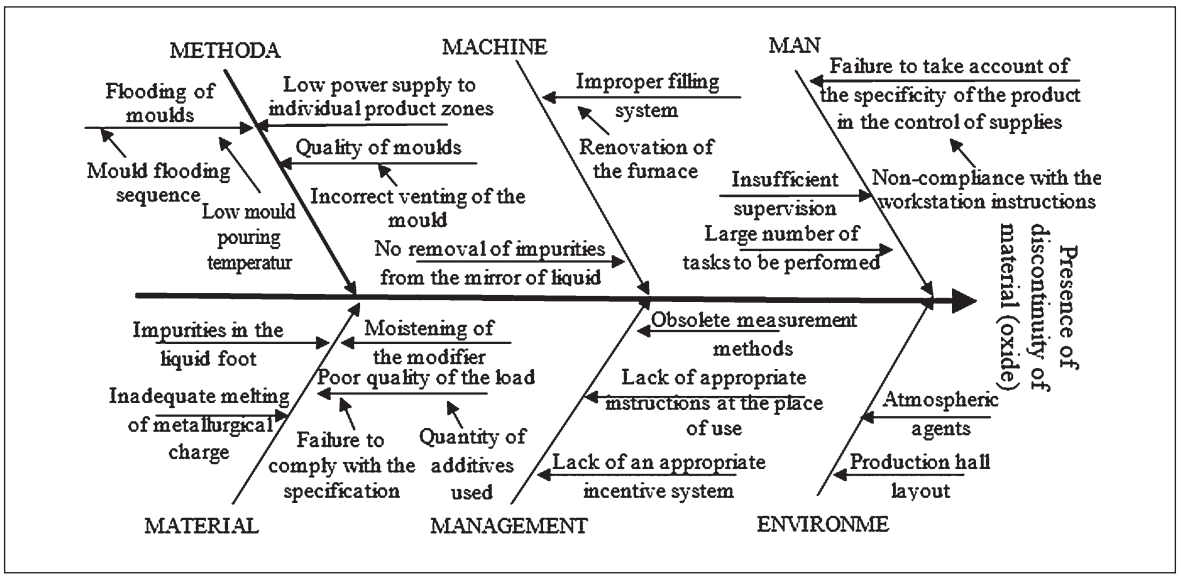

Figure 4 Ishikawa diagram of the causes of the presence of oxides in piston castings

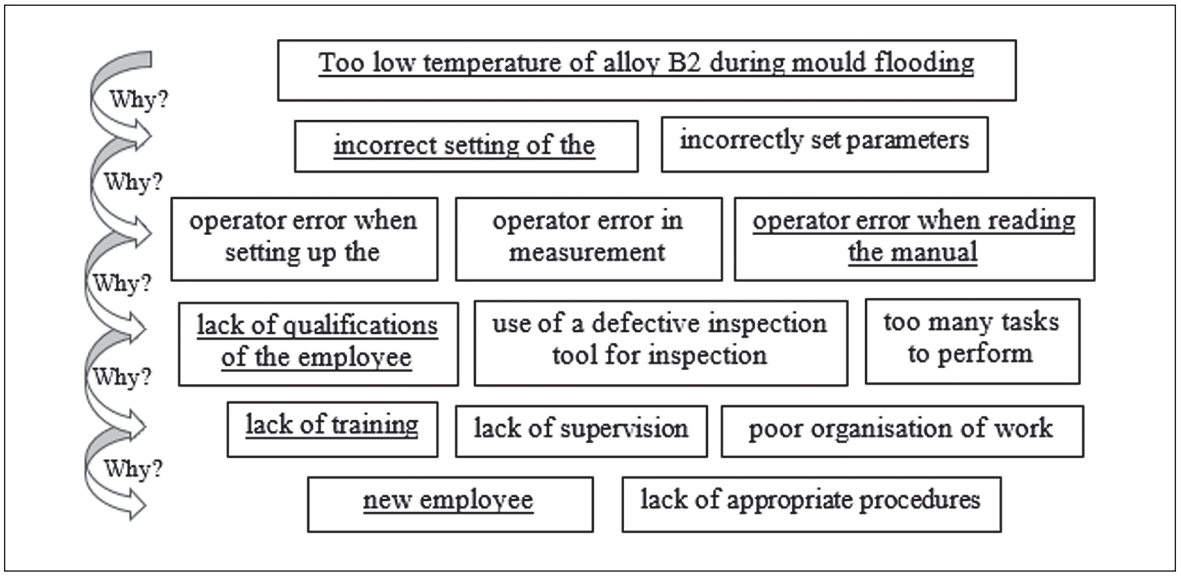

Figure 5 The course of the 5 WHY method for non-conformity of the product - too low pouring temperature of alloy B2

Non destructive eddy current testing was used to locate discontinuity in the combustion chamber area - casting defect (oxide) and its presence was confirmed by metalloghophysical testing. The occurrence of discontinuities disqualifies the piston. In order to prioritize certain phenomena and identify problematic zones, a diagram of causes and effects of Ishikawa was made. A 5WHY analysis was also carried out, according to which the key cause of non-compliance was the lack of experience of the new employee. The company should also pay attention to improving the qualifications of employees through training.

The eddy current method used in combination with quality management methods largely complement each other. The proposed combination may be a component of methods supporting quality management processes. The traditional Ishikawa Diagram technique can be extremely useful by incorporating it into the analysis cycle, in which the output of one tool is the input to the next quality management method (5 WHY).

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