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ISSN 0543-5846
METABK 55(3) 465-468 (2016)
UDC – UDK 621.791.052.004.67:620.179.1=111

RESEARCH OF THE ULTRASONIC TESTING PARTS RECONDITIONED BY WELDING

Received – Primljeno: 2015-10-01
Accepted – Prihvaćeno: 2016-02-25
Preliminary Note – Prethodno priopćenje

The paper presents the results obtained following the nondestructive ultrasonic testing of crankpin shaft of a crankshaft that were reconditioned by welding. After the ultrasonic testing, the reconditioned samples were cut and subjected to visual testing and microstructure examination. When the results obtained following the nondestructive tests were analyzed, it was observed that the ultrasonic nondestructive testing method is an efficient way to determine the conformity of the areas that were reconditioned by welding.

Key words: welding, reconditioning, crankshaft, ultrasonic testing

INTRODUCTION

Reconditioning by welding is an important technological process used in various industrial areas. Following the reconditioning by welding, nonconformities may occur in the reconditioned area, which may lead to the deterioration of the welded product during the operation. When the active elements, used in the automotive industry, are in operation, the wear process may occur due to the degradation of the surface layers of the friction couples elements, which is characterized either by material loss, or by the plastic deformation of the contact surfaces. If equipment parts are damaged during operation, they can be replaced or reconditioned so that they can be brought to their initial dimensional value so that they can regain their initial mechanical properties. If the replacement of the parts is expensive, they are reconditioned [1].

In the industrial practice concerning the crankshafts used in the automotive industry, it was observed that the most frequent defects occur in the main shafts and the crankpin shafts. If the defects (e.g. crack) are not identified in time and the respective zones are not repaired, this could lead to pretty significant effects such as breakdown of the car and even worse to the loss of human lives [1]. The efficiency of the technological process of reconstruction primarily depends on the behavior of the base layer - filler layer torque and how it connects marginal homogeneity between atoms of the two materials in the contact area and near the contact area [2]. The welding process is considered a special process as it is a production process that generates outputs that cannot be measured, monitored, or verified until it's too late, that is after the resulted products have been used. In order to prevent output deficiencies, these special processes must be validated so as to prove that they can generate the planned results [3].

The ultrasonic testing is a nondestructive method used for discovering nonconformities that may occur in the welded joint area. The process of ultrasonic nondestructive testing determines the existence of flaws, discontinuities, leaks, contamination or imperfections in materials, components or assemblies without impairing the integrity or function of the inspected component [4 - 6]. The process can also be utilized for real-time monitoring during manufacturing, measurement of physical properties such as hardness and internal stress, inspection of assemblies for tolerances, alignment, and periodic in-service monitoring of flaw/damage growth in order to determine the maintenance requirements and to assure the reliability and continued safe operation of the part [7].

EXPERIMENTAL PROCEDURE

The main purpose of the experimental procedure was the analysis of the nondestructive testing possibility of reconditioned parts as well as the validation of the testing method for the studied case. A series of 4 welded samples was performed in order to validate the welding process and the ultrasonic nondestructive testing method of reconditioned area. The reconditioning by welding of the crankpin shaft was carried out with the help of two frequently used reconditioning processes: shielded metal arc welding (SMAW) and tungsten inert gas (TIG).

For the experimental part there was used - for both processes - an inverter as welding power source (Caddy TIG 2200i-ESAB). The polarities used in this experi-

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mental procedure were direct current negative polarity (DC -) for TIG and direct current positive polarity (DC +) for SMAW. The values of the main welding parameters were: welding current intensity Is_1 = 100 / A (for the marginal layers of the crankpin shaft) and Is_2 = 140 / A (for the facing of the crankpin shaft surface), arc voltage Ua = 12 - 14 / V for TIG and Ua = 20 - 24 / V for SMAW [8 - 10].

Following the interpretation of the results obtained after the chemical composition analysis of the base material conducted with the Foundry Master equipment, it was concluded that the base material is a cast iron, type EN-GJS-600-3 according to DIN EN 1564:2012, whose chemical composition is presented in Table 1, while the mechanical characteristics are indicated in Table 2. [11]. Considering the nature of the base material and the working conditions of the crankshaft, there was chosen to use the following filler materials: E10-UM-60-CZ electrode with the diameter of 3,25 mm and the metal rod type Ø 3,2 mm WSG-3GZ-5-T – these materials were recommended by the producer for such depositing applications [12].

Table 1 **Chemical composition of the base material according to EN-GJS-600-3 / wt / %**

Base material	C	Si	Mn	P	S
EN-GJS-600-3	2,5 - 3,6	1,8- 2,8	0,3- 0,7	≤ 0,08	≤ 0,02

Table 2 **Material properties measured on test pieces according to DIN EN 1563:2012**

Material designation	Tensile strength R_m / N/mm²	Proof stress $R_{p0,2}$ / N/mm²	Elongation A / %	Micro-structure
EN-GJS-600-3	600	370	3	Pearlite/ ferrite

Before starting the welding process, the areas, which are strongly requested, were machined in order to remove the worn surface layer.

The resulted welded samples are presented in Figure 1.

After the welded samples were executed, they were subjected to cylindrical grinding in order to bring the sample to the nominal operation dimensions and to enable the execution of the nondestructive tests.

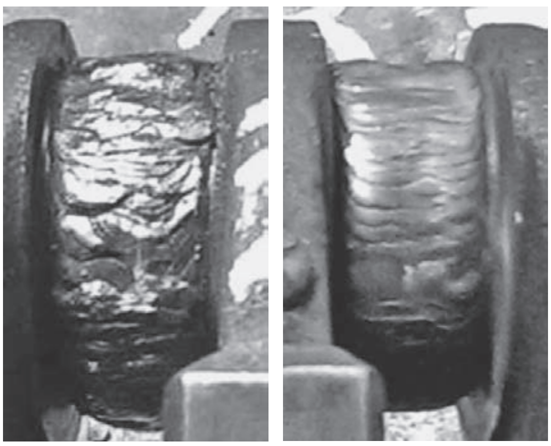
After the samples were processed, they were initially subjected to visual testing followed by an ultrasonic nondestructive test. In order to make the process more efficient, the testing was conducted on a semi-automated ultrasonic nondestructive stand.

The ultrasonic testing was conducted by using two testing methods: the “A – scan” method is a visualization method of the ultrasonic material testing results where the x-axis represents the time (microseconds) and the y-axis represents the amplitude of the reflection i.e. how strongly the sound is reflected. A-scan presentation displays the amount of received ultrasonic energy as a function of time. A-scan is a spot-by-spot testing method; the “B – scan” method is the display method during which the measurement of the acoustic parameters is carried out after a line on the surface of the sample, and the results are presented in coordinates – normal cross-section through the sample on testing the direction of wave amplitude [13, 14].

In order to identify the possible defects that may occur, the samples were examined by using the A-scan method in eight distinct areas (Figure 2 a) and by using the B-scan method on four directions on the circumference of the crankpin shaft (Figure 2 b).

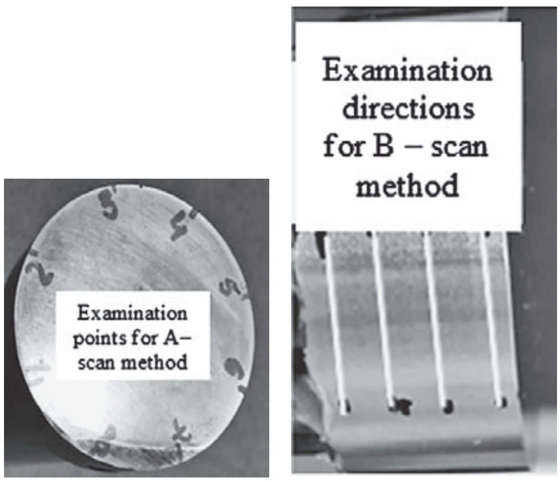
For the validation of the obtained results following the ultrasonic testing, the samples were cut on cross direction, in the area of the ultrasonic testing lines. After cutting, the samples were subjected to a visual testing and microstructure examination process of the interest areas in order to make a comparison to the obtained results following the nondestructive testing process.

In order to perform the metallographic analysis, the samples were cut using a special cutting system at low cutting speeds with continuous cooling so as to prevent the analyzed zone from being affected by the heat. After the cutting process, the samples were cleaned from impurities and subjected to a polishing process using metallographic paper with different granulations; finally, the samples were subjected to polishing with abrasive diamond paste [1].



a) b)

Figure 1 Depositing on the areas of the crankpin shaft; a – using SMAW, b – using TIG



a) b)

Figure 2 Ultrasonic testing areas: a - A-scan, b - B-scan

RESULTS AND DISCUSSIONS

The obtained results, following the ultrasonic testing, are presented in Figure 3 (A-scan testing method) and Figure 4 (B-scan testing method).

From the analysis of Figures 3 a and 3 b there could be observed that the higher resonance (Figure 3 b) was obtained following the reconditioning by SMAW and it has two components: the first component corresponds to a higher reflection coefficient, in which case the acoustic impedance of the transmitted wave environment is higher than the acoustic impedance of the incident wave environment; the second component of this signal is caused by the reflection on the nonconformities, existing at the connection area between the deposited material and the base material.

Following the analysis of Figures 4 a and 4 b, in case of B-scan testing there was discovered that the occurred discontinuities are distributed on the entire circumference of the SMAW welded sample.

For the validation of the ultrasonic testing method, the welded samples were subjected to the destructive testing so as to allow access to the welded joint areas. After cutting, the parts were subjected to micrographic examinations (Figure 5). Following the analysis of the samples presented in Figure 5, there was discovered that no nonconformities occurred for the TIG sample (Figure 5. a). For the SMAW sample (Figure 5. b) we

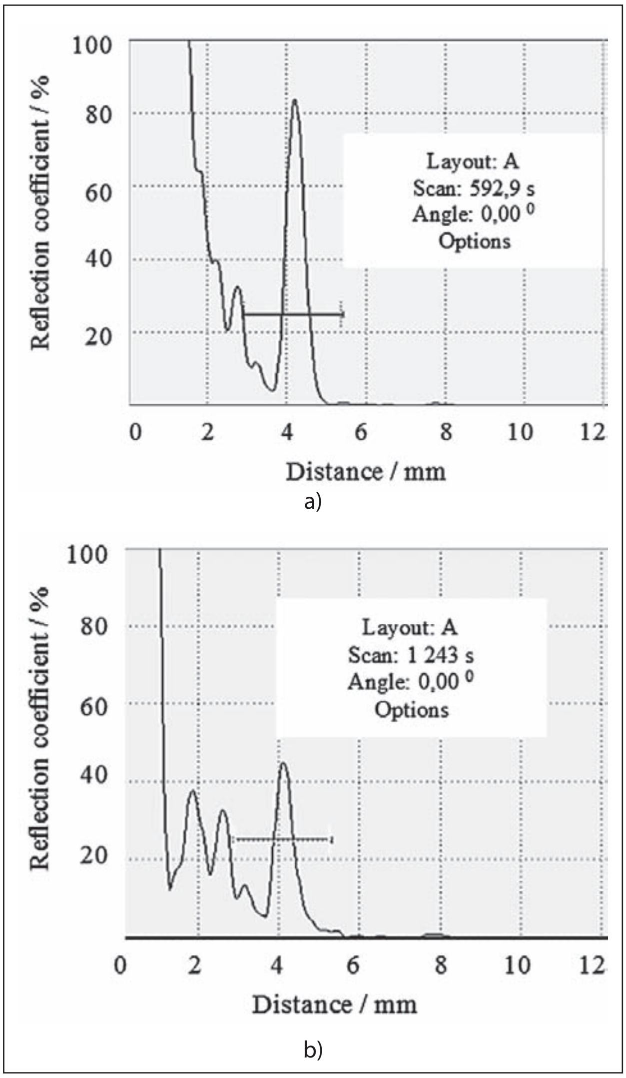


Figure 3 Results obtained following the A-scan testing method: a – conforming sample (TIG), b – nonconforming sample (SMAW).

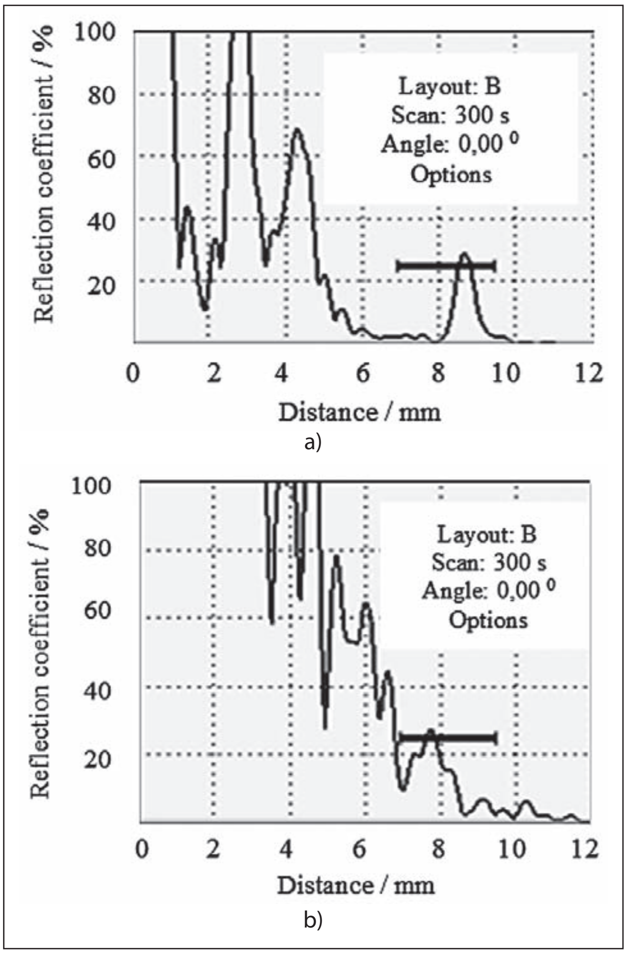


Figure 4 Results obtained following the B-scan testing method: a – conforming sample (TIG), b – nonconforming sample (SMAW)

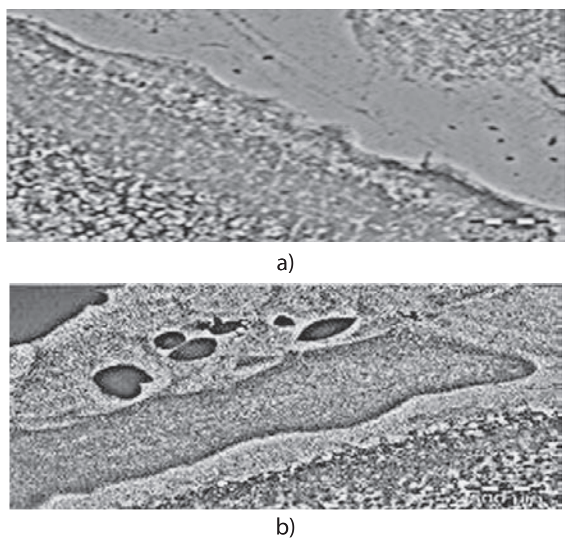


Figure 5 Results obtained following the micrographic examination: a – conforming sample (TIG sample), b – nonconforming sample (SMAW sample).

noticed that the joined parts did not mix, so nonconformities like pores and cracks occurred in the connecting area of the parts.

CONCLUSIONS

Following the analysis of the obtained results , the following conclusions can be drawn:

- the quality of the reconditioning by welding depends to a great extent on the employed welding technology;
- when using an improper reconditioning technology (as in the case of SMAW) nonconformities such as pores and cracks may occur in the reconditioned area;
- by comparing the results obtained following the nondestructive testing to the ones obtained following the destructive testing, there can be observed that the ultrasonic testing method can detect the possible defects occurred during the reconditioning by welding;
- the analysis of the results presented in the paper led to the validation of the ultrasonic testing method concerning the reconditioning by welding.

Acknowledgement

The work has been funded by the Sectorial Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/132397.

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Note: The responsible translator for the English language is Rontescu Aurora Mădălina, Bucharest, Romania