**O. CHIVU, C. RONTESCU, D.T. CICIC, G. BĂLAN**

ISSN 0543-5846
METABK 55(1) 55-58 (2016)
UDC – UDK 621.791.052.167.2/3:629.119:620.18=111

# THE EFFECTS OF RECONDITIONING BY WELDING OF CRANKSHAFTS IN AUTOMOTIVE INDUSTRY

Received – Primljeno: 2015-02-11
Accepted – Prihvaćeno: 2015-07-20
Preliminary Note – Prethodno priopćenje

The reconditioning by welding process applied to the crankshafts in the automotive industry can be carried out by using various reconditioning technologies that are based on different welding parameters and processes. This paper presents a comparison between Shielded Metal Arc Welding (SMAW) and Welding in Gas (WIG) reconditioning processes from the perspective of the metallographic analysis conducted on the zones resulted after the depositing process. The heat cycle resulted during the two welding processes influences in a different manner the welding behavior of the base material due to the occurrence of micro-structural changes in the main zones of the deposit. The occurred structural changes may influence to a significant degree the operating behavior of the structures repaired by welding.

*Key words:* welding, SMAW, WIG, reconditioning, metallographic structure

## INTRODUCTION

During the working processes of the active elements used in the automotive industry the wear process may occur due to the degradation of the surface layers of the elements of the friction couples, 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 or so that they can regain their initial mechanical properties. If the replacement of the parts is expensive, they are reconditioned [1].

During the reconditioning by welding process it is necessary to take into account the fact that the heat cycle the base material and the deposited material are subject to (heating – melting – cooling – solidification) determines changes in the chemical composition caused by the dilution phenomenon as well as changes in the functional and technological properties, as they are the result of the structural modification in the three distinct zones (base material, heat affected zone and deposited material). Following the reconditioning process the reconditioned element needs to have the proper dimension and the required properties according to the respective duty cycle [2, 3].

The use of the direct current welding process with reverse or direct polarity influences the geometric characteristics of the beads as well as process dilution. In certain situations, such as weld deposits, the penetration should be as shallow as possible and the heat affected zone of the bead should be reduced [4].

In the industrial practice concerning the crankshafts used in the automotive industry it was observed that the most frequent defects occur in the main journals and the crankpin journals (Figure 1). 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. Considering the rather high price of a new crankshaft and after the strength and economic calculations are made, in most cases the people in charge make the decision to repair the non-conformity zone. Welding is the technological reconditioning process that ensures short repair time but also the convenient quality of the deposited layer [5].

## EXPERIMENTAL PROCEDURE

Due to the improper working conditions and to the occurrence of the wear phenomenon, the crankshaft in Figure 1 went through dimensional changes at the level of the crankpin journals. The reconditioning process consists of the depositing of the affected zones so that - following the machining process - the newly obtained zones respect the dimensions and tolerances of the shop drawing of the product, as well as the functional properties of the base material.

The main purpose of the experimental procedure is to analyze the reconditioning by welding possibilities of the crankshafts used in the automotive industry, by using the SMAW and WIG process, based on the results obtained following the metallographic analysis in the interest zones of the deposit.

---

O. Chivu, C. Rontescu, D.T. Cicic, Polytechnic University of Bucharest, Romania, G. Bălan, Romanian-German University of Sibiu, Romania

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.

Considering the nature of the base material and the working conditions of the crankshaft, we chose 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.

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/mm$^2$ | Proof stress $R_{p0,2}$ / N/mm$^2$ | Elongation $A$ / % | Microstructure |
|---|---|---|---|---|
| EN-GJS-600-3 | 600 | 370 | 3 | Pearlite/ ferrite |

For the experimental part, for both processes, we used an inverter based welding power source (Caddy TIG 2200i - ESAB). The polarities used in this experimental procedure were direct current negative polarity (DC-) for WIG and direct current positive polarity (DC+) for SMAW. The values of the main welding parameters were: welding current intensity $I_{s1}$ = 100 / A (for the marginal layers of the crankpin journals) and $I_{s2}$ = 140 / A (for the facing of the crankpin journal surface), arc voltage $U_a$ = 12 - 14 / V for WIG and $U_a$ = 20 - 24 / V for SMAW.

Before starting the welding process, the zones to be hard faced were machined in order to remove the worn surface layer. For the reconditioning of the crankpin journals it is necessary to take into account the applied welding order so that the value of the stresses occurred during the welding process is minimal. For these purposes it is recommended to carry out the depositing process applied to the journals in the following order: 1 - 3 - 4 - 2 (Figure 1).

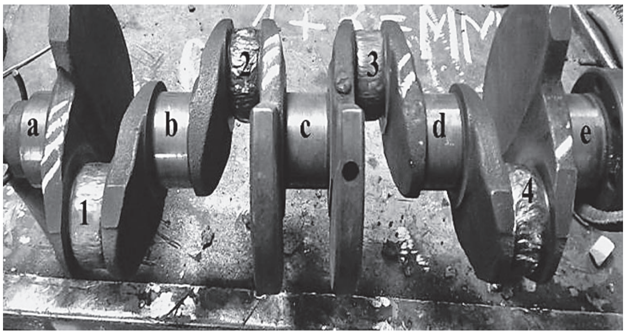
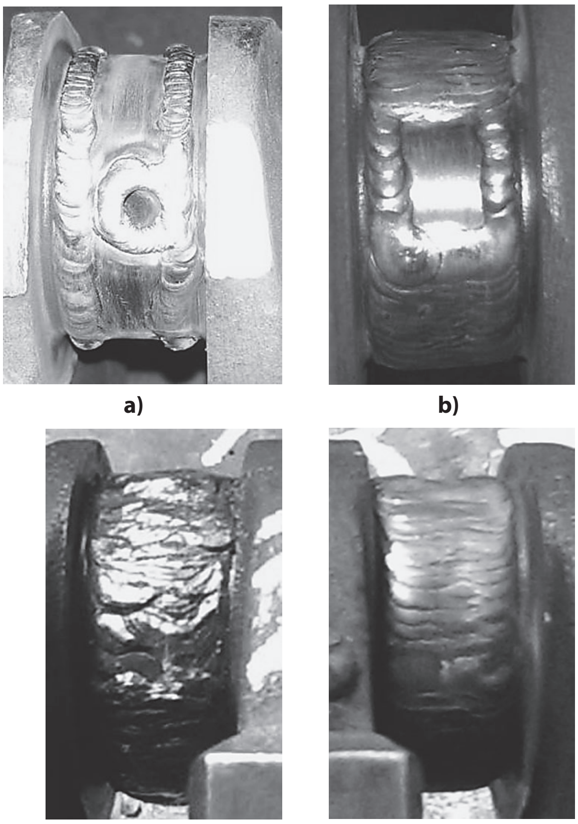


**Figure 1** Crankshaft parts: a, b, c, d, e – main journals; 1, 2, 3, 4 – crankpin journals.


a) b)

c) d)

**Figure 2** Depositing the initial beads on the marginal areas of the crankpin journal (a, b) and on the rest of the crankpin journal area (c – using SMAW, d – using WIG)

Furthermore, in order to avoid the occurrence of deformations during the welding process and to limit the waving width of the arc during the depositing process, we resorted to the initial depositing of the marginal layers on the crankpin journal and on the marginal zones of the crankpin oil holes as shown in Figure 2. The depositing process applied to each crankpin journal was made by dividing it into sectors and alternately depositing material on the antipodal zones [6, 7].

After the depositing 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 subject to a polishing process using metallographic paper with different granulations; finally, the samples were subject to polishing with abrasive diamond paste [8, 9].

## RESULTS AND DISCUSSIONS

In order to analyze as accurately as possible the influence of the reconditioning processes on the structure we made two samples for each discussed welding method.

After it obtained the samples, they were subject to non-destructive testing by using the visual method and the penetrating liquid method. No non-conformities resulted following the test.

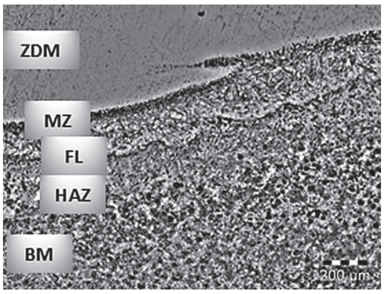
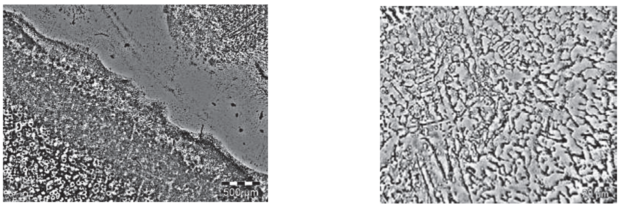


**Figure 3** Structure of the characteristic zones of the depositing process; BM – base material; HAZ – heat affected zone; FL – fusion line; MZ – mixed zone; ZDM – zone of deposited material

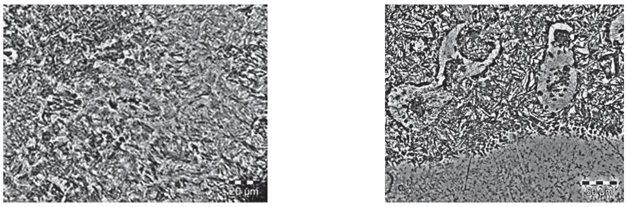
After properly processing the obtained samples we analyzed the micrographic structures obtained in the interest zones of the reconditioning by welding: base material (BM), the heat affected zone (HAZ), the fusion line (FL), mixed zone (MZ) as well as in the zone of deposited material (ZDM), zones presented in Figure 3.

The obtained metallographic structures are presented in Figure 4 for the WIG samples and in Figure 5 for the SMAW sample.

The analysis of the structures presented in Figure 4 reveals that the metallographic structure of the 4 analyzed zones is a different one, starting from a ferrite-pearlite structure corresponding to the base material (Figure 4, a) and getting to a structure made of troostite and residual cementite corresponding to the deposited material (Figure 4, b). Furthermore, when we analyze Figure 4, c respectively Figure 4, d we observe that in the material layers corresponding to the fusion line (FL), but also to the heat affected zone (HAZ) there is a series of precipitated metal carbides that are close to the fusion line, which affect the mechanical properties of the material in these layers, specially the hardness.

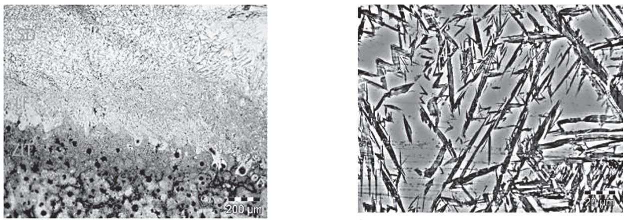


a. All the zones x 50 b. ZDM x 200

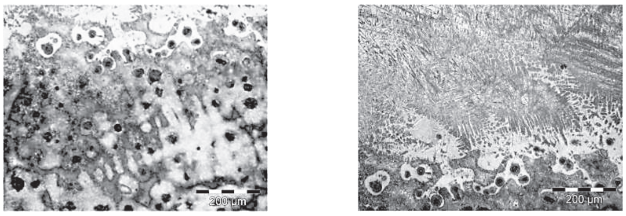


c. HAZ x 200 d. FL x 200

**Figure 4** Microscopic images obtained when using WIG



a. All zones x 100 b. ZDM x 200



c. HAZ x 200 d. FL x 200

**Figure 5** Microscopic images obtained when using SMAW

From the analysis of the structures presented in Figure 5 we can observe that the metallographic structure of the 4 analyzed zones, just as in the WIG case, is a different structure starting from the ferrite-pearlite structure of the base material and ending with a structure made of austenite and residual cementite, martensite as well as a great amount of Cr metal carbides corresponding to the deposited material. As far as the reconditioning by SMAW method is concerned, we can observe that the structure of the deposited material is mainly martensitic.

Furthermore, Figure 5 and Figure 6 reveals that the adherence between the base and the filler material is good, as well as that there are small nonconformities similar to porosities in the deposited material.

## CONCLUSION

Following the analysis of the obtained results we can draw the following conclusions:

- the SMAW and WIG methods can be applied when reconditioning the crankshafts in the automotive industry;
- the depositing method of the layers and the used procedure have a significant influence on the quality of the deposited layers;
- the analysis of the metallographic structure shows that in the deposited material layer we obtain a homogenous metallographic structure that only has small defects like porosities and corresponds to the increased resistance to wear of the crankshafts;
- when applying the depositing process by SMAW, in the deposited layer and in HAZ we obtain martensitic microstructures, which can lead to a significant hardening process in these zones as well as to the occurrence of certain non-conformities like cracks during operation;
- the reconditioning by welding process offers the possibility of a better control of the heat input into the reconditioned parts such as obtaining metallographic microstructures with lower risk of defects occurring during the operation.

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/134398.

## REFERENCES

[1] G. M. Dumitru, C. Radu, B. Dumitru, Recondiţionarea şi repararea produselor, Editura Printech, Bucharest, 2010, 111-115.
[2] D. Dobrotă, Structural modifications which appear in the area of welds of welded structures made of st 52.3 steel, Metalurgija 53 (2012) 2, 179-182.
[3] D. Dobrotă, Gh. Amza, Ultrasound influence on materials structure in parts reconditioned by welding with ultrasonic field, Metalurgija 52 (2013) 1, 87-89.
[4] C. Rontescu, D. T. Cicic, G. Iacobescu, C. Gh. Amza, The influence of the welding current polarity on the geometric configuration of the bead, Advanced Materials Research 1088 (2015), 797-801.
[5] D. T. Cicic, Gh. Solomon, G. Iacobescu, C. Rontescu - Method of establishing the optimum technique for reconditioning by welding, taking into account the consumption of filler metals and electrical power, U.P.B. Sci. Bull. Series D, 73 (2011) 1, 85-98.
[6] ***Esab Welding Handbook, eighth edition – Consumables for manual and automatic welding
[7] Information on http://www.esabna.com
[8] Information on http://www.twi-global.com
[9] Information on http://www.brazing.com/

**Note:** The responsible translator for English language is Rontescu Aurora Madalina, Bucharest, Romania, official Translator certified by the Ministry of Justice