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THE INFLUENCE OF THE RECONDITIONING BY WELDING PROCESSES ON THE HARDNESS OF CRANKSHAFTS IN THE AUTOMOTIVE INDUSTRY

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One of the aims of our modern society is to reduce the car maintenance costs. The part that most frequently breaks down in the engine block is the crankshaft - in the main journal and crankpin journal areas. This paper presents the effects of welding inert-gas (WIG) and shielded metal arc welding (SMAW) on the hardness of the material in the zones subject to reconditioning, more specifically the hardness values in the deposited material layer, in the fusion line and the heat-affected zone (HAZ).

Key words: welding, WIG, SMAW, reconditioning, hardness, crankshaft

INTRODUCTION

The most important components of the internal combustion engines of automobiles are four separate parts [1]:

- cylinder head cover;
- cylinder head;
- the engine block (the block is also called the crankcase or cylinder block);
- oil bath.

The delimitation of the engine block from the cylinder head and the oil bath is made using the cylinder head gasket, respectively the gasket that seals the oil bath. We should remember that, depending on the number and arrangement of the cylinders, the engine block can be made up of two separate parts called lower and upper half-crankcase. From the mechanical point of view, the crankshaft is the most strained part of the engine, since it takes on - through the piston and the connecting rod - the forces resulted from the pressure created in the cylinder. The crankshaft is the part that takes on the forces in the connecting rod, summarizes the mechanical works created in cylinders and transmits the resulting energy to the wheels through the transmission gear and sets in motion some auxiliary systems of the engine .

The elements composing a crankshaft for the engine are, as shown in Figure 1:

- main journals (through these journals the shaft rests on the engine block, in the bearings), crankpin journals (the connecting rods are attached to them);
- webs (they link the main journals to the crankpin journals; they often contain crankshaft counterweights as well);
- crankshaft ends (the flywheel is mounted on one end and the camshaft drive sprocket is mounted on the other end);

The flywheel ensures the regular rotation of the crankshaft for each engine operating cycle. Because the engine torque is not continuous, as it is produced only during the recoil of each cylinder, it is necessary to use a flywheel. The lubricating oil circuit inside the crankshaft is provided through [2]:

- oil ways in the main journals;
- balancing holes in the counterweights;
- oil ways in the crankpin journals.

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. If the defects 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

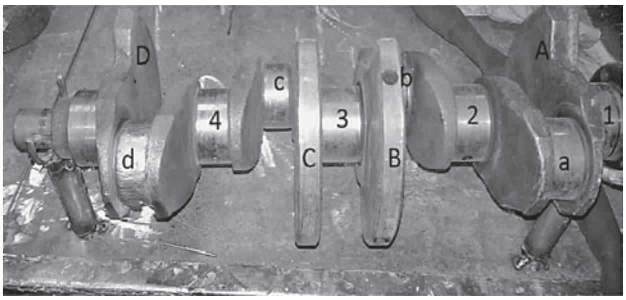

Figure 1 Crankshaft Items: 1, 2, 3, 4 – main journals, a, b, c, d, e – crankpin journals; A, B, C, D - counterweights

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short repair time but also the convenient quality of the deposited layer. The present paper suggests a technique and technology that can be applied to repair the crankshafts in the crankpin journals area. It is the prolongation of the investigation of reconditioning by welding of crankshafts [2, 3].

EXPERIMENTAL PROCEDURE

Due to the fact that the brand of the base material was unknown, 5 tests were conducted to determine the chemical composition with the help of the Foundry Master equipment. Following the interpretation of the results it emerged that the base material is a type of cast iron, EN-GJS-600-3 according to DIN EN 1564: 2012 [3, 4], whose chemical composition is presented in Table 1 and the mechanical characteristics are shown in Table 2.

Table 1 **The standardized chemical composition of the base material of 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 parts 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 / %	Micro-structure
EN-GJS-600-3	600	370	3	Pearlite/ ferrite

Taking into account the intended purpose of the crankshaft, it was decided to use an E10-UM-60-CZ electrode with the diameter of ∅ 3,25 / mm, and metal rod type ∅ 3,2 / mm WSG-3GZ-5-T, whose chemical compositions are shown in Table 3 [5].

The electrode brand and the metal rod wire were chosen based on the following criteria:

– the hardness of the welding bead: 59 - 63 / HRC;
– the obtained structure: austenite with large Cr carbides;
– the resistance to abrasion - very good;
– the resistance to temperature - 700 / ^{0}C;
– the resistance to corrosion – very good;
– machinability – by polishing.

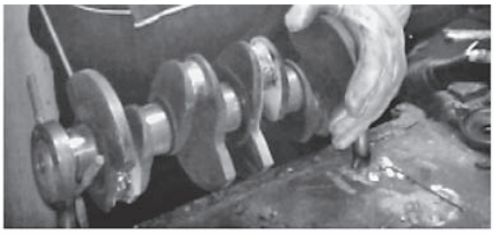
For the experimental part, for both processes, we used an inverter based welding power source (CaddyTIG 2200i - ESAB). The polarities used in this experimental procedure were direct current negative polarity (DC-) for WIG and direct current positive polarity (DC+) for SMAW. The values of the main welding 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.

Table 3 **The standardized chemical composition of the filler material / %**

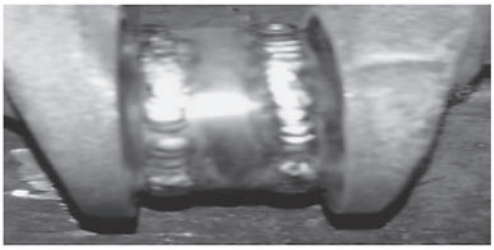
Filler material	C	Si	Mn	Cr
DIN 8555 - E10-UM-60-CZ	4,5	0,8	1,6	33
WSG-3GZ-5-T	0,38	1,0	0,4	5,0

The reconditioning technology consisted of: [6, 7]:

– visual testing and penetrating liquids testing of the crankpin journals area;
– machining of the surface subject to the depositing process until metallic luster is obtained;
– placing the crankshaft into the device, Figure 2a;
– depositing layers with a width of 3 - 4 / mm to the area where the crankpin journal intersects with the



a.



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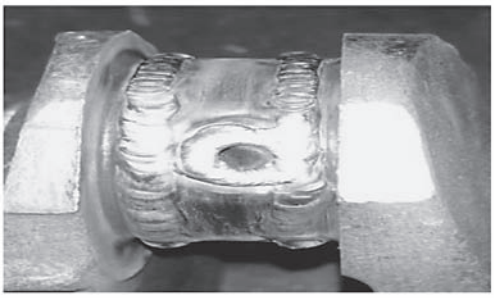

c.

d.

Figure 2 The stages of the reconditioning process by shielded metal arc welding, a - placing the crankshaft into the device , b - depositing the layers with a width of 3 – 4 / mm at the intersection point between the crankpin journal and counterweights, c - depositing a layer around the oil way on the crankpin journal; d - depositing a layer by waving

counterweights Figure 2b and around the oil way on the crankpin journal, Figure 2c , with the parameters mentioned above for both processes [8 - 10];
– depositing the layer by waving with the mentioned parameters, Figure 2d;
– non-destructive visual and penetrating liquid testing of the deposited areas;
– cutting and machining the samples for the macro and micro-structural examination and the hardness examination;
– retrieving macro-structural and micro-structural images and hardness measurement;

RESULTS

It should be noted that for the validation of the experimental results 2 sets of coded samples were carried out for each of the two processes.

After it obtained the samples, they were subject to non-destructive visual and penetrating liquid testing methods. No nonconformities emerged after the testing. From the obtained reconditioned parts samples were taken in order to be subject to micro-structural and macro-structural examinations and to the hardness HV0.2 testing method. All examinations were performed in an accredited laboratory, LAMET. After the hardness was measured with NAMICON 400 DTS, was obtained the values shown in Table 4 for sample P1 and in Table 5 for sample P2 (for SMAW) , in Table 6 for sample P3 and Table 7 for sample P4 (for WIG). It is worth mentioning that the measurement of the hardness was done on 4 directions materialized by 4 diameters that divide the samples into 4 equal parts. Furthermore, for each of the four directions, the hardness values were measured in 4 distinct areas, namely: DL - deposited layer; FL - fusion line (mixing zone); HAZ – heat affected zone; BM - base material. The hardness measurement had to be made in four different directions, but also in the four areas in order to be able to analyze the homogeneity of the material from the point of view of its mechanical properties and especially of hardness.

For each of the four measurement areas a hardness measurement was performed in 5 distinct areas so as to allow the determination of a medium hardness of each area.

Table 4 **Hardness values for test sample P1 / HV0.2 (SMAW)**

Zone	No.	Direction			
		No. 1	No. 2	No. 3	No. 4
DL	1	621	534	534	523
	2	583	560	545	543
	3	436	489	524	514
	4	549	530	535	516
	5	506	529	524	546
FL	6	726	800	820	812
	7	801	805	789	790
	8	831	799	816	820
	9	793	827	824	818
	10	826	787	815	818
HAZ	11	712	689	734	743
	12	765	723	732	730
	13	687	716	737	714
	14	714	745	732	745
	15	782	727	711	716
BM	16	284	287	291	299
	17	265	290	280	287
	18	295	399	299	278
	19	268	267	265	296
	20	206	270	270	278

Table 5 **Hardness values for test sample P2 / HV0.2 (SMAW)**

Zone	No.	Direction			
		No. 1	No. 2	No. 3	No. 4
DL	1	573	479	490	515
	2	491	475	502	521
	3	533	502	533	526
	4	513	526	531	554
	5	494	480	521	502
FL	6	720	689	690	701
	7	677	690	696	714
	8	682	720	699	721
	9	633	673	670	705
	10	745	625	635	709
HAZ	11	608	667	669	689
	12	612	662	662	690
	13	628	663	675	692
	14	592	665	650	681
	15	651	612	620	684
BM	16	383	354	325	333
	17	344	365	335	345
	18	382	345	334	325
	19	368	324	327	327
	20	354	330	345	334

Table 6 **Hardness values for test sample P3 / HV0.2 (WIG)**

Zone	No.	Direction			
		No. 1	No. 2	No. 3	No. 4
DL	1	426	465	470	500
	2	468	463	490	503
	3	455	487	455	510
	4	471	465	488	498
	5	526	483	445	499
FL	6	674	649	700	703
	7	559	670	688	699
	8	659	702	694	697
	9	713	673	654	665
	10	673	671	701	648
HAZ	11	367	488	498	478
	12	467	514	500	480
	13	439	522	478	499
	14	471	497	496	487
	15	462	486	498	465
BM	16	228	278	280	250
	17	275	248	238	233
	18	305	265	235	235
	19	321	233	239	243
	20	230	230	240	241

Table 7 **Hardness values for test sample P4 / HV0.2 (WIG)**

Zone	No.	Direction			
		No. 1	No. 2	No. 3	No. 4
DL	1	504	529	526	514
	2	577	561	562	523
	3	570	492	507	514
	4	504	455	498	499
	5	522	512	499	499
FL	6	677	662	664	657
	7	699	689	675	673
	8	689	743	679	645
	9	605	756	685	689
	10	691	708	699	685
HAZ	11	674	637	613	620
	12	678	687	621	619
	13	579	679	624	621
	14	549	623	641	631
	15	596	642	635	623
BM	16	306	333	306	310
	17	326	316	327	312
	18	365	342	345	321
	19	326	319	313	342
	20	383	324	321	345

From the analysis of the data in Tables 4, 5, 6 and 7 it can see that the tendency is similar for all 4 directions and thus the maximum hardness was obtained on the fusion line and the minimum hardness in the base material.

CONCLUSION

From the conducted researched we can draw the following conclusions:

– both welding processes can be applied when reconditioning crankshafts in the automotive industry;
– the hardness values depend on the used reconditioning process and parameters;
– the layer depositing method influences to a significant degree the quality of the deposited layers;
– the analysis of the hardness demonstrates that when using reconditioning by welding are obtained much higher hardness values in the deposited material layer than in the base material layer;
– the layer of deposited material has a much higher hardness value than the base material, and this is beneficial because we get an increase in the resistance to wear of the crankpin of the crankshafts through keeping the tenacity of the base material;
– the maximum hardness values were obtained when was used SMAW;
– due to the high hardness values obtained when applying SMAW, certain defects such as cracks may occur during operation.

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