The Combined Effect of Chemical Elements on the Properties of a Layer Deposited by Welding

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Layers deposited by welding ensure the corrosion resistance, resistance to wear, as well as high mechanical properties. Improving basic material characteristics can be done by adding alloying elements which, as a result of carrying out the welding process and chemical reactions from the bath of molten metal chemical compounds different from those of the basic matrix (e.g. chromium carbides) are formed. In this paper are presented the effects of chemical elements from the base material and filler material on some properties of the layers obtained through filing/depositing by welding procedure, denoted as the Tungsten Inert Gas (TIG) procedure. The effects of the chemical elements are indicated on the hardness, the structure and the chemical composition.

Keywords: welding, hardness, structure, deposited layers, TIG procedure

At the moment, it is looking for a range of solutions for materials which have superior properties and allowing their operation in much more drastic conditions of corrosion, high pressures and temperatures, etc., or for restoring damaged parts.

In a situation where all the product would be accomplished from these materials with superior features, its price would be very high and, therefore, solutions have been sought of establishing deposit layers, which correspond to the demands of running on cheaper support materials [1].

One of the technological operations often used for superficial layers with enhancement, is the welding operation. Depositing by welding can be performed by several welding processes such as manual welding with coated electrode (MMA) welding with release into the environment of inert gas (MIG) or active gas (MAG) with fusible electrode or welding in the inert gas environment with non-fusible electrode (TIG), welding under submerged flux (SAF) [2,3].

The welding procedure which gives a superior quality to the deposited layers is TIG process as the filler material melts due to arcing but is not transferred through it.

The new filler materials, with a high chromium content, provide superior mechanical properties of the material support but also a high corrosion protection by creating a layer of oxide on the surface of contact. Using specific filler materials, chromium and oxygen elements form a thick layer of chromium oxide (passive layer), which prevents the continuation of in-depth reaction [4-9]. The passive protective layer formation, as well as its hardness, primarily depends on the chemical composition of the alloy of steel. A series of reactions of passive layer formation occurring in the bath of the molten metal and in the surface area can be performed, as equations (1-5) show [10-11]:

$$4Cr + 3O_2 \rightarrow 2Cr_2O_3 \quad (1)$$

$$Cr_2O_3 + 3\ CrO_3 \rightarrow 5\ CrO_2 + O_2 \quad (2)$$

$$2Cr + O_2 \rightarrow 2CrO \quad (3)$$

$$C + O \rightarrow CO \quad (4)$$

$$2Cr + 3CO \rightarrow Cr_2O_3 + 3C \quad (5)$$

The characteristic related areas/zones to a deposition by welding are shown schematically in figure 1.

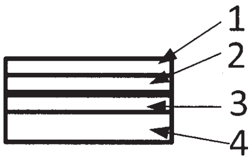

Fig. 1. Characteristic related areas/ zones to depositions by welding: 1- zone of deposited material (SD), 2 mixed zones (ZA); 3-heat affected zone (ZIT); 4-base material (MB)

In this paper are presented the effects of chemical elements from the base material and filler material on some properties of the layers obtained through filing/depositing by welding procedure, denoted as the Tungsten Inert Gas (TIG) procedure.

Experimental part

In order to determine the combined effects of chemical elements from the base material and the filler material on the deposited layers, a series of welding experiments were performed, which consisted of depositing/filling method TIG of the timezones on a car's crankshaft where cracks were discovered in the non-destructive examinations.

The base material of the crankshaft is EN-GJS-600-3 cast iron, whose chemical composition is presented in table 1 [12], while the mechanical characteristics are indicated in table 2 [12].

The polarities used in experimental procedure, TIG welding, were direct current negative polarity (DC-). The

Table 1
CHEMICAL COMPOSITION OF THE BASE MATERIAL EN-GJS-600-3 ACCORDING TO [12]

Base material	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Fe [rest]
EN-GJS-600-3	2.5 - 3.6	1.8- 2.8	0.3- 0.7	≤ 0.08	≤ 0.02	rest

Table 2
MATERIAL PROPERTIES MEASURED ON TEST PIECES ACCORDING TO [12]

Material	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

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Table 3
THE STANDARDIZED CHEMICAL COMPOSITION OF THE FILLER MATERIAL / % [DIN 8555, 1978]

Filler material	C [%]	Si [%]	Mn [%]	Cr [%]
WSG-3GZ-5-T	0.38	1.0	0.4	5.0

values of the main welding parameters were: welding current intensities Is_1=100 A (for the marginal layers of the crankpin journals) and Is_2=140 A (for the facing of the crankpin journal surface), and the arc voltage U_a=12-14V.

The used refractory electrode was a tungsten carbide electrode WC20 (EN 26848), with the diameter of 3.2 mm. The used filler material was a metal rod with ϕ3.2mm WSG 3-GZ-5-T, according to DIN 8555 (chemical composition is presented in table 3), the filler material that is recommended by the producer for such applications.

After we obtained the samples, they were subject to non-destructive visual and penetrating liquid testing methods. No nonconformities emerged after the testing. Some samples from the obtained reconditioned parts were taken in order to be subject to micro-structural and macro-structural examinations and to the hardness HV0.2 measuring method.

The equipment used for hardness measurement was Shimatzu HMV 2T and for microscopic analysis we use the Olimpus GX 51.

For chemical analyses was used the spectrometer method with an Foundry-Master Spectrometer equipment.

After the welding 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 [12]. 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.

Results and discussions

After properly processing the obtained samples (fig. 2) we analyzed the micrographic structures obtained in the interest zones of the reconditioning by welding: base material (MB), the heat affected zone (ZIT), the fusion line (LF), mixed zone (ZA) as well as in the deposited material zone (SD), zones presented in figure 3. The obtained metallographic structures for each zone are presented in figure 4.

A visual image of the sample obtained after processing is shown in figure 2.

Fig. 2. Photo image of the resulting sample after welding and prepared for examinations in 1, 2, 3, 4 directions

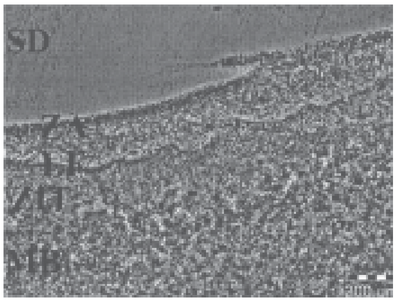

Fig. 3. Metallographic image of the structure of characteristic zones formed by welding (200x); MB- base material; ZIT – heat affected zone; LF – fusion line; ZA - mixed zone; SD – zone of deposited material

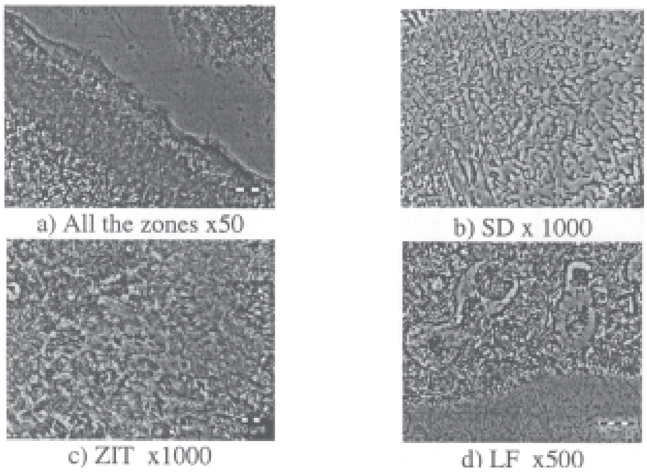

Fig. 4. Optical microscopy images obtained when using TIG

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 (fig. 4a) and getting to a structure made of troostite and residual cementite corresponding to the deposited material (fig. 4b). Furthermore, when were analyzed figure 4c and respectively figure 4d was observed that within the material layers corresponding to the fusion line (LF), but also to the heat affected zone (ZIT) there is a series of precipitated metal carbides that are close placed to the fusion line, which affect the mechanical properties of the material in these layers, specially the hardness.

After we have identified all the structures, the hardness values were measured in five distinct points, followed by determining the chemical composition in these 5 points for each zone.

The results obtained are shown as a summary in the tables 4-8.

Table 4
SUMMARY TABLE OF CHEMICAL COMPOSITION - MEASURING DIRECTION – 1

Zone	Chemical Elements [%] (medium values) rest Fe					
	C	Si	Mn	P	S	Cr
Basic Material (MB)	3.1	2.3	0.54	0.06	0.01	
Filler Material (MA)	0.38	1	0.4	-	-	5
Deposited Material (SD)	0.35	0.83	0.39	-	-	4.6
Mixing Zone Material (ZA)	0,924	1.26	0.428	0.012	0.002	4
Material of ZIT	2.79	2.07	0,486	0.054	0.009	0

Table 5
SUMMARY TABLE OF CHEMICAL COMPOSITION - MEASURING DIRECTION - 2

Zone	Chemical Elements [%] (medium values) rest Fe					
	C	Si	Mn	P	S	Cr
Basic Material (MB)	3.1	2.3	0.54	0.06	0.01	
Filler Material (MA)	0.38	1	0.4	-	-	5
Deposited Material (SD)	0.37	0.98	0.35	-	-	4.7
Mixing Zone Material (ZA)	0.65	1.13	0.41	0.01	0,00	4.50
Material of ZIT	2.95	2.19	0.51	0.06	0.01	0.00

Zone	Chemical Elements [%] (medium values) rest Fe					
	C	Si	Mn	P	S	Cr
Basic Material (MB)	3.1	2.3	0.54	0.06	0.01	
Filler Material (MA)	0.38	1	0.4	-	-	5
Deposited Material (SD)	0.37	0.98	0.35			4.6
Mixing Zone Material (ZA)	0.52	1.07	0.41	0.00	0.00	4.75
Material of ZIT	2.91	2.16	0.51	0.06	0.01	0.00

Table 6
SUMMARY TABLE OF CHEMICAL COMPOSITION - MEASURING DIRECTION – 3

Zone	Chemical Elements [%] (medium values) rest Fe					
	C	Si	Mn	P	S	Cr
Basic Material (MB)	3.1	2.3	0.54	0.06	0.01	
Filler Material (MA)	0.38	1	0.4	-	-	5
Deposited Material (SD)	0.37	0.97	0.38	-	-	4.6
Mixing Zone Material (ZA)	0.79	1.20	0.42	0.01	0.00	4.25
Material of ZIT	3.01	2.23	0.52	0.06	0.01	0.00

Table 7
SUMMARY TABLE OF CHEMICAL COMPOSITION - MEASURING DIRECTION - 4

Zone	HV 0.2 (on direction)			
	1	2	3	4
Basic Material (MB)	271	260	247	240
Deposited Material (SD)	470	473	470	502
Mixing Zone Material (ZA)	656	673	687	683
Material of ZITM	442	502	494	481

Table 8
SUMMARY TABLE OF HARDNESS VALUES

Based on the chemical analysis and hardness values in the selected measuring direction we can notice the followings:

- the welding process, performed in standard technological parameters, puts its mark on the chemical composition, on the resistance to wear and the mechanical properties for each zone/area individually;
- as a result of melting of the filler material, the percentages of the various chemical elements in it, are reduced in the deposited layer;
- due to the diffusion of certain chemical elements from the support layer to the deposited material and in reverse, it can be seen that the percentage values of chemical elements from the mixing area differ from those of the base material and the filler;

Conclusions

In order to obtain a certain percentage of a chemical element, the filler material should have a higher content of that element to compensate for losses incurred as a result of the welding process;

The depositing area/zone influences the chemical composition of the deposited layer.

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