SOME ASPECTS REGARDING THE MICROSTRUCTURAL AND MECHANICAL CHARACTERISTICS OF THE WELD DEPOSIT ON MICROALLOYED STEELS FOR DIES

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Lucrarea tratează analiza evoluţiei microstructurii şi microdurităţii materialului depus prin sudare cu electrozi înveliţi în cazul recondiţionării unor matriţe realizate din oţel bainitic microaliat, utilizate pentru deformarea plastică a materialelor compozite din fibre de sticlă sau a celor realizate din matrice polimerică ranforsate cu fibre de oţel. Noul tip de oţel microaliat cu Mo, V, B şi Al, utilizat pentru prelucrarea componentelor de automobile realizate din materiale compozite polimerice, necesită caracteristici foarte bune de rezistenţă mecanică şi tenacitate în timpul prelucrării la cald. Tehnica de reparare devine importantă în cazul acestor aplicaţii având în vedere preţul total al matriţei noi şi numărul foarte mare al ciclurilor de lucru. Pentru a obţine un metal depus fără fisuri, în cadrul regimului de recondiţionare, experimental, parametrii regimului termic au fost variaţi, după care s-a efectuat analiza microstructurală şi s-a măsurat microduritatea în zonele topite şi afectate termic.

The paper presents the analysis of the microstructural and microhardness evolution of the welded deposit that result after MMA welding in the case of reconditioned dies for plastic deformation that are carried out by micro alloyed bainitic steel, used for glass and steel fibers composite polymer plastic deformation. The new type of Mo, V, B and Al micro-alloyed steel, used for processing of the automobile's components made by polymer composite require very good characteristics of resistance and toughness during hot working. The repair technique becomes important for this application having in mind the total price of the new die and the high number of working cycles. In order to obtain a crack free weld metal, during the experimental reconditioning program the parameters of heating regime was varied, then metallographic analyze and microhardness measurements have done in the fusion and heat affected zones.

Keywords: micro alloyed steel, microstructure, wear, microhardness

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1. Introduction

One of common steel used for polymer hot processing of automobile components is the type 1.2738 (40CrMnNiMo8-6-4) according UNI EN ISO 4957. For fabrication of the massive die used in hot processing, mould and forged steel blooms with averages dimensions of 1x1x1.5 m are used. The material can be hot treated and heat processed for quenching, austenitization (840-850ºC) and tempering (550-600ºC) in order to obtain a value of average hardness situated in the range of 290-340 HV. One of the problems related of this steel is the inhomogeneous microstructure in the bulk of the material, which contain pearlite and bainite constituents, comparatively with those of the surface zone which contains tempered martensite and modified bainite [1].

Toughness values are very loss, measuring around 40 MPa/m and the transient temperature from ductile to fragile behaviour is only 270ºC (50% FATT), measured at the level of the sample surface, and 150ºC at sample's centre. For this reason the large pieces that are made of this steel are difficult to be heat processed, especially by quenching and welding [2, 3]. An optimized solution can be the use of a new micro-alloyed and heat treated steel, with chemical composition presented in table 1.

Table 1

Chemical composition of studied bainitic steels

Steel type	C [%]	Mn [%]	Ni [%]	Si [%]	Cr [%]	Mo [%]	V [%]	Nb [%]	B [%]	Al [%]
1.2738	0.35-0.45	1.3-1.6	0.9-1.2	0.2-0.4	1.8-2.1	0.15-0.25				
Micro alloyed	0.20-0.30	1.30-1.60	0.90-1.20	0.15-0.30	1.2-1.5	0.40-0.70	0.15	0.03-0.06	0.02-0.04	0.04-0.08

There are some chemical compositional differences of the micro-alloyed steels, comparatively with the classical steels, like the less values of carbon percent and the addition of micro alloying elements, like V, Nb, B and Al, used for uniform the microstructure and increase the microhardness. In order to forging some heat treatments are applied, like quenching from 950ºC in oil or water then tempering carried out at ±700ºC and maintaining time of approximately 60 minutes for each 25mm, followed by cooling with maximum velocity of 20ºC/h.

This heat treatment is followed by stress relief treatment at 550ºC and cooled with maximum velocity of 20ºC/h till 200ºC. The micro alloyed steel has a homogenous microstructure in bulk material, composed of constituents like upper and lower bainite, having the average hardness at the level of sample's surface of 360 HV, and of 320 HV in the bulk material [4, 5]. This alloy shows also difficulties at welding, the producer recommendations being for using the welding processes like MMA and TIG and preheating at 250 – 300 ºC, without specifying the appropriate consumables [6]. The main objective of this paper was to study two types of filler materials, with different contents of chromium, in order to obtain hardness values as close to those of the basic material.

2. Samples preparation

For the experimental program three samples made by micro alloyed steel with the dimensions of 120x47x23 mm numbered 1A, 3A, 5A has been used (fig. 1). On the each sample was deposited one weld pass using MMA process and different type of experimental electrodes: 5% Cr alloyed electrode (EI 58 H-SUDOTIM) and 1.5% Cr alloyed electrode (E8018-B2). The weld has been done using a welding power source LAW 320, with the same parameters values for both electrodes: welding current I_w = 150A, voltage U_w = 20V, welding time, $t_w \approx$ 60 second. Sample 5A was welded at room temperature using E8018-B2 electrode. The microscopic analyze was done using an INSPECT S SEM microscope and for microhardness measurements a Shimadzu Microhardness HMV 2T tester was used. The HV0.1 microhardness investigations (0.9807N and 10 second) were done both on transversal (OY) and longitudinal direction from the sample's surface (MZ – melting zone, HAZ 1, HAZ 2– heat affected zone) (fig. 2).

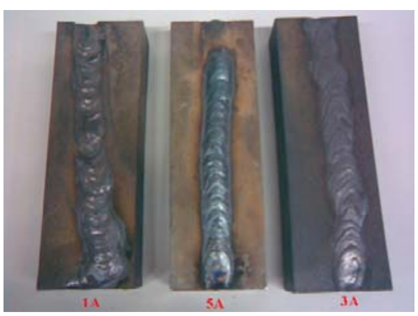


Fig. 1. Experimental welded samples

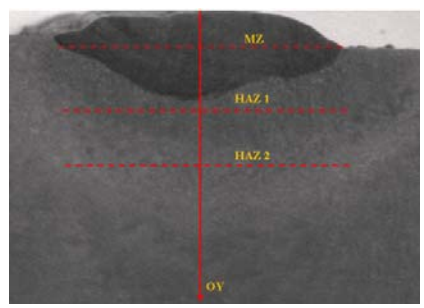


Fig. 2. The location of HV0.1/10 measurements: MZ – melting zone, HAZ – heat affected zone

Table 2

Samples filler material and heat treatments

Heat Processing	Sample 1A	Sample 3A	Sample 5A
Filler material	EI 58 H electrode 5% Cr	EI 58 H electrode 5%Cr	E8018-B2 electrode 1,5%Cr
Heat treatment	-	Preheated at 350ºC	-

Both 1A and 3A samples was welded using E I 58 H electrode, with the difference that the sample 3A has been preheated at 350ºC, over the maximum temperature recommended by the steel producer, using an Nabertherm LT 15/12/P320 furnace (table 2).

3. Experimental results

3.1. Microhardness

For the sample 1A, into the melted zone (MZ) has been obtained an average microhardness value of 623 $HV_{0.1}$, then in the first HAZ zone (HAZ1) the microhardness decrease at 516 $HV_{0.1}$, followed by the second HAZ zone with 477 $HV_{0.1}$. In the basic metal, at 15mm distance from the surface on the axe OY position has been obtained average microhardness of 360-370 $HV_{0.1}$ (fig. 3).

In the welded zone (MZ) the microhardness average value for the sample 3A was 677 $HV_{0.1}$, while in the first HAZ zone (HAZ1) was 537$HV_{0.1}$, and in the second HAZ zone (HAZ2) was 464$HV_{0.1}$. The basic material pre-heated at average 350ºC temperature, shows an increasing of the microhardness comparatively with the original steel 380-390$HV_{0.1}$. This microhardness increasing can be observed even in welded zone and HAZ comparatively with the sample 1A (fig. 4).

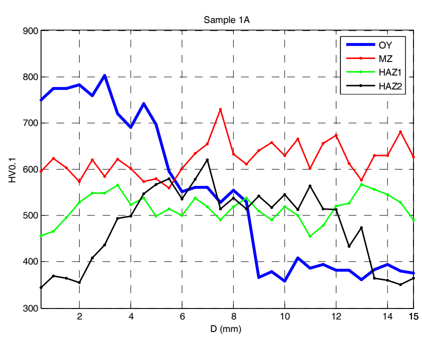


Fig. 3. Microhardness evolution for sample 1A

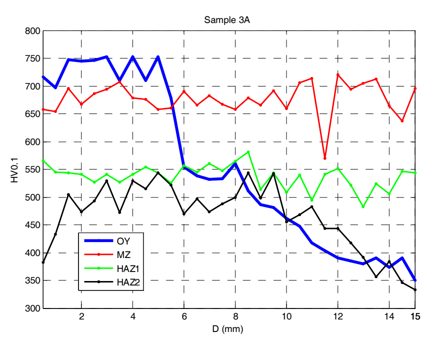


Fig. 4. Microhardness evolution for sample 3A

At the sample 5A, welded with different type of electrode (alloyed with maximum 0.12%C, 0.7 – 0.9%Mn, maximum 0.80%Si, 1 – 1.50%Cr, 0.45 – 0.65%Mo, maximum 0.02%S and maximum 0.015%P) the microhardness value in the melted zone was only 380$HV_{0.1}$, in first HAZ zone was 468$HV_{0.1}$ and in second HAZ zone was 434$HV_{0.1}$. In this case, the basic material microhardness value don't change very much, being 370$HV_{0.1}$ (fig. 5). The microhardness measurements carried out on the OY direction outlines the evolution of hardness in the three different areas of the weld deposit, i.e. melted zone, HAZ situated near the fusion line (positioned at 500 microns from the fusion line) and HAZ 2, positioned at 1.5 mm from the fusion line. The lower hardness values achieved in ZIT2 zone are included some areas closer to the basic material that has not suffer the hardening effects (table 3).

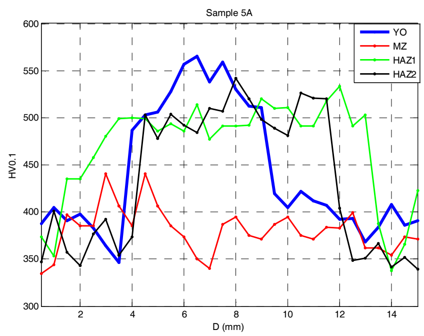


Fig.5. Microhardness evolution for the sample 5A

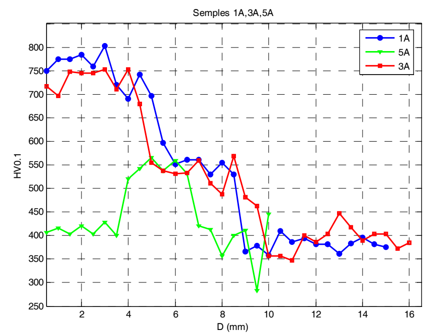


Fig. 6. Comparison of microhardness on OY direction

Table 3

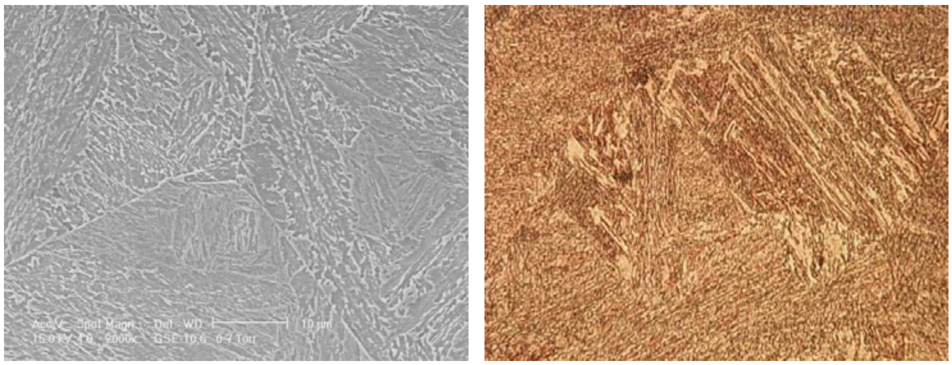
Average values of $HV_{0.1}$ microhardness for experimental weld deposits and basic metal

Sample	Measurement zone		
	MZ	HAZ1	HAZ2
1A	623 HV0.1	516 HV0.1	477 HV0.1
3A	677 $HV_{0.1}$	537$HV_{0.1}$	464$HV_{0.1}$
5A	380$HV_{0.1}$	468$HV_{0.1}$	434$HV_{0.1}$
Basic material	340-370 $HV_{0.1}$		

Comparing the three different evolution of microhardness measured on the OY direction it can conclude that the lowest microhardness value are obtained in the case of sample 5A, which have in HAZ zone only maximum100$HV_{0.1}$ units over the basic material value (fig. 6). This evolution seems to be acceptable for the die's material in working conditions (hot plastic deformation). Other important observation is that the microhardness values measured in the melting zone are greater on the transversal direction (OY, fig. 2) comparatively with horizontal direction, especially in the case of 1 A sample, welded without preheating. Sample 5A shows a visible difference in the microhardness evolution in the HAZ, which is more hardened in comparison with melted zone and basic material.

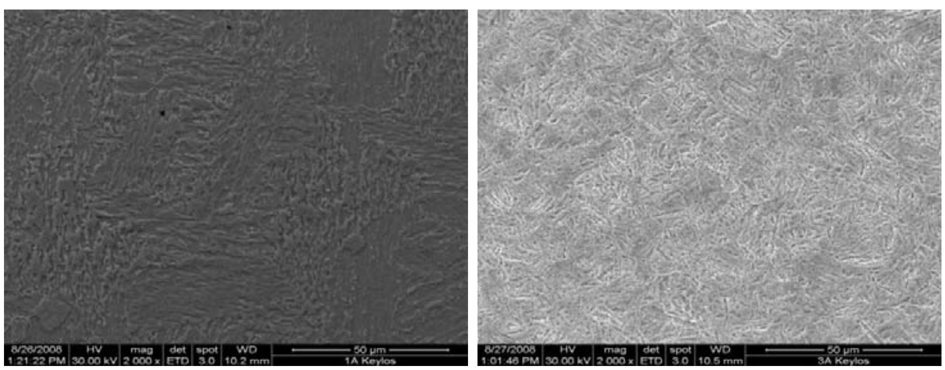
3.2. Microstructure

The microstructure analysis after a 2%Nital etching solution was done using optical and scanning electronic microscopy. For the samples 1A, 3A, 5A the microstructure of basic material consists mainly of bainite, with carbides precipitations (fig. 7). The as-quenched and tempered microstructures resulting from cooling conditions produce a mixture of martensite and bainite in weld and martensite, Widmanstätten phases and upper or lower bainite in HAZ (fig. 8).



a) b)

Fig.7. Microstructure of basic material (lower and upper bainite):
a) SEM; b) Optical microscopy, x400



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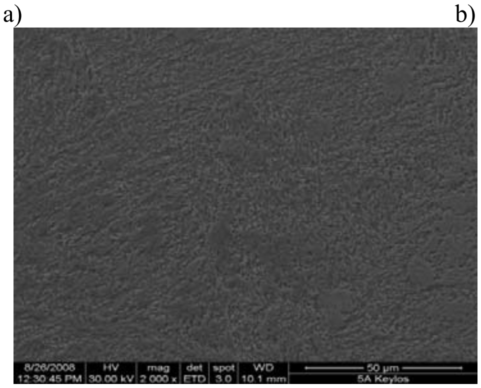
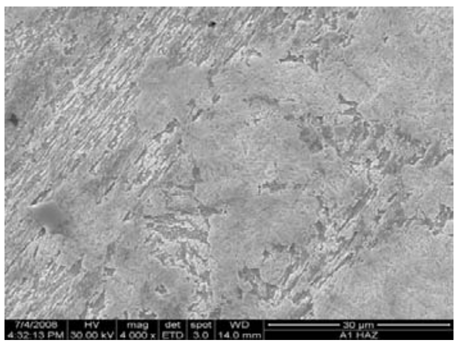


c)

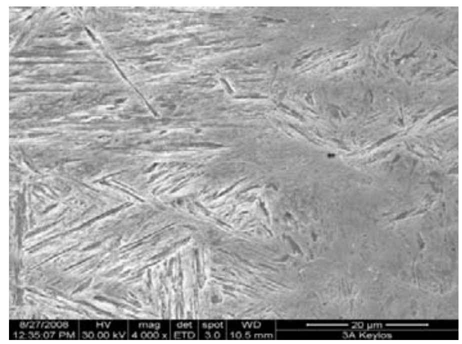
Fig.8. SEM microstructure of weld deposit: a) 1A; b) 3A; c) 5A.

The microstructure's HAZ for sample 1A is mainly acicular, oriented from hereditary austenite grains to Widmanstätten and bainite laths formed during quenching (fig. 8a). The HAZ contains coarse and fine grains, the diameter increasing with the distance from the fusion line (fig. 8b, 8c).

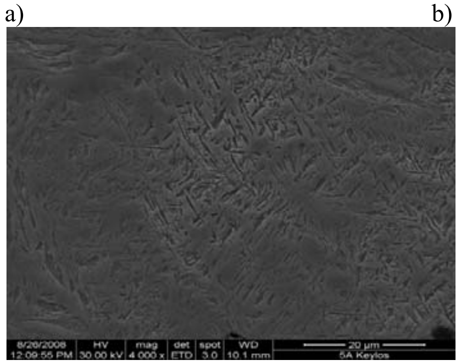
Different cooling rates after welding, resulted from pre-heating regime, affect the microstructure evolution by martensite proportion and average grains value (fig. 9).



a)



b)



c)

Fig.9. SEM microstructure of weld deposit: a) 1A; b) 3A;c) 5A.

For the sample 1A, welded without pre-heating, the weld microstructure is acicular and average diameter of grains is around 10.86µm (fig. 9a).

Sample 3A that was preheated at 350ºC exhibit a coarse grain with 27µm average diameter (fig. 9b). The microstructure of sample 5A differs significantly from previous samples, because of alloying elements effect.

4. Conclusions

Pre-heating performed at 350ºC was insufficient to ensure lower values of microhardness in the HAZ for all samples. If the values of hardness measured in weld or HAZ far exceed those of the basic material, the low plasticity of these zones lead to higher susceptibility to cracking. Therefore, the best choice for this application (reconditioning by welding using coated electrode deposited on the micro alloyed bainitic steel as basic material) is to use an electrode with lower alloying level (1-1.5% Cr) which allows the obtaining some hardness values close to those of basic material, and provides acceptable effects of hardening in HAZ (with the differences situated between 14 to 23%).

The decrease of the hardness values in HAZ can be obtained applying a post weld heat treatment that allows to 5% decrease of average hardness value.

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REFERENCES

[1] *M. Chiarbonello, D. Firrao et all*, "Comparison between traditional and innovative steels for large plastic moulds, Characterization of Minerals, Metals, and Materials", TMS (The Minerals, Metals & Materials Society), 2007

[2] *R. Davis*, "Hardfacing, Weld Cladding, and Dissimilar Metal Joining, Welding, Brazing and Soldering", ASM Handbook, Vol. 6, p. 789 – 829, 1993

[3] *D. A. Porter, K. E. Easterling*, "Phase Transformations in metals and alloys, International student edition", Oxford, U.K., 1981

[4] *A. C. Pavalache, I. M. Vasile, E. M. Stanciu, I. Voiculescu*, "Case Study about the Effect of Measurement Parameters Values on the Microhardness Results", 2009 IEEE International Workshop Advanced Methods for Uncertainty Estimation in Measurement Proceedings, UPB, 6-7 iulie, 2009, Bucuresti, Romania, ISBN 978-1-4244-3593-7, Publisher: IEEE, USA, ISBN: 978-1-4244-3592-0, p. 54-58, 2009

[5] *V. Popovici, A. C. Pavalache, I. M. Vasile, I. Voiculescu, E. M. Stanciu, D. Pausan*, "Finite element method for simulating the Vickers Hardness Test", 2010 1th International Conference on Mechanical Engineering, Robotics and Aerospace, ICMERA 2010, 2-4 dec. 2010, p. 382-385, ISBN: 978-1-4244-8867-4

[6] *G. R., C. Pradeep, A. Ramesh, B. Durga Prasad*, "A review paper on hardfacing processes and materials", International Journal of Engineering Science and Technology, Vol. 2(11), p. 6507-6510, 2010