N. BAJIĆ, D. BAJIĆ, D. VELJIĆ, M. RAKIN, Z. JANJUŠEVIĆ

ISSN 0543-5846
METABK 53(3) 361-364 (2014)
UDC – UDK 621.791.052:621.778:620.18=111

THE ADVANTAGES OF USING ACTIVATED FLUX-CORED WIRE COMPARED TO SOLID WIRE IN THE MAG WELDING PROCESS FROM THE ASPECT OF METALLURGICAL CHARACTERISTICS

Received – Prispjelo: 2013-08-30
Accepted – Prihvaćeno: 2013-12-30
Preliminary Note – Prethodno priopćenje

This paper analyzes, from the metallurgical aspect, the quality of the new flux-cored wire intended for the MAG welding process in function of changes in shielding gas composition and changes in welding parameters. The results of comparative analysis of the microstructure of the weld metal and Heat Affected Zone (HAZ) allow drawing conclusions about the feasibility of introducing a new quality flux-cored wire in industrial applications.

Key words: weld metal, activated flux-cored wire, microstructure, solid wire, HAZ

INTRODUCTION

The Metal active gas (MAG) – process is widely used for welding of constructions made of carbon and low alloyed steels, due to a number of advantages such as: high productivity, easy adaptation to different types of joints and welding positions [1-3]. The chemical composition and diameter of the wire in the welding filler are only part of the influential elements on melting of the electrode and the transfer of droplets through the electric arc [1-6].

In eliminating these deficiencies in the conventional MAG welding process apart from using a composition of a gas mixture (Ar + O_2 + CO_2), intensive work is being done on the development and implementation of a new class of flux-cored wires, primarily, of different qualities and forms of flux-cored wires [1-5]. The new quality flux-cored wire called activated has a metal casing up to four times thicker than the classical flux-cored wire and a core that consists of minerals, ferroalloys and activating compounds of alkaline and alkaline earth metals in the quantity of 5 - 8 % of wire mass.

EXPERIMENTAL WORK

In the experiment plan the main influential variables were defined, primarily the shielding gas mixture and type of filler. Boiler plate (Č.1204) was chosen as the base metal and two fillers (solid and activated flux-cored wire) CO_2 shielding and several systems of gas mixtures (Ar + CO_2 + O_2) [6-9].

Using previously defined criteria for root welding and groove filling (provided that the heat input was in the interval from 1,0-1,1 KJ/mm), a selection of optimal parameters for groove filling with activated flux-cored wire FW-10 and solid wire SW-60 was made, Table 1.

In the second part of the experiments welding of specimens was performed with activated flux-cored wire during which the composition of gas components in the three-component (Ar + CO_2 + O_2) gas mixture was changed.

Table 1 **Selected root welding and groove filling parameters**

Welding parameters	Filler mark	
	FW-I0	SW-60
Welding current	230 A	150 A
Welding voltage	24 V	28 V
Welding speed	5,0 mm/sec	2,6 mm/sec
Heat input	1,03 KJ/mm	1,02 KJ/mm
Throat groove opening	2 mm	2 mm
Preparation of groove shape	V-preparation	V-preparation
Type of current and polarity	DC, + pole on the electrode wire	

METALLURGICAL INVESTIGATIONS OF WELDED JOINTS

Investigation of weld metal chemical composition

Results of chemical analysis of weld metal in welded samples are shown in Tables 2, 3.

Investigation of nitrogen and oxygen content in the weld metal of welded joints was done on typical specimens obtained during welding with solid and activated flux-cored wire in CO_2 and a three component gas mixture (70 % Ar + 25 % CO_2 + 5 % O_2) shielding for the purpose of comparison. Results of testing of N and O content in the weld metal are shown in Table 4.

N. Bajic, Techno-experts d.o.o – Research and Development Center, Serbia, D. Bajic, University of Montenegro, Faculty of Mechanical Engineering, D. Veljic, Techno-experts d.o.o – Research and Development Center, Serbia, M. Rakin, University of Belgrade, Faculty of Technology and Metallurgy, Z. Janjusevic, Institute fot Technology and other mineral raw materials, Belgrade, Serbia

Table 2 **Chemical analysis of weld metal made with flux-cored wire in CO_2 and gas mixture shielding**

FW-10	Analysis / %					
Specimen marking	C	Si	Mn	P	S	Ti
1 FW	0,100	0,65	1,47	0,028	0,015	0,039
2 FW	0,093	0,61	1,44	0,028	0,014	0,030
3 FW	0,100	0,65	1,51	0,030	0,015	0,030
4 FW	0,116	0,55	1,29	0,028	0,015	0,026
5 FW	0,085	0,66	1,66	0,029	0,017	0,036
6 FW	0,087	0,63	1,54	0,032	0,017	0,029
7 FW	0,100	0,42	1,05	0,027	0,013	0,017

Table 3 **Chemical analysis of weld metal made with solid wire in CO_2 and gas mixtures shielding**

SW-60	Analysis / %					
Specimen marking	C	Si	Mn	P	S	Ti
1 SW	0,080	0,54	0,92	0,015	0,006	0,002
2 SW	0,086	0,53	0,89	0,015	0,009	0,002
3 SW	0,083	0,56	0,95	0,014	0,008	0,002
4 SW	0,071	0,48	0,85	0,015	0,008	0,002
5 SW	0,074	0,52	1,31	0,030	0,018	0,002
6 SW	0,100	0,56	0,93	0,014	0,011	0,002
7 SW	0,080	0,47	0,82	0,016	0,009	0,002

Table 4 **Content of nitrogen and oxygen in the weld metal**

Filler	Specimen marking	Gas composition / %			Content in the weld metal / %	
		Ar	CO_2	O_2	N	O
FW-10	**1 FW**	70	25	5	0,0069	0,0704
	7 FW	-	100	-	0,008	0,0730
SW-60	**1 SW**	70	25	5	0,011	0,0668
	7 SW	-	100	-	0,009	0,0750

Metallographic testing of welded joints structure

Testing the macro and micro structure of the base metal and welded joints was performed on an optical microscope Olympus PME. Samples were taken from the base metal and welded joints in order to study the structure of the base metal, weld metal and HAZ.

Metallographic analysis of welded specimens revealed the structure of the joints made with solid and activated flux-cored wire in different gas mixture compositions.

Rating of shapes and locations of non-metal inclusions was performed without etching the surface, while the microstructure was revealed by using nital.

In Figure 1a, b is given a comparison of the structure of samples 1FW with 1SW, and in Figure 2a, b is given a comparison of the structure of samples 7FW with 7SW.

Microstructural analysis of characteristic welded joins was done on selected specimens which were welded with activated flux-cored wire marked FW-10 and solid wire marked SW-60 in optimal three component gas mixture (70 % Ar + 25 % CO_2 + 5 % O_2) shielding, for the purpose of comparing test results.

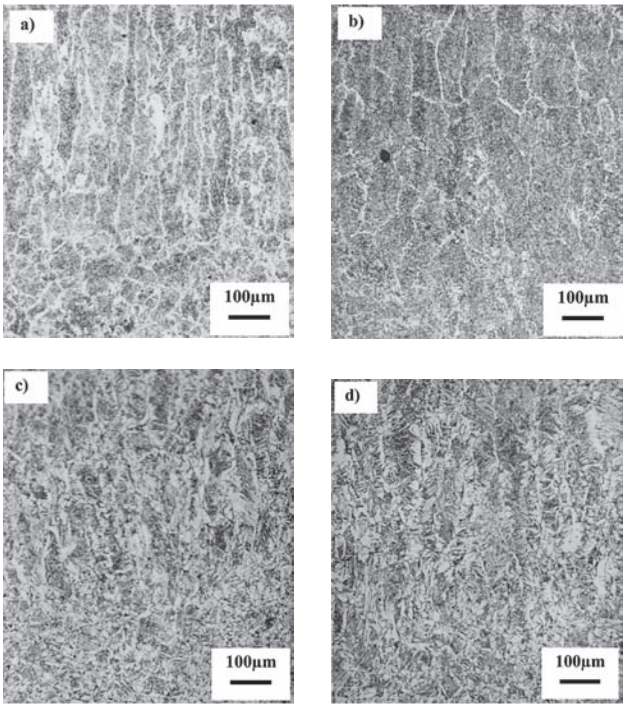

Figure 1 Comparison of weld metal microstructure welded with: a) FW-10 in 100 % CO_2 shielding; b) FW-10 in gas mixture (70 % Ar + 25 % CO_2 + 5 % O_2) shielding; c) SW-60 in 100 % CO_2 shielding; d) SW-60 in gas mixture (70 % Ar + 25 % CO_2 + 5 % O_2) shielding

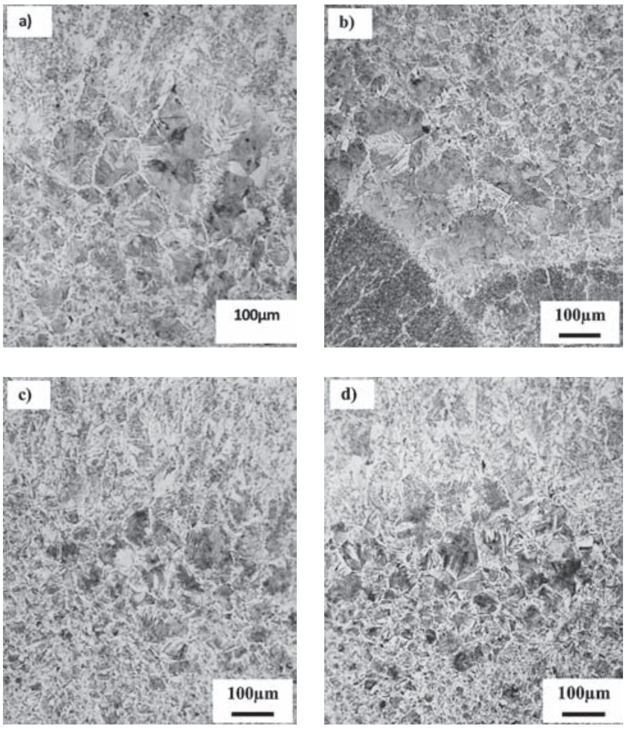

Figure 2 Comparison of microstructure in the HAZ of the welded joint made with: a) FW-10 in 100 % CO_2 shielding; b) FW-10 in gas mixture (70 % Ar + 25 % CO_2 + 5 % O_2) shielding; c) SW-60 in 100 % CO_2 shielding; d) SW-60 in gas mixture (70 % Ar + 25 % CO_2 + 5 % O_2) shielding

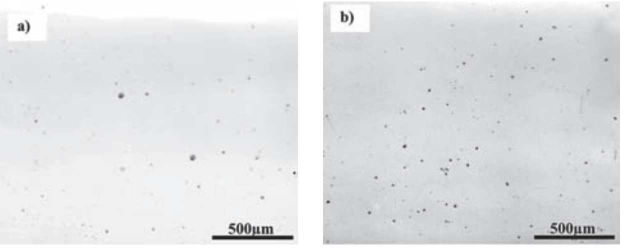

Figure 3 Microphotographs of inclusions in the weld metal of the welded joint made with solid wire mark SW-60 in 100 % CO_2 shielding (a, b)

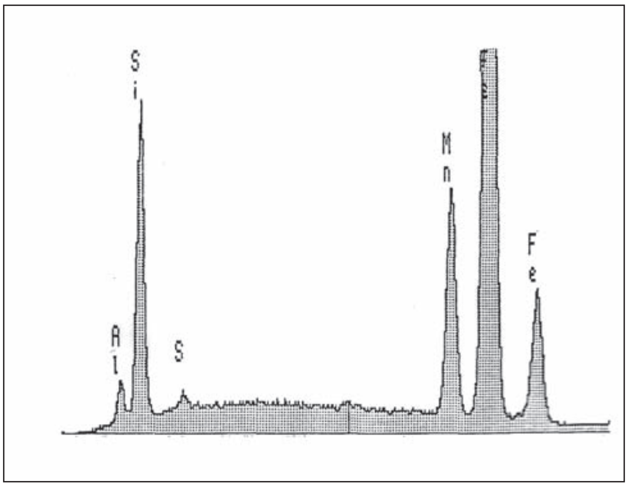

Figure 4 EDS analysis of non-metal inclusions, using the SEM, in the weld metal of the welded joint made with solid wire mark SW-60 in CO_2 shielding

Testing of non-metal inclusions in weld metal

Testing of non-metal inclusions in weld metal was carried out using an optical and scanning electron microscope (SEM). Then a comparative analysis was done of non-metal inclusions in weld metal made using classical solid wire and activated flux-cored wire.

Relative participation of non-metal inclusions in the weld metal made with classical solid wire mark SW-60 in CO_2 shielding can be seen in microphotographs Figure 3a, b. On specimen 7SW on the surface of the weld metal visible are a small number of oxide/sulfide inclusions about 10 µm in size, and in the zone nearer to the weld metal face observed is an increased concentration of fine inclusions on the Si base size 0,2 - 1,0 µm shown in micrographs, Figure 3a, b. The analyzed inclusion is of complex composition and 1,0 µm in size, and its specter is shown in Figure 4.

An analysis of the relative participation of non-metal inclusions in the weld metal made with activated flux-cored wire FW-10 on specimen 7FW showed on the surface of the weld metal rare oxide/sulfide inclusions up to 10 µm in size, Figure 5a, b. Also, on specimen 7FW in the zone nearer to the weld metal face fine inclusions size up to 1,0 µm appear of complex composition on the titan (Ti) base, Figure 5b. Analyzed is an inclusion 1,0 µm in size, and its specter is shown in Figure 6.

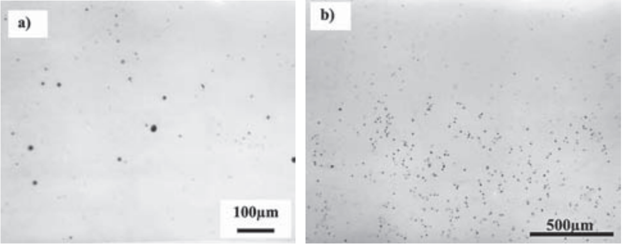

Figure 5 Microphotographs of inclusions in the weld metal of the welded joint made with activated flux-cored wire mark FW-10 in 100 % CO_2 shielding (a, b)

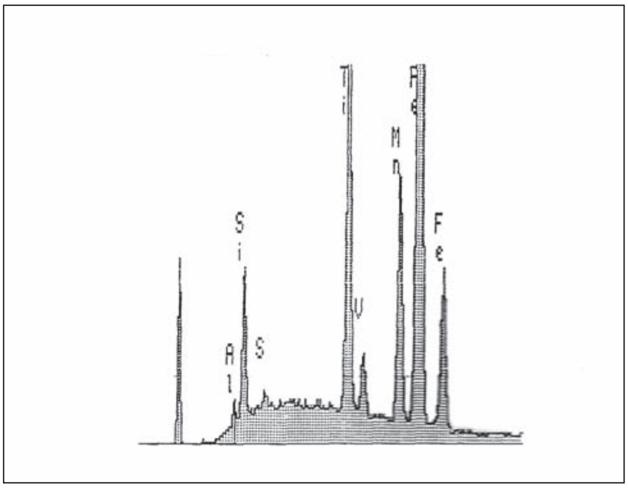

Figure 6 EDS analysis of non-metal inclusions, using the SEM, in the weld metal of the welded joint made with activated flux-cored wire mark FW-10 in CO_2 shielding

RESULTS AND DISCUSSION

Chemical composition of weld metal is determined by the degree of progress of individual reactions in the system metal - slag - gas and can range within wide limits depending on the selected combination of fillers, base metal and technological welding parameters. Analysis of the results of the chemical composition of weld metal in the last pass, Tables 2 and 3, shows a certain small difference of weld metal composition in relation to the composition of the filler due to differences in the number of passes, the percentage of mixing of base metal and filler and metal loss during welding.

Mechanical and technological properties of weld metal are primarily a function of chemical composition of filler, that is the quantity of added alloying elements.

The stated percentage of the alloying elements inserted in the technological process of forming the weld metal suggests their possible impact on the quality of the formed weld metal, also taking into account the percentage of mixing with the base metal.

The structure of the welded joints made with wire FW-10 in the weld metal in the location of the last pass consists of needle ferrite about 80 % with no bainite, polygonal and S.P.F (said-plate-ferrite) along the grain boundaries. There is no Widmannstätten ferrite in the structure. A fine grained ferrite structure without degenerated pearlite is present in the normalized weld metal zone.

The observed structure in the weld metal of the welded joint made with SW-60 wire in the locality of the last pass in a state immediately after welding consists of much primary ferrite, S.P. ferrite and Widmannstätten ferrite. Between these structures are islands of needle ferrite. In the normalized weld metal zone there is a fine grained ferrite-bainite structure. The ferrite is mainly polygonal with small amounts of needle ferrite. Lower bainite is the main form in which bainite ferrite appears.

During analysis of the welded joint structure in the HAZ starting from the base metal, which has a ferrite-pearlite structure, towards the fusion line, a fine grained structure appears which originates from decomposition of pearlite into fine grained ferrite with islands of decomposed pearlite along the ferrite grain boundaries. In the area along the fusion line pre-crystallization of ferrite grains occurs where the fine grained ferrite from the decomposed pearlite grows on account of the coarse grained ferrite.

In the HAZ region nearer to the weld metal face the coarse grains which did not undergo thermal influence from the heat of the next pass (layer) has ferrite along the grain boundaries and S.P. feritte within the grain, and the rest is upper bainite. This structure in the layer of thermal effect of the next layer has endured certain changes which lead to polygonization of ferrite along the grain boundaries as well as S.P. ferrite, and the bainite decomposed into ferrite + secondary phase.

Studying available literature and performing experiments of welding with classical solid and activated flux-cored wire in gas mixture shielding, and subsequently analyzing the test results we have obtained facts which support the research which stands for replacing classical solid wire with a new quality of activated flux-cored wire.

Acknowledgements

This work was supported by the Serbian Ministry of Education, Science and Technological Development (project number TR 34016, OI 174 004 & TR 35002).

REFERENCES

[1] N. M. Voropaj, N. K. Kostenjek, Vlijanije sastava aktiviranoj provoloki na karakteristiki processa svarki v ugleksilom gaze, Naučno-tehničeskoj razdel, Kijev (1986).

[2] N. M. Voropaj, i dr., Vzaimodejstvije rasplavljenogo metala s gazami i šlakom pri svarke v CO2 aktivirovanoj provoloki, Avtomatičeskaja svarka (1986).

[3] A. Radović, V. Grabulov: Quality improvement of welded joints of HIGH strehgth low-alloy steels using flux cored electrodes, International symposium – The days of welding-Budva (1986), 51-53.

[4] Z. Odanović, V. Grabulov, M. Arsić, M. Đurđević, B. Katavić, Selection of the Optimal Filler Material for On-Site Repair Welding of the Turbine Shaft at the Hydropower Plant, Welding & Welded Structures 4 (2011), 149-167.

[5] EN 14700 (2005) Welding consumables for hard-facing

[6] N. Bajic, V. Sijacki-Zeravcic, B. Bobic, D. Cikara, M. Arsic, Filler Metal Influence on Weld Metal Structure of Micro-Alloyed Steel, Welding Journal, 90, (2011), 55-62.

[7] N. Bajić, D. Bajić, D. Veljić, M. Rakin: Advantage of use of activated flux-cored wire instead of solid wirw with the MAG welding process from the mechanical proprties, Metalurgija 52 (4), (2013), 453-456.

[8] N. Bajić, V. Šijački–Žeravčić, M. Rakin, K. Kovačević, Effect of Welding Regime and Filler Content on Structure of Microalloyed Nb/Ti Steel Weldments, Materials Science, 46 (2010) 1, 123-133.

[9] J. Horvat, J. Prezelj, I. Polajner, M. Cudina, Monitoring Gas Metal Arc Welding Process by Using Audible Sound Signal, Strojniski vesnik-Journal of Mechanical Engineering 57 (2011) 3, 267-278.

Note: The responsible translator of the English language is T. Kelic, IHIS - Research and Development Center a.d. Zemun, Serbia