ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering
Tome XIII [2015] – Fascicule 2 [May]
ISSN: 1584-2665 [print]; ISSN: 1584-2673 [online]
a free-access multidisciplinary publication of the Faculty of Engineering Hunedoara

[1.] Mihailo MRDAK, [2.] Nikola BAJIĆ, [3.] Marko RAKIN, [4.] Slobodan STOJADINOVIĆ, [5.] Darko VELJIĆ

COMPARISON OF THE MICROSTRUCTURE OF WELD METALS IN WELDED JOINTS MADE WITH RUTILE ELECTRODES BASED ON DOMESTIC RAW MATERIALS AND ELECTRODES OF A WELL-KNOWN MANUFACTURER

[1.] Research and Development Center, IMTEL komunikacije a.d. Belgrade, SERBIA
[2,5.] IHIS Techno experts d.o.o.– Research and Development Center, Belgrade, SERBIA
[3.] Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, SERBIA
[4.] University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, SERBIA

Abstract: This paper presents the results of comparative testing of the quality of the weld metal of welded plates of low carbon non alloyed steel using rutile type coated electrodes produced in IHIS and electrodes JADRAN-S produced in Jesenice. The aim was to master the technological process of producing electrodes coated with a rutile coating based on domestic raw materials. For experimental testing used was an electrode with a medium thick rutile coating with a core of solid wire Ø 2.0 mm in diameter marked IHIS E 35 R. Based on comparative analysis of the weld metal test results of welded joints made with electrodes produced in IHIS in relation to the electrodes of the well known manufacturer the appropriate conclusions are given.
Keywords: rutile electrodes, solid wire, manual metal arc welding process

1. INTRODUCTION

Coated rutile electrodes for arc welding and surfacing have a metal core. The cores of the coated rutile electrodes as part of the electric circuit transmit power and also serve as a filler. The main functions of the electrode coating are: protection of the welding zone from the surrounding oxygen, nitrogen and hydrogen, stability and ionization of the electric arc, slowing down cooling of the weld metal, refining and alloying of the weld metal, allowing welding in forced positions. These are achieved in several ways: the drops of molten metal as they pass through the electric arc are covered by parts of the liquid coating of the electrode and the formed gases protect the surface of the drops from the surrounding atmosphere, while the metal bath is protected by slag which floats on the surface.

By the ratio of the total diameter (including the coating) D, and the core diameter d, the electrodes can be divided into thinly coated ($D/d<1.2$), medium coated ($1.2<D/d<1.4$) and heavy coated ($D/d>1.4$).

Metal cores of rutile coated electrodes consist of solid wires on to which a designed rutile type coating is applied using an appropriate technological process. The basic component of the rutile-coated electrodes is the mineral TiO_2. The coating consists mainly of components such as: rutile sand, marble, granite, kaolin, ferromanganese and ferrosilicon, mica, feldspar, talc, calcium fluoride, magnesite and Lucel. The means of transfer of filler in the E process is mostly influenced by the thickness and type of coating and current strength. By increasing the thickness of the coating and adding ingredients which reduce surface tension the transfer of droplets is improved. A stronger current also enables the transition from large to small drops, because it enhances the pinch effect and gas pressure.

In order to master production of coated rutile electrodes with a solid wire core, based on domestic raw materials, a medium coated electrode of solid wire marked IHIS E 35 R Ø 2.0 mm in diameter was experimentally produced. After that, to compare features, arc welding of low carbon steel plate was performed with the produced electrode labeled IHIS E 35 R and the rutile electrode JADRAN S Ø 2.5 mm in diameter from the manufacturer in Jesenice.

This paper presents the results of a comparative analysis of the weld metal of welded joints of low carbon steel plates made with the new rutile coated electrode produced from domestic raw materials and the rutile electrode from the well known manufacturer [1-4]. The new quality coated electrodes are expected to provide the most favorable microstructure of the weld metal and optimum mechanical properties, because the safety of the welded structure depends on the mechanical properties that are directly related to the microstructure [5-10]. The weld metal with a high proportion of acicular ferrite has the optimum microstructure and mechanical properties [11]. The chemical composition and cooling rate directly affect the microstructure of the weld metal [12-14]. The chemical composition of the weld metal is largely determined by the type of filler, and in smaller proportion determined by the base metal that melts during welding.

Results of comparative studies of the microstructure of the weld metal (WM) of welded joints performed with the rutile coated electrode produced in IHIS and rutile electrode JADRAN - S confirmed that the weld metal (WM) has a microstructure which enables its practical industrial application

2. MATERIAL AND METHODS

For examination of the microstructure of the weld metal (WM) of welded joints a coated rutile type electrode with a core of solid wire marked IHIS E 35 R Ø 2.0 mm in diameter with a medium thick rutile coating was used. For the production of medium thick coated electrodes of solid wire IHIS E 35 R, for the cores, selected was drawn steel wire marked Sv-08 and Sv-08A according to GOST standard containing C ≤ 0.10%, Si ≤ 0.03% and Mn 0.35-0.60%.

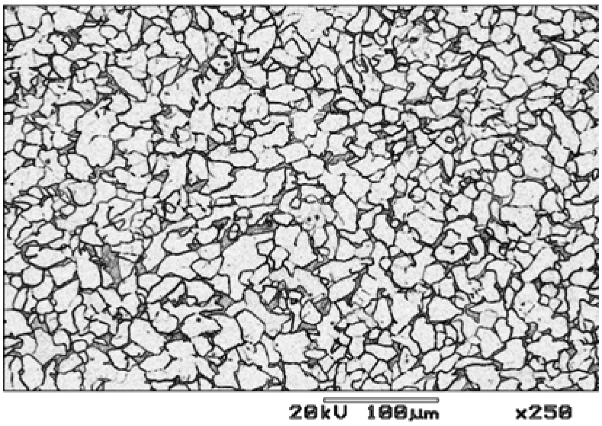
For comparison of the microstructure of the weld metal (WM) of welded joints, used as a parallel electrode was a coated rutile electrode JADRAN S - Jesenice Ø 2.5 mm in diameter with a core of solid low carbon steel wire marked Č.1931 (JUS C.B6.012) containing 0.80-0.89% C, 0.10-0.30% Si, 0.30-0.6% Mn, P and S ≤ 0.040%. The coated electrodes were standard length of 350 mm designed for manual arc welding and surfacing.

3. RESULTS AND DISCUSSION

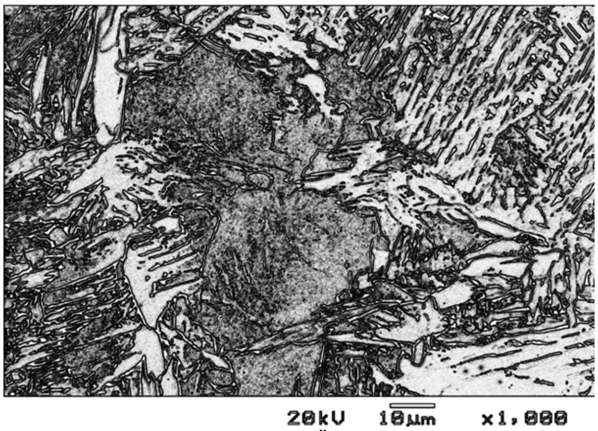
Examination of the microstructure of the base metal (BM) and welded joints of weld metal (WM) was performed on a scanning electron microscope (SEM). Examination of the microstructure of welded joints of low-carbon steel plates was done in accordance with standard SRPS EN 1321. Etching of microstructures was carried out in a solution of 3% Nital.

The microstructure of weld sample No1 with a rutile electrode produced by coating a solid wire marked IHIS E 35 R Ø 2.0 mm in diameter is shown in Figure 1a, b. The microstructure of the base metal (BM) is fine grained ferrite-pearlite, with a very small proportion of pearlite, Figure 1.a (250x). The thermal cycle of welding was optimal so there was no intensive growth of primary austenite grains. The microstructure of the weld metal (WM) consists of multiple morphologies of ferrite, Figure 1.b (1000x). The ferrite, which is distinguished by grain boundaries in the form of intermittent layers, is polygonal ferrite (PF).

In the interior of the grain two types of plate-like ferrite can be observed, ferrite with a directional secondary phase (FS) and Widmanstätten ferrite (WF) of a needle plate-like shape which increases in depth of the grains of polygonal ferrite, which is located on the grain boundaries. In the interior of the grains fine needles of acicular ferrite (AF) are observed.



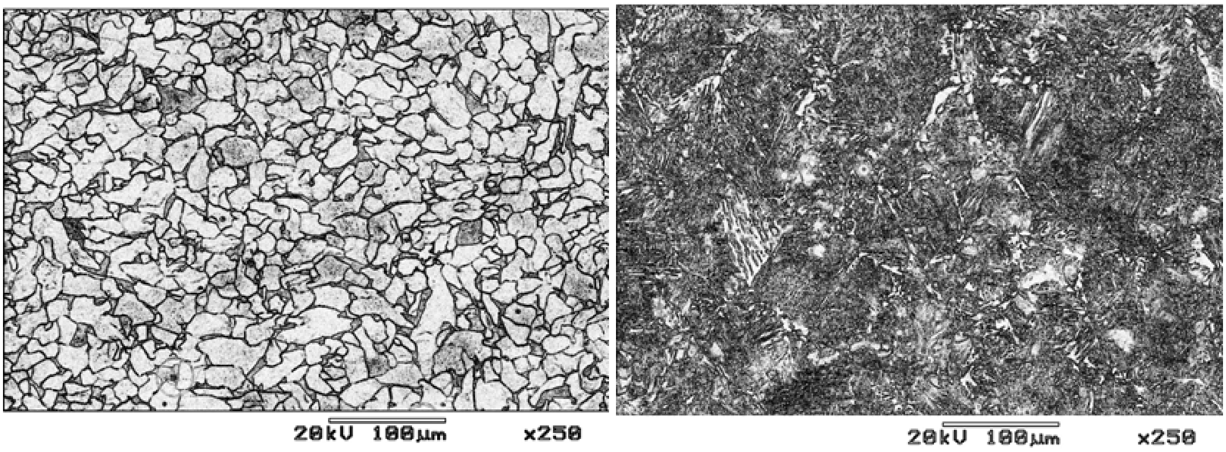
a) OM



b) MŠ

Figure 1. Microstructure of weld sample No.1: a) base metal (BM), 250x; b) weld metal (WM), 1000x

The microstructure of the welded joint in sample No. 2 with a standard rutile electrode JADRAN S from Jesenice Ø 2.5 mm in diameter is shown in Figure 2.a, b. The microstructure of the base metal (BM) of low carbon steel is ferrite-pearlite shown in Figure 2.a (250x). In the weld metal (WM) the ferrite, which is distinguished on the grain boundaries is in the form of intermittent layers and within the grain the ferrite is polygonal. The most common term for this type of ferrite is polygonal ferrite (PF) [15]. In the interior of the grains, found was a number of types of ferrite, such as a needle - acicular ferrite (AF) with a proportion of Widmanstätten ferrite (WF), or as it is also called side plate ferrite. It is plate needle-shaped and grows in depth of the grains directly from the polygonal ferrite which is located on the grain boundaries. In some crystal grains, ferrite with a directional secondary phase (FS) is present.



a) OM b) MŠ

Figure 2. Microstructure of weld sample No 2: a) base metal (BM), 250x; b) weld metal (WM), 250x.

Comparative analysis of the microstructure of the weld metal (WM) in welded joints derived from the coated electrode IHIS E 35 R Ø 2.0 mm in diameter and the electrode JADRAN S from Jesenice Ø 2.5 mm in diameter, were identical and in accordance with the contents of C, Si and Mn and solid wire that is was used for coating.

CONCLUSION

Based on the comparative analysis of the test results of the microstructure of the weld metal (WM) of welded joints made with rutile electrodes with a core of solid wire based on domestic raw materials marked IHIS E 35 R Ø 2.0 mm in diameter with a medium thickness of rutile coating in relation to an electrode of a known manufacturer labeled JADRAN S from Jesenice Ø 2.5 mm in diameter the following conclusions can be made: Produced rutile-type electrodes from solid wire marked IHIS E 35 R Ø 2.0 mm in diameter with a coating based on domestic raw materials showed satisfactory quality compared to the standard rutile electrode of solid wire Ø 2.5 mm in diameter marked JADRAN S from Jesenice.

The microstructures of the weld metal (WM) of welded joints were identical and along the weld metal there were no visible deviations observed in the microstructure. The results confirmed that the new coated electrode of solid wire marked IHIS E 35 R Ø 2.0 mm in diameter with coating based on domestic raw materials can be successfully applied for welding low carbon non alloyed steel as well as low carbon low alloyed steel.

ACKNOWLEDGEMENTS

This paper is supported by the Serbian Ministry of Science and Technological Development (project number TR34016) "Development of covering and core production technology based on local raw materials for manufacturing of special coated electrodes designed for steel arc welding" & TR 35002 "Development of new methodologies for revitalizing turbine and hydro mechanical equipment of hydroelectric power stations depending on the cause of degradation of the material".

REFERENCES

[1] Potapov, N.N., Baranov, D. N., Kakovkin, O. S., Vitman, D. B. i dr., ISBN 5-217-01236-8., Moskva, Mašinostrenie, 1993.

[2] Bajić, N., Mrdak, M., Stojadinovic, S., Pekez, J., Karastojkovic, Z. Rakin, M., Veljić, D., 45 th International October Conference on Mining and Metallurgy, Bor, pp.377-380, 2013.

[3] Bajić, S.N., Monografija: ISBN 978-86-89775-00-6, COBISS.SR-ID 204235020, 2013.

[4] Bajić, N., Veljić, D., Rakin, M., Stojadinović, S., Pekez, J., Mrdak, M., Welding&Welded Structures, LVIII, UDK/UDC:621.791.04, ISN 0354-7965, COBISS.SR-ID 105396743, No.4, I-deo, pp.157-161, 2013.

[5] Prasad Rao, K., Janvir, B.K., Effect of microstructure on Mechanical Properties of C-Mn Weld Metal, Pract. met. 25, 1988.

[6] Gianeto, J.A., Smith, N.J.G., McGrath, J.T., Microstructural Featureres Influencing the Notch Toughness and Dynamic Tear Fracture Resistance of High Strength Weld Metals, IIW Doc IX-1596-90.

[7] Effect of Microstructure on Weld Metal Toughness, GKSS Geesthacht GMBH, 90/E/21, ISSN 0344-9629.

[8] Bosansky, J., Evans, G.M., The Relationship Between Properties of V and Nb Micro-alloyed Weld Metals and their Structure and Substructure, IIW Doc II-A-844-91.

[9] Es Souni, M., Beaven, P.A., Evans, G.M., Microstructure and Mechanical Properties of Cu-Bearing Shielded Metal Arc C-Mn Weld Metal, Welding Journal, March, 80- 90-s, 1991.

[10] Cerjak, H., Letofsky, E., Pitoiset, X., Seirenger, A., Evans, G.M., The Influence of Microstructure on the Toughnes of C-Mn Multi run Weld Metal, IIW Doc II-A-955-95 (IX-1814-95).

[11] Oldland, P.T., Ramsy, C.W., Matlock, D.K., Olson, D.L., Significient Features of High-Strength Steel Weld Metal Microstructure, Welding Journal, April, 158-s, 1989.

[12] Liu, S., Indacochea, J.E., Control of Chemical Composition and Microstructure in Low -Carbon Microalloyed Steel Weldments, IIW Doc II-A-886-93.

[13] Evans, G.M., The Effect of Heat input on the Microstructure and Properties of all Weld Metal Deposits, Welding Journal, Vol.61, No.4, 125-s-132-s, 1982.

[14] Evans, G.M., The Effect of Heat input on the Microstructure and Properties of all Weld Metal Deposits, Welding Journal, Vol.61, No.4, 125-s-132-s, 1982.

[15] Evans, G.M., The Efect of Interpass Temperature on the Microstructure and Properties of all Weld Metal Deposits, Welding Review, Vol.1, No.1, pp.14-20, 1982.

[16] Evans, G.M., The Efect of Interpass Temperature on the Microstructure and Properties of all Weld Metal Deposits, Welding Review, Vol.1, No.1, pp.14-20, 1982.

[17] И.К. Походня, В.Ф. Грабин, В. “IHIS Science and Technology Park ZEMUN”, Belgrade, Serbia

[18] В. Головко, Д.П. Новикова: Автоматическая сварка, No.4, 529 с. 1997.

ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering