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MAIN ALLOY ELEMENTS IN COVERED ELECTRODES IN TERMS OF THE AMOUNT OF OXYGEN IN WELD METAL DEPOSITS (WMD)

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There were investigated properties of WMD, especially metallographic structure, toughness and fatigue strength of welds with various oxygen amount. The connection between the properties of welds with the content of oxygen in WMD were carried out. The research results indicate that it should be limited oxygen content in steel welds. Subsequent researchers could find more precisely the most beneficial oxygen amount in the welds in terms of the amount of acicular ferrite in welds.

Key words: welding, oxigen, classification, weld metal deposits, S-N curves

Glavni legirajući elementi obloženih elektroda u odnosu sadržaja kisika u depozitu zavara. Istražena su svojstva depozita zavara sa različitim sadržajem kisika, posebno metalografske strukture, žilavost i čvrstoća na umaranje. Utvrđena je veza između svojstava zavara i sadržaja kisika u depozitu zavara. Nadalje, istraživači su precizno utvrdili najpovoljniji sadržaj kisika s obzirom na sadržaj acikularnog ferita u zavaru.

Ključne riječi: zavarivanje, kisik, klasifikacija, depozit u zavaru, S-N krivulje

INTRODUCTION

Classification of welding processes of low-carbon and low-alloy steel in terms of the amount of oxygen was firstly suggested on ISOPE Conference in Brest in 1999 [1]. Since then, a new research has confirmed the valid of this concept [2-4]. Different coated electrodes (especially basic and rutile electrodes) were tested. The amount of oxygen and the percentage of acicular ferrite of weld metal deposits (WMD) were mainly analysed and the impact toughness of it. Metallographic structures and fractography tests of weld metal deposit were carried out by putting attention to non-metallic inclusions presence in deposit. S-N curves were done for typical deposits with varied amount of oxygen in WMD. Additional inclusions observation and measurements were prepared using a scanning electron microscope equipped with an energy-dispersive X-ray spectrometer. Effect of oxygen in weld is not the same like in steel [2-8]. Amount of oxygen in WMD is normally ten times higher in comparison with steel. Sometimes it could be more than 1 000 ppm oxygen in WMD, that corresponds with 0,3 % of oxide inclusions in metal weld deposit [3, 4]. It is also observed that oxygen amount in WMD could be lower than 200 ppm. Both values are not beneficial for good toughness properties [3, 5]. It was observed that oxide inclusions in steel metal weld deposit have main influence on the transformation austenite→ acicular ferrite (AF). Acicular ferrite is observed only in weld metal. The quality, quantity, type and size of inclusions determines the formation of acicular ferrite. Especially two non-metallic oxide inclusions TiO and $MnAl_2O_4$ have an important influence on the formation of acicular ferrite. Those oxide inclusions have a FCC lattice structure, and it could possibly be compatible with the BCC lattice structure of ferrite that is beneficial for the transformation austenite→acicular ferrite. Also the size of inclusions could have an influence on forming acicular ferrite and thereby resulting in obtaining better impact toughness properties. Thus the impact toughness of the metal weld deposits is affected by the amount of oxygen and the amount of acicular ferrite in the metal weld deposits. The impact toughness of the metal weld deposits is also affected by morphology and density of inclusions [5, 6]. This is the reason, why the amount of oxygen could be treated as the important factor on metallographic structures and impact properties of weld metal deposit. In metallurgy of steel, it is treated that the lowest amount of oxygen gives good toughness properties of steel.

EXPERIMENTAL PROCEDURE

Only shielded Metal-Arc Welding (SMAW) process were chosen to assess the effect of oxygen on mechanical properties of deposited metal electrodes. In order to analyse GMAW process, different low alloy steel electrodes (acid, rutile and basic coatings) were prepared in experimental way. The electrodes (acid, rutile, basic) contained coatings, constant or variable proportions of standard components in powder form. The principal

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composition was modified by separate additions of oxidiser (Fe_3O_4) and deoxedisers (FeTi, FeSi and Al in powder form) in electrode coatings. The principal diameter of the electrodes was 4 mm. The standard current was 180 A, and the arc voltage was 22 V. As a result after welding, the amount of oxygen in low-carbon and low-alloy steel metal weld deposits ranged between 200 and 1100 ppm.

Using these mentioned methods of welding (SAW, SMAW, GSAW processes) it was possible to obtain a typical structures, and chemical composition in all tested metal weld deposits. A typical low alloy low carbon weld metal deposits after welding had the following chemical composition is shown in Table 1.

For each the following deposits a chemical analysis, micrograph tests, and Charpy V-notch impact toughness test was carried out. The main Charpy tests were done mainly at +20 °C using 5 specimens from each weld metal. Charpy V-notch impact toughness tests of the selected weld metal at lower temperatures were also done with 5 specimens.

Table 1 **Chemical composition of typical tested WMD/ wt. %**

Element	Amount
C	bellow 0,06
Mn	up to 1,4
Si	up to 0,4
Al	up to 0,02
Ti	up to 0,02
P	max 0,013
S	max 0,013
N	max 80 ppm
O	200 to 1 100 ppm

RESULTS AND DISCUSSION

On the bases of the results shown in Figure 1 and Table 2, the role of oxygen in the SMAW process was analysed.

Figure 1. Impact toughness (at 20 °C) of deposits with variable amount of oxygen. Deposits were experimented by: acid electrodes (A), rutile electrodes (R) and basic electrodes (B) [1, 2]. In Figure 1 it is well shown that oxygen has an influence on impact toughness properties of metal weld deposit. Table 2 shows relationship between metal structure of deposits and impact toughness of deposits. To that comparison there were chosen deposits with the most beneficial impact toughness properties (taken from Figure 1).

Table 2 presents that acid electrodes are not able to provide neither good structure (AF amount above 40 %) nor good impact toughness properties (especially at -40 °C). Because of that only rutile and basic electrodes were further tested. To determine the reasons for the different values of impact strength results for weld metal deposits, metallographic and fractographic tests were carried out. Estimation of grain size by microscopic method are shown in Figures 2 and 3.

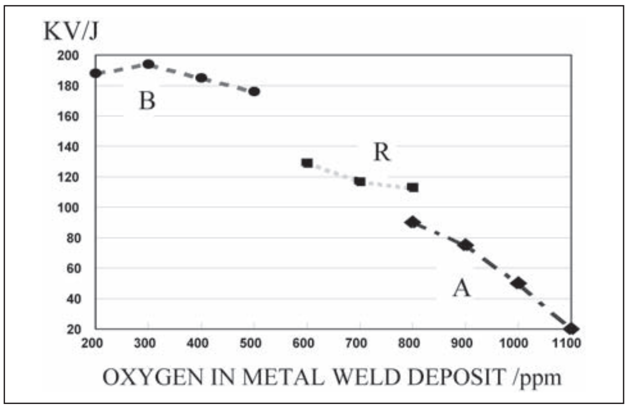

Figure 1 Impact toughness (at 20 °C) of deposits with variable amount of oxygen. Deposits were experimented by: acid electrodes (A), rutile electrodes (R) and basic electrodes (B) [1, 2]

Table 2 **Parameters of covered electrode**

Covered electrode	AF amount / %	Impact toughness at	
		+20 /°C /J	-40 /°C /J
acid	32	97	30
rutile	41	131	41
basic	55	192	49

The mechanism by which acicular ferrite grows is not well understood, but it is known that good impact toughness of WMD strongly depends on the percentage of acicular ferrite in deposit. Fractography tests indicate that amount of acicular ferrite in WMD is connected with the size of inclusions (and their chemical composition), Figures 4, 5.

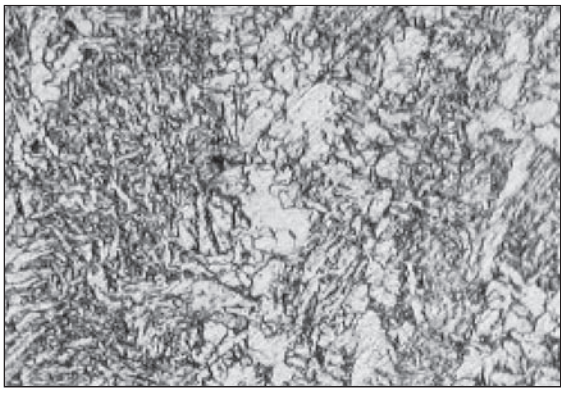

Figure 2 Estimation of grain size in rutile WMD, 37 % of acicular ferrite, 100 ×

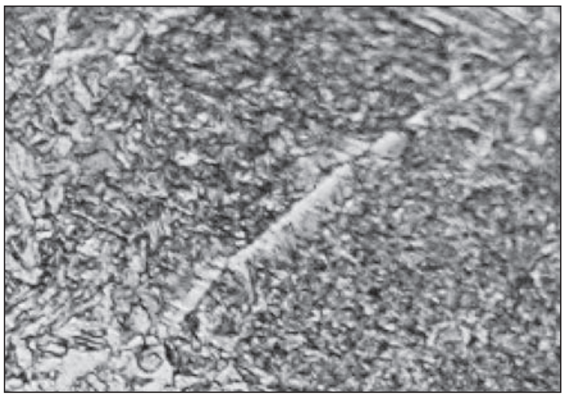

Figure 3 Estimation of grain size in basic WMD, 55 % of acicular ferrite, 100 ×

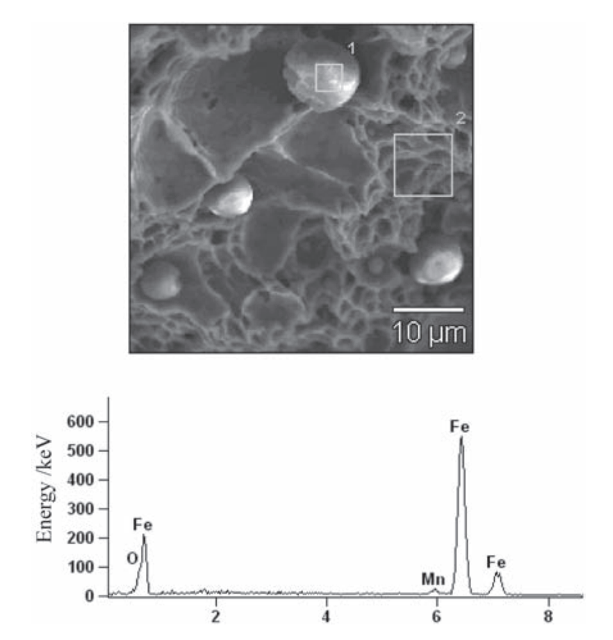

Figure 4 EDS of rutile WMD, big size of inclusions

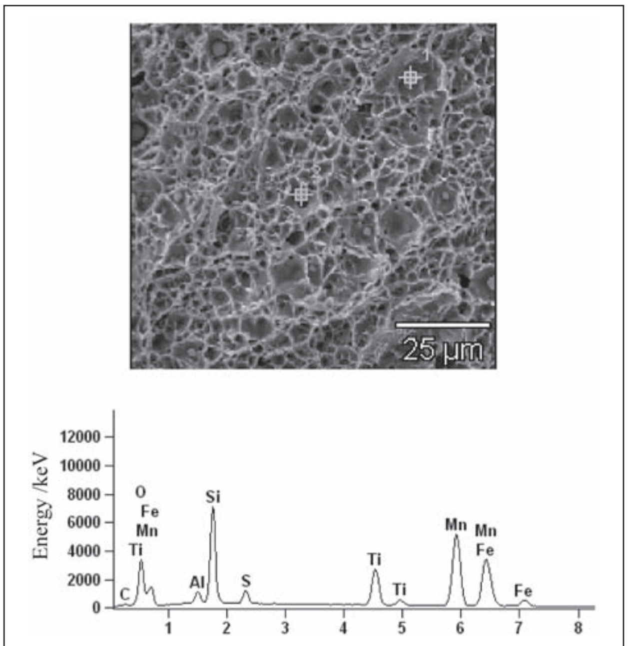

Figure 5 EDS of basic WMD, small size of inclusions

The quality, quantity, type and size of inclusions determines the formation of acicular ferrite. It is possible to deduce that inclusions are a heterogeneous nature and that the following oxides TiO, FeO, SiO_2, MnO, $MnAl_2O_4$, Al_2O_3 are dominant. Also the size of inclusions could have an influence on forming acicular ferrite and thereby resulting in obtaining better impact toughness properties. Thus the impact toughness of the metal weld deposits is affected by the amount of oxygen and the amount of acicular ferrite in the WMD.

Decrescent of impact toughness of low alloy metal weld deposit in terms of the increscent of the amount of oxygen in deposits was observed in all tested temperatures. Last part of the project was to compare S-N curves of typical deposits of basic and rutile electrodes giving

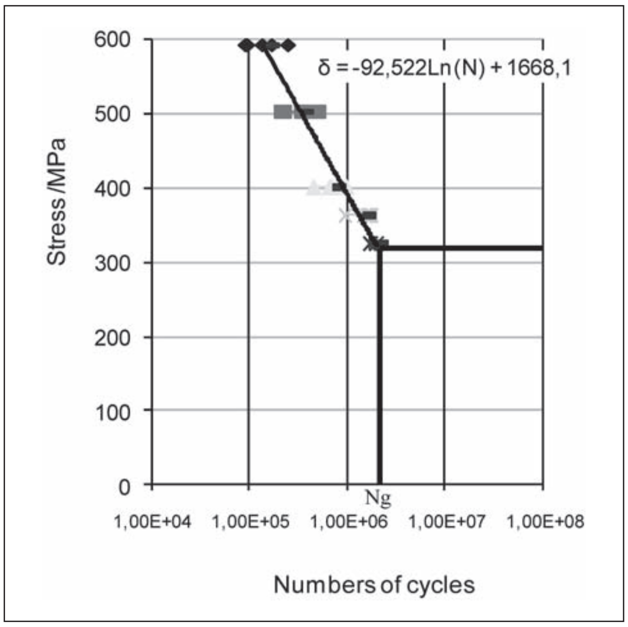

Figure 6 S-N Fatigue properties for WMD with 350 ppm O (basic electrode; Ng basic number of cycles)

various amount of oxygen in welds after process. Fatigue tests were generated for two deposits: with low amount of oxygen on the level of 350 ppm (typical for basic electrodes), and 800 ppm (typical for rutile electrodes). The samples and tests were done according to Polish Standards PN-H-04325:1976 (Figures 6, 7). Looking for the S-N curve for the deposit to make an estimate of its fatigue life it easy to deduce, that low amount of O (basic WMD) could be treated as beneficial (comparison with rutile WMD having 800 ppm O), Figure 6.

It was able to compare the fatigue values for deposits having various amount of oxygen. Also in this case deposits having lower amount of oxygen could be treated as more beneficial.

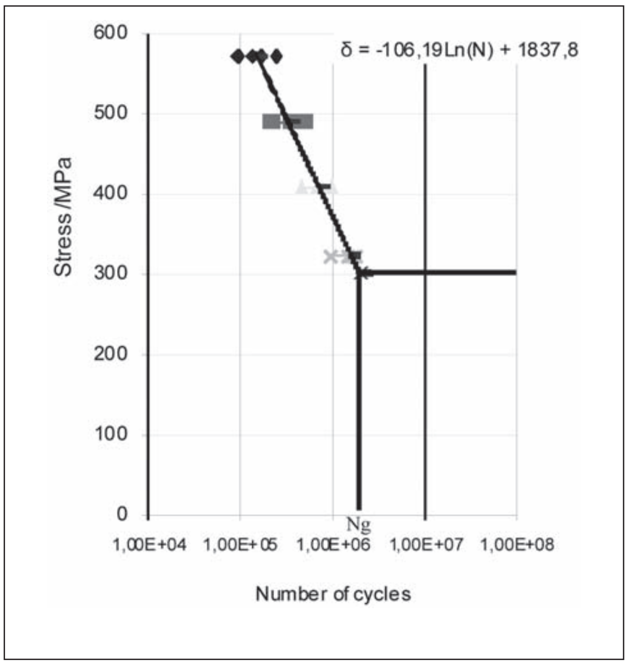

Figure 7 S-N Fatigue properties for WMD with 800 ppm O (rutile electrode ; Ng basic number of cycles)

CONCLUSION

Examination of the influence of amounts of oxygen on alloy steel metal weld deposit using variable electrodes allows to suggest that:

1. Acid electrodes are not able to provide neither good structure nor impact toughness of WMD.
2. Basic electrodes are most beneficial in low alloy steel welding because of the lowest amount of oxygen in WMD and higher impact toughness.
3. Classification for electrodes and welding is a very good and actual proposal.

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