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## Structure and Properties of Coatings Made with Self Shielded Cored Wire

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### Abstract

The welding technologies are widely used for design of protection layer against wear and corrosion. Hardfacing, which is destined for obtaining coatings with high hardness, takes special place in these technologies. One of the most effective way of hardfacing is using self shielded flux cored arc welding (FCAW-S). Chemical composition obtained in flux cored wire is much more rich in comparison to this obtained in solid wire. The filling in flux cored wires can be enriched for example with the mixture of hard particles or phases with specified ratio, which is not possible for solid wires. This is the reason why flux cored wires give various possibilities of application of this kind of filler material for improving surface in mining industry, processing of minerals, energetic etc. In the present paper the high chromium and niobium flux cored wire was used for hardfacing process with similar heat input. The work presents studies of microstructures of obtained coatings and hardness and geometric properties of them. The structural studies were made with using optical microscopy and X- ray diffraction that allowed for identification of carbides and other phases obtained in the structures of deposited materials. Investigated samples exhibit differences in coating structures made with the same heat input 4,08 kJ/mm. There are differences in size, shape and distribution of primary and eutectic carbides in structure. These differences cause significant changes in hardness of investigated coatings.

**Keywords:** Wear resistant alloys, Metallography, Hardfacing, Carbides, Hardness

### 1. Introduction

This paper is dedicated to the problem of wear-resistant surfaced plates, which are used for impact loading and transport elements and in the mining industry. Continuous advance in materials engineering and welding technology has resulted in new materials and techniques of applying layers and improving surfaces that provide completely new opportunities for application [1÷10]. One of such techniques is self-shielded flux-cored wire welding. The method of self-shielded flux-cored wire welding involves melting flux-cored wire and metal substrates from the heat of an electric arc burning between the metal wire tube, comprising a core powder, and the welded object. The

components of the core wire provide gas and metal vapour deposition insulating zone from the atmosphere. Slag is also generated during the melting of the core. It covers a thin layer of liquid metal droplets transferred from the wire to the molten weld pool. The slag that is formed during the melting process is primarily responsible for protecting the welding arc and molten weld pool from the atmosphere. Slag binds oxygen and nitrogen so effectively that it does not require any additional casing even in gusts of wind up to 6 m/s [1, 13]. The process of self-shielding flux cored welding SSA ( Self- Shielded Arc Surfacing ) combines the features of welding flux cored gas-shielded welding and manual welding with coated electrodes. The very process of surfacing from a technological point of view is the same as flux

cored wire welding with shielding gas. Sample sections of cored wires are shown in Figure 1 [1].

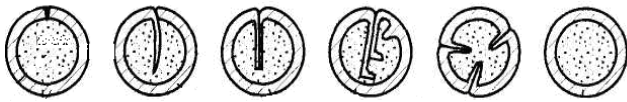


Fig. 1. Cross-sections of tubular cored electrodes [1]

Flux cored wires have numerous advantages over conventional solid wires such as weld metal increased yield, improved deposition rate and one of the most important advantages is the possibility of composing the chemical composition of the powder that would not be possible with solid wires [11÷12,14]. The important question in welding surfacing technologies is correct determination of significant basic parameters that affect on the quality and properties of the deposited layers [15÷17]. Changes in these parameters give chance to deposit layers with different hardness and microstructure by the same chemical composition of materials used for surfacing.

The present research work has the main goal in examinations of microstructure properties and hardness of hardfacing layers made with the same heat input but with different cooling rate.

## 2. Experimental procedure

Non-alloy structural steel of designation S235 for general purpose was selected as parent material for hardfacing layers. The thickness of deposited steel plate was 10 mm. Self shielded cored wire Cortthal 61 with a diameter of 2.8 mm and the chemical composition specified by the manufacturer in Table 1 were selected for hardfacing. The deposit hardfacings made by this wire are designed to work in conditions of abrasive wear metal-to-mineral.

Table 1  
Chemical composition of self shielded cored wire wt%

C	Cr	Nb	B	Fe
5,4	22	7	1	balance

The deposit was made on Lincoln Electric automated welding machine. Single-layer hardfacing weave bead was applied with the parameters shown in Table 2. There were two samples surfaced with the same heat input about 4,08 kJ/mm. The width of the weave bead was in both cases 25 mm. The position of welding was equipped in cooling table. Thanks to that it was possible to change the condition of cooling rate in the experiment.

Table 2.  
Deposit process parameters

Sample	Thermal conductivity [W/m*K]	Wire feed speed [m/min]	Electrode stick out [mm]	Speed of oscillation [m/min]
1	4,13	5,3	20	2,8
2	0,015	6,3	40	1,7

The samples for further investigations were cut with water jet to avoid changes in material structure and properties. Metallographic specimens were etched in a reagent with the following chemical composition of 80 ml C<sub>2</sub>H<sub>5</sub>OH, 10 g FeCl<sub>2</sub>, 10 ml HCl. Prepared samples were investigated with optical microscope for determination of microstructure of the obtained deposits. The microstructure of samples was examined using Bruker D8 Advance X-ray diffractometer. Diffraction of X-rays was performed using a copper lamp with a characteristic CuK radiation source. The samples were scanned at an angle range from 20° to 120° with the resolution of 0.02° and exposure time of 3s per step. The next step of investigation was hardness test.

## 3. Results and discussion

Structure and properties of crystallizing deposit show significant differences due to variable parameters which directly resulted in the amount of heat input and the rate of its cooling. Thus, using all the time the same filler material wide variation structure was achieved which entailed changes in the hardness of the deposits. As a result of the structure observation it was found that the deposit made at the same settings does not have the same structure throughout the cross-section. There are noticeable differences in the amount, form and size of carbide precipitates occurring. Sample number 1 has the average share carbides in the structure estimated at 32% while for the sample number 2 it was 43%. In the case of the deposit 1 (Fig. 2), we are dealing with a high dispersion of the structure, eutectic and primary carbides dominate in the entire volume of the weld and primary longitudinal large carbides are infrequent. Primary carbides are mainly in the form of elongated spindle-shaped precipitates. At the same time it can be seen in the structure of the occurrence of the primary carbides in the form of polygons and numerous minor separation of eutectic carbides. In the deposit number 2 a certain heterogeneity of the structure of carbide precipitates can be observed. It refers primarily to the orientation of the axis of carbides, which in part are oriented perpendicularly to the surface of the deposit and the presence of carbides arranged at a smaller angle (Fig. 3). In the structure of the deposit irregularly shaped carbides are observed and the size of the carbide precipitates decrease as the distance from the surface of the deposit increases.

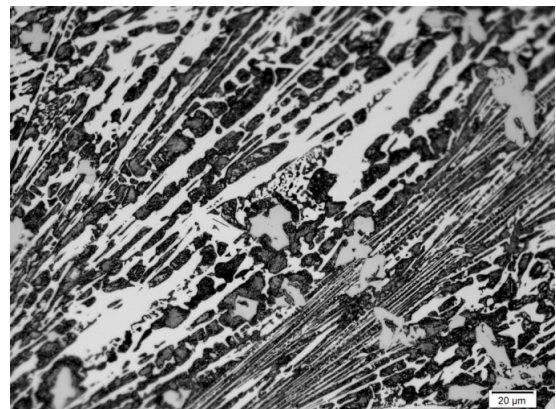


Fig. 2. Structure of deposit number 1, magnification x500

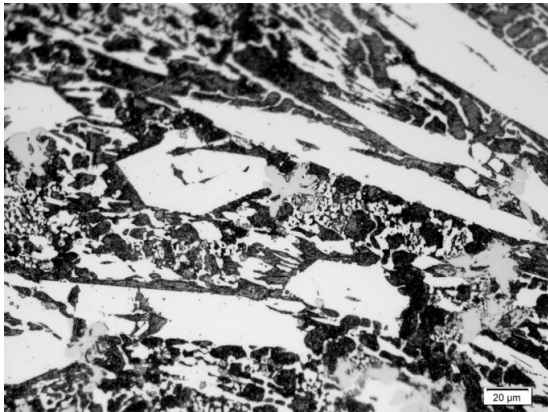


Fig. 3. Structure of deposit number 2, magnification x500

In all observed deposits grinding up carbides can be observed as it approaches the line of fusion. Characteristic fragmentation of the carbides in all the studied deposits, which increases with the distance from the surface is caused by a strong dissipation of heat in the direction of the parent metal. Fast heat dissipation from the weld areas lying near the fusion line limited diffusion process and prevented the formation of large carbide precipitates. The heat dissipation was much slower near the surface so the conditions for the diffusion of the alloying elements were much better and allowed to crystallize large primary carbides with the axes oriented in the direction of heat dissipation.

The obtained X-ray diffractions indicate that for the tested deposits phase composition of the structure is the same. The variable is, however, the intensity of the peaks on the graph (Figure 4), which should be explained by significant differences in the amount of the divisional structure of the carbides. The identification of the type of carbides was carried out based on the parameter network and catalog database phases and compounds. On this basis the presence of the tested deposits in the structure of chromium carbides  $Cr_7C_3$  and niobium carbide  $Nb_6C_5$  in  $\alpha$ -Fe matrix was discovered. It should also be remembered that there are often complex compounds, that may also contain atoms of other elements, in this particular case this is mainly about atoms of iron ( $Cr, Fe$ ) $_7C_3$ . The addition of niobium and precipitation of carbides of this element raises the hardness because the carbides of the element have a greater hardness than chromium carbides.

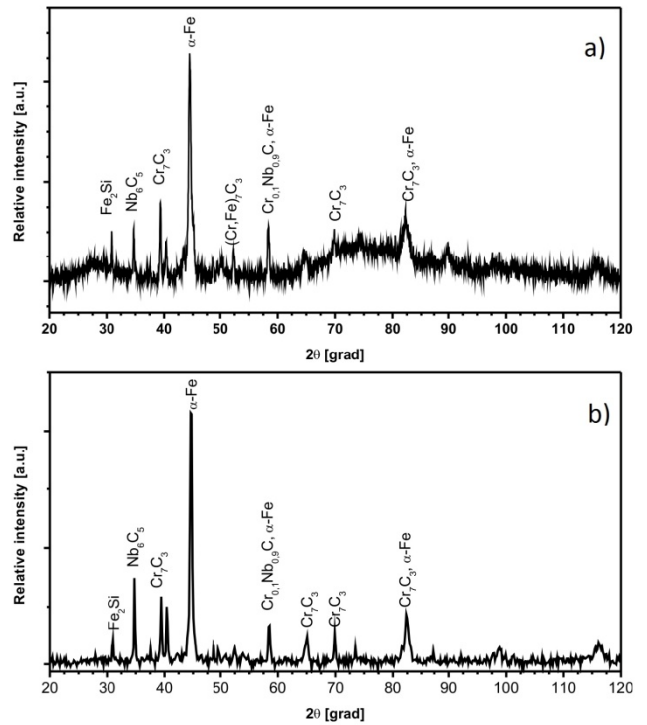


Fig. 4. XRD of the a) deposit number 1 and b) deposit number 2

The hardness measured on the obtained deposits show significant differences (Fig.5-6). The deposit number 1 characterizes by a significantly lower hardness in both the transverse and the longitudinal direction of welding. The reason for the differences in hardness reaching 200HV30 is mainly the size and amount of carbides in the structure of the claddings. In the case of the deposit number 2 large number of relatively large primary carbides had a positive impact on the growth of hardness.

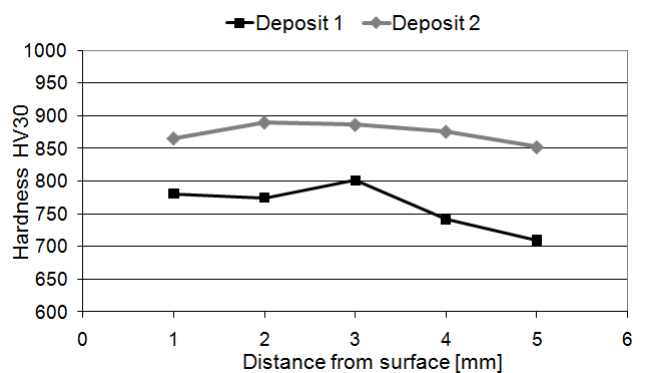


Fig. 5. Hardness distribution in the cross of the cladding

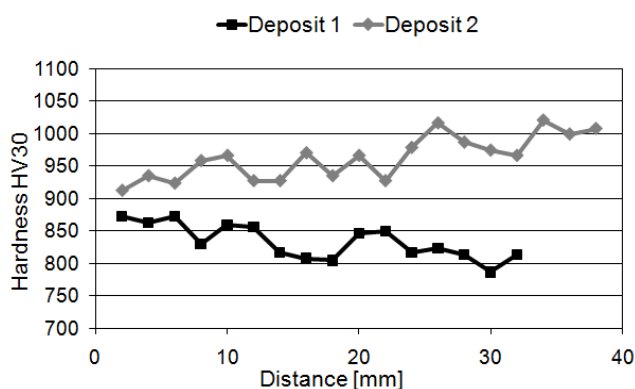


Fig. 6. Hardness distribution in the longitudinal direction of the cladding

## 4. Conclusions

The application of self shielded cored wires allows to obtain deposits of high hardness and diverse size of hard phases. The selection of appropriate parameters of the deposition process allows to obtain welds with the desired properties. In the case of the tested deposits the change of the speed of heat dissipation allowed to obtain deposits of different size and shaped carbide precipitates. The parameters of the deposition process did not have in this case a significant impact on the type of precipitates. A very important process parameter is the electrode stick out. Its extension increases the resistance heating wire and increases the melting rate which results into the heat balance of the process. This indicates a wide possibility of controlling the properties and structure of the deposits by appropriate selection of process parameters. Research on surfacing parameters would allow the determination of relevant technological factors and their influence on the properties of the deposits.

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