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Microstructure and Properties of the Steel Subjected to Overlaying Welding

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Possibility to apply chips of steel R6M5, steel R6M5K5, graphite, boron carbide and powder of alloying elements for arc overlaying welding is analysed in this research work. Spread out over the structural steel surface powder mixtures were melted by 1.2 mm diameter welding wire arc. Overlayed welded layers of high hardness and various alloying degree with characteristic high heat resistance were obtained. Investigations of microstructure and X-ray diffraction measurements were carried out.

Keywords: overlaying welding, powder, hardness, tempering.

1. INTRODUCTION

Surface condition of structural components has been a persistent problem in modern engineering application. Some components stop functioning due to only the minor damage on the surface. Using cladding techniques, it is possible to improve surface properties, such as the wear, the corrosion and oxidation resistances, and to take advantage of a longer service life and the consequent reduction of total cost. Cladding is defined as the deposition of dissimilar material on the surface of substrate to obtain desired properties, which the substrate initially does not possess, using special heat source such as arc, flame, induction heat and high energy beams. Submerged arc cladding has been used in modern industries, especially for the heavy section steels and for a large structure surfaces needing to be modified. Comparing with other welding process, submerged arc cladding offers higher deposition rate, higher layering capacity and better bead characteristic with less – sophisticated automatic equipment [1].

Submerged arc welding is a welding process in which the arc is concealed by a blanket of granular and fusible flux. Heat for submerged arc welding is generated by an arc between a bare solid metal (or cored) consumable wire or strip electrode and the workpiece. The arc is maintained in a cavity of molten flux or slag, which refines the weld metal and protects it from atmospheric contamination. Alloy ingredients in the flux may be present to enhance the mechanical properties and crack resistance of the weld deposit [2].

In submerged arc welding, there are several ways of increasing welding efficiency. The following are known multiple-wire welding, multiple-electrode welding, hot wire welding and welding with metal powder addition [3]. The investigations have shown that it is possible to submerged arc weld and clad with multiple-wire electrode and metal powder addition. In this way the deposition rate and productivity are increased, the consumption of shielding flux is reduced, and the arc efficiency is improved.

In work [4] a correlation was made of microstructure, high temperature wear resistance, and surface roughness in hardfacing alloys reinforced with complex carbides. The hardfacing alloys were deposited twice on a low carbon steel substrate by a submerged arc welding method. In order to investigate the effect of complex carbides, different fractions of FeWTiC and WTiC carbide powders included inside hardfacing electrodes were employed. Microstructural analysis indicated that cuboidal and rod-type complex carbides were homogeneously distributed in the bainitic matrix. Hardness, wear resistance, and surface roughness of the hardfacing alloys reinforced with complex carbides were improved in comparison to high speed steel rolls.

Work [5] examines the feasibility of applying wear resistant cladding to grey cast iron, which was usually used as, the material of machine tool structures, to improve their wear performance. Tungsten was used as a base powder, which was blended with copper, cobalt and nickel, respectively, in the ratio of 9 : 1 (tungsten : other metals) by weight percent. During blending, steel balls were placed into the ball-milling jar to ensure the powders are uniformly mixed. After blending for 24 h, composite powders were used to fill AISI 304 stainless steel tubes with an outer diameter of 3 mm and a thickness of 0.15 mm. These stainless steel tubes filled with cladding powders were then rolled to a size of $80 \times 3 \times 1$ mm. The rolled strips were stuck to the ground surface of the grey cast iron (ASTM class 35) using high-temperature silicone tape. Finally, cladding was performed by the gas tungsten arc welding method. Although W-Cu, W-Co and W clad layers had different shapes of precipitate, their wear performance was also better than that of the base metal, obviously. The normalizing process not only increased the bonding strength between the clad layer and the matrix, but also improved the wear performance of the layer under all cladding conditions.

The coatings investigated in source [6] were overlayed by special electrodes with a covering made of compound, consisting of titanium carbide and a binder (nichrom, high speed steel R6M5, carbon steel). Coatings with austenitic and martensitic matrix structure were obtained. In this structure titanium carbides are uniformly distributed. Titanium carbides passed to the coating from electrode covering or they were derived as a result of titanium and carbon reaction in melted layer. The hardness of overlayed

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composite coatings was in the range 20 – 30 HRC, when electrodes with austenitic steel bar were used and it was up to 60 – 65 HRC for electrodes with low carbon steel bar.

Steels are overlayed welded by various means, but most widely used is electric arc welding. Electrodes, powder wire and metal powder are used for electric arc welding. There is a little number of investigations devoted to research of arc welding using spread out powder layer.

Main objective of this work was to investigate arc overlaying welding for formation of hard, fine structure and wear resistant layer.

2. EXPERIMENTAL

Specimens of St3 (in Russ. Ст3) 4 mm thickness and 20 mm width structural steel were subjected to overlaying welding by two runs in bench – type turning machine tool by use of welding device INTEGRA 350 Professional with welding burner MIG/MAG EN 50078. The burner was fastened to the support moving at line-feed of 14.4 m/h. Low carbon steel wire (diameter 1.2 mm) was supplied through the burner continuously at 25.2 m/h speed.

Flux with high content of MgO and SiO_2 namely AMS1 was used for overlaying welding as well as manganese free flux AN-20P (in Russ. АН-20П).

R6M5 (in Russ. Р6М5) milling chips, R6M5K5 (in Russ. Р6М5К5) and metal powder were melted under flux by the electric arc between 1.2 mm steel welding wire and base metal (steel St3).

3. RESULTS AND DISCUSSIONS

3.1. Overlaying welding of a structural steel using R6M5K5 steel powder

During the arc welding under flux process, melted metal is well protected against environmental air influence, but at high temperature part of alloying elements is burnt-out. Use of R6M5K5 steel powder only for overlaying welding results the layer which contents is different from that of high speed steel. High-alloyed steel layer was obtained by use of R6M5K5 steel powder mixed with powder of alloying elements, the steel it contains (Table 1). Amount of alloying elements in the overlayed layer is decreased not only due to elements burn-out, but due to migration of the iron from low-carbon welding wire as well.

In all cases maximum hardness of overlayed layers was 62 HRC. Layers hardness after the welding was 47 – 50 HRC. Tempering at 650 °C resulted hardness increase up to 62 HRC (Fig. 1), due to residual austenite transformation into martensite.

Such hard layers (62 HRC) can be used for coating of metal cutting tools, because heat resistance of the layers is high enough, i.e., tool can be heated in the cutting process to 650 °C temperature.

Comparing the results presented in [7] one can conclude, that hardness of the layers welded by powder electrodes that were filled with the same mixture that (as that shown in the Table 1), maximum hardness of the layer welded under flux OSC-45 (in Russ. ОСЦ-45) and tempered at 600 °C temperature was 63 HRC.

Overlaying welding by use of powder layer is more simple and cheaper, it does not require the powder wire to be produced, production of that wire is complicated and expensive.

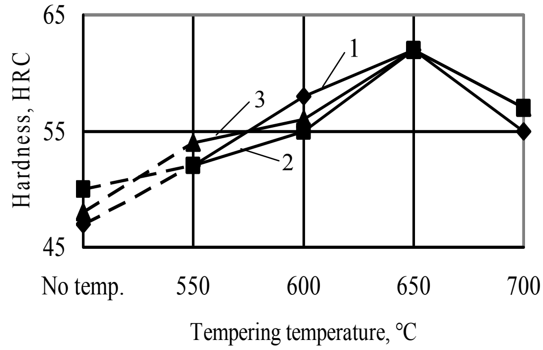

Fig. 1. Effect of tempering temperature on the hardness of overlaying welding layers (Table 1). Duration of tempering 1 hour

It was tried to obtain hard layer by overlaying welding of St3 steel with powder mixture composed of R6M5K5 steel, graphite, chromium and boron carbides. The highest percentage in content of the mixture made R6M5K5 steel powder (Table 2). Welded layers were alloyed by the elements from the powder and by manganese and silicon from the flux AMS1.

Using P6M5K5 steel and graphite powder mixture the layers of 49 – 52 HRC hardness were obtained. After tempering at 550 °C temperature their hardness increased to 60 HRC. Layer obtained by overlaying welding by mixture containing boron carbide, after cooling had hardness 62 HRC. This layer has less amount of residual austenite in comparison with other layers (Fig. 2). Maximum amount of residual austenite was in the layer produced by overlaying welding with powder mixture containing chromium

Figure 3 shows microstructure of layers after welding and after triple tempering at 550 °C temperature.

Table 1. Composition and layer thickness of the powder spread on the surface subjected to overlaying welding, of St3 steel under flux AMS1 or AN-20P

Composition of powder mixture, mass %							Thickness of powder layer, mm	Flux	Number of deposited layer
C	Cr	Mo	V	W	Co	R6M5K5			
7.0	17.0	14.0	16.0	20.0	18.0	8.0	4.0	AMS1	1
							5.0		2
							5.0	AN-20P	3

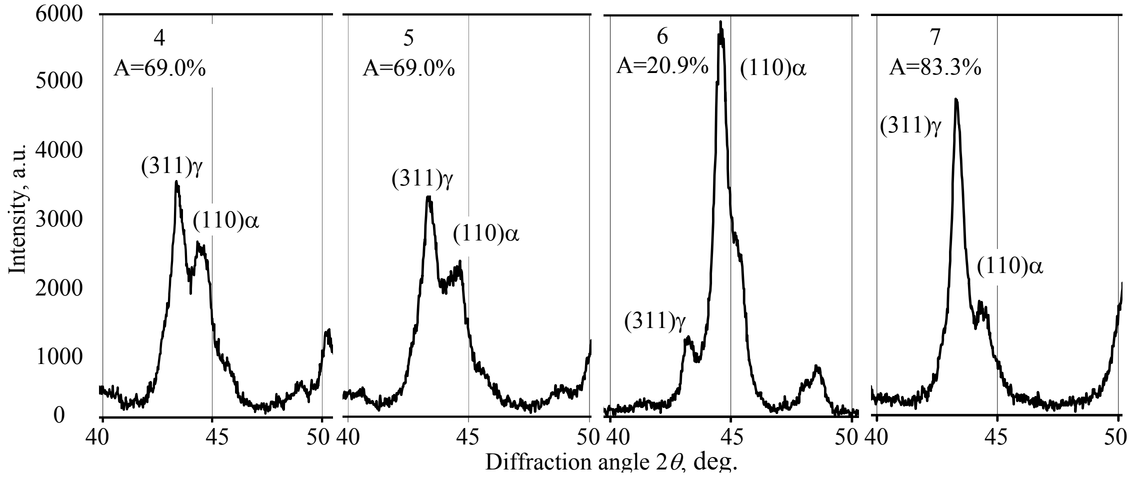

Fig. 2. X-diffraction patterns of overlaying welding layers

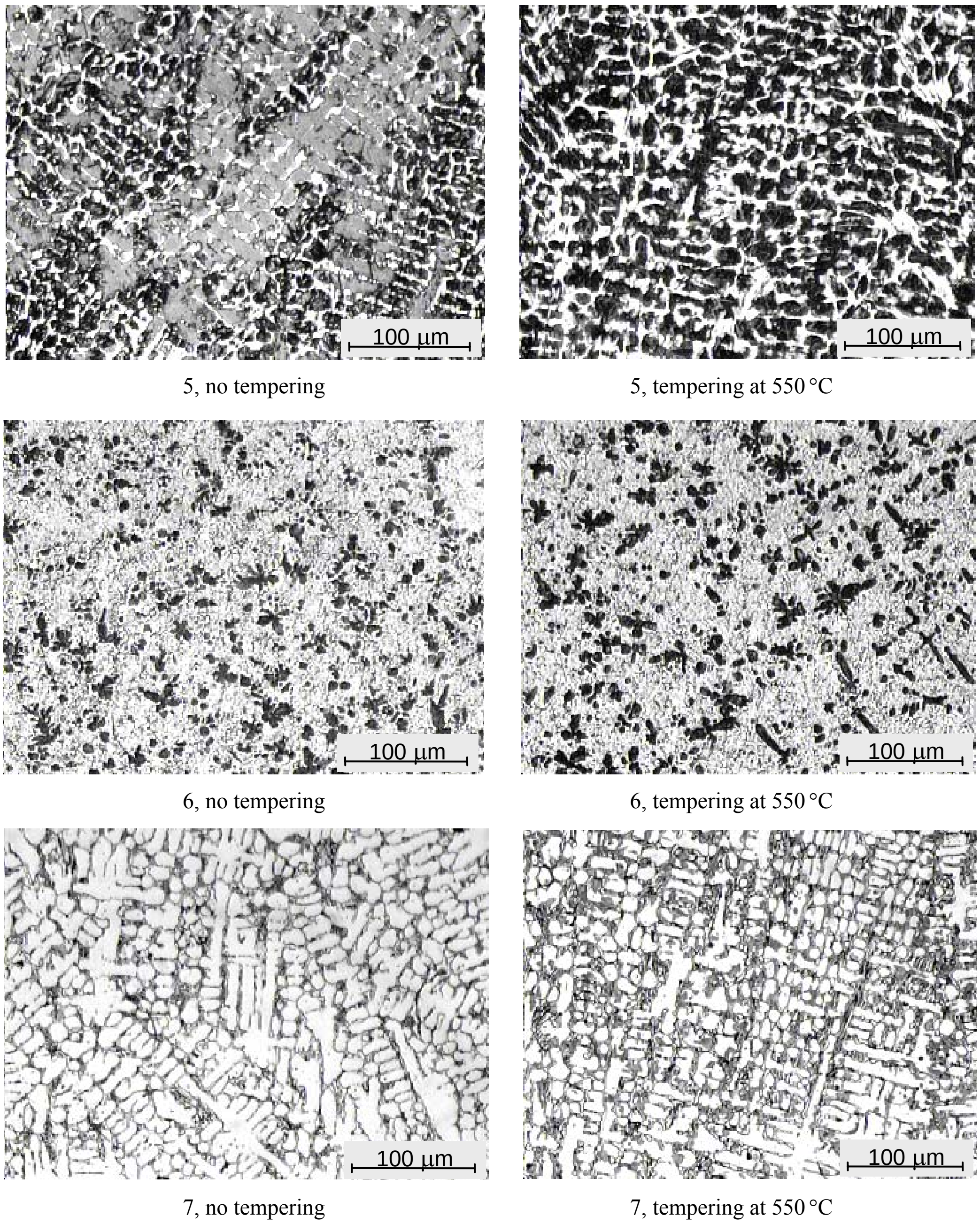

Fig. 3. Microstructure of overlaying welding layers (Table 2)

Table 2. Effect of the powder mixture composition, spread over the surface subjected to overlaying welding, thickness of the powder layer, and tempering temperature on the hardness of the layers welded under flux AMS1

Number of deposited layer	Composition of powder mixture, mass %				Thickness of powder layer, mm	Tempering temperature, °C			
	C	Cr	B_4C	R6M5K5		No tempering	550	600	650
4	10.0			90.0	5.0	52	60	57	56
5	10.0			90.0	4.0	49	60	57	54
6			10.0	90.0	4.0	62	61	60	58
7	9.7	24.4		65.9	5.0	43	46	55	55

Some structural diversity can be seen in the microstructure of the layer welded by mixture containing graphite powder. When the test piece was etched by 3 % nitrogen acid spirit solution, the areas having more residual austenite have remained brighter. Tempering at 550 °C temperature resulted transformation of residual austenite into martensite, and the microstructure had become more uniform. At high welding temperature dissociation of boron carbide results migration of carbon and boron into melted metal. Crystalization of liquid metal led to formation of carbidic-boridic phase part of carbon and boron have remained in hard solution. During the cooling the layer has hardened because there had been enough carbon, and because boron had increased hardenability. Slow cooling of the metal under the flux layer resulted it's hardening to 62 HRC. Boron acts as a modifier and, therefore, fine microstructure is obtained and structural uniformity is obvious. In the layer with increased chromium amount there is much residual austenite (83.3 %). It was difficult to etch this layer with nitrogen acid solution. This circumstance proves that layer of such composition has increased corrosion resistance.

Table 3. Effect of the number of tempering procedures at 560 °C temperature on the overlaying welding layers hardness (HRC). Duration of tempering 1 hour

Number of deposited layer	Number of tempering procedure		
	1	2	3
4	60	60	61
5	60	61	60
6	57	60	60
7	45	50	50

Usually steels, having characteristic for high speed steels composition, are tempering at 560 °C temperature three times aiming to abolish residual austenite and to increase hardness. Welded layers subjected to triple tempering at 560 °C showed no noticeable hardness changes, except those with increased chromium amount (Table 3). Second tempering resulted hardness increase by 5 HRC.

3.2 Overlaying welding of a structural steel using R6M5 steel chips

In drill production great amount of milling chips is formed, and it comes to the waste. The possibility to use R6M5 steel chips for overlaying welding has been investigated in this research. Use of R6M5 steel chips only gives low-alloyed and not enough hard layers. Therefore, the mixture of alloying elements powder was melted together with the chips. Table 4 presents composition of powder mixtures. There was no graphite powder in the mixtures. Graphite powder was mixed with flux AMS1 and through the liquid slag carbon migrated to the melted metal, resulting the layers having high enough carbon contents. The layer of highest hardness was obtained when the surface had been covered by Cr, Mo and V powder mixture (2 mm) and R6M5 steel chips (3 mm) (Fig. 4, curve 11).

Use of R6M5 steel chips and small amount of alloying elements powder for overlaying welding enables to obtain layers of high hardness and satisfactory high heat resistance.

Tests carried out in our investigation show that overlaying welding of structural steel under flux by spread out powder layer allows to obtain coatings of various alloying degree, various hardness and of fine microstructure.

Table 4. Composition of the powder spread on the surface subjected to overlaying welding and the thickness of powder and R6M5 steel chips layers for overlaying welding of St3 steel under flux AMS1 mixed with graphite (ratio 100 : 10)

Composition of powder mixture, mass %					Thickness of powder layer, mm	R6M5 chips layer thickness, mm	Number of deposited layer
Cr	Mo	V	W	Co			
22.2	44.5	11.1	22.2		2.0	3.0	8
22.2	44.5	11.1		22.2	2.0	3.0	9
44.5	44.5	11.1			2.0	3.0	10
22.2	66.7	11.1			2.0	3.0	11
					1.5	3.5	12
					1.0	4.0	13

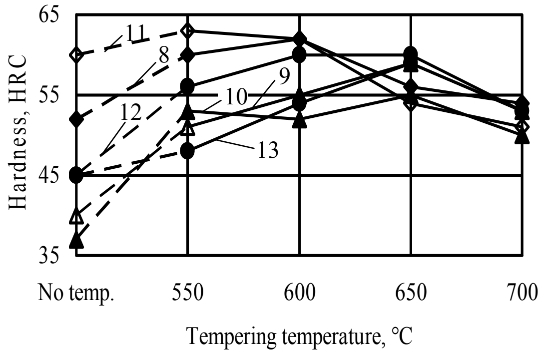

Fig. 4. Effect of tempering temperature on the hardness of overlaying welding layers (Table 2). Duration of tempering 1 hour

4. CONCLUSIONS

1. Overlaying welding by use of spread out powder is simple technological process. Expensive powder welding wire is not needed.
2. Using for overlaying welding R6M5K5 steel powder and it's alloying elements powder it is possible to obtain hard layer that can be heated in cutting process up to 650 °C temperature and retain initial hardness.
3. Using R6M5 steel milling chips for overlying welding hard (63 HRC) layer can be obtained by covering surface subjected to welding by chromium, molibdenum or vanadium powder mixture.

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