Formation of High Wear Resistance Surface Layers using Metals Powder

First A. Regita Bendikiene, Second B. Petras Ambroza and Third C. Lina Kavaliauskiene

Abstract— Submerged arc surfaced layers, obtained using half-automatic welding device, were investigated in the present work. Steels Ct3, 45, Y8, X12M, P6M5 (GOST) were deposited under the flux AMS1 (chemical composition: more than 50 % of SiO2 and MnO) mixed with chromium, molybdenum, graphite powder and powder of inoculant SiCaBa. Changing quantity of inoculant powder added to the flux, layers of various structure and mechanical properties were composed; while feeding of low carbon wire of 1.2 mm in diameter were continuously delivered into the welding zone. Initial and secondary hardness of layers, alloyed with chromium, molybdenum, manganese and silicon, was increased by powder of the SiCaBa. The opportunity of structural steel deposition using milling chips of high speed steels was estimated. Chips spread on the surface were fused under the flux AMS1, when arc was struck between welding wire and the substrate; layers were alloyed with alloying elements, presented in the chips and flux.

Keywords— Submerged arc surfacing, wear resistance, metals powder, overlaying.

I. Introduction

In the production of machines, devices and structures various materials satisfying diverse operational requirements are used. The main requirements are: high strength and satisfactory plasticity, high wear and corrosion resistance, resistance to oxidation, and some other specific properties. New materials for various applications are continuously developed using advanced technologies. Widespread application of composite materials is based on their ability to combine incompatible properties while in the compact materials perfect compatibility of the properties is difficult to achieve, e.g., it is difficult to achieve compatibility of the hardness and toughness in steels.

Complex properties for compact materials can be given using heat and thermo-chemical treatment, plastic deformation, spray deposition, overlaying and others.

Weld surfacing is the technique of depositing a layer of material onto the surface of a component to make it more resistant to wear, corrosion or high temperature than the parent metal or substrate. This enhances production economies by enabling the use of a cheaper, more easily machinable parent material coated with expensive metals and alloys for achieving desired properties in specific areas of products [1].

Strengthening of material surface can be achieved by electric arc overlaying; this process enables to obtain thick layers of various composition and properties on the surface of the parts. There are a lot of methods suggested for the solution of surfacing problems and increasing of surface wear resistance.

The paper [2] deals with multiple wire submerged arc welding and cladding with metal powder addition. By using the metal powder addition it is possible to alloy a weld or a cladding with optional chemical elements.

The influence of the composition and heat treatment of overlays on the abrasive wear resistance of iron base hardfacing alloy overlays is reported [3]. Overlays were deposited using a shielded metal arc welding process on structural steel using two commercial hardfacing electrodes. Abrasive wear resistance of overlays in as welded and heat treated conditions was tested using a pin on disc system. Significant variation in hardness was noticed across the interface, indicating the effect of dilution. Hardness of the coating adjacent to the interface was found to be comparatively lower than the coating further away from the interface.

Arc overlay welding under a flux, using various materials, technologies and regimes, enables to obtain thick, wear resistant coatings. Simple, easily realized is arc welding of spread over powder layer. In research [4] WC-8 % Co powder was spread on low carbon structural steel surface and melted by arc under the flux, containing graphite powder.

The paper [5] is an investigation into the use of nickel and cobalt base superalloys as wear resistant hard facing materials on H11 tool steel. Three weld overlay alloys including Inconel 625, Stellite 6 and Stellite 21 were deposited on H11 steel substrates using tungsten inert gas welding (TIG) process.

The aim of research [6] was to produce a surface layer on the parts made from the structural steel and showing the properties typical of commercial maraging steels. To this purpose a cored wire and an alloyed agglomerated powder for surfacing the Ni-Co-Mo alloys with different chemical compositions were developed and produced. Surfacing was

Manuscript received January 23, 2007. Revised received May 17, 2007

F. A. Regita Bendikiene is with International Studies Centre, Mickeviciaus str. 37, LT-44244 Kaunas, Lithuania (corresponding author to provide phone: 370-37 323-704; fax: 370-37 323-704; e-mail: regita.bendikiene@ktu.lt).

S. B. Petras Ambroza is with Kaunas University of Technology Faculty of Mechanical Engineering and Mechatronics, Kestucio str. 27, LT-44025 Kaunas, Lithuania (e-mail: petras.ambroza@ktu.lt).

T. C. Lina Kavaliauskiene is with Kaunas University of Technology Faculty of Mechanical Engineering and Mechatronics, Kestucio str. 27, LT-44025 Kaunas, Lithuania (e-mail: lina.kavaliauskiene@ktu.lt).

carried out with four differently alloyed Ni-Co-Mo alloys, related to the commercial maraging steels of the Ni-Co-Mo alloy type.

II. Problem Formulation

Submerged arc surfacing was chosen for the making of high alloyed surface layer. Composition of the layers was changed adding metals powder into the flux.

During overlaying process, when arc was struck between continuously feed welding wire and the parent metal, metals powder in the flux acts as alloying agent. When all components of the surfacing process (welding wire, the flux with materials powder and surface of parent metal) were melted, batch of liquid metal under the layer of the slag was formed. When cooled weld solidifies and hardens. Hardness of deposited layer depends on chemical composition which was changed adding into the flux powder of chromium, molybdenum, graphite and powder of SiCaBa and SB-5. Manganese and silicon oxides presented in the flux work as alloying agents too. Inoculant SiCaBa (15-20% Ca, 8% Ba, 2-3% Al) and SB-5 (68% Si, 1.5% Al, 1.5% Ca, 2-3% Ba) are often used in the production of cast iron. Usually influence of inoculants on the chemical composition of steel is negligible, but during solidification improves structure and changes properties. The overlying or surfacing is one of the most economical methods enabling to improve wear resistance of the machine components and tolls. Noticeable effect is achieved when chromium, tungsten or other elements carbides are presented in the structure of the weld, and these carbides strengthened the weld.

The overlaying is widely used in the production and renovation of agricultural machinery, mining and metallurgy equipment parts subjected to abrasive wear operation. Blanking and shaping dies as well as metal and wood cutting tools are subjected to overlaying.

Flux of grade AMS1 with more than 50 % of SiO_2 and MnO was used in the process. Low carbon steel wire with diameter of 1,2 mm, and with such chemical composition C ≤ 0,1 %; Si ≤ 0,03 %; Mn = 0,35 – 0,6 % was selected for overlaying process.

Test pieces prepared from steels (Table 1) were deposited using torch MIG/MAG EN 50078 and half-automatic welding device INTEGRA 350 Professional.

TABLE I
Chemical Composition of Test Pieces

Steel grade	C	Mn	Si
	mass %		
45	0.42 – 0.50	0.5 – 0.8	0.17 – 0.37
Ct3	0.14 – 0.22	0.4 – 0.65	0.12 – 0.3
Y8	0.75 – 0.84	0.2 – 0.4	0.15 – 0.35
P6M5	0.80 – 0.88	0.4	0.5
	3.8 – 4.4 % Cr; 5.5 – 6.5% W; 1.7 – 2.1 %V; 5.0 – 5.5 %Mo		
X12M	1.45 – 1.65	0.4	0.15 – 0.35
	11 – 12.5 %Cr; 0.4 – 0.6% Mo		

To ensure longitudinal motion, torch was fixed to the carriage of the turning latches. Layer of 8 mm width and 6 mm height was obtained by one passing. More wide layers could be obtained by second passing – after first one the torch is moved in transversal direction. Test pieces in the holders for the overlaying process were fixed into the clamp, which was fixed to the guide of latches. Regimes for welding process: current 180 – 200 A, voltage 22 – 24 V, rate of overlaying 14.4 m/h, rate of wire feeding 25.2 m/h.

III. Problem Solution

Generally components and details are subjected to the submerged arc surfacing in order to obtain high wear resistance or to renovate worn during exploitation surfaces. There is no matter to make details from expensive high alloyed steels, it is more cheaper to deposit plain structural steel making a high alloyed, high wear resistance surface layer. For the formation of superficial layer using processes of submerged arc surfacing it is possible to obtain layers with various composition, different structures and properties. It is possible in the large areas to make strong layers on the surface of various machine components.

Submerged arc surfacing by fusion of metals and compounds powder added to the flux was chosen. Advantage of this process is that is not necessary to produce integral powder wire, and it is possible to gain layers with different chemical composition, changing composition and quantity of adding elements.

Deposited layers were subjected to post weld heat treatment. They were tempered at the temperatures of 500 – 600 C for the purpose of achievement of secondary hardness. Retained austenite presents in the structure of deposited layer, which after tempering transforms into the martensite. If after welding layer hardens totally (primary hardness), hereof after high temperature tempering hardness of such a layer decreases.

Wear resistance of layers were measured according mass looses.

Test pieces were submerged arc surfaced using flux AMS1 (more than 50 % of MnO and SiO_2) with additives of chromium, molybdenum and graphite powder, also inoculant SiCaBa (15-20 %Ca, 8 %Ba, 2-3 %Al), which is generally used in the cast iron metallurgy. Graphite was added to increase carbon content in the layer. Chromium and molybdenum, silicon and manganese presented in the flux, also silicon from the inoculant alloys formed layer. Calcium and barium presented in the inoculant change solidification process, structure and properties of the layer. Chromium has an ability to expand austenite area, so in the structure of deposited layer austenite can remain. Chromium and manganese increase hardenability of steel. These elements and molybdenum increase wear resistance of steel. The highest wear resistance can be achieved when in the relatively touch matrix hard carbides, carboborides, borides are presented. The lower wear resistance attained when in the structure of layer cementite carbides were formed. Hardness of cementite is close to the hardness of martensite. In the structure of steel with 4-5 % of chromium exist two types of carbides: M_7C_3 (the highest wear resistance) and Fe_3C (lower wear resistance), that's why maximum wear resistance can not be achieved. When chromium content more than 5 %, just chromium carbides form and steel has relatively good wear resistance.

Tungsten and molybdenum when combined with carbon make stable carbides increasing wear resistance of steel. Molybdenum supersedes expensive tungsten in the high speed steel.

Surfacing is often used for carbon and low alloyed structural steels. However for the renovation of worn surfaces of dies tool steels and high alloyed steels can be surfaced. This investigation was done to clear out how surfaced layer fuses with high carbon and high alloyed matrix and to define influence of matrix to the properties and structure of layer.

Hardness of surfaced layers after welding was 29 – 35 HRC. Low hardness show that layers when cooled under the flux hardened not totally – high quantity of retained austenite. Post weld tempering shows (Fig. 1) hardness growth.

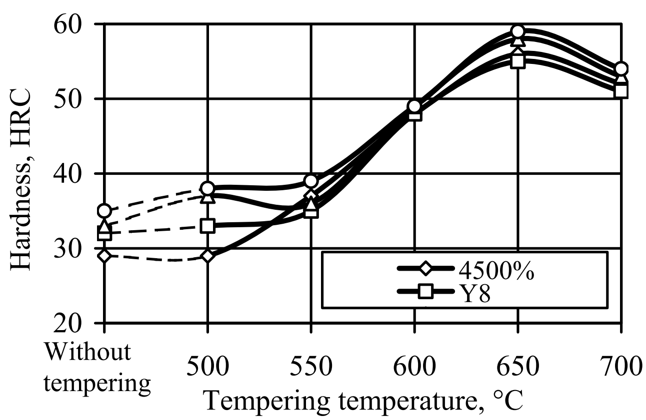


Fig. 1 Dependence of hardness of the surfaced layers on tempering temperatures

The highest hardness (59 HRC) was obtained when tempering temperature was 650 °C, because of retained austenite transformation into martensite and processes of dispersive consolidation. Slightly higher hardness show layers surfaced on the steels P6M5 and X12M. Those steels have much more alloying elements than structural steels. During welding process alloying elements of these steels flowed into the layer.

Microstructure of surfaced layer is presented in the Fig. 2. Structures obtained after surfacing on the different kinds of steels are similar. It shows that influence of matrix on the chemical composition of surfaced layers is negligible, but chemical composition of layers mainly depends on the elements added to flux (chromium, molybdenum and graphite). Microstructure consists of white dendrites and dark areas between dendrites (martensite-troostite mixture).

During surfacing process between continuously feed wire and matrix small amount of fused metal forms. Fine dendrites form during rapid solidification. Carbide phase did not form because of lack of carbon present.

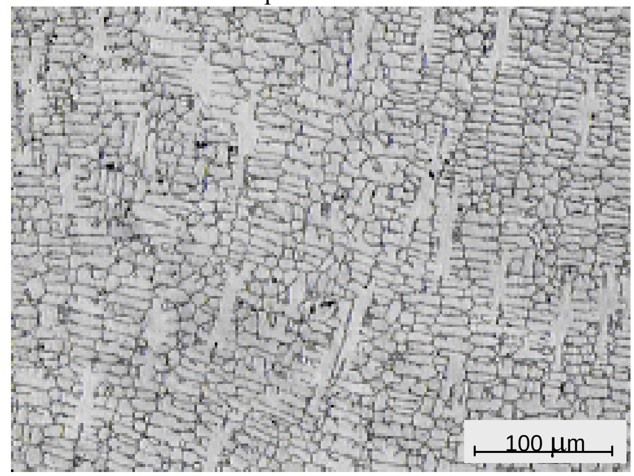
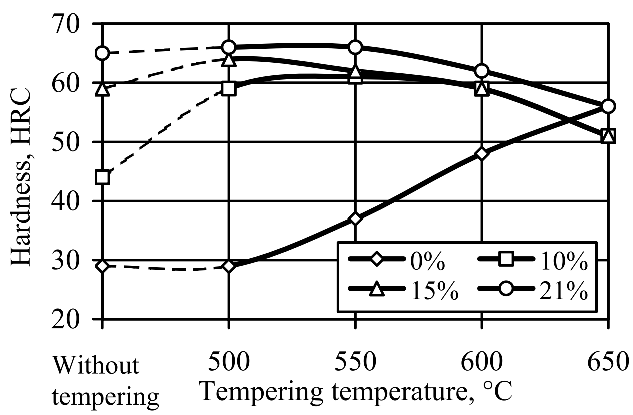


Fig. 2 Microstructure of layer obtained on the steel 45 using the flux mixed with chromium, molybdenum and graphite powder

Test pieces prepared from steel 45 were surfaced using inoculant. Test results showed that layers obtained using SiCaBa powder is much harder because of lower content of retained austenite (Fig. 3).



F

Fig. 3 Dependence of hardness of the layers obtained on submerged arc welded steel 45 under flux AMS1 with additives of chromium (12 %), molybdenum (16 %), graphite (12 %) and SiCaBa powder on tempering temperatures. Percentage in the legend shows quantity of SiCaBa in the flux. Dashed lines – no tests performed.

Increasing quantity of powder additives from 10 % to 21 %, initial hardness of the layers increases from 40 HRC to 59 HRC. After tempering the highest obtained hardness showed layer with 21 % of SiCaBa. When tempering temperature was 550 °C, obtained hardness of this layer reaches 66 HRC, however when SiCaBa quantity in the flux was very high, weldability of compound was very weak, porosity was observed, and adhesive properties of weld were pour. With increasing quantity of SiCaBa powder in the flux, temperature of maximum hardenability during tempering decreases. Maximum hardness (56 HRC) of the layers obtained without SiCaBa powder was achieved when tempering temperature was 650 C, while maximum hardness (66 HRC) of layers obtained adding 21 % of SiCaBa powder into the flux AMS1 was achieved at tempering temperature of 500 °C.

Examination of microstructure shows changing of microstructure as result of the inoculation. Increasing quantity of SiCaBa powder, structure of deposited layers changes (Fig. 4).

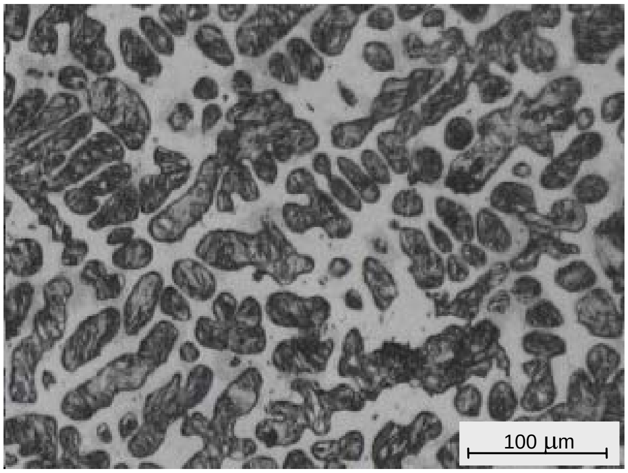


Fig. 4 Microstructure of layers obtained after submerged arc surfacing under the flux AMS1 mixed with powder of chromium, molybdenum, inoculant SiCaBa and graphite. Quantity of SiCaBa – 21 %.

The biggest quantity of very hard (until 9000 MPa) carbide structure (white areas) can be observed in the layers obtained after welding under the flux AMS1 with 21 % of SiCaBa.

Producing drills, large amount of milling chips remain after operation. These chips can be used for overlaying. Chips layer (2 mm thick), spread on the surface of steel 45 substrate, and were fused under the flux AMS1 mixed with powder of chromium, molybdenum, graphite and SiCaBa. Chips of high speed steel are very valuable, because of its chemical composition.

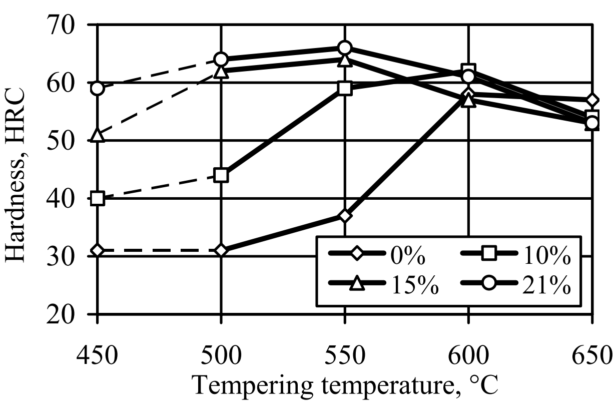


Fig. 5 Dependence of hardness of the layers obtained on submerged arc welded steel C45 under flux AMS1 with additives of chromium (12 %), molybdenum (16 %), graphite (12 %), SiCaBa powder and chips of high speed steel (2 mm thick) spread on the surface, on tempering temperatures. Percentage in the legend shows quantity of SiCaBa in the flux. Dashed lines – no test performed.

Obtained layers possess quantities of alloying elements such as tungsten, molybdenum and others. Alloying elements flow from the flux and chips, forming structural constituents. The hardest layers were obtained when SiCaBa powder was used (Fig. 5). Inoculant SiCaBa influences microstructure of layer too. The hardest obtained layer using AMS1 flux with 21 % of SiCaBa is shown in the Fig. 6. After tempering at 550 °C this layer hardens from 59 HRC until 66 HRC.

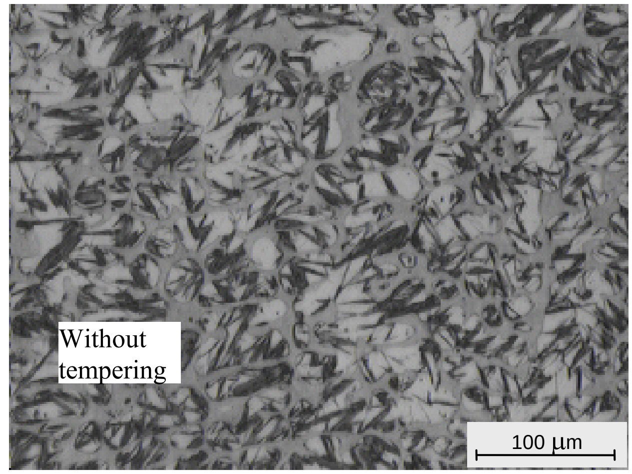


Fig. 6 Microstructure of layers obtained after submerged arc surfacing under the flux AMS1 mixed with powder of chromium, molybdenum, inoculant SiCaBa, graphite and chips of high speed steel (2 mm thick) spread on the surface

IV. Conclusions

1. It is possible to obtain layers of high quality and high mechanical properties, using process of submerged arc surfacing on the surfaces of any kind of steels.

2. Do not changing quantity of chromium and molybdenum powder in the flux AMS1, but increasing quantity of inoculant SiCaBa much more carbide phase composes, and hardness of the layers increases.

3. Layers of steels subjected to submerged arc surfacing, using chips of high speed steel, become alloyed with elements presented in the chips. It is possible to save expensive materials widely used in the surfacing and coating processes.

References

[1] Murugan, N., Parmar, R.S., Sud, S.K., Effect of Submerged arc Process Variables on Dilution and Bead Geometry in Single Wire Surfacing, *Journal of Materials Processing Technology,* Vol.37, n 1-4, 1993, pp.767-780.

[2] Tušek, J., Suban, M., High Productivity Multiple Wire Submerged Arc Welding and Cladding with Metal Pwder Addition, *Journal of Materials Processing Technology*, Vol.133, 2003, pp. 207-213.

[3] Dwivedi, D.K., Microstructure and Abrasive Wear Behaviour of Iron Base Hardfacing, *Materials Science and Technology,* Vol.20, n 10, 2004, pp. 1326-1334.

[4] Ambroza, P., Bočkus, S., Kavaliauskienė, L., Submerged Arc Overlaying Welding of Structural Steel by WC-Co Powder, *Archives of Metallurgy and Materials* 51, 2006, pp. 489-494.

[5] Kashani, H., Amadeh, A., Ghasemi, H.M., Room and High Temperature Wear Behaviors of Nickel and Cobalt Base Weld Overlay Coatings on Hot Forging Dies, *Wear 262,* 2007, pp. 800-806.

[6] Grum, J., Kejžar, R., Slabe, J.M., Submerged Arc Surfacing of Ni-Co_Mo Alloys Similar to Maraging Steels on a Structural Steel, *Journal of Materials Processing Technology*, 155-156, 2004, pp. 2011-2018.