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Utilization of waste materials for welding and surfacing

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1. Introduction

Wear of machinery components is one of the most common problems in engineering applications. Surface coating can be employed to increase the wear resistance of the components. There are many surface coating techniques, such as plasma spraying, thermal spraying, hardfacing, laser cladding, chemical and physical vapor deposition processes [1-3].

Hardfacing is a surface treatment of metals, in which welding metal having excellent resistance to wear and oxidation is deposited onto a surface of a substrate [4].

Hardfacing is one of the most useful and economical ways to improve the performance of components under severe wear conditions [5]. A study was made to compare the microstructure and abrasion resistance of hardfacing alloys reinforced with primary chromium carbides, complex carbides or tungsten carbides. Three different commercial hardfacing electrodes were employed to investigate the effect of microstructure. The abrasion tests showed that the wear resistance is determined by the size, shape, distribution and chemical composition of the carbides, as well as by the matrix microstructure. The best abrasion resistance was obtained in microstructures composed of eutectic matrix and primary M_7C_3 or MC carbides, while the higher mass losses were measured in completely eutectic deposits.

Fe-C-Cr weld surfacing layers with different compositions and microstructures can be obtained by submerged arc welding with welding wire of the low carbon steel and high alloy bonded flux [6]. With the increase of Cr and C in the layers the microstructures are changed from hypoeutectoid steel, hypereutectoid steel to hypoeutectic iron and hypereutectic iron. Good erosion resistance can be obtained when the proportion of primary carbides is within 10 %. The experimental results give a background to make double metal percussive plates by surfacing wear resistant layers on the substrates of low carbon steels.

In the study [7], Fe-based hardfacing coating reinforced by TiC particles was obtained by manual shielded metal arc welding in which H08A bare electrode was coated with fluxes, to which different measures of ferrotitanium, rutile, graphite, calcium carbonate and calcium fluoride had been added. The results indicate that TiC particles are produced by direct metallurgical reaction between ferrotitanium and graphite during welding. TiC particles are uniformly dispersed in the matrix of lath martensite and retained austenite with particle sizes in the range 3-5 μm.

Based on lath martensite and carbides, the surfacing electrode with high hardness was developed owing to adding graphite, ferrotitanium, ferrovanadium, etc., in electrode coating. Although the content of carbon element in deposited metal is very high, the lath martensite is generated in welded metal because TiC-VC particles are formed by means of high temperature arc metallurgic reaction [8]. The results show that hardness of the surfacing metal is above 60 HRC. Surfacing layers have fine crack resistance and high wearibility.

Production of welding electrodes, powder wire and fluxes, which are used for steel parts arc deposition, requires the application of alloying elements, carbides, borides and other expensive materials. Due to high cost of these materials it is purposeful to use waste materials for steel parts surfacing. Lack of literature sources related to the use of metal cutting waste (chips, abrasive slurry) for arc deposition is noted. In [9] the use of steel ШХ15 abrasive slurry for restoration of agricultural and mining machine parts is analyzed. Resistance welding of the particles separated from abrasive slurry steel ШХ15 to the part surface resulted in wear resistant layers.

Steel ШХ15 powder recovered from grinding abrasive slurry may be used in production of wear resistant parts applying powder metallurgy methods [10]. The authors of [11] recommend using waste materials in production of alloying compositions assigned for the correction of surfacing metal composition and structure. Application of thermo chemical treatment and high temperature synthesis enables to obtain Fe-Me (Cr, Ti, Si, and W) – B/C type alloying compositions.

The possibility to reuse already used in production processes materials based on WC and TiC carbides was investigated in [12]. Plates of these carbides after the use can be milled into powder, which may be applied for new plates production or thermal spraying.

An objective of this investigation is to analyze the possibilities to utilize waste materials for welding and surfacing. Surface layers of different composition and microstructure can be overlayed by simple automatic arc deposition, when base metal surface is covered by the layer of powder; the powder is melted by electric arc between the continuously supplied welding wire and base metal. Preparation of the waste material for such process is simple: it is enough to mill the waste into powder or, in same cases, to apply fat extraction, whilst the powder for thermal spraying should be prepared very carefully.

2. Experimental procedures

Specimens of a low carbon structural steel Cт 3 (0.12-0.30 % C; 0.40-0.65 % Mn) were overlay welded in the device, assembled from the lathe and semiautomatic welder [13]. Powder spread over the surface, subjected to overlay welding, was melted in the arc between continuously supplied 1.2 mm diameter low carbon steel Cв 08 (<0.09 % C, <0.1 % Si, 0.5 % Mn) and structural steel Cт 3 plate (6x10x60 mm). The powder was simply poured on the specimens and the welded layer was obtained by one pass welding.

To obtain layers of various composition and microstructure the powder mixture was spread over the surface subjected to overlaying (steel Ст 3), and melted by electric arc heat. Automatic submerged arc welding was used. As a flux milled glass powder was used. Silicon glass usually used for windows, packaging, etc., containing from 60 to 80% SiO_2, up to 20% CaO and 10-25% NaO [14] was utilized. SiO_2 in the glass composition is dominating. SiO_2 is used as a main component in a great majority of fluxes, for example, for submerged arc welding of carbon and low alloy steels the flux AMS1 having in the composition more than 50% MnO and SiO_2 is used. For comparison one specimen was subjected to submerged arc welding with AMS1 flux, which, when mixed with the powder of various materials, enables to obtain hard, wear resistant layers [15].

Other waste materials were used without the glass. The following waste materials were utilized: drills milling chips of P6M5 steel, carbide T15K6 plates after service, waste parts of grinding disks containing SiC or B_4C.

Aiming to obtain the layers containing more carbon, the graphite powder was added into the composition; silicon amount was increased adding sand.

Aiming to improve chemical composition of surfacing layers waste materials were crushed into powder and mixed with industrial production materials powder. Powder of Fe-70% Mn, chromium and cobalt was utilized for the purpose. Powder of SiCaBa was used as well, because it is utilized very often as a modifier improving steel and cast iron microstructure and mechanical characteristics.

The powder composition was spread over the base metal in the amount resulting formation of the thick liquid slag layer, protecting melted metal from the air environment. When the glass is melted, silicon from liquid slag deoxidizes base metal and partially remains in it as an alloying element. Higher alloying by silicon can be achieved overlaying by the composition containing sand, SiC or SiCaBa powder.

In some compositions Fe-70% Mn powder had been inserted aiming to alloy by manganese. Manganese acted as deoxidizer and decreased oxygen amount in surfacing metal.

3. Results and analysis

Overlay welding by low carbon wire Св 08 of structural steel Ст 3, which surface was covered by glass powder or glass powder mixed with the powder of materials has resulted mild layers of various microstructures. Hardness of the layer is shown in Table 1. Hardness of surfacing layers is low, what indicates low carbon amount.

Table 1

Hardness of the layers produced by welding the powder of glass and other materials spread over the surface of the base Ст 3 steel and welded by arc with low carbon wire Св 08

Powder of various materials mixed with glass powder (%)	Hardness of surfacing, HRC
Glass powder (100)	7
Standard flux AMS1 (100)	14
Iron boride (9)	28
Graphite (9)	10
Fe-70% Mn (9)	15
Powder of P6M5 steel chips (35)	19

Various microstructures of the layers are obtained, when glass powder was mixed with the powder of other materials. Overlay welding of Ст 3 steel under glass powder layer resulted coarse – grain ferritic microstructure with small perlite amount (Fig. 1, a). In the weld there is no strict border between surfacing and base metals. In microstructure of the metal, welded under standard AMS1 flux layer, the bainite and ferrite may be seen on grain boundaries (Fig. 1, b). When Ст 3 steel was face surfaced by glass and boron nitride powder mixture, the layer with obvious dendritic crystallization features had been received (Fig. 2, a); face surfacing with glass and graphite powder resulted coarse – grain microstructure (Fig. 2, b).

Addition of Fe-70% Mn or P6M5steel chips powder into glass powder resulted bainitic microstructure of face surfacing, Smaller ferrite amount is noted in the layer welded with P6M5 steel chips (Fig. 3, b) in comparison with that, welded with the mixture of glass and Fe-70% Mn powder (Fig. 3, a). Continuous bainitic microstructure has to ensure good mechanical characteristics of both the weld and face surfaced material.

In the course of welding under the layer of glass powder and standard flux AMS1 the electric arc between continuously supplied Св 08 wire and base metal (Ст 3 steel) was stable, and the formation of surfacing layers was rather good. Melted glass well protected liquid metal from the air influence; metal's surface was bright (Fig. 4).

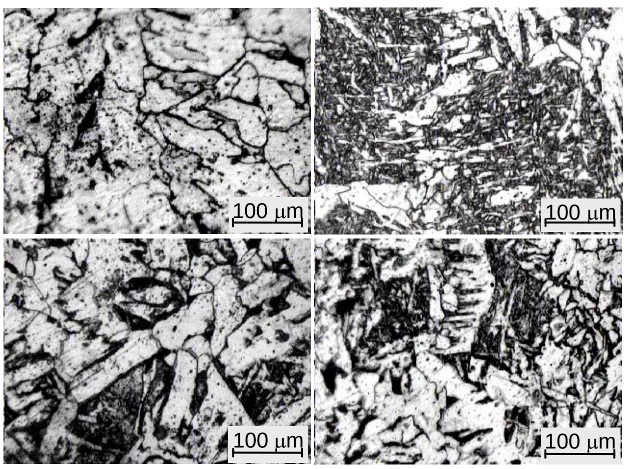
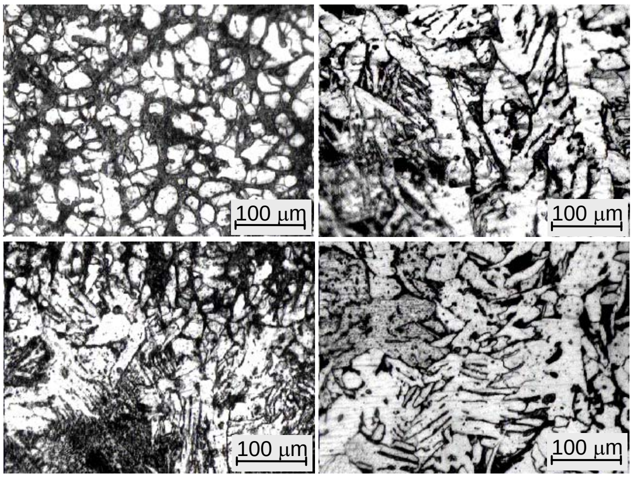
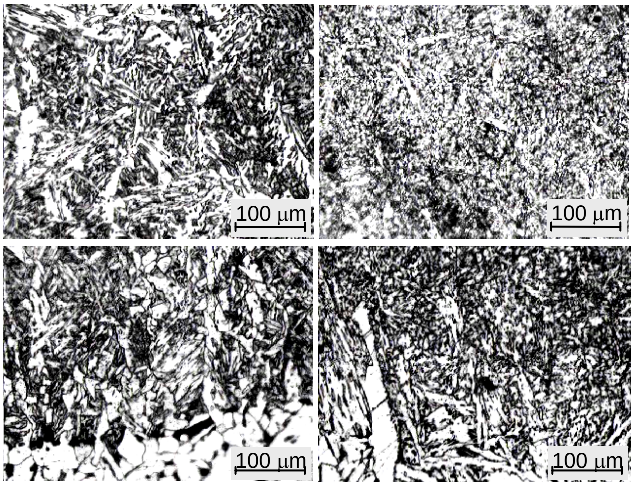


Fig. 1 Microstructures of Ст 3 steel subjected to face surfacing with Св 08 wire arc and spread over glass (a) and standard AMS1 flux (b) powder. Upper views – middle of the layer, lower views – welding zone



a b

Fig. 2 Microstructures of face surfacing welded with glass powder mixed with: a -iron boride powder (9%), b – graphite powder (9%). Upper view – middle of the layer, lower views – welding zone



a b

Fig. 3 Microstructures of face surfacing welded with glass powder mixed with: a – Fe-70% Mn (9%), b – P6M5 steel chips powder (35%). Upper views – middle of the layer, lower views – welding zone

a

b

Fig. 4 Single – pass welded layers: a – welded under glass powder, b – under standard AMS1 flux

In both cases hardened slag was easy to separate from cooled overlaying metal. Fig. 5 show hardened slag separated from layers.

a

b

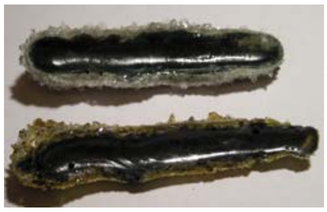


Fig. 5 Hardened slag removed from the layers welded under glass powder (a) and under standard AMS1 flux (b)

Higher hardness (41 HRC) was noted for Ст 3 steel subjected to overlaying welding with mixture containing 70% glass and 30% graphite powder (Table 2). This layer after heating at 900°C temperature for 40 min. and water cooling has hardened to 59 HRC. At this temperature negligibly small amount of graphite was formed (Fig. 6, c); silicon from the glass facilitated graphitization. Hard (62 HRC) layer after heat treatment was obtained when sand (20%) had been added into the mixture.

Surfacing of Ст 3 steel with mixtures, containing SiC and B_4C powder, obtained from grinding wheels crushed into powder, resulted 38-50 HRC hardness layers. Heat treatment at 900°C temperature and water cooling increased hardness of the layers to 55-64 HRC. Maximal hardness (64 HRC) was obtained for the layer welded with the mixture, containing chromium and graphite powder.

Table 2

Hardness of heat treated layers produced by melting in the Св 08 wire arc materials powder spread over Ст 3 steel surface

Composition of powder mixture, %						Hardness of surfacing, HRC	
Glass	Graphite	Grinding wheel (SiC)	Grinding wheel (B_4C)	Chromium	Sand	After welding	Heating at 900°C temperature for 40 min. and water cooling
70.0	30.0					41	59
65.5	14.5				20.0	47	62
39.0	9.0	18.5	18.5	15		50	64
46.5		19.0	19.0	15.5		46	61
52.0	10.0	19.0	19.0			38	55

Microstructure of the surfacing consists of martensite and retained austenite (bright areas), troostite (dark areas) and carbides (narrow – bright strips, Fig. 7, a). In the course of heating at 900°C temperature (40 min), due to atoms diffusion, the microstructure became uniform. In the microstructure of surfacing hardened in water (Fig. 7, b) very small carbides had been formed due to heat effect. Graphite inclusions and primary carbides are seen in the microstructure. Graphite inclusions are very well seen in the photos of not etched specimen's (Fig. 7, c). Graphite was formed because graphite powder was present in the welding mixture and because carbon amount increased due to cleavage of SiC and B_4C powder. Graphitization process was stimulated by the silicon coming from glass and SiC powder, whilst boron from B_4C powder and inserted into the mixture chromium improved hardenability of the surfacing. Chromium together with other elements and carbon formed carbides. Hardness of the layer obtained in welding with the mixture containing chromium powder was lower.

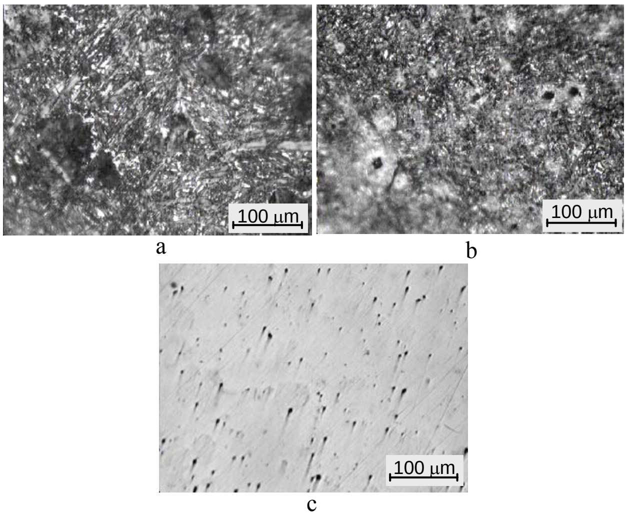


Fig. 6 Microstructures of face surfacing welded with glass (70%) and graphite (30%) powder: a – after welding, b – after 40 min heating at 900°C and water cooling, c – same as b, only the specimen was not etched

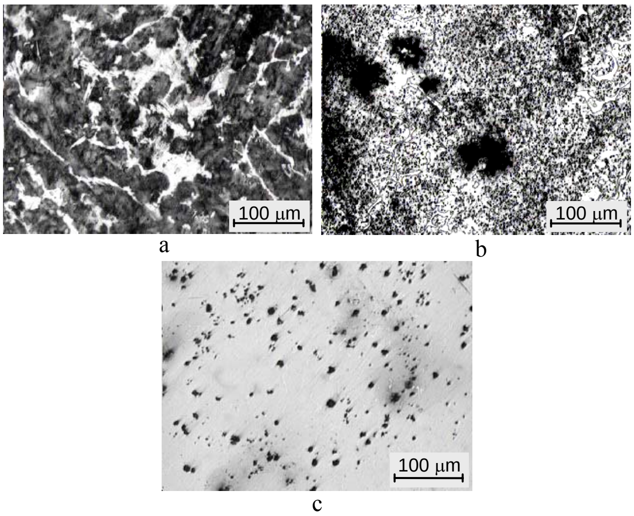


Fig. 7 Microstructures of face surfacing welded with glass (39%), graphite (9%), SiC (18,5%), B_4C (18,5%) and chromium (15%) powder: a – after welding, b – after 40 min heating at 900°C temperature and water cooling, c – same as b, only the specimen was not etched

In drill production considerable amount of P6M5 steel goes to chips, which can be utilized for overlaying welding. In welding process P6M5 steel chips are melted, and the weld is alloyed by elements consisting in chips (W, Mo, Cr, V).

Crushed P6M5 steel milling chips were mixed with glass, graphite, Fe-70% Mn and cobalt powder. Into the mixture of these powders, 35% of P6M5 steel chips powder was added. Cт 3 steel was overlayed; powder mixtures were melted by Cв 08 wire arc.

Hardness of the layers obtained in such a way was 59-62 HRC depending on the composition of powder mixture (Fig. 8). High hardness of the layer can not be obtained when only glass and P6M5 powder mixture is used for surfacing. It is because alloying elements from P6M5 steel in high temperature of electric arc partially burn out.

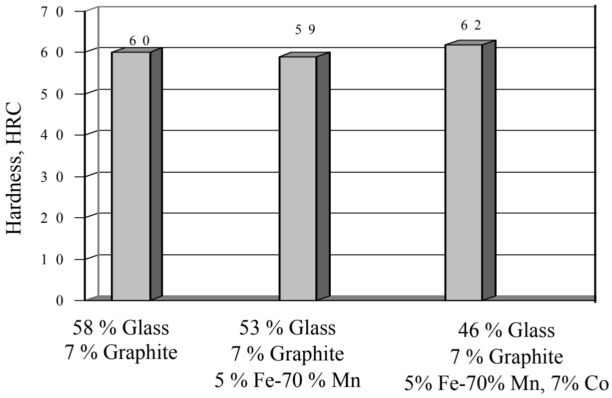


Fig. 8 Effect of glass, P6M5 chips (35%) and other materials powder on the hardness of surfacing layers. Surfacing formed by melting in Cв 08 wire arc powder mixtures spread over Cт 3 steel surface

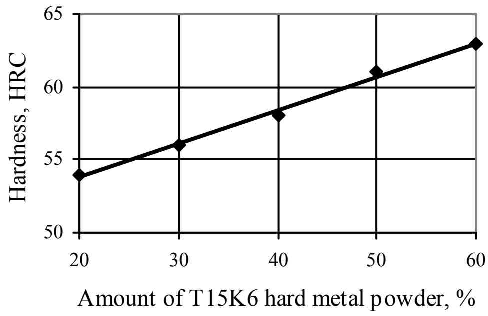


Fig. 9 Dependence of surfacing obtained melting by Cв 08 wire arc glass and crushed T15K6 hard metal powder spread over Cт 3 steel surface hardness on the amount of T15K6 powder. Specimens tempered at 550°C temperature

In metal cutting tools T15K6 carbide cutting inserts often are used. Broken inserts can be crushed into powder and utilized for overlaying welding. When this procedure is applied to Cт 3 steel, the layers alloyed by tungsten, titanium and cobalt were obtained. Besides, cleavage of tungsten and titanium carbides enriches the layer with carbon. Hardness of the layers welded by powder mixture of glass and T15K6 cutting inserts depends on the mixture concentration (Fig. 9). The investigation shows that secondary hardness is increasing with the increase ofT15K6 carbide powder amount in the mixture. The increase of T15K6 powder amount in the mixture up to 60% resulted in the layers hardness of 63 HRC, after tempering at 550°C temperature.

3. Conclusions

1. When crushed glass powder is utilized instead of a flux for automatic arc deposition, the electric arc is stable, liquid metal is well protected from air influence, and high quality surfacing is achieved. Addition of other materials powder into the glass powder enables to change microstructure and properties of the overlaying or weld metal.

2. Hard surfacing layers (up to 64 HRC), can be

obtained using for overlaying welding SiC and B_4C powder made of crushed grinding wheels waste. Layers with carbides and graphite inclusions can be obtained changing the amount of glass, graphite, SiC and B_4C powder.

3. Surfacing of Ст 3 steel with P6M5 chips and the powder of crushed T15K6 carbide mixed with glass powder allowed to obtain layers of high heat resistance. After tempering at 550°C temperature number the layers of hardness 63 HRC was obtained.

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ANTRINIŲ ŽALIAVŲ NAUDOJIMAS SUVIRINIMUI IR APVIRINIMUI

R e z i u m ė

Darbe buvo tiriamos dangos, gautos ant plieno Ст 3 užbertus miltelių mišinius išlydžius Св 08 vielos lanku. Mišiniams buvo panaudoti susmulkinto stiklo, nesunaudotų šlifavimo diskų SiC ir B_4C, P6M5 plieno drožlių bei kietlydinio T15K6 milteliai. Keičiant antrinių žaliavų ir kitų elementų miltelių kiekį gauti įvairaus kietumo ir struktūros sluoksniai. Galima gauti sluoksnius su karbidiniais intarpais, atsparius abrazyviniam dilimui, arba su grafitiniais intarpais, atsparius adheziniam dilimui.

P. Ambroza, L. Kavaliauskienė

UTILIZATION OF WASTE MATERIALS FOR WELDING AND SURFACING

S u m m a r y

The properties of surfacing obtained by melting powder mixtures in electric arc between Св 08 wire and Ст 3 steel plate are investigated. Crushed glass, SiC and B_4C powder from grinding wheels waste, P6M5 steel chips and T15K6 carbide powder was utilized for the mixtures. Changing the amount waste materials and other elements powder in the mixtures, layers of various hardness and microstructure were obtained. Surfacings both with carbides inclusion resistant to abrasive wear or with graphite inclusions resistant to adhesive wear can be obtained.

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ИСПОЛЬЗОВАНИЕ ВТОРИЧНЫХ МАТЕРИАЛОВ ДЛЯ СВАРКИ И НАПЛАВКИ

Р е з ю м е

В работе исследованы покрытия, полученные расплавлением дугой проволоки Св 08 смесей порошков, насыпанных на сталь Ст 3. Для смесей были использованы порошки измельченного стекла, шлифовальных SiC и B_4C дисков, стружек стали Р6М5, твердого сплава Т15К6. При изменении количества порошков вторичных материалов и других элементов, получены слои разной твердости и структуры. Можно получить слои с карбидными включениями, стойкие к абразивному изнашиванию или с графитными включениями, стойкие к адгезионному изнашиванию.

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