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Automatic arc welding and overlaying welding of steel using waste materials powder

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1. Introduction

Mechanical characteristics of a weld depend on the flux composition and welding process parameters used in the arc automatic welding [1]. Investigation [2] shows that resistance of welded joint to tension stresses and dynamic loads is higher when microstructure of the weld contains acicular ferrite. Acicular ferrite can be formed when flux contains boron, titanium, vanadium and other material's oxides [3].

When the flux containing TiO_2 is used in welding the weld is alloyed by titanium and acicular ferrite which improves mechanical characteristics of the joint [4].

Paper [5] deals with the effect of molybdenum, boron and titanium on microstructure and mechanical characteristics of the weld metal. The flux containing 21.24% SiO_2 + TiO_2; 27.29% CaO + MgO; 33.86% Al_2O_3 + MnO; 17.55% CaF_2 was used. There were 0.2% Mo; 0.072% C; 1.3 – 1.5% Mn, up to 0.4% Si, 0.012% Ti and up to 0.018% B in the overlay. Small and evenly distributed inserted particles stimulated formation of the acicular ferrite. Boron distributed around austenite grains retarded formation of polygonal ferrite.

Addition of TiO_2 into a flux influences microstructure and properties of arc welded joint [6]. Four fluxes containing 9, 12, 15 and 18 % of titanium were used for welding with low carbon wire. The same welding regimes but increasing titanium amount in the flux resulted the increase of acicular ferrite and improvement of mechanical characteristics.

Automatic submerged arc welding of pipe steel APJ H5 LA – 70 resulted welded joint containing 0.7 - 0.99% Mo and 2.03 - 2.91% Ni which showed higher resistance to dynamic loads at low temperatures [7]. Microstructure of the weld consisted of acicular ferrite and bainite.

The effect of titanium on the APJ 5L – X70 steel subjected to submerged arc welding weld microstructure is investigated in [8]. The best proportion between microstructure and toughness was obtained at 0.02 - 0.05% of titanium in the weld. Depending on titanium amount the microstructure can contain acicular ferrite, grained ferrite, widmanstatten ferrite, bainite and others.

Various composition fluxes are used in automatic submerged arc welding of steels. Change in flux composition results the change of the weld composition and microstructure and it improves mechanical characteristics of the welded joint. No investigation related to the use of waste materials for welding is found. The objective of this investigation is to analyze microstructure and properties of the steel metal obtained in welding and overlaying welding by the use of waste material, i.e. to determine the effect of waste materials elements on the weld and overlay metal microstructure and properties.

2. Materials and test procedures

Steel Cт3 widely used in machine production and low carbon not alloyed welding wire Cв08 were selected for welding and overlaying welding tests. Specimens were prepared from 8 mm Cт3 steel bar which has been grinded and cut into 8 × 14 × 40 mm pieces. Quality of the welded joint was assesed by tension test of the 8 mm thick 40 mm width and 70 mm length plates obtained by welding of the specimens after the edges were removed. Specimens by size 6.5 × 15 × 80 mm were produced for tension tests.

Structural steel Cт3 (Russian grade) (0.14 - 0.2% C; 0.12 - 0.3% Si; 0.4 - 0.65% Mn) was subjected to automatic submerged arc welding [9] when powder mixtures were sprayed over the specimens surface and melted by welding wire Cв08 (Russian grade) (C < 0.1%; Si < 0.03%; Mn = 0.35 - 0.6%, Cr < 0.15%, Ni < 0.3) arc.

Mostly fluxes containing SiO_2 and MnO are used for the welding. When the flux is melted a slag is formed in the arc burning zone, Si and Mn from it's content deoxidize welding bath metal and assure necessary metallurgical processes. It was tried instead of standard flux to apply for welding and overlaying welding powder mixtures whose main component is grinded glass. Glass component SiO_2 deoxidized weld metal and alloyed it by silicon. Powder mixtures contained crushed grinding wheels (containing SiC) and cast-iron and high speed steel P6M5 (Russian grade) crushed chips. TiO_2 and TiC powder obtained heating titanium chips at 1050°C temperature without protective atmosphere or at 950°C temperature in carbiurizing surrounding (carbiurizer). The use of titanium chips not subjected to heat treatment is complicated because the chips are plastic and it is difficult to crush them into powder. To alloy weld and surfacing metal by manganese and chromium the industrial production Fe -70% Mn and Fe – 60% Cr powder was added to the mixtures.

3. Results of the investigation and data analysis

Overlaying welding of the Cт3 steel by various materials powder mixtures resulted the layers alloyed by elements contained in powder. Composition of the powder mixtures and hardness of the surfacing layers are shown in Table 1.

The most mild layers is welded under glass powder, because it contains least carbon amount. This is proved by microstructural investigation (Fig. 1, b): amount

Table 1

Composition of powder mixtures and hardness of the layers obtained in overlaying welding

Composition of powder mixture, %								Hardness, HRC
Glass	Cast iron	P6M5	SiC	TiO_2	TiC	Fe – 60% Cr	AMS1	
							100.0	14
100.0								7
70.0	30.0							19
60.0	30.0			10.0				23
60.0	30.0				10.0			49
70.0	20.0		10.0					38
70.0		30.0						24
70.0		20.0	10.0					49
70.0						30.0		32

of pearlite is smaller than in case of welding under standard AMS1 flux layer (Fig. 1, a). Even harder layers can be obtained using glass powder mixtures with other materials powder. The hardest layers were obtained in submerged arc welding using mixtures containing TiC or P6M5 powder. At high arc burning temperature welded layers were enriched by carbon, influencing layers hardenability. At the same time the layers were alloyed by titanium, tungsten, molybdenum and etc. Depending on materials used for overlaying welding, layers of various microstructures were obtained. Overlaying welding of the Cт3 steel by glass and cast iron powder mixture resulted the layer which microstructure was similar to that obtained in welding under standard flux (Fig. 1, a). More ferrite was obtained in the layer welded with powder containing TiO_2 (Fig. 1, d). Even bainite microstructure was formed using for overlaying welding P6M5 steel chips (Fig. 1, e). Insertion of Fe – 60% Cr powder into glass powder resulted dendrite microstructure of the surfacing (Fig. 1, f).

Aiming to assess weld strength structural steel Cт3 was welded using standard AMS1 flux and powder mixtures: 100% glass; 70% glass and 30% cast iron; 60% glass, 30% cast iron and 10% TiO_2; 70% glass and 30% steel P6M5. In tension test fracture through base metal (not weld) was obtained in the cases, when standard flux, glass powder, and powder mixture of 70% glass and

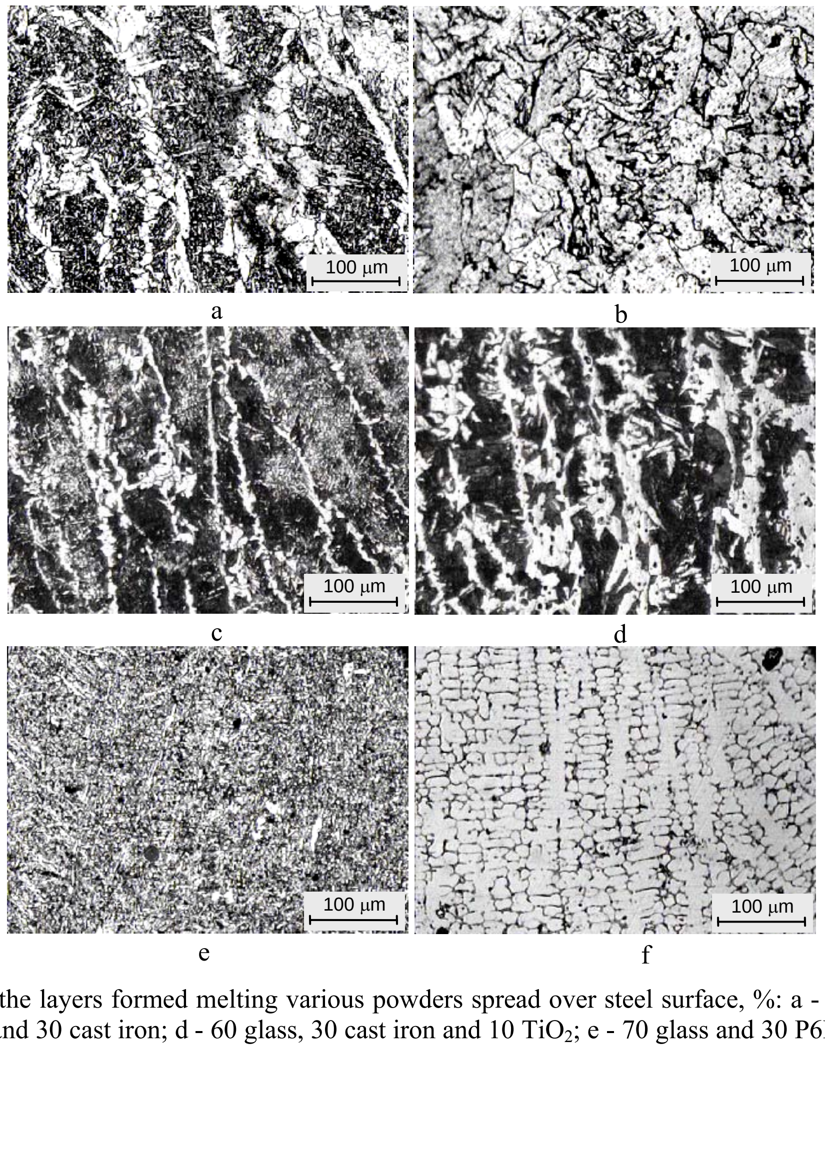

Fig. 1 Microstructures of the layers formed melting various powders spread over steel surface, %: a - 100 AMS1; b - 100 glass; c - 70 glass and 30 cast iron; d - 60 glass, 30 cast iron and 10 TiO_2; e - 70 glass and 30 P6M5; f - 70 glass and 30 Fe – 60 Cr

30% cast iron was used in the welding process. Ultimate tensile strength in these test was 447 - 451 MPa what corresponds to bare metal steel Cт3 used in the welding tensile strength. The specimens welded using powder mixtures containing TiO_2 and P6M5 steel chips in tension tests fractured across the weld at stress 379 - 432 MPa. Not satisfying strength of the weld is due to incomplete fusion, what is seen in the fracture. Incomplete fusion can be avoid by the use of different welding regime.

Machine part wear is one of important problems which is solved strengthening contact surfaces. Very often resistance to wear is improved by overlaying welding [10], which forms hard surfacing, or by oiling, which decreases friction between sliding surfaces [11, 12].

Steel parts often are overlaying welded by arc automatic welding using various kinds of wire and flux. In this investigation steel Cт3 was overlaying welded instead of standard flux using waste materials powder spread over the surface and welded by the electric arc between the base metal and continuously supplied welding wire Cв 08. Compositions of materials powder mixtures and welded layers are shown in Table 2. Welded layers were alloyed by elements contained in P6M5 steel chips (W, Mo, V, Cr), grinding wheels powder (Si) and manganese in case when in to the powder mixture was inserted Fe–70%Mn powder. Carbon came to the layers from decayed SiC carbide and from P6M5 steel chips.

Table 2

Chemical composition of the steel overlaying welded by powder mixtures

Composition of powder mixture, %			Elements amount in layer, mas, %							
P6M5	SiC	Fe-70%Mn	C	Si	Mn	Cr	Mo	V	W	Fe
80.0	20.0		0.83	1.92	0.95	0.6	0.71	0.28	0.75	Balance
60.0	20.0	20.0	1.06	1.69	4.73	0.76	0.88	0.36	1.10	Balance

Welded layers are used to alloy in course of cooling. The highest primary hardening (up to 62 HRC), was obtained for the layer welded with powder mixture containing SiC and P6M5 powder (Fig. 2). The layer containing manganese in course of cooling after welding hardened up to 49 HRC, and it's tempering at 550°C temperature resulted 57 HRC hardness (secondary hardening). Secondary hardening was possible due to great amount of residual austenite in the welded layer containing manganese. Manganese is an element expanding austenite zone. Presence of residual austenite is prooved by white areas seen after etching of the test piece with 3% spirit solution of nitric acid; weak acid solution does not effect on them (Fig. 3).

X-ray examination shows presence of residual austenite. X-ray photograph of overlaying welded specimen shows that the peak of residual austenite is more intensive in comparison with martensite peak (Fig. 4, a). Such ratio of the intensities corresponds to 83% residual austenite amount. Tempering of the specimen at 550°C temperature, when residual austenite was transformed to martensite, the amount of residual austenite decreased to 13%, and X-ray photograph (Fig. 4, b) does not show any austenite peak.

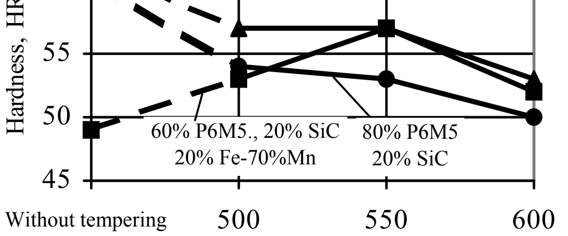

Fig. 2 Effect of tempering temperature on hardness of overlay welded layer

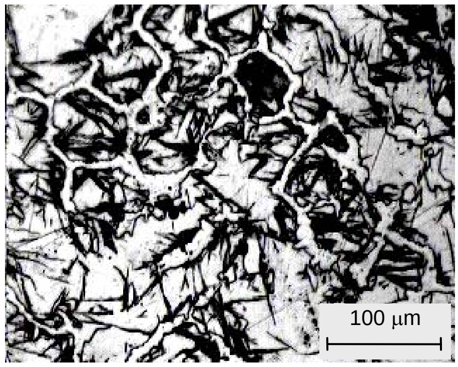

Fig. 3 Microstructure of the layer overlay welded with 60% P6M5, 20% SiC and 20% Fe-70% Mn powders mixture

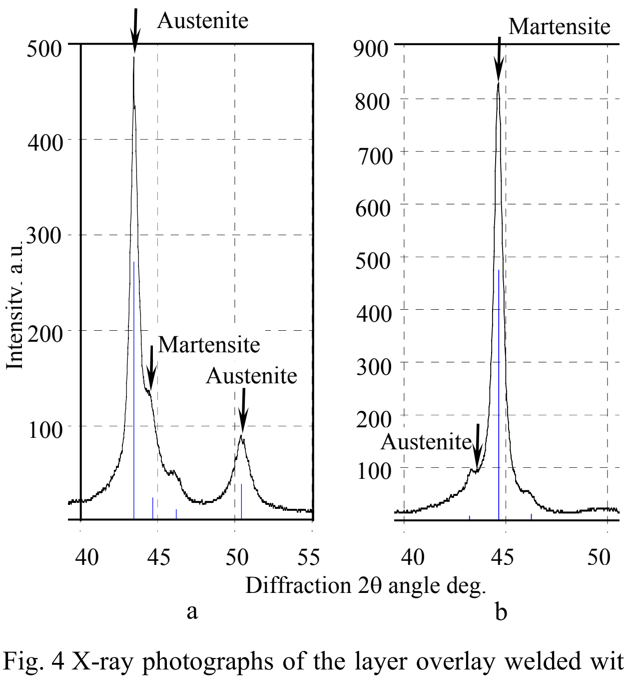

Fig. 4 X-ray photographs of the layer overlay welded with 60% P6M5, 20% SiC and 20% Fe-70%Mn powder mixture: a - without tempering; b - after tempering at 550°C temperature

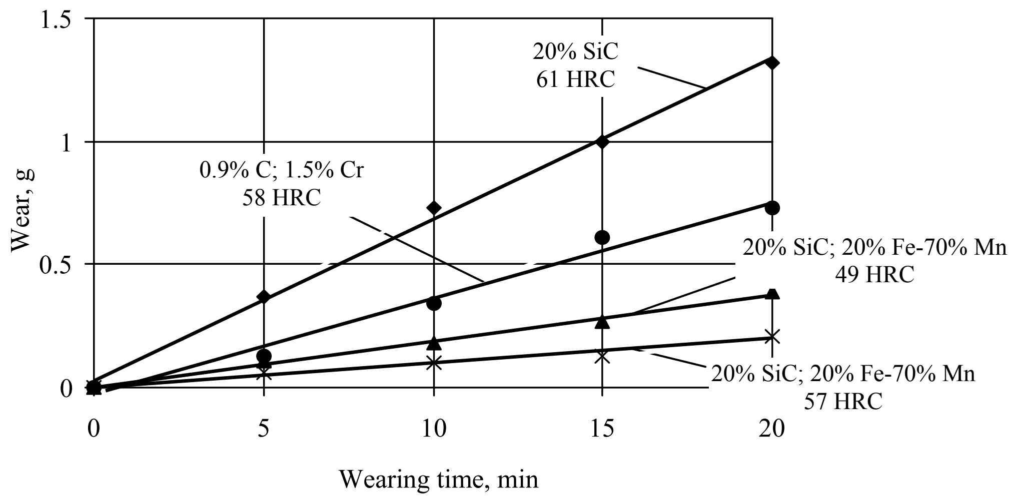

Fig. 5 Wear of standard steel (0.9% C; 1.5% Cr) and welded layers depending on wearing time. All used in welding powder mixtures contained crushed P6M5 chips

Abrasive wear resistance of welded layers was determined in the test, when rotating abrasive wheel was pushed to the specimen rotating in the opposite direction [12]. A decrease of the specimen weight was measured (Fig. 5). Wear of welded layers depends on materials used for overlaying welding. The smallest wear out was obtained in the layer welded with 60% P6M5, 20% SiC and 20% Fe-70% Mn powder mixture. Microstructure of this layer contained carbide phase and great amount of residual austenite (Fig. 3). After tempering at 550°C temperature hardness increased, wear decreased. Overlaying welding of the Cт3 steel with suitably selected materials powder mixture can result more wear-resistant layer than that of standard tool steel.

3. Conclusions

1. The use of waste material powders in welding process due to alloying elements in the powder enables to produce welded joints of necessary microstructure and properties. Welds produced using glass powder or glass and cast iron powder mixture have higher than the main metal (Cт3 steel, 447-451 MPa) tension strength.
2. Overlaying welding of Cт3 steel with glass and grinding wheels SiC powder resulted hard (up to 62 HRC) layer; addition of Fe-70% Mn powder into this mixture enabled to produce welded layer, which after tempering at 550°C temperature hardened from 49 HRC to 57 HRC.
3. The Cт3 steel subjected to overlaying welding with 60% P6M5 chips, 20% grinding wheel SiC and 70% Fe-70% Mn powder mixture in comparison with hardened tool steel (0.9% C; 1.5% Cr) was 3-4 times more abrasive wear – resistant.

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LANKINIS AUTOMATINIS PLIENO SUVIRINIMAS IR APVIRINIMAS NAUDOJANT ANTRINIŲ MEDŽIAGŲ MILTELIUS

R e z i u m ė

Darbe ištirta apvirinto ir suvirinto plieno Cт3, naudojant antrinių medžiagų miltelius, struktūra ir savybės. Ant plieno Cт3 užberti stiklo, nepanaudotų šlifavimo diskų SiC ir P6M5 plieno ir ketaus drožlių, TiO_2, TiC, Fe – 70% Mn bei Fe – 60 % Cr miltelių mišiniai buvo išlydyti nenutrūkstamai tiekiamos Cв 08 vielos lanku. Plieno Cт3, suvirinto naudojant stiklo bei stiklo ir ketaus miltelius, siūlės stiprumas tempiant ne mažesnis, kaip plieno Cт3, suvirinto Cв08 viela po standartiniu fliusu AMS1. Plieną Cт3 aplydant antrinių medžiagų milteliais gauti abrazyviniam dilimui atsparūs sluoksniai. Tinkamai parinkus ant plieno Cт3 užberiamų medžiagų miltelių mišinių sudėtį ir juos išlydžius Cв08 vielos lanku, galima gauti sluoksnius, atsparesnius abrazyviniam dilimui, lyginant su grūdintais įrankiniais plienais.

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AUTOMATIC ARC WELDING AND OVERLAYING WELDING OF STEEL USING WASTE MATERIALS POWDER

S u m m a r y

Microstructure and properties of the Cт3 steel subjected to welding and overlaying welding with waste materials powder is investigated. Glass, unused grinding wheel SiC, steel P6M5 and cast iron chips, TiO_2, TiC, Fe-70% Mn and Fe-60% Cr powder mixtures were spread over the Cт3 steel surface and melted by continuously supplied welding wire's Cв08 arc. Tensile strengths of the Cт3 steel weld produced using glass and glass and cast iron powder mixture was not less than that of Cт3 steel welded by Cв08 wire under standard flux AMS1. Resistant to abrasive wear layers ware obtained in overlaying welding of the Cт3 steel with waste materials powder. Selecting composition of powder mixture spread over the Cт3 steel surface and melting the powder with Cв08 wire arc enables to produce the layers more resistant to abrasive wear than those of hardened tool steels.

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АВТОМАТИЧЕСКАЯ ДУГОВАЯ СВАРКА И НАПЛАВКА СТАЛИ С ИСПОЛЬЗОВАНИЕМ ПОРОШКОВ ВТОРИЧНЫХ МАТЕРИАЛОВ

Р е з ю м е

В работе исследована структура и свойства стали Ст3, сваренной и наплавленной с использованием порошков вторичных материалов. На сталь Ст3 насыпанные смеси порошков стекла, неиспользованных щлифовалъных кругов SiC, стружек стали Р6М5 и чугуна, TiO_2, TiC, Fe – 70% Mn, Fe – 60% Cr были расплавлены дугой непрерывно подаваемой, проволоки Св08. Прочность при растяжении стали сваренной с использованием порошков стекла, или с использованием смеси порошков стекла и чугуна не ниже, чем стали Ст3, сваренной проволокой под стандартным флюсом AMS1. Наплавкой стали Ст3 вторичными материалами получены слои, стойкие абразивному изнашиванию. Соответственно подобрав состав смеси порошков вторичных материалов насыпаемых на поверхность стали Ст3, расплавляя дугой проволоки Св08 можно получить слои, более стойкие абразивному изнашиванию по сравнению с закаленными инструментальными сталями.

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