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Influence of the tempering temperature and laser beam on hardness and wear of the overlay welded layers

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1. Introduction

The working surfaces of many technologically applied materials work in specific conditions and are exposed to different kinds of wear, namely abrasive, thermal and adhesive. The proper shaping of machine surface properties and devices, often working in the conditions of changing dynamic loads, is very important. This process, called the surface modification, aims at the reconstruction of the worn out surface of machine parts and the supplementation of decrements. It can be in of the change of the stucture of surface layer and/or change of its chemical compositions [1].

Hard surfacing is the deposition of a special alloy material on a metallic part, by various welding processes, to obtain more desirable wear properties in order dimensions. The properties usually sought are greater resistance to wear from abrasion, impact, adhesion (metal-to-metal), heat, corrosion or any combination of these factors. A wide range of surfacing alloys is available to fit the need of practically any metal part. Some alloys are very hard, others are softer with hard abrasion resistant particles dispersed throughout. Certain alloys are designed to build a part up to a required dimension, while others are designed to be a final overlay that protects the work surface [2].

The economic importance of hardfacing derives from the feasibility of selectively applying expensive materials, chosen for their properties, and depositing them onto a common inexpensive base metal where they are required for best performing in their specialized function. The base metal provides the bulk of the structure and saves the end-user 95% in superalloy costs [3].

Carbon and low-alloy steels with carbon contents of less than 1% can be hardfaced. High-carbon alloys may require a special buffer layer.

Stainless, manganese steels, cast irons and steels, nickel-base, copper-base alloys can be hardfaced [4].

Submerged Arc Welding (SAW) is a semiautomatic or fully automatic consumable electrode arc process in which the arc is protected by a granule, fusible flux which blankets the weld puddle and surrounds the base metal to protect it from the atmosphere.

Powder alloys can be added with the flux. This utilizes the existing heat produced by SAW to melt powders and thereby increase deposition rates. The flux stabilizes the arc, provides slag coverage, and also controls the properties of the deposit [5].

Surface treatments that are affected by laser beam irradiation include laser hardening, laser alloying, and laser cladding [6, 7].

If conventional hardening technologies are not suitable because of certain geometric shapes, material and wear conditions, laser hardening can be ideal for produce wear-resistant parts with an increase in service life [8].

Surface treatment by means of laser-beam radiation is a relatively new technology in the field of surface heat treatment. Laser treatment has advantages and of course disadvantages in comparison with conventional heat treatments. The most important advantages are the following: radiation by a laser beam allows the treatment of the surface only, with very little damage to the bulk; the properties which are obtained, for example hardness, are higher than those obtained by other means; it is possible to heat treat a very small and localized region [9].

Laser surface melting (also known as skin melting or glazing) involves melting of a thin surfaces layer of material which subsequently undergoes rapid solidification as a result of self-quenching, resulting in alterations in the local microstructure [10].

The purpose of this work is to investigate structure and properties of overlay welded layers by using material powders and impacted by laser beam.

2. Testing procedure

For the hard facing of parts the various techniques of submerged arc welding are used: manual, semi-automatic, fully automatic under the flux and others. To increase effectiveness of the process material powders are used. Its can be sprayed over the surface of part, inserted into flux or compounds with binder. Costlier alloyed wire not required in order to obtain various composition and microstructure of overlay welded layers.

Specimens (8×8×60 mm) of structural steel Ст3 (C = 0.14 – 0.22%; Si = 0.12 – 0.3%; Mn = 0.40 – 0.65%) were overlay welded with material powders sprayed over the surface and melted under the flux or material powder mixtures sprayed over the surface melted unemployed standard flux. All the components were melted by arc between continuously supplied 1.2 mm diameter low carbon steel wire Св 08 (<0.1%C) and structural steel Ст3. Specimens were overlay welded in the device, assembled from the lathe and semiautomatic machine INTEGRA 350 Profesonal.

Regimes for welding process:

- Current I = 180-200 A;
- Voltage U = 22-26 V;
- Rate of overlaying $V_{welding}$ = 14.4 m/h;
- Rate of wire feeding V_{wire} = 25.2 m/h.

The following materials were used for overlay welding:

- standard flux AMS1 (have more 50% MnO and SiO_2);metallurgical industry chromium and tungsten powders for the alloying of overlay welded layers;
- Fe – 70% Mn powders to increase the effectiveness of reduction and for alloying by manganese;
- SiCaBa powder (consist 15 - 20% Ca, 8% Ba, 2 – 3% Al).
- graphite;
- secondary material powders (glass, high speed steel P6M5 chips, metal ceramic plates BK – 8, SiC from grinding disks).

Overlay welded layers were periodically impacted by laser beam in microscopical analyser MLA10 by using modulate cassette no. 2, diaphragm with 90 µm diameter, planechromatical objective-lens L 16x/0.2/0. Overlay welded layers after impaction by laser beam are presented in Fig. 1.

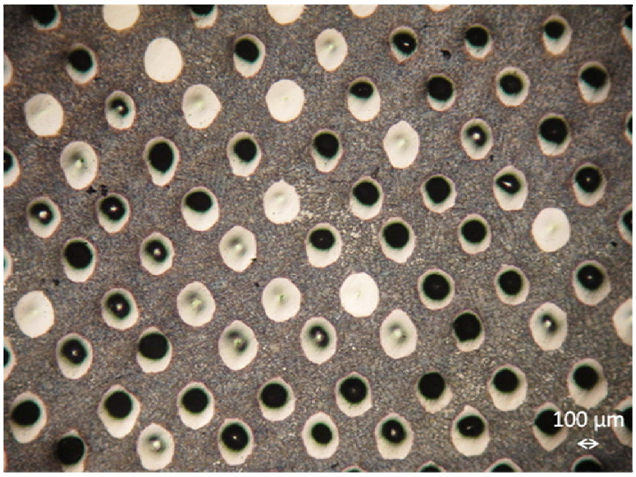


Fig. 1 The overlay welded layer after impaction by laser beam

Wear resistance test of overlay welded specimens (6 mm width) was carried out by rotating hardmetal disk (41 mm diameter, 14 mm width), load 320 N. Wearing of layers after 20 minutes (sliding distance 6.69 m) was tested according to mass loss.

The scheme wearing device is presented in Fig. 2.

By using the materials powder addition, it is possible to obtain alloyed layers with different structure and hardness. Layers were formed in the arc burning zone by melting the substrate surface, welding wire, and sprayed powders. To obtain high alloyed layers metal powders containing a higher percentage of alloying elements was used due to the fact that iron migrate from the wire to the welded metal.

Arc power restricted the amount of melting powder. Too large amount of powders or less fusible components resulted difficult melting process, and layer worse molten with the main metal.

Depending on the powders mixture and its amount it is possible to gain the layers, which during the cooling hardens totally or hardening process takes place partially. Not totally hardened layers contain high amount of retained austenite and may be solidify during tempering at high temperatures. Overlay welded layers one hour were heated in the electrical furnace and cooled in air. Retained austenite transforms to martensite as resulted increase the hardness of layers.

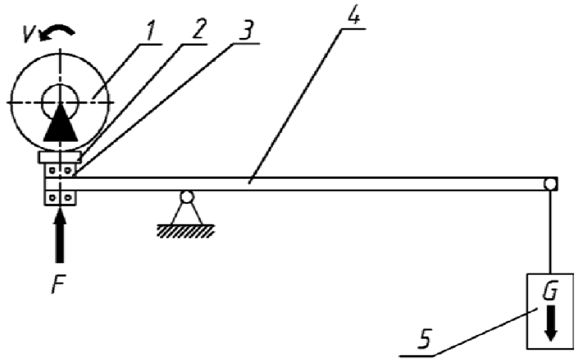


Fig. 2 Wearing device scheme view: *1* - hardmetal disk; *2* - specimen; *3* - bear; *4* - lever; *5* - load

Softer overlay welded layer is easier manufactured by cutting after that hardness of the layer is possible to increase by tempering. Thus hardening process is not required and energy recourses are saved.

3. Results and discussion

The overlay welding is commonly used with a purpose to obtain wear resistance layers. Wear resistance of steel depends on its hardness and structure formed in the zone of arc during the metallurgical and cooling processes. The overlay welded layers wear less when the structure was formed of martensite or layers consisting of carbides, borides and others. Any amount of retained austenite increases wear resistance.

During the overlay welding structural steel by unalloyed wire Св 08, the composition of the layer is possible to change by the composition of powders mixture. Powders mixture (Table 1) sprayed over the surface of specimen melted by wire Св 08 arc resulted formation of liquid slag containing alloying elements that enrich overlaying layer. The influence of tempering temperature on hardness (HRC) of the layers is presented in Fig. 3.

The highest hardness (64 HRC) after tempering at 600°C temperature was noticed for layer overlay welded by powder mixture containing BK-8 hard metal powder (specimen No. 1).

Table 1

Composition of powders mixture

Specimen No.	Composition of powders mixture, %								
	Glass	SiC	AMS1	Graphite	BK–8	Cr	Fe–Mn	W	SiCaBa
1			59	6	29		6		
2	46	23		8		23			
3	31			9			14	37	9

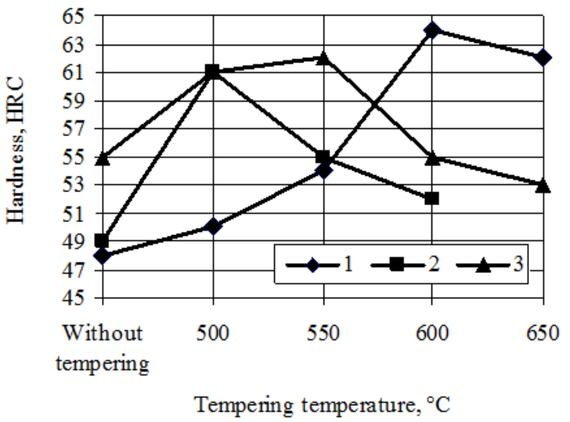


Fig. 3 Influence of tempering temperature on hardness of overlay welded layers obtained by spread over the steel Ст3 surface powders mixture and melted by arc welding wire Св 08

The alloyed layer with tungsten and cobalt and enriched with carbon resulted when BK-8 was melted at high temperature. Tungsten, cobalt and carbon stimulate processes of dispersive solidify during the tempering.

Ferromanganese (Fe-Mn) powders alloyed layers by manganese which increased the amount of retained austenite during tempering transformed to martensite. Flux of grade AMS1 consists the manganese oxide. At the decompounding process of MnO, manganese migrates from the slag to overlay welded layer. Higher hardness (62 HRC) was noted for the third layer alloyed by tungsten and manganese after tempering at 550°C temperature. This layer was overlay welded by mixture containing glass powder which silicon acted as deoxidizer. Higher hardness (61 HRC) of second layer alloyed by chromium was obtained after tempering at 550°C temperature. Heat resistance of second layers is less in comparison with the layers alloyed by tungsten.

In this investigation specimens (8×60 mm) of Ст3 structural steel were overlay welded with materials powders mixture (6 g.) sprayed over the surface and melted by arc under the flux. Experiments were carried out using flux AMS1 mixed with the powders of graphite and boron carbide. Graphite and boron carbide in the overlay welded layers increased the amount of carbon and alloyed by boron (Table 2). Dependence of layers' hardness on tempering temperature is presented in Fig. 4.

Table 2

Composition of powders mixture

Specimen No.	Composition of powders mixture, %					Flux
	BK–8	SiC	Cr	Fe–Mn	P6M5	
4	100					87% AMS1+13% graphite
5	27	36	28	9		AMS1
6					100	85% AMS1+15% B_4C

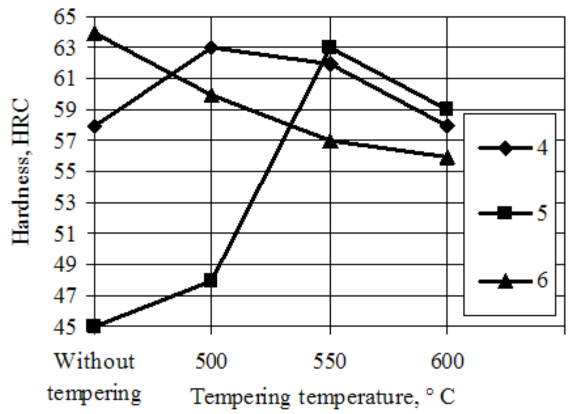
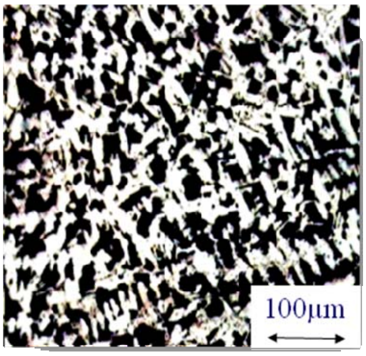


Fig. 4 Dependence of layers hardness on tempering temperature of overlay welded layers obtained by spread over the steel Ст3 surface powder mixtures and melted by arc welding wire Св 08 under the flux

Overlay welding under the flux AMS1 mixed with graphite powder by arc wire Св 08 of structural steel Ст3 which surface was covered by BK-8 hard metal powders (specimen no. 4) resulted alloying layer by tungsten and carbon with high amount of carbide phase (Fig. 5, a). Hardness of the layer increased after tempering at 500-560°C temperature (5 HRC units). Overlay welded layer (specimen no. 5) by powders mixture consists of chromium powders hardened to 45 HRC and after the tempering at 550°C temperature the hardness increase to 63 HRC. Chromium has the ability to expand austenite area so that in the overlay welded layer was found any amount of retained austenite, which during the tempering transformed to martensite. The polished specimen unaffected by etching it with 3% nitrogen acid spirit so it is true to says presenting of retained austenite. The phases of microstructure with retained austenite are not visible by examining it with microscope (Fig. 5, b). The sixth layer was alloyed by the elements presented in the P6M5 steel chips and by boron from flux containing boron carbide. Boron is the element increasing hardenability, that overlay welded layer was totally hardened on cooling (64 HRC, Fig. 4), whereas on tempering the hardness decreases, and no secondary hardening was not obtained.

Laser beam treatment of steel as a high concentrated heat source at high speed was used heating up a small metal area, which due to the moving of heat does not heat the area, totally hardened on rapid cooling.

Low-power laser beam was used, so the surfaces were treated by laser beam pulses development of the melt pools (Fig. 6, a). Some the zones affected by laser beam heat up below the temperature of solidus and harden on rapid cooling. Etching by 3% nitrogen acid spirit resulted as bright zones (Fig. 6, b). The laser beam treated surfaces were polished to remove splashes of metal. Hardness of the overlay welded layers (for wear testing) and micro hardness of zone impaction by laser beam are shown in Table 3.



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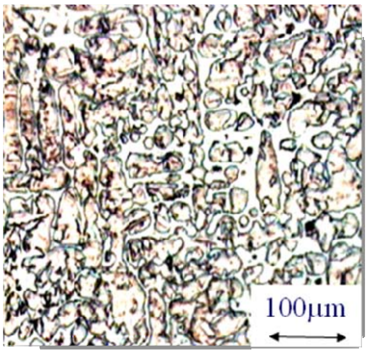

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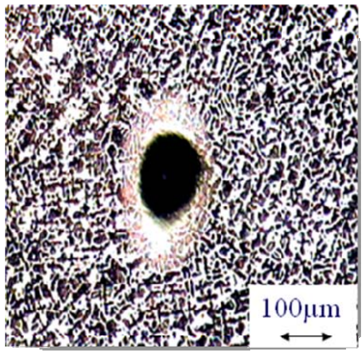
Fig. 5 Microstructures of overlay welded layers: specimen No.4 (a), specimen No.5 (b)



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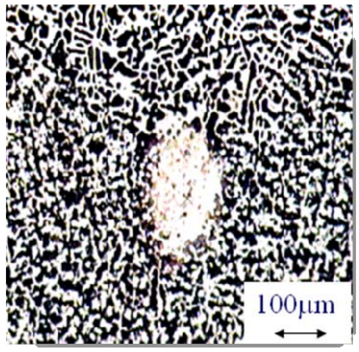


b

Fig. 6 Microstructure of third specimen impacted at laser beam impulse

Table 3

Hardness of the overlay welded layers and microhardness of the zone impacted by laser beam

Specimen No.	Layer hardness, HRC	Laser beam impacted zones microhardness, MPa
1	64	5776
2	57	3884
3	60	4589
4	59	7926
5	60	4214
6	60	7926

Wear testing results of overlay welded layers presents Fig. 7.

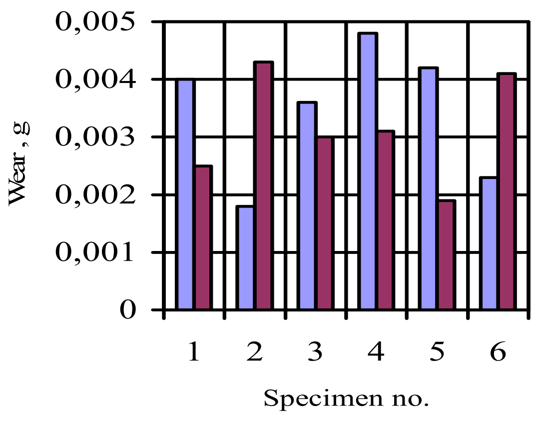
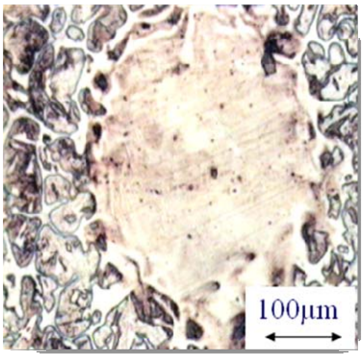


Fig. 7 Wear of the overlay welded and tempered layers (bright columns) and impacted by laser beam (dark column)

Wear resistance of steel depends on its structure and hardness. The wear tests have been done by abrading welded and laser beam treated specimens at applied load 320 N. Wearing of layers after 20 minutes (sliding distance 6.69 m) was tested according to mass loss. Surface of structural steel Cт3 covered by BK-8 powders (specimen No. 4) and melted under the AMS1 flux mixed with graphite powder resulted the formation of carbide phase (Fig. 5, a), so the layer wear at most due the fact that carbides crushed. Similar to hardness and overlay welded layer by powders mixture containing chromium and ferromanganese (specimen No. 5) wear less, because carbides combined matrix contains any amount of retained austenite. Second specimen overlay welded by glass and particularly SiC powders wear at least. Powder mixtures containing graphite and chromium powders increase the amount of retained austenite in the layer. Wearing is low of layer overlay welded with P6M5 steel chips (specimen No. 6) under the flux AMS1 containing boron carbides powder thought the containing of carbides and borides.

The overlay welded layer's (specimen No. 6) impaction zone by laser beam has high hardness (7926 MPa), so the wear resistance has no been increased. The layer impacted by laser beam wears more in comparison to the no impacted (Fig. 7). The influence presented coarse carboboride consisting of liquid phase during cooling process (Fig. 8, b). The brittle carboboride was leaded to fracture. The hardness of laser beam affected zone (specimen No. 5) is low (4214 MPa), so the wear resistance has been increase. The microstructure of impacted zone is uniform (Fig. 8, a) and more ductility as concerning retained austenite.



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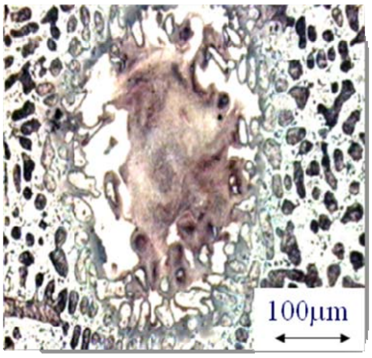

b

Fig. 8 Microstructures of overlay welded layers after impaction at laser beam: a- specimen No. 5, b- specimen No. 6

4. Conclusions

1. Overlay welding of structural steel Ст3 with material powders sprayed over the surface and melted by arc between continuously supplied low carbon steel wire Св 08 obtained layers solidifying during tempering at heat temperatures. For overlay welded layer with the mixture of powders consisting of BK-8 hard metal powder higher hardness was noted after tempering (600°C, 64 HRC).

2. Overlay welding of structural steel Ст3 with material powders sprayed P6M5 steel chips and melted under the flux AMS1 mixed with the powders of boron carbide layer harden on cooling (64 HRC, primary hardness), whereas on tempering the hardness decreases, and no secondary hardening was obtained.

3. Laser beam treatment of overlay welded layers in no senses increase the wear resistance. It depends on the hardness and microstructure of impacted zones.

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ATLEIDIMO TEMPERATŪROS BEI LAZERIO SPINDULIUOTĖS ĮTAKA APLYDYTO SLUOKSNIO KIETUMUI IR DILUMUI

R e z i u m ė

Šiame darbe ištirta automatiniu būdu po fliusu aplydytų sluoksnių struktūra, kietumo priklausomybė nuo atleidimo temperatūros, nustatytas lazerio spinduliuotės poveikis struktūrai ir dilumui.

Konstrukcinio plieno Ст3 bandiniai aplydyti naudojant medžiagų miltelius, kurie buvo beriami ant paviršiaus ir išlydyti po fliusu arba medžiagų miltelių mišiniai užberti ant paviršiaus išlydyti nenaudojant standartinio fliuso. Komponentai išlydyti degant lankui tarp pagrindinio metalo (plienas Ст3) ir mažaanglės nelegiruotosios vielos Св08. Aplydymui naudotas standartinis fliusas AMS1,

turintis daugiau kaip 50% SiO_2 ir MnO, chromo, volframo, Fe – 70% Mn ir boro karbido (Ba_4C) ir modifikatoriaus (SiCaBa) milteliai, bei antrinių žaliavų milteliai, gauti susmulkinus silikatinį stiklą, eksploatacijai netinkamas BK – 8 kietlydinio plokšteles ir šlifavimo diskus (SiC), greitapjovio plieno P6M5 frezavimo drožles. Anglies kiekiui sluoksnyje padidinti naudoti grafito milteliai.

Aplydyti sluoksniai buvo periodiškai paveikti lazerio spinduliuote, mikroskopiniame analizatoriuje MLA 10. Sluoksnių atsparumui dilimui nustatyti, 6 mm pločio bandiniai buvo dilinami besisukančiu 41 mm skersmens kietlydinio disku, spaudžiant 320 N apkrova. Nustatyta, kad aplydytų sluoksnių dilumui įtakos turėjo cheminė sudėtis, struktūra ir kietumas. Lazerio spinduliuotės poveikis ne visais atvejais padidino sluoksnių atsparumą dilimui.

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INFLUENCE OF THE TEMPERIG TEMPERATURE AND LASER BEAM ON HARDNESS AND WEAR OF THE OVERLAY WELDED LAYERS

S u m m a r y

In this paper we report the results of overlay welded layers by automatic device under the flux, its hardness depending on tempering temperature and influence of laser beam on structure and wear.

Specimens of structural steel Cт3 were overlay welded with material powders sprayed over the surface and melted under the coating of flux or material powder mixtures sprayed over the surface melted unemployed standard flux.

The all components were melted by arc between continuously supplied 1.2 mm diameter low carbon steel wire Cв 08 and structural steel Cт3. For overlay welding standard flux AMS1 (have more 50% MnO and SiO_2), chromium, tungsten, Fe – 70% Mn and boron carbide (Ba_4C) and SiCaBa powder, secondary material powders (glass, high speed steel P6M5 chips, metal ceramic plates BK – 8, SiC from grinding disks) and to increase amount of carbon the graphite powders were used.

Overlay welded layers was periodically impacted by laser beam in microscopical analiser MLA10. The wear tests have been done by abrading welded specimens at applied load 320 N. For the wear of overlay welded layers influence of structure, chemical composition and hardness was obtained. Laser beam treatment of overlay welded layers in no all senses increase the wear resistance.

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