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Janette BREZINOVÁ, Ján VIŇÁŠ*, Dagmar DRAGANOVSKÁ*,*
Anna GUZANOVÁ, Jakub BREZINA**

POSSIBILITIES OF RENOVATION FUNCTIONAL SURFACES OF EQUIPMENTS IN THE MECHANICAL ENGINEERING INDUSTRY

Abstract

The paper analyzes the possibilities of increasing the lifespan of rollers in continuous steel casting line. There are analyzed the causes of the surface rollers damage and the impact of degrading factors in metallurgical production. Three types of welding consumable electrodes designed for restoration layers formation applied by SAW surfacing technology were analyzed. There were analyzed microstructure, microhardness and properties of weld clads in tribological conditions.

1. INTRODUCTION

The technology of continuous casting of steel slabs was introduced for full range of dead-melted steels, deep-drawing, so-called pseudodead-melted steels and also effervescing steels, which replaced the traditional method of making slabs by rolling ingots (Brezinova et al., 2017; Blaskovits & Čomaj, 2006). Continuous casting line is in generally one-strand or two-strand (Nadooshan, Saeedi, Rasooli, Izadi & Poursina, 2009; Olson, Dixon & Liby, 2012). The rollers have been made from the material C-Cr-Mo, or C-Cr-Mo-V type, they are solid (forged or split), alternately warmed-up by hot cast slab and cooled by

* Technical University of Košice, Faculty of Mechanical Engineering, Masiarska 74, 040 01 Košice, Slovakia, +421 55 602 3542, janette.brezinova@tuke.sk; jan.vinas@tuke.sk; dagmar.draganovska@tuke.sk; anna.guzanova@tuke.sk; jakub.brezina@tuke.sk

external water-vapour-air cooling system (Lorincova 2012; Mikuš, Szabó, Drlička & Bakajová, 2014). In the upper part of continuous casting line temperature of slab is approximately of 1250°C and in the bottom part about 800°C (Vinas, Brezinová, Guzanová & Lorincová, 2011; Vinas, Brezinová, Guzanová & Svetlík, 2013).

The rollers of continuous casting line are exposed to combined abrasive-adhesive load, connected with high temperature cyclic fatigue stress in corrosion environment, what results in changing of material structure and properties of functional surface (Houldcroft, 2014; Wu, Xiang, He, Chen & Hu, 2015). Application of cladding layer created using high-alloy welding wires in combination with flux enables creating functional roller surface with higher lifespan than new rollers (Vinas, Greš & Vaško, 2016; Paulicek, Kotus, Daňko & Žúbor, 2013, Kotus, Andrássyová, Cico, Fries & Hrabe, 2011). For renovation by hard surfacing are generally used at least three cladding layers (Toyserkani, Khajepour & Corbin, 2004; Lekhov, Mikhalev, Bilalov & Shevelev, 2017).

Thermal treatment of the roller with clad applied shows Fig. 1.

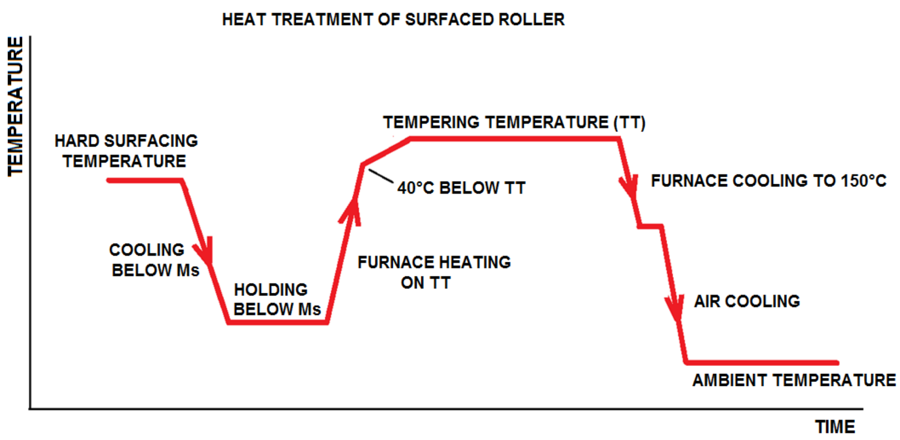


Fig. 1. Thermal treatment of the roller

2. EXPERIMENTAL PROCEDURE

In the experimental part of work, the twice renovated roller with diameter of 180 mm, made from forged steel X20Cr13 EN 10088-3 was used. The chemical composition of the roller is given in Table 1.

Tab. 1. Chemical composition of the roller X20Cr13 in [%]

C	Cr	Si	Mn	P	S	Fe
0,16–0,25	12,00–14,00	max. 1,00	max. 1,50	max. 0,040	max. 0,015	bal.

Wear size of roller was assessed by visual check. Worn layer (with thickness of 7 mm) was removed from roller surface by turning. Turned surface was checked visually again. The presence of inner defects was checked by ultrasonic test. Considering chemical composition of roller, there was necessary to preheat it before cladding on temperature of 350°C–400°C. Chemical composition of welding wires used is given in Table 2**.**

Tab. 2. Chemical composition of weld wires [in wt. %], balance of Fe

Wire	C	Si	Mn	Ni	Cr	Mo	Nb	V
W 3	0.1	0.6	1.0	2.5	12.2	0.8	0.15	0.15
W 5	0.25	0.6	1.0	0.25	9.0	2.0	–	–
W 8	0.3	0.6	1.0	–	12.2	0.75	–	0.15

For cladding was used universal flux AWS A5 17-89 EM 13K, which chemical composition can be found in Table 3.

Tab. 3. Chemical composition of universal flux AWS A5 17-89 EM 13K

$\frac{S_iO_2 + T_iO_2}{20}$	$\frac{C_aO + M_gO}{38}$	$\frac{AL_2O_3 + M_nO}{17}$	$\frac{C_aF_2}{19}$

Welding wire W3 (W3-WLDC 3) is commercially used for cladding of continuous casting rollers. Welding wires W8 (W8-WLDC 8) and W5 (W5HT-WLDC 5) were still not used for cladding of continuous casting rollers. The roller was renovated using welding equipment Weldclad GU125LZ, COREWIRE. The parameters of cladding are listed in Table 4. After cladding, roller was cooled down in electric furnace in isothermic wrap. Cooling speed was 40°C per hour up to room temperature. Then it was tempered in furnace at 500°C / 8 hours.

Tab. 4 Parameters of cladding

Wire	Diameter [mm]	Voltage [V]	Current [A]	Oscillations [mm]
W 3	3.2	28	450	45
W 5	3.2	26	600	47
W 8	3.2	26	450	50

After the surfacing and heat treatment the roller was turned to specified diameter. Quality of weld layers was assessed by non-destructive testing according to STN EN ISO 23277 and STN EN ISO 11666. Microhardness tests were realized by Vickers diamond pyramid, load applied: 980.7 mN (HV 0.1), time of indentation: 15 s, distance of indentations: 1–16 mm (with step of 1 mm). Test samples were subjected to cyclic thermal load in high-temperature chamber furnace. Test samples were heated to temperature of 400°C and 900°C. Heating temperature 400°C was chosen to verify the resistance of weld deposits against temperatures, to which the roller is exposed during its normal operation in continuous steel casting line. Heating temperature 900°C was chosen to verify the resistance of weld deposits against thermal load when continuous casting line is stopped due to emergency reasons. After reaching the sample temperature of and remaining at stated temperature for 5s, the samples were rapidly cooled by water with temperature of 20°C. The cycle of heating and cooling of the samples was repeated 20 times.

Erosive wear of weld clads was simulated by mechanical abrasive blasting process. Brown corundum with grain size 0.71 mm was used as blasting abrasive, velocity of abrasive grains was 70.98 mps, impact angle was 45° and 90°. Abrasive grains impinged the cover layer of cladding. Wear resistance of weld clads was evaluated by mass loss of the cladding.

3. RESULTS AND DISCUSSION

Microstructure of cover layer, first cladding layer and HAZ are presented in Table 5 and in Fig. 2. At a depth of 16 mm below the surface, microstructure of the base material consists of low-carbon martensite.

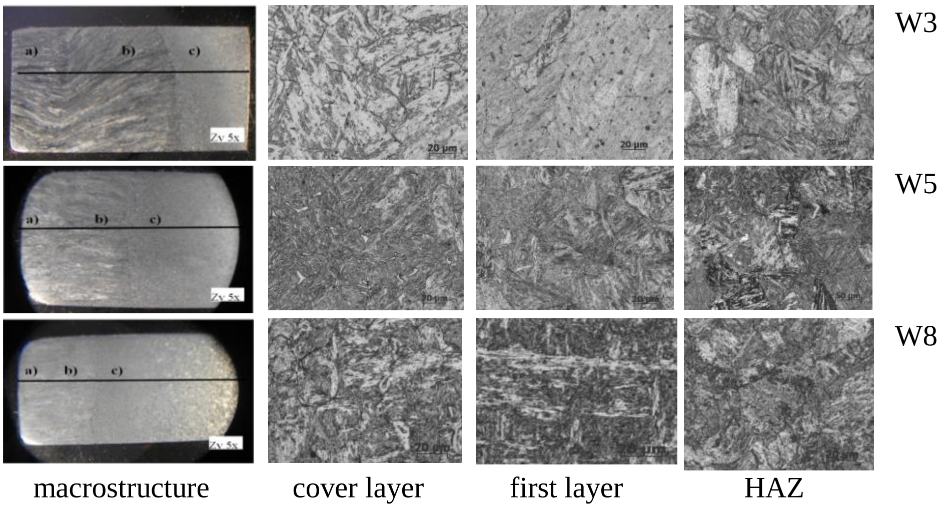


Fig. 2. Macro- and microstructure of weld clads (a – cover layer, b – first layer, c – HAZ)

Tab. 5 Microstructure of weld clads

	Cover layer	First layer	HAZ
W 3	low-carbon high-tempered martensite (sorbite)	low-carbon high-tempered martensite, carbide phases	low-carbon tempered martensite without carbids
W 5	martensite with islands of ferrite	low-carbon tempered martensite	low-carbon tempered martensite
W 8	tempered martensite with small carbide particles	of low-carbon tempered martensite	low-carbon tempered martensite

Fig. 3 shows the microhardness of particular weld layers and HAZ of weld deposits W3, W5 and W8. Higher microhardness was found in clads made using welding wires W5 and W8, from the cover layer to the base material the hardness decreased.

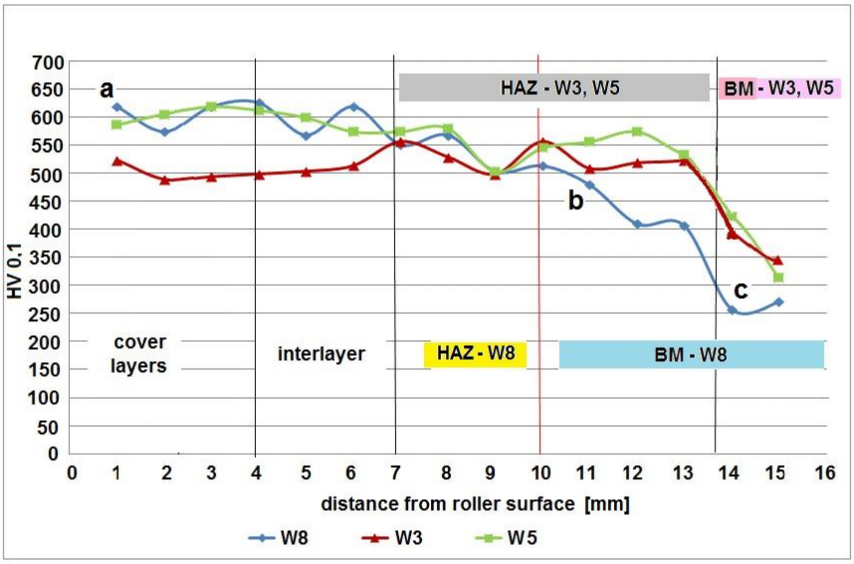


Fig. 3. Microhardness of particular layers of weld clads

At temperature of 400°C weld deposits were loaded up to 20 thermal cycles and there were still not observed breach of integrity, but when samples were thermally loaded at 900°C, after the 5th cycle thermal cracking of W5 weld deposit occurred, Fig. 4. In weld deposit W3 and W8 cracks on test specimens were not recorded.

W 3 W 5 W 8

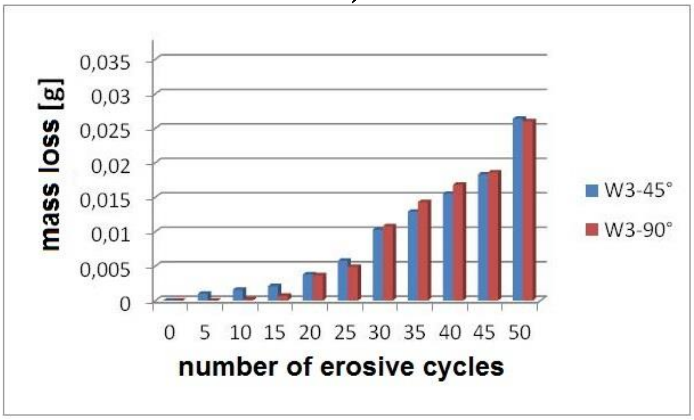
Fig. 4. Cracks on test samples due to thermal cyclic loading after thermal cycles at 900°C

The structural analysis of the test samples after different stages of thermal stress points to an increased incidence of carbide particles and grain refinement after the thermal load in the cladding metal. HAZ showed no significant change in microstructure.

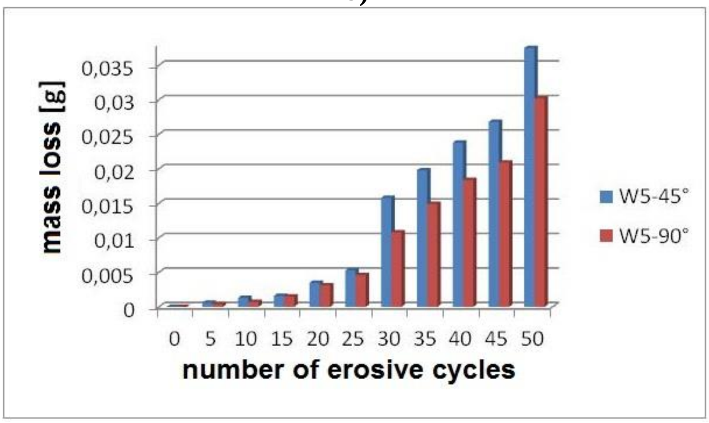
Mass loss of weld deposits at two impact angles of abrasive is presented in Fig. 5.

Weld deposits W5 and W8 showed greater mass loss after 50 erosive cycles compared to W3. Forging effect of incident grains caused exhaustion of weld clad plasticity. It led to fatigue failure of surface of the weld deposit and subsequently release microparticles of material from the surface. Weld deposits W5 showed greater mass loss at blasting angle 45°, which can be caused by chemical composition of the weld, especially lower Cr content compared to other evaluated weld clads. Effect of the blasting angle on wear resistance of weld deposit W3 had not significant impact.

a)



b)



c)

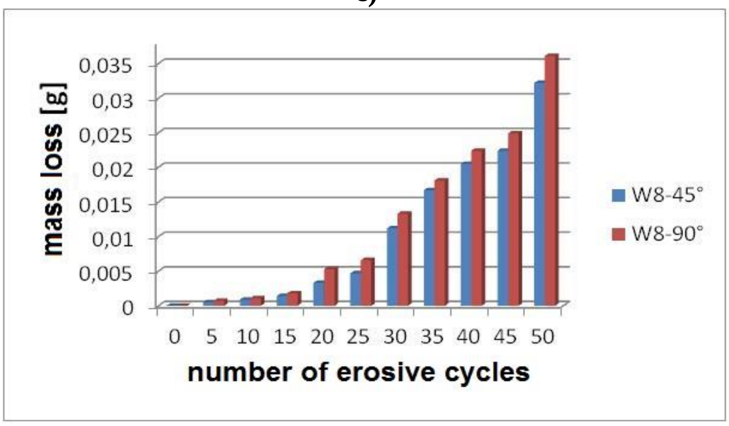


Fig. 5. Mass loss of weld deposits a) W3, b) W5 and c) W8 at two impact angles

4. CONCLUSIONS

Based on the realized experimental work can be concluded, that the highest value of microhardness before thermal cycles were found in the cover layer of weld deposit made of welding wire W8-WLDC 8, 620 HV 0.1. This value is consistent with the chemical composition of the welding wire used, especially with the highest carbon content among the assessed filler materials and also with high chromium content.

Based on the evaluation of results obtained by simulation of degradation phenomena affecting the continuous casting rollers during their operation, newly developed welding wire W8-WLDC 8 can be designated as the best material for renovation of continuous steel casting rollers.

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REFERENCES

Blaškovitš, P., & Čomaj, M. (2006). *Renovation by welding and thermal spraying*. Bratislava: STU.

Brezinová, J., Viňáš, J., Maruschak, P. O., Guzanová, A., Draganovská, D., & Vrabeľ, M. (2017). *Sustainable renovation within metallurgical production*. Lüdenscheid: Verlag.

Houldcroft, P. T. (2014). *Submerged-Arc Welding*, Elsevier.

Kotus, M., Andrássyová, Z., Cico, P., Fries, J., & Hrabe, P. (2011). Analysis of wear resistent weld materials in laboratory conditions. *Research in Agricultural Engineering, 57*, 74–78.

Lekhov, O. S., Mikhalev, A. V., Bilalov, D. K., & Shevelev, M. M. (2017). Cyclic-deformation system for the reduction of continuous-cast slabs. *Steel in Translation 4(47)*, 225–228. doi: 10.3103/S0967091217040064

Lorincová, D. (2012). *Analysis of quality of renovation layers from aspect of degradation phenomena* (doctoral dissertation). Technical University of Kosice: Kosice.

Mikuš, R., Szabó, V., Drlička, R., & Bakajová, J. (2014). Hardness and microstructure analysis of deposit material based on Fe-Cr-Ni. *Advanced Materials Research*, *1059*, 35–42. doi: 10.4028/www.scientific.net/AMR.1059.35

Nadooshan, A. A., Saeedi, A., Rasooli, M., Izadi, J., & Poursina, M. (2009). Calculation of possibility for parameter design in changing central cooling system to revolver cooling system for continuous casting rollers. *World Academy of Science, Engineering and Technology*, *49*, 252–257.

Olson, D. L., Dixon, R. D., & Liby, A. L. (2012). *Welding: Theory and Practice, Materials Processing: Theory and Practices.* Elsevier.

Pauliček, T., Kotus, M., Daňko, M., & Žúbor, P. (2013). Resistance of hard-facing deposit created by laser surfacing technology. *Advanced Materials Research, 801*, 117–122. doi:10.4028/www.scientific.net/AMR.801.117

Toyserkani, E., Khajepour, A., & Corbin, S. F. (2014). *Laser Cladding*. CRC Press.

Viňáš, J., Brezinová, J., Guzanová, A., & Lorincová, D. (2011). Properties of renovation layers applied by submerged arc welding. *Chemické listy, 105(17),* 858–859.

Viňáš, J., Greš, M., & Vaško, T. (2016). Cladding of wear-resistant layers in metallurgy and engineering. *Materials Science Forum, 862*, 41–48.

Viňáš, J., Brezinová, J., Guzanová, A., & Svetlík, J. (2013). Degradation of renovation layers deposited on continuous steel casting rollers by submerged arc welding. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 227(12),* 1841–1848.

Wu, Y., Xiang, Q., He, Y., Chen, H., Hu, B. (2015). Main technical route of renovation heat-treatment of aero-engine turbine blades. *Jinshu Rechuli/Heat Treatment of Metals, 11(40),* 176–178.