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Quality of Surfaced Running Wheels
Kvaliteta navarjenih tekalnih koles

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Results of tribologic testing of samples of running crane wheels as well as of crane rails show that wear resistance of running wheels can be considerably improved by surfacing. The wear of the wheels coated with higher-alloyed claddings is insignificant. It is only the wear of crane rails which becomes significant, and which increases with the increase of hardness of the running wheel surface (it depends only on alloying of the surfaced cladding). Hard running wheel surfaces are interesting mostly in the case of greater stresses because they permit operation with lower friction moment, and consequently lower heating of contact surfaces in sliding as well as in rolling friction.
Key words: wear of running crane wheels, submerged-arc surfacing, alloyed agglomerated fluxes, tribologic testing of wear resistance of surfacings.

Rezultati tribološkega testiranja vzorcev tekalnih koles žerjavov in tirnice so pokazali, da lahko z navarjanjem znatno izboljšamo obrabno ostojnost tekalnih koles. Obraba koles, ki jih platiramo z močneje legiranimi prevlekami, je neznatna. Pomembna postane samo obraba tirnice, ki pa se s trdoto tekalne površine kolesa (odvisna je od legiranja navarjene prevleke) povečuje. Trde tekalne površine koles so zanimive predvsem pri večjih obremenitvah, ker zagotavljajo obratovanje z nižjim momentom trenja in s tem manjše segrevanje stičnih površin tako pri drsnem kot tudi kotalnem trenju.
Ključne besede: Obraba tekalnih koles žerjavov, navarjanje pod praškom, legirani aglomerirani praški, tribološke preiskave obrabne odpornosti navarov.

1. Introduction

Wear mechanisms are simulated by tribologic testing. The state of stress of a material depends on the load applied, number of revolutions, and slip. Stresses generated in a material due to the operation of a machine element exert a decisive influence on its applicability[1-6].

Quality of the surfaces subject to wear is of extreme importance. Life of the machine element depends on the steel or alloy applied. Its making of high-alloy steels or special alloys, which would result in its high wear resistance, however, would be very expensive. It is surfacing processes which make it possible that solely the surfaces and edges subject to wear during operation need to be made of special wear-resistant steels or alloys[7-9]. The very submerged-arc surfacing of wheels with alloyed wire "EPP Cr 6" and with fused flux somewhat improves their wear resistance with regard to that of unsurfaced wheels. An even more distinct improvement of wear resistance of the wheels can be achieved if running wheel surfaces are submerged-arc surfaced with alloyed agglomerated fluxes or high-efficiency alloyed thick-coated electrodes to obtain higher-alloyed and harder claddings. These filler materials permit us to surface structural unalloyed steels in one layer with high-alloyed claddings[10-12].

2. Quality of samples for tribologic testing

Multi-layer submerged-arc surfacing of worn-out running wheels with wire "EPP Cr 6" and fused flux provides quite an acceptable quality of the repaired running wheels. The running wheels repaired in this way are even a little more wear-resistant than the unsurfaced ones. This was proved also by tribologic testing[13,14].

Surfacing of the worn-out running wheels with alloyed wire "EPP Cr 6" can be replaced by submerged-arc surfacing with unalloyed wire "EPP 2" and alloyed agglomerated flux. The surfacing is alloyed with chromium and other selected elements coming from the alloyed agglomerated flux. The compositions of one-layer and multi-layer surfacings, i.e. deposited metals, obtained in submerged-arc surfacing with unalloyed wire "EPP 2" and with the new alloyed agglomerated flux "0–7 SM" correspond very well to those of the surfacings obtained in submerged-arc surfacing with wire "EPP Cr 6" and fused flux (see **Table 1**).

Testing of wear resistance of the surfacings has shown that the alloyed agglomerated welding flux "0–7 SM" in combination with the unalloyed wire "EPP 2" is quite a suitable substitute to be applied for submerged-arc surfacing of the running wheels with alloyed wire "EPP Cr 6" and fused flux.

For surfacing of higher-alloyed wear-resistant claddings, high-alloyed agglomerated welding fluxes "U-Mo 1" and "BM-2" have been developed in addition to the alloyed agglomerated welding flux "0–7 SM".

Samples for tribologic testing (**Fig.1**) have been made of steel Č.4732. They have been automatically submerged-arc sur-

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Table 1: Chemical analyses of one-layer and multi-layer submerged-arc surfacings (deposited metals) made with wires
- EPP Cr 6 and fused flux and
- EPP 2 and alloyed agglomerated flux "0-7 SM" respectively.

Tabela 1: Kemične analize enoslojnega in večslojnega navara (čistega vara) z žico
- EPP Cr 6 pod taljenim praškom in
- EPP 2 pod legiranim aglomeriranim praškom "0-7 SM"

Surfacing	C (%)	Si (%)	Mn (%)	Cr (%)	Mo (%)
EPP Cr 6/fused flux					
– one-layer	0,20	0,24	0,65	4,53	–
– multi-layer	0,10	0,25	0,70	7,00	–
EPP 2/alloyed flux "0–7 SM"					
– one-layer	0,32	0,35	0,87	3,56	0,31
– multi-layer	0,11	0,55	1,21	9,12	0,48

faced with wire "VAC 60" ∅1.2 mm (I = 140 A, U = 21 V, and $v_{weld.}$ = 30cm/min; q = 5 KJ/cm) and alloyed agglomerated fluxes "0-7 SM", "U-Mo 1", and "BM-2" which, during surfacing, heated up to the temperature of 350°C. Cooling rates of the surfacing and of the heataffected zone correspond to those in surfacing of preheated running wheels carried out in practice[13,14].

Chemical compositions and hardness values for the surfacings and the heat-affected zones are given in **Table 2**.

Table 2: Chemical compositions and hardness values of the samples surfaced for tribologic testing (50 % overlapping of runs)

Tabela 2: Kemične sestave in trdote navarjenih vzorcev za tribološke preiskave (50%-no prekrivanje varkov)

Surfacing	C (%)	Cr (%)	Mo (%)	W (%)	V (%)	Hardness in HV: Final layer	Weld centre	HAZ
VAC 60/0-7SM	0,31	5,3	0,3	–	–	410	366	183
VAC 60/U-Mo 1	0,55	9,8	2,3	–	0,9	687	556	172
VAC 60/BM-2	0,85	5,1	4,2	5,0	1,9	707	586	163

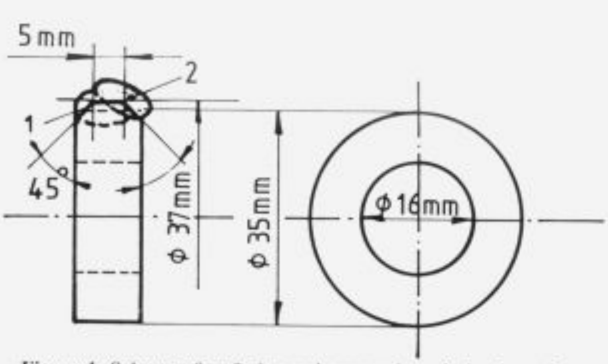

Figure 1: Scheme of surfacing and preparation of a hard running surface by specimens for tribologic testing (1 - first surfacing, 2 - second surfacing).

Slika 1: Skica navarjanja in priprave trde tekalne površine pri vzorcih za tribološke preiskave (1 - prvi navar, 2 - drugi navar)

Quality running surfaces of the surfaced rollers are obtained if the surfacings are broached at an angle of 45 (**Fig. 1**). The samples of the rail not being broached, it is the surfaced samples which determine the gap width in tribologic testing (5 mm). The running contact surfaces of the rollers surfaced and of the rail samples have been ground and polished to Ra = about 0.3 mm before being tested on a tribometer "Amsler".

3. Results of tribologic testing of the surfacings and of the rail

Parameters for tribologic testing of the running crane wheels and of the rail have been chosen in such a manner that Hertz's pressure in the case of our test carried out between two rollers (Amsler) is the same as that in actual condition existing the running wheel and the crane rail[13].

Testing conditions in rolling friction are as follows:
P = 600 N/cm, 1200 N/cm, and 2000 N/cm
v = 200 r.p.m. (0.42 m/s), and 400 r.p.m. (0.84 m/s)
t = 24 min

Diagrams of friction moment are given in **Fig. 2**.

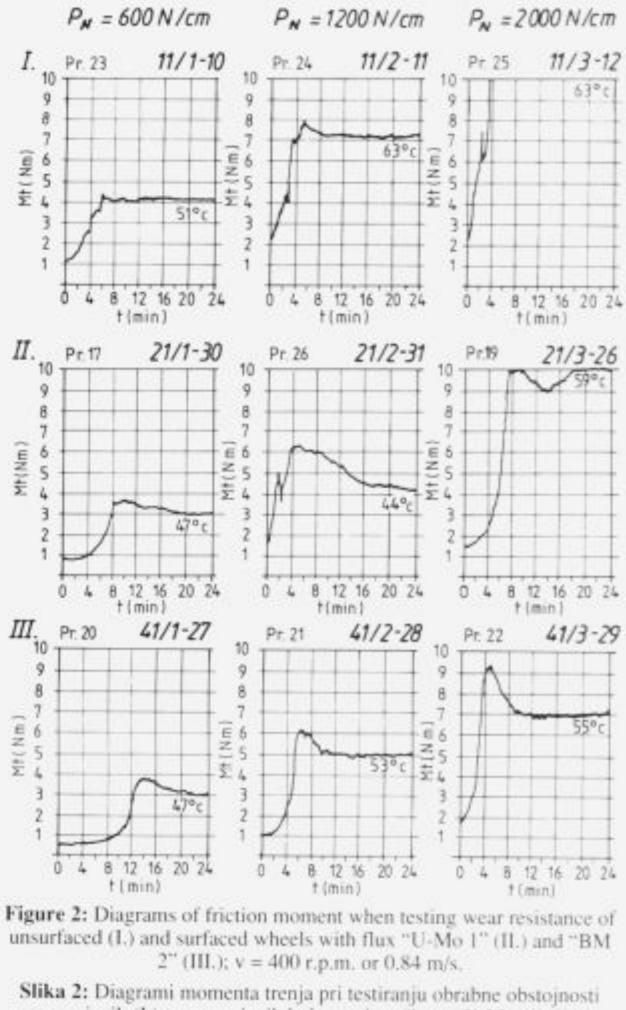

Figure 2: Diagrams of friction moment when testing wear resistance of unsurfaced (I.) and surfaced wheels with flux "U-Mo 1" (II.) and "BM 2" (III.); v = 400 r.p.m. or 0.84 m/s.

Slika 2: Diagrami momenta trenja pri testiranju obrabne obstojnosti nenavarjenih (I.) ter navarjenih koles pod praškom "U-Mo 1" (II.) in "BM 2" (III.); v = 400 obr./min. oz. 0.84 m/s

Wear of the wheels surfaced with higher-alloyed claddings is insignificant. It is only wear of the rail which becomes important and which increases with the increased hardness of the running wheel surface (which itself depends on alloying of the cladding surfaced). Hard running wheel surfaces are of interest most of all with higher stresses because they make possible op-

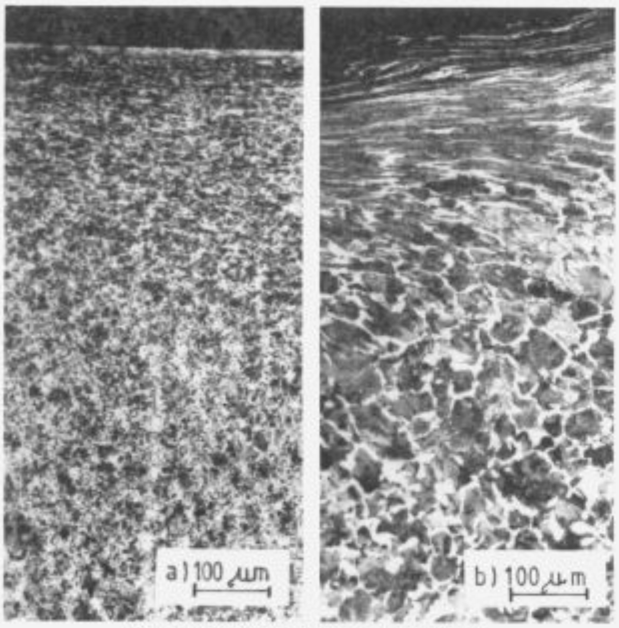

Figure 3: Microstructure of a rail section
a) Pr. 10 - high friction moment; more than 10 Nm
b) Pr. 5 - low friction moment; about 6 Nm

Slika 3: Mikrostruktura preseka tirnice
a) Pr. 10 - visok moment trenja; preko 10 Nm
b) Pr. 5 - nizek moment trenja; okoli 6 Nm

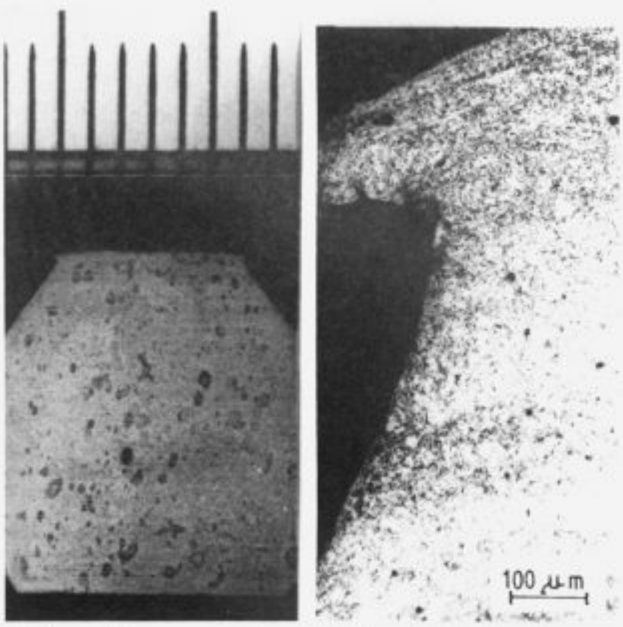

Figure 4: Appearance of an unsurfaced running wheel section and its microstructure

Slika 4: Izgled preseka nenavarjenega tekalnega kolesa in njegova mikrostruktura

eration with a lower friction moment, and consequently result in a weaker heating of the contact surfaces in sliding friction as well as in rolling friction.

Heating of the contact surfaces, which is particularly strong with high friction moments, results, in the case of strong loads, in a considerable deformation of the surface layers of the rail **(Fig.3)** and of the running wheels **(Fig.4)** if they have not been

Figure 5: Damaged running surface - parts of oxides, stickers of metals... (unsurfaced running wheel)

Slika 5: Poškodovana tekalna površina - delci oksidov, nalepi kovine... (nenavarjeno tekalno kolo)

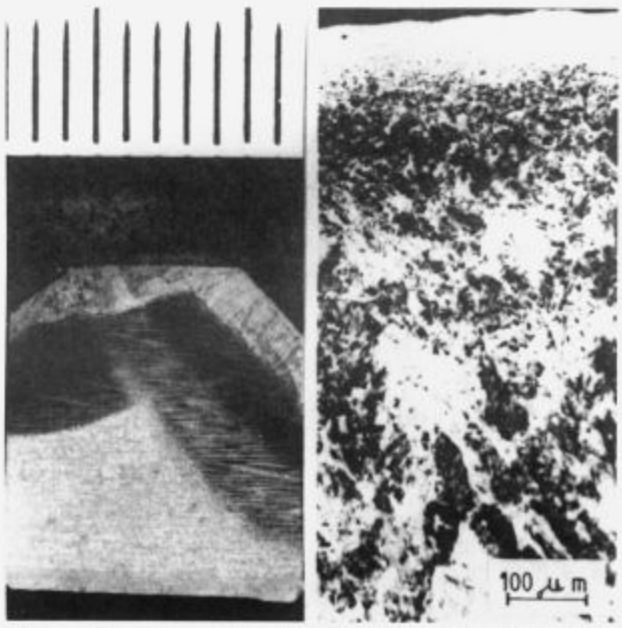

Figure 6: Appearance of a surfaced (0-7 SM) running wheel section and its microstructure.

Slika 6: Izgled preseka navarjenega (0-7 SM) tekalnega kolesa in njegova mikrostruktura

surfaced, i.e. refined with a hard cladding. Plastic deformation is accompanied also by crystalline modification of the surface layer if the latter heats above 555°C due to rolling friction[15]. If heating during rolling, which strongly depends on friction moment, is very intensive, the crystalline modification zone can extend also beyond the deformation zone **(Fig.3)**. The deformation zone in rails goes approximately 0.4 mm deep, while the crystalline modification zone, in the case of high friction moments, goes even 2 mm deep **(Fig.3)**.

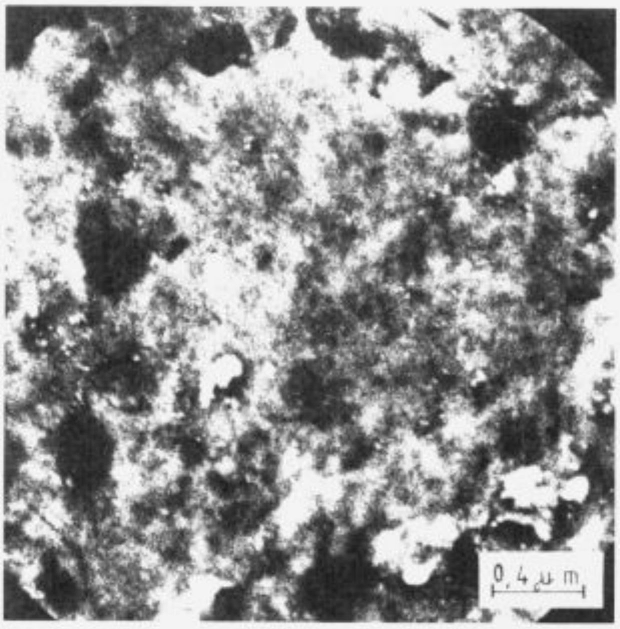

Figure 7: Damaged running surface - parts of oxides, stickers of metals... (surfaced running wheel; 0-7 SM).

Slika 7: Poškodovana tekalna površina - delci oksidov, nalepi kovine... (navarjeno tekalno kolo; 0-7 SM)

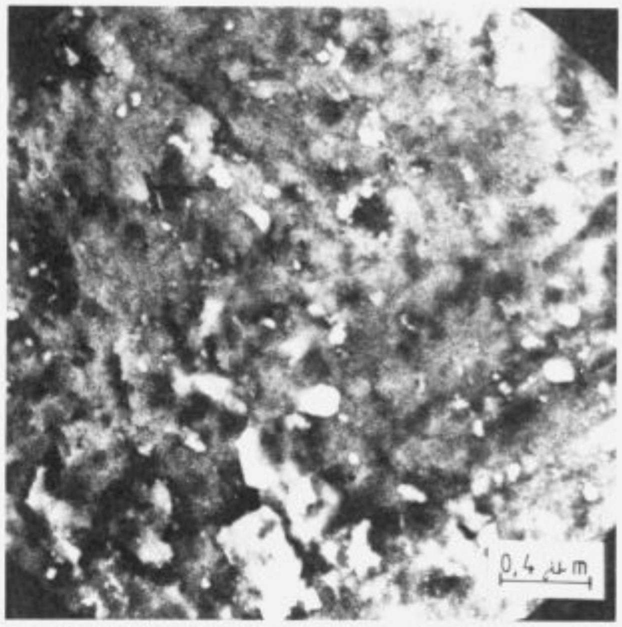

Figure 9: Damaged rolling surface - parts of oxides, stickers of metalls... (surfaced rolling wheel; BM-2)

Slika9: Poškodovana tekalna površina - delci oksidov, nalepi kovine... (navarjeno tekalno kolo; BM-2)

A distinct deformation and oxidation of the surface due to intensive heating of the contact surfaces during rolling results in damages to the running wheel surface (**Fig. 5**).

Submerged-arc surfacing itself with alloyed agglomerated flux "0-7 SM" highly improves wear resistance of the running wheel. Deformation of the surface layer is considerably weaker. The contact surface increases, due to wear and plastic deformation, only by 15 % (**see Fig. 6**). With the unsurfaced sample, the contact surface has increased by even 30 % during testing. Also the deformation depth with the surfaced sample is only 80 to 100 μm (**see Fig. 6**), which is easy to understand since the surfaced-layer has martensitic-bainitic structure while with the unsurfaced sample (**Fig. 4**, deformation depth 200-250 μm), the surface layer has ferritic structure.

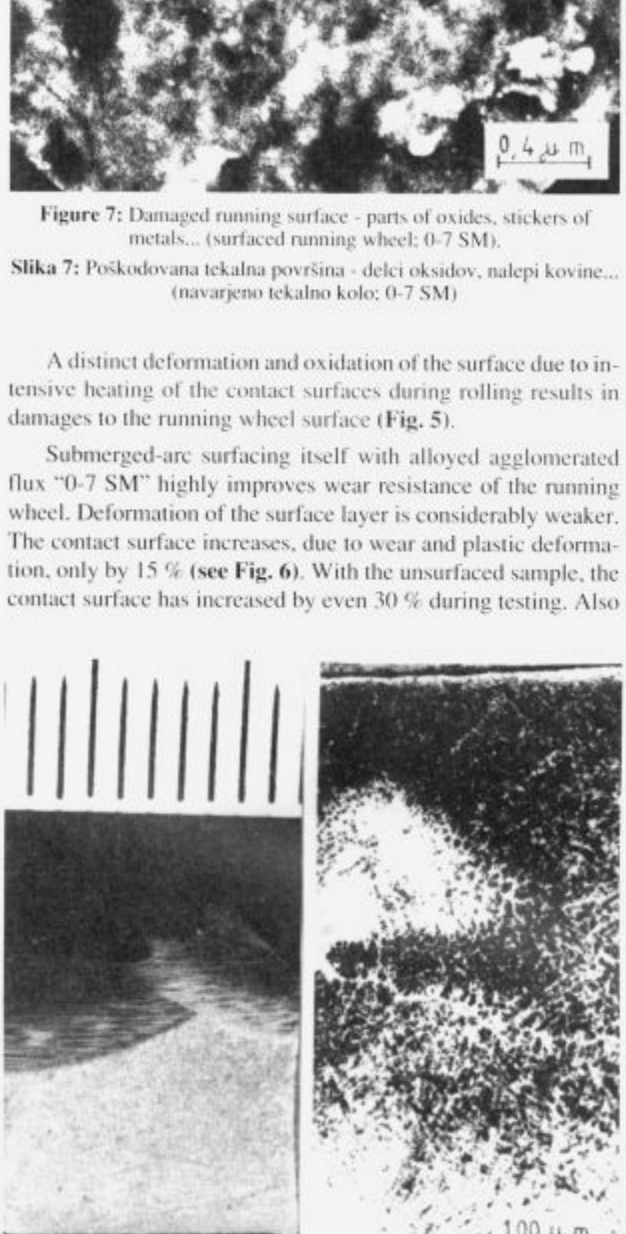

Figure 8: Appearance of a surfaced (BM-2) running wheel section and its microstructure.

Slika 8: Izgled preseka navarjenega (BM-2) tekalnega kolesa in njegova mikrostruktura

With the surfaced samples of the running wheels, deformation and oxidation cause damages to the contact surface, i.e. folded metal and stickers of metals and oxides (**Fig. 7**). These are, however, essentially weaker than those to the unsurfaced samples (cf. **Figs. 5 and 7**).

Even weaker deformation and lesser damages of the running surface occurred with the samples which were submerged-arc surfaced with high-alloyed welding fluxes "U-Mo 1" and "BM-2" (**see Fig. 9**). After tribologic testing, the surface layer has been very little deformed (**Fig. 8**). Increase of the contact surface due to deformation and oxidation of the surface (**Fig. 8**) is insignificant too (around 5 %).

4. Conclusion

Wear resistance of running wheels can be improved by surfacing. The very submerged-arc surfacing of the wheels with alloyed wire "EPP Cr 6" and with fused flux somewhat improves their wear resistance with regard to that of unsurfaced wheels. An even more distinct improvement of wear resistance of the wheels can be achieved if running wheel surfaces are submerged-arc surfaced with alloyed agglomerated fluxes or high-efficiency alloyed thick-coated electrodes to obtain higher-alloyed and harder claddings. These filler materials permit us to surface structural unalloyed steels in one layer with high-alloyed claddings.

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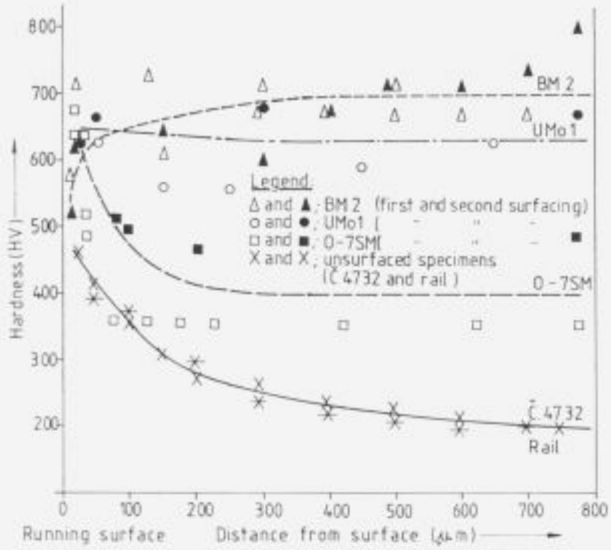

Figure 10: Hardness of sections of unsurfaced and surfaced specimens
Slika 10: Trdote na prerezu nenavarjenega in navarjenih tekalnih koles

High wear-resistance of the claddings which were submerged-arc surfaced on the running wheel with alloyed-agglomerated flux "0-7 SM" is resulting from surface hardening (600-700 HV; **Fig. 10**) due to deformation of the surface layer. The claddings which were submerged-arc surfaced with high-alloyed agglomerated fluxes "U-Mo 1" and "BM-2", however, are hard (around 700 HV; **Table 2**) right after surfacing; therefore, they practically neither deform nor harden during tribologic testing. In the case when the wear resistant cladding was made by submerged-arc surfacing with high-alloyed agglomerated flux "BM-2", stress and heating of the running surface resulted even in stress relieving and insignificant decrease of hardness immediately upon the surface (**Fig. 10**, upper curve).

Wear of the wheels surfaced with higher-alloyed claddings is insignificant. It is only the wear of the rail which becomes important and which increases with the increased hardness of the running wheel surface (which itself depends on alloying of the cladding surfaced). Hard running wheel surfaces are of interest most of all with higher stresses because they make possible operation with a lower friction moment; and consequently result in a weaker heating of the contact surfaces in sliding friction as well as in rolling friction. Wear resistance of the running crane wheels can be considerably improved by surfacing and by appropriate selection of filler materials without essentially influencing the wear of the rail.

References

[1] L. Föppl: *Beanspruchung von Schiene und Rad beim Anfahren und Bremsen*, Munchen 1963.

[2] K. H. Kloos, E. Broszeit, M. Koch: *Eigenspannungsänderungen beim Überrollen von gehärtetem Wälzlagerstahl 100 Cr 6"*. Institut für Werkstoffkunde, Darmstadt.

[3] H. Poritsky, N. Y. Schenectady: *Stresses and defletions of cylindrical bodies*, New York 1949.

[4] Dr. Marko Kos: *Raziskava trajnostne meje tekalnih koles in tirnice*, Ljubljana 1972.

[5] J. Vižintin, A. Vesel: Popis napetostnega stanja na tekalnem kolesu in tirnici. *Poročilo ZRMK Ljubljana za RP 03–2663-227–88*, Delovni stroji, strojni elementi in konstruiranje, Ljubljana, 1988, 88/106.

[6] A. Vesel, R. Kejžar, J. Vižintin, M. Anželj: Tribološki parametri navarjenih tekalnih koles žerjavov. *Poročilo ZRMK Ljubljana za URP C2-1528-227-89*, Konstruiranje delovnih strojev in motorjev, Ljubljana, 1989, 30/52.

[7] R. Kejžar: Hardfacing by Submerged Arc Welding", *Proceedings of the 2nd International conference on Tooling: Neue Werkstoffe und Verfahren für Werkzeuge*, Bochum, 1989, 301/314.

[8] R. Kejžar: Izdelava in obnavljanje orodij z navarjanjem, *Strokovne informacije 17, Materiali in sodobna izdelava*, Ljubljana, 1991, 117/136.

[9] R. Kejžar: Oplemenitenje površin z navarjanjem in metalizacijo. *Kovine zlitine tehnologije*, 26 (1992), 1/2, 79–84.

[10] R. Kejžar: Perspektive aglomeriranih varilnih praškov, *38. Posvet o metalurgiji in kovinskih gradivih*, Portorož/Ljubljana 1987, 87–98.

[11] R. Kejžar: Legirani aglomerirani praški za posebna navarjanja, *Rudarsko-metalurgki zbornik*, Ljubljana 38 (1991), 2, 275/290.

[12] R. Kejžar: Navarjanje močno legiranih nanosov na konstrukcijska jekla, *Varilna tehnika* 41 (1992), 4, 96–101.

[13] R. Kejžar, J. Vižintin, L. Kosec, J. Cankar, P. Žmitek: Tribološke lastnosti površinsko oplemenitenih jekel – tekalno kolo žerjava. *Poročilo ZRMK Ljubljana URP C2-1528*, Konstruiranje delovnih strojev in motorjev, Ljubljana, 1990, 91 in 92.

[14] R. Kejžar, M. Hrženjak, V. Živkovič, J. Vižintin, L. Kosec, J. Cankar: Izbira dodajnega materiala in tehnologije navarjanja tekalnega kolesa žerjava. *Kovine zlitin tehnologije* 27 (1993) 3, 267.

[15] Ahlert: Erkenntnisse und Entwicklungen der Thermit – Schweisstechnik, *ETR – Eisenbahntechnische Rundschau* 12 (1969) 105.