Wear

REPARATORY HARD FACING OF THE ROTATIONAL DEVICE KNIVES FOR TERRAIN LEVELLING

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ABSTRACT

The aim of this work was to study the possibilities for expanding the working life of certain parts of the civil engineering mechansation. This is why the mechanism of the impact abrasive wear of parts that wear the most, was analysed first, especially knives of the rotational device for terrain levelling. Then the possibility for their reparation was considered.

Dominant types of wears, regarding these parts occur because of abrasion, adhesion and impact, depending on structure and composition of the terrain. Damages on knives in conditions of intensive, abrasive wear, while being in contact with knives working surface with materials of mineral origin, are regarded as a separate subject.

The cutting edges of knives were regenerated by hard facing, and then they were sharpened by grinding to the similar shape and size as the new knives. After that, onto the working machine rotors were mounted alternatively new and repaired knives and their wear was monitored under the same working conditions.

It was established that the endurance of the hard faced knives is better than that of the non hard faced ones, which can be explained by the more favourable microstructure of the hard faced layer that better corresponds to the given working conditions.

Keywords: reparatory hard facing, civil engineering mechanisation, abrasive wear, hardness, microstructure.

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AIMS AND BACKGROUND

The appearance of unworn (new) knife is presented in Fig. 1.

Main causes of damages on surfaces of parts, machines and devices are tribological processes (50–80%) and costs caused by these damages are extremely high. In order to reduce them, it is necessary to be familiar with contemporary accomplishments from the tribology field which relate to design, as well as exploitation, having in mind the requirements for more economic consumption of materials, rational consumption of energy, effective maintenance, longer life and reliability of the product.

Fig. 1. Appearance of a new knife

Reparation of parts, machines and equipment damaged due to tribological processes is of the highest importance. One should also have in mind that, besides reparation of parts worn in regular operation, parts damaged in accidents, as well as new cast pieces manufactured with defects, could also be hard faced. Besides this, today it is very common that new parts are hard faced by hard alloys, which are replacements for some types of heat treatment. Such a wide use contributed to hard facing taking an important place among the so-called advanced technologies. The responsible parts of machines, assemblies, devices are most often manufactured from very expensive alloys, thus by repairing them, besides shortening the down time; the expensive base metals are saved. In a large number of cases, hard facing is cost-effective since the reparation costs do not exceed the price of the new part. This is of extreme importance for parts of large dimensions and in mass production, while the reparation of unique machines and devices sometimes has to be done, regardless of the price[1–7].

Wear can have many forms, depending on the surface topology, conditions of constructions and environment. The process of wear analysis occurs in three phases: mutual impact of surfaces due to friction, changes that take place on contact surface layers of the contact pair elements and damage of surfaces. These phenomena are not occurring one after another, but simultaneously, which means that the mutual impact of surfaces is changing during their relative movement.

Various authors[8–10] gave different categorising of wear process. However, all of them were based on the way in which the contact between the two parts is being realised, thus one has: the adhesive, abrasive, erosion, cavitational, vibrational and corrosive wear. This work is aimed to evaluating the filler materials for hard facing of parts exposed to impact abrasive wear.

Abrasive wear is defined as a process of surface destruction due to hard material (abrasive) sliding across the softer one, which causes plastic deformation and leads to micro-destructions; most commonly present during grooving-cutting the soft materials. According to statements of many authors[3,5,8–10], abrasive wear takes about half of all other types of wear. The parts that are most exposed to abrasion are parts of agriculture machines, elements of transport devices, various parts of metallurgical plants, certain parts of machine tools, pats of railway equipment, driving shafts of hydraulic and gas turbines, drillers for drilling oil and water sources, parts of sand blasting equipment, etc. Based on the character of material interaction during abrasive wear, two basic wear models have been suggested[8–10]. The first model relates to interaction between the two bodies – the particle and the working surface. Typical example is wear of parts during land cultivation, mine extractions, etc. Another case is wear caused by particles, located between the two working surfaces, so generally this is the three bodies of interaction.

Experimental research confirmed that the metals resistance to abrasive wear depends on some of its mechanical properties[8]. That primarily relates to hardness, being one of indicators of behaviour of metals exposed to wear. The depth of foreign particle penetration into the metal directly depends on surface layers hardness. Graphical presentation of relative resistance to abrasive wear, shown in Fig. 2, came out as a result of a number of experiments[8]. One can notice the linear dependence of resistance to wear on hardness; for steels that have not been subjected to heat treatment this linearity is also applicable for relatively low hardness. For steels that have been subjected to heat treatment, the relation between the resistance to wear and hardness is shown by the dotted straight lines *2* in Fig. 2, which do not pass through the coordinate origin. This means that by choosing the heat treatment procedure, i.e. the surface hardness, different values of resistance to wear can be obtained. Alloying steel with the carbide forming elements has the same effects.

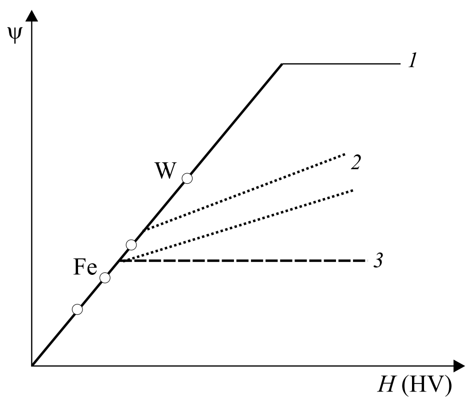


Fig. 2. Dependence of relative resistance to wear on hardness: *1* – pure metals, *2* – heat treated steels, *3* – strain hardened steels[8]

Strain hardened pure metals and steels reach a certain level of resistance to wear (line *3*), which then remains constant – independent of further increase of hardness. This effect can be explained by the fact that during the particle segregation they reach limiting hardening, which can generally occur by plastic deformation in cold conditions.

The mentioned results relate to those cases when hardness of abrasives is significantly higher than the one of tested materials. Majority of authors[3,4,8–10] agree that resistance to abrasive wear of alloys with the same hardness can be different, depending on chemical composition and structure of the alloy. In other words, this resistance depends not only on hardness, but also on shape, volume and distribution of structural phases. For now, there is no an unique opinion on the most favourable type of the steel structure from the aspect of resistance to abrasive wear. This is the consequence of diversity of abrasive wear and wide range of real working conditions[8–10].

Fig. 3. Appearance of the worn knife

The change of exploitation conditions causes change of intensity and mechanism of abrasive wear. That refers to abrasive properties, shape and size of particles, types of connections, specific pressure on contacting surfaces, relative sliding speeds, wear scare length, humidity and chemical aggression of the working environment, etc. In terms of all other exploitation characteristics, one should mention the impacts of the wear scare length, the specific pressure, relative humidity and aggressive matters from the working environment.

The wear of knives for terrain levelling has been tested in this study. Dominant forms of wear of these parts appear due to abrasion, adhesion and impact. The issue that was separately analysed was the damages of knife in conditions of abrasive wear during the contact of working surfaces with materials of mineral origin. The appearance of the worn knife is presented in Fig. 3.

SELECTION OF THE PROCEDURE, FILLER MATERIALS AND HARD FACING PARAMETERS

By spectrographic analysis of base metals it was found that knives were made of low-alloy steel for tempering (Table 1). After cutting one of the worn knives, the appropriate metallographic abrased samples were prepared for hardness measurements and analysis of the base metals microstructure. Maximum measured hardness was 488 HB and microstructure was estimated as an interphase tempered structure (mostly the sorbite one). This kind of microstructure is not highly resis-

Table 1. Chemical composition and comparative marks of C4830 (Ref. 11)

C4830	Chemical composition (%)							Reference to other standards
	C	Si	Mn	P	S	Cr	V	DIN
Standard	0.47–0.55	0.15–0.4	0.7–1.10	≤ 0.035	≤ 0.035	0.9–1.2	0.10–0.20	50CrV4

tant to abrasive wear, which causes relatively fast wear of these parts, especially when working in conditions of extremely abrasive impact. For this reason, it was decided to try to extend their operating life by hard facing.

The following electrodes were chosen for filler materials: E DUR 600, E Mn14 and E Mn17Cr13 (Ref. 11) (Table 2). According to manufacturer recommendations, the hard faced layers made by this electrode have higher resistance to wear, high toughness and can withstand high impact loads during exploitation. Those are the blades on bulldozer shanks, teeth on dredger scoops, blades on dredgers, conveyer elements exposed to intensive wear, parts of the crushers plants, blades and mixers for processing industry, etc.

Table 2. Mechanical properties and application of filler materials[11]

Electrode mark		Chemical composition (%)				Type of current	Hard faced parts hardness, HRC	Purpose
Fiprom Jesenice	DIN 8555/33	C	Mn	Cr	Mo			
E DUR 600	E 6–UM-60	0.5	–	7.5	–	= (+)	57 – 62	hard facing of parts exposed to extremely high abrasive wear when working in hot and cold conditions
E Mn14	E7-UM-200-KP	1.2	12.5	–	0.7	= (+)	220 HB – prior to forging 48 HRC – after forging	high resistance of hard faced parts to impacts and friction
E Mn17Cr13	–	0.6	16.5	13.5	–	= (+)	220 HB – prior to forging 48 HRC – after forging	high resistance of hard faced parts to impacts and cavitation, valid for intermediate layers application

The hard facing parameters, chosen according to recommendations from literature[3,5,9,12] are given in Table 3.

Table 3. Technological parameters of hard facing of model by MMA welding method[5]

Electrode marks		Electrode core diameter d_e (mm)	Weld current I (A)	Working voltage U (V)	Hard facing speed v_z (cm/s)	Input heat (energy) q_1 (J/cm)
Fiprom Jesenice	DIN 8555/33					
E DUR 600	E 6-UM-60	3.25	120	25	≈ 0.119	20168
E Mn14	E7-UM-200-KP	3.25	120	25	≈ 0.148	16218
E Mn17Cr13	–	3.25	130	25	≈ 0.152	17105

EXPERIMENTAL

Models tests. After the mentioned considerations, the experimental hard facing was applied, first on the selected models and after that on the real parts. Model tests were aimed at specifying the optimal technology for hard facing. A number of hard facings, with one or several passes, in conditions with and without pre-heating, have been performed on models (Fig. 4,*a*,*b*,*c*)[5]. Metallographic hard faced portions were prepared by grinding from the parts that were hard faced in such a way (Fig. 4*d*). Hardness was measured on these parts and the microstructure of the characteristic zones of surfaced portions estimated. The measured maximum values of hardness of the hard faced portions were dependent on type of material applied and on treatment of the hard faced portion: E DUR 600 (600 HV1), E Mn14 (240 HV1 – without forging and 520 HK – after forging) and E Mn17Cr13 (290 HV1 – without forging and 520 HK – after forging). Metallographic microstructures of the characteristic zones of the hard faced portions and the very hard faced layers were dependent on the filler material were estimated as: the martensite-carbide one with residual austenite (E DUR 600), dendrite-austenite one with extracted carbides along grain boundaries (E Mn14) and the sorbite one with prominent boundaries of austenite grains and carbides uniformly distributed (E Mn17Cr13)[1,2,4–7].

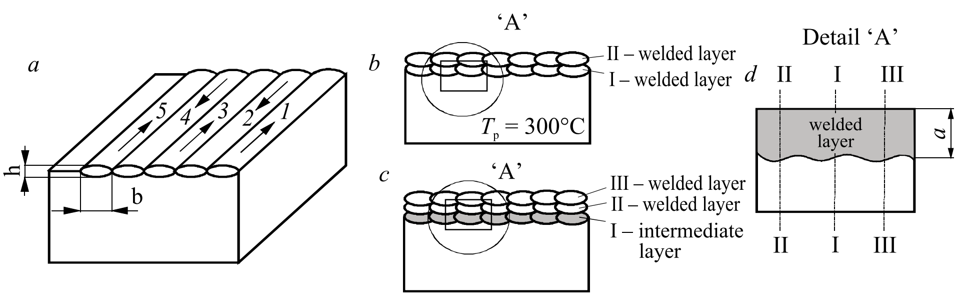


Fig. 4. Order of hard faced layers placement: *a* – 1st layer, *b* – 2nd layer, *c* – 3rd layer, *d* – metallographic block

Characteristic example of hardness distribution and the appearance of microstructures of certain zones of the two-layered hard faced portion with an intermediate layer are presented in Fig. 5 (Refs 5 and 6).

Tribological tests. Tribological tests were performed for contact block-disc, on tribometer TPD-93 at Faculty of Mechanical Engineering in Kragujevac. The goal of these tests was to determine resistance to wear of a coupling between the material and the hard faced layer. The prismatic-shaped blocks were prepared for tribological tests (6.5×15×10 mm) from the mentioned samples (three of them

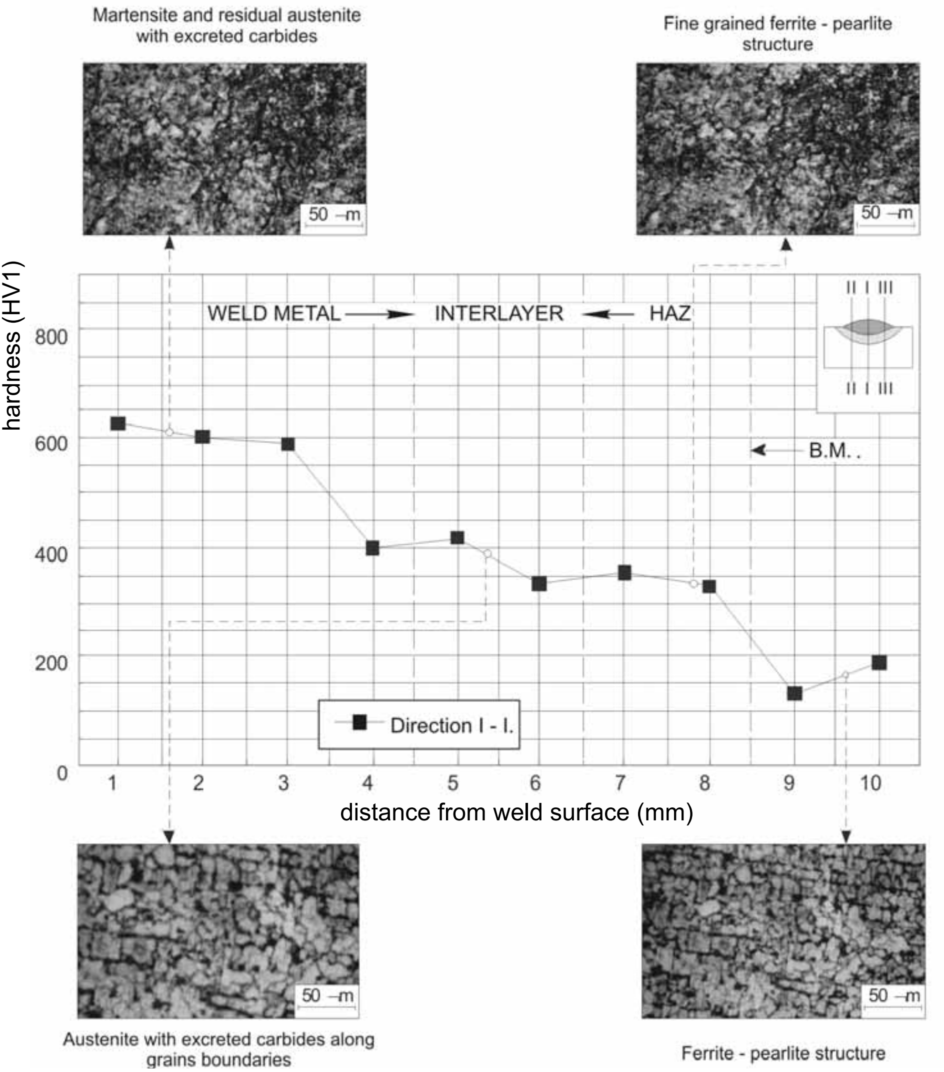


Fig. 5. Hardness distribution and microstructure of typical hard faced zones (weld metal-E DUR 600) (Ref. 5)

from the hard faced portion and two from the base metal). During the very test process the line contact 'block on disc' has been realised. External variables for a series of samples were: the contact force, sliding speed as well as the lubricating agent. Motor oil GLX 2 SAE 15-W-40 has been used for these tests[2,4–7].

Prior to tests, the topography of disc and block surfaces has been measured on a computer measuring system Talysarf 6, and then the contact was realised, with the adopted normal force F_N = 300 N and sliding speed v_{kl} = 1 m/s. During

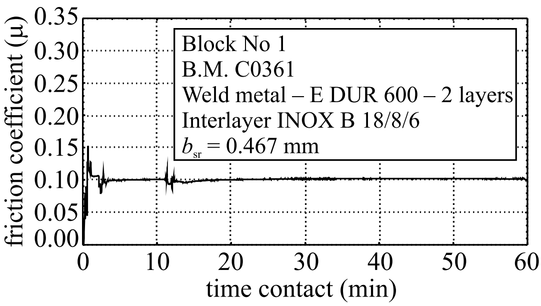


Fig. 6. Variation of friction coefficient during the contact period of 60 min (weld metal – E DUR 600)

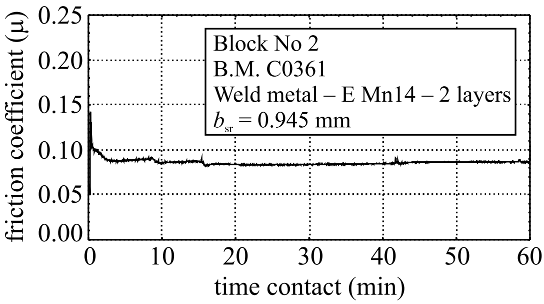


Fig. 7. Variation of friction coefficient during the contact period of 60 min (weld metal – E Mn14)

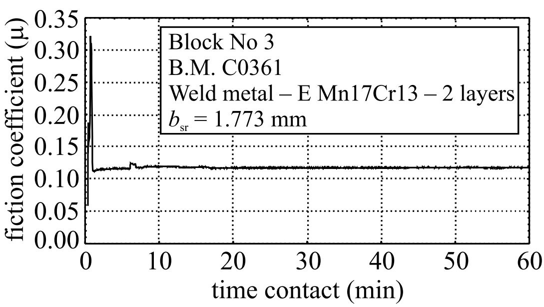


Fig. 8. Variation of friction coefficient during the contact period of 60 min (weld metal – E Mn17Cr13)

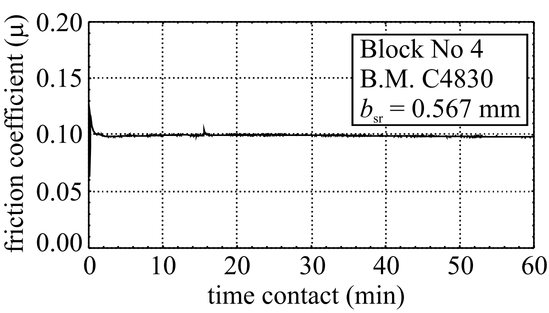
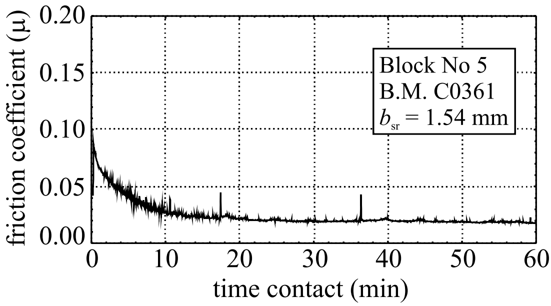
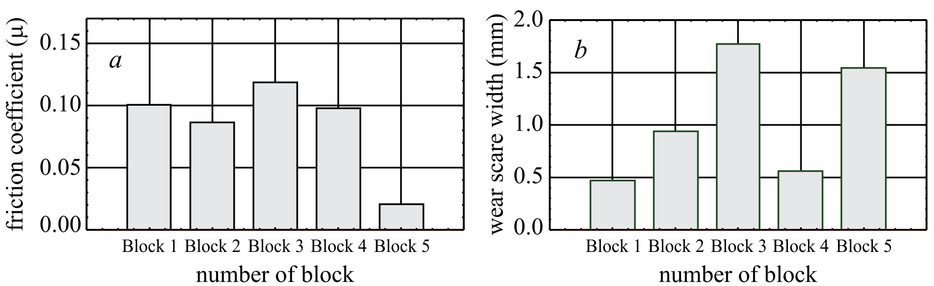


Fig. 9. Variation of friction coefficient during the contact period of 60 min (B.M.–C4830)

the contact, which lasted ≈ 60 min variation of friction coefficient was recorded (Figs 6–10), and after the contact was terminated, topography of disc and block surface was investigated, namely, the area of block wear scare was measured. In this way, the tribological characteristics of blocks were determined. The width of

Fig. 10. Variation of friction coefficient during the contact period of 60 min (B.M.–C0361)





Block 1–E DUR 600, Block 2–E Mn14, Block 3–E Mn17Cr13, Block 4–C4830, Block 5–C0361

Fig. 11. Histograms of mean values of friction coefficients (*a*), and wear scare width (*b*) after the 60 min contact

the wear scare was measured on an universal microscope UIM-21, amplification 50× (Ref. 5).

Graphical presentation of average values for the friction coefficient is given in Fig. 11*a* and average value of wear scare width on tested blocks is presented in Fig. 11*b* (Ref. 5).

Based on these tests, by measuring the wear scare width, one can notice that the hard faced layers have significantly higher resistance to wear than the non-hard faced ones. That particularly concerns those hard faced layers done by the E DUR 600 electrode and without pre-heating of basic materials. The last conclusion implies that the complex procedure of selecting technology for hard facing and filler materials is required for real technological conditions of civil engineering machines.

Hard facing of real parts. After hard facing of the test samples, the optimal defined technology was 'transferred' to real parts. It was decided to apply two-layer hard facing, taking into account the limitations of the base metal thickness, the height of the realised hard faced layer and the electrode cross-section. The parts that have been hard faced were the cutting edges of knives from the back and the front side of blade along its length. The width of the hard faced layer was about

Fig. 12.Appearance of the hard faced knife

Fig. 13. Appearance of a knife hard faced by grinding

25 mm (Fig. 12). The knives hard faced in such a way were finally sharpened by grinding and in this way prepared for operation (Fig. 13).

In order to perform real exploitation investigations, both new and regenerated knives were mounted on a rotor of a working machine Unimag (Fig. 14). Such mounted knives were put into operation on terrain and they were dismounted from time to time in order control the worn area. It was found that the consistency of knives hard faced in accordance with the proposed technology exceeds two or three times that of the non-hard faced knives, which can be explained primarily by microstructure of the hard faced portion which is more favourable for these working conditions[4–7].

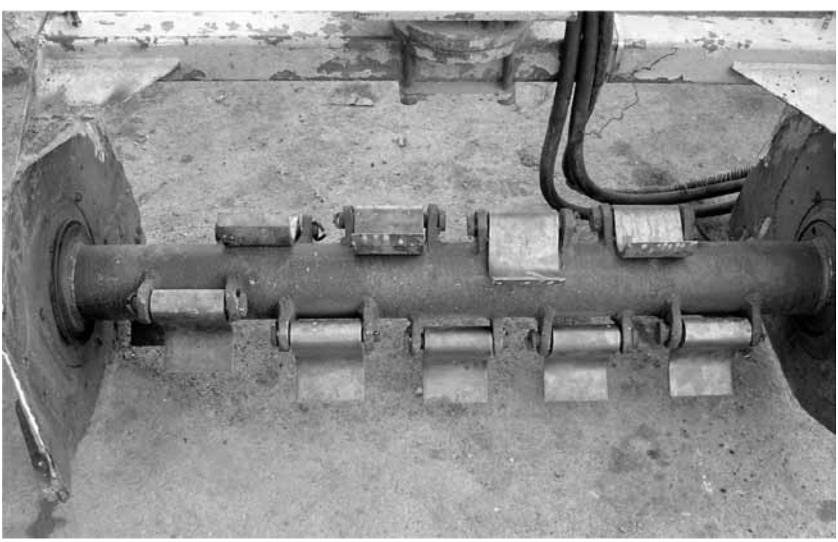


Fig. 14. Appearance of the machine for terrain leveling

CONCLUSIONS

Investigations conducted in this work point to a complex procedure of selecting the optimum technology of reparatory hard facing. That selection is also related to the complex procedure of checking the hard faced layer quality, which assumes metallographic, tribological and real parts investigations.

Based on the obtained results, it can be concluded that optimum combination was established of the hard facing reparatory technology and the filler metal, especially from the aspect of the wear resistance. It was confirmed that the working life of knives hard faced according to this technology exceeds the working life of the new knives several times. This is primarily explained by the realised microstructure of the hard faced layers, which is the most favourable for the presented working conditions. In this way are decreased both the replacement costs and the down times of the working machines, namely the favourable techno-economic effects of reparatory hard facing are realised.

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