ТВРДЕ ЛЕГУРЕ ЗА НАВАРИВАЊЕ ЗУБА БАГЕРА

HARDFACING ALLOYS FOR EXCAVATOR TEETH COATING

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Rezime: Капацитет ротобагера у значајној мери зависи од зуба за копање. Абразивно хабање резних зуба и резних ивица је типично када се копа песак, песковита глина и шљунак у уобичајеном каменом окружењу. Од посебног значаја је допринос правилне геометрије зубаца, њиховог положаја на корпу, а посебно њихове оштрине, коју временом губе. Временом, зуби постају тупи због абразивног хабања и мења се њихова геометрија. Отпор копања постаје већи, а самим тим и ефикасност ротобагера се смањује. Бели ливени гвожђе се издваја као основна легура која има отпорност на хабање, али има ниску жилавост и често долази до кртог лома под ударним оптерећењем. Мангански челик, иако има својство јачања, при копању у песку нема отпорност на хабање. Ово стање се може побољшати одабиром неког материјала отпорнијег на абразивно дејство. Зуби багера који отказују услед абразивног хабања могу се заштитити од абразивног хабања употребом тврдог облагања. Ове тврде легуре су представљене у овом раду.

Ključne reči: абразивно хабање, рото багер, зуби за ископ, тврдо наваривање

Abstract: The capacity of the rotor excavator depends to a significant extent on the backet teeth. Abrasive wear of cutting teeth and cutting edges is typical when digging sand, sandy clay and gravel in common rock environments. Of particular importance is the contribution of the correct geometry of the teeth, their position on the backet, and especially their sharpness, which they lose over time. Over time, teeth become blunt due to abrasive wear and their geometry changes. The digging resistance becomes greater, and therefore the efficiency of the rotor excavator decreases. White cast iron stands out as a base alloy that has wear resistance, but has very low toughness and often brittle fracture under impact loads. Manganese steel, although it has the property of deformation strengthening, has no wear resistance when digging in sand. This condition can be improved by choosing a material more resistant to abrasive action. Excavator teeth that fail due to abrasive wear can be protected from abrasive wear by the use of hardface coating. These hardfacing alloys are presented in this paper.

Key words: abrasive wear, roto excavator, bucket teeth, hardfacing alloys

1. INTRODUCTION

In the mining industry, the abrasion of the components is a common occurrence in machines that perform excavation, transport and processing of ores and minerals. Abrasion is often significant, leading to component failure (fig.1) that has a significant economic effect on the process [1].

Bucket wheel excavators are used for removing surface refuse at the open-pit lignite mines. Surface refuse is mainly sandy and causes strong abrasion. One of the most exposed components to abrasive wear are the excavator teeth. Materials usually employed to make these elements are white cast iron, steel castings and hard alloys [2] that do not always have enough anti-wear properties.

Figure 1: Blunt bucket teeth

The excavator bucket teeth commonly undergo the dynamic of wear processes on which material characteristics of bucket teeth should have good strength, good toughness and surface hardness. Toothed excavators work under very complex circumstances with loading and unloading periods, and consequently, the steel to make these components should be selected applying a balanced criterion between a relatively good toughness and enough hardness to withstand abrasive factors. Nevertheless, under load, the teeth coated with hardened materials may be subjected to cracks propagating through the thickness of the coating or interfacial decohesion (fig.2) which leads to failures.

Figure 2: Decohesion of welded layers

Weldability is an additional property to be considered in the selection of the base material in order to allow for easy coating application in those zones exposed to abrasion [3].

The different types of hard facing materials which are wear resistant can be employed on the substrate surface of excavator bucket teeth material. For example, steel alloys containing Cr, V and Nb could be welded onto the steel surface. This protection method may be an efficient solution for excavator bucket teeth wear protection.

Nowadays, an excavator tooth is considered successful in terms of abrasion resistance, if it is replaced after a week of excavation on the rotor excavator.

2. PRINCIPLE OF SUBSTRATE SELECTION AND COATING APPLICATION

In order to evaluate the teeth and study which hardfacing alloy is most suitable in terms of abrasion for a given excavation case, it is necessary to select a substrate and weld metal overlay alloy.

Non-hardfaced excavator teeths used for excavation are made of high tensile steels that can be hardened and tempered [4] and offer good combination of ductility and hardness combined with excellent resistance to shock. Usually, if these teeth are insufficient in terms of abrasion, they are used as a surfacing substrate. Such an example is shown in table 1.

Table 1: Chemical composition (wt.%) of high tensile steel 22Mn6 (w.nr.1.1160)

C [%]	Si [%]	Mn [%]	Ni [%]	Cr [%]	Mo [%]	S [%]	P [%]
0.15-0.25	0.10-0.35	1.30-1.70	0.40 max	0.25 max	-	0.06 max	0.06 max

Tool steels can also be considered as a substrate material because they have good wear resistance [5]. However, they have high hardness wich makes them sensitive to notches. This may lead to large carbides acting as crack initiators in the fatigue process. Fatigue occurs when the material is exposed to altering/pulsating load. Also, sharp corners and sharp edges in combination with high hardness may also act as places for crack initiation at fatigue loading. For this reason, the high tensile steel with proper heat treatment is more apropriate as excavator bucket teeth substrate.

The welding of hardfacing alloys on the substrate is usually performed in minimum two steps [6]: a first layer is directly applied over the metalic base, with high procent of dilution. Because of that this layer is not representative of the actual composition of the coating material. This is basic bonding interlayer. So, a second layer is applied over the first one avoiding the dilution problems especially with the carbon. It is the second layer that really resists abrasion (fig.3). If it is economic, 3 layers are applied, therefore the last two layers are both wear resistant.

The deposition is usually of stringer beads without any transverse oscillation of the electrode wich controls the dillution rate within limits.

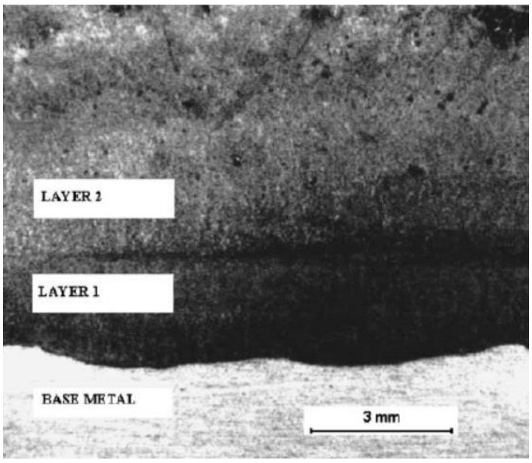

Figure 3: Application hardfacing alloy in two layers (interlayer and abrasion resistant layer)

3. MATERIALS USED FOR HARDFACING

Hardfacing consumables can be broadly classified into four groups [7]: iron-based, cobalt-based, nickel-based, and tungsten alloys. They are commercially available in different forms.

Iron-based alloys are most cost-effective group of hardfacing alloys and are mostly used for applications including abrasion, impact, and thermal fatigue resistance. They can be further divided into two subgroups: iron-based with less than 20% alloying elements (steel alloys) and iron-based with more than 20% alloying elements (usually, Cr cast iron alloys) [8].

Alloying elements for the iron-based hardfacing consumables include C, Mn, Cr, Mo, Cu, Ni, Co, V, Ti, W, Nb, and B. They form one or more of the microstructures, including austenite, ferrite, martensite, and carbides, depending on the constituent alloying elements. Iron-based hardfacing alloys with high content of Cr and Mo promote formation of hard carbide and boride phases, which enhances their abrasion resistance properties. These alloys can posses varios matrix structures, including austenitic, martensitic, perlitic, ferritic, or combination of these structures. Some iron-based alloys, like high cromium carbides, may have transferse surface cracks on hardfacing deposits. Dispite these cracks ('relief checks'), the deposits are suitable for many applications in the mining and earth engaging industries.

Table 2: Chemical composition (wt.%) of four hardfacing iron-based electrodes

hardfacing alloy	C [%]	Si [%]	Mn [%]	Nb [%]	Cr [%]	Mo [%]	S [%]	P [%]
OK 83.50 (H6.25Cr)	0.4	0.6	1.0	0.6	6.0	1.3	-	-
OK 84.78 (H33Cr)	4.5	0.8	1.6	-	33	-	-	-
OK 84.80 (H23Cr)	5.0	2.0	0.7	-	23	-	-	-
OK 83.65 (H2Cr)	0.75	0.4	0.6	-	2.0	-	0.03	0.03

Cobalt-based group of alloys are used for applications that require good wear, oxidation, corrosion, and heat resistance combined with high hot hardness. The cobalt–chromium–tungsten alloy is one of the most versatile and expensive alloys in hardfacing industries [9].

Nickel-based alloys are used mostly for applications that require wear and corrosion resistance at high temperatures [10].

Tungsten Alloys are used for extreme abrasion resistance applications. Tungsten carbide is one of the hardest materials in industrial use and is brittle. Tungsten carbide particles do not melt with the welding arc flames [11].

Based on previous research, high chromium iron-based alloys are the most common and economical alloys for abrasion resistance hardfacing, while nickel-based and cobalt-based alloys are suitable for wear and corrosion resistance hardfacing at high temperatures [12].

Fig.4 provides a general idea of different groups of consumables based on specific application requirements [13]. Standards and guidelines provided in relevant technical publications should also be considered for optimal consumable selection.

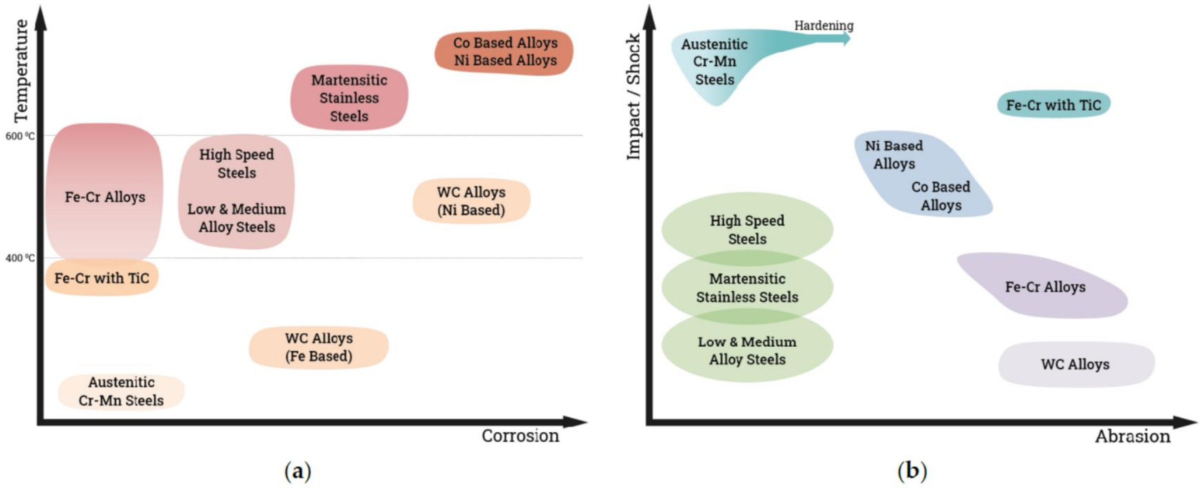

Figure 4: Hardfacing consumables for (a) corrosion and temperature, and (b) abrasion and impact resistance application

4. TESTING METHOD

The performance of hardfacing coating can be verified in two ways, in the laboratory or through field testing. In both methods, the mass loss parameter is used as an indicator of how successful the hard alloy is in terms of abrasion [14].

Laboratory tests used to evaluate the degree of abrasion are the methods: pin on dry disc with 62-65HRC, dry test of rotating vulcanized rubber disc with abrasive granule against the sample (fig.5), and test of rotating vulcanized rubber disc with abrasive granule submerged in water against the sample.

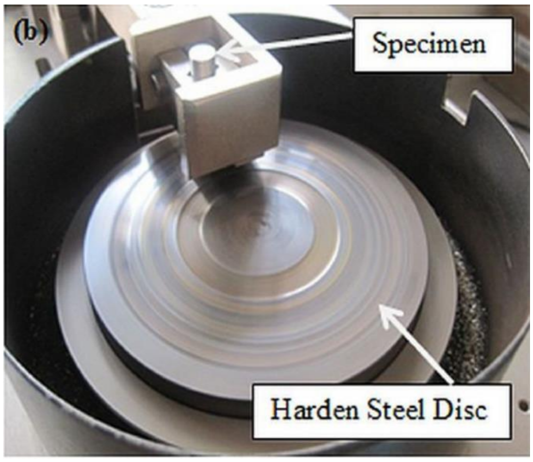

Figure 5: Test methods: speciment against rubber disk with abrasive material and pin on dry disk

A testing force is applied to the sample which, depending on the standard, can be from 30 to 200N. The linear testing velocity of the speciment is aproximatelly around 1 m/s.

Test speciment for the pin on disk method is cylindrical pin of diameter 8mm and length 30mm, hardfaced at their cross-section on one side and subsequently machined to specified sized.

Test samples for test method against vulcanized rubber and abrasive sand are prismatic blocks with dimensions 54x20mm, and 20-24mm thick. They are previosly coated with hardfacing alloy on one side.

Figure 6: Influence of tooth position on degree of abrasion in SRS 2000 rotor excavator

Unfortunatly, the only method that ensures a right evaluation of the component performance is to carry out real field test, wich is very tedous and expensive procedure. Field testing of the bucket teeth is complicated because the position of the teeth on the bucket has an important influence on wear. More testing should be carried out, where the teeth will be changed to different positions and on different baskets to minimize the influence of their position [15].

Other important inputs to the field test, not related to the alloy and welding are: hight of support of the arm, displacement of the support of the arm, number of buckets, angle of attack, avarage height of the excavation, etc.

Most importantly, no direct correlation between laboratory and field results is possible.

5. COMPARATIVE RESULTS

A test was made that included MMAW of different hardfacing alloys on a substrate of high tensile steel 22Mn6. Welding parametars used in the test are given in tab.3.

Table 3: Welding parameters used in the test

Parameters	OK 84.78	OK 84.80	OK 83.50	OK 83.65
Electrode diameter (mm)	3.2	3.2	3.2	3.2
Arc voltage (V)	26	24	18	25
Welding current (A)	128	118	119	125
Welding speed (mm/min)	90-110	90-110	90-110	90-110
Preheating for 1 hour (°C)	180°C	180°C	180°C	180°C
Deposition rate (kg/h)	2.4	2.2	2.1	2.4

The dilutation rate, during the process of hardfacing is minimized with three layered multi-pass welding. First layer is done with 2 mm thick layer, and then the surfacing of the second and third layers is done with simular electrodes.

The hardfaced teeth were fitted onto the excavator bucket in place of the standard (un-coated) teeth and field experiment was carried out. After the test, the teeth reveald varios amount of wear shown in tab.4. The wear damage starts from the end of the leading edge and moving iwards, towards the base of the tooth were very little or no wear can be observed. Because of the high abrasiveness of and Moss hardness of the sandy soil, the abrasion is relatively severe.

Table 4: Wear rates and wear rate indices (WRI)

Hardfacing electrode	Wear rate (gr/hr)	WRI
Un-coated tooth	1.900	17.27
OK 84.78 (33Cr)	0.110	15.87
OK 84.80 (23Cr)	0.250	7.60
OK 83.50 (6Cr)	0.933	2.03
OK 83.65 (2Cr)	1.436	1.32

5. CONCLUSION

Hardfaced tooth with 33Cr alloy shows almost no wear damage. This is due to the high abrasive wear resistance of the chromium carbides in the coated layers.

The tooth hardfaced with 23Cr alloy shows very little damage after field test. The substrate material was not exposed.

The 6Cr hardfaced after testing period showed some wear damage and wear of the underlying substrate.

The tooth with 2Cr coated layer, underwent severe wear damage. Hardfacing alloy with 2%Cr does not provide much aprasive wear resistance in comparison to other alloys.

The outcome of the field test shows that as the procent of chromium (Cr) composition increases in the hardfacing alloy, the abrasive wear resistance improves. Also, the alloy with 2% Cr cannot provide additiona wear resistance.

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