Application of hardfacing layers for renovation of functional surfaces exposed to abrasive wear

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Abstract: *The paper presents results of quality evaluation of hardfacing layers applied to functional parts of dredger teeth. Layers were made by arc welding methods MMAW and FCAW. High-alloy types of filler materials were used in the experiment. Their chemical composition allows the production of overlay layers with a high content of carbide particles. These particles ensure high resistance to abrasive wear of the layers. Excavator teeth were made by casting high-grade manganese steels Grade B-3 A 128 / A128M-93. In the experiments, the presence of surface defects of the weld deposit was assessed by visual inspection. The resistance of the hard-facing layers to the effects of abrasive wear was assessed using a Di-1 experimental apparatus and evaluated on the basis of weight loss.*
Keywords*: HARDFACING LAYERS, RENOVATION, WEAR, CLADDING*

1. Introduction

One of the heavy equipment mostly used in construction activities is excavator. This heavy equipment, which is best known as backhoe, is a digging machine used for various applications such as mine materials dredging, digging, levelling of the ground, river dredging and demolition. In excavator, the component used for digging and loading material is called excavator bucket [1]. Excavator bucket is generally equipped with protruding teeth on its edge, which is named bucket teeth. In the application of excavator, bucket teeth will have a direct contact to the ground so that it has a significant impact on the performance in a whole. Therefore, the material used for making the component of bucket teeth should have high endurance to wear and high power [1,2].

Bucket teeth is a component of excavator which is replaced periodically since it has relatively short usage time and is very crucial for ground penetration. One of the failures of bucket teeth is a wear in the part of bucket teeth itself (Fig. 1).

Bucket teeth are one of important parts of an excavator. Bucket teeth functions as material digger. It consists of some components, i.e., bucket, adaptor, and teeth [3,4].

As part of a comprehensive research, the quality of the welds was assessed by a hardness test, a microstructure test and an evaluation of abrasive wear. This paper presents the results of the assessment of abrasive wear.

Fig. 1 *Bucket excavator*

2. Experimental Materials and Methods

Worn teeth (see Fig. 2) made by casting from the material Grade B-3 A 128 / A128M-93, whose chemical composition and mechanical properties stated by the manufacturer are in Table 1.

Fig. 2 *Wearing excavator teeth*

Table 1: *Chemical composition and mechanical properties of steels Grade B-3 A 128 / A128M-93.*

Chemical composition in (% wt.)					
C	Mn	Si	P	S	Fe
1.22	13.48	0.911	0.042	0.004	Bal.
Mechanical properties					
Yield strength Rm [MPa]	Proof stress Rp0,2 [MPa]	Elongation [%]	Impact Strength [J]	Hardness [HB]	
896	396	40	140	224	

Before the renovation, each damaged component is assessed whether its extent of damage is technically and also economically profitable. Inspection of the component, mostly visual resp. ultrasound, surface and internal defects of components (eg. the presence of cracks) are detected, which could cause damage to the component under cyclic dynamic loading. Wear was analyzed by visual control for detecting damage to functional parts of the teeth (see Fig. 3).

Fig. 3 *Damage to the tooth clamping part*

Due to damage to tooth surfaces by corrosive fumes, soil and rock impurities, the tooth surface was blasted before hardfacing. (Fig.4).

Fig. 4 *Tooth after blasting*

Used filler material and cladding parameters

Manual arc welding(hardfacing) technologies were chosen for the restoration of worn parts of the teeth of earthmoving machines. MMAW method (manual arc welding - marked 111 N ISO 4063) and FCAW method (self-protection tubular wire welding, method marked 114 EN ISO 4063).

For MMAW welding, the additional material E 10-UM-60-CGP - DIN 8555 with a diameter of ø 3.2 mm was used. The chemical composition of the coated basic electrode is in Tab. 2. Clad is not heat treated.

Table 2: *Chemical composition filler material E 10-UM-60-CGP – DIN 8555*

Chemical composition in (% wt.)				
C	Mn	Si	Cr	Fe
3.5	0.8	0.8	27.5	Bal.

For hardfacing by the FCAW method, an additional material was used marked as MF10 – GF – 60 – CG - DIN 8555-83, the chemical composition (Tab. 3). It is a tubular electrode with a diameter of ø 1.6 mm with its own protection. Preheat is not necessary.

Table 3: *Chemical composition filler material MF10–GF–60–CG – DIN 8555-83*

Chemical composition in (% wt.)					
C	Mn	Si	Cr	Al	Fe
4.2	1.6	1.3	25.4	0.6	Bal.

Teeth made by forging from material - Grade B-3 A 128 / A128M-93 do not need to be preheated before hardfacing, as they are austenitic manganese steels.

The used parameters of tooth hardfacing are in Tab. 4. Clads were made with a CLOOS 303 MC pulse welding rectifier.

Table 4: *Used cladding parameters*

Cladding parameters					
Method	Filler material	Cladding current [A]	Cladding voltage [V]	Current type / polarity	Wire feed speed [m.min^{-1}]
111	E 10-UM-60-CGP	90-120	24-26	DC +	-
114	MF10-GF-60-CG	240-300	28-30	DC +	6

The surface of the clads was cleaned of slag by brushing with a steel brush to eliminate the possible negative effect of slag on the results in the assessment of abrasive wear.

Hardfacing layers were exposed to abrasive wear in a Di-1 device. The effect of loose abrasive on renovated areas was monitored by weight loss.

Mass wear was determined by the relationship.

Mass wear was determined by:

$$W_A = m_0 - m_i \,[g] \qquad (1)$$

m_0 – weight of sample before test [g],
m_i – weight of sample after i-th wear [g],

The elementary increase in mass wear Δ Wh was determined according to the relation:

$$\Delta W_h = W_{h/i-1/} - W_{hi} \,[g] \qquad (2)$$

$W_{h\,/i-1/}$ - weight of sample before i-th wear [g],

W_{hi} - weight of sample after i-th wear [g],

Experimentally, alumina with a grain size of dz = 0.9 mm was used as an abrasive for the wading test, which was replaced every 5,103 m.

Test parameters used:

- the speed of movement of the samples in Di-1 is 1,738 m.s^{-1},

- the test specimens were clamped vertically in the plate head,

- the samples examined were 10mm x 20mm x 90mm,

- immersion of the samples in free abrasive was 60 mm,

- the angle of inclination of the sample to the abrasive was 70º,

- number of samples with weld-on E 10-UM-60-CGP - 3pcs, / sample A /

- number of samples with weld MF10 – GF – 60 – CG - 3pcs, / sample B /

- sample wading distance [m] depending on wading time [min]: (60min = 6260m; 180min = 18780m; 300min = 31300m; 600min = 62600m)

3. Results and discussion

The clad deposits were evaluated by visual inspection (Fig. 5). In both renovated teeth, transverse cracks formed in the weld metal during cooling. Based on the literature [5], it is not necessary to crack these cracks. ledeburitic cast irons to remove and repair. They are permissible for this type of component.

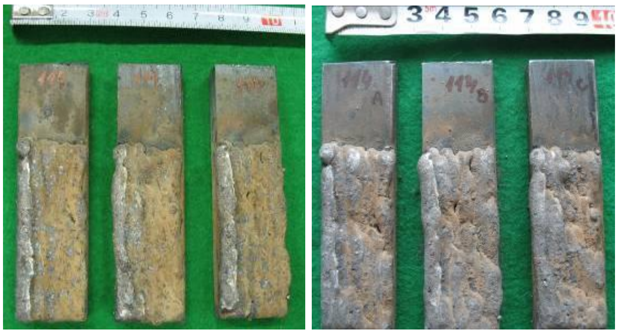
Fig. 5 *Tooth after cladding*

In FIG. 6 and FIG. 7 documents the test specimens before and after the wading test in bulk abrasive (brown corundum). Radvag XA 220 analytical balances were used to determine the weight of the samples before the experiment and to monitor the effect of the bulk abrasive on the individual samples during the experiment. The measurement results are recorded in (Tab. 5.).

a) b)

Fig. 6 *Samples A1 – A3*

a) before abrasive test b) after abrasive test



a) b)

Fig. 7 *Samples B1 – B3*

a) before abrasive test b) after abrasive test

Based on the weight losses recorded during the experiment, it can be stated that the hardfaced layers made of both types of additional materials were resistant to the action of the abrasive medium.

Table 5: *Weight differences of the examined samples (in [g])*

Sam.	Before wear [g]	60 [min]	180 [min]	300 [min]	600 [min]	W_A [g]
A1	197.3877	197.3797	197.3772	197.3748	197.3700	0.0177
A2	196.2786	196.2694	196.2668	196.2625	196.2571	0.0215
A3	195.1061	195.0992	195.0970	195.0937	195.0875	0.0186
B1	194.9027	194.8972	194.8950	194.8925	194.8875	0.0152
B2	196.0040	195.9984	195.9952	195.9924	195.9869	0.0171
B3	190.6379	190.6323	190.6296	190.6272	190.6216	0.0163

The effect of the abrasive on the hardfacing layers can be described as cleaning. All residues of slag and oxide coatings from the flux of filler materials were removed from the hardfaced beads.

Clads made with technology 114 (samples B) showed higher wear resistance due to WA mass wear, which was probably due to the small volume of slag and oxide compounds on the surface of the clads, due to the diameter of the tubular wire used (or less slag on the surface of caterpillars after hardfacing).) compared to the amount of slag on the surface of clads made by technology 111 (samples A), where the clads (made of additive material E 10-UM-60-CGP) were covered with a thicker layer of slag due to the diameter of the additive material and its thickness.

4. Conclusions

Paper presents part of the experiments carried out in evaluating the quality of hardfacing layers of functional surfaces of earthmoving machine components. In practice, these components are stressed by combined wear. It is mainly an abrasive-adhesive wear in combination with high pressures and corrosion. Hardfacing renovation is one of the effective and economically advantageous solutions for extending their service life. Due to the number of renovated components, e.g. dredger teeth are mainly manual welding (hardfacing) methods such as (MMAW - 111; FCAW - 114, 136 FCAW - S - 137 and GMAW - 131, 135, STN EN ISO 4063). The MMAW 111 method is suitable for repairing a small number of parts. Its disadvantage compared to other presented technologies is the limited length of additive material. A more effective way of surface renovation is hardfacing by FCAW methods, resp. GMAW, which enable continuous hardfacing of larger areas, e.g. walls of scoops. Based on the performed experimental tests, it can be stated that both additional materials E 10-UM-60-CGP - DIN 8555) and also MF10 – GF – 60 – CG - DIN 8555-83 are suitable for the renovation of functional - friction surfaces of earthmoving machines. The clad metal shows high resistance to abrasive wear due to a chemical composition which exhibits in microstructure shows carbides precipitated along austenite grain boundaries and sparsely dispersed in the grains

Acknowledgments: This work was supported by scientific grant agency of the Ministry of Education of the Slovak Republic VEGA No. 1/0497/20, KEGA 001STU-4/2019 and of the Slovak Research and Development Agency APVV-16-0359.

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