POSSIBILITIES TO USE WASTE MATERIALS FOR MANUFACTURING OF HIGH ABRASIVE WEAR RESISTANT SURFACED COATING

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Abstract

This research indicates the possibility to replace commercial materials and surfacing techniques by submerged arc welding under the flux and powder of industrial waste materials to obtain the chute with high abrasive wear resistance but for a lower price. Industrial waste of hard metal inserts, emery wheels, chips of case hardened stainless steels were grinded, granulated and blended. Prepared powder mixture served as alloying source increasing precipitation of hard particles during solidification of the weld. Abrasive wear resistance of coating six times exceeds wear resistance of industrial materials, while hardness exhibited very similar values. The results presented in this paper are based on micro-structural analysis of the surfaced and commercial coatings and are supported by analyses of the hardness and abrasive wear resistance. The complementary value of this research is a possibility to recycle industrial waste, which accumulates in huge quantities in the metals working industry.

Keywords: Abrasive wear; surfacing; industrial wear; waste materials

1. INTRODUCTION

The service life of worn machine components, machinery and their essential parts can be successfully prolonged by regular maintenance and well-timed repair of damaged surfaces. In previous works it has been demonstrated that with the systematic control of machinery performance the expenses of the whole manufacturing process can be considerably reduced [1]. A more efficient way is to manufacture less significant auxiliary industrial machinery, such as chutes, transporters and conveyors from low-cost, tough structural steel on which a layer of wear-resistant alloy has been surfaced [2].

The wear process initiates degradation of machinery performance and causes its transition from the 'fitness for use' to 'unfitness for use' state [3]. These processes are very unfavourable in the industry, because during exploitation first, some the minor damages occur on the surface of machinery, however, the final result of this process is an irreversible destruction of machinery. Wear problems can be easily solved by selecting suitable expensive high wear resistant grades for chutes, conveyors and transporters, but it will definitely increase expenses of industrial objects.

The wear problems in the industry represent a very important role in the exploitation and functionality of most products [4-7]. Wear of machine components and machinery: shafts, conveyors, tram wheels, chutes, rotor blades, transporters results in huge industrial faults, various types of damages and even severe accidents. There are numbers of different types of wear and each requires a different practical approach to wear reduction [8], therefore wear is one of the costliest problems within the industry [9]. Characteristic feature of abrasive wear process is the removal of material from the surface of components by a cutting action; in other words, the surface of a product is seriously damaged. This may be an intended and controlled process used in manufacturing of component (filing, grinding), or it may occur accidently during exploitation. However, it is possible to avoid or minimise this effect by changing either design or materials of the product whilst reducing percentage of industrial wear. Furthermore, it is important to understand the mechanism by which damage occurs in any particular case.

Sorting or processing equipment, transporters, chutes and conveyors in the extractive or heavy manufacturing industry undergo different types of wear, although due to the nature of the materials being sorted or transported (rocks, ores, stones, gravel of various fraction, etc.) is subjected mostly to abrasive or erosive wear [10]. Erosive wear is caused by ploughing of hard and sharp particles to machinery surface or edge, and removing material from that surface due to momentum effects. This type of wear is noticeable in components with high velocity flows. Particles repeatedly striking the surface may also cause denting and eventual fatigue of the surface. Taking an industrial rather than a research standpoint, it is worth mentioning one more type of wear that specifically occurs in the mining industry - thermal wear. The temperature of transported materials is one of the significant criteria of the damaging process of the conveyor. An increased degradation of machinery construction may be affected not even by flow of coarse materials but also due to a heat influence (temperature of transported roasted ore 120 °C) [11].

The first challenge of the presented work was to solve industrial wear problems of chute for scattering of gravel of different fraction in the most economically efficient way. In this research the possibility to replace industrial wear plate by surfaced coatings using submerged arc welding (SAW) technique and flux powder prepared from waste materials is presented. The main practical goal of this research was to find the right chemical composition of flux powder mixture in order to achieve high abrasive wear resistant surfaced coating of chute for the individual Lithuanian firm that was contacted.

2. EXPERIMENTAL PROCEDURE

EIPA (Eisen Palmen GmbH) wear plate (**Table 1**), manufactured using EIPA500 Filler Wire Plus process, was tested on abrasive wear tester and compared with plain carbon steel coatings.

Table 1 Typical applications and properties of EIPA wear plates [12]

Wear plates	Hardness, HRC	Carbides, %	Temperature resistance	Typical applications
EIPA480	60-62	60	Medium	Mixing tools, screws, bunker cladding, chutes, screens, excavator shovels, piping, cyclones
EIPA500	61-63	57		
EIPA480T	59-62	55	Good	Rotor blades for fans in the cement industry, wearing parts for dedusting systems, cladding, piping
EIPA550	63-65	62	Very good	Rotor blade, sinter crushers, bunker cladding, chutes, screens, piping, tilting tables in the iron and steel industry, also for high temperature load
EIPA590	58-60	52	Good	For corrosive of wearing components

The base material for surfacing was cheap plain carbon steel Ст3 (C 0.14-0.22 %; Si 0.12-0.13 %, Mn 0.4-0.65 %, S ≤ 0.05 %, P ≤ 0.04 %) provided as an 8 mm thick plate. The surfacing process was performed in a single pass using SAW technique with alloying waste materials mixture spread on the surface under the flux. The chemical composition of materials mixture and flux is presented in **Table 2**. The silicon carbide (SiC) is naturally used as deoxidizer in the welding flux. Deoxidizers react with oxygen at the welding temperature, and significantly decrease the quantity of oxides in the bead increasing quality of the weld [13]. Adding silicon into the flux improves the metal mass transfer coefficient, forms and modifies slag.

A single 2 mm diameter electrode low carbon wire (C < 0.1 %; Si < 0.03 %, Mn 0.35-0.6 %, Cr < 0.15 %, Ni < 0.3%) was used for the surfacing. The SAW was carried out with an automatic welding device (torch

MIG/MAG EN 500 78), with welding parameters: welding current 180-200 A, voltage 22-24 V, travel speed - 4 mm/s, and the wire feed rate - 7 mm/s. All the flux coating ingredients were sieved using mesh size of 2 mm for hard-metal, and 0.5 mm for other constituents of powder. Blended powder of waste materials was spread on the surface of the base metal and fused by metal arc. Additional flux was used to shield and to prevent the welding pool from the oxidation. The thickness of obtained coatings was 4 mm.

Table 2 Chemical composition of materials mixture and flux

Coating No	Composition of materials mixture wt. %				Flux composition, wt. %	
	Fe-70 % Mn	BK8	T15K6*	AISI 316	Glass	SiC
1			100		100	
2	20	80			50	50
3		80		20	50	50

The samples were etched using 3 % Nital solution; subsequent microstructural analysis was applying by the conventional metallographic techniques: light microscope Carl Zeis Axio Scope A1 with the magnification of 100-350.

Mechanical behaviour of coatings and commercial EIPA500 wear plate was assessed in the terms of hardness and abrasive wear properties. Hardness and microhardness measurements of tested coatings were conducted on the coating immediately after surfacing using Rockwell tester TK-2 at the load of 1470 N and Vickers tester UHL VMHT at the load of 0.49 N with diamond indenters.

The abrasive wear tests [2] were performed and results of all the obtained coatings were compared with conventional standard high speed steel P6M5 (C 0.80-0.88 %, Cr 3.80-4.40 %, W 5.50-6.50 %, V 1.70-2.10 %, Mo 5.00-5.50 %) by weight loss (with an accuracy of ± 0.1 mg) [11].

Abrasive wear results were achieved by sliding [14] of 120 mm^2 cross sectional test pieces (6 × 20 mm) on the electrocorundum/white aluminium oxide 15A8HM which simulates the actual practical conditions of chute wear at a controlled speed and constant load 5 N, and observing the rate at which metal is removed after 10 min of sliding (sliding distance 5 m).

3. RESULTS AND DISCUSSION

After the completion of surfacing procedures, obtained coatings were examined under an optical microscope. No cracks and porosity in the coatings were observed. The microstructure of the commercial wear plate consisted of huge amount of carbides with microhardness of 11500 MPa (**Figure 1**). The coarse hard metal powder (average size Ø 2 mm) presented in the mixture did not dissolve in the melt during welding, therefore, surfaced coatings indicated even higher values of microhardness than EIPA500 wear plate (from 12400-16200 MPa), and showed better results of Rockwell hardness after surfacing (**Figure 2**).

Comparing results of previous studies, the following statement can be confirmed: as the hardness increases, the abrasive wear resistance also increases [10,15-18]. However, excessive hardness should be avoided so as not to cause industrial wear problems (crumbling) in exploitation, or in failure caused by lack of impact strength.

Based on the analysis of hardness values (**Figure 2**), it was obvious that Coating No 1 had better results because of the chemical composition of the surfaced layer: presence of titanium, tungsten, cobalt and carbon in the alloying flux. The microstructure of this coating indicated existence of martensite, carbides and partially fused hard metal particles with microhardness of 16200 MPa.

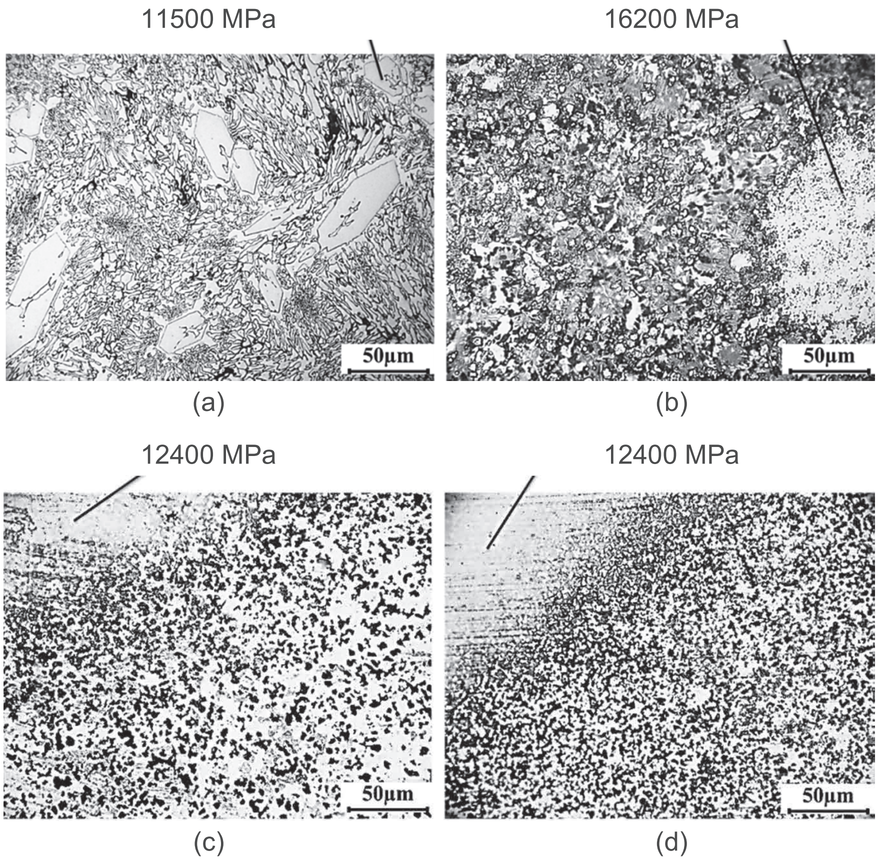

Figure 1 Micrographs of tested coatings: a) EIPA500; b) Coating No 1; c) Coating No 2; d) Coating No 3

Micrographs of Coatings No 2 and No 3 (**Figure 1 c, d**) showed hard metal particles with microhardness of 12400 MPa. The retained austenite remained in the microstructure of these coatings, as natural phenomenon of presence of alloying elements which stabilize the austenite (expands γ-field) (No 2 - Mn; No 3 - Cr and Ni).

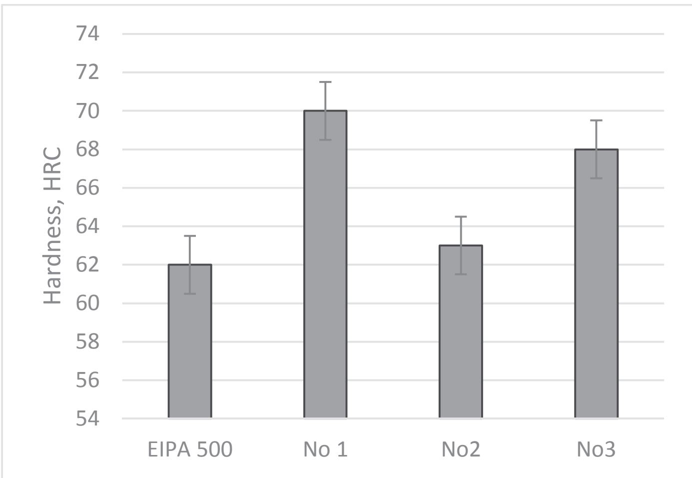

Figure 2 Hardness of coatings

The greatest wear was observed with conventional high speed steel grade (**Figure 3**). The commercial EIPA500 wear plate had more than twice higher resistance to abrasive wear than previously mentioned steel grade: high quantity of carbides in this plate (57 %) allowed achieving these results. Finally, coatings obtained using SAW technique and waste materials mixture spread on the surface of plain carbon steel and fused under the flux, confirmed the anticipation of this survey and exhibited minimal abrasive wear. Furthermore, it is important to mention that the weight loss of the coating obtained using T15K6 hard metal powder was six times lower than the weight loss of EIPA500 wear plate.

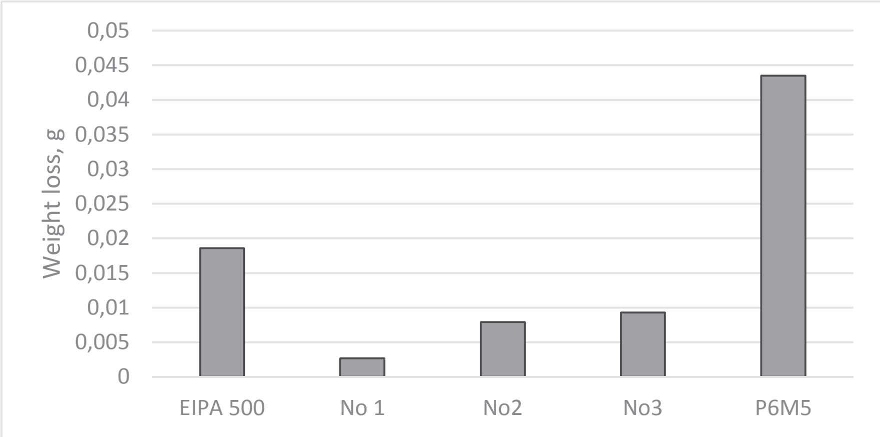

Figure 3 Wear resistance of coatings and standard steel grade

4. CONCLUSION

Based on the results presented above, it can be concluded that the coatings obtained using the powder of waste materials (crushed hard metal inserts, chips of case hardened stainless steel, ferromanganese) covered with flux and SAW technique, can replace commercial EIPA500 wear plate for chute manufacturing and application in the industrial plant. Abrasive wear resistance of coating 6 times exceeded wear resistance of commercial industrial material and showed better wear behaviour when compared with standard steel grade. Moreover, an important practical application based on the research results is the possibility to use manufacturing industrial waste for the preparation of alloying materials mixture: firstly, minimising expenses of manufacturers of auxiliary machinery and secondly, solving the environmental pollution problems by recycling the industrial waste.

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