Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 37 ISSUE 2 December 2009

Comparison of abrasion resistance of selected constructional materials

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Received 12.09.2009; published in revised form 01.12.2009

Properties

ABSTRACT

Purpose: The aim of this work was to define and compare abrasion resistance of selected constructional materials widely used in the industry. Chromium cast iron wear resistant plates were compared with typically used wear resistant plates made from Hardox 400 steel and two different, wear resistant, materials cladded by welding technologies.

Design/methodology/approach: The tests of abrasive wear were conducted in accordance to procedure "A" of standard ASTM G 65 - Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus.

Findings: Abrasion resistance tests shows that the best properties among investigated samples has chromium cast iron plate. Abrasion wear resistance of this plate is two times higher than wear resistance of layer made by welding technologies and nine times higher than typical Hardox 400 steel plate.

Practical implications: Application, of abrasion resistant materials, results in significant material and economy savings, due to wear and costs reduction (decreasing stop times needed to change worn parts for a new one).

Originality/value: Wear plates are modern solution in regeneration of worn machines parts and also for producing a new parts which connect high wear and abrasion resistance with costs reduction.

Keywords: Wear plates; Abrasion resistance; Cladding; Welding technologies

Reference to this paper should be given in the following way:
M. Adamiak, J. Górka, T. Kik, Comparison of abrasion resistance of selected constructional materials, Journal of Achievements in Materials and Manufacturing Engineering 37/2 (2009) 375-380.

1. Introduction

The present scientific, engineering and economic problem is the wear of mechanical parts equipment caused by decrease of working surfaces properties. The wear mechanisms are very complex, because of interlinked factors, which intensity of interaction depends on the conditions type of environment, in which the mechanical parts are used but also on the type and parameters of the work. Based on the analysis of parameters responsible for the wear of mechanical parts, about 50% (of the parts) works in abrasive wear, 15% - adhesive wear, 8% - erosion, 8% - fretting, 5% - wear is due to corrosion and about 14% is just a combination of abrasive, erosive and corrosive wear [6]. The variety of the types of wear leads towards the use of specialized welding materials in order to ensure the highest possible wear resistance of the surface layers, in working conditions. One of those typical material used in industries are wear resistant plates. The type of the wear resistant plate and its properties are the factors influencing on individual parts in the mechanical equipment durability. This make contribution to get significant material and economical savings. Wear resistant plates are modern solution in regeneration of worn machines parts and also for producing a new parts which connect high wear and erosion resistance with costs reduction. Main economic advantage of these plates is regeneration possibility of big worn machines surfaces and equipment when a construction mass is not the most important working parameter. In the wear resistant plates production, most common process solution is a cladding using high alloy filler materials. By proper choice of structure and surface layer chemical composition it is possible to extend the effective life-time of wear resistant plates and the result the life-time of mechanical equipment [2, 3, 11].

Wear resistant plates can be cut on different shapes and formed by bending or rolling. Then they are fixed to the regenerated parts by continuous or discontinuous fillet welds depending on load type for taken wear resistant plate. Necessity to obtain an uniform layers with a thickness of about 50÷80 [%] of base material, impose that processes have to be mechanized [6, 9, 15].

During cladding processes stresses can be formed as a result of a volume changes of cool down metal. Because of differences of expansion coefficients between the deposited and base material cracks mesh forms which do not decrease properties of deposit. Widest practical application of wear resistant plates is in power, extractive and cement industries. These plates works in intensive scratching and erosion wear conditions. Thanks to using them, we can get significant material and economy savings (resulted from costs reduction, decreasing stop times needed to change worn parts for a new one) [1-14].

2. Materials and experimental

The aim of this work was to define wear resistance of chosen constructional materials widely used in industry. The newest chromium cast iron wear resistant plate was compared with typicaly used Hardox400 steel and two different wear resistant layers cladded by welding technologies, Table 1.

Chromium cast iron wear resistant plate

Chromium cast iron wear resistant materials were produced as a plates (plain, chamfered – on special requests), bars, buttons (in dome shape, for protection of bolt heads). Chromium cast iron wear plate is a layer material, made from Cr-Mo white cast iron metallurgically bonded with mild constructional steel base material. Chemical composition and properties of chromium cast iron wear plate are presented in Table 2.

Table 1.
Materials used in metal-mineral wear resistance tests

Specimen designation used in researches	tested material description
Chromium cast iron	Wear resistant plate - chromium cast iron bonded with mild steel
ABRADUR	Wear resistant layer cladded by MMA technology (ABRADUR 64 electrode)
WC	Wear resistant layer cladded by GMA technology (cermets wire with tungsten carbides amount about 50%)
HARDOX	HARDOX 400 wear resistant plate

Table 2.
The chemical composition and mechanical properties of chromium cast iron wear plate

Chemical composition, wt- %					
C	Cr	Mo	Mn	Si	Ni
2.8-3.6	14.0-18.0	2.3-3.5	0.5-1.5	1.0 max.	5.0 max.
Mechanical properties					
Hardness, HB/HRC		Heat resistance, [°C]		High-temperature creep resistance, [°C]	
700/64		540		595	

High wear resistance of chromium cast iron plates is a result of surface layer structure. Special heat treatment of cast iron provides to obtain a special microstructure composed from Cr-Mo carbides in almost fully martensitic matrix. The base material of these plates is mild constructional steel. White cast iron surface layer is soldered to base using soft filler material based on copper because of good stresses transfer. Important advantage of these plates is also amount of wear resistant material in proportion to the base one (about 3:1).

Wear resistant surface layer cladded by MMA ABRADUR 64 coated electrode

Wear resistance layer, was made by manual cladding of S335JR steel plate with E 10-UM-65-GR coated electrode (DIN 8555) with 5.0 mm diameter and cladded with a current 270 [A]. MMA cladding process was leaded with buffer layer cladded with ERWS 19-12-3 L 3,25 mm diameter coated electrode with a 110 [A] current. Buffer layer assure good stresses transfer between soft base material and hard layer. Chemical composition and properties of ABRADUR 64 coated electrode was shown in Table 3.

Table 3.
Chemical composition and properties of ABRADUR layers

Chemical composition, wt- %			Hardness
C	Cr	Nb	HRC
7.0	24.0	7.0	64

Wear resistant surface layer cladded by GMA with cermet wire

Wear resistance layer was made by mechanized GMA cladding of 15HM steel with cermet wire. Chemical composition and properties of WC plate was shown in Table 4.

Table 4.
Chemical composition and hardness of GMA cladded layers with cermet wire

Chemical composition, wt- %								Hardness
Fe	Si	Mn	Cr	Mo	Nb	W	B	HRC
<5.0	<2.0	<5.0	<20.0	<10.0	<10.0	<10.0	<5.0	71

HARDOX 400 steel plate

Hardox 400 is a wear resistant steel from high quality steels group. This group comes from low-alloyed toughened steels and is a new generation of machinable and weldable constructional steels. Hardox steels are used in applications where a good wear resistance is needed with wide loads parameters, for example in fedding devices, crushing mills, sieves, shaft pins, skip hoist elements, conveyors, blades, gear and sprocket wheels, self-dumping cars elements, loading machines, trucks, front casting bulldozers, buckets and worm transporters.

All Hardox steel types are delivered in hardened state (water quenching) and in case of applicable hardness needed they can be also tempered. These steels can be bended, cut and machined treated by drilling, milling and turning in strictly specified conditions. Hardox steel plates can by machined treated with using high-speed steel (HSS) or sintered carbides tools. Chemical composition and mechanical properties of Hardox 400 steel were shown in Table 5.

Table 5.
Chemical composition and properties of HARDOX 400 steel plate

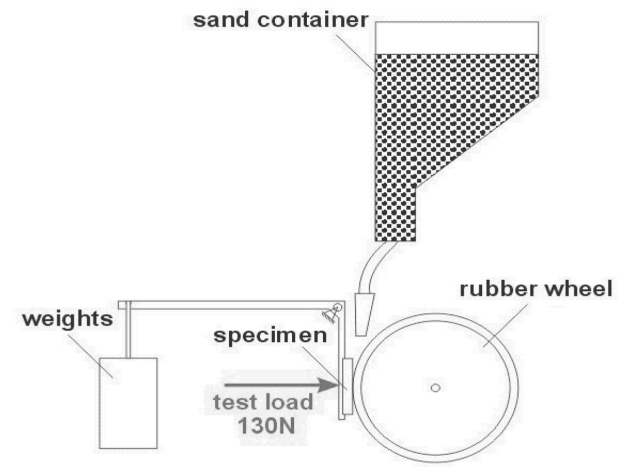
Chemical composition, wt- %					
C	Mn	Mo	Cr	Si	Ni
0.14-0.32	1.60	0.25-0.60	0.30-1.40	0.70	0.25-1.50

Mechanical properties		
Hardness, HB	Tensile strength, [MPa]	Yield point, [MPa]
370-430	1250	1000

2.1. Metal-mineral wear resistance tests according to ASTM G65 - 00 standard

The tests of abrasive wear type metal-ceramic were conducted in accordance to standard ASTM G 65 - Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus. Procedure "A" of the ASTM G65 standard was chosen Fig.1. Quartz Ottawa sand was used for these tests Fig.2. Sand had tightly limited particle size in U.S. sieve size -50 to +70 (-300 to +212 microns) and moisture content under 0.5% weight. The rate of sand flow through the special nozzle, in the shape of thin layer between the test piece and a hard rubber wheel 229 [mm] diameter, was adjusted at the rate 300-400 [g/min]. The force applied pressing the test coupon against the wheel was TL= 130 [N] (test load - TL) and 6000 revolutions of the rubber wheel at 200 [rpm]. The 25 [mm] wide and 75 [mm] length abrasive wear resistance test specimens were cut from wear of the deposit were surface ground was smooth. Then the tested specimens were weighed with accuracy 0.0001 [g] as required in ASTM G65 between and after the test. Mass loss was reported directly and relatively in comparison to the mass loss with the reference to HARDOX 400 steel plate, Figs. 3 and 4, Table 6.

$$\text{Volume loss, } [mm^3] = \text{mass loss } [g] : \text{density } [g/cm^3] \times 1000 \qquad (1)$$



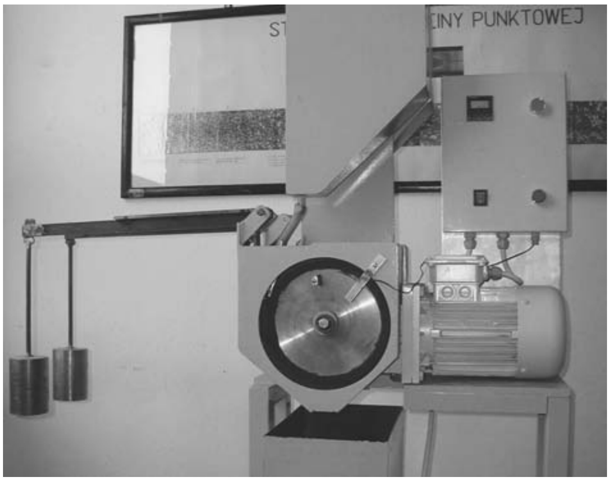


Fig. 1. Metal-mineral wear resistance test stand – according to ASTM G65-00 standard

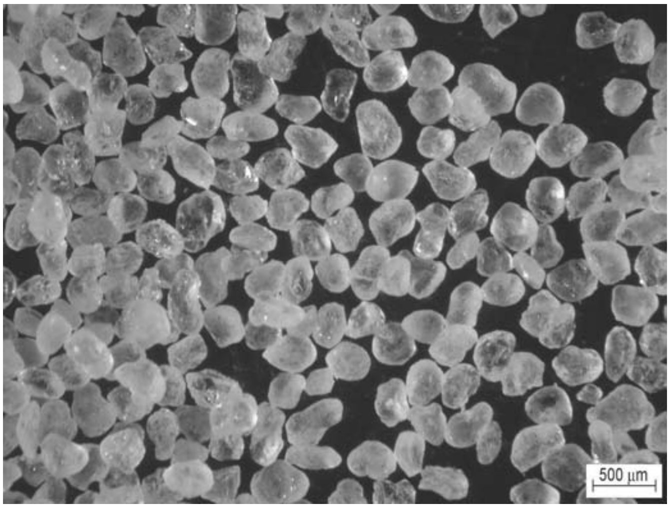


Fig. 2. Wear particles - Ottawa sand

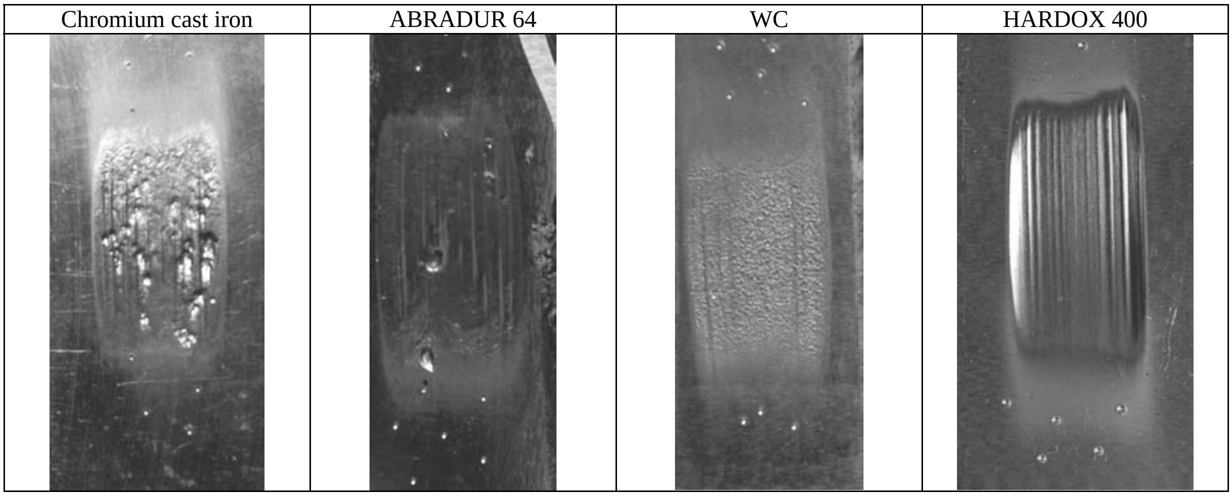


Fig. 3. Specimens views after wear resistance tests

Table 3.
Results of low-stress abrasive wear resistance to metal-ceramic scratching by Ottawa quartz sand

Specimen designation/ density, [g/cm^3]	Spec. number	Mass before test [g]	Mass after test [g]	Mass loss [g]	Average mass loss [g]	Average volume loss [mm^3]	Relative* abrasive wear resistance
Chromium cast iron / 7.5961	1	173.7335	173.6133	0.1202	0.11635	15.3170	1.00
	2	173.6714	173.5589	0.1125			
ABRADUR 64 / 7.1544	1	136.2893	136.0933	0.1960	0.19825	27.7102	1.81
	2	139.6675	139.4670	0.2005			
WC / 10.6808	1	179.6026	179.3009	0.3017	0.32360	30.2974	1.98
	2	181.8750	181.5295	0.3455			
HARDOX 400 / 7.7115	1	62.1029	61.0320	1.0709	1.0691	138.8705	9.07
	2	62.5591	61.4918	1.0673			

* - relative abrasive wear resistance to chromium cast iron

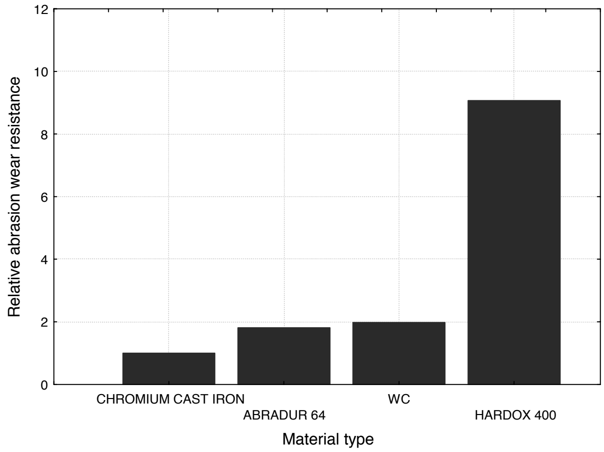


Fig. 4. Relative wear resistance of tested materials

2.2. Metallographic examinations

Microscopic examinations allows to define structure of tested materials. Examinations do not indicate internal defects, in the layers made with welding technologies, and material defects in Hardox 400 plate and chromium cast iron plate (Figs. 5 to 9).

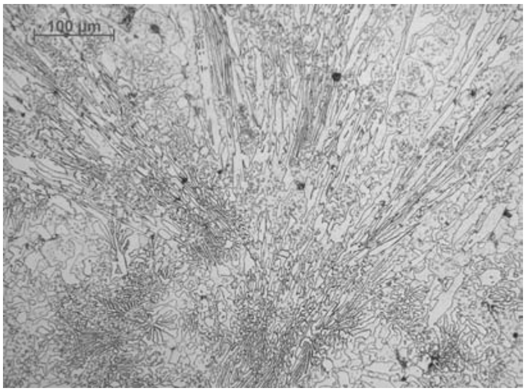


Fig. 5. Microstructure of chromium cast iron plate

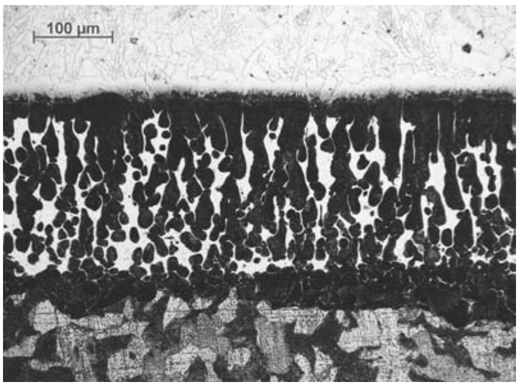


Fig. 6. Microstructure of bond in chromium cast iron plate

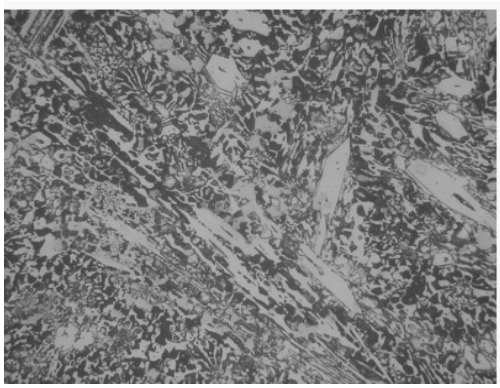


Fig. 7. Microstructure of ABRADUR 64 plate

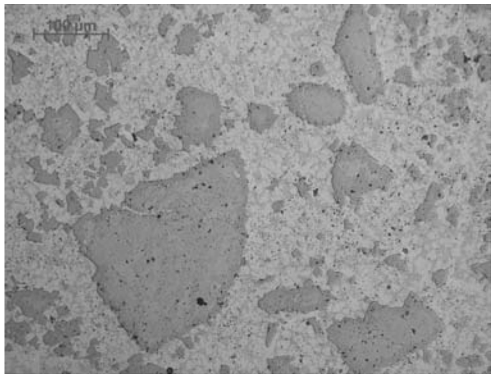


Fig. 8. Microstructure of WC plate

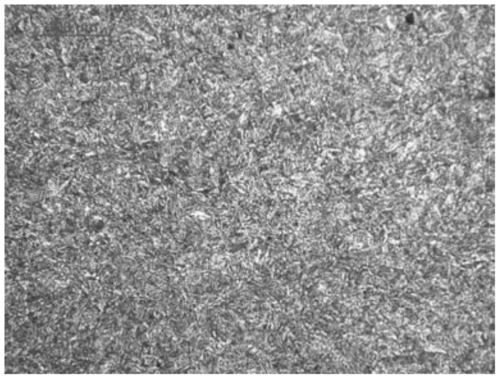


Fig. 9. Microstructure of HARDOX 400 plate

2.3. Hardness tests

To define the hardness of tested materials, Rockwell hardness was measured in 5 places on plate face using C scale. Also Vickers hardness (testing load – 1000 [g]) was measured in 4 places on plate cross-section, Fig. 10 and 11, Table 7.

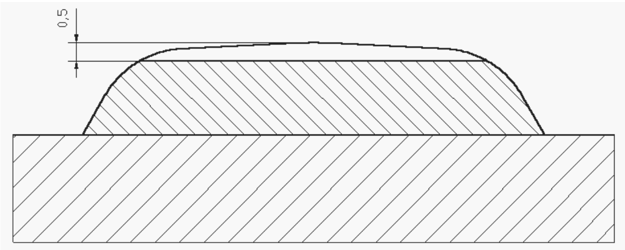


Fig. 10. Face preparation method to hardness measurements

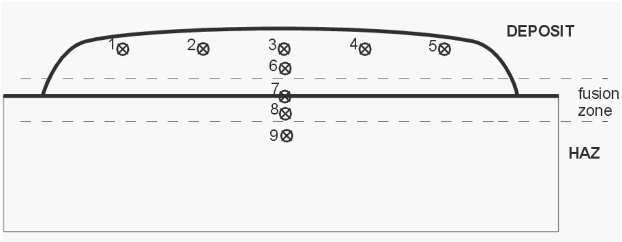


Fig. 11. Measurement points distribution in hardness tests

Table 7.
Hardness tests results of tested layers on face and cross-section

Material	Rockwell hardness, HRC					Vickers hardness HV 1			
	1	2	3	4	5	6	7	8	9
Chromium cast iron	60	58	61	61	62	663	154	148	106
ABRADUR 64	57	56	57	54	52	556	174	304	290
WC	54	50	48	51	49	563	486	180	167
HARDOX 400	41	40	39	40	39	380	378	377	378

3. Summary

Metallographic examinations do not indicate any of internal or external defects on layers made by welding technologies. Chromium cast iron wear resistant plate has chromium cast iron structure with Cr-Mo carbides precipitations. As a connection of this layer with base material soft weld metal based on copper matrix was used. This type of buffer layer is perfect to transfer stresses between different layers.

ABRADUR 64 layer has hypereutectic microstructure with precipitations of niobium and chromium carbides. Using stainless steel buffer layer provides to avoids cracks propagating to base the material. Surface layer was made by GMA cermets wire cladding technology has nickel matrix with a lot of tungsten carbides precipitations.

It was observed (as a result of thermal cycle influence) tungsten carbides were partially dissolved. This dissolution can significantly decrease wear resistance of tested wear plates. Hardox 400 steel plate has tempered martensite structure.

Hardness measurements of tested layers indicates that all tested materials has hardness close to value, guaranteed by manufacturers. Highest surface hardness has chromium cast iron wear plate - max. 61 HRC. Measurements on the cross-section indicates that hardness of this plate is equal through whole thickness.

This uniform distribution of hardness on tested surface and cross-section was possible to obtain thanks to volume quenching of chromium cast iron.

Wear resistance tests according to ASTM G 65 - 00 standards shows, that the best properties has Chromium cast iron wear plate. Wear resistance of this plate is 2 times higher than wear resistance of layer made by welding technologies and 9 times higher than typical Hardox 400 steel plate.

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