APPLICATION OF OVERLAY MATERIALS FOR REDUCING ABRASIVE WEAR

Jiri Cieslar[1], Milan Brozek[2]
[1]ATG s.r.o. (Advanced Technical Group), Czech Republic;
[2]Czech University of Life Sciences Prague
j.ceslar@seznam.cz, brozek@tf.czu.cz

Abstract. Nowadays, the quickly developed sophisticated industrial sectors have made considerable demands on the quality of applicable parts. The current lifecycle of the machine is determined by a combination of the quality of the used parts and by new materials, which will better satisfy the requirements of various operational conditions. Overall lifecycle of the structure is mainly determined by theapplied materials, eventually by their replacement, which brings better values to their users. The key benefit of overlay welding is relatively high increase in resistance to abrasive wear. The results of experimental measurements have confirmed the hypothesis of increased resistance to abrasive wear with increasing the quality of the applied overlay. The experimental evaluation of material resistance to abrasive wear was performed by the equipment with fixed grinding particles and rotational motion. Abrasive wear was conducted in accordance with well-respected Czech national standard CSN 01 5084. A similar standard is ASTM G 132. For comparison, measurement of overall macro hardness was also conducted by the HV method. The essential influence on mechanical properties of materials has their metallography structure. Therefore, this paper also includes description of metallography of the applied overlaid materials. All overlaid materials are compared with reference standard made of steel S235JR.

Keywords: overlay materials, abrasive wear, hardness, metallography.

Introduction

This article evaluates the effect of overlay materials for reducing abrasive wear. This contribution is described by an experimental assessment of overlay welding technology in terms of resistance to abrasive wear, hardness and metallographic structure. There is a common industrial practice to replace the current non-conforming parts by new components with better durability at either mechanical engineering or agricultural sectors. The five different kinds of overlay materials were tested, compared and their wear resistance determined. Abrasive wear is characterized by separation and transfer of material particles while the sample is catted or grooved by hard particles. The cutting particles are likely to be either free or bounded by suitable means.

Modern mechanical equipment has to fulfill the constantly increasing demands for low maintenance, high durability and, in particular, low failure rates [1-4]. The critical step, while the assembly is assessed for its wear resistance, is to determine, which particular components will be worn out more, the wear mechanism and wear rate. The knowledge of wear mechanism will help select an appropriate material or combination of materials to be applied in the most effective way.

Abrasive wear is supposed to be reduced by selecting the right material. As it was described earlier [5-7], in both the engineering and agricultural industries, the inadequate engine parts are now being replaced with new components. To make the right decision about the component replacement, it is vital to have a complete picture of the parameters about how the specific materials behave in such an environment [8; 9]. In addition, the appropriate choice of materials for a particular purpose depends on many different factors, one of the most important is the cost of the materials and initial investment for their production.

In some cases, the fact is that the designers make up their minds of a preferred material without proper knowledge of materials and their combinations. If the proper material is chosen, abrasive wear will be decreased significantly [1-4; 10]. Likewise, it is possible to apply new material to a damaged surface in one of the conventional ways, such as by welding [3; 11].

The presence of overlay materials is the principal carrier of material and mechanical properties. Experimental measurements describe the results of the test measurement of relative hardness according to the standard of the Vickers hardness test HV 30, the relative resistance to abrasive wear and the study of metallographic structure. As described [4; 12] in their work, a study of relative resistance to abrasive wear exists in various types of materials in different environments [1; 5-7; 10; 13]. Resistant overlay materials with better properties can be used for components used in hard-facing, shafts, racks and pinions, links and pins, valve seats of cast steel, mixer arms, feed gear, knives, loading buckets and track rollers [2; 7; 12]. In their mechanical properties metal overlay materials are better than many other types of materials.

Materials and methods

Preparation and production of five samples for the experiments were carried out in collaboration with the Institute of the Czech University of Life Sciences Prague and with the company ATG Ltd., which contributes through providing the workshop and technology capacity for practical overlay material deposition. The welding process was performed in accordance with written procedures. The steel S235JR was used as a base material to produce the test sample. The plates made of this material were coated by a hard overlay material. The cladding materials with various chemical compositions were chosen. The main focus was to compare particular chemical components and their influence – mainly carbon (C), chromium (Cr) and manganese (Mn). The overlaying material consists of the products from ESAB and WELCO companies. All tested overlaying materials are recommended for use in extremely abrasive conditions by their manufacturers. The following welding rods were used:

Table 1

Industrial designation of used overlaying materials

Type of electrodes	Appropriate use	Used welding current
ESAB OK 84.52	Suitable for coating of dynamically loaded surfaces, working in chemically aggressive conditions. Overlay metal has martensitic structure.	170 A
WELCO 1702 S	Suitable for coating of tools dynamically loaded (including pressure, and impacts).	210 A
WELCOLLOY 1745	Suitable for application of overlay with increased content of chromium-carbide and molybdenum-carbide, creates hard and tough matrix.	150 A
WELCOLLOY 1750	Suitable for coating of tools dynamically loaded (including pressure, and impacts). Dedicated for repairs of crashing and shredding tools.	215 A
WELCO 1701 S	Suitable for deposition of thick layers during repairs of shredding machines. Suitable to be used as interlayer under hard Mn-steel finish overlay.	140 A

The overlay materials were applied by MMA (SMAW) technology. Three layers of the overlaying material were applied to each sample. The sample surfaces to be tested were prepared for the experiment by means of machining (spinning and grinding) from weld board. A sample was prepared of dimensions 10.2 mm diameter and 30 mm of length. Main experiments were carried out with respect to valid Czech national norms as well as international standards [14; 15]. The experiments were focused particularly to the effect of specimen hardness and microstructure to abrasive wear resistance. The experimental data were evaluated with usage of basic statistical methods.

A machine with fixed abrasive particle segments and with rotational movement was used for evaluation of abrasion progress (see Figure 1). Abrasive wear was based on the Czech National Standard [14]. The guiding principle of the experiment is the so-called two body abrasion, where the abrasive particles firmly attached to the abrasive material penetrate into the test sample and gradually wear it down. After machine setting the tests may begin. The reference specimens were used for relative wear resistance determination. This eliminates fluctuations caused by the different abrasive cloth quality. The first two specimens were used for "aging" of apparatus. These specimens were not used for evaluation. Then the specimens were periodically alternated according to the scheme 1 – 2 – 1 – 2 – 1 etc. The test runs using one reference specimen all the time.

For the tests, abrasive cloth with granularity abrasive grain P60 (mean size of the particles 275 μm), P120 (mean size of the particles 115.5 μm) and P240 (mean size of particles 44.5 μm) was used. The wear on the samples was assessed using the decrease in weight of the samples on analytical and digital scales down to 0.01 mg.

$$\psi_{abr} = \frac{W_{hPZ}}{W_{hZ}} \cdot 100 , \quad (1)$$

where W_{hPZ} – average weight loss of the test standard, g;
W_{hZ} –average weight loss experienced bodies, g [14].

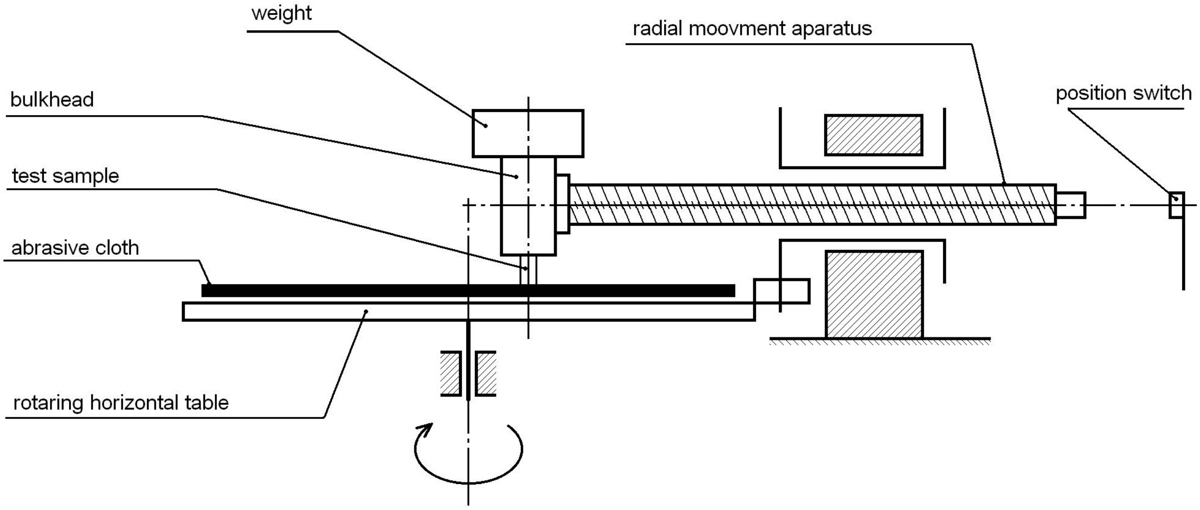

Fig. 1. **Test of resistance to abrasive cloth [10; 12]**

Results and discussion

The assessment of the experimental results was performed with usage of laboratory equipment of the Czech University of Life Sciences Prague. The prepared test samples were subjected to chemical analysis with the Q4 table spark optical emission spectrometer in collaboration with Škoda Plzeň s.r.o. The results of the chemical compositions are shown in Table.2.

Table 2

Chemical composition of tested materials

No.	Tested samples	Chemical composition, wt. %										
		C	Si	Mn	P	Cu	Cr	Mo	Ni	V	W	Fe
1	ESAB OK 84.52	0.22	0.30	0.55	0.01	0.01	12.1	0.02	0.02	-	-	
2	WELCO 1702 S	0.83	0.10	10.1	0.004	0.01	0.64	0.27	2.8	-	-	
3	WELCO 1745 S	4.9	0.02	1.2	0.02	0.01	37.2	0.01	0.04	-	-	
4	WELCO 1750 S	0.33	0.24	12.9	0.02	0.01	14.1	0.02	0.04	0.8	-	
5	WELCO 1701 S	4.0	0.02	1.1	0.01	0.01	36.8	0.3	0.05	-	1.6	
6	S235JR (etalon)	0.08	0.16	0.52	0.02	0.03	0.07	0.12	0.11	-	-	

Measuring the hardness of the test samples was according to the Vickers' HV 30 test. Experimental measuring was carried out in compliance with thestandard [15], when a regular quadrilateral pyramid is fitted to the material being tested under the test load 294 N. The results of the material hardness tests are shown in Table 3.

From Table 3 it is possible to derivate a conclusion, that while sample No. 3 has the highest hardness, the sample No. 2 has the lowest hardness. The results based on the acquired data from the measurements of overlaying materials indicate that the highest hardness was recorded at the sample number 3, the lowest at the sample number 2. This is in accordance with the results of the authors [11], who found that thechemical composition of a material has an essential influence on alternation of the mechanical properties of the material. The recorded results are shown in Table 3.

The difference in mechanical properties is determined by the structure of the material. As a result of this, metallography of all five tested overlay samples was carried out. The structure of overlay ESAB OK 84.52 is martensitic with residual austenite. Other samples of overlying materials were austenitic. There are the pictures of metallography of the tested samples No. 3 and 7 in Fig. 2, 3.

Table 3

Hardness HV 30, wear resistance

No.	Tested samples	Hardness HV 30	Wear resistance		
			$\psi_{abr.}$ mean size of the particles 44.5 µm	$\psi_{abr.}$ mean size of the particles 115.5 µm	$\psi_{abr.}$ mean size of the particles 275 µm
1	ESAB OK 84.52	538	1.94	2.01	2.09
3	WELCO 1702 S	252	1.74	1.73	1.28
4	WELCO 1745 S	803	4.23	3.16	3.11
5	WELCO 1750	299	1.92	1.75	1.87
6	WELCO 1701 S	647	2.98	2.46	2.28
7	S235JR (etalon)	161	1.00	1.00	1.00

The experimental results confirm that materials with a higher chromium content have higher hardness (compare Tables 2 and 3). The sample properties were compared to S235JR steel, which exhibits the hardness of 161 ± 16 HV. The highest hardness value of 803 ± 35 HV is exhibited by the sample No. 3, while the lowest hardness of 252 ± 23 HV by the sample No. 2.

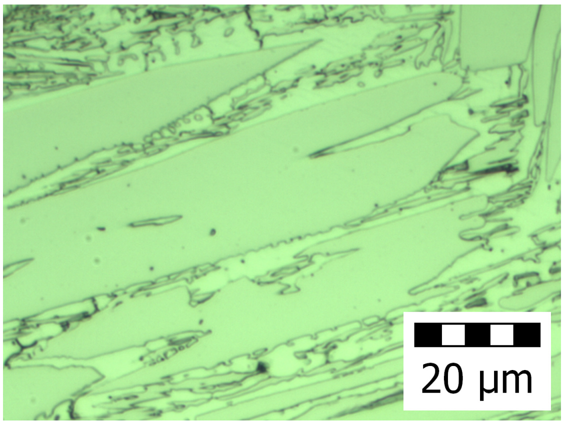

Fig. 2. **Microstructure of sample 3**

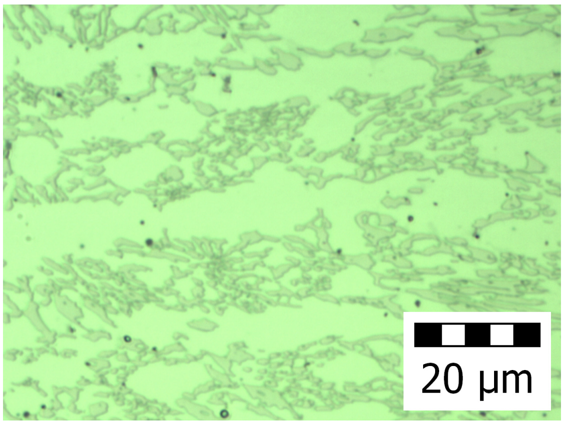

Fig. 3. **Microstructure of sample 5**

Figure 4 depicts the resistance to abrasive wear. From the results of [8; 11; 12] on abrasive wear, the hypothesis that resistance to abrasive wear depends on the used size of the abrasive parts and on the structure of the material has been confirmed. For all materials tested, the mass loss decreases with increasing the size of the abrasive parts.

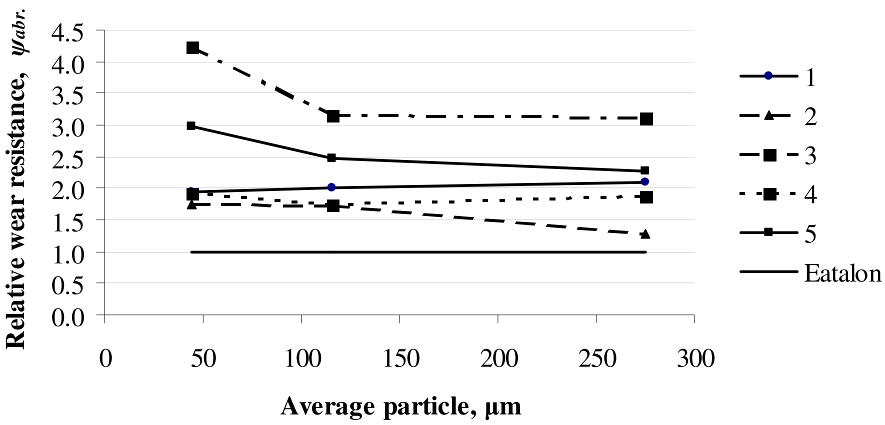

Fig. 4. **Wear resistance**

The sample No. 3 exhibits the highest abrasive wear resistance. For the mean abrasive part size of 44.5 µm the relative wear resistance was 4.23 ± 0.02, while for the mean abrasive part size of

115.5 μm and 275 μm it was 3.16 ± 0.09. So the wear resistance of WELCO 1745 S is approximately three to four times higher than that of S235JR steel. The results shown in (see Table 3), likewise show that the least resistant material was steel with the designation S235JR which was selected as the etalon for comparison. The relative resistance to abrasive wear is considerably different for individual types of materials. That difference is the result of the very different structures of the materials.

Generally, we can state that with an increase in the percentage of chromium in the material, the relative resistance to abrasion $\psi_{abr.}$ increases. It is always necessary to determine the resistance to abrasive wear with regard to the internal structure of the material and to its chemical components.

Conclusion

From the achieved results it could be stated that the process of abrasive wear is a very sophisticated process. The main focus of the test measurements was to establish the relative effect based on different contents of the chemical composition. The document confirms the hypothesis that the alternation in mechanical properties depends on the chemical composition of the amount of carbon, chromium and manganese in the structure of materials. Difference of composition to these three substances resulted in affecting the mechanical properties of the materials.

The results are that a higher Cr content in the material structure is significantly beneficial for increasing the resistance of materials against abrasive wear. It is also obvious that the sample with the highest Cr percent has the biggest hardness from the whole group of the tested materials. The selection of the most convenient overlay material for particular application should be based on the characteristics of environment in which the component will be operated and the way how it will be operated. The resulted mechanical behavior of the overlay material in real operation could be affected by the base material on which the overlay is applied. For these reasons, it is always necessary to verify the right behavior of materials in the environment by long-term testing in the environment.

References

1. Vocel M. Návrh materiálové volby na strojní součásti pracující v intenzívní abrazi. [Výzkumná zpráva]. (The material selection project for machine parts working in intensive wear area. Research project). Prague, SVÚM 1978. 26 p. (In Czech).
2. Legat V. et al. Hodnocení jakosti orby a plužních cepelí (The evaluation of ploughing and plough shares quality). Research project CZU 309/10/16196/0. Prague, Czech University of Life Sciences Prague 1999. 28 p. (In Czech).
3. Suchanek J., Blaskovits P., Brozek M. Abrasion Resistance of Selected Hardfacing Materials. Trends in Agricultural Engineering. Prague, CUA - Technical Faculty 1999. pp. 606-610.
4. Brozek M., Novakova A., Mikus R. Study of wear resistance of hard facings using welding powders on the NiCrBSi basis. In.: Trends in Agricultural Engineering (TAE) 2010. Prague, Czech University of Life Sciences Prague. pp. 115-118.
5. Kambakas K., Tsakiropoulos P. Solidification of hight-Cr white cast iron - WC particle re-inforcered domposites, Elsevier, Materials Science and Engineering. 2005. pp. 538-544.
6. Kragielskiego, I. V. Trenije i iznos. Moskva, Mašgiz. 1962. (in Russian).
7. Gülenc B., Kahraman N. Wear behaviour of bulldozer rollers welded using a submerged arc welding process. Materials and Design, no. 24, 2003. pp. 537-542.
8. Chasuj A., Morigaki O. Naplavka i napylenije. (Surfacing technology). Moskva, Mašinostrojenije 1985. 240 p. (In Russian).
9. Friction and Wear Testing. American Society for Testing and Materials, West Conshohocken, PA, 1987. 186 p.
10. Brožek M., Nováková A. Evaluation of sintered carbides wear resistance. In.: Engineering for rural development. Jelgava, Latvia University of Agriculture, Faculty of Engineering 2008. pp. 209-213. ISBN 1691-3043.
11. Cieslar J., Brožek M. Experimentální posouzení vlastností litin se zvýšenou odolností proti abrazivnímu opotřebení (Experimental assessment of cast iron with increased resistance to abrasive wear). Strojírenská technologie. No. 5-6, 2012. pp. 290-296 (in Czech).

12. Brozek M. Technicko – ekonomické hodnocení aplikace návaru u plužních čepelí (Technic-economical Evaluation of the Overlays Application on the Plough Shares). Acta univ. agric. et silvic. Mendel. Brun., 2007, LV, No. 4, pp. 129-136. (In Czech).
13. Sevim I., Eyurek B.I. Effect of abrasive particle size on wear resistance in steels. Materials and Design, no. 27, 2006. pp. 173-181.
14. CSN 01 5084. Stanovení odolnosti kovových materiálu proti abrazivnímu opotřebení na brusném plátne (Determination of metal material resistance against wear by abrasive cloth). 1974. (In Czech).
15. CSN EN ISO 6507. Zkouška tvrdosti podle Vickerse (Metallic materials - Vickers hardness test), Vickers hardness test - Part 1: Test method, 2006. p. 21 (In Czech).