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Two body abrasion of composites containing filler on the basis of hard cast iron deposits utilisable in agrocomplex

P. Valášek* and M. Brožek

Department of Material Science and Manufacturing Technology, Faculty of Engineering, Czech University of Life Sciences, Kamýcká 129, Praha – 6 Suchdol, 16521, Czech Republic; *Correspondence: valasekp@tf.czu.cz

Abstract. A row of industrial branches including agriculture requires materials resistant to different types of wear. The contribution is concerned with polymeric particle composites containing filler on the basis of hard cast iron deposits chips. The interaction of polymeric matrix and such filler creates wear resistant material and at the same time makes possible the low costly recycling of the secondary raw materials. From measured values it is evident that by the addition of hard cast iron deposits chips in the polymeric matrix the sharp increase of wear resistance occurs compared with wear resistance of polymeric material without filler. Such wear resistant composite systems can find utilisation in the agrocomplex field.

Key words: composite, epoxy resin, tribological properties, wear.

INTRODUCTION

The carried out experiment aims to define the wear resistance of composite system with filler on the basis of hard cast iron deposits chips using the pin-on-disk machine (CSN 01 5084) and to evaluate the interaction of different dimensions of these chips and epoxy resin.

Reliability of agricultural machines and their operation in a previously determined interval of technical-economical parameters is crucial. Agricultural machines and devices work mostly in specific conditions, which can cause different types of wear – influencing materials used for construction. One well represented type of wear, which can work contemporarily with other types of wear, is abrasive wear. The abrasive wear can be characterised as the parting and transfer of material particles at grooving and cutting by hard particles (Suchanek et al., 2007). The typical example is the wear on agricultural machines working tools owing to the consequence of hard work conditions (Brozek, 2008). From an economic point of view it is right to renovate the worn parts (Brozek, 2008). In agriculture renovation using cladding is conventionally used. Cladding is a common way of renovating worn out parts of soil working machines, combine harvesters and other agricultural machines (e.g. plough systems, sowing boots edges, screw conveyors etc.) (Brozek, 2007; Brozek, 2011; Muller at al., 2011). But in many cases the renovation can be made using the application of composite systems, in practice commonly called liquid metals.

Composite can be characterised as material consisting of two or more phases, which differ distinctively in their physical and mechanical properties, and which interaction defines the composite final properties. If we talk about a polymeric particle composite, the first phase is the matrix in the form of polymer – mostly of reactoplastic (e.g. epoxy resin, polyurethane resin), the second phase is filler in the form of particles (Posta et al., 1998). The mechanical characteristics of a complete system (mutual compactness – cohesion and adhesion of the system to the adherend) define the application possibilities. Lee et al. (2002) count the boundary matrix – filler, geometric and mechanical properties of filler – in the critical factors, which influence the composite wear resistance.

According to Xue Qunji et al. (1997) it is possible to number the increased wear resistance and the increased hardness at a relatively low price among considerable advantages of polymeric particle composites. The low price can be even lowered by the use of a secondary raw material, such as a filler (Valasek et al., 2012). Strength characteristics and impact strength can be considered as limiting factors of composites with microparticles applied.

Fillers on the waste basis can be used only when it does not contradict the valid legislation (in the Czech Republic attachments Nos. 2 and 5 to the law 185/2001 of the statute book). If the waste is used as filler of the polymeric particle composite, this composite is the bearer of the material recycling, which is inexpensive, environment-friendly and should be preferred. According to the Waste Catalogue of the Czech Republic the chips from hard deposits fall under the designation 12 01 01 (Sawdust and chips ferrous metals). It is a cause of waste, which owing to its character does not belong to dangerous waste. During the year 2010 413,533 tons of this waste were produced in the Czech Republic (according to ISOH – Waste Management Information System). Just the interaction with the polymeric matrix is one of the waste possible utilisation. In the field of agriculture Muller et al. (2012, 2011) mentions the technology of sugar beet growing and harvest as a possible application field. In the field of sugar beet growing it is possible according to Muller et al. (2011) to use primarily composite systems with polymeric basis and filler on the basis of microparticles Al_2O_3 (corundum). Similar two body abrasive wear resistant systems with Al_2O_3 particles are described by Xian Jia et al. (2005). Between anorganic particles, which according to Mohan et al. (2012) increase considerably the polymers tribological properties, graphite and silicon carbide can be numbered.

MATERIALS AND METHODS

The composite systems contained filler of 25% by volume. This concentration was chosen with respect to the filler sedimentation minimisation during the composite curing. This concentration makes simultaneously possible the easy adhesion to the adherend (Valasek et al., 2012). As the composite matrix the epoxy resin Eco Epoxy 1200/324, and as filler eleven different chips types gained by cutting of hard cast iron deposits (No. 1 to No. 11), which are commonly used for machines functional surfaces renovation, were used. The hard cast iron deposits are very abrasive and wear resistant (Novak, 2011). The same properties can be expected from chips gained by their turning. The epoxy resin and filler on the basis of chips the waste were mechanically mixed and afterwards cast using prepared moulds from two-component silicone rubber, whose separation ability to cast resin is very high. Then the curing followed according to producer demands.

As a guide for the hardness determination of the composite systems the standard CSN EN ISO 2039-1 (2000) was used. The tested specimens dimensions were of 35 x 25 x 9 mm. Considering the chips size the ball from hard metal of 10 mm diameter was used. The tested specimens were loaded using the force of 2.452 kN for the duration of 30 s (HBW 10/250/30).

As guide for the abrasive wear resistance determination the standard CSN 01 5084 (1973) was used. This method for testing of metallic materials was implemented for polymeric particle composites. The tests were carried out using the abrasive clothes of P120 and P240 grit. The tested specimens were cylindrical of 10 mm diameter and 25 mm height. The specific pressure was of 0.09 N (mm)$^{-2}$, friction path of 50 m. The tested specimen moved from the edge to the centre of the abrasive cloth. Owing to the decreasing friction path during one revolution the sliding speed decreases from 0.45 m s^{-1} to 0.08 m s^{-1}. Using the contactless thermometer Testo 845 (Testo Ltd., Prague, CZ) the temperature on the boundary of the specimen and the abrasive cloth was measured. The volume losses were determined using the laboratory scales of 0.1 mg sensitivity. The real composite density was calculated using their weight and volume, which was defined by tested specimen dimensions measured using the dial measuring gauge (0.01 mm). For the composite system comparison with the steel S235JR (169 ± 19 HV) the relative wear resistance ψ was used according to (1):

$$\psi = \frac{W_{St.}}{W_{Ts.}} \qquad (1)$$

where ψ – relative abrasive wear resistance; $W_{St.}$ – average volume loss of standard (S235JR) [cm^3]; W_{Ts} – average volume loss of tested specimens [cm^3].

The proportional representation of single phases and the measuring of chips dimensions were carried out using a stereoscopic microscope (owing to the chips shape irregularity expressed in 2D flat surface).

RESULTS AND DISCUSSION

The size of chips represented by their surface *(A)*, measured before the single specimens casting, presents for single filler types *(No.)* Table 1, including standard deviation *(s)*. After the specimens casting their porosity *(P)* was determined. It expresses the difference between the real density and the theoretical one. At the theoretical density calculation the difference between single deposits was neglected. The value of 7.7 g (cm)$^{-3}$ was used (the cured matrix density was of 1.15 g (cm)$^{-3}$). The theoretical composites density was of 2.8 g (cm)$^{-3}$. After the wear resistance test the proportional representation of single phases on the specimen worn surfaces was evaluated, using a stereoscopic microscope. The proportional representation of filler – chips *(Ph)* and their number *(n)* are presented in Table 1. The chips number *(n)* considers all chips surfaces, surrounded by the matrix (owing to the irregular chips shape the surface of one chip can be included more times, when single surfaces are surrounded by the matrix). On the basis of the filler surface, the total worn surface and the proportional representation of the filler *(Ph)* the surface corresponding to one chip

(A_c) according to the single chips number *(n)* was determined, see Table 1. Table 1 presents the average values of data files obtained from tests using the abrasive cloth both P120 and P240. Coefficient of variation of data *P, Ph* and *n* did not exceed 15%.

Table. 1. Chips dimensions, porosity and phases proportional representation

Nr.	A mm^2	s mm^2	P %	Ph %	n	A_c mm^2
1	1.82	0.78	2.9	15.4	160	0.07
2	1.32	0.46	2.0	16.4	107	0.12
3	1.18	0.47	6.9	13.2	191	0.05
4	1.12	0.41	8.3	13.9	221	0.05
5	0.99	0.50	8.1	14.0	250	0.04
6	0.93	0.71	2.8	14.5	241	0.05
7	0.60	0.19	9.2	12.8	245	0.04
8	0.59	0.31	13.4	10.1	816	0.01
9	0.47	0.19	7.9	15.1	299	0.04
10	0.47	0.24	7.3	15.9	236	0.05
11	0.29	0.18	11.4	11.7	306	0.03

From Table 1 it is evident that the surface size of hard deposit chips, coming into contact with the abrasive conditions, depends on the chip orientation in the composite system. During the epoxy resin curing (24 hours) owing to the gravitational force the sedimentation occurs (Valasek et al., 2012). This process, causing the mutual contact between chips and mould wall, defines the final particles arrangement, which influences the filler particles proportional representation on the contact of the tested specimen with the abrasive.

On the worn surface of the test specimen the phases ratio of the chips surfaces $A = 1.32$ mm^2 (No. 1) and $A = 0.59$ mm^2 (No. 8) is presented in Fig. 1, where except the single phases ratio the noticeable occurrence of air bubbles is evident. This air bubbles occurrence causes the increased porosity (13.4% at the composite No. 1).

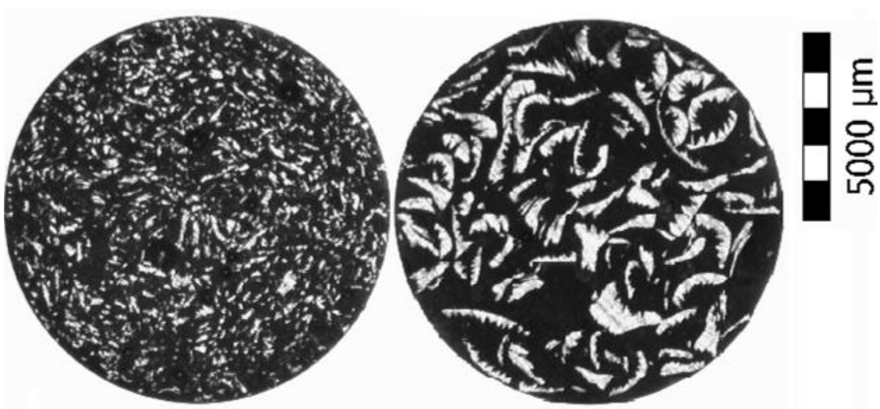

Figure 1. Structure of the worn surfaces (left No. 8, right No. 1).

During the wear process the test specimen moves from the edge of the abrasive cloth to its centre and its sliding speed decreases. The sliding speed influences the temperature on the boundary of the test specimen and the abrasive cloth. The temperature depends on the used abrasive cloth. At the abrasive cloth P120 and the sliding speed 0.45 m s^{-1} this temperature was 43 ± 4°C (P240 40 ± 4°C). This temperature was measured at the testing of all test specimens. Owing to the decreased speed this temperature decreased to the level of 30°C.

The tested specimens volume losses, dependent on the composite hardness compared with the volume loss of the resin without filler (0.02673 ± 0.0043 cm^3) and the composite on the basis of the primarily raw material SiC (0.0225 ± 0.0003 cm^3) for the abrasive cloth P240, presents Fig. 2. The highlighted symbol marks the composite of the smallest volume loss (0.0164 ± 0.0009 cm^3). The data in brackets (x, y) correspond to the variation coefficient of hardness ʼxʼ and volume loss ʼyʼ values.

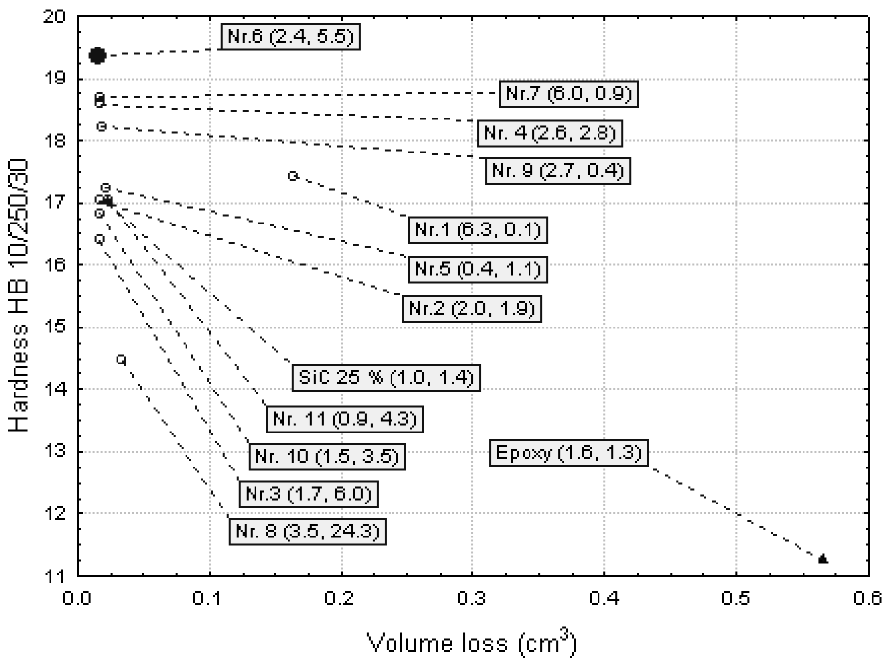

Figure 2. Volume losses of composites and resin – abrasive cloth P240.

In the resin without filler using the abrasive cloth P240 the volume loss of 0.5658 ± 0.0129 cm^3 was determined, which is presented with other composite systems in Fig. 3.

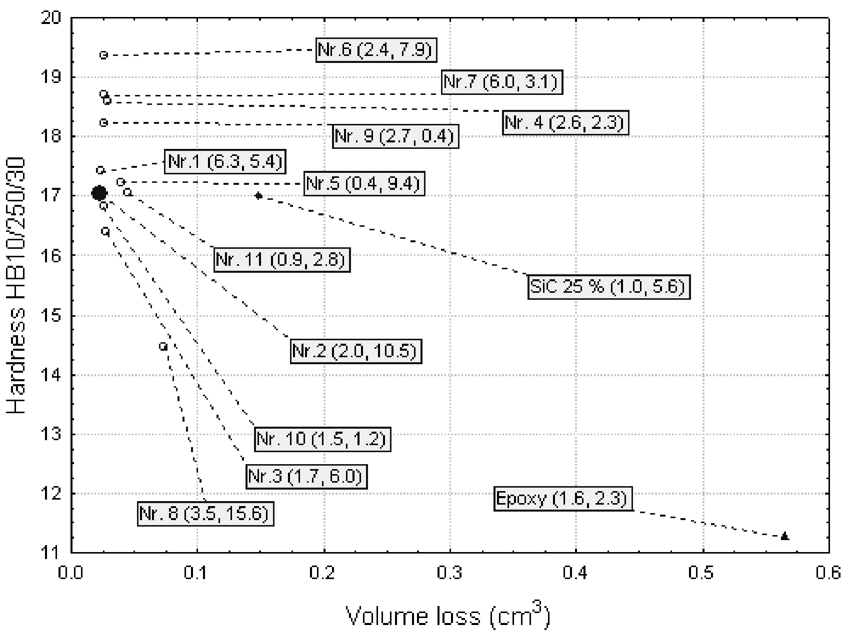

Figure 3. Volume losses of composites and resin – abrasive cloth P120.

The abrasive wear resistance comparison with the steel for the two most and two least wear resistant systems is presented in Table 2.

Table 2. Wear resistance – comparison with steel

Material	abrasive cloth P120 (ψ)	abrasive cloth P240 (ψ)
Composite with chips No. 8	0.34	0.21
Composite with chips No. 11	0.33	0.50
Composite with chips No. 2	0.68	0.69
Composite with chips No. 1	0.63	0.70

At the comparison of developed composite systems on the basis of hard cast iron deposit chips with the composite on the basis of SiC particles the increase of volume losses with increased grit of abrasive cloth is evident (P240; $\psi = 0.51$, P120; $\psi = 0.10$ – the relative wear resistance difference – 0.41). This fact is caused by the filler particles critical size. At the composite system with chips from hard cast iron deposits such an increase was not observed – the highest relative wear resistance difference did not exceed the value 0.17 (average value 0.11) between values of both abrasive clothes.

CONCLUSIONS

On the basis of carried out experiments it is possible to summarise the most substantial results in the following points:

- The presence of hard cast iron deposit chips in the composite system matrix caused a considerable hardness increase compared with the resin without filler (up to 72%).
- The inclusion of hard cast iron deposit chips in the epoxy matrix leads to a relative wear resistance increase of up to 93.8% compared with resin without filler.
- The unambiguous dependence between the composite hardness and the two body abrasion

From the results it is evident that composite systems on the basis of epoxy resin and filler in the form of hard cast iron deposit chips are abrasive wear resistant on the use of the bonded abrasive. This fact was confirmed by Muller et al. (2011, 2012) and Satapathy et al. (2002), who mention polymeric particle systems as material resistant to different kinds of wear. The difference between the chips size influenced the final filler abundance on the worn surface (distribution and orientation of filler particles influence also other variables, e.g. chips shape). These variables reflected in the composite ability to be resistant to abrasive conditions. Composites of big numbers of single chips of small dimensions were less resistant (they were distinguished by more significant porosity) than composites of chips in lower numbers and bigger dimensions on the worn surface. It is evident that the chips shape in interaction with the definite mould shape (or adherend shape which is composite system applied on) can influence owing to the gravitational force effect on filler particles (during the polymer curing process) the final representation of filler on the worn surface – and so the wear resistance of the given system.

In agrocomplex these materials can find their application in the renovation of screw conveyors, wanes of ventilators, in puttying and coupling of hoppers, cracks in machine housings, smoothing of weld points, repairs of small cracks, sealing of cracks in tanks, etc.

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REFERENCES

Brožek, M. 2011. Layer number influence on weld deposit chemical composition. In 10th *Internacional Scienfic Conference Engineering for rural development*. Jelgava, Latvia, pp. 393–397.

Brožek, M., 2008. Evaluation of sintered carbides wear resistance. In *7th Internacional Scienfic Conference Engineering for rural development*. Jelgava, Latvia, pp. 209–213.

Brožek, M. 2007. Technic-economical evaluation of the overlays application on the plough shares. Brno. Acta univ. agric. Et silvic, pp. 129–136.

ČSN EN ISO 2039-1, 2000. Plastics – Determination of hardness – Part 1: Ball indentation Metod.

ČSN 01 5084, 1973. Determination of metal materiále resistence against wear by abrasive cloth.

ISOH, Informační systém odpadového hospodářství. Avaible at *http://isoh.cenia.cz/groupisoh/fin.php*

Lee, G.Y. & Dharan, C.K.H., 2002. Ritchie, R.O. A physically-based abrasive wear model for composite materials. *Wear*. **252,** 322–331.

Mohan, N. & Natarajan, S. & Kumaresh Babu, S.P. 2012. The role of synthetic and natural fillers on three-body abrasive wear behave our of glass fabric-epoxy hybrid composites. *Journal of applied polymer science*. **124**, 484–494.

Müller, M. & Valášek, P. 2012. Abrasive wear effect on Polyethylene, Polyamide 6 and polymeric particle composites. *Manufacturing technology*. **12,** 55–59.

Müller, M. 2011. Influence of surface integrity on bonding process. *Research in Agricultural Engineering*, 57(**4**). 153–162.

Müller, M. & Valášek, P. & Novák, P. & Hrabě, P. & Paško, J. 2011. Aplikace návarů a kompozitů v oblasti technologie pěstování a sklizně cukrové řepy. *Listy cukrovarnické a řepařské*. **9**, 304–307.

Novák, M. 2011. Surface duality hardened steels after grinding. *Manufacturing technology*. **11**, 55–59.

Pošta, J. & Havlíček, J., 1998. Renovace strojních součástí (Renovation of machine parts). Česká tribologická společnost, Prague, 160 pp.

Satapathy, B.K. & Bijwe, J. 2002. Analysis of simultaneous influence of operating variables on abrasive wear of phenolic composites. *Wear*. 253, 787–794.

Suchánek, J. & Kuklík, V. & Zdravecká, E. 2007. *Abrazivní opotřebení materiálů*, Prague, 162 pp. (in Czech).

Valášek, P. & Müller, M. & Proshlykov, A. 2012. Effect of sedimentation on the final hardness of polymeric particle composites. *Research in Agricultural Engineering*. **3,** 92–98.

Xia, Jia & Xiaomei, Ling. 2005. Influence of Al_2O_3 reinforcement on the abrasive wear characteristic of Al_2O_3/PA1010 composite coatings. *Wear*. **258**, 1342–1347.

Xue, Qunji & Wang, Qihua. 1997. Wear mechanisms of polyetheretherketone composites filled with various kinds of SiC. *Wear,* **213**, 54–58.