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ABRASION OF POLYMERIC COMPOSITES ON BASIS OF MACHINING SPLINTERS FROM HARDFACING ALLOYS – USABLE IN AGROCOMPLEX

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Abstract

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A paper focuses on a description of two-body and three-body abrasion wear of polymeric particle composites with fillers on a basis of machining splinters from hardfacing alloys. The abrasive wear is typical for functional surfaces of agricultural machines processing the soil. One of possibilities of the functional surface renovation is an application of resistant layers in a form of composite systems. Just the inclusion of hard inorganic particles into a polymeric matrix significantly increases its wear resistance. So long as the primary filler is replaced by the waste – by particles from the material machining – the matrix in which the filler is dispersed is a bearer of a material recyclation. This way of the recyclation is inexpensive, economic and sensitive to environment. The paper focuses on the experimental description of the two-body and three-body abrasion and the composites hardness, it describes a production of a prototype for field tests with the functional surface on the basis of the investigated composite system at the same time.

Keywords: epoxy resin, inorganic particles, waste recyclation, wear

INTRODUCTION

Exacting conditions which affect the functional surface of tools contacting the processed soil lead to a gradual degradation of surface layers and to a deterioration of functional properties of the tool which show themselves on an efficiency of the tillage. The service life of individual parts of the tools processing the soil is limited by time from this point of view. A choice between buying new tool or renewing old tool is an economic question above all. This process is a typical negative example of the abrasive wear in the agriculture. That is why it is necessary to take into regard basic pieces of knowledge from a tribology branch when constructing agricultural machines processing the soil. The right construction of machines and machines parts should lead to their reliability and minimize costs connected with their maintenance prospectively with the renovation. An overlaying can be mentioned as one of conventionally used renewing technology in the sphere of the renovation of functional surfaces of tools processing the soil. One of the overlaying advantage is the fact that it is relatively easy way of functional areas renovation. Müller *et al.* (2011) recommend overlaid materials UTP DUR 600, UTP DUR 650 Kb and UTP LEDEBURIT 65 above all for the sphere of the renovation of functional areas of tools processing the soil. They are martensitic overlays and ledeburitic overlay (UTP LEDEBURIT 65) whose price ranges in the interval 8–30 Euros per 1 kg. Ceramic materials can be also used for renovation in agriculture (Müller *et al.*, 2013).

Another technology of the functional areas renovation of tools processing the soil can be an application of resistant composite systems. They are composite systems based on a polymeric matrix which is created by reactoplastics in most cases and by filler in a form of hard inorganic microparticles.

Hard inorganic particles can be from primary as well as secondary raw materials (Valášek and Müller 2013; Valášek *et al.*, 2013). A possibility in a sphere of raw materials (waste) is waste from ferrous metal splinters – hardfacing alloys from machining process (Valášek *et al*, 2013). Splinters created that way excel with similar properties as the monolithic material from which they are taken and they usually do not have any further use. The common attribute of these materials is high level of a hardness and resistance to abrasive wear.

As it results from references hard inorganic particles significantly increase the abrasive wear resistance. Particles with sizes between 40–100 µm were used by Satapathy *et al.* (2002) for increasing the wear resistance of phenolic resins (two-body abrasion). Basavarajappa *et al.* (2010) also describe a significant influence of SiC particles on resultant resistance of polymer matrix to three-body abrasion. Mohan *et al.* (2012) used in their experiment also SiC particles (the particle size of 20–25 µm), they describe the improvement of tribologic properties of the polymeric composites. Inorganic particles can optimize other mechanical properties too. E.g. Abenojar *et al.* (2009) describe the increasing of the strength characteristics of SiC/Epoxy composite by using the apparatus for optimizing the micro particle surface. Authors observed considerable increasing of the material wear resistance during the experiment which was filled with 6–12 wt% of SiC particles of sizes 10 µm.

The aim of the experiment is to experimentally define the resistance to two-body and three-body abrasion, the hardness of composites and used filler and matrix. The experiment results led to developing a prototype of a ploughing body which will be used for field tests for evaluating the process of composite layers abrasion under the real conditions.

MATERIAL AND METHODS

Preparation of test samples and prototypes

The matrix was represented by a reactoplastic on a base of two-component epoxy resin GlueEpox Rapid (DCH-Sincolor, a. s.) with high liquidity and with increased speed of the hardening. The hardening speed is key in the area of putting and sticking of the composite system to renewed areas. It also influences an undesirable sedimentation of particles. A viscosity of the epoxy resin soaks the particles surface and it creates corresponding interphase boundary after hardening. The mixture of the resin and the filler was prepared by a mechanical mixing. Test samples were created by 25 vol% of the filler, they were cast into forms from rubber with an ability to separate from cast systems and subsequently they were hardened according to technologic requirements. The mixture was also applied to grit blasted and degraded surface of ploughing body parts – a production of prototypes for field tests. Particles arisen from the process of materials machining were ordered according to a content of carbon (chrome vanadium cast-iron, see Fig. 1).

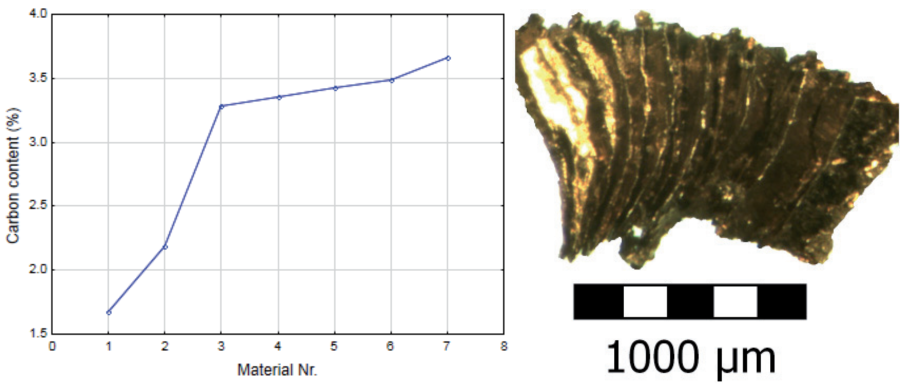
Cutting conditions during machining are not a subject of this paper. The cutting process did not use liquids which would contaminate arising particles. This waste does not belong among dangerous waste and it is not used namely by smaller workplaces – it is tipped without another possible usage.

Two-body abrasive wear

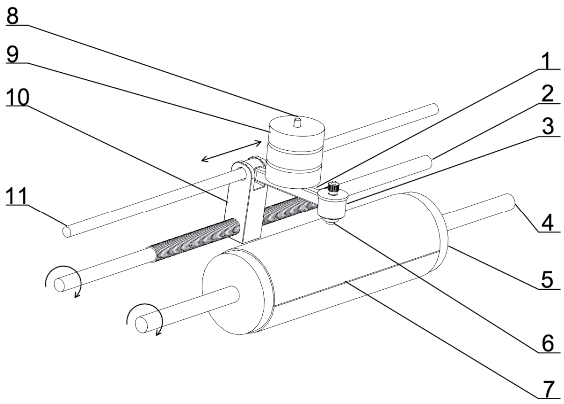
The two-body abrasion was tested on a rotating cylindrical drum device with the abrasive cloth of the grain size P120 (Al_2O_3 grains) according to the standard CSN 62 1466 (see Fig. 2). The tested sample is in the contact with the abrasive cloth and it covers the distance of 60 m. During one drum turn of 360° it is provoked the tested sample left above the abrasive cloth surface. Consequent impact of the tested sample simulates the concussion. The pressure force is 10 N. The mean of the tested samples was 15.5 ± 0.1 mm and their height was 20.0 ± 0.1 mm.

Three-body abrasion

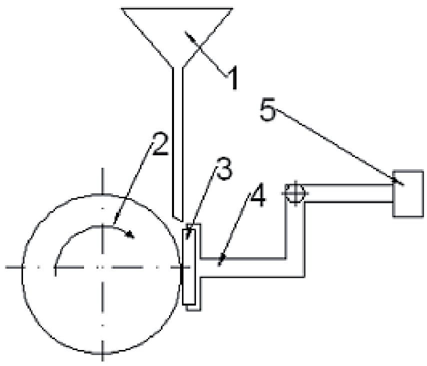
For the experimental definition of three body abrasion we used a machine with a rubber disc which simulates the process of abrasive wear by free particles (modifying standard ASTM G6, see



1: *Content of carbon in machined materials and example of used filler*



2: *Schema of equipment for two-body abrasive wear testing*



3: *The machine with the rubber disc*

Fig. 3). The particles used for the experiment were the particles of fire sand with grain size between 0.1 and 0.3 mm (the sand for this fraction was suctioned there through mesh screens). The trial samples with the size 39.0 ± 0.1 mm, 24.5 ± 0.1 mm and 8.0 ± 0.1 mm were pressed to the rubber disc by a pressing force of 36.4 N, the diameter of the disc was 130 mm and the frictional distance 350 m.

Composite systems hardness

As guide for the hardness determination of the composite systems the standard CSN EN ISO 2039-1 was used. The tested samples dimensions were of 35 x 25 x 9 mm. Because of the size of the filler, a ball of hard metal with the diameter D = 10 mm was used. The tested samples were loaded using the force of 2.452 kN for the duration of 30 s.

Particles hardness

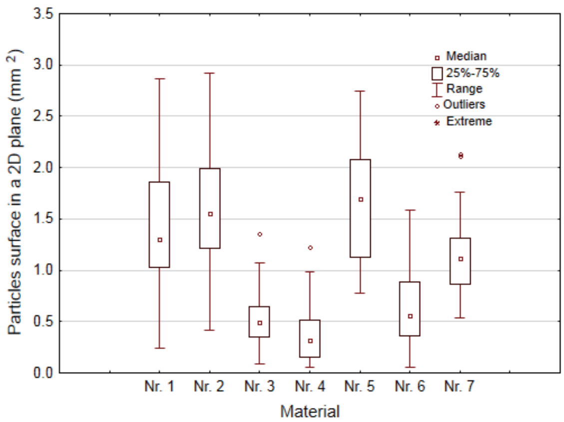
The hardness of single phases (the matrix and the micro – particles – chips) was reviewed at the same time at the tested samples when the micro- hardness according to Vickers (HV 0.2/30) was used. Average values stated in this paper do not contain extremes which would be set aside from the statistical data sets on the basis of normal distribution.

Porosity

The porosity was set on the base of the theoretical and real density difference which characterizes the quality of composite systems. When calculating the porosity, the theoretical density respectively, the matrix density 1.15 g·cm^{-3} and the particles density 7.3–7.8 g·cm^{-3} were reasoned (according to the density of monolithic material from which the particles were taken).

RESULTS

The particles size and their morphology influence the strength of the interphase boundary above all. Mutual adhesion of particles with the epoxy resin prevents an excessive breaking out of particles. The particles size was measured as the area in 2D plane by a stereoscopic microscope (see Fig. 4). The composite porosity did not exceed the limit 10%, the average porosity corresponded to 6% (density of resin was 1.15 g·cm^{-3}, composites density 2.7–2.8 g·cm^{-3}).

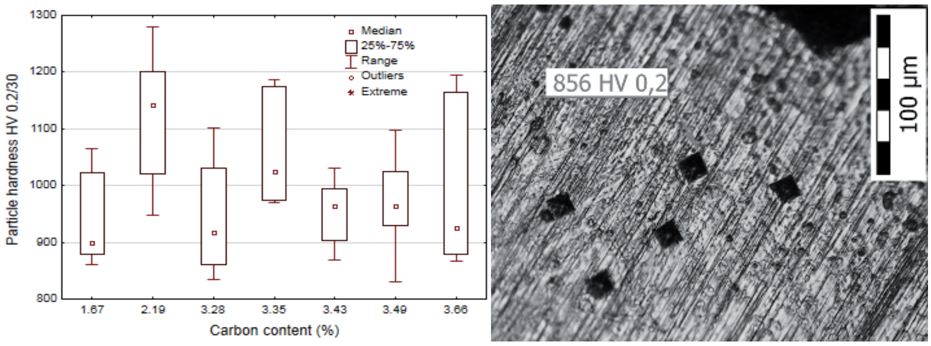


4: *Particle dimension*

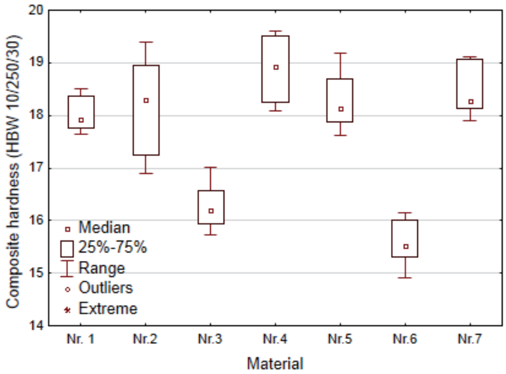
The content of carbon in the alloy is one of important factors influencing the resultant hardness of metal material. Then the material hardness can be in a given correlation with the abrasive wear resistance. The particles hardness on worn surface depending on the carbon content in the monolithic material is presented in Fig. 5, further the figure shows characteristical traces of the indentor on the particle surface.

Great dispersion of measured values of the particles hardness can be caused by cutting conditions and various hardenability of splinters particles at machining. The micro hardness corresponded to 9.11 ± 1.18 HV 0.2/30 (resin). The hardness of composite systems is presented in Fig. 6. The hardness of the resin without the filler corresponded to 14.14 ± 1.21 HBW 10/250/30).

Volume losses for two-body abrasion and three-body abrasion for filled systems and the epoxy resin are presented in Fig. 7. The volume losses of composites ranged after the two-body abrasion from 0.022 (Nr. 1) to 0.051 cm^3 (Nr. 6) after the three-body abrasion from 0.007 cm^3 (Nr. 2) to 0.025 cm^3 (Nr. 6). A sample Nr. 6 significantly differed from average



5: *Particle hardness (left) and tested surface (right)*



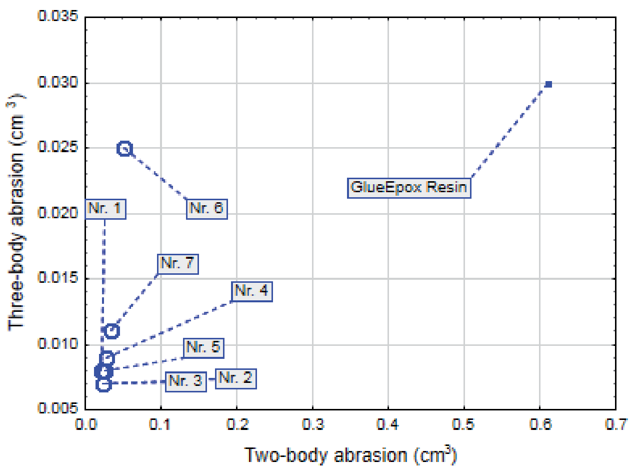
6: *Composite hardness*

values of composite systems. This composite also manifested the lowest measured hardness (15.58 ± 0.42 HBW 10/250/30). This composite system exhibited a low interaction between phases – breaking out of particles. A variation coefficient of measured values did not exceed 10%.

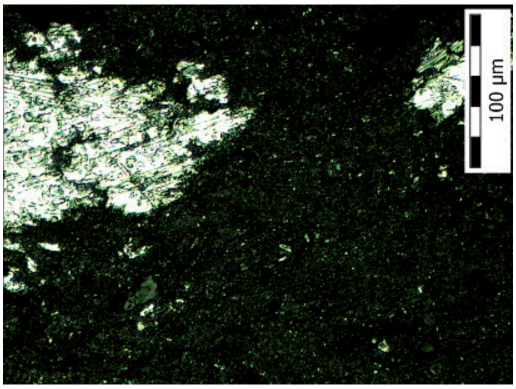
A principle of the wear at the two-body and three-body abrasion is entirely different. At the two-body abrasion the wear speed of both phases is accordant – it comes to a creation of a smooth grooved surface when the size of grooves corresponds to the size of used fixed abrasive grains. At the three-body abrasion the resin worn faster and a plastic surface comes into being (see Fig. 8).

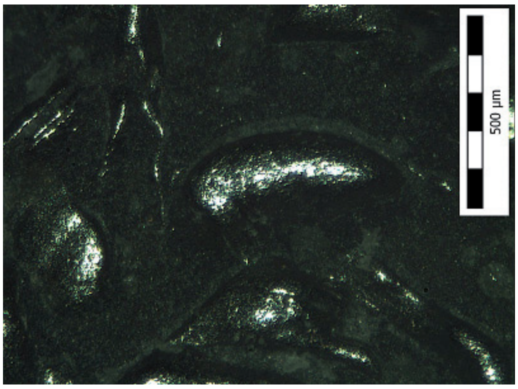
DISCUSSION

The experiment proved that the particles arisen from the process of machining of hardfacing alloys showed considerable hardness. These particles are able to increase the tribologic properties of reactoplastics – epoxy resins. Interphases bonds secure resultant properties of the composite – during the abrasive wear the excessive breaking out of particles did not occur. The experiment proved the porosity of systems which, however, did not significantly decrease the abrasive wear resistance but it can considerable influence other mechanical qualities in a negative way. Increasing of abrasive wear resistance is in the accordance with conclusions of authors (Satapathy and Bijwe 2002; Mohan *et al.*, 2012; Abenojar *et al.*, 2009) who used hard inorganic particles of SiC and Al_2O_3 for increasing the tribological properties of plastics. Increased hardness and abrasive wear resistance, easy manipulation and simple application requirements predetermine described composite systems for the application to the functional surfaces of tools and for creation of resistant surface layers. One of application possibilities of these materials in the agriculture is the renovation of functional areas



7: *Abrasive wear – volume losses*





8: *Surface after wear – two-body abrasion (left), three-body abrasion (right)*

9: *Prototype with renovated surface from composite with particles from machining process*

of the ploughing body (see Fig. 9). The experiment led to the preparation of the ploughing body with the layer of described composite system on the basis of machining splinters from hardfacing alloys. The treatment of the renewed surface is key for securing the adhesion of the composite system. The surface, onto which the composite system was applied, was at first blasted using synthetic corundum. In this way the average surface roughness of Ra = 1.93 ± 0.49 and Rz = 10.39 ± 0.57 was reached.

The advantage of filled reactoplastics is according to Müller *et al.* (2011) their low surface energy which can show itself in the adhesion of processed soil to the composite surface.

CONCLUSION

The application of composite materials based on waste is the material recyclation which should be preferred in accordance with directives of the EU. The matrix in the form of the epoxy resin is the bearer of this material recyclation. Arisen composite can be characterized in following way comparing with the unfilled resin:

- It came to increase of the hardness (HBW) up to 33%.
- The volume losses decreased compared with the resin without the filler of 96% (two-body abrasion) and of 77% (three-body abrasion).
- The influence of the carbon content and the hardness of used particles on above stated properties of the composite was not explicitly confirmed.

When choosing the application areas it is necessary to respect together with above mentioned mechanical properties also other mechanical qualities which were not the subject of this experiment.

SUMMARY

The goals of performed experiment were to describe two-body and three body abrasion wear of polymeric particle composites with fillers on a basis of machining splinters from hardfacing alloys. As a polymeric matrix was a component epoxy resin GlueEpox Rapid with increased speed of the hardening was used. The matrix density was 1.15 $g \cdot cm^{-3}$ the particles density 7.3–7.8 $g \cdot cm^{-3}$ and composites density 2.7–2.8 $g \cdot cm^{-3}$.

The porosity of composite systems was set on the base of the theoretical and real density difference. Used waste particles do not belong among dangerous waste. Test samples were created by 25 vol. % of the filler in the matrix. The two-body abrasion was tested according to the standard CSN 62 1466. For the experimental definition of three body abrasion we used a machine with a rubber disc (modifying standard ASTM G6). The hardness of single phases was reviewed at the same time at the tested samples when the micro- hardness according to Vickers was used.

The composite porosity did not exceed the limit 10%. The hardness of fillers ranged from 900 to 1142 HV 0.2/30. Great dispersion of measured values of the particles hardness can be caused by cutting

conditions and various hardenability of splinters particles at machining. Composite systems hardness ranged from 15.5 to 18.9 HBW 10/250/30 (unfilled resin 14.14 ± 1.21 HBW 10/250/30). The volume losses of composites ranged after the two-body abrasion from 0.022 to 0.051 cm^3, after the three-body abrasion from 0.007 to 0.025 cm^3.

The presence of waste particles on a basis of machining splinters from hardfacing alloys has a positive impact on the resistance to abrasive wear at the same time this filler increased the hardness. One of application possibilities of these materials in the agriculture is the renovation of functional areas of the ploughing body but it is necessary to respect also other mechanical qualities which were not subject of this experiment. The experiment led to the preparation of the ploughing body with the layer of described composite system on the basis of machining splinters from hardfacing alloys. The described use of waste is inexpensive and offers the possibility of the material recycling.

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