RECYCLING OF WASTE RUBBER POWDER AND MICRO-PARTICLES AS FILLER OF THERMOSETS – ABRASIVE WEAR

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Abstract. Recycling of waste is still a current issue – saving primary sources and energy should be a priority. Inexpensive recycling which is environmentally friendly should be preferred. The EU Waste Management is focused on the material recyclation of waste. One of the ways of the material recyclation of waste rubber powder and micro-particles is their inclusion into polymeric materials - thermosets are suitable examples. The waste rubber powder (average dimension 23.8 µm) and micro-particles (average dimension greater than 955.6 µm) were gained as outputs of the recycling line which handles tyres and rubber waste generated in the automotive industry. The recycling of rubber tyres is important in relation to the environment. Thermoset was represented by the two-component epoxy resins (PU resin was also used). The combination of the polymeric matrix and the waste filler gives birth to qualitatively brand new materials – polymeric particle composites. Adding waste to thermosets decreases their price and changes their mechanical properties. The testing samples were prepared with 5, 10, 15 and 20 vol.% of the waste filler. The variable filler concentration can describe the influence of the concentration on the resultant mechanical properties. The paper deals with two-body abrasion wear, hardness, density and porosity of such composites. The two-body abrasion was tested on a rotating cylindrical drum. The experiment results quantify the mechanical properties and can help expand the application area of filled systems.

Keywords: composite systems, mechanical properties, micro-particles.

Introduction

Composites are materials which combine the properties of the matrix and of the filler. As filler inorganic and organic micro- and nano-particles can be used. If micro-particles are used as a filler and a polymer material as a matrix, we can speak about polymeric particle composite systems. The mechanical properties of these systems depend on the mechanical and physical properties of the individual phases and their mutual interaction. The micro-particles can also improve the range of mechanical properties. Kim et al. [1] and Park et al. [2] increased the abrasive wear resistance of resin without the filler by inclusion of nano-particles. Basavarajappa et al. [3] describe in their experiments a significant positive influence of SiC micro-particles on the three-body abrasive wear resistance of the polymeric matrices. The resistance to abrasive wear can be increased by using different types of micro-particles based on waste. Valášek et al. [4-6] used in their experiments hardfacing alloys from the machining process and synthetic corundum (micro-particles) which was taken from a sand blaster. These materials showed higher hardness and higher resistance to abrasive wear.

The rubber micro-particles can be also used as a filler of polymers. E.g., Cerbu and Curtu [7] describe improving the impact strength of polymers just by the presence of recycled rubber particles. Subramaniyan et al. [8] improved mechanical properties of polyurethane foam filled with Kenaf fibres by recycled rubber particles.

The aim of the performed experiment was to describe the abrasive wear resistance of epoxy resin and polyurethane resin with waste rubber micro-particles which were taken from a line devoting to an ecological liquidation of tyres. The waste rubber comes into being as one of products just during the ecological liquidation of tyres. The rubber waste particles are of different sizes and they find their application, e.g., in an area of sports surfaces or panels which are used for lowering noise etc. The experiment describes the abrasive wear of filled epoxy resin and its hardness. It reviews mutual interaction of rubber particles of various sizes and the epoxide. So far, as breaking of micro-particles has occurred during the abrasion, this material would not be suitable for putting on various surfaces of materials. As Valášek et al. [9] state that rubber micro-particles need not decrease the shear strength of epoxy resins, that is why the filled epoxy resins can be used for cementing and adhesive bonding of greater units, where they can also have damping impacts on the surface of a part. They can be exposed more or less to the abrasive wear in some of these applications.

Materials and methods

As a matrix the two-component epoxy resins and polyurethane resin were used: EcoEpoxy 1200/324, GlueEpox Rapid and SikaForce-7723 L175. SikaForce (PU) is resin based on the polyol which was hardened by polyadition by isocyanates according to the technologic requirements of the producer. For epoxy resins the curing agent P11 based on bisphenol A was chosen.

As fillers two different sizes of waste rubber powder and micro-particles (waste rubber) were used. The waste rubber micro-particles were gained as one of the outputs of a recycling line (Czech-Prague).

Mixing of the matrix and the filler was performed by mechanical mixing; the test samples were cast into forms from two-component silicone rubber. The test samples were prepared in such a way so that the influence of the filler on the observed mechanical characteristics could be described – the filler concentration 5-20 vol.%.

The hardness of the test samples was conducted via Shore D method. The two-body abrasive wear was tested on a rotating cylindrical drum device with the abrasive cloth of the grain size P220 according to the standard CSN 62 1466, see Fig. 1.

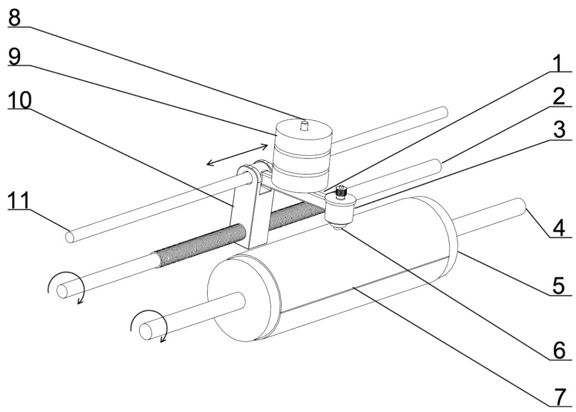

Fig. 1. **Schema of equipment for abrasive wear testing:** 1 – handle; 2 – screw; 3 – head; 4 – abor; 5 – cylinder; 6 – test sample; 7 – abrasive cloth; 8 – holder; 9 – weight; 10 – nut; 11 – rod

The testing machine with the abrasive cloth consists of the rotating drum on which the abrasive cloth is affixed by means of bilateral adhesive tape. The test sample is secured in the pulling head and during the test it is shifted by means of a mowing screw along the abrasive cloth from the left edge of the drum to the right one. The test sample is in contact with the abrasive cloth and it covers the distance of 60 m. During one drum turn of 360° it is provoked that the test sample left above the abrasive cloth surface. Consequent impact of the testing sample simulates the concussion. The pressure force is 10 N. The mean of the test samples was 15.5±0.1 mm and their height was 20.0±0.1 mm. The mass losses were measured on analytic scales weighing on 0.1 mg. The volume losses were calculated on the basis of the ascertained volume and the density of the composite systems.

Results and discussion

Distribution size of the particles was determined on the stereoscopic microscope, see Fig. 2.

The porosity of the filled resins was calculated according to the theoretical and real composite density. The density of waste rubber powder was 1.12 $g \cdot cm^{-3}$, density of EcoEpoxy resin and GlueEpox Rapid 1.15 $g \cdot cm^{-3}$and density of PU resin 1.50 $g \cdot cm^{-3}$. The composite density differed depending on the filler concentration in the matrix, in the interval 1.14-1.15 $g \cdot cm^{-3}$(epoxy resins) and 1.42-1.48 $g \cdot cm^{-3}$ PU resin. The porosity moved to 6 %.

The hardness of the composites was reviewed by Shore D method. The inclusion of waste rubber micro-particles into the resin led to the fall of the hardness at all filled resins comparing with unfilled material. Fig. 3 presents the particular values measured with ANOVA analysis.

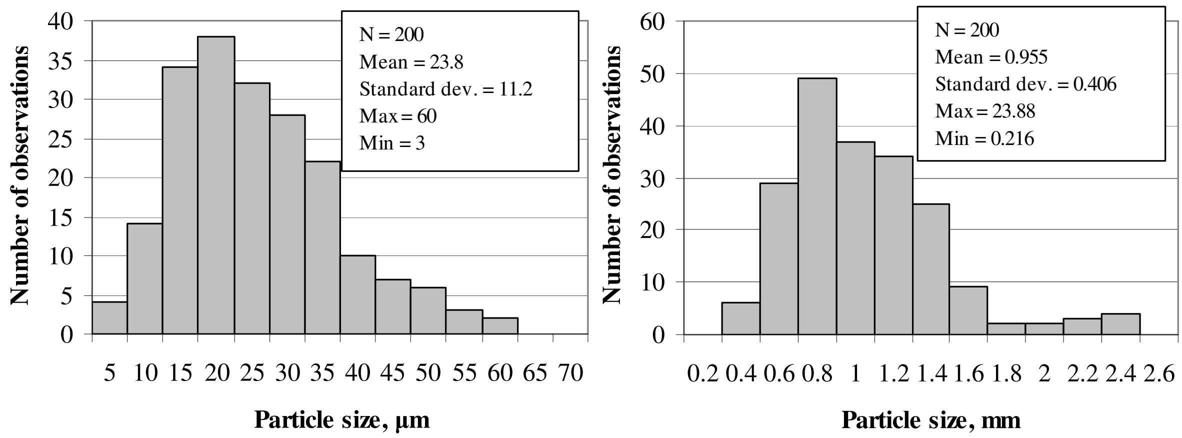

Fig. 2. **Histograms of particle size 23.8 µm (left), 955.6 µm (right)**

The abrasive wear resistance was expressed by means of volume losses. This comparison enables to compare materials with different densities – e.g., composites with different filler concentration in the matrix. The results of the wear resistance (the two-body abrasion) are divided into two graphs according to the size of the rubber particles (Fig. 4, 5).

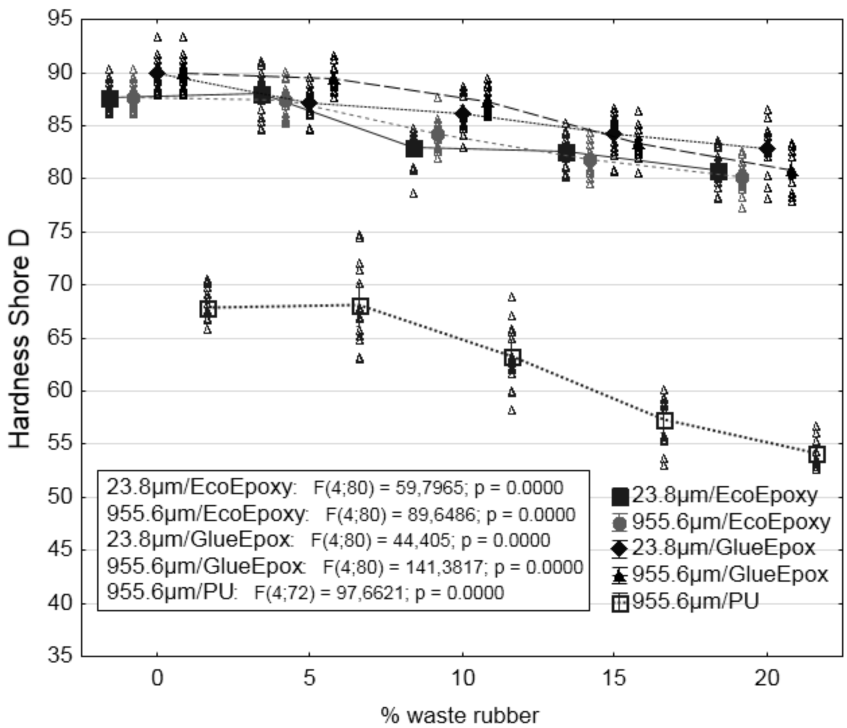

Fig. 3. **Hardness Shore D of filled systems**

As it is visible from the results the rubber presence always led to the increase of the volume losses, so to the decrease of the wear resistance. The presence of larger rubber particles more considerably increased the volume losses than the micro-particles of smaller sizes. This fact was confirmed by a consequent optical analysis where the assumption was confirmed that larger particles of rubber divide more easily from the matrix owing to affecting of abrasive particles of the abrasive wheel. An example – a comparison of a worn surface – is visible in Fig. 6. The variation coefficients of measuring did not exceed 15 %.

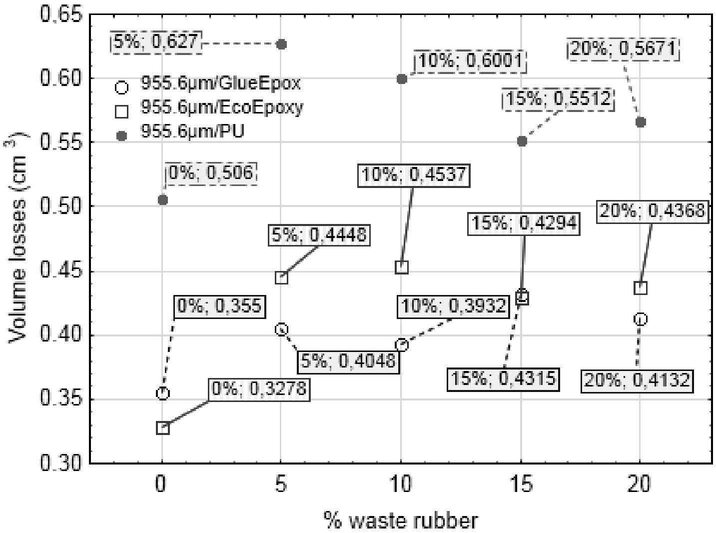

Fig. 4. **Resistance to abrasive wear – particles 955.6 µm**

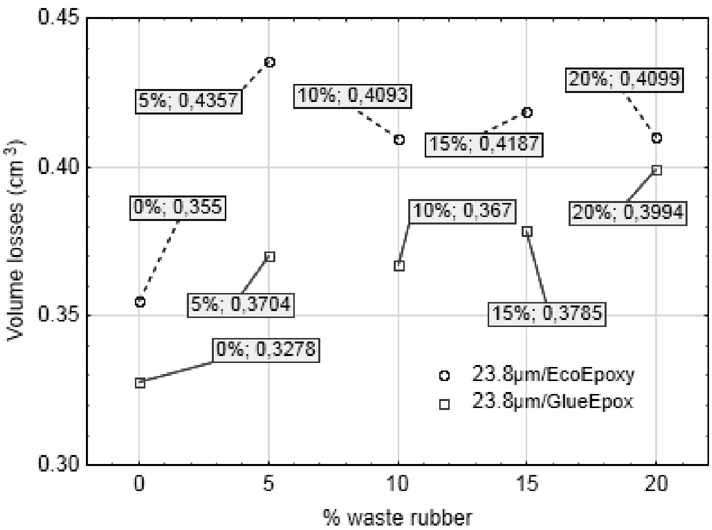

Fig. 5. **Resistance to abrasive wear – particles 23.8 µm**

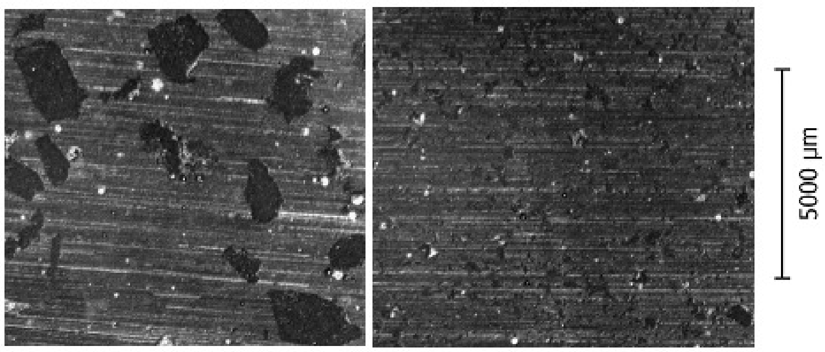

Fig. 6. **Surface of materials after wearing – GlueEpox 10 %:** 955.6 µm – left, 23.8 µm – right

Conclusion

The carried out experiments confirmed the authors' Xue Qunji and Wang Qihua [10] assumption that the filler application in epoxy resins influences the final properties considerably. The conducted experiments do not confirm the presumption based on the works of the authors [1; 3; 11] who claimed that the inclusion of filler in the matrix of epoxy resin increases hardness and resistance to abrasive wear – rubber particles are quite different than hard inorganic particles (e.g., SiC). The hardness of the epoxy resin EcoEpoxy was decreased the most by the rubber with sizes 955.6 µm – a fall of 8.3 %.

This size of rubber led to 9.65 % fall of the hardness at the epoxide GlueEpox and to 20.4 % fall of the hardness at the PU resin. Similar fall of the hardness was set by Valášek et al. [9] who investigated cohesive and adhesive properties of polymers filled with waste rubber.

The rubber with a middle size of the particles 955.6 µm led up to 38 % increase of the volume losses at EcoEpoxy, however, smaller particles sizes 23.8 µm led to considerably smaller increase of the volume losses – 22 %. The volume losses at both particle sizes were comparable at the resin GlueEpox – the increase of cca 21 %. The rubber particles led up to 24 % increase of the volume losses at the PU resin.

It is necessary to respect all mechanical properties in case of the application of these materials on the surface of parts. However, these surfaces will not be resistant to wear. Utilization of these materials is possible also in the area of cementing and adhesive bonding, also in the agrocomplex – the presence of waste rubber micro-particles decreases the resultant price of the material, however, it also decreases the cohesive and adhesive properties [9].

The results of the laboratory experiment describing the chosen material properties of the composites with the waste – rubber micro-particles and powder gained from the recyclation line which ecologically liquidates the tyres can be summarized in the following way:

- These materials enable the material recyclation of the described waste.
- The polymers hardness decreases with increasing the concentration of rubber particles, as in the case of epoxy resin, so the polyurethane ones.
- These materials lead in no case to increasing of the abrasion resistance, but they decrease the abrasion resistance.

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