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MECHANICAL PROPERTIES OF POLYMER COMPOSITES BASED ON BIOPARTICLES (JATROPHA CURCAS L.)

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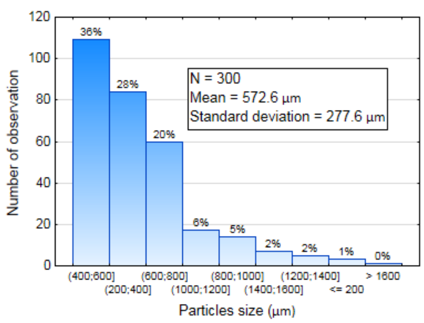
Graphical abstract



Abstract

Composites are materials which synergically combine properties of each phase – matrix and filler. Polymer materials can be used as matrix while inorganic and organic particles can be used as fillers. Composite systems based on renewable resources can be designed as an interesting material for engineering. This paper describes on the tribological and other mechanical properties of biocomposites based on polymer resins and microparticles - seed cakes, which were obtained from seeds of the plant Jatropha Curcas L. during pressing. The particle size obtained was 573 μm. The results confirmed that the epoxy and polyurethane resins were capable of forming which corresponds to the interaction with the organic particles prepared from the seeds of Jatropha Curcas L. The presence of particles however, changed the mechanical properties of the resins. In the case of epoxy resins and polyurethane (Sika Force 7723), the hardness according to Shore D identically decreased with a maximum of 1.9. Abrasion resistance decreased due to the presence of particles of 0.0393 cm^3 for Glue Epox Rapid, 0.0449 cm^3 for Epoxy 1200/324 and 0.0567 cm^3 for Sika Force 7723.

Keywords: Abrasive wear, epoxy resin, polyurethane resin, material utilization.

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1.0 INTRODUCTION

Jatropha Curcas L. grows in tropical and subtropical areas in South Asia (eg. Indonesia), Africa and South America. The seeds of this plant are used for oil extraction which is described in many publications [1, 2, 3]. For economic prosperity and profitability of the pressing process is important a subsequent use of all incurred commodities so even for the secondary row materials, i.e. seed cake (SC). These commodities (seed cake) can be used for energetic process (combustion), also for feeding (there is a problem with a presence of phorbol ester - PE, a toxic constituent, which restricts the cake use for animal feeding) or they can be materially utilized [4]. For material utilization of these secondary row materials SC particles can be applied in a form of biocomposite systems. Shivamurthy et al. [2] described in their experiment that the strength and stiffness values of epoxy matrix increased with the addition of microparticles prepared from seed cake of Jatropha curcas L. Kumar et al. [5] described the tribological properties of fabric of epoxy composites with incorporated SC particles itself and they also described it in combination with silicon carbide. Description of properties of composites with particles from renewable sources (biomaterials) is necessary for determination of possible application areas of these materials. [6]

This work describes chosen mechanical properties (density, porosity, hardness and two-body abrasive wear) of polymeric biocomposites with a filler on a basis of microparticles of seed cake (SC) which were obtained by a crushing without using subsequent sieve or another sorting method.

Used filler can be regarded as a secondary product which is forming during the processing of renewable resources. Use of these secondary raw materials is important in terms of the profitability of the entire molding process. The mechanical properties of filled epoxy and polyurethane resins are thoroughly described. These resins were deliberately chosen. According to a number of authors [2, 3, 7], these resins (adhesives) are among the resin which can be easily filled with both, inorganic and organic fillers. These resins are also used in combination with natural fillers in many types of industries - for example in the automotive industry, where epoxides, but also polyurethane, are used with the fiber but also the particle reinforcements.

2.0 EXPERIMENTAL

2.1 Materials and Methods

Microparticles prepared from the seed cake (SC) after oil extraction were used as a filler. Jatropha Curcas L. seeds were pressed by Labor Tech MP Test 5.050 machine, and the pressure of 5 kN was applied. Deformation speed corresponded to 10 $mm \cdot min^{-1}$. After oil pressing, the knife mill (20 000 $turns \cdot min^{-1}$) was used for milling of seed cake. Microparticles were dried at 105 °C for 20 hours before their were applied as a filler into the resins.

Matrix was formed by epoxy resins Glue Epox Rapid, Epoxy 1200/324 and by polyurethane resin Sika Force 7723. Test samples were created by 5-35 vol.% of the filler (SC) in the matrix. The mixture of the resins and the filler was prepared by a mechanical mixing. The test samples for hardness and abrasive wear testing were cast into forms which are made of the silicone rubber and were hardened according to technological requirements of the resins producer.

Perfect wetting ability of particles' surface was expected in interaction between filler and polymer matrix. It was necessary to define porosity (*P*) as an index of quality of polymer composites (see Eq. 1):

$$P = \frac{\rho_{The} - \rho_{\mathrm{Rea}}}{\rho_{The}} \cdot 100 \qquad (1)$$

where:

P – porosity (%),
ρ_{The} – theoretical composite density ($g \cdot cm^{-3}$),
ρ_{Rea} – real composite density ($g \cdot cm^{-3}$).

The hardness of test specimens was measured by the method Shore D – CSN EN ISO 868. The two body abrasion was tested on a rotating cylindrical drum device with the abrasive cloth of the grain size P220 (Al_2O_3 – F80) according to the standard CSN 62 1466. The testing machine with the abrasive cloth consists of the rotating drum on which the abrasive cloth is affixed by means of a bilateral adhesive tape. The testing specimen is secured in the pulling head and during the test it is shifted by means of a moving screw along the abrasive cloth from the left edge of the drum to the right one. The testing specimen is in the contact with the abrasive cloth and it covers the distance of 60 mm. The testing specimens left above the abrasive cloth surface after one drum turn of 360°. Consequent impact of the testing specimens simulates the concussion. The pressures force is 10 N. The mean of the testing specimens 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 weight and on the theoretical density of the composite systems.

3.0 RESULTS AND DISCUSSION

The average particle size was 573 ± 278 μm, the size distribution of the SC particles is shown in Figure 1 - histogram.

A density of epoxy resins (Epoxy 1200/324, Glue Epox Rapid) corresponded to 1.15 $g \cdot cm^{-3}$, a density of polyurethane resin Sika Force 7723 corresponded to 1.50 $g \cdot cm^{-3}$, a density of microparticles was 0.81 ± 0.11 $g \cdot cm^{-3}$. The porosity and density of the biocomposites are shown in Table 1.

The hardness (Shore D) of biocomposite systems is presented in Fig. 2. The hardness of the unfilled resins corresponded to 87.6 (Glue Epox Rapid), to 89.8 (Epoxy 1200/324) and to 67.5 (Sika Force 7723). The presence of SC particles reduces hardness (see ANOVA analysis Figure 2). The variation coefficient does not exceed 3.1%.

Two-body abrasive resistance expressed by volume losses is presented in Figure 3. The presence of particles increased the volume losses, i.e. decreased the two-body abrasion resistance of these biomaterials. Temperature of the interface of worn areas of test samples was measured during abrasion wear by noncontact laser thermometer. Average temperature measured on two body abrasion reached value of 39.8 ± 3.2 °C.

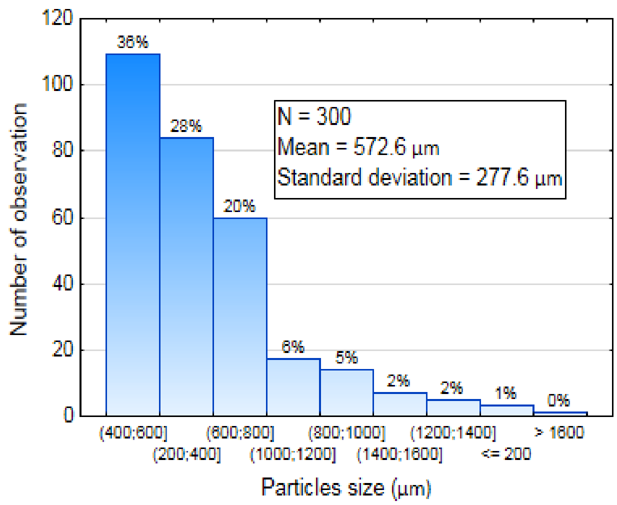

Figure 1. Histogram – Pareto analysis (left), Microparticles (filler) and their preparation – from top: original commodity - seeds, secondarily arisen product after pressing - seed cake, milled SC particles (right)

Table 1 Theoretical density and porosity of biocomposite systems

vol.%	**Glue Epox Rapid**		**Epoxy 1200/324**		**Sika Force 7723**	
	ρ_{The} (g cm^{-3})	**P (%)**	**ρ_{The} (g cm^{-3})**	**P (%)**	**ρ_{The} (g cm^{-3})**	**P (%)**
0	1.15	-	1.15	-	1.50	-
5	1.13	3.2	1.13	3.4	1.47	4.1
10	1.12	1.8	1.12	4.6	1.43	3.3
15	1.10	4.2	1.10	3.9	1.40	5.3
20	1.08	3.1	1.08	4.0	1.36	3.5
25	1.07	2.5	1.07	3.9	1.33	2.6
30	1.05	2.2	1.05	4.4	1.29	3.1
35	1.03	1.8	1.03	3.7	1.26	4.9

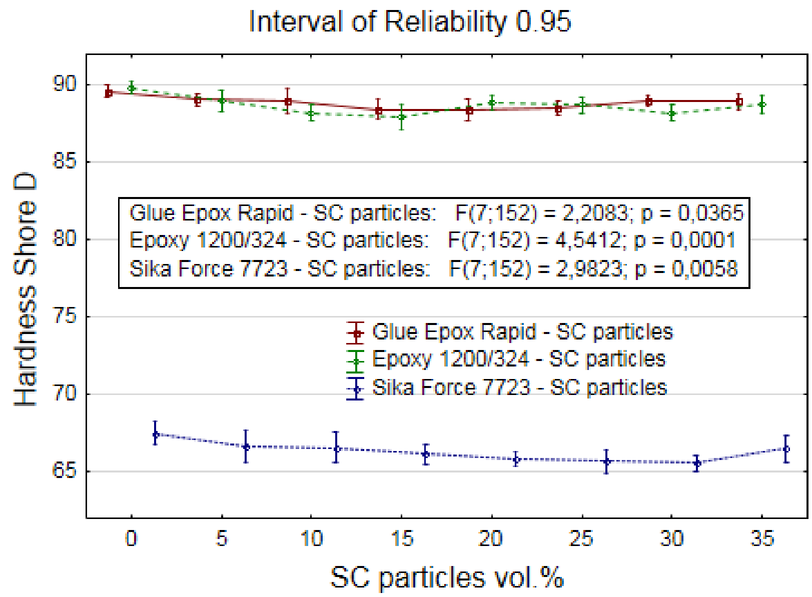

Figure 2 Biocomposites hardness – Shore D

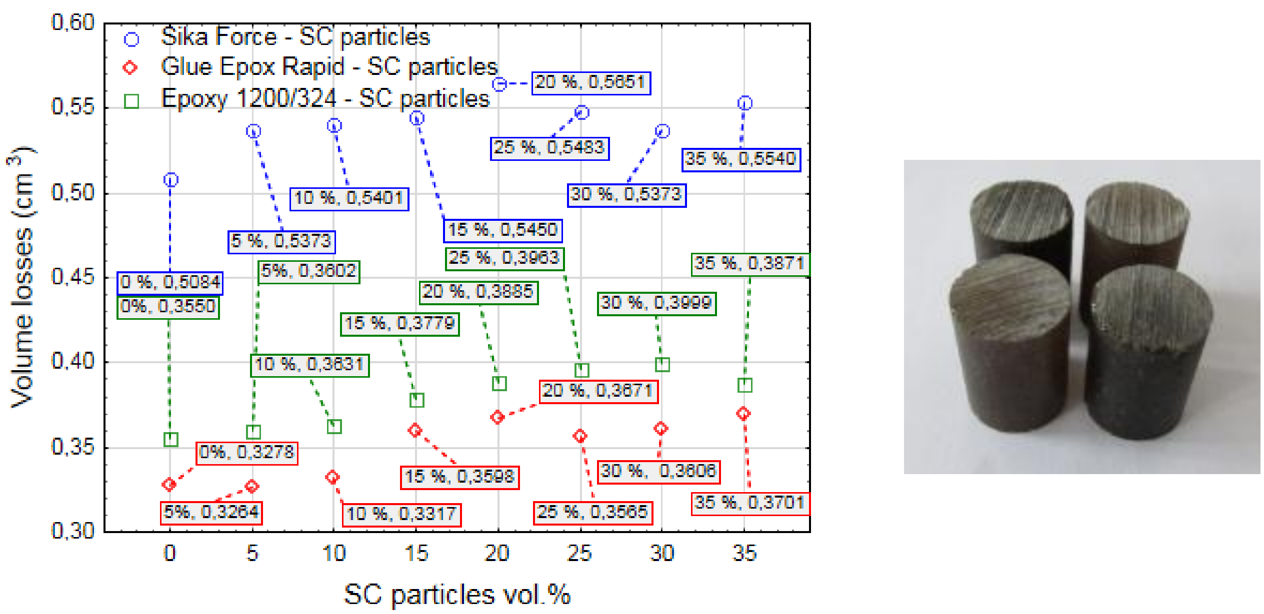

Figure 3 Abrasive wear resistance of biocomposites (upper), test samples after abrasion (lower)

4.0 CONCLUSION

Used resins together with SC particles created new materials - mutual interaction between phases was satisfactory and the porosity did not exceed 5.3%.

The results of this experiment confirmed that it is possible to use parts of plant Jatropha Curcas L. in the interaction with reactive resins (epoxies, polyurethane), which are commonly used in composite systems. Used microparticles can be considered as secondary materials generated during the pressing of the seeds. To make the whole process of pressing oil from these seeds profitable, the use of secondary commodities that arise in this process must be considered. The mechanical properties, which are described in this experiment, are important for determining the application areas. The mutual interaction of these particles and resins can be used for example when creating boards which can substitute with similar products made of conventional materials - wood. Since the renewable materials are increasingly preferred, describing the possible use of secondary commodities produced during their processing is an important topic. A material utilization described in this paper should be preferred over other options (eg. Energy recovery).

The measured results show that there is not a significant difference between resins and changes in the mechanical properties which arisen by microparticles inclusions. Inclusion of filler led to similar changes in the mechanical properties of both epoxides and polyurethane.

The results of the experiment can be summarized as follows – the highest decrease of hardness (Shore D) was 1.8% - Epoxy 1200/324, 1.5% - Sika Force 7723 and 1.4% - Glue Epox Rapid. The decreases in abrasive wear resistance of biocomposites corresponded to 12.6% (Epoxy 1200/324), to 11.2% (Sika Force 7723) and 11.1% (Glue Epox Rapid). Experiment has proved the same results as were obtained in work by Shivamurthy et al. [2] and Kumar et al. [5], who described the interaction of polymer resins and fillers based on microparticles from Jatropha Curcas L. seed cake.

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