Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 136 (2016) 169 – 174

Procedia Engineering

www.elsevier.com/locate/procedia

The 20th International Conference: Machine Modeling and Simulations, MMS 2015

Three-body abrasive wear of polymer matrix composites filled with Jatropha Curcas L.

Petr Hrabě[a,*], Miroslav Müller[a]

CULS Prague, Faculty of Engineering, Department of Material Science and Manufacturing Technology, Kamycka 129, Praha 6 – Suchdol, Czech Republic

Abstract

Polymers and their composites are widely used for their specific properties. This paper deals with composite materials based on Jatropha Oil Cake. The research was focused on influence of a mass concentration of Jatropha Oil Cake, as the filler in epoxy adhesive, on hardness and abrasion resistance. In the experiments various mass concentrations of Jatropha Oil Cake from 5 to 30% were used. Composite materials were subjected to measurement of Shore D hardness and abrasion resistance of the three-point method according to ASTM - G65. The results were analysed by statistical method ANOVA. Moisture of filler was 4.59 ± 0.22% WB. Results show that composite materials have higher weight loss than the matrix if free abrasives (fraction F60) were applied. When the free abrasives F400 were used, composite material showed comparable results with the matrix. Using of filler had no effect on changes of hardness according to Shore D. The advantage of composite systems based on Jatropha Oil Cake is utilization of waste from the presswork process that is difficult to use in the future. For example it cannot be used as a feed for animals.

Peer-review under responsibility of the organizing committee of MMS 2015

Keywords: abrasive; Jatropha Curcas L.; composite, hardness; Jatropha Oil Cake

1. Introduction

With the increasing use of a biological material in the composite production, a reduced demand for oil-based raw materials can be expected [1]. A fibre or particle reinforced polymer matrix has considerable attention in recent years due to the high specific strength, specific modulus and wear resistance in a comparison with metal-based

* Corresponding author. Tel.: +420224383274; fax: +420234381828.
E-mail address: hrabe@tf.czu.cz

1877-7058
Peer-review under responsibility of the organizing committee of MMS 2015
doi:10.1016/j.proeng.2016.01.192

materials. Pieces of equipment that are used for the treatment of soil, coal and cement are typical examples of abrasion during their work. Composite parts such as gears, seals, cams etc. are used in the automotive industry and can be found also in aerospace applications [2–4]. In light of the above mentioned information a thorough understanding of tribological properties of composite materials can be seen as very important [5, 6]. Tribological interactions of solid material, composite surface on the exposed side of the interface material and the environment, may lead to loss of material from the surface and they are known as a "wear" [7–10]. Abrasive wear is caused by hard particles that slide on a solid surface [11]. The mechanism of abrasive wear of polymers and polymer composites was dealt in some publication in the past [12–14].

Improvement of polymer tribological properties, when the filler is used, is well known. The use of fibres showed as positive as negative results on tribological properties of the polymer [2, 8]. There are two reasons to use the filler in a combination with a polymer: firstly to improve the tribological, [7] mechanical and thermal properties, and secondly to reduce the cost of final product. The high cost of conventional fillers leads to the use of alternative low-cost fillers to improve tribological properties of composites. One possibility is to use Jatropha Oil Cake, it is a by-product from the mechanical oil extraction of Jatropha seed. In the process of extraction of seeds about 500 – 600 $g.kg^{-1}$ of Jatropha Oil Cake can be obtained [15]. The protein content of Jatropha Oil Cake is higher than soya cake or semolina [16]. It is edible and renewable source, and in the future it may have a great potential in the production of biodiesel [17–19]. During the next years it is expected increasing use of biodiesel as an alternative source to oil, due to the depletion of fossil fuels and with respect for the environment. A current research is therefore focused on the evaluation of Jatropha Oil Cake as the filler in composites for tribological applications.

This article deals with the wear of composite material, where a two-component adhesive is as a matrix and filler (discontinuous phase) is Jatropha Oil Cake. The aim of the research was material use of the waste from the presswork/extraction process of Jatropha seeds.

2. Material and methods

Objects of experiments were polymer composites consisted of two phases: continuous phase in the form of a two-component epoxy adhesive, and the discontinuous phase (reinforcing particles) in the form of Jatropha Oil Cake (Fig. 1). The wear and hardness according to Shore D were experimentally investigated.

The filler was obtained as a waste from the seeds of Jatropha during the presswork process. This waste of the process (Cake) was dried to a moisture content 4.59 ± 0.22 % WB and subsequently adjusted the size of particle by crushing. The filler thus obtained has not been further modified, e.g. fractionated.

Fig. 1. Jatropha Oil Cake.

The concentration of subcomponents was determined and expressed in percentages by weight. Test specimens were made in the concentrations of 5, 10, 20, 30, 40 and 50 % of Jatropha Oil Cake.

The moulds for casting were made from the material Lukapren N using models. The form and size of moulds meets the corresponding standards.

Hardness SHORE D: Material hardness was measured by Shore D i.e. by pressing the tip of the instrument durometer Shito HT. The hardness SHORE D was measured according to the standard CSN EN ISO 868. Test specimens were 5 mm high.

In the wear tests the device utilizing free abrasive particles, specifically apparatus with a rubber wheel was used, which is shown in Fig. 2. The device has a diameter of the rubber wheel 130 mm, width of the wheel 10 mm and a speed of 345 r.p.m. The test load was achieved by weight of 580 g, it means that the specimen was pressed by force of 32 N. As abrasive the synthetic corundum of a fraction F60 and F400 was used. A proper amount of abrasive was weighted to ensure 1 minute for the test process. For this purpose scales OHAVC CL SERIES with accuracy 0.1 g was used. The specimens were washed and dried after each test and then weighted on the scales KERN ABS with accuracy 0.0001 g.

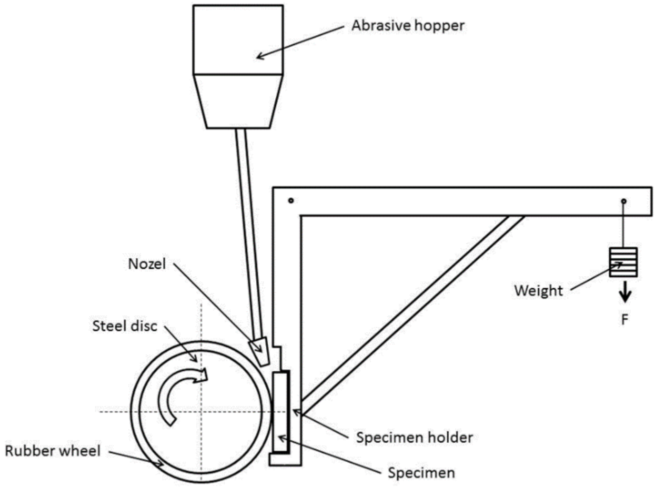

Fig. 2. Scheme of device with rubber wheel.

3. Results and discussion

Hardness SHORE D: Material hardness was measured by Shore D i.e. by pressing the tip of the instrument durometer Shito HT. The hardness SHORE D was measured according to the standard CSN EN ISO 868. Test specimens were 5 mm high.

During the statistical comparison ANOVA F-test was used. The zero hypothesis H_0 was determined as a state when there is no statistically significant difference among the mean values of compared data sets: $p > 0.05$.

In terms of the effect of the Jatropha Oil Cake concentration and using of abrasives F60 and F400 to wear, there can be found results of ANOVA F-test as follows:

- H_0 hypothesis was not confirmed in the wear when the free abrasive F60 ($p = 0.00001$) and F400 ($p = 0.0064$) was used, i.e. the difference is in the significance level of 0.05 among the particular tested concentrations of fillers.
- H_0 hypothesis was not confirmed in abrasive wear of composite materials at a filler mass concentration of 5 % ($p = 0.0027$), 10 % ($p = 0.0036$), 20 % ($p = 0.0051$), 30 % ($p = 0.0008$), 40 % ($p = 0.0047$) and 50 % ($p = 0.0035$), i.e. the difference is in the significance level of 0.05 among the particular tested abrasives F60 and F400. The hypothesis H_0 was confirmed in the matrix, i.e. the composite consisting of 0 % of filler ($p = 0.8623$), i.e. there is no difference in the significance level of 0.05 among the particular tested abrasives F60 and F400.

In terms of the influence of the concentration of Jatropha Oil Cake on hardness by Shore D, the results of ANOVA F-test are as follows:

- H_0 hypothesis was confirmed in the case of hardness by Shore D, i.e. there is no difference in the significance level of 0.05 among the particular tested concentration of filler (p = 0.0609).

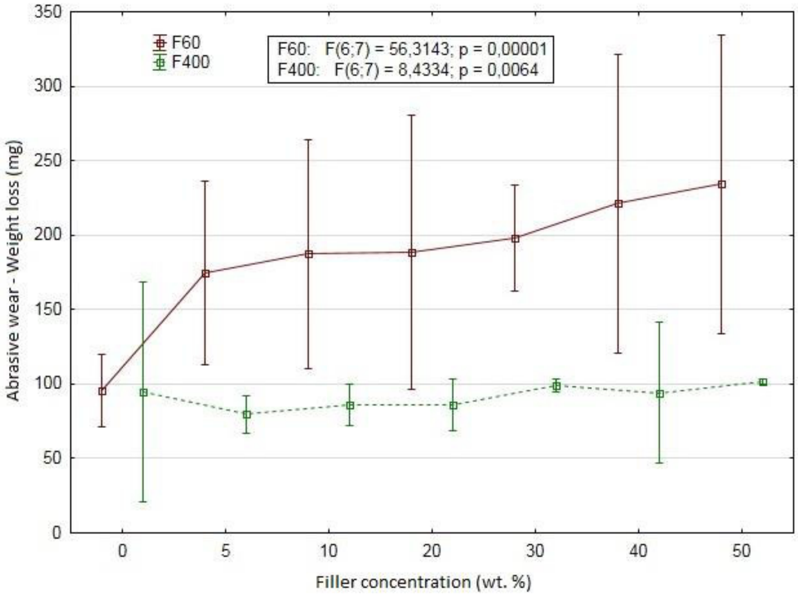

Fig. 3. Effect of mass concentration of Jatropha Oil Cake on abrasive wear of composite materials.

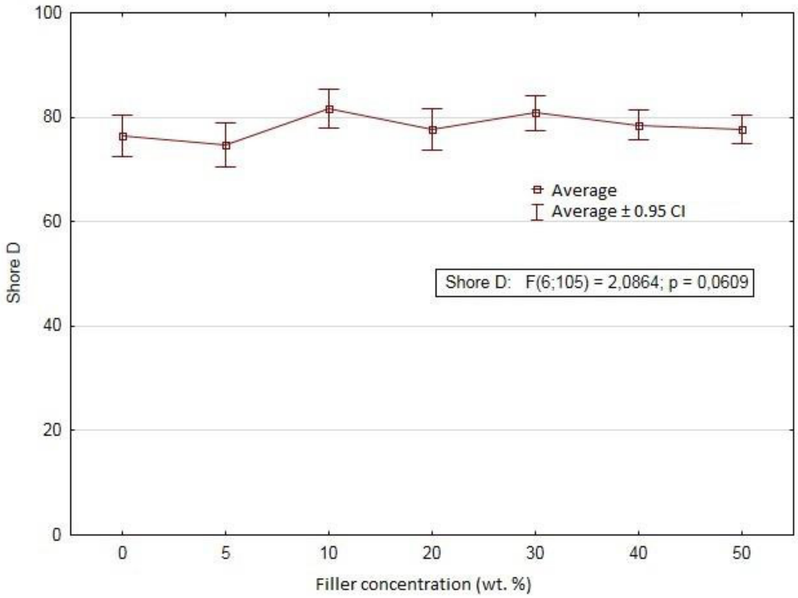

Fig. 4. Effect of mass concentration of Jatropha Oil Cake on hardness by Shore D.

When the free abrasives F60 were used, a composite material showed higher weight loss than the matrix. The worn surface was rougher in the compare to surface after abrasive F400. It was achieved higher weight loss that is probably affected by bigger size of abrasive and also to fact that during the process of abrasion there are some particles ripped out from the composite matrix. The specific size of abrasive grains in a fraction F60 was mainly 275 μm and in a fraction F400 was 17.3 μm. According to above mentioned facts it can be said that the application of the F60 leads to higher wear. As it can be seen on the Fig. 5 the abrasion wear is almost exclusively on the matrix, the filler is protuberant above the surface, or ripped out from the matrix.

When the free abrasives F400 were used, composite material showed comparable results with the matrix. As it can be seen from the Fig. 5, the matrix is worn as well as filler, i.e. there is any delamination of filler and matrix. The worn surface is shiny and scratched due to abrasive grains, which is visible also on the filler.

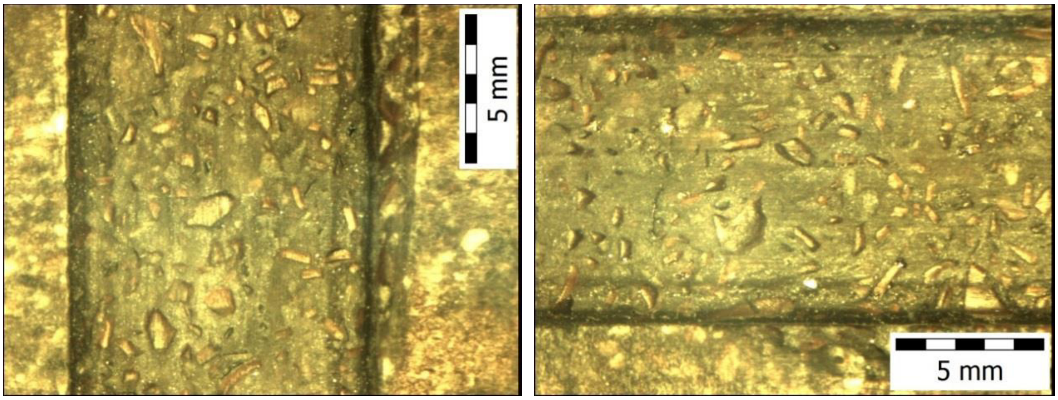

Fig. 5. Test samples after abrasive wear: left – fraction F400 was used, right – fraction F60 was used.

In Fig. 3 it can be seen that increasing mass concentration of Jatropha Oil Cake in the matrix does not lead to increase of hardness (by Shore D) of the composite materials in the range of 5 to 50 %. The different experiments were performed for different types of fillers [2, 3, 6, 7], as for example SiC, glass fibres etc. It was verified that the final hardness depends on the type of filler that is used. In the case of the experiments which are described in this paper, the addition of Jatropha Oil Cake as a filler has no effect on hardness with increasing ratio of the filler in the composite in comparison with the unfilled composite. The addition of Jatropha Oil Cake as a filler does not affect the hardness of the material under consideration.

Adding filler into thermosetting epoxy-based matrix affects the mechanical properties of the composite as it is described in the literature [20–23].

Filler composite material may be different Al_2O_3, SiC, glass beads, minerals, various metals, rubber particles [9, 10]. Mechanical properties of polymer composites strongly depend on the particle size of filler [24].

A synergic effect is not always achieved, i.e. a significant improvement of mechanical properties. In some cases the cost of adhesive can be reduced due to its composite based while the properties can be comparable with unfilled adhesive. If the final results are negative, the Jatropha Oil Cake may be used for energy purposes [25–27].

4. Conclusion

The following conclusions can be written from the experimental tests of three-body abrasive wear of filled and unfilled composite materials, where Jatropha Oil Cake was used as the filler.

- The weight losses were similar for filled and unfilled composites when the abrasive F400 was used. Even the change of a mass ratio of the Jatropha Oil Cake in the composite has no effect on the weight losses.
- It was a found that in the case when the abrasive F60 was used, the increasing weight ratio of Jatropha Oil Cake in the composite led to increase weight loss.

- The hardness did not change with increasing ratio of Jatropha Oil Cake in the composite.
- Using Jatropha Oil Cake as filler in composites, may reduce the cost of manufacture of composites, therefore the direction of next research is how a fraction size of Jatropha Oil Cake affects the mechanical properties of composites.

Acknowledgement

This paper has been done when solving the grant IGA TF (No.: 2015:31140/1312/3106).

References

[1] J. Ružbarský, M. Müller, P. Hrabě, Analysis of physical and mechanical properties and of gross calorific value of Jatropha curcas seeds and waste from pressing process, Agronomy Research 12 (2014) 603–610.
[2] N.S.M. El-Tayeb, B.F. Yousif, T.C. Yap, Tribological studies of polyester reinforced with CSM 450-R-glass fiber sliding against smooth stainless steel counter face, Wear 261 (2006) 443–452.
[3] H. Pihtili, N. Tosun, Effect of load and speed on the wear behaviour of woven glass fabrics and aramid fibre-reinforced composites, Wear 252 (2002) 979–984.
[4] J. Krmela, V. Krmelová, Investigation of tire as a composite structure, in: 11th International Symposium on Stability, Vibration, and Control of Machines and Structures, 2014, 165–179, ISBN 978-80-8075-655-0.
[5] N.S.M. El-Tayeb, B.F. Yousif, Evaluation of glass fibre reinforced polyester composite for multi-pass abrasive wear applications, Wear, 262 (2007) 1140–1151.
[6] B.F. Yousif, N.S.M. El-Tayeb, Effect of water as lubricant on friction and wear properties of CGRP composite evaluated by POD and BOR techniques, Surf. Rev. Lett. 14 (2007) 185–191.
[7] P. Valášek, M. Müller, Abrasive wear in three-phase waste-based polymeric particle composites, Tehnicki Vjesnik-Technical Gazette 12(2) (2015) 257–262.
[8] M.N. Satheesh Kumar, Z. Yaakob, N Mohan, Siddaramaiah, S.P. Kumaresh Babu, Mechanical and Abrasive Wear Studies on Biobased Jatropha Oil Cake Incorporated Glass–Epoxy Composites, Journal of the American Oil Chemists' Society 87 (2010) 929–936.
[9] P. Valášek, M. Müller, Aplikace otěruvzdorných polymerích částicových kompozitů v oblasti konstrukce orebního tělesa, Listy cukrovarnické a řepařské 130(9-10) (2014) 284–288.
[10] M. Müller, P. Novák, P. Hrabě, Inovace materiálově konstrukčních řešení plužní čepele v oblasti konvenčního zpracování půdy při pěstování cukrové řepy, Listy cukrovarnické a řepařské 130(3) (2014) 94–99.
[11] Standard terminology relating to wear and erosion, Annual book of standards, ASTM, 1987, 03.02:243–250.
[12] J. Pirso, M. Viljus, K. Juhani, S. Letunovits, Two-body dry abrasive wear of cements, Wear 266 (2009) 21–29.
[13] K. Friedrich, P. Reinicke, Friction and wear of polymer based composites, Mech Compos Mater 34 (1998) 503–514.
[14] H. Pihtili, N. Tosun, Investigation of the wear behaviour of a glass-fibre-reinforced composite and plain polyester resin, Compos. Sci. Tech. 62 (2002) 367–370.
[15] M.N. Satheesh Kumar, Z. Yaakob, R.S. Abdulla, Applications of jatropha oil seed crop, Recent Pat. Mater. Sci. 2 (2009) 131–139.
[16] H.P.S. Makkar, G. Francis, K. Becker, Protein concentrate from Jatropha curcas screw-pressed seed cake and toxic and antinutritional factors in protein concentrate, J. Sci. Food Agric. 88 (2008) 1542–1548.
[17] M. Petrů, O. Novák, D. Herák, S. Simanjuntak, Finite element method model of the mechanical behaviour of Jatropha curcas L. seed under compression loading, Biosystems Engineering 111(4) (2012) 412–421.
[18] D. Herak, A. Kabutey, M. Divisova, S. Simanjuntak, Mathematical model of mechanical behaviour of Jatropha curcas L. seeds under compression loading, Biosystems Engineering 114(3) (2013) 279–288.
[19] D. Herak, A. Kabutey, P. Hrabe, Oil point determination of Jatropha curcas L. bulk seeds under compression loading, Biosystems Engineering 116(4) (2013) 470–477.
[20] D. Galusek, J. Sedláček, R. Riedel, Al2O3-SiC composites prepared by warm pressing and sintering of an organosilicon polymer-coated alumina powder, Journal of the European Ceramic Society 27(6) (2007) 2385–2392.
[21] H.S. Kim, M.A. Khamis, Fracture and impact behaviours of hollow micro-sphere/epoxy resin composites, Composites Part A: Applied Science and Manufacturing 32(9) (2001) 1311–1317.
[22] B. Agoudjil, L. Ibos, J.C. Majeste, Y. Candau, Y.E.P. Mamunya, Correlation between transport properties of Ethylene Vinyl Acetate/glass, silver-coated glass spheres composites, Composites Part A: Applied Science and Manufacturing 39(2) (2008) 342–351.
[23] M. Müller, P. Valášek, Abrasive wear effect on Polyethylene, Polyamide 6 and polymeric particle composites, Manufacturing Technology 12(12) (2012) 55–59.
[24] F. Shao-Yun, F. Xi-Qiao, L. Bernd, M. Yiu-Wing, Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate–polymer composites, Composites: Part B 39 (2008) 933–961.
[25] J. Ružbarský, M. Müller, J. Mareček, M. Geršl, Jatropha curcas-analysis of gross calorific value, Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 62 (2014) 1381–1384.
[26] J. Malaťák, J. Bradna, Use of waste material mixtures for energy purposes in small combustion devices, Res. Agr. Eng. 60 (2014) 50–59.
[27] J. Malaťák, T. Dlabaja, Hydrothermal carbonization of stabilized sludge and meat and bone meal, Res. Agr. Eng. 61 (2015) 21–28.