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Recycling of Polyamide from Scrap Tyres as Polymeric Composites

M. Müller[1], J. Žarnovský[2], R. Drlička[2]

[1]*Department of Material Science and Manufacturing Technology, Faculty of Engineering, Czech University of Life Sciences Prague, Prague, Czech Republic*
[2]*Department of Quality and Engineering Technologies, Faculty of Engineering, Slovak University of Agriculture in Nitra, Nitra, Slovak Republic*

Abstract

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Rubber granulate, metal waste and textile waste (polyamide fibres) come into the mechanical process of waste tyres recycling. The pollution and degradation processes are problematic in using of secondary raw material. The matrix was in the form of three various adhesives in testing – two-component epoxy adhesives and a polyester adhesive. The filler was in the form of textile waste (polyamide fibres) from the process of tyres recycling containing approximately 10–12% of rubber granulate. The filler was added in app. 15% of weight ratio into the matrix. The aim of the research was to determine a possible utilisation of unsorted textile waste from the process of tyres recycling in the area of polymeric composite systems.

Keywords: adhesives; composite mixture; deformation; impact strength; tensile strength; polymers; waste

The present consumer society has to deal with an effective recycling of waste (especially polymeric) globally (Müller, Valášek 2012).

An improvement has been achieved in the technology of polymers recycling. Depolymerisation by chemical recycling is a way to replay original monomers. However, the complexity of systems and high cost of operation are two difficulties of this method. The burning of polymers to recover the energy is used, too. In this situation, environmental benefits are questionable. Mechanical recycling is an interesting alternative that can combine the technical viability, acceptable costs and environmental benefits. Contamination with impurities and other polymers as well as the degradation of the material are the main difficulties of this method of recycling polymers (Ferreira et al. 2013).

One of the significant representatives of waste is tyres. When the tyre cannot be already further used in the original form, the material can be unvalued for the production of new products, e.g. in the form of composite products. The rubber granulate, metal and textile are outcomes from the mechanical process of recycling. These materials are possible to be used as the filler for the production of composite materials.

Fillers are used for the optimisation of some mechanical properties and price. Fillers based on secondary raw materials are specific for their low prices; however, fillers on the basis of waste can be

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of inconstant properties, which can be checked by destructive methods. The utilisation of secondary raw materials – waste materials – as the fillers of composite systems is an alternative to another handling with these commodities (Valášek et al. 2013; Valášek, Müller 2014).

Composite materials find their application in many industrial branches for their specific properties (Kejval, Müller 2013; Valášek, Müller 2014). Polymer particle composites combine the mechanical properties of the filler and matrix (Valášek et al. 2012). For specification of mechanical properties with consideration of economic indicators at the same time, their behaviour and the research connected with it are important.

The substantial change of mechanical properties can be reached by addition of optimum filler content into adhesives. In this way, the polymeric composite of specific properties comes into being (Drlička et al. 2004; Mikuš et al. 2005; Valášek, Müller 2012a,b, 2013).

All the parameters on which the properties of composite materials depend are connected either with their structure or with interphase relations. Single phases influence the material resulting properties partly by their own characteristics, partly by the mutual interaction of the matrix and the filler (Dong et al. 2006). Thanks to interactions among single components, it is possible to reach other good-quality materials (Byung et al. 2008; Weizhou et al. 2009).

From the point of view of composite systems strength, the interphase boundary is a key. Unperfected wetting of the matrix and filler leads to initiation of cracks and to their spreading, which can lead up to failure.

A basic assumption for optimum choice of materials is the knowledge of applied material behaviour. The aim of the research was to set a possible utilisation of unsorted textile waste from the process of tyres recycling in the area of polymeric composite systems.

MATERIAL AND METHODS

The subject of performed experiments was the polymeric composite, the continuous phase of which was in the form of two-component epoxy and polyester adhesive and the discontinuous phase (reinforcing particles) in the form of polyamide (PA) (fibres). Tensile stress, deformation and impact strength were determined by experiments.

The following matrices were used for the research:

– Two-component epoxy constructional adhesive Lepox (Lach-Ner, Neratovice, Czech Republic) (marked L);
– Two-component epoxy constructional adhesive Gluepox Rapid (DCH Sincolor, Plzeň, Czech Republic) (marked R);
– Polyester grouting resin MTB (DCH Sincolor, Plzeň, Czech Republic) (marked P).

The determination of component parts concentration was expressed by means of ratios in weight percentage.

The filler was added in app. 15% of weight ratio into the matrix (L, R and P).

The moulds for casting of tested samples were made from the material Lukapren N (Lučební závody, Kolín, Czech Republic) using the prepared models. The shape and sizes of moulds meet the corresponding standards.

By mixing the specified ratio of the matrix and filler, the composite was made, which was used for preparation of test specimens according to the specified standards.

Test specimen preparation and destructive tests were performed according to the standard ČSN 64 0611:1968 (Determination of the impact resistance of rigid plastics by means of Dynstat apparatus). Impact strength was determined by destructive testing.

Test specimens for tensile properties determination according to the standard ČSN EN ISO 527-1:1997 (Plastics – Determination of tensile properties – Part 1:

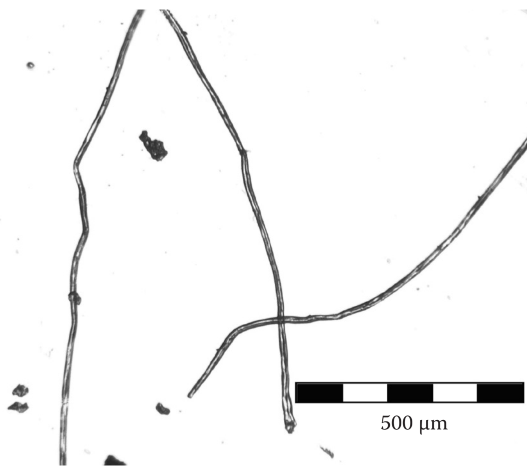

Fig. 1. Filler – polyamide fibre and rubber particles

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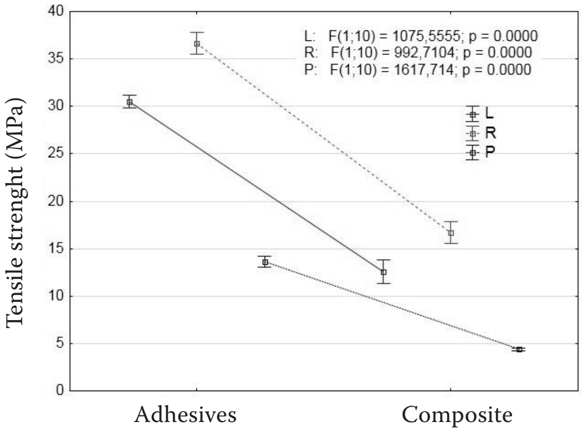

Fig. 2. Tensile strength of adhesives and composites systems

L – Lepox; R – Gluepos Rapid; P – Polyester MTB

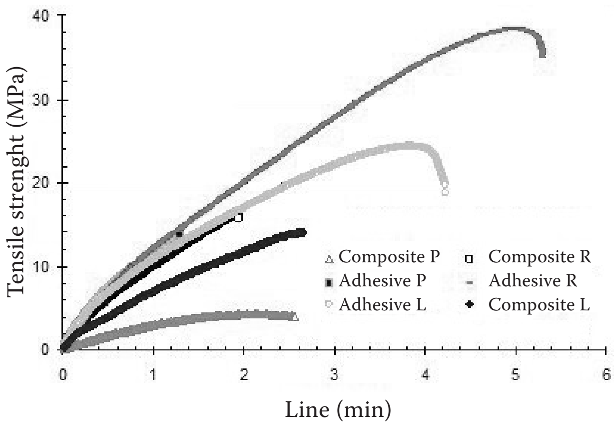

Fig. 3. Tensile diagram

L – Lepox; R – Gluepos Rapid; P – Polyester MTB

General principles) were prepared according to the standard ČSN EN ISO 3167:2015 (Plastics – Multipurpose test specimens). Tensile strength and deformation were determined by destructive testing.

The tensile strength and the deformation tests were performed using the universal tensile strength testing machine LABTest 5.50ST (the sensing unit AST type KAF 50 kN, evaluation software Test&Motion). Speed of deformation corresponded to 6 mm/min.

RESULTS AND DISCUSSION

The tests set from 10.26% to 11.46% of rubber at the polyamide mixture. The meaning of recycling the fibre was evaluated on the basis of picture analysis. Evaluation was performed using the microscope Jenavert PA HD with the camera ARTCAM 300 MI (ARTRAY, Tokyo, Japan) (Fig. 1). The width of the fibre was 16.27 ± 4.24 μm.

The graphic presentation of results of the tensile strength of adhesives and composite systems prepared by ANOVA can be seen in Fig. 2.

ANOVA was used for statistical comparison. The zero hypothesis H_0 presents the state when there is no statistically significant difference ($P > 0.05$) among the tested sets of data (adhesives and composite) from the point of view of their mean values.

The hypothesis H_0 was not confirmed. There is a difference among the tested sets at the significance level 0.05. The dependence curves of the cross-bar motion line and tensile strength in particular variants of experiment are visible from tensile diagrams (Fig. 3).

The graphic presentation of results of the deformation of adhesives and composite systems can be seen in Fig. 4a. No explicit trend follows from the results. The deformation of composite systems

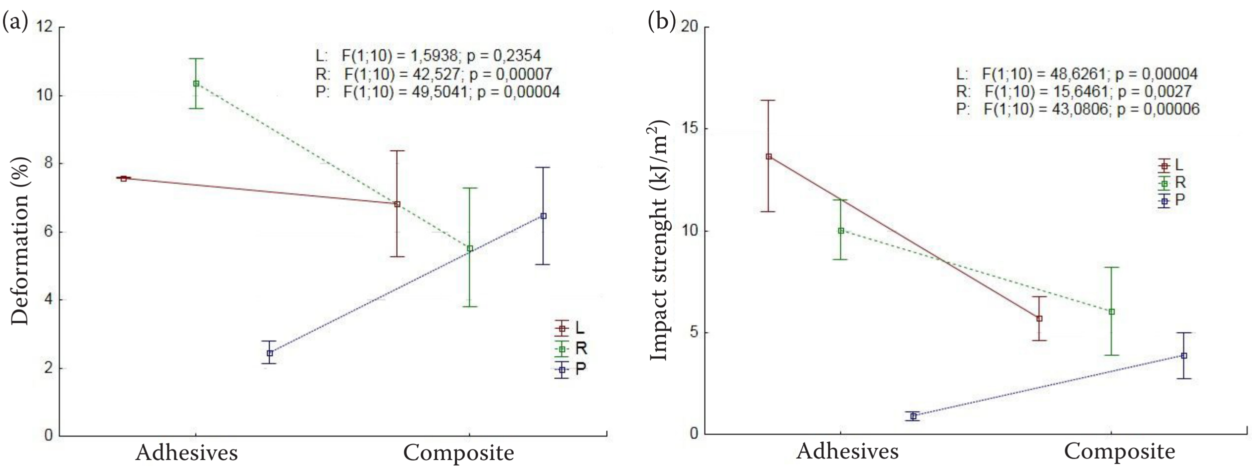

Fig. 4. Deformation (a) and (b) impact strength of adhesives and composite systems

L – Lepox; R – Gluepos Rapid; P – Polyester MTB

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based on the matrix L and R is decreasing. It is increasing in the system based on the matrix P.

The zero hypothesis H_0 presents the state when there is no statistically significant difference (P > 0.05) among the tested sets of data (adhesive and composite) from the point of view of their mean values. The hypothesis H_0 was not confirmed in the systems R and P. There is a difference among the tested sets at the significance level 0.05.

The hypothesis H_0 was confirmed for the adhesive and composite L (P = 0.2354), so there is no difference among single tested sets (adhesive and composite) at the significance level 0.05.

The graphic presentation of results of the impact strength of adhesives and composite systems can be seen in Fig. 4b.

No explicit trend follows from the results. The impact strength of composite systems based on the matrix L and R is decreasing. It is increasing in the system based on the matrix P. Similar results were ascertained in deformation.

The zero hypothesis H_0 presents the state when there is no statistically significant difference (P > 0.05) among the tested sets of data (adhesive and composite) from the point of view of their mean values. However, the hypothesis H_0 was not confirmed. There is a difference among the tested sets at the significance level 0.05.

The composite mixture is visible in Fig. 5. It was the composite material with disarranged fibres. The fibres could not be arranged owing to the nature of waste on the basis of polyamide.

On the basis of laboratory results, it is possible to agree with the statement of Weizhou et al. (2009) that epoxy adhesives are of low impact strength and they are brittle.

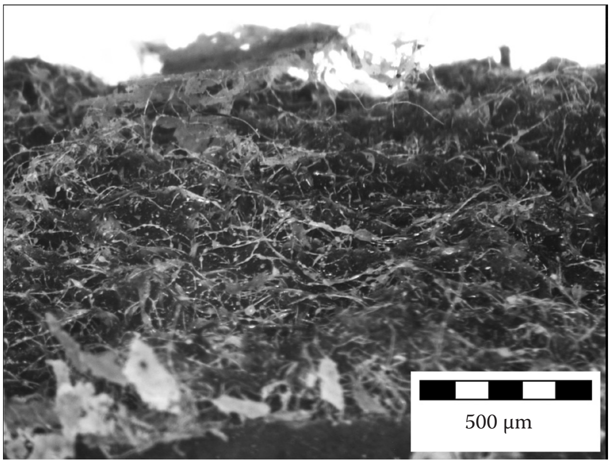

Fig. 5. Composite mixture

The polyester adhesive is of considerably lower impact strength.

Brittleness and decreasing strength are the disadvantages of propounded composite materials. Impact strength increased in the composite with the matrix in the form of polyester adhesive.

The presence of rubber particles can be one of the factors of tensile strength lowering. They can lower the mechanical properties (tensile strength) (Ferreira et al. 2013). Many authors dealt with the research of polymeric particle composites based on the rubber granulate. Mechanical properties showed throughout negative trend (Valášek et al. 2013; Valášek, Müller 2014).

CONCLUSION

The knowledge of applied materials behaviour is the basic presumption for the optimal material choice.

The research results did not prove a benefit in the application of waste polyamide fibres in the composite systems on the basis of polymers.

In the end, it is possible to state the following:

– Tensile strength decreases. The average fall of tensile strength was from 54% to 67% in the application of polyamide fibres.
– Deformation did not have the explicit trend. Deformation in the composite based on the adhesive R decreased. Deformation in the composite based on the adhesive L was stagnating (from the statistical testing point of view). Deformation in the composite based on the adhesive P increased.
– Impact strength did not have the explicit trend. Impact strength in the composite based on the adhesive L and R decreased. It increased in the composite based on the adhesive P.

References

Byung Ch.K., Sang W.P., Dai G.L. (2008): Fracture toughness of the nanoparticle reinforced epoxy composite. Composite Structures, 86: 69–77.

Dong Ch.P. et al. (2006): Wear characteristics of carbon-phenol woven composites mixed with nanoparticles. Composite Structures, 74: 89–98.

Drlička R., Mikuš R., Kročko V. (2004): Optimalizácia materiálu tesnenia veka ježkovacích komôr. In: Quality and Reliability of Machines, Nitra, 2004: 167–169.

doi: 10.17221/51/2015-RAE

Ferreira C.T., Perez C.A.B., Hirayama D., Saron C. (2013): Recycling of polyamide (PA) from scrap tires as composites and blends. Journal of Environmental Chemical Engineering, 1: 762–767.

Kejval J., Müller M. (2013): Mechanical properties of multi-component polymeric composite with particles of Al_2O_3. Scientia Agriculturae Bohemica, 44: 237–242.

Mikuš R., Drlička R., Kročko V. (2005): Riešenie utesňovania ježkovacích komôr plynovodov. Technical Diagnostics, 14: 246–252.

Müller M., Valášek P. (2012): Abrasive wear effect on polyethylene, polyamide 6 and polymeric particle composites. Manufacturing Technology, 12: 55–59.

Valášek P., Müller M. (2012): Influence of bonded abrasive particles size on wear of polymeric particle composites based on waste. Manufacturing Technology, 12: 268–272.

Valášek P., Müller M. (2012): Polymeric particle composites with filler saturated matrix. Manufacturing Technology, 12, 272–276.

Valášek P., Müller M. (2013): Changes of polyurethane mechanical properties filled with glass powder. Manufacturing Technology, 13: 563–568.

Valášek P., Müller M. (2014): EPDM rubber material utilization in epoxy composite systems. Agronomy Research, 12: 291–298.

Valášek P., Müller M., Proshlyakov A. (2012): Effect of sedimentation on the final hardness of polymeric particle composites. Research in Agricultural Engineering, 58: 92–98.

Valášek P., Žarnovský J., Müller M. (2013): Thermoset composite on basis of recycled rubber. Advanced Materials Research, 801: 67–73.

Weizhou J., Youzhli L., Guisheng Q. (2009): Studies on mechanical properties of epoxy composites filled with the grafted particles PGMA/Al_2O_3. Composites Science and Technology, 69: 391–395.

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Corresponding author:

Ing. Róbert Drlička, PhD., Slovak University of Agriculture, Faculty of Engineering, Department of Quality and Engineering Technologies, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic; robert.drlicka@uniag.sk