Degradation of polymer particle systems in agrocomplex

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Abstract

Valášek P., Brožek M., 2013. **Degradation of polymer particle systems in agrocomplex**. Res. Agr. Eng., *59*: 46–50.

One of the possibilities of recycling waste from blasting processes is the application of these secondary materials in polymeric matrix, where the primary material is replaced with the secondary one. By this quite specific recycling process a new material arises – polymeric particle composite. It is a case of two phase system, properties of which are defined by the mutual interaction of single components. One of the possible applications of these systems is agrocomplex. Systems used in agrocomplex environment can be subjected to specific influences, which change their mechanical properties in some time – degradation occurs. This contribution occupies with degradation processes of polymeric particle composites on the basis of waste-corundum after exposure to chosen degradation media, which are typical for agrocomplex environment. Changes of hardness, abrasive wear resistance and tensile strength in dependence on exposure time were tested.

Keywords: abrasive wear; hardness; polymeric particle composites; tensile strength

Polymeric particle composite can be characterized (Berthelot 1998) as material composed from two or more phases that differ in their mechanical, physical and chemical properties. As polymeric matrix a reactoplast can be used in form of epoxy resin. Filler can be deputized by anorganic particles whose dimensions in all three directions are approximately equal (Machek, Sodomka 2008). If the character of these particles does not fall in the category of dangerous waste (according to the valid legislation of the Czech Republic – Act No. 185/2001), we speak about the filler on the waste basis. The application system of waste fillers in the polymeric matrix offers relatively an easy and low-cost way of the material recycling. From literature so-called synergic effect is well known in relation with composite systems, when the final composite properties are determined by connection of single phases, which the composite is composed of (Agarwal, Broutman 1987). The final properties are often better than those which are equivalent to the common summation of properties of the single phases.

From some works (Pošta, Havlíček 1998; Valášek, Müller 2011) it follows that hardness and abrasive wear resistance belong to the important mechanical properties of polymeric particle composites. Then the expected fields of application of the polymeric particle composites on the waste basis are various systems of machine parts renovation and systems for binding (Pošta, Havlíček 1998). These materials application can be relatively wide. Particle composite systems can be applied e.g. in the field of sugar beet technology harvesting, at function parts of combined harvesters, in the field of soil treatment – in the design of plough bottoms, in the field of screw conveyors renovation (Müller et al. 2011).

At application of these materials in agrocomplex, they can be exposed to various aggressive substances

Supported by the Internal Grant Agency of the Faculty of Engineering, Czech University of Life Sciences Prague, Czech Republic, Project No. 31140/1312/3104.

and environs. Therefore it is important to determine in general features their behaviour from the point of view of degradation processes that influence their final mechanical properties and can lead to the limit stage (Müller et al. 2009). In the case of polymeric particle composites it is necessary to verify the hypothesis that at various environs exposure the waste filler does not accelerate substantially the degradation process and that the single phases interaction ensures expected properties in the composite lifespan.

MATERIAL AND METHODS

The reactoplastic matrix was represented by the epoxy resin Eco Epoxy 1200/324 (DCH-Sincolor, Pilsen, Czech Republic), the filler by the waste material from blasting process (catalogue No. 12 01 17 according to the Waste Catalogue of the Czech Republic), blasted material was a common steel. The degradation processes were evaluated using test specimens containing filler on the basis of waste corundum of the fraction F80 (median grain size 147 ± 52 μm, measured by the use of stereoscopic microscope (Artray Co., Ltd., Tokyo, Japan), magnification 300×). The matrix contained 10 volume per cents of the filler. These test specimens were used as reference specimens, too. The shapes and dimensions correspond to relevant standards. They were mould. Moulds were made from silicone rubber.

Hardness Shore D. Hardness *(T)* was measured according to the standard ČSN EN ISO 868 (2003) using test specimens of dimensions 25 × 25 × 17 mm. This surface was later used for the determination of wear resistance. The test basis consists in the measurement of the specific indenter depth of indentation impressed under specified conditions. The hardness value is inversely proportional to the indentation depth and it depends on the modulus of elasticity and on the material viscose-elastic properties.

Abrasive wear resistance. The abrasive wear resistance was based on the standard ČSN 01 5084 (1973). This method was implemented on polymeric materials, analogically as in the following works (Brožek, Nováková 2008; Suresha, Ravi Kumar 2010; Valášek, Müller 2011), where the abrasive cloth on the basis of SiC and of grits 320 and 600 were used for tests.

In the tests carried out the test specimen of dimensions 25 × 25 × 17 mm (Brožek, Nováková 2008) were worn out using the abrasive cloth of the grit P 220. The specimen was pressed against the abrasive cloth by weight of 2.35 kg and during the test was shifted from the edge to the centre of the abrasive cloth fixed on the rotating disk. This process leads to the material separating. The consequence is the weight loss. The weight losses (W_{vz}) were determined by weighing using analytical balance of 1 mg accuracy.

Tensile strength. The tensile strength determination was carried out in accordance with the standard ČSN EN ISO 527-1 (1997). This method is suitable for reactoplastics inclusive those with fillers. The test principle lies in the test specimen deformation in the main longitudinal direction by the constant speed up to its failure or up to the chosen tension or elongation reaching. In the test course the acting force was measured. It is the case of the material destructive testing. The tensile strength is calculated according to the Eq. (1):

$$\sigma_M = \frac{F}{S} \quad (1)$$

where:

σ_M – tensile strength (MPa)

F – measured force value (N)

S – surface of the test specimen initial cross-section (mm^2)

The test specimens for the tensile strength determination were made according to the standard ČSN ISO 3167 (2004).

Due to exposure for 75 days the mechanical properties changes of test specimens were watched in the following mediums: water bath, 15% water solution of NaCl, diesel fuel, 15% water solution of Cererit and air-laboratory environment of 23 ± 1°C. On the basis of analysis of media that can negatively influence the composite system applied in the agrocomplex, the degradation media were chosen. The exposure time of these media action, was 15, 25, 50 and 75 days. After the determined exposure time the test specimens were pulled out from the degradation medium, washed, dried out and tested according to the relevant standards. The test results of the chosen mechanical properties were statistically processed.

RESULTS AND DISCUSSION

In each graphic representation the mean value of the concrete mechanical value is marked. The mean value was calculated from all measured values. After 75 days of exposure time the laboratory environment did not influence any of evaluated mechanical properties. This prerequisite followed from the data

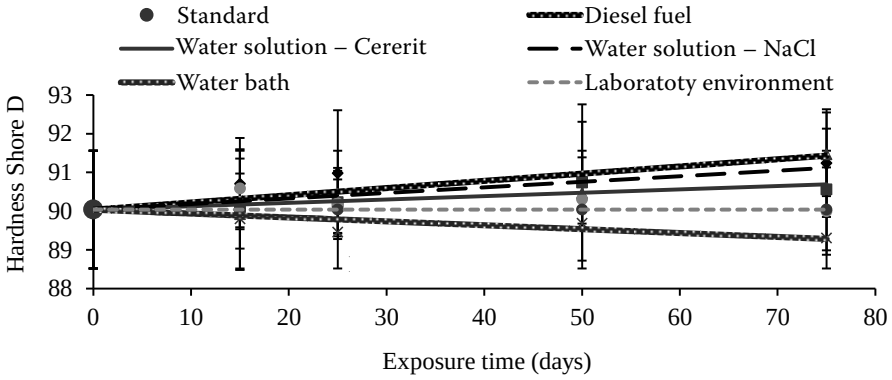

Fig. 1. Degradation process: hardness Shore D – exposure time laboratory environment – const.

Table 1. Functional equations: hardness Shore D (T) – exposure time (d_g)

Diesel fuel	Water solution – Ceretit	Water solution – NaCl	Water bath
$T = 0.0186\ d_g + 90.04$	$T = 0.0087\ d_g + 90.04$	$T = 0.0143\ d_g + 90.04$	$T = -0.0101\ d_g + 90.04$
$R^2 = 0.49$	$R^2 = 0.72$	$R^2 = 0.75$	$R^2 = 0.57$

statistical analysis. It is possible to say that in the given exposure time these data are constant. Therefore it is not possible to create the linear model, the function ANOVA – analysis of variance was used.

Hardness Shore D

The hardness of the composite system before the degradation process was 90.04 ± 1.52 Shore D (standard). Fig. 1 presents the hardness changes in dependence on the exposure time.

The course of the hardness Shore D (T) changes (Fig. 1) in dependence on the exposure time (d_g) in single media is described by following function equations (Table 1). The influence of the laboratory environment did not show any hardness change – the hardness mean value was 90.23 ± 0.21 (const.).

From the measured values it follows that the negative influence on hardness was observed at composites, which were exposed to water bath. After 75 days exposure a slight hardness increase (of 1%) was observed at composites in the medium of diesel fuel. Before the exposure the hardness was 90.04 ± 1.52, after 75 days exposure 91.24 ± 1.39. Owing to the standard deviation value it is possible to say that the final hardness was not substantially influenced by any of degradation media.

Abrasive wear resistance

The abrasive wear resistance expressed by the composite weight loss is presented in Fig. 2. Weight losses before the degradation process were 0.0752 ± 0.003 g. During the exposure time in the laboratory environment the mean weight loss value was 0.0759 ± 0.001 g.

The relationship between the exposure time (d_g) and the composite (with filler on the waste basis) weight loss (W_{vz}) in different degradation media (Fig. 2) can be described by following functional equations (Table 2).

On average the composite systems weight losses were influenced after the exposure time of 75 days by the medium of water bath, when weight losses increase was 9% (abrasive wear resistance decreased). But the maximum weight loss value was measured at the use of degradation medium diesel fuel, even 0.0826 ± 0.008 g. At this degradation medium the big differences of weight loss measured values were determined during the degradation. After 25 days of exposure time the weight loss was of 0.0820 ± 0.005 g, after 50 days of 0.0763 ± 0.004 g. The differences in measured values could be caused by the not perfect filler distribution in the matrix, by the different character of particles (size, shape, admixtures) between single composites or by air bubbles occurrence. The media NaCl water solution and laboratory environment did not considerably influence the abrasive wear resistance.

Tensile strength

The measured values of tensile strength are presented in Fig. 3. Before the degradation process the tensile strength corresponds to the value of 28.33 ± 0.89 MPa (standard).

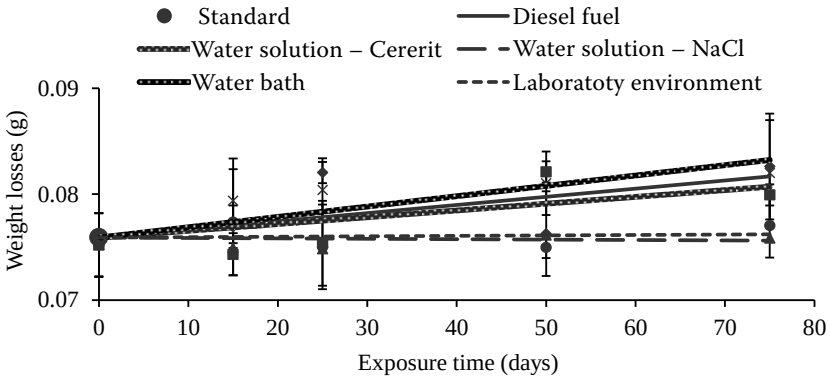

Fig. 2. Degradation process: abrasive wear resistance – weight loss water solution NaCl, laboratory environment – const.

Table 2. Functional equations: weight loss (W_{vz}) – exposure time (d_g)

Diesel fuel	Water solution – Ceretit	Water solution – NaCl	Water bath
W_{vz} = 8E-05 d_g + 0.0759	W_{vz} = 6E-05 d_g + 0.0759	W_{vz} = 0.7538 (const.)	W_{vz} = 1E-04 d_g + 0.0759
R^2 = 0.35	R^2 = 0.55	–	R^2 = 0.64

The following equations (Table 3) describe the relationship between the exposure time (d_g) in single media and the final tensile strength values (σ_M). In the laboratory environment after degradation the tensile strength mean value was 28.21 ± 0.54 MPa (const.).

The highest tensile strength decrease was recorded at the water solution – Cererit degradation medium, when after exposure time of 75 days the tensile strength values decreased from 28.33 ± 0.89 MPa to 15.93 ± 1.3 MPa (decrease of 44%). After the same exposure time at the diesel fuel degradation medium the tensile strength decrease was of 35%, at the water bath of 34% and at water solution NaCl of 31%. The laboratory environment did not considerably influence the tensile strength values.

CONCLUSIONS

In the laboratory conditions and at the exposure time of 75 days (air temperature 23 ± 1°C) the degradation of polymeric particle composites with the filler on the basis of waste corundum was not proved. It is in accordance with (Doležal 1981) that epoxy resins from bisphenol A are not susceptible to weather degradation up to two years exposure time. On the basis of tests carried out it is possible to agree also with (Ducháček 2006) that epoxy resins are of a medium resistance to degradation media action. After 75 days of exposure time in used degradation media neither the hardness Shore D nor the abrasive wear resistance were substantially influenced. On the contrary, un-

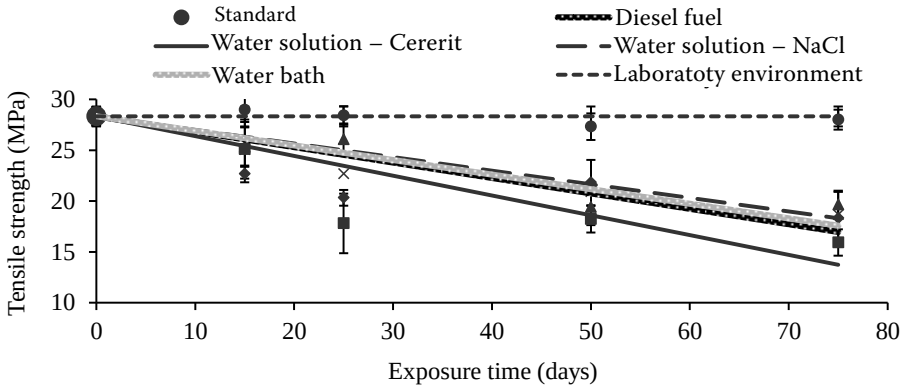

Fig. 3. Degradation process: tensile strength – exposure time laboratoty environment – const.

Table 3. Functional equations: tensile strength – exposure time

Diesel fuel	Water solution – Ceretit	Water solution – NaCl	Water bath
$\sigma_M = -0.1517 d_g + 28.33$	$\sigma_M = -0.1947 d_g + 28.33$	$\sigma_M = -0.1335 d_g + 28.33$	$\sigma_M = -0.1435 d_g + 28.33$
R^2 = 0.43	R^2 = 0.67	R^2 = 0.87	R^2 = 0.88

der the same conditions the tensile strength values substantially decreased. The degradation process confirmed conclusions of work by Kinloch (1987) that joints made using epoxy resin are much more influenced by water than by NaCl water solution.

On the basis of experiments carried out it is possible to say that in the field of agrocomplex the chosen degradation media would not influence the important properties of polymeric particle composites on the waste basis, i.e. abrasive wear and hardness. These properties are owing to the mentioned application media crucial. It is necessary to become aware that at the concrete application it is necessary to assess the mechanical properties comprehensively so that the borderline will not occur owing to degradation.

At the same time the experiments carried out confirmed that from the point of view of degradation processes composite systems on the basis of waste material from blasting are standing in important mechanical properties (abrasive wear resistance, hardness) and thus they offer a sensitive way of material recycling. These systems can replace composites with primary fillers, but it is necessary to respect their limits, which find expression by high standard deviations in this experiment. In laboratory conditions the mixture of the composite system was prepared without the use of vacuum owing to practice where vacuum increases costs of the composite systems preparation. For the used technological procedure of the mixture preparation the porosity is typical. This fact finds expression in increased values of standard deviations.

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Received for publication March 2, 2012
Accepted after corrections July 19, 2012

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