

Polymer matrix influence on stability of wood polymer composites

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The aim of the presented work is to show the influence of the various polymer matrices and the different amounts of the cellulose filler on the composites properties. Samples based on polypropylene, polystyrene, polyoxymethylene, acrylonitrile butadiene styrene, polyester resin, and polylactic acid with different contents of cellulose fibers were prepared by injection molding process. The mechanical and dielectric properties of these composites were studied in order to check whether investigated wood polymer composites fulfill requirements for their application in electrical devices. For all tested composites, a linear increase of modulus with cellulose content was observed. Addition of cellulose to the tested polymers significantly reduces strain at break. In the case of polypropylene and polyoxymethylene composites, the tensile strength increases with the content of the filler. For other materials, there is an inverse relationship, namely the addition of cellulose decreases the tensile strength. The electrical strength decrease was observed with increased cellulose content for the majority of the investigated composites. Polar groups incorporated by cellulose fibers have led to dielectric constant increase. Furthermore, aging of composites in mineral oil and evaluation of water uptake for wood–plastic samples were performed. Wood polymer composites have changed significantly after aging. The water diffusion coefficients were determined, and the significant influence of the amount of cellulose on the water absorption was shown. Copyright © 2015 John Wiley & Sons, Ltd.

Keywords: wood polymer composites; dielectric tests; polymer aging; water uptake

INTRODUCTION

Over the last few decades, cellulose fiber polymer composites have been undergoing a remarkable transformation. These materials have become more and more attractive, as new compositions and processes have been intensively researched, developed, and, consequently, incorporated in order to obtain a material with desired properties.

Wood polymer composites (WPCs), dating back to the early 1900s, are a hybrid material composed of natural wood fibers and plastic matrix.^[1–3] Furthermore, they can be labeled as composite materials, possessing properties of both major ingredients, where wood is used as inexpensive filler to increase strength and stiffness of thermoplastic or to reduce raw material costs. The key mechanical properties such as strength and stiffness of wood polymer composites materials may vary significantly as it depends on the properties of each individual material that was used to compose the WPCs. The structure morphology plays a vital role in defining most of the functional attributes of WPCs. The excellent moisture resistance of polymers compared with wood directly relates to the molecular structure of plastic material that was used in WPC, which also makes it more durable and attractive.^[4] The mechanical and physical properties of wood–plastic composites such as stiffness, strength, impact resistance, and density play an important role in determining the suitability of these products in various applications.^[4,5] Recent advances in the catalyst technologies for the polymerization of the polyolefin resin and the process engineering have made WPC a material of choice for different applications.

In recent years, wood polymer composites are increasingly being used for outdoor applications and construction industries, such as deck boards and railings, due to their ability to resist

moisture intrusion and better stability as compared with ordinary wood material.^[1,2] Properties of WPCs depend on many factors: the characteristics of matrix and fillers, the fractional composition of wood fillers, chemical interaction between wood fibers and polymer, humidity absorption, and processing conditions.^[6–10] Many of these studies were focused on the problem related to the compatibility between fibers and the polymer. The hydrophobic character of polyolefins is contrasted with the hydrophilic character of the wood fibers. The compatibility of natural fibers and the matrix are emphasized in many other studies. The coupling agents, pre-treatment of wood fiber and/or the polymer through surface-coating treatment, and graft copolymerization—there are just some solutions which allow to overcome these limitations.^[11–13]

Low thermal resistance of wood fibers (thermal degradation beginning at about 200°C) is another major limitation affecting its use in applications.^[14,15]

The hygroscopicity is one of the factors that need to be addressed to attain a full understanding of the mechanism of moisture absorption. The moisture absorption by composites containing natural fibers can affect their long-term performance.^[16]

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It was found by Espert *et al.*^[17] that degradation in mechanical properties and water absorbed at saturation have increased with increasing filler loading. In the studies conducted by Espert *et al.*,^[17] Rangaraj and Smith,^[18] and Najafi *et al.*,^[19] it was shown that water absorption matches with the kinetics of a Fickian diffusion process. A two-part equation to describe the moisture absorption process of wood-based composites was used by Shi and Gardner.^[20] In these studies, moisture absorption was predicted as a function of time, initial weight of specimen, and equilibrium moisture content.^[20] Higher temperature was found to accelerate the absorption process due to the increased rate of diffusion.^[17]

The influence of water on mechanical properties of polymer-cellulose composites have been the subject of many papers. Less work is concerned with the electrical behavior of such composites. The usage of polymer composites with natural fibers in electrotechnics is hindered by the inherent high moisture absorption of cellulose, which could lead to reduction of electrical properties: increase of electrical conductivity, dielectric losses and dielectric constant, and decrease of the breakdown voltage.^[20] Chemical surface treatment of cellulose fiber could decrease influence of water absorption.

The aim of the presented work is to show the influence of the various polymer matrices and the different amounts of the cellulose filler on the WPCs properties. Samples based on polypropylene (PP), polystyrene (PS), polyoxymethylene (POM), acrylonitrile butadiene styrene (ABS), polyester resin (PES), and polylactic acid (PLA) with different contents of cellulose fibers were prepared by injection molding process. The mechanical and dielectric properties of these composites were studied in order to check whether investigated wood polymer composites fulfill requirements for their application. In some industrial applications, chemical resistance to the oil at elevated temperatures is required. There is very little information in the literature on this topic. Therefore, in this paper, the results of the WPC materials aging in oil are presented.

EXPERIMENTAL

Materials

In this study, 10 kinds of commercially available composites based on thermoplastics materials filled with cellulose fibers were used for tests. The details of the used composites are listed in Table 1.

Sample preparation

The samples were fabricated using a HAITIAN HTF300X injection molding machine. The injection molding was performed in accordance with the following description:

- Before injection molding, the compounds were dried using the dried air at a maximum temperature of 120°C in 2 h. There were some problem with the content of moisture for two composites based on PLA and PES. For these materials, an all night long drying process was used. Additionally, a dryer with drawers was used for better moisture removal.
- The barrel temperature was kept low at a recommended temperature about 175–195°C to prevent degradation of the wood, which starts at approximately 200°C.

Two types of sample sizes, for mechanical and electrical tests, were prepared by injection molding. Samples for mechanical

Table 1. WPCs types used for investigation

Nr	Sample name	Polymer content [wt.%]	Cellulose fiber content [wt.%]	Density [g/cm ³]	The producer
1	PP 50/50	50	50	*	BEOLOGIC
2	PP 75/25	75	25	*	BEOLOGIC
3	PS 50/50	50	50	1.32	BEOLOGIC
4	PS 75/25	75	25	1.08	BEOLOGIC
5	ABS 65/35	65	35	1.25	BEOLOGIC
6	ABS 75/25	75	25	1.06	BEOLOGIC
7	POM 75/25	75	25	*	PLASTHILL OY
8	POM 60/40	60	40	*	PLASTHILL OY
9	PES 50/50	50	50	1.23	BEOLOGIC
10	PLA 70/30	30	70	0.96	FKuR GmbH

*it was not possible to evaluate density because wood polymer composite (WPC)'s density was lower than that of water (the density was determined based on Archimedes' principle).

tests were performed according to standard SS-EN ISO 527-2: 2012 (E).

In order to evaluate the dielectric properties of wood polymer composites, samples for electrical tests were prepared. The samples were rectangular-shaped, with 150 mm width and about 2 mm thickness.

Specimens for water absorption tests were cut from larger sheet, which was prepared by injection molding. Their dimensions were 100 × 100 mm (±1 mm), and thickness was varying from 2.20 to 2.70 mm (±0.05 mm), depending on which specimen was considered. The specimens were not machined because that could influence the properties of WPC. Specified edges of specimens were protected by metal adhesive tape.

Mechanical tests

Tensile and flexural properties are the most commonly investigated mechanical properties of natural fiber-reinforced plastic materials. A universal tensile testing machine Instron 3367 was used to carry out the tensile test according to ISO 527-1. All tests were carried out under standardized conditions (temperature 20°C and humidity 65%). The data were evaluated by using Instron software. The tensile tests were performed using standardized test samples and were carried out 13 times for each mixture to obtain a significant average value. The test velocity for measuring the Young's Modulus was set to 1 mm/min, however, for the determination of the tensile strength and the strain at break, the test speed was increased to 5 mm/min.

Tensile tests were performed for two types of samples:

- samples without modification, as obtained after injection molding,
- samples which were immersed in boiling water for 8 h.

Electrical properties tests

The relative permittivity tests were carried out according to the IEC 60250-1 standard. The following devices were used:

- Solartron 1260—Frequency Response Analyzer,
- Solartron 1296—Dielectric Interface,
- System of flat disk electrodes with a guard ring and a micrometer screw.

The dielectric strength tests were carried out according to the IEC 60243-1 standard. The breakdown voltage was measured using an unequal steel electrode setup of 25 and 75 mm diameter. The measurement setup consisted of a 60 kV test transformer, an electrostatic kilovoltmeter, and a voltage regulation system. All of the tested samples were placed in an oil bath, in order to limit the surface flashover. Dielectric strength tests were performed at AC 50 Hz voltage.

The electrical tests were performed using standardized test samples and were carried out three times for each WPC type to obtain an average value.

Aging in oil

In this paper, attempts to assess changes in WPC materials during aging in transformer oil were undertaken. All samples were dried at temperature 100°C for 12 h before testing. The water content before and after drying was measured. Aging was carried out in oil without treatment and also in degassed oil at 100°C. The table in the subsequent discussion shows total aging time for all samples (Table 2).

Water uptake tests

Investigation was carried out in accordance with the ISO62:2008 (E) standard. The tested specimens were placed in a glassy container filled with distilled water maintained at 23°C. After immersion for 24 h (± 1 h), the tested specimens were then removed from the water and dried with the use of a clean, dry cloth or with filter paper. The dried specimens were re-weighed to the nearest 0.1 mg within 1 min after removing them from the water (mass M2).^[21]

The water content at saturation was measured by re-immersing the test specimens and reweighing them at given time intervals. The applied immersion time scale was 24, 48, 96, 192 h, and so on (± 1 h at each of these intervals).

Table 2. Total aging time for all samples

Nr	Sample name	Total aging time [h]	
		Oil without treatment	Degassed oil
1	PP 50/50	18	168
2	PP 75/25	18	168
3	PS 50/50	18	—
4	PS 75/25	18	—
5	ABS 65/35	18	—
6	ABS 75/25	18	—
7	POM 75/25	18	96
8	POM 60/40	18	96
9	PES 50/50	18	96
10	PLA 70/30	18	96

PP, polypropylene; PS, polystyrene; POM, polyoxymethylene; ABS, acrylonitrile butadiene styrene; PES, polyester resin; PLA, polylactic acid.

The water diffusion coefficients for all of the investigated samples were determined using Fick's laws in accordance with the ISO62:2008(E) standard.

At temperatures well below the glass transition temperature of the wet polymer, the water absorption of most polymers (determined by used methods) correlates well with Fick's laws.^[21] Fick's law mathematically describes the diffusion, which is based on the transport phenomena of matter from one part of a system to another as a result of random molecular motions.^[22] This mathematical theory of diffusion in isotropic substances is based on the hypothesis that the rate of transfer of diffusing substance through a unit area of a section is proportional to the concentration gradient measured normal to the section.^[22] Fick's law of diffusion can be mathematically expressed as follows:

$$\frac{\partial C}{\partial t} = D_x \frac{\partial^2 C}{\partial x^2} \quad (1)$$

where C is the concentration of diffusion substance, x is the space coordinate measured normal to the section, and D_x is the diffusion coefficient.

Assuming a correlation with Fick's laws, a linear dependency between $\lg(c(t)/c_s)$ and $\lg(D \cdot t)$ can be assumed to be approximately true for small values. Including the theoretical values from the ISO62:2008(E) standard, the diffusion coefficient in the linear range can be expressed as follows.^[21]

$$\sqrt{D} \approx \frac{1}{c_s} \cdot \frac{d}{0.52\pi} \cdot \frac{c(t)}{\sqrt{t}} \quad (2)$$

where c_s is the water absorption at saturation, d is the thickness of the specimen, t is the exposure duration, and $c(t)$ is the measured water absorption at time t .

RESULTS AND DISCUSSION

Morphology observations

The details of fracture surfaces morphology of the investigated WPC materials were observed by means of scanning electron microscopy. It is clearly seen that in the case of WPCs based on POM, PP, and PES, the cellulose fillers incorporated into the polymer matrix have more fine structures in relation to the fibers observed in other types of WPCs (Fig. 1). Especially large cellulose fibers are visible for PS-based WPC with length approaching 100 μm and width of 20 μm . Also in the case of ABS and PLA matrix, one can distinguish places where large cellulose fibers were pulled out from the sample.

Mechanical properties

The mechanical characteristics of the composites were investigated by means of tensile tests. The static mechanical properties were evaluated from the stress-strain diagrams.

The results show that the stiffness and brittleness of the materials increase with increasing filler content (Figs 2 and 3). For all cases, there is a linear increase of Young's modulus with cellulose content. The elastic modulus reaches a value of 3.7, 4.1, 3.9, and 5.8 GPa, respectively, for composites with PP, PS, ABS, and POM at a filler content of 25 wt. At higher filler contents, the elastic modulus significantly increases for all samples to a maximum value of 5.6, 6.8, 4.6, and 8.3 GPa, respectively, for composites with content of 50 wt.% PP, 50 wt.% PS, 65 wt.% ABS, and 75 wt.% POM. The Young's modulus for samples with content

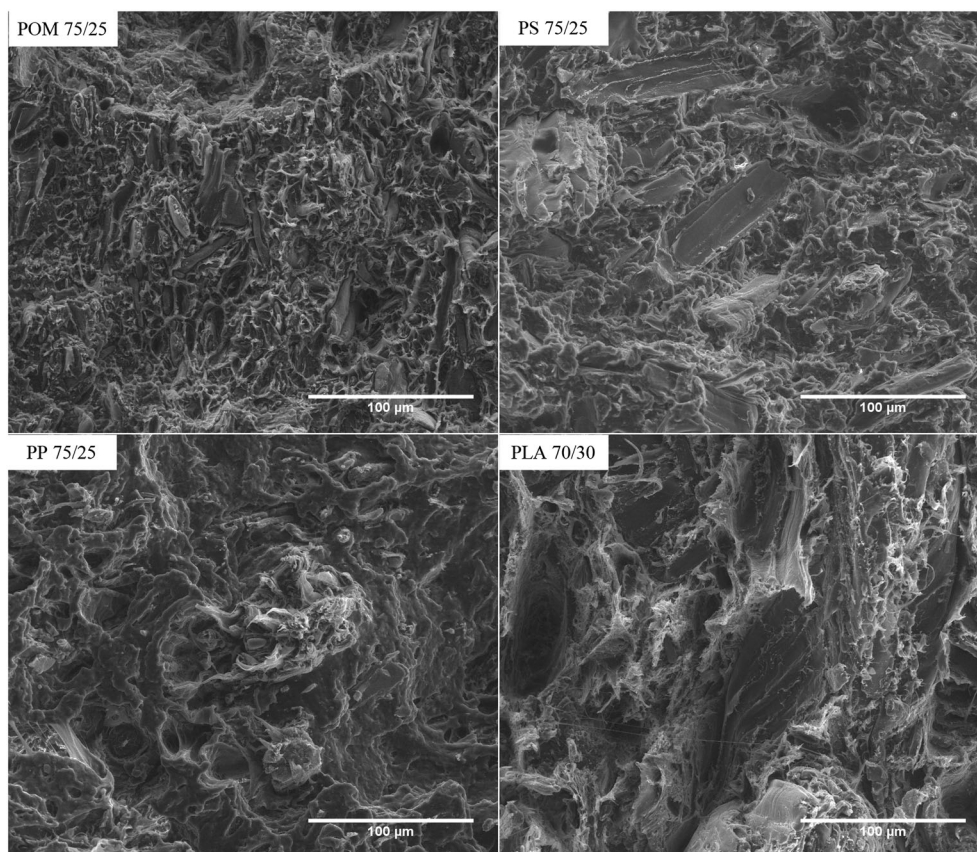


Figure 1. Scanning electron microscopy images of the following: polyoxymethylene (POM) 75/25; polystyrene (PS) 75/25; polypropylene (PP) 75/25; polylactic acid (PLA) 70/30.

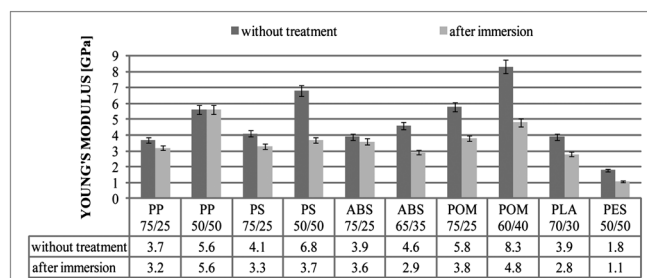


Figure 2. Young's Modulus of wood polymer composite materials without treatment and after immersion. PP, polypropylene; PS, polystyrene; POM, polyoxymethylene; ABS, acrylonitrile butadiene styrene; PES, polyester resin; PLA, polylactic acid.

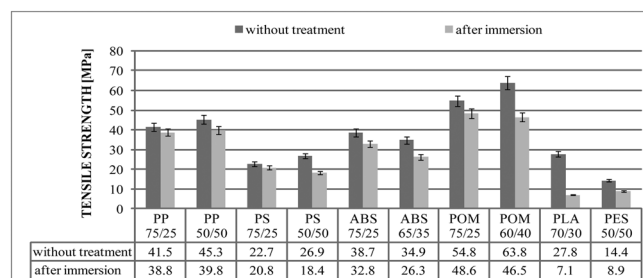


Figure 3. Tensile strength of wood polymer composite materials without treatment and after immersion. PP, polypropylene; PS, polystyrene; POM, polyoxymethylene; ABS, acrylonitrile butadiene styrene; PES, polyester resin; PLA, polylactic acid.

of 50 wt.% PES and 70 wt.% PLA reaches, respectively, values of 5.8 and 8.3 GPa. Addition of cellulose to the tested polymers significantly reduces strain at break. This kind of behavior is common for polyolefins.^[23] It is an acceptable level for a filled thermoplastic material useful for packaging purposes.

In the case of PP, PS, and POM composites, the tensile strength increases with the content of the filler. The tensile strength increases from 41.5, 22.7, and 54.8 to the level of about 45.3, 26.9, and 63.8 MPa, respectively, for composites based on PP, PS, and POM with low and higher filler content. Only in the case of ABS composites, there is an inverse relationship, namely,

the addition of cellulose decreases tensile strength from 38.7 to 34.9 MPa. The maximum tensile strength of about 64 MPa is achieved with a filler content of 40 wt.% for POM composite. It shows that a good adhesion between filler and POM matrix is present.

Most of the physical and mechanical properties of wood composites depend on the adhesion between wood and polymer matrix. Scanning electron microscopy micrographs of POM and PP-based wood composite (Fig. 1) revealed a good dispersion of wood particles in the polymer matrix (no wood agglomerates were observed). In these cases, the interfaces between the wood

fibers are well filled with plastic that could increase the strength of the composites because of mechanical interlocking and, hence, better adhesion. In the case of PLA and PES, obvious gaps between fiber and polymer matrix, large size of holes, and wood particle pull-outs were observed, indicating poor interfacial adhesion, and as a result, the observed tensile strength was much lower in relation to other matrices.

In order to investigate the influence of water on mechanical properties of polymer–cellulose composites, the tensile tests of samples after immersion in boiling water for 8 h were carried out, and the results are shown in Fig. 2. For PP, PS, and POM composites, there is a linear increase of modulus with cellulose content. Addition of cellulose to the tested polymers significantly reduces strain at break. In the case of PP composites, the tensile strength increases with the content of the filler. For the other three materials (PS, ABS, and POM), there is an inverse relationship—addition of cellulose decreases tensile strength.

It can be easily observed that the mechanical properties are strongly affected by immersion. For all cases, the immersion in boiling water significantly reduces mechanical properties. The largest decrease in tensile strength can be observed for PLA and POM 60/40, whereas for the composites based on PP, the differences in tensile strength before and after immersion are insignificant. In the case of composites based on the same matrix but with different wood fiber content, it can be seen that the addition of higher amount of the filler results in a greater reduction in the mechanical properties. Water absorption mainly occurs at the outer layer of composite materials. The wood particles at the surface absorb water and starts to swell, resulting in localized yielding in polymer matrix, as reported by Joseph *et al.*^[24] Furthermore, the mechanical properties decrease due to the micro-cracks appearing in polymer matrix.

Determination of electrical properties

The results of dielectric properties measurements are collected in Table 3. One can observe that for all the WPC samples, the dielectric permittivity increases simultaneously with the incorporation of cellulose filler. As a consequence, the dielectric dissipation factor is also increased. Most of the matrixes investigated in this work are non-polar hydrophobic polymers which show ionic and electronic polarization. Due to the filling of such polymer with a hydrophilic cellulose fiber, the polar groups are inserted into non-polar matrix, and as a result, the polarization related to the dipole reorientation can be observed. It is worth to point out that the presence of the hydroxyl groups in the cellulose enhances moisture absorption from the atmosphere, as a result of water molecules interaction with hydroxyl groups. Therefore, the overall polarization of the WPC material is the sum of polarization related to electronic, ionic, and dipole reorientation.^[25] As it is shown later in the paper (Water uptake test section), one can correlate the highest relative increase of dielectric constant for PS with its highest water uptake at room temperature, whereas in the case of PP, increase of dielectric permittivity is less pronounced due to lower moisture absorption. The relationship between water absorption and dielectric behavior of WPC materials is well known in literature.^[26]

On the basis of the obtained results, it can be concluded that the presence of cellulose within the WPC material leads to a

Table 3. Electrical properties

WPC type	Dielectric permittivity, ϵ'	Dielectric dissipation factor, $\tan(\sigma)$	Dielectric strength [kV/mm]
PP 100/0*	2.3	$2.5 \cdot 10^{-4}$	35–40
PP 75/25	2.5	$2.5 \cdot 10^{-3}$	27.2
PP 50/50	3.1	$4.8 \cdot 10^{-3}$	24.9
PS 100/0*	2.4–2.5	$1\text{--}2 \cdot 10^{-4}$	55–65
PS 75/25	2.9	$2.8 \cdot 10^{-3}$	28.8
PS50/50	3.5	$5.6 \cdot 10^{-3}$	22.9
ABS100/0*	2.8–3.1	$9\text{--}16 \cdot 10^{-3}$	30–40
ABS75/25	3.2	$7.2 \cdot 10^{-3}$	21.5
ABS65/35	3.3	$7.0 \cdot 10^{-3}$	22.4
POM100/0*	3.5–3.8	$3\text{--}5 \cdot 10^{-3}$	25–35
POM75/25	4.1	$7.2 \cdot 10^{-3}$	>25
POM60/40	4.6	$9.1 \cdot 10^{-3}$	>25

Asterisk is present for neat polymers indicating data from literature [26].
PP, polypropylene; PS, polystyrene; POM, polyoxymethylene; ABS, acrylonitrile butadiene styrene.

subsequent decrease in dielectric strength value as compared with that of the pure polymer. For example, in the case of PP matrix, dielectric strength decreases from 35 to 27.2 kV/mm as a result of 25 wt.% cellulose addition and decreases even further to 24.9 kV/mm when cellulose content is 50 wt.%. In the case of POM-based WPC, the measured dielectric strength was above the detection limit of the experimental setup. One can suppose that the decrease of the dielectric strength for this sample was not significant. Such an effect can be attributed to a lower number of pores (Fig. 1) and, as consequence, increase of inception voltage of partial discharges and decrease in partial discharge level. Additionally in case of POM-based composites, the cellulose fibers are more fine. The composites are more compactness then and their dielectric properties are better.

Aging in oil

In order to verify whether a material is resistant to oil at elevated temperature (or in other words compatible with transformer oil), samples of the WPC materials were placed in mineral oil and kept at 120°C. Initial short-term tests were performed (18 h), allowing to identify the most promising WPC, which were subsequently subjected to long-term aging tests. PP 50/50, PP 75/25, POM 60/40, POM 75/25, PES 50/50, and PLA 70/30 were considered promising and subjected to long-term aging (Table 2).

The relatively rapid aging process was observed, in particular for the composites based on PS. After the tests, the PP 50/50 and PP 75/25 samples were visually inspected. The aged samples exhibited a significant change to darker color, additionally, blisters releasing a sticky clear gel and internal delamination was observed. Moreover, they became soft and flexible. The oil analysis showed highly increased water content and, consequently, an increased loss tangent. The obtained results give a clear indication that the composites are not compatible with transformer oil. There was no clear difference between aging in degassed and untreated mineral oil.

Water uptake test

According to the literature,^[1] the main factors affecting the water absorption of wood material composites include the following: fiber volume fraction, orientation of fibers, exposed surface area, and temperature. In the case of WPC materials that are composed of water repellent plastics, it can be assumed that wood filler is mainly responsible for water absorption.^[2]

On the other hand, the addition of wood particles to WPC materials allows the reduction of the costs and improves the mechanical properties like stiffness. However, after exposure to water or humid environment, the hydrophilic character of the wood particles causes a significant reduction in the overall performance of the WPC material.^[2] It was stated that with higher percentage of filler content, the increase of moisture content of the overall material is observed. Moreover, the water absorption capability increases with increase in particle size.^[1,2]

Tamrakar and Lopez-Anido^[2] reported the behavior of WPC material in contact with water. The subsurface wood particles absorb water and start to swell, resulting in localized yielding in polymer matrix, and as a result, the micro-cracks are created, which facilitates penetration of water. This process leads to swelling of the wood particles and, consequently, yielding and cracking of polymer matrix throughout the cross-section.^[2]

Wood polymer composites material dried after contact with water will not regain its original shape due to localized yielding. A gap between the wood and the polymer surfaces will be formed as a result of the shrink of wood particles in absence of moisture. This leads to loss of adhesion between the wood particles and the polymer matrix. This phenomenon will result in higher and deeper penetration of WPC material by water next time in a relatively shorter time.^[2]

For the absorption tests conducted at 23°C, changes in surface color of specimens were observed only after a week of immersion. Water became turbid, and dust particles started to appear in water. After about 28 days of immersion, the water and the surface of the specimen became oily, and water became even more turbid and dark. The dust particles were identified as cellulose particles detaching from the specimens. However, after around 8–10 weeks of immersion, the cellulose particles floating and suspending in the water settled down and the water

Table 4. Obtained parameters for the absorption tests conducted at 23°C

Material type	Water absorption 23°C [%]	Diffusion coefficient 23°C [mm ² /s × 10 ⁻⁷]
POM 60/40	8	9.52
POM 75/25	4	4.97
PES 50/50	15	4.97
PLA 70/30	10.5	4.90
PP 75/25	1.8	5.95
ABS 75/25	6.5	3.28
ABS 65/35	9	5.16
PS 75/25	7	9.77
PS 50/50	12	9.52

PP, polypropylene; PS, polystyrene; POM, polyoxymethylene; ABS, acrylonitrile butadiene styrene; PES, polyester resin; PLA, polylactic acid.

became clearer, suggesting that the detaching of cellulose particles from the specimens had stopped. Uneven swelling and warping of some specimens were observed.

Water absorption for the used method does not show a linear trend in time (Fig. 4). The rapid increment in absorption occurs after about 100 hours. Subsequently, the absorption process slows asymptotically until approaching the point of saturation. As per ISO62:2008(E), the specimen was considered as saturated when the average increase of its weight per 2-week period does not exceed 1%. Cellulose addition significantly increases the absorption of water relative to pure polymers. The water absorption reaches a value of 0.2, 0.1, and 1.6, respectively, for pure PP, PS, and ABS.

Obtained values of the water absorption and diffusion coefficient are shown in Table 4.

CONCLUSIONS

For all tested WPC materials, a linear increase of modulus with cellulose content was observed. It was shown that the addition of cellulose fibers to the tested polymers significantly reduces strain at break. In the case of PP and POM-based composites, the tensile strength increases with the content of the filler. For other WPC materials, there is an inverse relationship, namely the addition of cellulose decreases the tensile strength.

Presence of the cellulose fibers within the WPC material leads to subsequent decrease in dielectric strength value as compared with that of the pure polymer. The polar groups incorporated by cellulose fibers have led to dielectric constant increase. The influence of the cellulose fibers size was shown, namely fine structure of cellulose fibers has led to greater composite compactness and, as a result, better dielectric properties.

The phenomenon of loss of mechanical properties due to swelling of wood fibers was observed as a result of localized yielding of polymer matrices and loss of adhesion between wood filler and polymer matrix. For all composites, decrease in the value of elastic modulus was dependent on the filler content. It was observed that higher content of cellulose fiber causes significant decrease of elastic modulus. The same relationships can be observed for tensile strength.

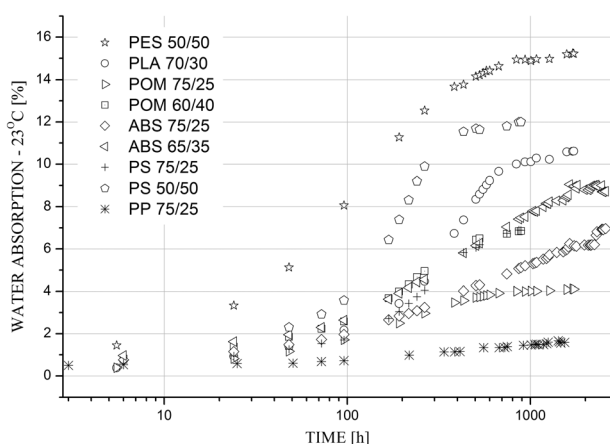


Figure 4. Water absorption curves for first method—immersion in water at 23°C. PP, polypropylene; PS, polystyrene; POM, polyoxymethylene; ABS, acrylonitrile butadiene styrene; PES, polyester resin; PLA, polylactic acid.

Aging of wood polymer composites in mineral oil changed significantly their structure, namely, oil turbidity can be observed and blisters appeared on the samples surface.

The obtained results of the water absorption test have shown that PES-based WPC has the highest water uptake. It was observed that absorption process in WPC material very closely resembled the kinetics of Fickian diffusion, and it was possible to determine water diffusion coefficients.

The presented results show that special attention must be taken during the selection of WPC materials, for applications which require specific working conditions, especially for devices exposed to moisture, oil environment, and high temperature.

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