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# COMPATIBILISERS IN WOOD-POLYETHYLENE COMPOSITES AND THERE INFLUENCE ON THE MECHANICAL PROPERTIES AND WATER ABSORPTION

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## ABSTRACT

*In this paper the improvement of the compatibilisation between wood particles and HDPE-matrix composites was investigated. A series of methods of compatibilisation and modification of the composite were performed and compared. The objective was to find the most suitable method for industrial up scaling, based on mechanical properties obtained. The tensile test of samples was performed, before and after water absorption investigation. Water absorption of composites was studied at two different temperatures: 25°C and 50°C. The water absorption kinetics was studied and it was found that water is absorbed in composites following the kinetics described by the Fick`s diffusion theory. After absorption, an important loss of properties was observed, due to the destruction of the wood structure due to the water absorbed.*

**Keywords:** wood-plastic composites, compatibiliser, mechanical properties, water absorption

## 1. INTRODUCTION

Wood plastic composites (WPCs) are composite materials made from thermoplastic polymers, wood flour, and a small amount of process- and property-enhancing additives; they are principally used in the automotive industry and as secondary building materials. Besides wood and polymer, some additives are added in small amounts to enhance processing and performance of WPCs. The most often used additives include compatibilizers, lubricants, colorants, pigments, and foaming agents, etc. The majority of WPCs are manufactured by profile extrusion, while other processing technologies such as injection moulding and compression moulding are also used.

Research efforts in WPCs have been mostly focused on improving the internal bonding between the wood particles and the matrix. The hydrophilic wood particles are generally incompatible with hydrophobic thermoplastic polymers. The incompatibility between wood and polymer matrix is a major problem for interfacial adhesion between these two component materials, which is of critical importance for the mechanical properties of the composite. The tensile properties of natural fibre reinforced plastics depend on a number of parameters including fiber length, loading and orientation, and the degree of adhesion between the fibers and the matrix [1, 2]. Therefore the correct chemical treatment and choice of fiber can provide composite materials with excellent tensile properties.

Moisture penetration into composite materials is conducted by three different mechanisms:
(1) diffusion of water molecules into the microgaps between polymer chains, which is the main mechanism, (2) capillary transport into the gaps and flaws at the interfaces between fibers and polymer, due to incomplete wet ability and impregnation, and (3) transport by micro cracks in the matrix, formed during the compounding process [3].

These three diffusion cases can be distinguished theoretically by the shape of the sorption curve represented by the following expression:

$$\frac{M_t}{M_\infty} = k \cdot t^n \qquad (1)$$

where $M_t$ is the moisture content at time *t*; $M_\infty$ is the moisture content at the equilibrium; and *k* and *n* are constants.

The value of coefficient *n* shows the different behavior between cases; for Fickian diffusion it is $n$ = 0,5 while for Case II $n = 1$ (and for Super Case II $n > 1$). For anomalous diffusion, n shows an intermediate value (0,5 < n < 1). Moisture absorption in natural fibre reinforced plastics usually follows the Case I Fickian behavior, so further attention will be focused on its study.

In this study the compounding of WPC with different additives was performed, and mechanical properties and water apsorbtion was investigated.

## 2. EXPERIMENTAL

WPC samples were compounded using Haake rheomix with process parameters: temperature 150 °C, 50 cycles per minute, MFR = 0,355. The polymer was the HDPE HIPLEX HHM 722 supplied by „HIP-Petrohemija“ a.d. Pančevo (HHM-722 sa 2,16 kg; 190°C), and the sawmill wood particles 40 – 60 mesh. The coupling agents with lubricant Fusabond WPC 576 D and Glicolybe, DuPont, and the antioxidation additive IRGANOX B-225 were added. In some samples the di-cumil peroxide was added (Table 1).

Water absorption of composites was studied at two different temperatures: 25°C and 50°C. The samples were immersed in water, and the mass was measured periodically. From absorption curves, according equation (1), the coefficient *n* was obtained, and the values are presented in Table1.

The tensile testing of samples was performed on Universal hydraulic tensile-compressive testing machinebefore and after immersion in water. The results are presented inTable.1.

*Table 1. The composition of WPC and results of tensile testing and water absorption investigation*

| ID: | HIPLEX HHM 722, mas. % | Wood particles, mas. % | Coupling agent+ lubricant, mas. % | Di-cumil pero xide, mas. % | IRGA -NOX B-225, mas. % | $R_m$, MPa | $R_{m25}$, MPa | $R_{m50}$, MPa | $n_{25}$ | $n_{50}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 72202 | 70.10 | 23.500 | 6.000 | | | 18.62 | 16.27 | 17.91 | - | 0.40 |
| 72203 | 47.00 | 47.000 | 6.000 | | | 19.09 | 16.96 | 12.45 | 0.39 | 0.41 |
| 72204 | 23.50 | 70.500 | 6.000 | 0.00 | | 15.55 | 7.59 | 9.21 | 0.46 | 0.52 |
| 72205 | 93.80 | 0.000 | 6.000 | 0.20 | | 19.79 | 18.68 | 20.84 | - | |
| 72206 | 70.30 | 23.500 | 6.000 | 0.20 | | 18.12 | 18.11 | 16.50 | 0.41 | 0.38 |
| 72207 | 46.90 | 46.900 | 6.000 | 0.20 | | 16,12 | 16.49 | 18.09 | 0.33 | 0.39 |
| 72208 | 23.50 | 70.300 | 6.000 | 0.20 | | 10.54 | 11.22 | 13.35 | 0.41 | 0.43 |
| 72209 | 94.00 | 0.000 | 6.000 | 0.00 | 0.10 | 19.09 | 16.59 | 16.46 | | |
| 72210 | 70.50 | 23.477 | 6.000 | 0.00 | 0.10 | 18.62 | 18.74 | 19.14 | 0.71 | 0.53 |
| 72211 | 47.00 | 46.953 | 6.000 | 0.00 | 0.10 | 16.77 | 15.27 | 19.08 | 0.40 | 0.43 |
| 72212 | 23.50 | 70.430 | 6.000 | 0.00 | 0.10 | 14.93 | 14.34 | 13.74 | 0.44 | 0.52 |
| 72213 | 93.00 | 0.000 | 6.000 | 1.00 | | 17.37 | 15.89 | 15.60 | | |
| 72214 | 34.87 | 23.30 | 6.000 | 0.75 | | 14.50 | 17.22 | 15.11 | 0.22 | 0.35 |
| 72215 | 23.25 | 46.734 | 6.000 | 0.50 | | 15.74 | 12.90 | 16.81 | 0.32 | 0.35 |
| 72216 | 11.625 | 70.277 | 6.000 | 0.25 | | 7.14 | 6.41 | 9.33 | 0.41 | 0.42 |
| 72217 | 37.500 | 25.000 | | | | 15.70 | 13.25 | 12.93 | 0.25 | 0.39 |
| 72218 | 25.000 | 50.000 | | | | 8.77 | 12.71 | 9.29 | 0.40 | 0.39 |
| 72219 | 12.500 | 75.000 | | | | 5.96 | 4.93 | 4.28 | 0.50 | 0.40 |

Where $R_m$ is the tensile strength of WPC before water absorption, $R_{m25}$ and $R_{m50}$ are the tensile strengthts of WPC after water absorption on the corresponding temperature, *n* is experimentally obtained coefficient from the absorption curves (Figure 1).

## 3. RESULTS AND DISCUSSION

The water absorption curves represent the change in moisture content with time for the samples immersed in water at 25°C and 50°C (Figure 1). It can be seen that the fibre content in the composites clearly influences the absorption curves. The increase in the fibre percentage leads to higher values of moisture absorption for the same values of immersion time. This was already expected, because of the hydrophilic nature of the natural fibres. Moreover, the increase of the fibre content in the composite material also increases the volume of the interfacial region, where the water molecules can be easily included. The temperature of the absorption process also has a remarkable influence on the water absorption curves. It can be concluded that the temperature stimulates the water uptake of the composite materials.

The values of the parameters *n* and *k* are calculated from the fitting of the experimental data according to Eq.1 and *n* is presented in Table 1.From the results of diffusion case selection analysis, it can be concluded that the diffusion behavior approaches towards the Fickian case, since all the results for the parameter *n* are close to the value 0.5 representative for Fickian diffusion.

After studying the performance of the hydrothermal ageing of wood composites at 23°C and 50°C, their mechanical properties were analyzed by means of tensile tests. The properties of composite materials are greatly decreased after the uptake of moisture, because the water molecules affect the structure and properties of the fibres, matrix and the interface between them.

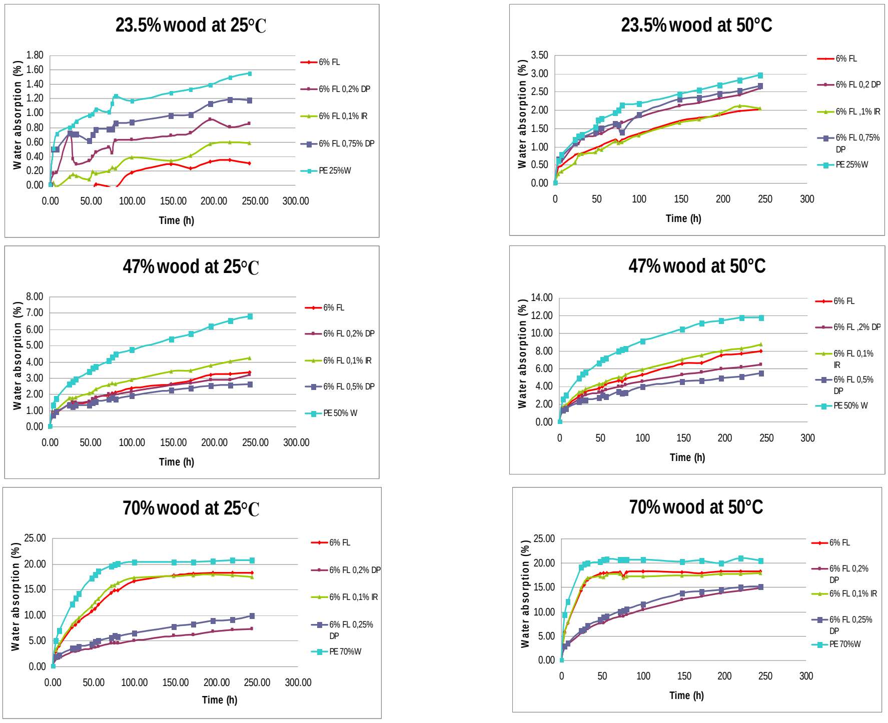


*Figure 1. Absorption curves of WPC samples*

## 4. CONCLUSION

In this paper the influence of HDPE-wood composite composition on the mechanical properties and water absorption was investigated. The samples of different composition were processed, and influence of some additives was investigated. The increase in the fibre percentage leads to higher values of moisture absorption and lower tensile strength. Water absorption causes important changes in the morphology of the composites. This is because it causes: (a) the swelling and degradation of the fibres, (b) alters the configuration of the matrix, and (c) reduces the compatibilisation between fibres and matrix. The mechanical properties are drastically reduced after hydrothermal ageing. The coupling agent- compatibiliser was improved the wood-matrix interface and consequently mechanical properties and of WPC. Small amount of di-cumil peroxide was improved the tensile strength and weather ability, while the antioxidant was decreased both. The optimum composition for industrial production of WPC should be balanced with all of the components, requested properties and price of future wood-composite.

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