INFLUENCE OF HOLLOW GLASS MICROSPHERES AND MULTI WALLED CARBON NANOTUBES ON THE WATER ABSORPTION IN POLYAMIDES

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ABSTRACT: The aim of the present paper is to evaluate the influence of hallow glass bublles (HGB) and multi-walled carbon nanotubes (MWCNT) in the polyamide 6 (PA6) matrix on water absorption. The research was carried out in the laboratory on six compositions of hybrid materials with HGB content between 30% and 10% and MWCNT between 2% and 15%. After 336 hours of immersion, it was highlighted that water absorption has increased over time, and the growth rate is a maximum of 168 hours. HGB increases water absorption while MWCNT decreases polyamide water absorption by 10%.

KEY WORDS: water absorption, polyamides, glass microbes, carbon nanotubes

1. Introduction

In today's context, pollution has become one of the global problems facing mankind, and studies and research [1] have concluded that about three-quarters of greenhouse gas emissions come from road transport, exactly from high-capacity vehicles that consume a lot of fuel. The research has also highlighted the fact that this amount of fuel consumed is related to the mass of the car [1]. Therefore, there is the issue of reducing the weight of cars, by using hybrid materials with polymeric matrix and lightweight reinforcing materials such as carbon nanotubes. One of the factors that accelerates the aging process of polymeric products is the absorption of water and other chemical compounds. Precise modelling of moisture absorption in hybrid materials based on organic polymers is required to assess the durability and to make a correct prediction of the life of the products. Chemical exposure, especially exposure to moisture, is a key degradation mechanism in polymeric systems. The process of penetration of chemicals through polymers is the consequence of two interdependent processes that take place, the dissolution in the polymer and the diffusion through the polymer [2]. Dissolution is the process of absorbing chemicals into the polymer and depends on the affinity of the polymer for the absorbing molecules, ie. the interaction energy, the volume available for absorption and the concentration of the absorbing chemical. There is a limit to the amount of absorbed chemical under a given set of conditions and this limit is solubility. Diffusion is the process of transporting the substance through material phases whose driving force is the concentration gradient of the species that diffuses between two points (areas) of the material phase. The absorbed molecules are transported by diffusion inside the polymer and the diffusion properties are characterized by the diffusion coefficients. Often, especially in thick sections, the parameter that determines the speed of the aging process is the time required for the spread of harmful species in sufficient concentrations in critical regions. One of the usual approaches in the interpretation of stationary diffusion is the application of Fick's law I in which the steady state flux of diffuser per unit area, or the diffusion flow (J) is a function of the concentration gradient with the diffusion distance [3]:

$\boldsymbol{J = -D\frac{dc}{dx}}$ Fick's law I, where the diffusion coefficient (D) does not depend on the concentration, then Fick's second law can be used to determine the time dependence of the diffuser concentration in the specimen.

$\frac{dc}{dt} = D\frac{d^2c}{dx^2}$ Fick's Second Law (non-stationary broadcast)

The aim of this research is to evaluate the influence of glass globules (HGB) [2] and multi-walled carbon nanotubes (MWCNT) from the polyamide 6 matrix (PA6) on water absorption.

2. Materials and methods

2.1 Materials

The composition of polyamide 6-based hybrid materials reinforced with glass micro-balloons (HBG) and multi-walled carbon nanotubes (MWCNT) under study are presented in Table 1, in volumetric percentages.

Table 1. Composition of specimen used in current study, in volume percentage

Sample	HGB content (% vol.)	MWCNT content (% vol.)	PA6 content (% vol.)
1	0	0	100
2	30	0	rest
3	0	15	rest
4	10	2	rest
5	10	4	rest
6	20	4	rest
7	30	4	rest

2.2 Methods

Specimens with dimensions of approximately 40x10x4 mm cut from strips obtained by the mould injection at 260°C were used in experiment.

The protocol for determining the influence of glass microbubbles and carbon nanotubes on the water absorption of polyamides was in accordance with the ASTM D 570-98 standard for plastics and is shown in Figure 1.

Fig. 1 Working methodology for determining the percentage of water absorbed

The labelled specimens were cleaned in the distilled water under ultrasonic field, conditioned by keeping them in the oven at 50 ± 3 ° C for 24 hours, cooled in a desiccator with calcium chloride (fig.2), then weighed to determine the initial mass at the precision analytical balance 10^{-4} g, fig.3.

Fig. 2 Conditioning samples at 50 ºand drying in a desiccator, with $CaCl_2$ as the moisture removal agent in the enclosure

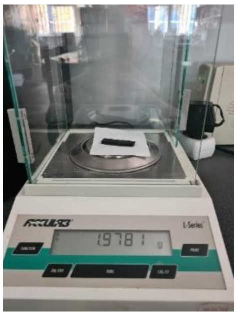
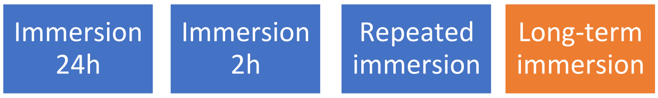


Fig.3. Weighing samples at precision analytical balance 10-4 g

The ASTM D 570 standard provides for four different immersion situations, with the current favourable case being long-term.



Long-term immersion

To determine the total water absorbed when saturated, the conditioned samples are immersed in distilled water and kept for 24 hours, then wiped with a dry cloth, weighed to the nearest 0.001 g and then reintroduced into water. Weighing shall be repeated at the end of the first week and thereafter every two weeks, until the weight gain over a period of two weeks represents, on average, less than 1% of the total weight gain, or 5 mg; when the test piece is considered to be substantially saturated.

Fig. 4. Place samples in distilled water according to the established procedure and keep at a temperature of 23 ° C in a thermostated water bath

3. Experimental results and discussions

The absorbed water concentration is calculated according to ASTM D 570 with relation:

$$c = \frac{m_t - m_c}{m_c} x100$$

where m_t represents the mass of the test specimen at time t, m_c - the mass of the conditioned (dry) test piece.

The obtained results are systematized in table 2 and figure 5.

Table 2. Results of water uptake during 336 h

test SAMPLE	m_c, g	m_{24},g	Wup 24, (%)	m_{168},g	Wup 168, (%)	m_{336},g	Wup 336, (%)
1	17,429	1,768	0,014401	18,144	0,041024	18,456	0,058925
2	16,553	17,252	0,042228	19,129	0,155621	20,422	0,233734
3	16,813	17,036	0,013264	17,381	0,033783	1,77	0,052757
4	15,479	15,788	0,019963	16,287	0,0522	16,731	0,080884
5	18,868	19,199	0,017543	19,779	0,048283	20,336	0,077804
6	1,562	15,745	0,008003	16,776	0,074008	17,854	0,143022
7	14,346	14,888	0,037781	1,631	0,136902	17,194	0,198522

Wup=water uptake
m_c = mass of the test conditioned specimen
m_{24} = mass of the conditioned specimen after 24 hours of immersion
Wup $_{24}$ = water absorption durring 24 hours of immersion
m168 = mass of the conditioned specimen after 168 hours (one week) of immersion
Wup168 = water absorption during 168 hours of immersion
m336 = mass of the conditioned specimen after 336 hours of immersion
Wup336 = water absorption during 336 hours

Usually [2,4] it is used the dependence of water absorption C (t) with respect to the square root of the immersion time (fig 5) to characterize the capacity of a polymeric material to absorb moisture.. It is observed that the introduction of a quantity of 30HGB in PA6 increases the water absorption 4 times while the introduction of MWCNT decreases water absorption by 10%.

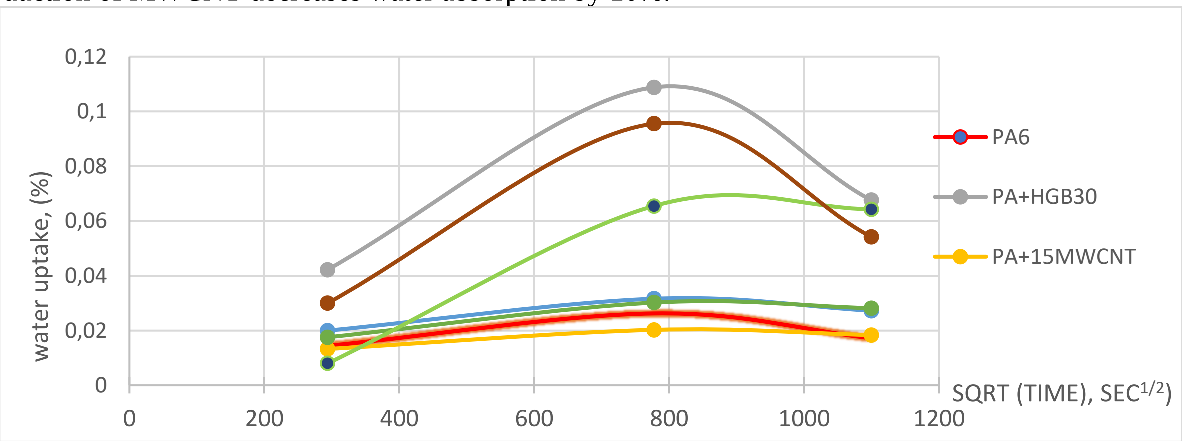


Fig. 5 Dependence of water absorption C (t) on the square root of the immersion time in distilled water at 23 ° C for the seven test specimens

4. Conclusions

Following the research carried out, the following conclusions can be drawn:

- Organic polymers absorb water;
- Water absorption depends on the composition of polymetric hybrid materials
- Carbon nanotubes reduce water absorption in PA6
- Glass microbubbles promote water absorption in PA6

5. Bibliography

[1]. Alexandra Banu, Octavian Radovici, Elemente de Stiinţa şi Ingineria Suprafeţei, Ed Printech, Bucureşti, 2013

[2]. B C Duncan and W R Broughton. (2007), "Absorption and Diffusion of Moisture In Polymeric Materials", în: Measurement Good Practice Guide No. 102 National Physical Laboratory Teddington, Middlesex, United Kingdom, TW11 0LW ISSN 1368-6550;

[3]. Loreto M. Valenzuela,1 Doyle D. Knight,2 and Joachim Kohn, (2016), "Developing a Suitable Model for Water Uptake for Biodegradable Polymers Using Small Training Sets", International Journal of Biomaterials Volume 2016, doi.org/10.1155/2016/6273414,

[4]. G. Bascheka , G. Hartwiga, *, F. Zahradnik (1999) „ Effect of water absorption in polymers at low and high temperatures", Polymer 40 (1999) 3433–3441

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