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Effect of moisture on the mechanical properties of glass fiber reinforced polyamide composites

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ABSTRACT

The effect of moisture on the mechanical properties of glass fiber reinforced polyamide composites was investigated. The composites of short glass fiber/polyamide with different weight percent (0–30 wt%) were prepared. To investigate the effect moisture on mechanical properties of these composites, the specimens were prepared and then immersed in distilled water for a period of 60 days. The weight changes of the specimens were daily measured to determine the amount of moisture absorption of the specimens. Tensile test and flexural test were conducted based on ASTM D638-02a and ASTM D790-02, respectively. The effect of moisture on the microstructure of the composites was also investigated. The moisture absorption of the glass fiber reinforced polyamide composites could be divided into four stages: (I) the beginning stage (1–7 days), (II) the second stage (8–24 days), (III) the third stage (25–35 days) and (IV) the saturated stage (36–60 days). Yield strength, ultimate tensile strength and flexural strength of all specimens significantly decreased at the beginning stage of moisture absorption and then these mechanical properties were almost constant. The modulus of elasticity of all specimens decreased at the beginning stage and saturated stage. In addition, ductility (%Elongation) of all specimens did not change at the beginning stage. However, ductility of all specimens significantly decreased in the third stage, and then their ductility were almost constant. Based on the microstructure analysis, the results indicated that the transition of brittle to ductile properties of the glass fiber reinforced polyamide composites after moisture absorption would be attributed to the changes in their mechanical properties.

1. Introduction

Recently, glass fibers are widely used as the reinforcement for composite materials, because of their various advantages compared to natural fibers. The advantages of glass fibers are high-temperature resistance, corrosion resistance, good dimensional stability, extremely lightweight, strong material and support the continuous production process of automotive industry, almost no moisture absorption [1–7]. Polyamide and polyamide plastic composites are extensively used in automotive structural application. However, a serious water absorption during utilization the important is a major limitation of polyamide and polyamide plastic composites. Water absorption in PA 66 depends on the increase of relative humidity and the increases of moisture content in PA 66 [8]. It has been reported that the water absorption of polyamide (PA 66) strongly influences on its mechanical properties at moisture content up to 6.9 wt% [8]. Glass fiber reinforced polyamide composites are promising materials for automotive part because of their better mechanical properties, lower weight and lower cost for mass-production compared to pure polyamide plastic. Senthilvelan and Gnanamoorthy reported that the reduction of damping factor due to the incorporation of glass fibers was found in glass fiber/polyamide composite [9]. Mortazavian and Fatemi studied the effect of fiber orientation on tensile strength and elastic modulus of short fiber reinforced polymer composites [10]. Güllü et al. found that polyamide reinforced with glass fiber exhibited improvement in their tensile strength and impact strength mechanical strength with the fiber reinforcement [11]. Kumosa et al. reported the moisture absorption properties of various grades of commercially glass fiber reinforced polymer composites [12]. Thongchuea et al. reported that the moisture absorption significantly effects on the ductility of the glass fiber/polyamide composites [13]. However, the effect of moisture on the mechanical

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properties of glass fiber reinforced polyamide composites has not been studied in depth. In this study, the short glass fiber/polyamide composites with different weight percent were prepared to investigate the effect of moisture on their mechanical properties.

2. Experimental

2.1. Preparation of specimens

Polyamide 66 pellets (PA 66, Lot. NK4CC8J1, Invista Engineering Polymers, USA) and E-glass fiber (Lot. M201120751, Nippon Electric Glass, Malaysia) were used as raw materials for prepared the short glass fiber/polyamide composites at 0, 10, 20 and 30 wt% of glass fiber. Density of polyamide 66 pellets was 1.14 g/cm^3 and density of E-glass fiber was 2.55 g/cm^3. Diameter and length of the E-glass fiber were, respectively, 10.5 μm and 3.3 mm. The raw materials were mixed using parallel twin screw extruder at 280 °C. The rotation speed of extruder was fixed at 70 rpm. Then, the extruded glass fiber/polyamide composites were formed to the specimens by injection molding process based on ASTM D638-02a standard [14] as shown in Fig. 1.

2.2. Measurement of moisture absorption

The prepared specimens were dried in oven at 100 °C and measured the initial weight prior to immerse into distilled water for a period of 60 days. The weight changes of the specimens were daily measured to determine the amount of moisture absorption of the specimens. For the moisture absorption measurements, the specimens were withdrawn from the distilled waters, wiped dry to remove the surface moisture, and then weighted using an electronic balance to measure the weight uptake in the process. The moisture content of each specimen was calculated from Eq. (1) using its initial weight and the weight of the wet specimen at given time using.

$$M_c = \frac{W_t - W_o}{W_o} \times 100 \quad (1)$$

where M_c is moisture content, W_t is the weight of the wet specimens at given time t and W_o is the initial weight of the specimens.

2.3. Tensile test

After measurement of moisture absorption, the tensile test of the composites was carried out using a computerized universal testing machine (Shimadzu, AGS-X) according to the ASTM D638-02a standard [14] at a pull up speed of 5 mm/min at 25 °C. Four specimens for each condition were carried out to minimize errors. Yield strength (σ_Y), modulus of elasticity and ultimate tensile strength were estimated based of their stress–strain curve.

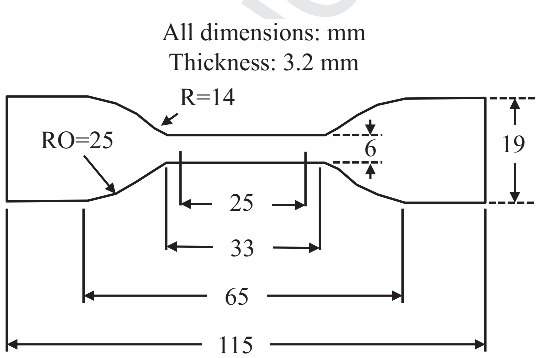

Fig. 1. Dimensions of prepared specimen based on ASTM D638-02a standard.

%Elongation (%EL) was calculated to determine the ductility of the specimens using Eq. (2)

$$\%EL = \frac{l_f - l_o}{l_o} \times 100 \quad (2)$$

where l_f is the length of the specimens at time and l_o is the initial length of the specimens.

2.4. Flexural test

The flexural tests were performed on the same machine, using the 3-point bending fixture according to ASTM D790-02 [15] with the push down speed of 5 mm/min. Flexural strength (σ_F) was computed using Eq. (3).

$$\sigma_F = \frac{3FL}{2Wh^2} \quad (3)$$

where F is the maximum load at crack extension, L is the span of the specimens, W is the specimens width and h is the specimens thickness.

2.5. Microstructure analysis

The microstructure of surface fracture of the specimens after tensile test was examined using scanning electron microscopy (SEM, Model MA10, ZEISS).

3. Results and discussion

3.1. Moisture absorption behavior of the glass fiber/polyamide composites

The relation between the moisture absorption content on the glass fiber/polyamide composites and immersed time is shown in Fig. 2. It is obviously seen that the moisture absorption contents decreased with increasing of the weight percent of the glass fiber in the glass fiber/polyamide composites. This is indicated that the moisture is mainly adsorbed into polyamide due to the almost no moisture-absorption property of glass fiber. The absorbed moisture content of all samples increased with an increasing immersion time and reached the saturation around 50 days after immersion. The moisture absorption behaviors of the glass fiber/polyamide composites can be divided into 4 stages as follows: (I) Days 1–7: Initiation, rapid moisture absorption was observed; (II) Days 8–24: Reduction of moisture absorption; (III) Days 25–35: Near saturation stage, more reduction of moisture absorption was observed; and (IV) Days 36–60: Saturation stage, the moisture absorption was almost constant and then reached the saturation.

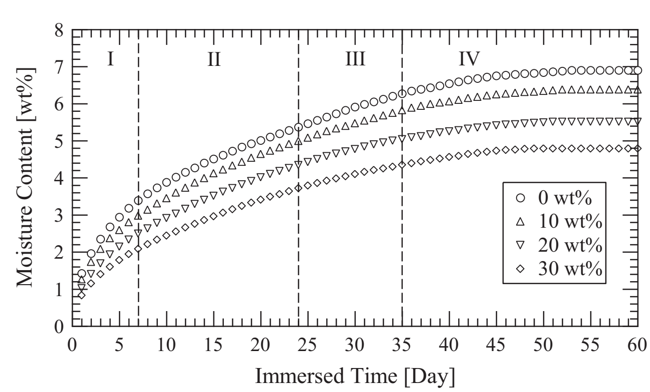

Fig. 2. Relation between the moisture absorption content on the glass fiber/polyamide composites and immersed time.

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