EFFECT OF WATER ABSOPTION ON THE DYNAMIC MECHANICAL PROPERTIES OF PULTRUDED JUTE FIBRE REINFORCED POLYESTER COMPOSITES

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Introduction

Fibre reinforced polymer composites (FRP) have been widely used to replace metal and wood because of their high specific tensile strength, good fatigue resistant, low density, reduced tool wear, enhanced energy recovery, good biodegradability and corrosion resistance, [1]. Recently, there is the tendency of replacing synthetic fibre such as glass fiber with natural fibre for polymer composites. The reasons are mainly due to the low cost, sustainability and environmental issues [2]. However, one of the main concerns of using natural fibre reinforced polymer composites is their susceptibility to moisture absorption which can affect the physical, mechanical and thermal properties. Moisture diffusion in polymeric composites has shown to be governed by three different mechanisms [3]. The first involves diffusion of water molecules inside the micro gaps between polymer chains. The second involves capillary transport into the gaps and flaws at the interfaces between fibre and the matrix. The third involves transport of microcracks in the matrix arising from the swelling of fibers (particularly in the case of natural fibre composites). Apparently, natural fibre reinforced polymer composites will be subjected to various water conditions where the diffusion mechanisms are expected to differ significantly between one conditions to another. Therefore, in this study, three different water treatments were chosen. The effect of three different water treatments on the dynamic mechanical properties was investigated. The dynamic mechanical properties between standard and immersed samples were compared and the effects of pH and immersion time were also recorded.

Experimental

Materials

The PJRC contains approximately 70% of the fibre and typically 30% of unsaturated polyester matrix was used in this study. Jute fibres were supplied by Alam Fiber Impex Ltd, Bangladesh in roving form. Unsaturated polyester resins (Crystic P9901) was supplied by Revertex (Malaysia) Sdn. Bhd. The pultruded composite specimens were produced by pultrusion process which manufactured using a thermoset pultrusion machine at MMFG Composites Sdn. Bhd, Subang Jaya, Selangor, Malaysia. The PJRC were immersed in typical water treatments such as sea water (pH 8.9), distilled water (pH 7), and acidic water (pH 5.5) for 21 days (504 hours).

Apparatus and Procedures

Dynamic Mechanical Analysis (DMA) was performed using Mettler Toledo (Model 861) under three-point bending configuration (ASTM D5023-7). The PJRC samples were tested in temperature range from 0 ^{o}C -300 ^{o}C, with a heating rate of 5 ^{o}C per min, operating frequency of 10 Hz, forced amplitude of 4.5 kN and the displacement amplitude of 10 µm.

Results and Discussions

i) Water Absorption Behaviour

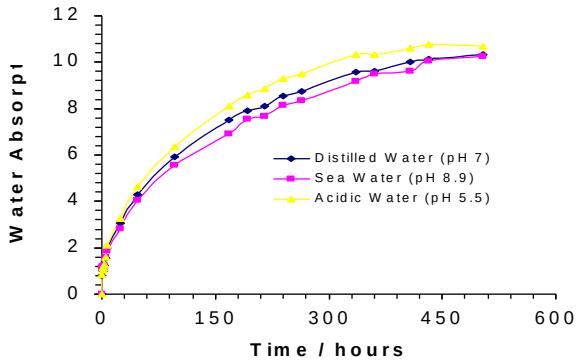

Fig.1 Variation of water absorption (%) of PJRC samples in various treatments for a period of 21 days

Figure 1 shows the amount of water absorbed by PJRC after 504 hours of immersion time. From Figure 1, a sharp increase in water absorption is seen over the first period of 24 hours. This trend can be attributed to the extraction of highly soluble materials and hydrolysis reaction which causes the extraction of low molecular weight polyester styrene and glycol into the water [4]. After 24 hours of immersion time, the amount of water absorbed is still increasing but with slower absorption rate. This can be due to the leaching out of the polyester resin which is more difficult to dissolve as compared to styrene and glycol and takes longer period of time resulting in slower rate. Finally the amount of water absorption reaches the saturated level where the absorption is almost zero over a given period of time.

ii) Dynamic Mechanical Analysis

Figure 2 represents a variation of storage modulus of PJRC after 21 days of immersion under various water treatments. As expected, water absorption has significantly reduced the storage modulus of PJRC with greatest reduction is recorded for PJRC immersed in

acidic water (pH 5.5). It can be clearly seen that immersion in seawater has the least effect on storage modulus as far as PJRC is concerned over the range of temperature studied.

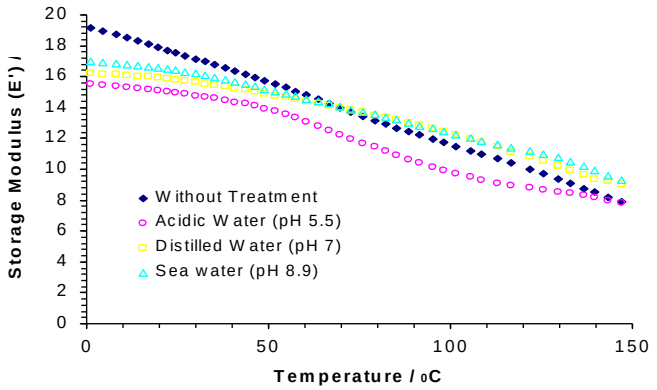

Fig.2 Variation of storage modulus (E') for PJRC immersed in various environment treatments for 21 days

It is reported that the reduction in storage modulus as a result of water absorption is due to the deterioration of interfacial adhesion and bond strength between jute fibre and polyester matrix [4]. The deterioration of storage modulus is further affected by the moisture expansion, a mismatch between jute fibre and polyester matrix which facilitate the reduction in interfacial strength. Furthermore, the absorbed moisture will make the matrix to swell and break the water molecules through hydrolytic and plasticizing reactions which damages the structure of the matrix and the interface [4].

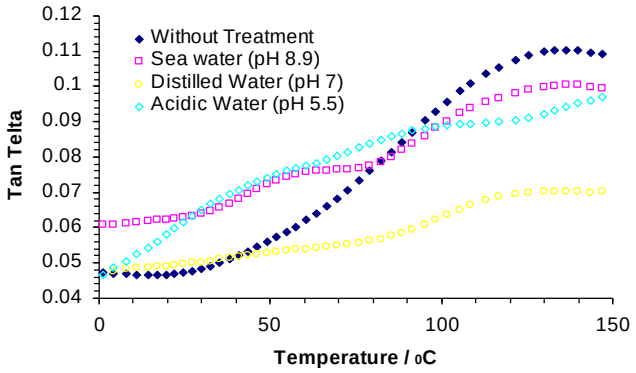

Fig.3 Variation of damping coefficient tan δ for PJRC immersed in various environment treatments for 21 days

Figure 3 shows a typical damping coefficient (energy dissipation), tan δ for PJRC immersed in various environment treatments against temperature for a period of 21 days. In general, the tan δ value represents a mechanical damping or internal friction in a visco-elastic material system. High value of tan δ indicates the material has a high, non-elastic strain component, while a low value indicates material that is more elastic. From the figure, PJRC samples immersed in sea water showed a greatest value of tan δ followed by acidic water and the distilled water. This again can be attributed to the interface degradation as a result of water absorption in PJRC samples after duration of 21 days. When the polyester is deformed, one part of the energy may be stored in a form of potential energy, another part would be dissipated in the form of heat energy. It is reasonable to anticipate that the decreased damping of the PJRC with prolonged immersion time was caused by the energy dissipation of the matrix which results in the change of properties of PJRC from less elasticity to greater elasticity materials. When immersed in various treatments. Consequently, the dissipation energy was smaller as compared to standard PJRC in terms of energy recovery. From the same curve, the glass transition temperature, T_g may determined as temperature when maximum value of the damping (tan δ) was reached. From Figure 3, it is clear that the decreased trend of T_g is observed after immersion. The decreased value reflected the plasticization effect of absorbed moisture in the matrix. When the moisture entered the matrix, it may plasticize the resin which could lead to the molecular chains of the matrix expand and increase the distance between the molecules and breaking of hydrogen bonding resulting in decreased T_g value. On the other hand, the oxidation and hydrolysis of the matrix and the cracking of the interface caused by the absorbed moisture will also responsible for lowered T_g value.

Conclusion

Effect of water absorption behaviour on the dynamic mechanical properties of the Pultruded Jute Fiber Reinforced Composite (PJRC) has been successfully evaluated. It may be concluded that environmental conditions have a huge impact on the properties of PJRC. From this study, storage modulus, tan delta has seen to decrease with increasing immersion time in acidic water affect the properties of the most. The main mechanisms for the deterioration of dynamic mechanical properties are reduction in interfacial adhesion and moisture coefficient mismatch between fiber and matrix.

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