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INVESTIGATION OF PHYSICO-MECHANICAL PROPERTIES OF NATURAL PALM FIBER REINFORCED POLYVINYL CHLORIDE COMPOSITES

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ABSTRACT

Fiber reinforced polymer composites played a dominant role in a variety of applications for their high specific strength and modulus. The present work describes the effects of palm fiber addition on physico-mechanical properties of polyvinyl chloride (PVC) composites. The tensile strength and Young's modulus of the fabricated products increased, while the bulk density, flexural strength and tangent modulus decreased with the increase of fiber addition. The tensile strain decreased with the increase of fiber addition up to 10% and after that it remained nearly constant, while flexural strain remained increasing. There was an initial differential thermal analysis (DTA) peak for both palm fiber and composite, whereas PVC did not have that peak due to water absorption. Thermal analysis of PVC-palm fiber composites has shown that thermal degradation of PVC started ahead of palm fiber. The thermal stability of composite was found to be the average of palm fiber and PVC foam sheet.

Key words: Natural fiber, Polyvinyl chloride composite, Mechanical properties, Differential thermal analysis

INTRODUCTION

The natural polymer is biodegradable, abundantly available, and easily decomposable in the environment and eco-friendly. Modification of natural fibers in order to obtain fiber of improved textile performance is the subject of several groups of scientists and technologists. Natural fiber is completely biodegradable. On the other hand, there are several safety and environmental issues on PVC. Vinyl-chloride can cause serious health problem. Mixing PVC with natural fibers could reduce its disadvantages while conserving its advantages (Ayora *et al.* 1997). There are about two thousands plant species from which fibers can be extracted, but a few of them have economical value. Recently natural fibers have been used as reinforcement-filler in low melting thermoplastic (Mohanty *et al.* 2000). Because of lower density, easy processibility, biodegradability and availability in nature, combined with a better cost-performance

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ratio, cellulosic materials show bright potentiality as filler in thermoplastics. *Borassus flabilifer* (Palm) fiber is high quality fiber and can be produced without any sufficient care and cost. Over about three decades composite materials, plastics and ceramics have been the dominant emerging new materials. The volume and number of applications of composite materials have grown steadily. Modern composite materials constitute a significant proportion of the engineered materials (Willoughby 2002). While composites have already been proven their worth as weight saving material (Bledzki and Gassan 1999) the current challenge is to make them cost effective. The efforts to produce economically attractive composite components resulted in several innovate manufacturing techniques currently being used in the composites industries. The present work shows the investigation of physical, mechanical, thermal and water absorption properties of PVC-palm fiber polymer composite. If these properties are studied, these composite will find application in industries and house hold applications.

MATERIALS AND METHODS

The chief raw materials used for the sample preparation of composite were palm fibers and PVC collected from rural area and local market, respectively. The diving end of the middle hard part of the palm leaves were beaten gently with a hummer and were soaked in water where microorganisms were present for 20 days. This process is called retting which can partially decompose the leaves. The rotten materials were then washed with clean water and the loose fibers were separated. After drying in the room temperature, fibers were cut into length of 125 mm with the help of a pair of scissors. These fibers were kept at a dry environment (Oven-Memmert, Model-600) for 24 hrs at 100°C for palm partial removal of moisture.

Arrangement of chopped palm fibers and PVC were done homogeneously for the better quality of the products. A special molding device was made by mild steel to very close tolerance for the molding process. The mixture of fiber and matrix is cast by simply arranging the raw materials into the mold and leveling it to the desired thickness. Only slight stamping or hammering on the mold is required for sufficient compaction. PVC-palm fiber (long) reinforced composites were fabricated using a simple hot press molding method (450 KN Weber-Press). The press consisted of pressing, heating and cooling system. The mixtures were taken after using a little amount of mold releasing agent. The heating temperatures and initial pressure were set at 160°C and 50 KN, respectively. After reaching the set temperature, the holding time was taken 15 minutes. Then pressure was increased up to 100 KN and stopped the heating system. Then the system was allowed to cool by tap water through the outer area of the heating plates of Weber press machine and the specimen was then de-molded by a set up device which was made as a makeshift device.

The bulk density of the specimen was determined according to the ASTM C134-76 (2002). The tensile test method covers the determination of the tensile properties of reinforced plastics composites when tested under defined conditions of the testing machine speed. Tensile specimen was prepared according to ASTM D638-98 (2002) and the test speed was 2 mm/min. Flexural specimen was prepared according to ASTM D790-98 (2002). The specimen average dimension was (116 × 11 × 4.2) mm^3 and support -span was 96 mm. The test speed was taken as 2 mm/min. Hounsfield UTM 10 KN (H10KS) was used to test tensile, flexural strength, compression and shear properties of materials. Electric balance (HF 200) was used for measuring weight of the sample. Thermal analysis included a group of techniques where some physical properties of the sample were monitored under controlled conditions with variation of temperature at a programmed rate. Composites were taken using a computer controlled TG/DTA 6300 system controlled on an EXSTAR 6000 STATION, Seiko Instrument Inc., Japan. The TG/DTA module uses a horizontal system balance mechanism. The specifications of the instrument were: Heating rate; 0.01 to 100.00 K/min., TGA measuring range: ± 200 mg (0.2 µg), DTA measuring range: ± 1000 µV (0.06 µV), gas flow: ≤ 1000 m/min. Water intake specimen was prepared according to ASTM designation: D 570-81 (2002). The test specimen was 76 - 76.2 mm length, 25.4 - 25.6 mm. width, and 3 - 4 mm height. In all cases a protective gel coat (araldite) was applied on the cut sides to prevent penetration of water from cut sides.

RESULTS AND DISCUSSIONS

Fig. 1 shows the effect of palm fiber addition on density of PVC-palm fiber composites. The density of PVC product without addition of fiber was 1.32, the value is in the range of 1.3 - 1.58 found in the article of Akter *et al.* (2006). With the increase of fiber content the density decreased. This followed the mixture rule (Askeland 1991).

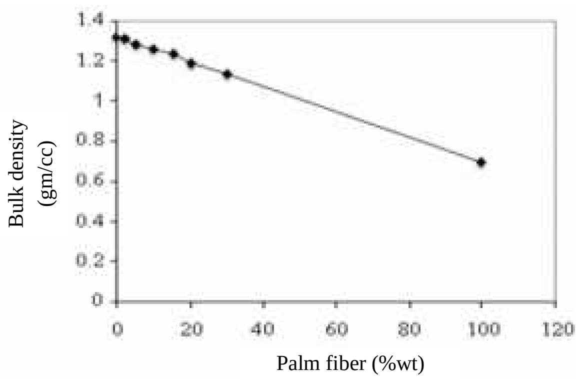

Fig. 1. Dependence of density of PVC-Palm fiber composites on palm fiber content.

Fig. 2 shows the effect of fiber addition on flexural strength of PVC-palm fiber composites. For PVC the flexural strength is 37.79 MPa and for 5% addition of palm fiber, the composite has flexural strength of 42 MPa. Similar result was reported by Zuhri *et al.* (2010). At first the flexural strength of fabricated product increased from 0 to 10% fiber addition and then finally decreased with the increase of fiber addition. The initial increase in the flexural strength up to 10 wt.% of fiber content loading is mainly attributed to reinforcing effect imparted by the fibers, which allowed a uniform stress distribution from continuous matrix phase to dispersed fiber phase (Bozlur *et al.* (2010)). Above 10 wt.% fiber content, flexural strength has decreased. This decrease in the flexural strength at high fiber content implied poor fiber-matrix adhesion which promoted micro-crack formation at the interface. The flexural strength of composites containing up to 20% fiber was higher than that of PVC sheets. Fig. 3 shows the effect of fiber addition on flexural strain of PVC-palm composites. It revealed that the flexural strain of the fabricated product increased with the increase of fiber addition

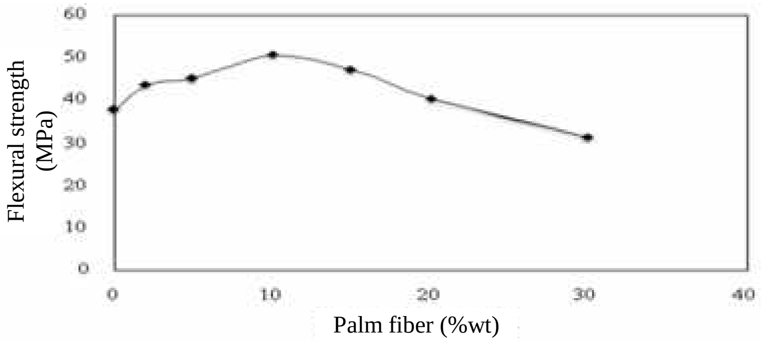

Fig. 2. Effects of palm fiber addition on flexural strength of PVC-palm fiber composites.

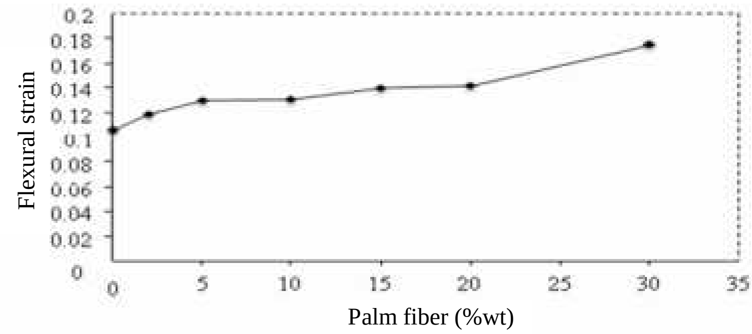

Fig. 3. Effects of palm fiber addition on flexural strain of PVC-palm fiber composites.

experienced ductile fractures. It can be notified that the evolution of the composite flexural strain with increasing fibers volume fraction is very big since the strain at break of palm fibers and PVC matrixes are too distant. Fig. 4 shows the effect of fiber addition on tangent modulus of PVC-palm fiber composites. This result showed that addition of palm fiber and PVC matrix, resulting in well-dispersion of the fiber in the matrix and excellent interfacial bonding between them and the palm fibers did not impose any restriction in matrix yielding.

Fig. 5 shows the effects of fiber addition on tensile strength of PVC-palm fiber composites. It revealed that the tensile strength of fabricated product increased with the increase of fiber addition up to 20%. After that it was found to be nearly constant. This result reflected the excellent interfacial adhesion between fiber and PVC matrix, as it is known that fibers provide a toughening or building mechanism to strengthen or prolong the composite life (Shaikh *et al.* 2003, Brahim *et al.* (2006)) and both the fiber and the matrix bear the load and fibers make resistance to slip.

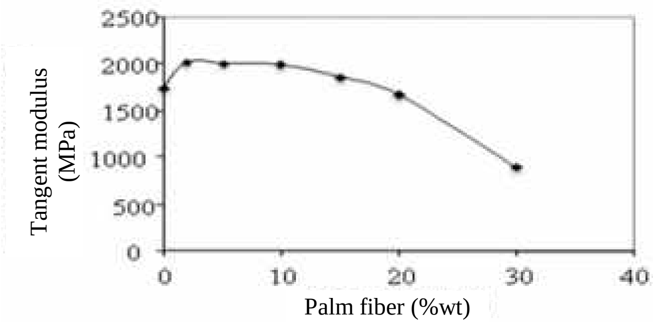

Fig. 4. Effects of palm fiber addition on tangent modulus of PVC-palm fiber composites.

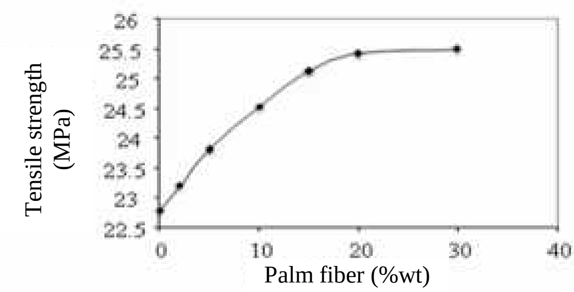

Fig. 5. Effects of palm fiber addition on tensile strength of PVC-palm fiber composites.

Fig. 6 shows the effects of palm fiber addition on tensile strain. It revealed that the strain decreased with the increase of palm fiber addition. The presence of fiber addition restricted the slip by creating fewer voids in the continuous phase. This resulted in lesser ductility and toughness and consequently the per cent of elongation decreased continuously with the increase of palm fiber addition. It also revealed that the randomly oriented palm fiber reinforced the PVC matrix from 0 to 20% of fiber addition both the fibers and the matrix bear the load. Fig. 7 shows the effects of fiber addition on Young's modulus of PVC-palm fiber composites. The Young's modulus of PVC was found to be 1003.759 MPa. It revealed that the Young's modulus of fabricated product decreased from 0 to 10% of fiber addition and then the Young's modulus increased slightly. Young's modulus decreased which indicated lesser contribution of fibers towards the static machanical properties of composites. The minimum value of Young's modulus was obtained for 10% increase of the palm fiber addition which specifies ineffective stress transfer between the palm fibers and PVC matrix (Naveen and Yasaswi 2013) and after that the fiber and polymer were well-distributed and Young's modulus increased (Sapuan *et al.* 2003, Brahmakumar *et al.* 2005). Young's modulous is a measure of stiffness of a material.

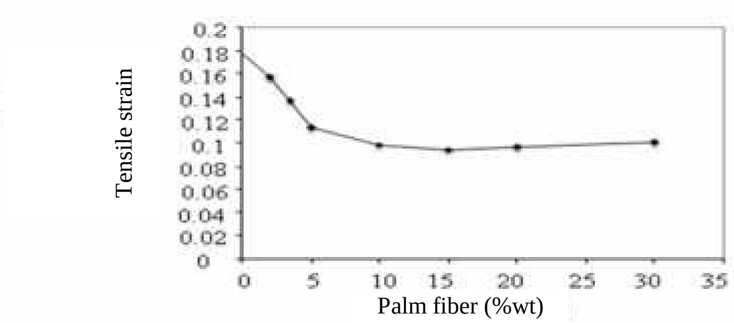

Fig. 6. Effects of palm fiber addition on tensile strain of PVC-palm fiber composites.

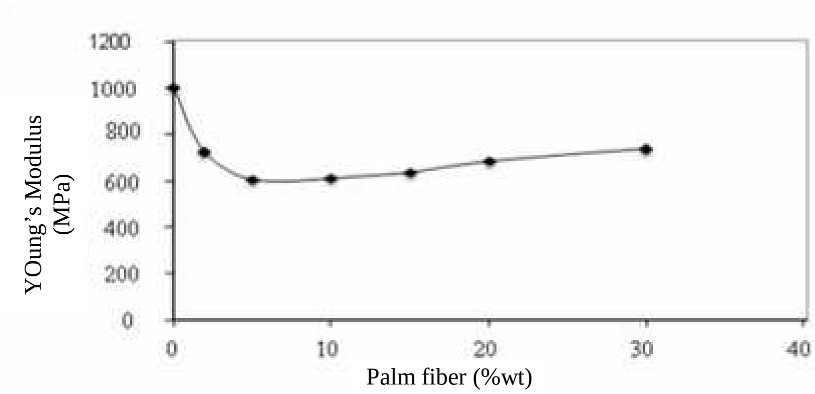

Fig. 7. Effects of palm fiber addition on young's modulus of PVC-palm fiber composites.

Fig. 8 shows that the TG, DTA and DTG curves of PVC and palm composites. The top one is the TG, the bottom one is the DTG and the middle one is the DTA curves for PVC and palm composites. The TG curve of composites revealed two stage degradation one was sharp, and the other one was weak and broad. The first peak for PVC/natural fiber composites arises from degradation of natural fibers and the second one from degradation of PVC matrix. Similar result was obtained in the report of Xu *et al.* (2008). The TG curve also shows an initial loss of 0.6% which is due to moisture content. The DTA curve of palm fiber shows four endothermic peaks at 95.8, 233.6, 293.1 and 356.9°C. The first peak at 95.8°C was due to removal of moisture. The second and third peak is due to lighter and the forth peak corresponds to major degradation respectively. While the DTA curve for PVC foam sheets showed only one endothermic peak at

302.9°C and the PVC-palm fiber composites showed three endothermic peaks at 87.6, 287.9 and 447.8°C. The DTG curve also revealed that there are two peaks at the temperature of 287.9 and 431.4°C. The DTG curve showed maximum degradation occurs at 287.9°C with the rate of 1.216 mg/min. Fig. 9 shows that the TG, DTA and DTG curves of PVC foam sheet, composites and palm fiber. The top one is the curve for PVC foam sheet, the bottom one is for palm fiber and the middle one is the curve for composites. The TG curve showed an initial loss of 5.9% which corresponded to moisture content. The lighter materials are removed initially and then heavier materials are removed. The TG curve showed that major degradation occurred at three stages for the fiber. However, for neat PVC only one major degradation peak was observed. Obviously, incorporation of palm fibers lowered the thermal stability of PVC- palm fibers composites compared with neat PVC. Similar result was also found by Xu *et al.* (2008). Thus, the thermal stability of composites is found to be the average of PVC and palm fiber (long) composites.

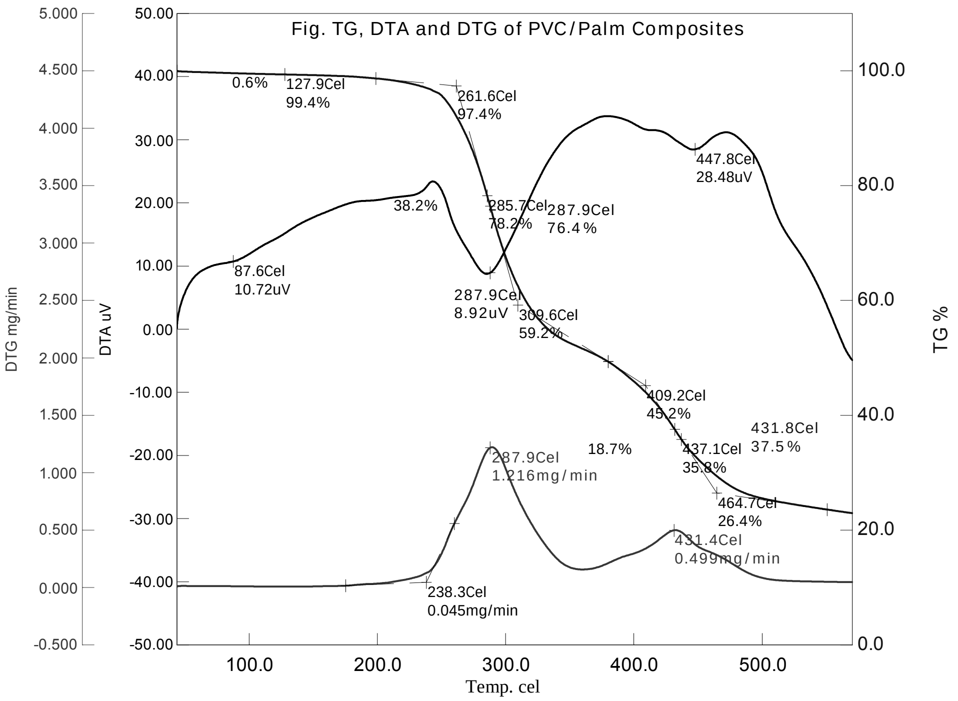

Fig. 8. TG, DTA and DTG of PVC and Palm composites.

The effects of fiber content (wt. %) and soaking time on water absorption are shown in Fig. 10. Water absorption was monitored at 30°C and at relative humidity (RH) 65% (± 5%). Water absorption increases with the increase of soaking time. As the fiber content increased, the composite was more prone to water. The water absorption ability of these composites was measured by soaking the composites in water contained in a static bath for different period of time, *viz*. 24, 48, 72 and 144 hrs. The Fig. 10 revealed that water absorption rate was very fast within the initial 24 hrs, and then the absorption rate became steady as time passed. The cellulosic effect, the lignin effect and also void spaces that present in the composites might be responsible for the increase of soaking rate.

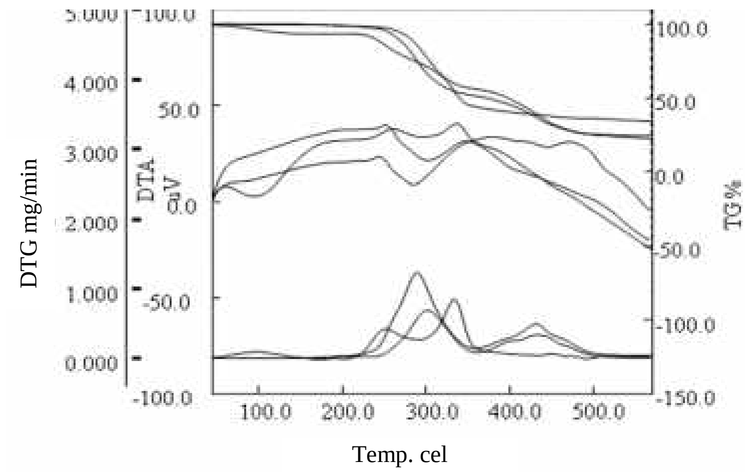

Fig. 9. TG, DTA and DTG of PVC foam sheet, composites and palm fiber.

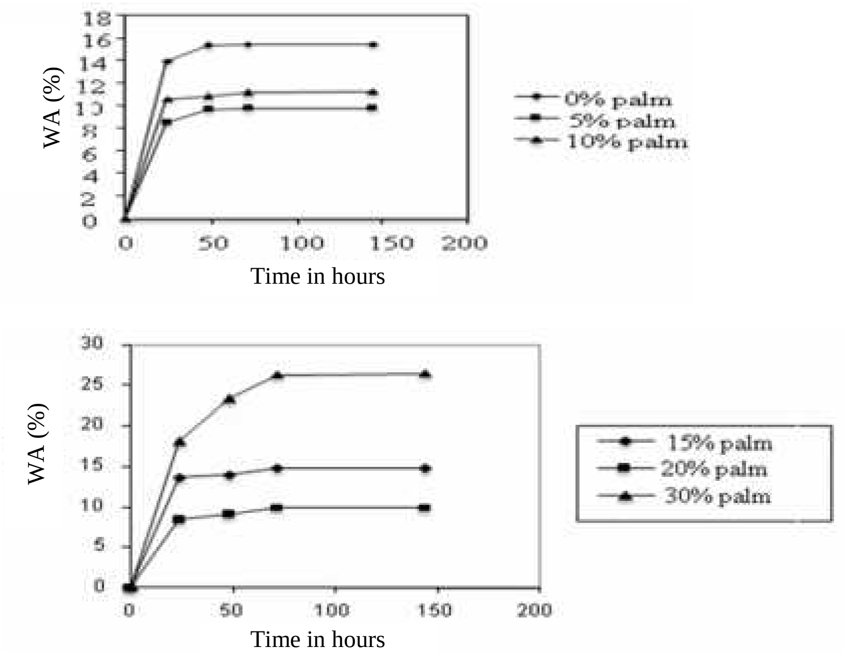

Fig. 10. Effects of immersion time on water absorption (WA) of 5, 10, 15, 20 and 30% palm-PVC composites.

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