 DOI: 10.1002/masy.201251134

Effect of the Different Sizes of the Alfa on the Physical, Morphological and Mechanical Properties of PVC/Alfa Composites

A. Boukerrou, N. Hamour, H. Djidjelli, D. Hammiche*

Summary: The changes in mechanical properties and the water absorption capacity of poly (vinyl chloride)/alfa fibre composites were studied as a function of alfa fibre content (10, 20 and 30 wt %) and its particle size. The study showed that composites samples exhibited higher tensile modulus compared with the virgin PVC, whereas elongation at break and tensile strength were observed to decline. Moreover, the amount of absorbed water depends on the amount of fibre in the composite. The comparison of the results obtained from the samples with different sizes 160, 200, 250, and 315 μm called F160, F200, F250 and F315 and the virgin PVC indicated that the presence of small particle sizes exhibited a beneficial effect on the water absorption by improving the quality of adhesion between polymer and fiber.

Keywords: alfa fiber; composites; particle size; poly(vinyl chloride)

Introduction

Composites are usually developed to improve the properties of the individual components.[1] Reinforcement of polymer matrices was initially achieved with man-made fibers, such as glass, carbon and aramid resins, to take advantage of their high tensile modulis.[2] Over the last few years, significant amount of work has been carried out to allow for use of natural fillers extracted from vegetable source.[3,4] Different works have been devoted to thermoplastics/wood composites; in general, these composites are based on high density polyethylene (HDPE),[5] poly(propylene) (PP) [6] and poly(vinyl chloride) (PVC).[3,4] In addition, PVC as one of the most important commodity polymers, finds many technical applications and is of enormous economic importance.[7,8]

Mechanical and physical properties of natural polymer composites depend on various parameters such as volume fraction, aspect ratio, fiber orientation, dispersion level, polymer adhesion, mixing time, and processing conditions. Most studies involved the investigation of the mechanical properties of natural fiber-based polymer composites in terms of particle size and natural fiber content.

Saini et al. [9] investigated the effect of filler [obtained from bark of Acacia (Babool)] content and its particle size (ranging from 100 to 150 μm and <50 μm) on the properties of poly(vinyl chloride) (PVC) composites. Bark of the fast-growing species Acacia was used as powder for making PVC composites, which may find applications as a substitute to high-cost wood and to avoid deforestation. Tensile strength and percentage of elongation at break decreased, whereas modulus increased with an increasing amount of bark flour. Improvement in properties was significant in the presence of filler, having a particle size <50 μm as compared to filler, having a particle size ranging from 100 to 150 μm.

The main objective of the present study was to investigate the effect of content (10, 15 and 20 wt %) and particle size (160 μm,

Organic Materials Laboratory, Department of Genie of Processes, University A. Mira, Targa-Ouzemmour, Bejaia 06000, Algeria
E-mail: aboukerrou@yahoo.fr

200 μm, 250 μm and 315 μm) of alfa fiber on the physical and mechanical properties of the PVC composites. The study showed that composites samples exhibited higher tensile modulus compared with the virgin PVC, whereas elongation at break and tensile strength were observed to decline. Moreover, the amount of absorbed water depends on the content of fibre in the composite. The comparison of the results obtained from the samples with different sizes 160, 200, 250, and 315 μm called F160, F200, F250 and F315 and the virgin PVC indicated that the presence of small particle sizes exhibited a beneficial effect on the water absorption by improving the quality of adhesion between polymer and fiber.

Experimental Part

Materials

All the PVC/alfa formulations used in this work were based on PVC type SE-1200 provided by CABEL "Cablerie Electrique" located in Algiers (Algeria). The polymer has the following physical characteristics: Kwert (parameter that characterizes the viscosity of a material), 70.2–72.0; powder density, 0.521. The additives used in the preparation of the various formulations were dioctyl phthalate as plasticizer, a thermal stabilizer system based on Ca/Zn, and stearic acid as a lubricant. The alfa used as reinforcing filler was collected at M'Sila in Algeria and different sizes ($< 160\,\mu m$, $< 200\,\mu m$, $< 250\,\mu m$ and $< 315\,\mu m$) were selected.

Preparation of the Composites and Characterisations

PVC powder and the various additives were placed in a high-speed twin steel-wall mixer and processed at a speed of 3000 rpm at 70 °C, below the glass transition temperature of PVC. The different PVC formulations obtained were used to prepare films by the calendering process at 140 °C with a residence time of 8 min. Alfa and PVC were compounded in a tworoll mill. The temperature of the two rolls was maintained at 140 °C. After the addition of the matrix the fiber was added as soon as the polymer had reached a steady plastifying state, which needed about 3 min. After mixing for 3–4 min, the resulting mixture was compression-molded. All of the samples were performed in a preheated press at 170 °C under a pressure of 250 KN for 5 min, and following by cooling to room temperature. The 2 mm thick plates obtained were then used in various characterizations. The preparation of composites was carried out in the laboratory of CABEL "Cablerie Electrique" located in Algiers (Algeria).

The morphology of composites was examined using a FEI CONTA 200 electron microscope. The compression molded sheet was cryogenically fractured in liquid nitrogen. The micrographs were taken at a magnification of 200.

Water absorption of composite was examined by immersion of the 2 mm thick sheet sample in distilled water at room temperature for 1080 h (45 days), according to standard ASTM D570. The samples were first placed in an oven set at 50 °C for 24 h. The oven-dried weight (W_d) was determined and used to calculate the degree of moisture absorption as follows:

$$\text{water absorption}(\%) = \frac{w\text{-}w_d}{w_d}$$

The tensile test for the composites was conducted according to standard "ISO 527, June 1993" at ambient temperature, using a tensile testing machine of the type "Zwick/Roell." Five measurements were conducted and averaged for the final result.

Results and Discussion

Water Absorption Behaviour

The evolution of water content versus time at different fiber contents is shown in Figure 1. The results reveal that all composites showed higher degree of water absorption as compared to the PVC matrix.

Subsequently, with the increase in the alfa fiber content of a composite, more water residence sites will be available,

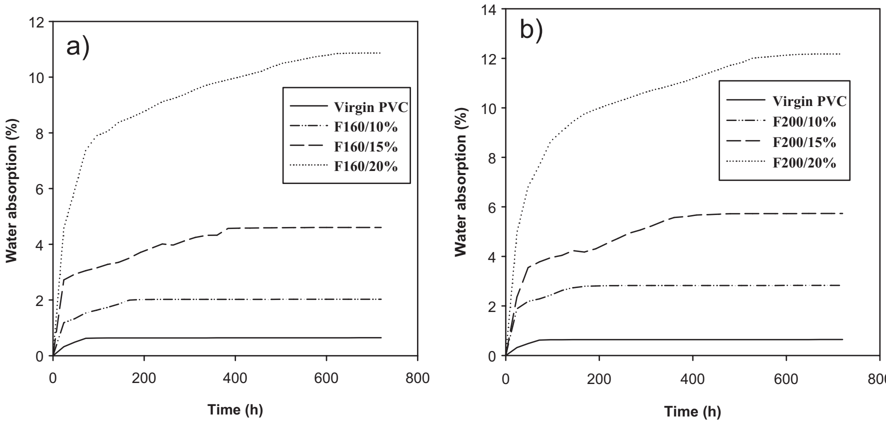

Figure 1.
Water absorption of PVC and PVC/alfa composites (0, 10, 15 and 20 wt % alfa fiber). a) PVC/F160, b) PVC/F315.

which results in more water absorption. In general, polymers do absorb very little moisture, indicating that the cellulosic material in the composite absorbs the moisture. As alfa fiber content increases, the number of hydrogen bonds between OH groups of cellulose and water molecules increases. On the other hand, cellulosic fibers are hydrophilic in nature, and therefore, they can absorb water, which leads to weight increases.[10] Thus, composites with higher alfa fiber (20 wt %) loading show maximum water absorption in all interval times. Smaller particles are more likely to be coated with matrix and also present a less continuous pathway for moisture ingress.[11] Both of these characteristics may help to explain the slower moisture uptake of F160 compared to F315 composites.

Scanning Electron Microscopy (SEM)

The scanning electron micrographs of fractured surfaces of PVC/alfa composites (15 wt%) analyzed by the SEM is illustrated in Figure 2 with an enlargement of 200×.

Composites displayed a rough morphology with the presence of many voids and cavities resulting from fiber pullout (Figure 2. b). This indicates poor interfacial adhesion that reveals the low affinity between the polymer matrix and the alfa fiber. At lower content of fiber, loading alfa fiber is well dispersed; however, agglomeration of fibers was seen at higher filler loading. Water can be easily absorbed by

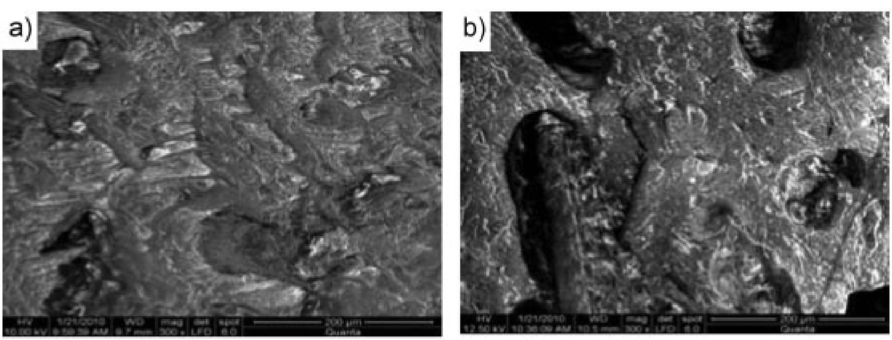

Figure 2.
SEM micrographs of PVC/alfa composites having fiber loading of 15 w%: (a) PVC/F160, (b) PVC/F315.

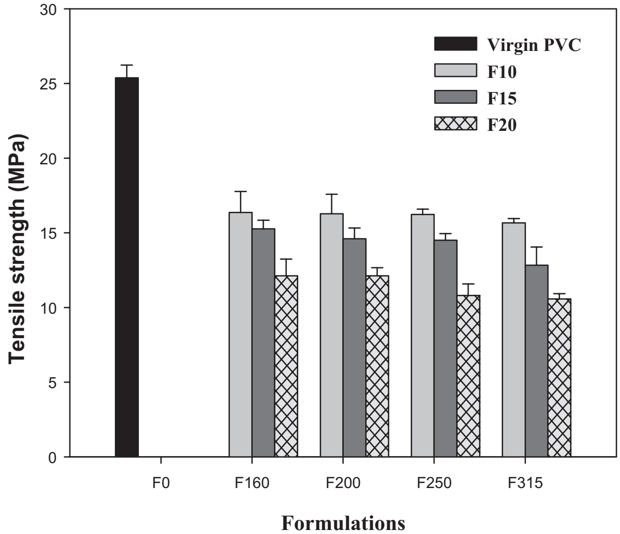

Figure 3.
Effect of fiber content and particle sizes on tensile modulus of PVC compound and composites.

the voids and cavities, thus explaining the high level of moisture absorption found for composites.

On the other hand, less of voids and cavities were observed (PVC/F160), which implies the existence of a substantial degree of adhesion between the two components. For alfa fiber having lower particle sizes most of the fiber surfaces are covered with the matrix material attesting for adequate compatibility between the two phases.

Mechanical Properties

Mechanical properties depend on various factors like filler content, particle size and shape, degree of adhesion and dispersion between filler and the polymer matrix.

One can also observe the decrease of tensile strength (Figure 4) and elongation at break (Figure 5). The decrease of tensile strength is probably due to the increase of interfacial defects, as one might already expect. These results clearly show that the presence of alfa fiber in the matrix reduces the ability of the sample to deform by restricting the mobility of the polymer chains. As as consequence, it is difficult for the segments of the material to easily slip past each other. For the composite containing PVC/F16O, there is a slight increase in elongation at break compared to PVC/F315. This may be due to the uniform distribution of the alfa having a lower particle size. Similar results were found by Anna et al.[12]

As the fiber content increased, modulus increased from 441 MPa to 558 MPa in PVC/F315 composites (Figure 6), whereas in the case of PVC/F160, it increased from 347 MPA to 377 MPa. Tensile modulus of PVC/F315 composites was almost higher compared to PVC/F160 composites at equal loading. This could be due to better reinforcing action of the microfiller. Similar behavior has been reported by several authors with different matrices.[13]

Conclusion

In the present study the effects of fiber content and particle sizes on the physical, surface morphological and mechanical properties of alfa reinforced PVC composites were investigated. The results obtained reveal that the values of tensile strength and elongation at break were found to decrease gradually with an

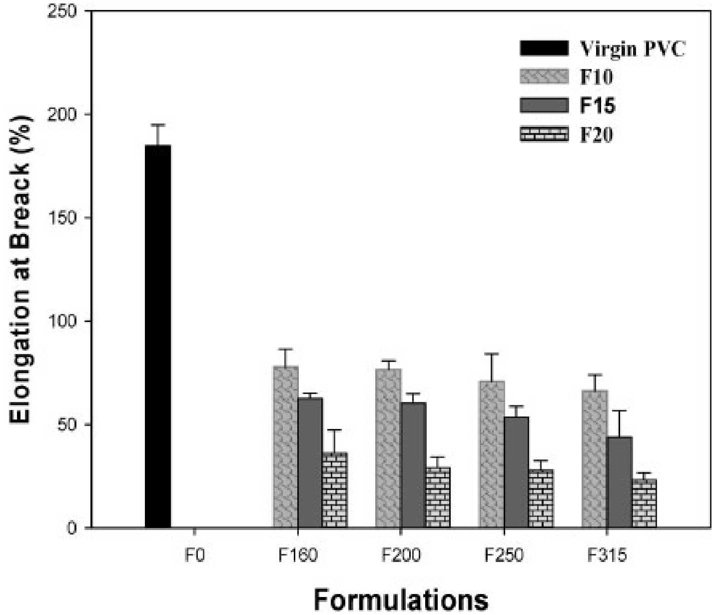

Figure 4.
Effect of fiber content and particle sizes on tensile strength of PVC compound and composites.

increase in fiber loading. However, the increase in modulus was observed. Mechanical properties of PVC/F160 were found to be much higher than those of the PVC/F315 ones. This result was evident from our SEM study. The composites containing more fraction of alfa exhibited maximum water absorption during the whole duration of

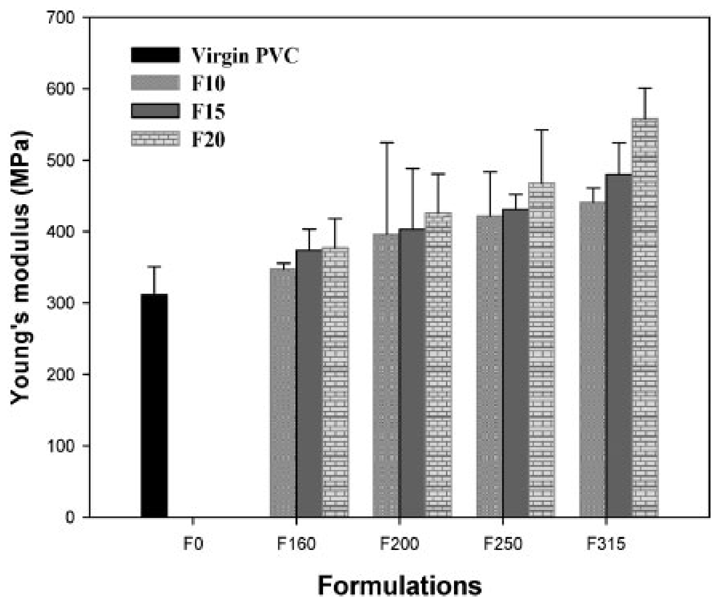

Figure 5.
Effect of fiber content and particle sizes on the elongation at break of PVC compound and composites.

immersion. The presence of small particle sizes exhibited a beneficial effect on the water absorption by improving the quality of adhesion between polymer and fiber.

[1] M. Bengtsson, P. Gatenholm, K. Oksman, *Compos. Sci. Technol.* **2005**, *65*, 1468.
[2] C. Joly, R. Gauthier, M. Escoubes, *J. Appl. Polym. Sci.* **1996**, *61*, 57.
[3] D. Hammiche, A. Boukerrou, H. Djidjelli, M. Beztout, S. Krim, *J. Appl. Polym. Sci.* **2012**, *124*, 4352.
[4] A. Boukerrou, M. Beztout, H. Djidjelli, S. Krim, D. Hammiche, *Mol. Cryst. Liq. Cryst.* **2012**, *556*, 223.
[5] R. G. Raj, B. V. Kokta, F. Dembele, B. Sanschagrain, *J. Appl. Polym. Sci.* **1989**, *38*, 1987.
[6] M. Natow, S. Wassilewa, S. Kowatschewa-Welewa, *Angew. Makromol. Chem.* **1995**, *225*, 73.
[7] M. W. Sabaa, E. H. Oraby, A. S. Abel Naby, R. R. Mohamed, *Polym. Degrad. Stabil.* **2006**, *91*, 242.
[8] K. Z. Hong, J. Vinyl, *Addit. Techn.* **1996**, *2*, 193.
[9] Gajender. Saini, 1. Rashmi. Bhardwaj, 3. Veena. Choudhary, 2. A. K. Narula, *J. Appl. Polym. Sci.* **2010**, *117*, 1309.
[10] Y. Hamzeh, A. Ashori, B. Mirzaei, *J. Polym Environ* **2011**, *19*, 120.
[11] W. Wang, J. J. Morrell, *Forest Prod. J.* **2004**, *54*, 209.
[12] P. Anna, E. Zimonyi, A. Marton, *Macromol Symp.* **2003**, *202*, 245.
[13] R. Mansur, M. Natov, S. J. Vassileva, *Univ Chem Technol Metallurgy* **2002**, *37*, 77.