Effect of Chemical Modifier on the Properties of Polypropylene (PP) / Coconut Fiber (CF) in Automotive Application

K. Shahril, A. Nizam, M. Sabri, A. Siti Rohana, H. Salmah

***Abstract*—**Chemical modifier (Acrylic Acid) is used as filler treatment to improve mechanical properties and swelling behavior of polypropylene/coconut fiber (PP/CF) composites by creating more adherent bonding between CF filler and PP Matrix. Treated (with chemical modifier) and untreated (without chemical modifier) composites were prepared in the formulation of 10 wt%, 20 wt%, 30 wt%, and 40 wt%. The mechanical testing indicates that composite with 10 wt% of untreated composite has the optimum value of tensile strength, and the composite with chemical modifier shows the tensile strength was increased. By increasing of filler loading, elastic modulus was increased while the elongation at brake was decreased. Meanwhile, the swelling test discerned that the increase of filler loading increased the water absorption of composites and the presence of chemical modifier reduced the equilibrium water absorption percentage.

***Keywords*—**Coconut fiber, polypropylene, acid acrylic, ethanol, chemical modifier, composites.

I. Introduction

DRASTIC changing in automotive industries brings to the discovery of new materials. Most of the researchers come out with several ideas to produce lightweight material which is related to fuel economy and eco-friendly. Automotive parts and components made from the polymer composites material are one of the solutions to reduce the weight of the vehicle for better fuel consumption. The properties of polypropylene such as resistance to stress, low density, high tensile strength, chemically inert, resistance to heat, and recyclable become this thermoplastic material widely used in the automotive industries [1]. For instance, gear consul, door trim, pluck in clip and cabin lining in an automobile. In addition, polypropylene is relatively low-cost material and easy to form.

In order to develop biodegradable composites to resolve the current ecological and environmental problems currently, natural fibers are used as filler in polymer composites [2]. Coconut fiber [3], [4] are quite new in reinforcing thermoplastics compared to other natural fibers. Coconut fiber (also known as coir fiber) is a lignocellulosic fiber obtained from the fibrous mesocarp of coconuts, the fruit of coconut trees (Cocosnucifera) cultivated extensively in tropical countries. It is used for making certain traditional products like furnishing materials, rope and others that consume only a small percentage of the total coir production [5]-[7]. Natural fiber is economy materials rather than glass fibers. However, natural fibers are generally hydrophilic and are inherently incompatible with hydrophobic thermoplastics such as polypropylene (PP). The main problem of using natural fibers with thermoplastics is the poor interfacial bonding between the fiber and thermoplastic.

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The chemical modifier is one of the solutions to improve the incompatibility between matrix and filler in polymer composites. Some of the researchers claim that Acrylic acid (AA) is a superior chemical modifier in natural fiber/thermoplastic composites [8], [9]. Acrylic acid or 2-propenoic acid is a chemical compound ($C_3H_4O_2$), and it is the simplest unsaturated carboxylic acid with both a double bond and a carboxyl group linked to its C_3. In its pure form, acrylic acid is a clear, colorless liquid with a characteristic acrid odor. It is miscible with water alcohols, ethers, and chloroform. Acrylic acid is produced from polypropylene, a gaseous product of oil refineries.

In this study, effects of chemical modifier on tensile strength, Young's modulus, and elongation at break of Polypropylene/Coconut Fiber composites were investigated. Moreover, the swelling behavior analysis is used to study the percentage of water absorption of the composites.

A. Types of Fiber

Generally, fibers can be divided into two main groups which are natural fibers and man-made fibers. Natural fibers can be divided into three sources which are from plants, animals, and minerals. Man-made fibers are categorized to synthetics and natural polymers. Fig. 1 shows the major types of fibers used until now.

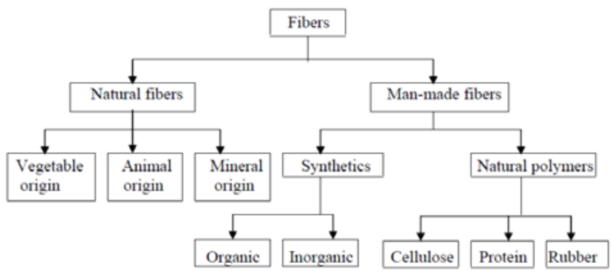

Fig. 1 Classification of fibers.

World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:9, No:7, 2015

B. Natural Fibers

Natural fibers may also be known as lignocellulosic fibers, are desirable from the environmental point of view. Nevertheless, natural fibers may be the viable substitute for expensive and non-renewable synthetic fibers if only they hold a higher value such as better functionality or lower cost. In addition, the contents of lignin and cellulose in natural fibers may give improvement to composites. The advantages of natural fibers over traditional fibers such as carbon or glass are their low density, high stiffness, relatively low cost and biodegradability. Due to these factors, natural fibers have the balance of low cost and environmental friendly allowing them to be considered for application in automotive, building, furniture, and packaging industries. Markus Kaup and colleagues (2003) have made an overall survey on the natural fibers application in automotive industries. Fig. 2 shows one of their surveys for selected natural fibers.

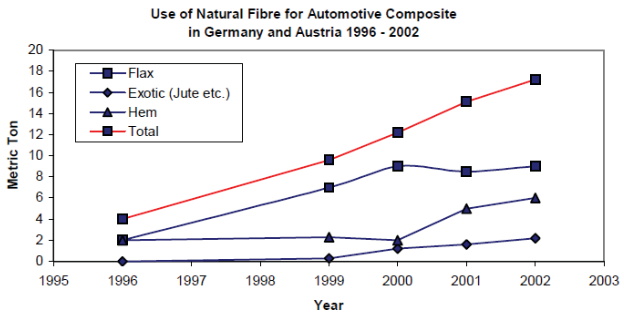

Fig. 2 A survey of natural fiber for automotive composites in Germany and Austria

C. Coconut Fiber

Coir or coconut fiber (Fig. 3) is the natural fiber of coconut husk where it is thick, coarse, and durable. It is relatively water-proof and able to resist damage from salt water and microbial degradation. Even though it has advantages properties, the coconut fiber also have undesirable properties such as dimensional instability, flammability which not suitable for high-temperature application and degradability with humidity. Besides that, coconut fiber has the properties that tend to absorb humidity or moisture that made coconut fiber application very limited.

Fig. 3 A sample of coconut/coir fiber

A good example of coconut fiber application in the automotive grounds is the use of coconut fiber with natural latex as a seat cushion for the Mercedes-Benz E-Class. The coconut fiber ability to absorb humidity and moisture leads to better comfort and mitigate mold growth for cleaner air. This gave another point to coconut fiber benefits in terms of safety and health.

II. Experiments

A. Materials

Polypropylene (PP) used is supplied by Polypropylene Malaysia Sdn Bhd in the form of a pellet with a grade S12232 G112. Coconut fiber is supplied by Chip Chuan Trading & Co in the form of coconut husk. The coconut fiber is extracted from the fiber of coconut husk and cut into tiny pieces with an average length of 2 mm to 4 mm. The Acrylic acid (AA) and Ethanol are supplied by ZARM Scientific & Supplies Sdn Bhd from Sigma-Aldrich.

TABLE I
Formulation of PP/CF Composites Untreated and Treated with Chemical Modifier at Different Filler Loadings

Materials	PP/CF without chemical modifier	PP/CF with chemical modifier
Polypropylene (PP) (wt%)	100	100
Coconut Fiber (CF)* (wt%)	0, 10, 20, 30, 40	0, 10, 20, 30, 40
Aryclic acid (wt%)	-	3

B. Filler Treatment

Acrylic acid (AA) as chemical modifiers agent delivered in liquid form. Before application, it is diluted in ethanol to make 97% solution. The amount of AA used 3% by weight of filler. The filler is added into a chamber mixer (beaker) and the solution is added slowly to ensure uniform distribution of AA. After AA completely discharged, the filler was continuously mixed for another 1 hour. The treated filler then dried at 80 ^{0}C for about 24 hours to allow complete evaporation of the ethanol. Calcium carbonate was modified by using 3% acrylic acid in ethanol and stirred for 1 hour. The calcium carbonate was filtered out, washed with distilled water and dried in an oven at 80 ^{o}C for 24 hours.

C. Compounding Process

The composite is mixed by using Haake Polydrive Mixer Machine for 8 minutes at the temperature of 180°C and rotor speed of 50 rpm. Firstly, polypropylene has entered the mixing chamber and will completely melt after 3 minutes. After that, the coconut fiber (CF) is added into the mixing chamber r. The mixing is completed at 8 minutes. After mixing process, the composite is compressed in a Hot-Press Machine (GT 7014) to perform 1.0mm thickness dumbbell shape by using dumbbell shape mould which complies with ASTM D638 standard. The hot press procedures involve preheating at 180ºC for 6 minutes, compressing for 4 minutes at the same temperature, and subsequent cooling under pressure for 4 minutes.

D. Measurement of Tensile Properties

The tensile test is done according to ASTM (D638), dumbbell shape (Type IV) specimen is needed for reinforced composite testing. The testing was done in standard laboratory atmosphere of 23°C ± 2°C and 50 ± 5% relative humidity. The tensile testing machine was used with a cross-head speed of 10 mm/minute. The test is carried out on 5 specimens for each formulation.

E. Water Absorption Test

Water absorption test is carried out according to ASTM D570. The specimen is dried oven at 80ºC for 24 hours before the original weight is recorded. Then, the specimen is immersed in distilled water at room temperature. The specimen weight is recorded at a regular interval using balance model AND GR-200 with the precision of 1 mg. The percentage of water absorption, *Mt*, is calculated by:

$$WaterAbsorption, M_t = \frac{W_N - W_d}{W_d} \times 100 \quad (1)$$

where W_N is the weight after exposure and W_d is the original dry weight.

III. Results and Discussion

A. Tensile Strength

Fig. 4 shows the effect of fiber loading on the tensile strength of untreated and treated PP/CF composites with acrylic acid (AA). The result indicates that the tensile strength of both composites decreased with increasing the fiber loading. This is due to the size or irregular shapes of the coconut fibers. The increases of filler give more filler bundles formed from the hydrogen bonding and deteriorate the ability to transfer stress from the matrix of the composite resulting decreases in tensile strength [10]-[13]. Munirah (2005) and her co-researchers reported that the end of short fibers are normally weak points where high stress concentrated at composites matrix. Therefore, the form of short fiber resulted in a decrease of tensile strength [14]. In addition, the figure clearly shows that the treated composites showed higher tensile strength than untreated composites at the same filler loading. The application of surface modifiers such as acrylic acid improved the compatibility, dispersion, and adhesion between filler and matrix of the composites.

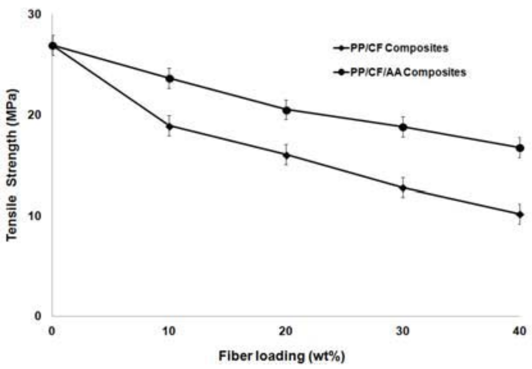

Fig. 4 Effect of fiber loading to tensile strength of PP/CF composite with and without AA

B. Young Modulus

The effect of fiber loading on Young's modulus of untreated and treated PP/CF composites with acrylic acid (AA) is shown in Fig. 5. The Young's modulus of treated composites exhibits higher than untreated composites at the similar fiber loading. It is because of the composite which is experienced surface modifications will overcome the dispersion problem and enhance the mechanical strengths of composites by improving adhesion the interface between filler and matrix. In addition, the graph indicates that Young's modulus of both treated and untreated composites increased with increasing filler loading [1]. It is due to composites becomes stiffer when fiber content is increased. [14].

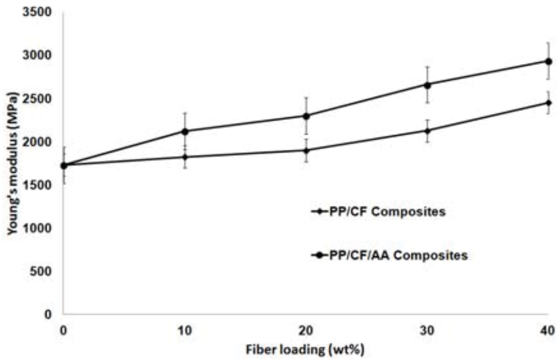

Fig. 5 Effect of fiber loading to Young's modulus of PP/CF composite with and without AA

C. Elongation at Break

Fig. 6 shows that the effect of fiber loading on elongation at break of the treated and untreated PP/CF composites with AA. It can be seen that, the elongation at break of both composites is decreased by increasing filler loading. The composite becomes more brittle and tend to break easily due to a weak bonding between the thermoplastic and fiber when fiber loading is increased [15]. At the similar filler loading, the elongation at break of treated composites is lower than untreated composites. This happened because the presence of AA improved the compatibility of the PP/CF composites.

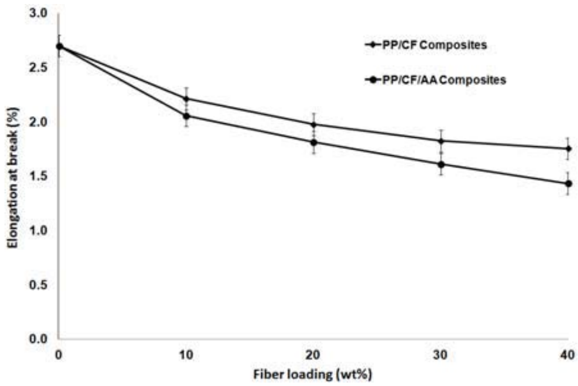

Fig. 6 Effect of fiber loading to elongation at brake of PP/CF composite with and without AA

D. Water Absorption

The percentage of water absorption of untreated and treated PP/CF composites with AA is shown in Fig. 7. The relationship between water absorption and fiber loading of untreated and treated composites with AA at 0, 20 and 40 wt% coconut fiber was observed. From this figure, in the beginning, the water absorption is increased tremendously until 14 days. Then, it is increasing slowly for all curves [16]. The untreated composites indicate a higher percentage of water absorption compared to treated composites. The chemical treatment of coconut fiber with acrylic acid has eliminated a great amount of hydroxyl group, which consequently reduces the filler hygroscopic characteristics.

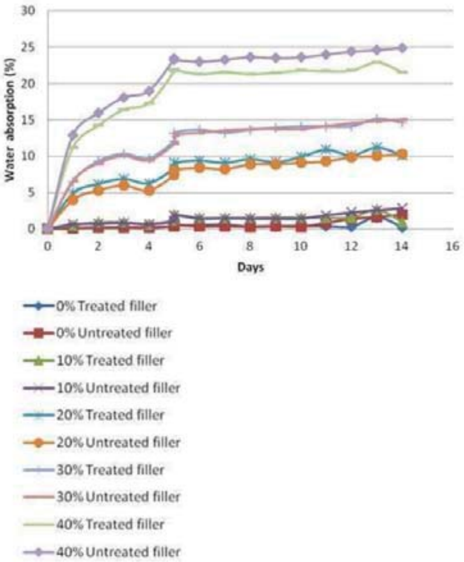

Fig. 7 Comparison of PP/CF composites between treated filler (with chemical modifier) and untreated filler in equilibrium water

The increasing fiber loading for both composites, the percentage of equilibrium water absorption also increased. At a similar fiber loading, incorporation of AA has reduced the amount of water absorption in the composites. The presence of AA showed that the chemical treatment composites have a better water resistance compared to untreated composites. The reduction in equilibrium water absorption with chemical treatment is attributed to improve interfacial adhesion, which reduces water accumulation in the interfacial void and prevent water from entering the composites.

IV. CONCLUSION

In conclusion, the presence of AA as chemical modifiers improved the properties of PP/CF composites. Furthermore, treated CF as filler in composites may serve as prospective material in automotive industries which now moving to plastic composites due to its lightweight and low cost. CF which is a waste product from coconut husk is seen as one of the cheap natural fibers which can reinforce plastic composites. PP/CF composites treated with a chemical modifier (AA) indicates the improvement of mechanical properties and more resistance to water uptake, may give way to new opportunity and a variety of applications.

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