Chemical and Mechanical Treatments of Recycled Carbon Fiber Reinforced Polymer

Adel M. Alkaseh, Mohd Edeerozey Abd Manaf*, Zurina Shamsudin, Edynoor Osman

Engineering Materials Department, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding e-mail: edee@utem.edu.my

Keywords: Recycled carbon fiber; Fiber treatment; SEM analysis

ABSTRACT - The use of carbon fiber waste is a reasonable approach to benefit the performance of carbon fiber and considered as green effort for disposal management. In this study, recycled carbon fiber reinforced polymer (CFRP) was chemically treated using nitric acid to remove the resin. The treated fibers then pulverized to obtain short carbon fibers of about 90 µm. Individual carbon fibers were successfully removed from the matrix resin by the chemical treatment. Scanning electron microscopy (SEM) images showed a very limited damage of the chemically treated fibers. Pulverized fibers showed a rougher surface due to the mechanical abrasion. However, thermogravimetric analysis (TGA) showed that the chemically treated fiber still contained other elements at about 7 wt%, even after the chemical treatment. The actual identity of the elements needs to be characterized in details by using equipment such as energy dispersive X-Ray (EDX).

1. INTRODUCTION

The demand of carbon fiber reinforced polymer (CFRP) as an engineering material can be related to their high specific strength and stiffness, which provides them a considerable advantage over metals especially in applications such as in the automotive and aerospace industries [1].

The utilization of CFRP continues to increase rapidly in numerous industries. For this reason, there is an increased concern regarding the disposal of these materials at the end of their life cycle. As these waste disposal problems arise, increasing emphasis is being placed on the need to recycle CFRP [2]. In addition, there is a strong interest in developing processes for recovering and recycling carbon fiber from waste materials due to the high cost of virgin carbon fiber and the consumed energy in its manufacturing process [3].

Results in the literatures indicate that interaction between the fiber-matrix highly depends upon the surface functional groups of the carbon fibers and the matrix. Oxidation of carbon fibers surface is one of the techniques that can increase the number of functional groups on the carbon fiber surface, thus supports the interfacial bonding [4].

Hence, the aim of this study is to assess the effectiveness of the chemical treatment in resin removal and observe the effects of chemical and mechanical treatment to the surface and structure of the carbon fibers by using SEM and TGA analyses.

2. METHODOLOGY

The waste carbon fiber composite was in prepreg form and supplied by a local company. The nitric acid and ethanol were supplied by Polyscientific Enterprise Sdn. Bhd. Initially, the as-received carbon fiber prepreg was cut into smaller sizes of about 3 mm before dried at 70 °C in the oven for 1 hour to cure the attached resins existed on the surface of the carbon fiber. For the chemical treatment, the cut prepregs were oxidized with 65% nitric acid at 120 °C for 15 min, before rinsed with a slow and continuous flow of distilled water for half an hour to reach the same pH value as the distilled water (pH=5.5-6). Subsequently, the fibers were soaked in ethanol for 1 hour in an ultrasonic bath. Then, the extracted fibers (rCF) were dried in an oven at 70 °C for 24 h to remove moisture. For the mechanical treatment, the chemically treated fibers were further pulverized into finer sizes (about 90 µm) by using a pulverizer and vibratory sieve shaker (Fritsch, Germany). Finally, the treated fibers underwent morphological and thermal analyses, which were performed by using scanning electron microscopy (SEM) and thermogravimetric analyzer (TGA), respectively.

3. RESULTS AND DISCUSSION

The SEM images in Figure 1 show the differences in surface structure of the untreated and treated (chemically and mechanically) rCF. Figure 1(a) shows the surface condition of the untreated CFRP chips, in which the carbon fibers resin can be clearly observed to be impregnated in the matrix resin. Figure 1(b) and (c) show the SEM images of the chemically treated fibers and chemically-mechanically treated fibers,

respectively. Upon the chemical treatment, resin had been successfully removed and individual carbon fiber strands were obtained. As observed here, the surfaces of the rCF are clean and seem to be resin free.

In addition, any physical damage such as fissures or cracks, or morphological changes (in diameter) is not found for the chemically treated fibers in Figure 1(b). However, the chemically-mechanically treated fibers show an increase in surface roughness and a slight decrease in diameter as observed in Figure 1(c). Moreover, the finer recycled fibers also became more agglomerated upon the pulverization process.

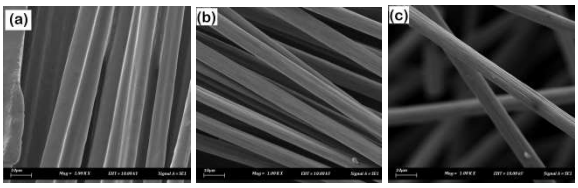

Figure 1 SEM images (500X magnification) of recycled carbon fiber in CFRP after different treatments: (a) untreated; (b) chemically treated and (c) chemically and mechanically treated into size of about 90 µm.

Figure 2 and 3 show the thermal degradation as obtained via TGA, of the untreated rCF (impregnated in resin) and chemically treated rCF, respectively. Degradation of resin is demonstrated by the weight loss occurs at 300 – 500 °C as shown in Figure 2. The initial 2 wt.% weight loss occurs around 100 °C can be associated to the moisture loss. The remained 70 wt.% after heating up to 800 °C represents the amount of carbon fiber in the CFRP prepreg.

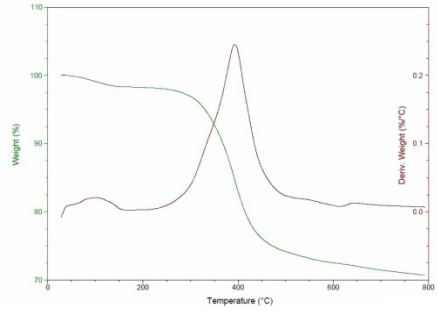

Figure 2 TGA curves of untreated rCF

For the chemically treated rCF (Figure 3), about 7 wt.% of weight loss is observed at 500 – 630 °C. It could be the remaining resin or other chemicals but the actual matter needs to be clarified using other analysis such as EDX.

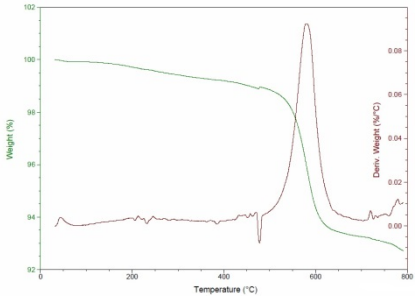

Figure 3 TGA curves of chemically treated rCF

4. CONCLUSION

Nitric acid treatment is found to be helpful in removing epoxy resin from the recycled carbon fibers. Pulverization manages to obtain fine fibers of micron size but also made the surface rougher due to mechanical abrasion. The finer recycled fibers are also more agglomerated. Although SEM analysis showed no resin on the chemically treated fiber surface, a presence of small amount of other substance besides rCF was indicated by the TGA analysis, which requires further investigation through elemental analysis using equipment such as EDX.

ACKNOWLEDGEMENT

The authors would like to thank the Faculty of Manufacturing Engineering for providing the equipment and technical supports, and to CTRM Aero Composites Sdn. Bhd. for the kind supply of the samples employed in this study, which made this work possible.

REFERENCES

[1] J. Howarth, S.S.R. Mareddy, and P. T. Mativenga, "Energy intensity and environmental analysis of mechanical recycling of carbon fibre composite," *J. Clean. Prod.*, vol. 81, pp. 46–50, 2014.

[2] C.C. Knight, C. Zeng, C. Zhang, and R. Liang, "Fabrication and properties of composites utilizing reclaimed woven carbon fiber by sub-critical and supercritical water recycling," *Mater. Chem. Phys.*, vol. 149–150, pp. 317–323, 2015.

[3] M.H. Akonda, C.A. Lawrence, and B.M. Weager, "Recycled carbon fiber-reinforced polypropylene thermoplastic composites," *Compos. Part A*, vol. 43, no. 1, pp. 79–86, 2012.

[4] J.J. Sha, J. X. Dai, J. Li, Z.Q. Wei, J. Hausherr, and W. Krenkel, "Applied Surface Science Influence of thermal treatment on thermo-mechanical stability and surface composition of carbon fiber," *Appl. Surf. Sci.*, vol. 274, pp. 89–94, 2013.