Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

5th International Conference on
Chemical & Environmental
Engineering
25 - 27 May, 2010.

PT-5

PREPARATION AND CHARACTERIZATION OF COMPOSITE MATERIAL BASED ON CARBON FIBER AND DIFFERENT THERMOSET RESINS

Hany A. Elsawy*, Mostafa A. Radwan*, Khaled S. Ghith* and
Mohammad A. El-Sayed*

ABSTRACT

In the present investigation two types of thermoset resins (epoxy and phenol formaldehyde resin) were used with carbon fiber (CF) to produce composite materials. CF/epoxy resin and CF/phenolformaldhyde resin composite were fabricated by hand lay-up technique with ratio 1:1 by weight (CF:resin matrix). The mechanical properties of the two produced resin such as compression, tension and flexural were evaluated. The influence of increase of number of layers of fibers on the mechanical properties of composite material based on CF/epoxy resin has been studied. The result show that the flexural strength of CF/epoxy resin composite is higher by 52% than the flexural strength of CF/phenolformaldhydr resin composite. The result of flexural as number of layers increased by two layers increased by 11.5%.

Keywords

Carbon fiber, epoxy resin, phenolformaldhydr resin, composites, mechanical properties.

* Egyptian Armed Forces

1. INTRODUCTION

There is an increasing demand for advanced materials with better properties to meet new requirements or to replace existing materials. The carbon fibers have a unique combination of outstanding mechanical, physical and chemical properties, such as high strength, high modulus, and thermal resistance [1-3]. The carbon fibers reinforced resin matrix composites is widely used in aerospace, marine and automobile industries during the past few decades due to their good engineering properties such as high specific strength and stiffness, lower density[1-5]. Resin matrix of composites based on carbon fiber determines the chemical and thermal resistance of the composite while the carbon fibers provide strength and stiffness[4].When a composite is subjected to stress, the load is transferred from the matrix to the carbon fibers via the interface and good interfacial adhesion is therefore important. It is well known that the fiber matrix adhesion strength plays an important role on the mechanical properties of fiber reinforcened polymer composites because when load applied to composites, it will be distributed and transferred through fiber/matrix interface [6-9]. A strong bonding promotes better involvement of more fiber, accordingly increases the strength of composites. However, carbon fibers usually perform a poor bonding behavior to polymer matrix due to their nature of smoothness and chemical inertness [6]. In order to improve the bonding properties of carbon fibers, various approaches can be applied, which were classified in to oxidative and non oxidative treatments according to Park and Kim [10].another approach to improve bonding properties between fiber and matrix in composite material by using resin matrix has excellent adhesion properties as epoxy resins . The increases in the use of the composite materials mean that it is necessary to know their behaviors under working conditions. Many researches applied on composite materials to improve their properties as research of Asma Yasmin, Isaac M. Daniel, research of Yuan Xu, Suong Van Hoaand research of Farhana Pervin, Yuanxin Zhou, Vijaya K.Rangari, Shaik Jeelani [11-13].When epoxy resins are reinforced with high-strength carbon-fibers, the product obtained is used in structural applications requiring high strength and low weight. They are of relatively low density and they can be tailored to have stacking sequences to provide high strength and stiffness in the directions of high loading [13-14]. In this work composite material based on carbon fiber/epoxy resin and carbon fiber/phenol formaldehyde resin were prepared to compare their mechanical properties as tension, compression and flexural characteristics in order to replacement phenolformaldhyde resin by epoxy resin due to disadvantages of phenol formaldehyde resin as forming air bubbles during solidification process and also volatiles produced during reaction may cause respiratory irritation. The effect of increase number of layers of fibers on the mechanical properties of carbon fiber/epoxy resin composites was studied as well.

2. Experimental

2.1. Materials

The carbon fiber used was PAN based carbon fiber made from polyacrylonitrile precursor which has moderate strength; moderate modulus and carbon fiber yarn contained 3000 filaments. The epoxy resin used in this study is based of (EPON 828) cured with polyamide (versamide 125) hardener, with proportions of 1:1 by weight. This two component system obtained from HEXION Company, France.

2.2 Preparation of epoxy samples
Epoxy resin systems consist of two parts A (EPON 828) and B hardener (versamide 125). EPON 828 part A was carefully weighed and a stoichemetric amount of versamide part B was added. The mixture was then gently stirred for 10 min to prevent air trapping. Then the matrix was used with CF to produce composite material [13].

2.4 Composite fabrication
Composite material based on CF/epoxy resin was prepared by hand lay-up technique. Special brush and roller were used to perform different lay-up layers. The epoxy resin was prepared firstly as stated in section 2.3. The epoxy resin was brushed on the surface of CF. the epoxy-brushed fiber tape was carefully stacked up and aligned together layer above layer then compressed under load 50 Kg over the upper surface and left at room temperature for 24 hrs for complete curing of the resin [11]. The weight ratio of carbon fiber and resin was 1:1. Composite material based on CF/phenolformaldhyde resin was prepared by the same way. However, the curing step was done at elevated temp 150^{o}C under pressure of 70 bars for 2hrs.

2.5 Mechanical testing
Two types of mechanical testing machines were used. The MTS810 Servo-hydraulic material test system with100 KN axial loading Figure 1 was used to investigate tensile modulus and strength. The RT30 Electro-mechanical Alliance test system with 30 KN axial loading Figure 2 was used to measure both flexural and compression strength. The two machine systems were obtained from MTS Company, United States. Table 1 illustrated composition of each formulation.

2.5.1 Compression test
The compression strength of the composite samples were measured using a specimen of dimensions [10mm ×10 mm ×20mm]. The test speed was kept constant at 2mm/min. Three specimens of each composition were measured and an average value was reported. The compression strength was measured in both directions (axial and radial directions) as shown in Figure (3).

2.5.2 Flexural test (the three-point bending test)
The Flexural strength is the maximum stress developed when a bar–shaped specimen is subjected, as single beam, to a bending force perpendicular to the bar. The Flexural strength of composite specimen of 12.7mm width, 200mm length and thickness was measured according to the number of layers. Three specimens of each composition were measured and an average value was reported.

2.5.3 The tensile test
The tensile strength of composite specimen of 12.7mm width, 203mm length and thickness was measured according to number of layers Figure 4. Three specimens of each composition were measured and an average value was reported.

3. Result and discussion

3.1 Mechanical properties of composite formulations

3.1.1 Comparison between mechanical properties of composite material based on CF/epoxy resin and composite material based on CF/phenolformaldhyde resin

The mechanical properties of CF/phenolformaldhyde resin as tensile strength, flexural strength, radial compression strength and axial compression strength were lower than that of CF/epoxy resin this is because that adhesions force of epoxy resin higher than that of phenol formaldehyde resins which shown in Figure 4.

It was found that tensile strength of composite material based on CF/epoxy resin higher by 12% than tensile strength of composite material based on CF/phenolformaldhyde resin and flexural strength of composite material based on CF/epoxy resin higher than that of composite material based on CF/phenolformaldhyde resin by 52%. In compression strength it was found that the two composites have the same compression strength in radial direction but in axial direction compression strength of CF/epoxy composite was found higher than that of CF/phenolformaldhyde composite by 23%. The higher mechanical properties of composite material based on CF/epoxy resin may be due to strong adhesion force of epoxy resin due to presence of large number of polar OH groups in chains provide possibility of hydrogen bonding and hence strong adhesion with all surfaces.

3.1.2 Effect of number of layers of fibers on mechanical properties

The effect of number of layers of composite based on CF/epoxy resin was shown in Figure (5). The result shows that as the number of layers of fibers in composite material based on CF/epoxy resin increases the tensile and flexural strength increases. However, the flexural modulus decrease and the tensile modulus remain nearly the same with increasing number of layers. As number of layers increased by two layers tensile strength increased by about 10:16 % and flexural strength increased by 11.5%.

This increase in mechanical properties as increase number of layers of fibers due to as number of fibers increase thickness of composite material increase and so mechanical properties increase also with increase thickness of composite materials. it was found that thickness of one layer of fiber equal about 0.4 mm.

4. Conclusion

The following facts are observed from experimental findings.

1. The mechanical properties of CF/epoxy resin composite material were higher than that of CF/phenol formaldehyde resin composite.
2. The flexural strength of CF/epoxy resin composite material was higher than that of CF/phenoloformaldhyde resin composite material by 52.3%.
3. The tensile strength of CF/epoxy resin composite material was higher than that of CF/phenoloformaldhyde resin composite material by 12.3%.
4. The axial compression strength of CF/epoxy resin composite material was higher than that of CF/phenoloformaldhyde resin composite material by 23%.
5. The radial compression strength of CF/epoxy resin composite was the same that of CF/phenolformaldhyde resin.

6. As number of layers of fibers in CF/epoxy resin composite increase the mechanical properties increase.

7. As number of layers of fibers increased by two layers tensile strength increased by 15% and flexural strength increased by 11%.

References

[1] Schwartz MM. composite materials hand book. McGraw-Hill; 1992.

[2] Whitcomb JD. Composite materials testing and design. ASTM; 1988.

[3] S.T.Peters. Hand book of composites.CHAPMAN&HALL; 1998.

[4] Deborah D. L.Chung.Carbon Fiber Composites. Butterworth-Heinemann; 1994.

[5] Ronald F.Gipson. Principles of composite materials mechanics. McGraw-Hill.

[6] Hui Zhang, Zhong Zang, Claudia Breidt. Comparison of short carbon fiber surface treatments on epoxy composites, institute for composite materials, university of Kaiserslautern, Erwin schrodinger strasse 58; 2004.

[7] Park BY, Kim SC. A study of the interlaminer fracture toughness of a carbon-fiber/epoxy composite containing surface modified short Kevlar fiber. Compos sci technol; 1998.

[8] Fux, Chung DDL. Improving the bond strength between carbon fiber and cement by fiber surface treatment and polymer addition to cement mix. Cement concrete Res; 1995.

[9] dong S,Gauvin R. Application of dynamic mechanical analysis for the study of the interfacial region in carbon fiber/epoxy composite materials.Polym compos, 1993.

[10] Park S-J,Kim M-H. Effect of acidic anode treatment on carbon fibers for increasing fiber-matrix adhesion and its relationship to interlaminer shear strength of composites. J Mater sci; 2000.

[11] Asma Yasmin, Isaac M. Daniel. Mechanical and thermal properties of graphite platelet/epoxy composites. Northwestern university, Evanston; 2004.

[12] Yuan Xu,Suong Van Hoa.mechanical properties of carbon fiber reinforce epoxy/clay nanocomposites.center for research in polymer and composites,Canada;2007.

[13] Farhana Pervin,Yuanxin Zhou,Vijaya K.Rangari,Shaik Jeelani. Testing and evaluation on the thermal and mechanical properties of carbon nano fiber reinforced SC-15 epoxy. Center of advanced material, Tuskegee; 2005.

[14] J.B. Donnet, compos.Sci. Technol. 63(2003) 1085-1088.

[15] Xiang Li , Haibin Yang , Wuyou Fu , Cunxi Wu , Shikai Liu , Hongyang Zhu , Xiaofen Pang. Preparation of low-density superparamagnetic microsphere by coating glass microballons with magnetic nanoparticles. National laboratory of superhard materials , china ;2006.

[16] Jing Wei , Jianhua Liu , Songmei Li. Electromagnetic and microwave absorption properties of Fe3O4 magnetic films plated on hollow glass spheres.Journal of magnetism and magnetic materials; 2007.

[17] Xueai Li, Xijiang Han, Yanjiang Tan, Ping XU. Preparation and microwave absorption properties of Ni-B alloy-coated Fe3O4 particles. Journal of alloys and compounds; 2007.

Figure 1: RT30 Material Testing System used for compression and flexural tests

Figure 2: MTS810 Material Testing System used for tensile test

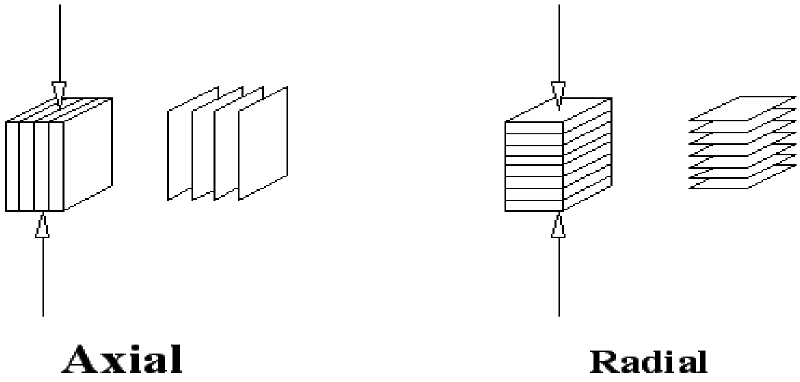

Figure 3: Axial and radial compression specimens for composite material

Figure 4.a

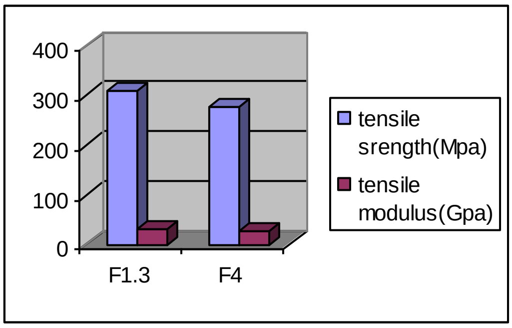

Figure 4.b

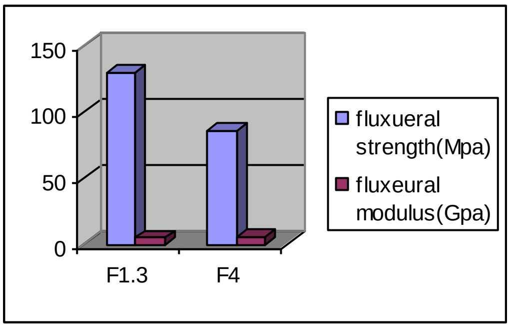

Figure 4.c

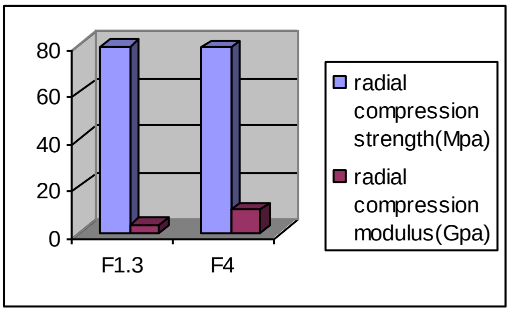

Figure 4.d

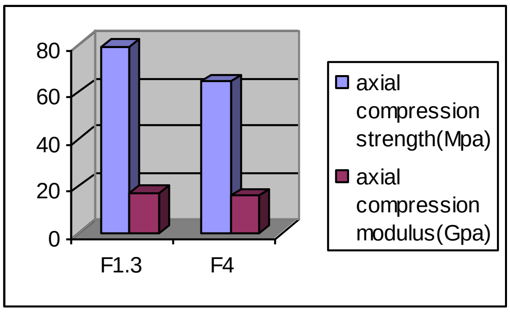

Figure 4: Comparison between mechanical properties of composite material based on CF/epoxy resin and composite material based on CF/phenolformaldhyde resin.

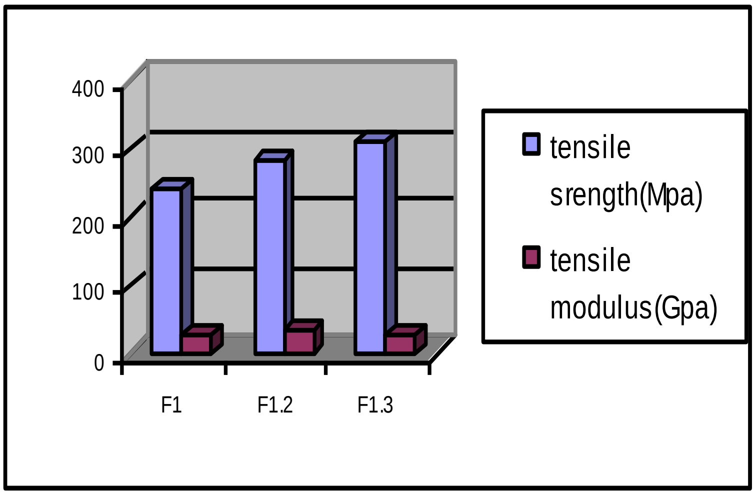

Figure 5.a

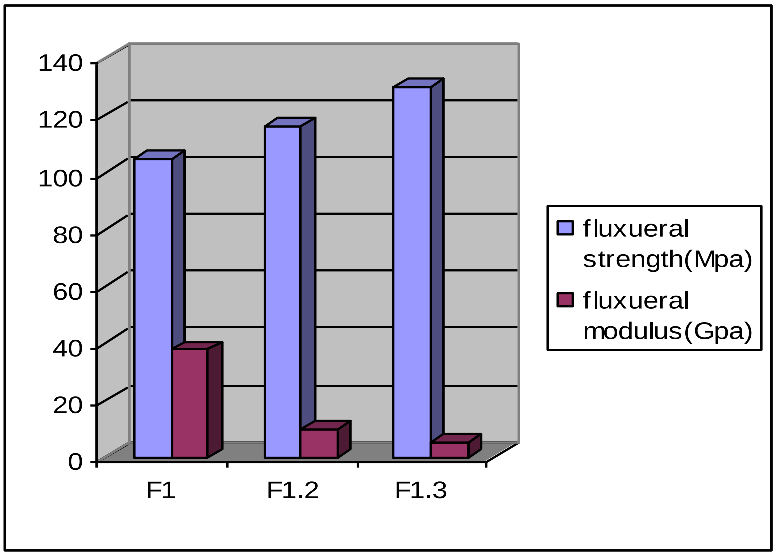

Figure 5.b

Figure 5: the effect of increase number of layers of fibers on mechanical properties of composite material based on CF/epoxy resin.

Table 1: Details of composition of each formulation

formulation	composition
F1	4 layers[CF+ epoxy]
F1.2	6 layers[CF+ epoxy]
F1.3	8 layers[CF+ epoxy]
F4	8 layers[CF+ phenol formaldehyde]

Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

5th International Conference
on
Chemical & Environmental Engineering
25 - 27 May, 2010.