CARBON FIBER REINFORCED BISMALEIMIDE COMPOSITES

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INTRODUCTION

Bismaleimide (BMI) resins are developed very rapidly due to the demands of the defense and aerospace industries. They are cross-linked polymers which process like epoxy resins but have an upper use temperature of 230°C, compared to the epoxy upper use temperature of 175°C. Also due to the available intrinsic properties of BMI resins such as higher thermal stability and lower toxicity than those of epoxy resins, they are prime candidates as matrix resins for advanced fiber-reinforced composites.

The most serious disadvantage of BMI resins, however, is their extreme brittleness. A brittle nature of such resins necessitates modification in molecular structure in order to improve the fracture toughness and the inherent processability [1,2].

The objective of the present study is to provide an understanding of the effects of toughening aid in the dominant resins. The thermal properties of the resins and the mechanical behaviors of the fiber-reinforced BMI composites, with toughening agent concentrations, are also discussed.

EXPERIMENTAL

One kind of polyacrylonitrile (PAN)-based high strength carbon fiber (Toray T-300, 6000 monofilaments, weave density: 317 $g.m^{-2}$, thickness: 0.38 mm) was used in the form of plain weave made from the surface treatment of fibers by a commercial standard oxidation. The commercial bismaleimide resins; namely Compimide 796 (supplied by Boots Technochemie Co.) were used as matrix resins.

The 0.2 wt.% of 1,4 diazabicyclo-2,2,2-octane to Compimide 796 was used as an accelerator for the curing system of the resins. The 0, 15, 30, and 60 phrs of the TM120 (Triaryl Cyanurate Compound, supplied by Boots Technochemie Co.) to Compimide 796 were added in order to investigate the effects of toughening aid in the resins of the composites.

The resin impregnated carbon fabrics were prepared in an autoclave at 4 atm and 190°C for 3 hours. Post-curing was done at 240°C for 12 hours. The thermal stability and the activation energy (E_a) of decomposition of Compimide 796 were measured using thermo-gravimetric analysis (TGA). The composites were then characterized by three-point bending test for the mechanical flexural test (distance between supports/thickness of specimen=40, cross head speed=2 $mm.min^{-1}$). Flexural strength (FS) and flexural modulus (FM) of the composites are calculated by the following equations :

$$FS = \frac{3PL}{2bd^2} \qquad FM = \frac{L^3 m}{4bd^3}$$

where P = fracture force [N], L = span length [m], b = width of specimen [m], d = thickness of specimen [m], m = slope of the tangent to the initial straight-line portion of the load-deflection curve [$N.m^{-1}$].

The bulk fiber volume fraction of the composites was about 60% (± 2%), and more than five specimens were tested in each case of the composites.

RESULTS AND DISCUSSION

Table I shows the results of TGA analysis for the thermal stability of the Compimide 796 prepared with the toughening agent concentrations. It reveals that the thermal stability given by the temperature of maximum rate of weight loss largely shows a decrease with increasing concentration of TM120 in Compimide studied. However, the first 15phr addition results in an increasing the thermal stability of the resins. The results in the activation energy of decomposition of the resins under a N_2 atmosphere which was calculated from TGA curves by Horowitz-Metzger integration method [3] are also shown in Table I. From these results, a considerable effect of toughening aid on the activation energy of decomposition clearly shows in the resins, especially the first 15phr addition of TM120.

The results of mechanical flexural strength (FS) and flexural modulus (FM) of the composites with the toughening agent concentrations are shown in Table I. It is observed that the mechanical properties for samples containing 15phr TM120 are better than those of the other samples studied. In particular, further increase in the concentration of TM120 results in a decrease in FS and the values are even lower than for the composites as-received.

These phenomena could be explained from the toughening of the matrix by the copolymerization reaction at the moderate concentrations of the TM120, and from the chain extending of the TM120 at the higher concentrations which may result in decreasing cross linking density of the resin matrix.

CONCLUSIONS

It is then concluded on the basis of these investigations that both thermal and mechanical properties in Compimide 796 are increased in the presence of toughening agents if its concentration was at about 15phr. However, a marginal decrease in the thermal and mechanical behaviors are observed in the fiber-reinforced BMI composites studied.

REFERENCES

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TABLE I. Effect of Concentration of TM120 on Thermal Properties of the Resin and Mechanical Properties of the Fiber Reinforced BMI Composites.

Concentration of TM120 (phr)	Max. dw/dt Temp. (°C)	E_a (kJ.mol^{-1})	FS (MPa)	FM (GPa)
0	455	89.5	1530	166
15	458	145.7	1860	200
30	439	105.4	1490	186
60	425	113.1	1300	174