MECHANICAL PROPERTIES OF CARBON/pCBT COMPOSITES PRODUCED BY RESIN TRANSFER MOLDING

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1 General Introduction

Low viscosity cyclic butylene terephthalate (CBT) oligomer is a very promising material for a new generation of thermoplastic and composite applications. As far as the application of CBT for continuous fiber reinforced composites is concerned there are only a few published works on this subject. Parton and Verpoest [1] first described the production and properties of glass fiber reinforced pCBT composites which were polymerized in situ. However, this in-situ polymerization and crystallization isothermal processing is quit time consuming without efficiency. It is therefore, our objective was to develop a fast processing method via higher temperature polymerization and nonisothermal cooling for crystallization. Effects of polymerization temperature and cooling conditions on the performance of the resulting composites were investigated in this study. The performance evaluation of the composites will involve tensile, flexural, short beam shear and impact testing.

2 Experiment

2.1 Materials

In this study, CBT pellets (Grade:160) purchased from Cyclics (Schenectady, NY; www.cyclics.com) were used. This CBT is produced using a Butyl tin chloride dihydroxide (XB3) catalyst with an average molecular weight M_W = $(220)_n$ (n=2~7) for the purpose of engineering plastic and composite applications. CBT was dried in a vacuum oven for overnight at 85℃ and kept in a desiccator until further use. The reinforcement used was 3K plain-woven construction carbon fabric. It was purchased from Mitsubishi Corp., Japan.

2.2 Sample preparation

The carbon/pCBT composites were produced by using high temperature RTM method. CBT oligomers were molten in a blending mixer at 160℃ no longer than 5min. The low viscous CBT oligomers were then vacuum infused into a closed mold containing the seven layers of carbon fiber perform. Once the mold was completely filled, inlet and outlet ports were closed. The mold temperature were controlled at various temperatures (T_p: 210℃, 220℃, 230℃, 240℃) for 6 min to polymerize the CBT oligomers. Two crystallization conditions: fast cooling (20℃/min) and slow cooling (1℃/min) were used. In this experiment, the fiber volume fractions of the carbon fiber/pCBT composites were approximately 40~50%

2.3 Rheology

The viscosity was studied by plate-plate rheometry (Taiwan Instruments, AR2000 series, Waters, U. S. A.) to understand the flow behaviors of the CBT matrix. The chamber was preheated to the given temperature, and the specimen (diameter 25mm) was placed in between the plate. The gap height is about 1 mm. Viscosity changes as functions of time and temperature were measured.

2.4 Mechanical Test

In this study, a universal testing machine (AG-100kNX, Shimadzu, Japan) was used to perform the tensile, three-point bending flexural and short beam shear tests at room temperature. Tensile tests were performed on the carbon/pCBT composites in accordance with ASTM-D638 and ASTM-D3039, respectively. Three-point bending and short beam shear tests were done according to ASTM ASTM D790 and D-2344, respectively, to estimate the flexural and apparent inter-laminar shear strength

(ILSS). The Izod impact test was performed at room temperature according to ASTM D256 on a pendulum impact tester (CPI, Atlas electric devices, USA) at impact energy of 2.6 J. The average values were derived from five parallel tests for each material. In order to get information on the failure, broken specimens were inspected in SEM.

3 Results and discussion

3.1 Rhelogical Studies

Figure 1 shows the typical plot for the viscosity as functions of time for CBT160 at different temperatures: 150~180℃. As the testing temperature increased, the initial viscosity decreased. The initial viscosity of CBT was about 0.12 Pa.s at 180℃. An abrupt change in viscosity was observed and could be attributed to the polymerization reaction. Therefore, the pot life for the holding temperature at 180℃ was 100 seconds and 200 sec. for 170℃, 300sec for 160℃. The viscosity increased within a short time period indicated the fast nature of a ring-opening polymerization taking place in the melt, thus limited the time window for melt processing and impregnation. The polymerization reaction was retarded at the temperature below 160℃. That is, we can melt process the CBT resin between 150~160℃ within 300sec.

3.2 Effects of polymerization temperature on tensile properties of carbon/pCBT composites

As showed in Table 1, the tensile properties increased with increasing the polymerization temperature and exhibited the best performance at 230℃. This result could be attributed to the higher molecular weight of the pCBT matrix at 230℃. However, poor tensile properties were obtained for the sample prepared at 240℃. Owing to low viscosity will lead to too fast mold filling and leaving behind porosity in the fiber bundles. Besides, the viscosity built up too fast at higher processing temperature (240℃) will lead to poor impregnation and mold filling difficulty.

The cooling conditions manifested that higher tensile modulus yield strength and post-yield modulus were obtained by slow cooling compared to that of fast cooling. This could be attributed to higher crystalinity and the transcrystalline morphology.

References

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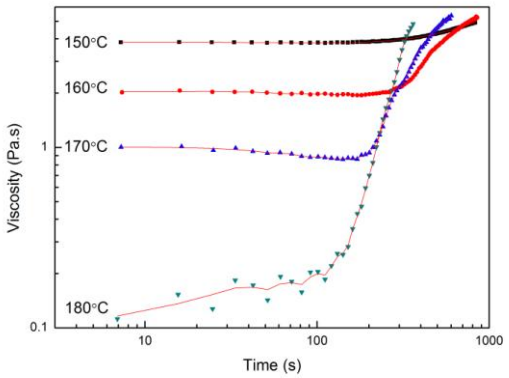

Figure 1. The viscosity behaviors of CBT160 resin at temperatures 150 ~180℃

Table.1. Mechanical properties of the carbon/pCBT composites at various T_p.

Samples	Strength (MPa)	Modulus (GPa)	Yield strength (MPa)	Post-yield modulus (GPa)
210s	378 ± 16	24.9 ± 0.1	126±5	14.9±1.5
220s	474 ± 21	29.7 ± 0.1	128±8	19.4±0.3
230s	525 ± 27	29.9 ± 0.2	134±5	20.0±0.6
240s	378 ± 95	24.5 ± 6.3	119±16	15.7±3.6
210f	332 ± 28	18.6 ± 2.0	82±3	13.5±0.5
220f	430 ± 20	26.6 ± 0.1	105±2	16.7±0.6
230f	514 ± 30	27.3 ± 1.1	110±2	18.6±0.2
240f	376 ± 85	23.9 ± 5.8	89±18	16.5±2.4