FABRICATION OF LOW-COST COMPOSITES USING ROVING-LIKE MESOPHASE PITCH-BASED CARBON FIBERS

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Introduction

Continuous mesophase pitch fibers are produced with a new patented high speed melt blown process at the University of Tennessee Space Institute (UTSI). Carbon fibers are subsequently produced in an economical way which involves a relatively fast thermal stabilization in air and a relatively low-temperature carbonization at 1050^{o}C. The prepared carbon fibers display good mechanical properties and potential low-cost due to very high carbon yield of mesophase pitch, low-cost fiber spinning method, and economical thermal processes. Such low-cost carbon fibers are expected to provide superior cost effectiveness in the manufacturing of carbon fiber composites (CFCs) which will generate improved materials to meet existing and future needs for a number of advanced technology applications [1-2].

The common form of UTSI's low-cost carbon fibers is continuous roving or non-weave mat (See Fig.1) with ~10 cm in width and ~1 cm in thickness. Without further weaving process (e.g. from tow fiber to fabrics for commercial PAN-based carbon fiber), the fiber can be directly used to fabricate different shape of carbon fiber composites (CFCs) with polymer resins, which will also decrease the cost of the fabrication of CFCs. However, such a fiber form could not be convenient for use by currently known fabrication processes. Therefore, it is most important for us to explore new or improved fabrication processes to better understand the relationship between fabrication and properties of the UTSI CFCs.

The objective of this study is to determine the best fabrication processes for UTSI CFCs. Different polymer resins are used to prepare UTSI CFCs. The effects of fabrication parameters on the physical properties of the CFCs are investigate. The trend of the properties with fabrications is discussed.

Experimental

Materials

UTSI mesophase pitch-based carbon fibers produce in the UTSI spin lab. Typical fiber form is shown in Fig. 1.

Epoxy resin 105 and extra slow hardeners 206 and 209 was obtained from West System.

Vinyl ester resin 411-350PA and Mekp Norac catalyst was purchased from Aircraft Spruce and Specialty Co.

Phenolic resin GPRI® BKS-2600 was produced by Georgia-Pacific Inc. It is readied in an alcohol solution, which contains some volatile solvents.

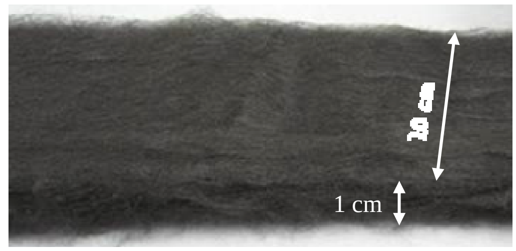

Fig.1 Typical UTSI carbon fiber form

Apparatus and Procedures

A vacuum bagging resin infusion (VBRI) technique plus a hot press were employed to prepare carbon fiber composites. Several lays of carbon fiber were stacked up inside the space between two plates as shown in Fig.2. The carbon fibers were pressed at different pressures to achieve higher density of carbon fiber. Polymer resin with hardener or catalyst were allowed to enter the system from one end while keeping the vacuum pump running in another end under a vacuum level at 29" Hg. The composite plate was post cured in the oven after the plate was removed from the bag.

The tensile and flexural properties of the CFCs were tested in an MTS machine with a 550 kN load cell and a head speed of 0.1 inch per minute. A precision extensometer was used to measure strain. ASTM D3039 and ASTM D 6272 standards were used as guides for the testing and calculations.

Apparent density and electrical resistivity of CFCs were calculated by the measurements of mass, dimensions and electrical resistance with a balance a calibrator and an electrical bridge, respectively.

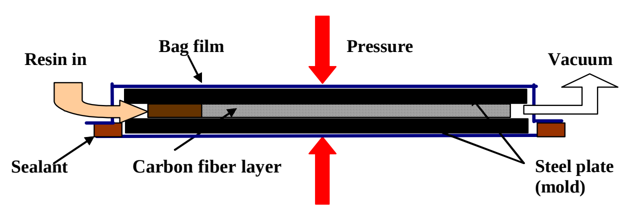

Fig. 2 Vacuum bagging resin infusion for making CFCs

Results and Discussion

Table 1 lists physical properties of the cured epoxy and epoxy CFCs fabricated with vacuum bagging (VB), and vacuum bagging resin infusion (VBRI) technique. Adding CF into epoxy resin greatly increases its tensile strength and modulus and E-conductivity. As compared with VB method (pouring epoxy resin on the lay of CF and then fabricating within vacuum bagging; excess epoxy was absorbed by breath fabric), VBRI method provide CFCs with higher tensile properties. as well as higher apparent density and low porosity which was proven by SEM observation. VBRI also provides an ability to control fiber volume/content by applying pressure during fabrication. However, the resin infusion time prolonged with increasing pressure. It was found that extra slow hardener # 209 is better than slow hardener # 206 in the process of VBRI with hot press.

Table 1 Properties of the cured epoxy and its CFCs

Property	Cured Epoxy	CFC by VB	CFCs by VBRI	
			Without press	With press
CF content (wt %)	0	13-18	10-13	26
Density (g/cm^3)	1.20	1.13	1.20	1.31
E- resistivity (Ω∗cm)	>10^6	0.057	0.103	0.032
Tensile strength (Mpa)	27.2	75.9	84.4	124.7
Ultimate strain (%)	1.15	0.76	0.92	0.88
Tensile modulus (Gpa)	2.71	9.8	8.9	14.6

Fig.3 shows the effect of applied pressure on the physical properties of the epoxy CFCs. With increasing applied pressure carbon fiber content increases and the flexural modulus increases.

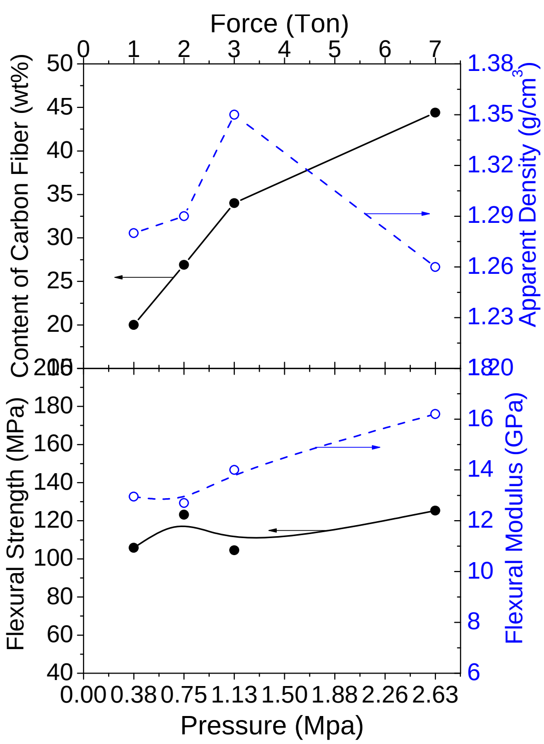

Fig. 3 Effect of applied pressure on physical properties of the epoxy CFCs

However, the apparent density and flexural strength not always goes up with applied pressure. Too high pressure will lead to a difficulty for the resin infusion and causing high content porosity inside the CFC which was observed on a polished surface of the CFC under an optical microscope. It was also found that high pressure leads to carbon fiber crashed which negatively affect physical properties of the CFCs.

Same trend was observed on vinyl ester composites as listed in Table 2. Applied pressure plays a key role for the improvement in the physical properties of the vinyl ester CFCs.

Table 2 Properties of the cured vinyl ester and its CFCs

Property	Cured Vinyl ester	CFCs by VBRI	
		low press	high press
Apparent density (g/cm^3)	1.16	0.97	1.31
E- resistivity (Ω∗cm)	>10^6	0.04	0.09
Tensile strength (Mpa)	23.8	42.3	76.2
Ultimate strain (%)	0.75	0.67	0.77
Young's modulus (Gpa)	3.3	7.4	10.1

Three CF/Phenolic resin composites were prepared using three different fabrication conditions as shown in Table 3. Degas process is required to remove solvents in phenolic resin before thermally curing. High degas temperature at 150^{o}C leads to fast curing of phenolic resin, which makes the CF lays uncompactible and forms many pores in the composites (see composite A). Appropriate pressure applied is helpful to increase apparent density and flexural properties of the CFCs.

Table 3. Properties of phenolic resin composites

Conditions and Property	A	B	C
Applied pressure (Mpa)	0.3	1.1	2.0
Degas Temp. (^{o}C)	150	100	100
CF content (wt %)	37.7	32.3	32.4
Apparent density (g/cm^3)	0.79	1.15	1.23
E- resistivity (Ω∗cm)	0.10	0.10	0.12
Flexural strength (Mpa)	72	105	104
Flexural modulus (Gpa)	9.6	14.4	14.9

Conclusion

Low-cost CFCs have been fabricated by using UTSI roving-like mesophase pitch-based carbon fibers. VBRI plus hot press is proven to be optimal technique for the fabrication of the CFCs. The prepared CFCs display higher electrical conductivity and reasonable mechanical properties.

References

1. Vakili, A., Yue, Z., Fei, Y., Cochran, H., Allen, L., and Duran, M. Pitch based carbon fiber processing and composites. *SAMPE 2007*, Baltimore, MD, June 3-June 7, 2007.
2. Fei, Y., Meganathan A. and Vakili, A. *Carbon Conf.* 2007.