Cryogenic performances of T700 and T800 carbon fibre–epoxy laminates

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Background

Composite materials have been extensively applied to the areas of aerospace, aircraft, sports and military industries because of their advantages over traditional materials, for example, a possibility to obtain a required combination of properties, which cannot be achieved for unfilled polymers. Advanced composite materials have progressed from a laboratory curiosity to a production reality. the ability to control the properties of composites over a wide range by adjusting the reinforcing elements and changing the degree of filling is the key for increased interest in composite materials.

Objectives

- The fabrication of T700 CF/epoxy composites and T800 CF/epoxy composites .
- Investigation of the mechanical and thermal properties of the composites at low temperature.

Conclusion

- The CTE of the T700/ DGEAC C and T800/ DGEAC carbon fibre/epoxy systems in 0° is smaller than that in 90°;
- the CTE of the T800/ DGEAC is very low in the temperature range of 120-300 K, which is -0.4×10^{-6} K^{-1};
- Under the same condition, the whole thermal and mechanical properties of the T800/ DGEAC are apparently better than those of the T700/ DGEAC;
- The value of compressive strength of the T800/ DGEAC at 77K is about 2310 MPa, while the thermal conductivity is 0.5 W/m.k;
- This composite material may possibly be exploited to design the critical components for practical applications such as hydrogen storage tanks.

Methods

Sample preparation

The material used was T700, T800 carbon fiber(CF) and the diglycidyl ester of aliphatic cyclo (DGEAC) type epoxy resin.

The epoxy is one of the most widely used matrices for carbon fiber reinforced composite materials by virtue of its good impregnation and adhesion to carbon fiber.

The DGEAC type epoxy resin was provided by Tianjin Jindong chemical factory (epoxy value, 0.85) and both T300 and T800 CFs were obtained from Toray Co., Japan.

The resin casts and unidirectional composite laminates with 60% volume content of carbon fibers were cured at 80 ℃/2 h + 120 C/2 h + 150 ℃/4 h

Experimental Procedures

The linear thermal expansion data (ΔL/L(300K)) were characterized using a dilatometer (L75 PT Vertical, LINSEIS, Germany) in the temperature range of 120–300 K in helium gas with a heating rate of 2 K/min.

The thermal conductivity was measured by means of a heat and sink steady-state method, which is to establish a stationary temperature gradient, and supplies heat at one end of the sample while the other end is maintained at a constant temperature. By measuring the temperature difference between a given distances, the temperature difference of the two ends of the sample was stabilized with an accuracy of better than 0.01 K.

Tensile and compression tests were conducted with a MTS SANS CMT 5000 model test machine (load capacity, 100 kN). More than six specimens with dimensions of 20 mm×6 mm×2 mm were tested for each experiment to get an average value according to ASTM 3039 test standard specifications

Results

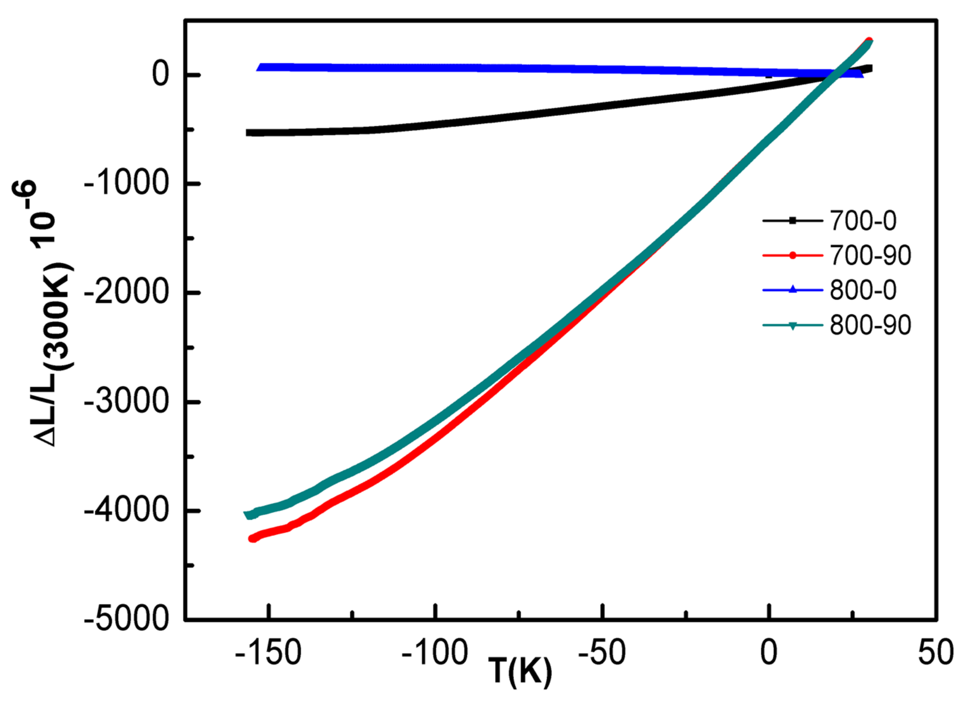

Figure 1. The temperature dependence of the linear thermal expansions ΔL/L(300K)

Table 1. The CTE for carbon fibers/epoxy composites

Samples	Direction(°)	CTE(10^{-6} $\times K^{-1}$)
T700/ DGEAC	0	3.1
T700/ DGEAC	90	24.7
T800/ DGEAC	0	-0.4
T800/ DGEAC	90	23.4

According to the ΔL/L(300K) data of the T700/DGEAC and T800/ DGEAC, It is observed that all samples show a linear volume expansion as function of temperature at room temperatures and the slope decreases gradually with decreasing temperature. We calculated the CTE (T700-0°, T700-90°, T800-0°, T800-90°) and it is determined to be around 3.1, 24.7, -0.4, 23.4×10^{-6} K^{-1}(Table 1) respectively. The results show that compared the composite materials T700 CFs with T800 CFs, the CTE of T800 CFs(0°/90°) are all smaller than those of T700 CFs.

Results

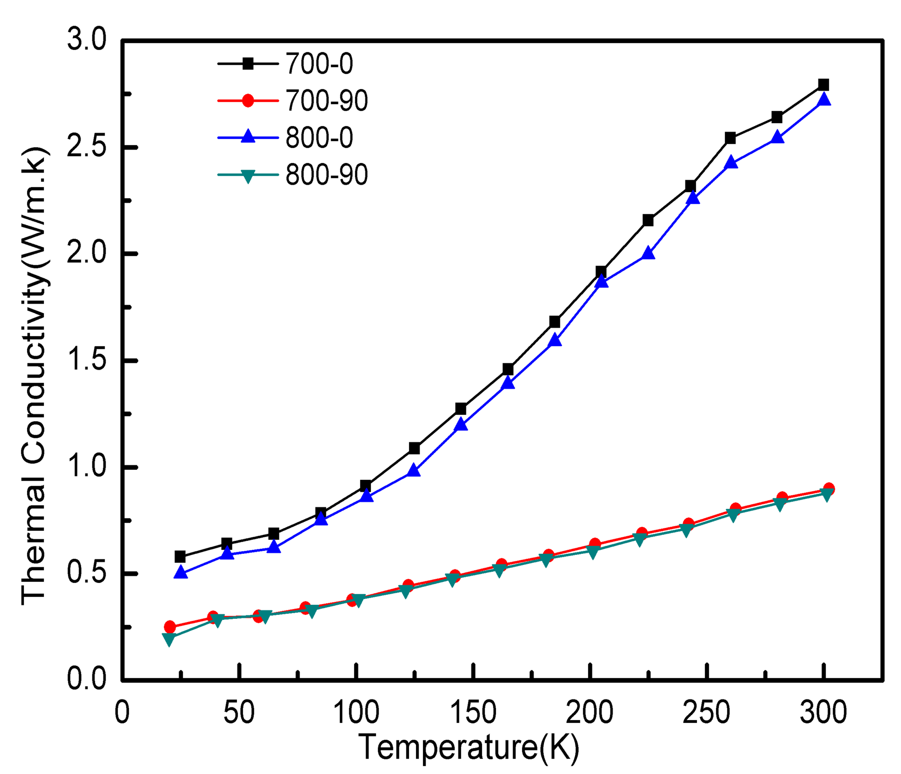

Figure 2. The temperature dependence of the thermal conductivity

The thermal conductivities of T700-0° are all larger than that of T800-0° more or less from 25 to 300K.

The thermal conductivity of the composites in 0° are all larger than that in 90° because of higher thermal conductivity of carbon fibers than that of resins.

The gap between 0° and 90° became smaller from 300K to 20K, which is beneficial to the practical applications such as hydrogen storage tanks.

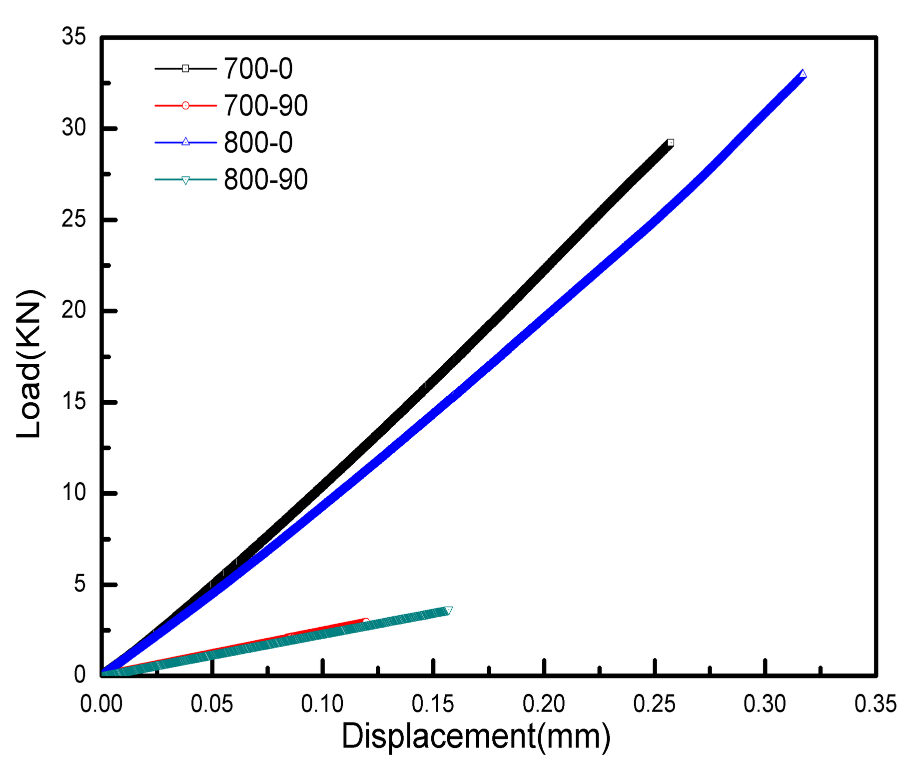

Figure 3. Load - displacement curves of the T700/ DGEAC and T800/ DGEAC laminate by the tensile test

Take the T800/ DGEAC in 0° for example, the whole test curve of the laminate is changed as a line.

When the load reached 25000N, the specimen started to make a cracking sound.

As the load continued, the whole laminate was seriously deformed, and then, completely broken.

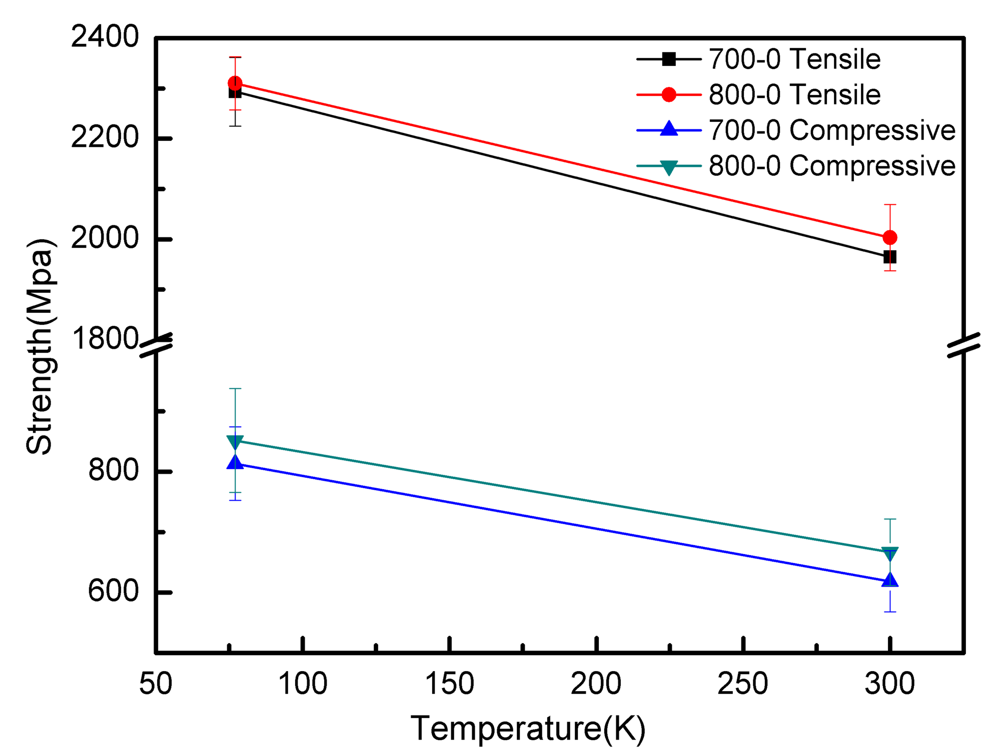

Figure 4. The tensile and compressive strengths for the T700/ DGEAC and the T800/ DGEAC laminates in 0° direction

Both the tensile strength and the compressive strength of the composites all increases monotonically with decreasing temperature.

The value of tensile strength of the T800/ DGEAC in 0 ° direction at 77K is about 2310 MPa and under the condition of same physical dimension, the tensile and compressive properties of the T800/ DGEAC are slightly higher than those of the T700/ DGEAC.

Considering the thermal properties of the materials, the whole properties of the T800/ DGEAC are apparently better than those of the T700/ DGEAC.

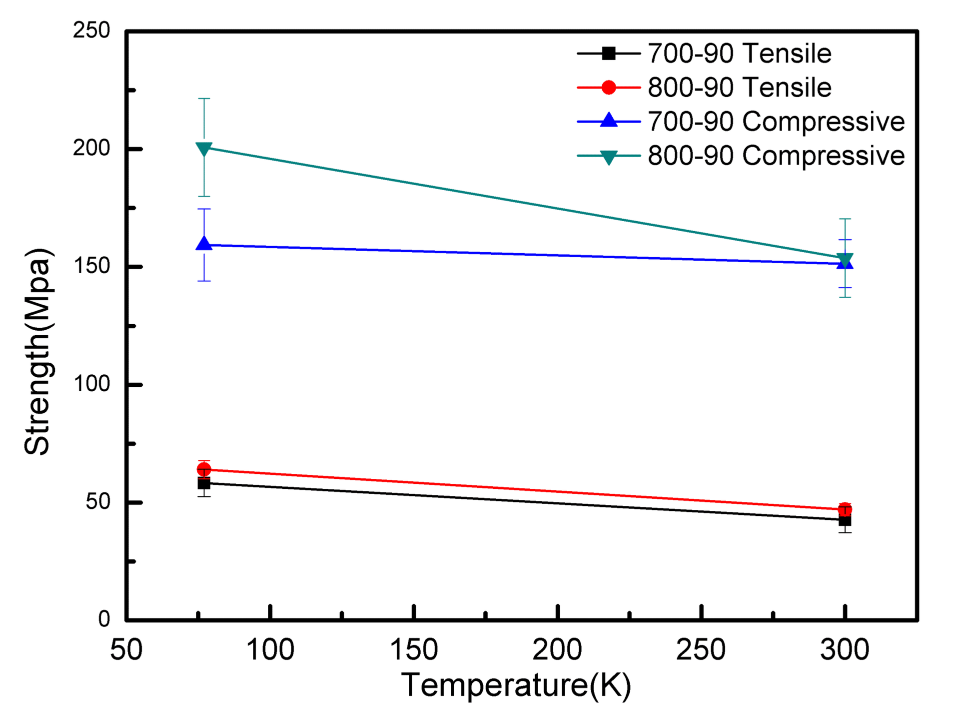

Figure 5. The tensile and compressive strengths for the T700/ DGEAC and the T800/ DGEAC laminates in 90° direction

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