Design and development of vehicle cryo-compressed hydrogen storage vessel

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1. Introduction

Fiber reinforced composite materials are the main materials for hydrogen storage containers. Due to the widespread application and increasingly mature technology of hydrogen storage containers at room temperature and high pressure, engineers have gained a deep and extensive understanding of the mechanical properties of fiber reinforced composite materials at ambient temperatures. However, for hydrogen storage at low temperature and high pressure, fiber composite materials are applied in the low temperature range (350~20K). Compared with normal temperature, Strength of materials properties at low temperature have a great change. In order to safely and reliably design these hydrogen storage vessels for low temperature applications, it is necessary to understand the influence of low temperature conditions on the mechanical properties of fiber composite Strength of materials One of the most important applications of carbon fiber composite materials is in the storage and transportation of hydrogen energy. Therefore, studying the mechanical properties of carbon fiber composite materials under low temperature conditions is of great significance.

2. Preparation of unidirectional carbon fiber composite board

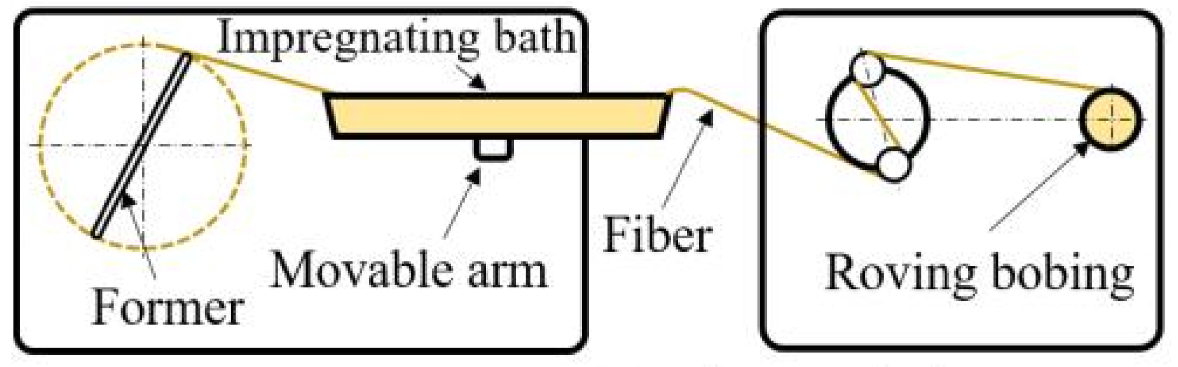


Figure 1. UN-CFRP composites fabrication process.

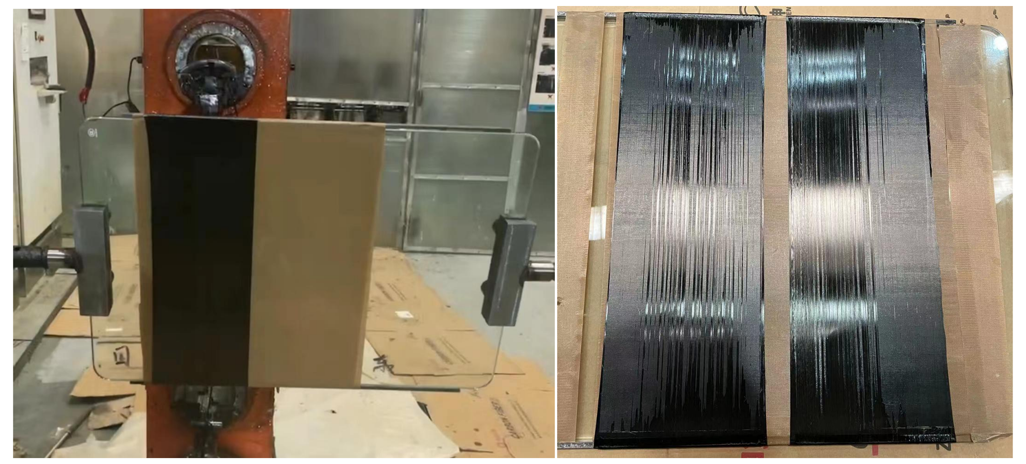


Figure 2. Winding (left) and curing (right) during fabrication process for UN-CFRP composites.

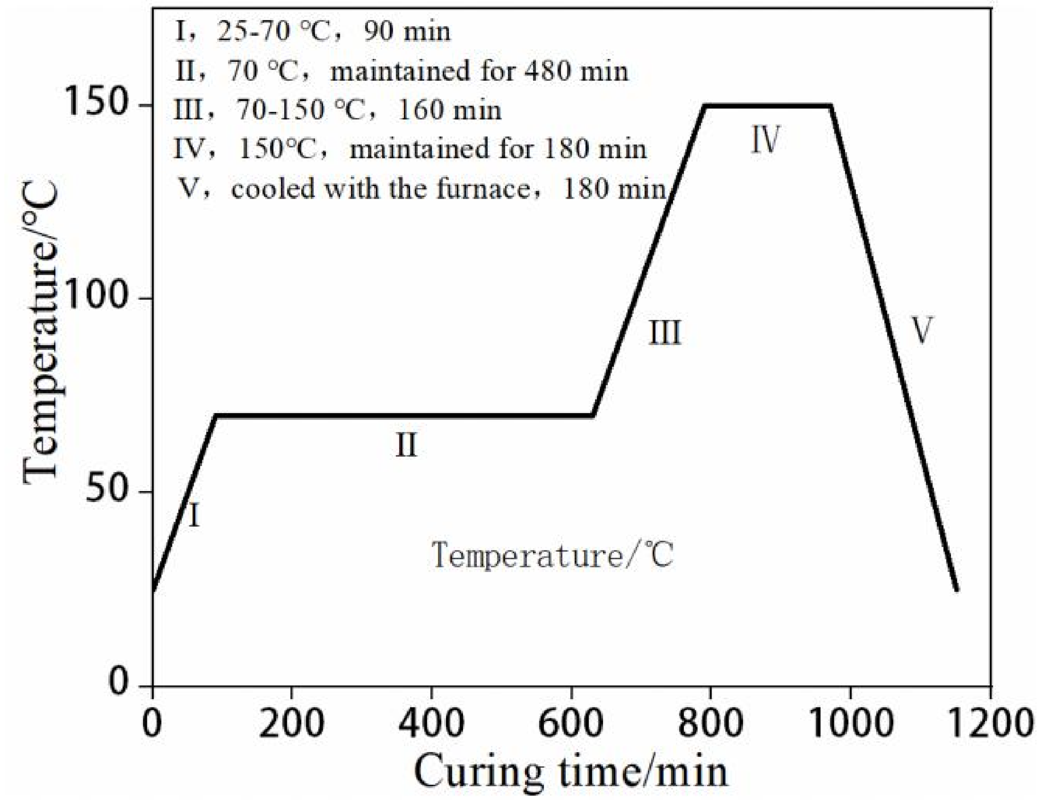


Figure 3. Curing curve of resin system.

3. Performance test results of one-way board

Table 1. Tensile properties of UN-CFRP at room temperature and liquid nitrogen.

	Performance Index	Room temperature	Liquid nitrogen temperature
0 ° tensile specimen	Tensile strength (MPa)	2053.9±52.5	2101.7±31.2
	Tensile modulus (GPa)	135.4±13.8	148.0±22.8
	Fracture strain (%)	1.46±0.156	1.45±0.19
90 ° tensile specimen	Tensile strength (MPa)	13.7±4.0	28.8±9.7
	Tensile modulus (GPa)	7.8±1.5	18.7±0.7

Table 2. Flexual properties of CFRP at room temperature and liquid nitrogen.

	Performance Index	Room temperature	Liquid nitrogen temperature
0 ° Bending	Tensile strength (MPa)	1138.8±49.3	2304.1±75.0
	Tensile modulus (GPa)	100.5±2.4	116.2±5.4

Table 3. Compression properties of CFRP at room temperature and liquid nitrogen.

Performance Index	Room temperature	Liquid nitrogen temperature
0° Compressive strength (MPa)	1132.9±36.9	1208.8±163.8
90° Compressive strength (MPa)	84.2±10.2	157.4±21.6

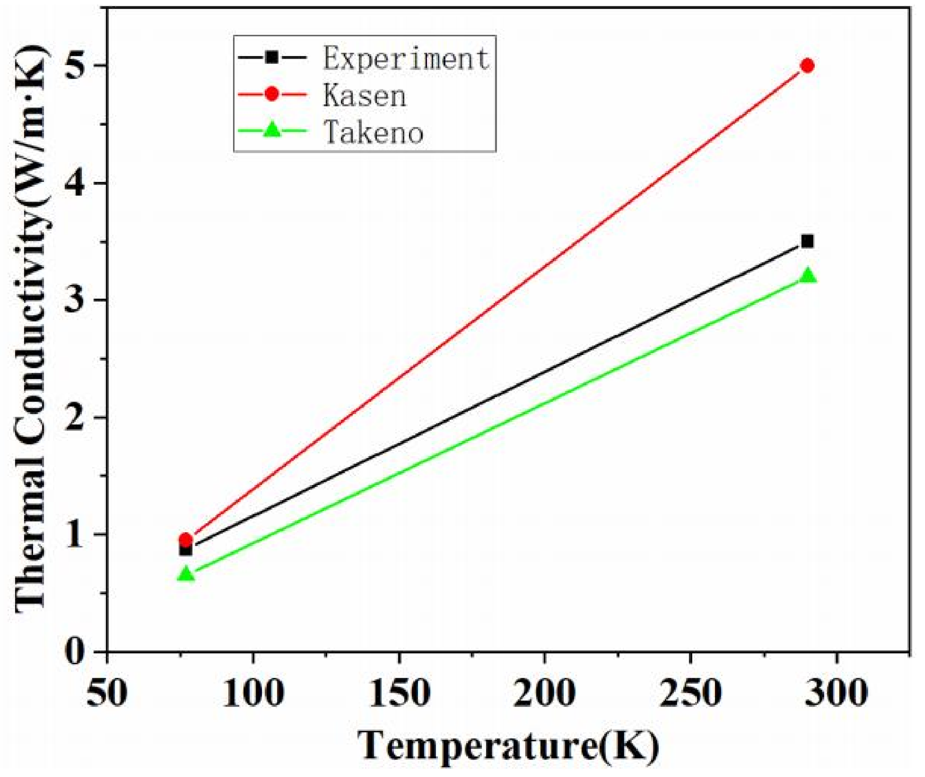


Figure 4. Thermal conductivity test results of CFRP for 0°direction.

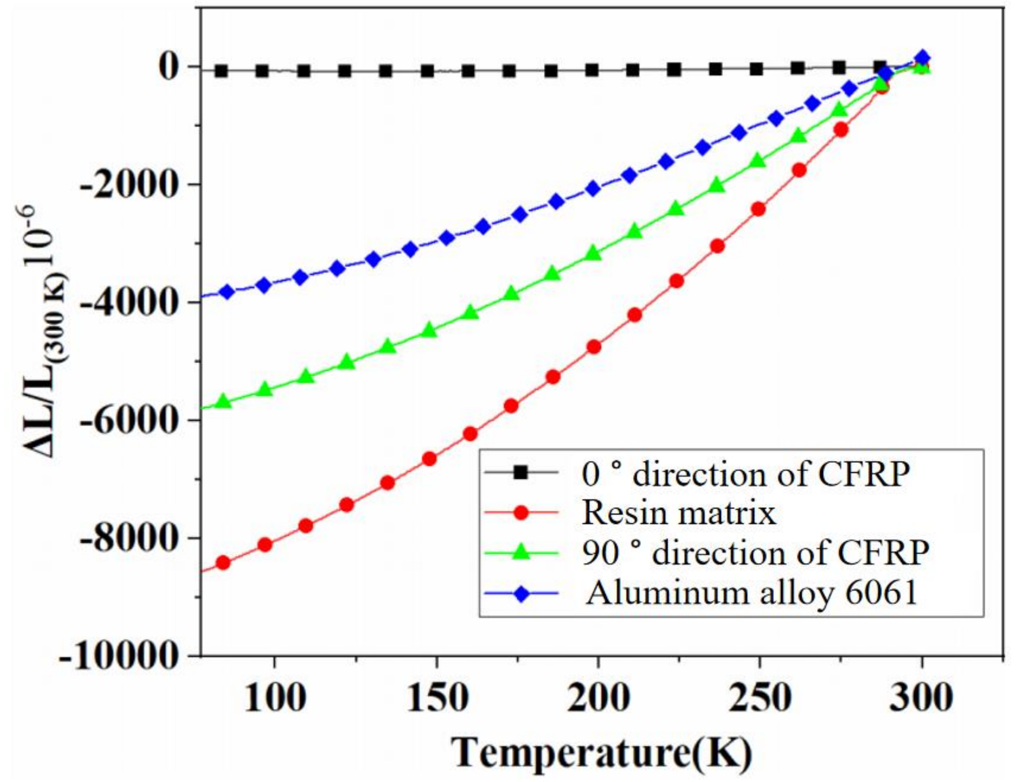


Figure 5. Thermal contraction of materials from 300 to 77 K.

4. Structural design of cryo-compressed hydrogen storage tank

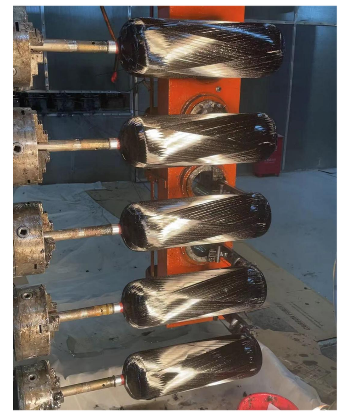
The working pressure of the storage tank is 35 MPa, and the minimum bursting pressure is generally 2.25 times the nominal pressure, which is 78.75 MPa. The cylindrical radius of the aluminum lining is 62.5 mm, the polar hole radius of the front head is 15 mm, and the thickness of the lining is 2mm. **The ultimate strength of the carbon fiber composite material is 2054 MPa.**

Using **grid theory** to calculate the winding angle and layer thickness of carbon fibers.

The spiral winding angle is: $\sin\alpha_0 = \frac{r_0}{R}$

The circumferential winding thickness is: $t_{f90} = \frac{RP_b}{2f\sigma_b}(2 - tg^2\alpha_0)$

The thickness of spiral winding is: $t_{f\alpha} = \frac{RP_b}{2k_f f\sigma_b \cos^2\alpha_0}$



5. Conclusion

- ✓ Compared with room temperature, the tensile properties, compressive properties and bending properties of carbon fiber composites at low temperature are enhanced to varying degrees. The tensile strength at 0 ° direction increased by 2%, tensile modulus increased by 9%, bending strength increased by 102%, Flexural modulus increased by 16%, and compressive strength increased by 7%.
- ✓ At room temperature, the thermal conductivity of carbon fiber composite materials is 3.5 W/m·K. At around 77 K, the thermal conductivity is 0.87 W/m·K.
- ✓ Carbon fiber composite materials are suitable for use in low-temperature and high-pressure hydrogen storage Type III bottles.