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Tensile Property Analysis of NCF Composite Laminated Structure for HP-CRTM Forming Process

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HP-CRTM 성형공법을 적용하기 위한 NCF 복합재 적층구조에 따른 인장특성 분석

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ABSTRACT

In recent years, the HP-CRTM method, which has the ability to produce carbon fiber-reinforce plastic composites at high speeds, has come into the spotlight in the automotive parts industry, which demands high productivity. Multi-axial carbon fabric, an intermediate material used in this HP-CRTM molding process, consists of layered fibers without crimp, which makes it better in terms of tensile and shear strength than the original woven fabrics. The NCF (non-crimp fabric) can form the layers of the carbon fiber, which have different longitudinal and lateral directions, and $\pm\theta$ degrees, depending on the product's properties. In this research, preforms were made with carbon fibers of ±45° and 0/90°, which were lamination structures under seven different conditions, in order to create the optimal laminated structure for automobile reinforcement center floor tunnels. Carbon fiber composites were created using each of the seven differently laminated preforms, and polyurethane was used as the base material. The specimens were manufactured in accordance with the ASTM D3039 standards, and the effect of the NCF lamination structure on the mechanical properties was confirmed by a tensile test.

Key Words : Carbon Fiber(탄소섬유), Non Crimp Fabric(다축직물), Composite(복합재), Tensile Strength(인장강도)

1. Introduction

Recently, composite materials have been drawing attention in the development of automotive materials and parts due to the strengthening of international regulations on environmental standards and fuel efficiency and the rising prices of energy resources. In general terms, if the weight of vehicles is reduced by 100 kg per vehicle, this will have the effect of saving 1.6 million liters of fuel and 2 million kilograms of greenhouse gases per day on average. As the materials and parts industry for lightweight vehicles is growing, research on molding

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and production equipment, which is essential for mass production and cost reduction, is also increasing[1~3].

Composite materials can be divided into composites using nonferrous metals (Al, Mg) and polymer composites. The commercialization of nonferrous metals has been slow due to limited resources and difficulty of molding or processing. Carbon fiber reinforced plastic (CFRP) composites have fewer such disadvantages and a strong lightweight effect; thus, they demand intensive research and further development in the automotive parts industry[4-6].

CFRP is a mixture of synthetic resin and carbon fiber, and resins can be classified into thermosetting and thermoplastic types. In general, thermosetting resin epoxy or polyurethane are used because they have better properties than thermoplastic resins.

Table 1 Material properties of carbon fiber

Tensile strength (MPa)	Tensile modulus (GPa)	Strain (%)	Tex (g/1000m)	Density (g/cm^3)
4900	230	2.1	800	1.8

However, due to the addition of the molding cycle by curing reaction, they are not frequently applied in the automotive industry, which requires rapid production[7~8]. To overcome this problem, the high-pressure compression resin transfer molding (HP-CRTM) system is drawing attention as a CFRP molding system appropriate for automotive parts production.

However, the high-priced equipment is only manufactured in developed countries, which is a big obstacle to the production of automobile parts using HP-CRTM. When localizing the HP-CRTM molding system, which injects molten resin at high pressure and then compresses it, the mold design and fabrication directly determine the shape of the CFRP product and are critical elements for the quality and performance of the product. Localization requires mutually complementary fusion technology with major processes such as the resin, preform, and molding systems before the design stage [9~11]. This study investigates the characteristics of products according to the laminated structure of a non-crimp fabric (NCF) preform for application to the HP-CRTM molding method. The results of this study will be used as the basic data for producing a “reinforcement center floor tunnel” product for automobiles.

Table 2 Configuration of Non-crimp fabric(NCF)

Configuration		Type1			Type2			Type3
		±45 2ply, 0/90 4ply			±45 4ply, 0/90 2ply			0/90 6ply
Case		Case1	Case2	Case3	Case4	Case5	Case6	Case7
Laminated conditions	1	±45	0/90	0/90	±45	0/90	±45	0/90
	2	0/90	0/90	±45	±45	±45	0/90	0/90
	3	0/90	±45	0/90	0/90	±45	±45	0/90
	4	0/90	±45	0/90	0/90	±45	±45	0/90
	5	0/90	0/90	±45	±45	±45	0/90	0/90
	6	±45	0/90	0/90	±45	0/90	±45	0/90

Table 3 Experimental conditions

Material properties	Process conditions
- Resin : Polyurethane - Mixing ratio : Polyol : ISO = 100 : 137 - Carbon fiber : 12K - Preform Weight : 343g - Matrix Weight: : 550g	- Pressure : 3000kN - Molding Temperature : 120℃ - Curing time : 10min

Table 4 Layout of CFRP

	Carbon fiber composite
Layout	Peel ply
	Perforation film
	Matrix
	Non-crimp fabric(NCF)
	Perforation film
	Peel ply

2. NCF Composite

2.1 Production of Composite Materials

To design the optimal laminated structure of the center floor-reinforcing tunnel, an NCF preform for the laminated structure was produced and its properties were tested. For reinforced fiber, a carbon fiber 12K (Toray, T700SC), which has excellent rigidity and elongation, was used. Its mechanical properties are listed in Table 1.

In this study, NCFs, which are the preforms of the composite, were fabricated by laminating carbon fiber fabrics in seven conditions in total at angles of ±45° and 0/90°, as shown in Table 2, using a carbon fiber multi-axis weaving machine [12~13].

Polyurethane was used for reinforcement, as it has a thermosetting property and good resistance to low-temperature embrittlement. Polyurethane's application to RTM equipment has been increasing recently because it is appropriate for mass production due to advantages such as low viscosity compared to epoxy, fast resin injection time due to low viscosity, and short curing time. In this experiment, resins were formed by mixing them with polyol, which is the basic component material for polyurethane, and a hardener, which forms urethane by reacting with polyol. The polyol and hardener were mixed at a ratio of 100:137 [14].

2.2 Manufacturing the Composite

The composite manufacturing process was carried out manually. The composite molding process conditions are listed in Table 3. The NCF preform and the mixed resin were sequentially put into the molding press. The press pressure, which is a process condition for maintaining the molding force of the composite material, was set to 3000 kN. The mold temperature was 120℃, and the curing time was 10 min. Many voids were generated on the surface of the composite due to the nature of the process. Thus, the void content in the composite was minimized by adding a perforated film and a peel ply to both sides of the NCF in Table 4. Fig. 1

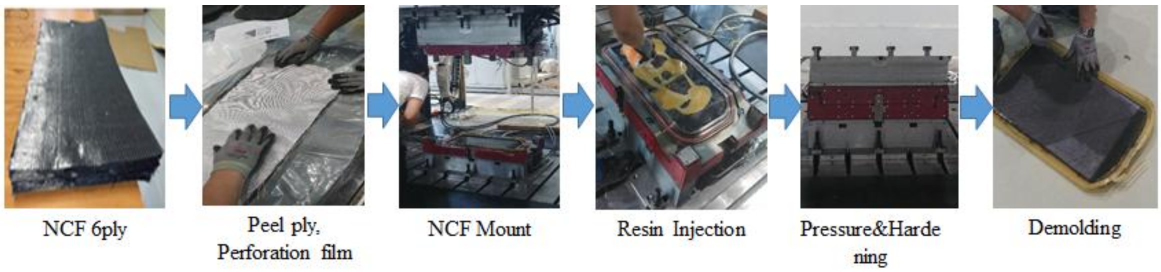

Fig. 1 Manufacturing process

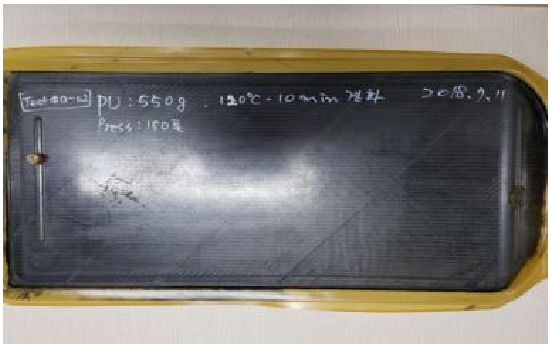

Fig. 2 Molded NCF composites

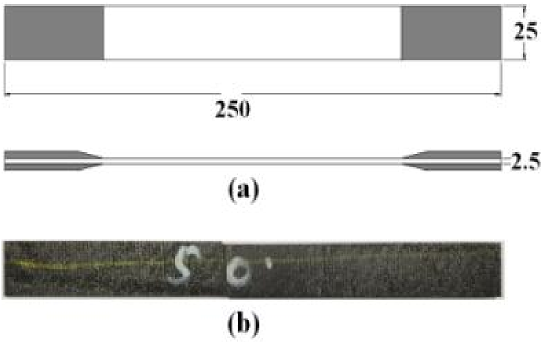

Fig. 3 (a) Shape of NCF composites specimen
(b) Molded NCF composites specimen

shows the manufacturing process of the NCF composite.

3. Tensile Strength Test

3.1 Test Method

The specimen for analyzing the tensile strength of the composite was fabricated in the direction of the molded product arrangement in Fig. 2 in accordance with the ASTM D 3039 standard. The test was conducted at room temperature with a displacement of 2 mm/min, and the data were extracted through 10-Hz sampling. The tensile tests were performed three times for each sample. Figs. 3 shows the fabricated specimens[15~18].

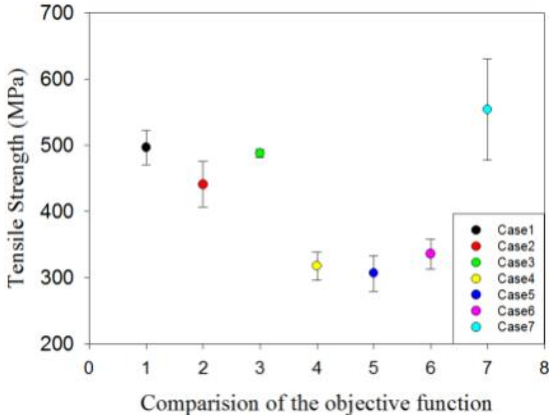

Fig. 4 Tensile strength according to laminated pattern

3.2 Test Results

Fig. 4 shows the tensile strength of the carbon fiber composite according to the lamination condition of the NCF. The test results showed that the average tensile strength was the highest in the lamination condition of six sheets of fabric with 0/90° angles. Furthermore, as the number of laminations of the fabric with 0/90° angles increased, the tensile strength also increased. When the tensile strength was analyzed for the lamination pattern of the fabrics with ±45° and 0/90° angles in the same lamination structure, the tensile strength increased more when the fabrics with ±45° angles were dispersed than when they were concentrated at the center of the laminations.

4. Conclusions

This study produced carbon fiber composites according to the NCF lamination structure. The specimens for testing the tensile strength, which is a mechanical property of the molded product, were fabricated. From the experimental results, the following conclusions were obtained.

1) The tensile strength of the NCF composite increased as the number of laminations of the fabric

with 0/90° angles increased. The tensile strengths were similar in the same lamination structures. The composition of the fabrics with ±45° and 0/90° angles is the factor that has the largest impact on the tensile strength of the composite.

2) When Types 1 and 2 with the same lamination structure were analyzed, the tensile strength was the lowest when the fabrics with ±45° angle were concentrated in the middle. This confirms that the lamination pattern affects the strength of the composite even for the same fabric composition.

Finally, the molded products were manufactured manually. Thus, the void content was high and the average tensile strength was low. It is possible to minimize the void content and improve the impregnability through the HP-CRTM molding method, which includes a high-pressure resin injector, vacuum pump, and high-pressure compression molding processes.

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