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FABRICATION OF CF/AF FIBER HYBRID THERMOPLASTICS COMPOSITE

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SUMMARY: In order to improve the mechanical properties of composite, concept of "fiber hybrid composite" was applied into the woven fabric reinforced thermoplastics composite. Thermoplastic resin has difficulty in impregnating into the reinforcing fiber bundles because of their high molten viscosity. Micro braided-yarn is one of the solutions to this problem. Micro-braided yarn is fabricated by tubular braiding machine. The reinforcing fiber bundle is straightly inserted in the center and the matrix resin fiber bundles are braided around the reinforcing fibers. In this study, hybrid long fiber reinforced thermoplastic composite was proposed. The micro-braided yarn was made by aramid fiber and carbon fiber and then two types of woven fabrics were fabricated by these fibers. For one of them, aramid fiber was used as a weft and warp fiber. In the case of the other one, the weft fiber was aramid micro-braided yarn and the warp fiber was aramid and carbon micro-braided yarn alternatively. First, fabrication of aramid/carbon woven fabric composite with Micro-braided yarn was introduced. Next the mechanical properties of composites were investigated by using tensile test with Acoustic emission technique. As a result of tensile test, tensile modulus and strength of intra-layer fiber hybrid composite realized the highest value.

KEYWORDS: fiber hybrid composite, thermoplastic, micro-braided yarn

INTRODUCTION

In recent year, for the purpose of developing properties of composite materials, which cannot be obtained by using sole materials, hybrid composites have been researched. Hybrid composite is defined as "Composite consists of two or more kind of components" [1]. In hybrid composite, construction components fill in gaps and utilize the advantage and characteristics of each other. In our definition, there are three types of hybrid composite; Fiber Hybrid, Matrix Hybrid, and Interfacial Hybrid. Fiber hybrid composite is the most popular hybrid composite. Fiber Hybrid means using different fibers in one fabric. Generally, only one type of reinforcement fiber among Glass, Carbon, aramid and so on has been selected in one fabric. Mechanical properties and cost of the Fiber Reinforced Plastics (FRP) depend on feature of the fiber bundle. T. Hayashi et al. [2] are the first people who discovered the positive effect in which the fiber hybrid composites have higher mechanical property than that of single material system called "Hybrid Effect".

There have been increasing interests in the use of thermoplastic matrices for the manufacture of continuous fiber reinforced composites. Thermoplastic resins have the disadvantage of their high melt viscosity in molding. Therefore, it is difficult to impregnate resin into reinforcement. In order to overcome this problem, various intermediate materials have been developed, for example, commingled yarn and powder coated yarn [3, 4]. These intermediate materials have good impregnation properties and drapability, however, the cost is high in most cases, and only limited combinations of reinforcement fiber and matrix resin are available. In these circumstances, we have developed Micro-braided yarn as shown in Fig. 1. Tubular braiding machine was employed to produce Micro-braided yarns. The reinforcing fiber bundle is straightly inserted in the center and the matrix resin fiber bundles are braided around the reinforcing fibers. The reinforcement fiber bundles suffer no damage during micro-braided process and provide better protection for further processing such as producing textile preforms. Matrix resin fiber bundles are melted and impregnated into dry reinforcing fiber bundle by heating at a proper molding method. In this study, hybrid long fiber reinforced thermoplastic composite was proposed. First, fabrication of aramid/carbon woven fabric composite with Micro-braided yarn was introduced. Then tensile test with Accoustic emission (AE) technique was carried out.

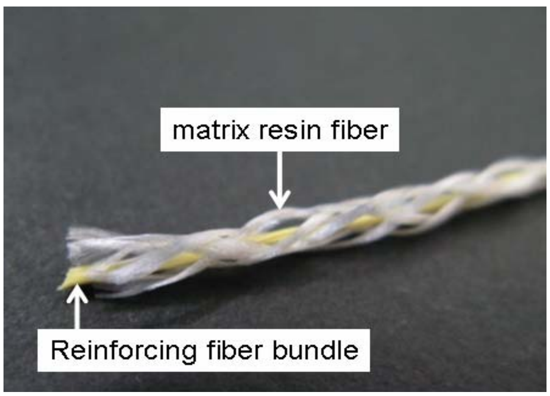
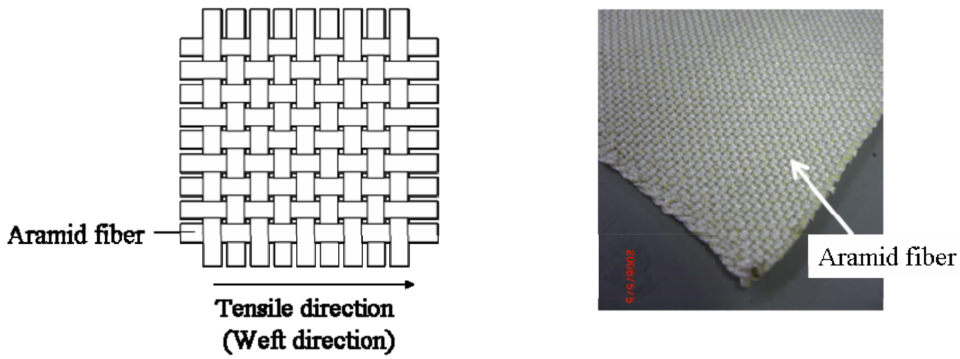


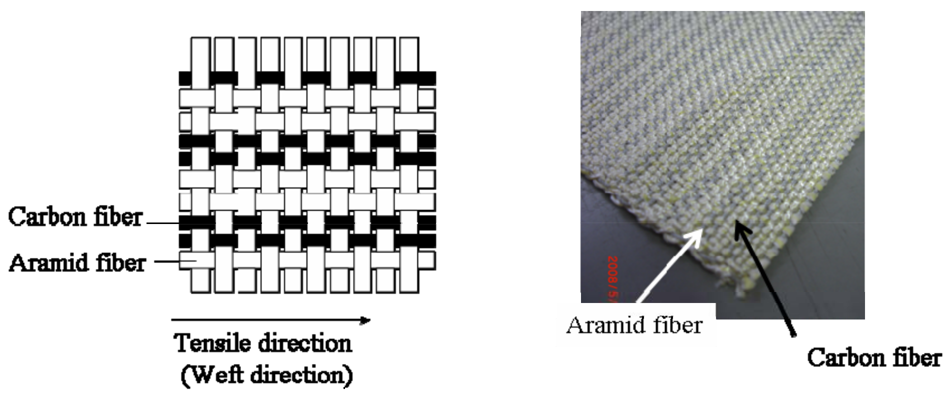
Fig. 1 Micro-braided yarn.

MATERIALS AND PROCESSING

Aramid fiber bundles (kevlar 29; 1000 filament; 1670 tex; TORAY) and carbon fiber bundles (pyrofil TR30S 3L A1, MITSUBISHI RAYON Ltd.) as reinforcement and PA66 resin fiber bundles (235dtex, TORAY Co., Ltd.) as matrix were used and two types of Micro-braided yarn were fabricated. Then Micro-braided yarns were used to produce two types of plain woven fabrics. Fig. 2 shows the schematic drawings and photographs of woven fabrics. In Fig. 3a, aramid fiber was used as a weft and warp fiber. In the case of Fig. 3b, aramid fiber was used as a weft fiber and aramid fiber and carbon fiber were used as a weft fiber alternatively. In this study, Fig. 3a was named AF and Fig. 3b was named CF/AF. In AF, the weaving density of warp direction was 17 yarns/25 mm and that of weft direction was 15 yarns/25 mm. In the case of CF/AF, warp direction was 17 yarns/25 mm and that of weft direction was 17 yarns/25 mm. These textiles were stacked into 4 layers. The molding method is compression molding with heat. The molding temperature was 290 degrees, the pressure was 10 MPa and the molding time was 40 minutes [5].



(a) AF



(b) CF/AF

Fig. 2 Schematic drawings and photograph of woven fabrics: (a) AF; (b) CF/AF.

Tensile test was carried out by using INSTRON universal testing machine (type 4206). The specimen size was 200 mm in length, 20 mm in width 1 mm in thickness and aluminum tabs (thickness 1 mm, width 20mm, length 50 mm) were put on both ends. The span length was 100 mm and the crosshead speed was 1mm/min. At the same time, strain was measured by a 10 mm strain gage. Acoustic emission (AE) monitoring was simultaneously performed to identify the damage initiation and propagation.

RESULT AND DISCUSSION

Fig. 3 shows the photograph of aspect and cross section of (a) AF and (b) CF/AF composites after molding. From the cross sectional photograph, there were no dry regions on both specimens and the PA resin was completely impregnated in spite of high melt viscosity. Stress-displacement curves are shown in Fig. 4. In both AF and CF/AF, with increase in displacement, the stress increased linearly. After the maximum stress, the stress decreased drastically. The slopes of curves and the maximum stress of CF/AF were higher than those of AF. Table 1 shows the summary of tensile test. Tensile modulus and strength of CF/AF (49.3 GPa, 399 MPa) were higher than those of AF (21.9 MP, 215MPa).

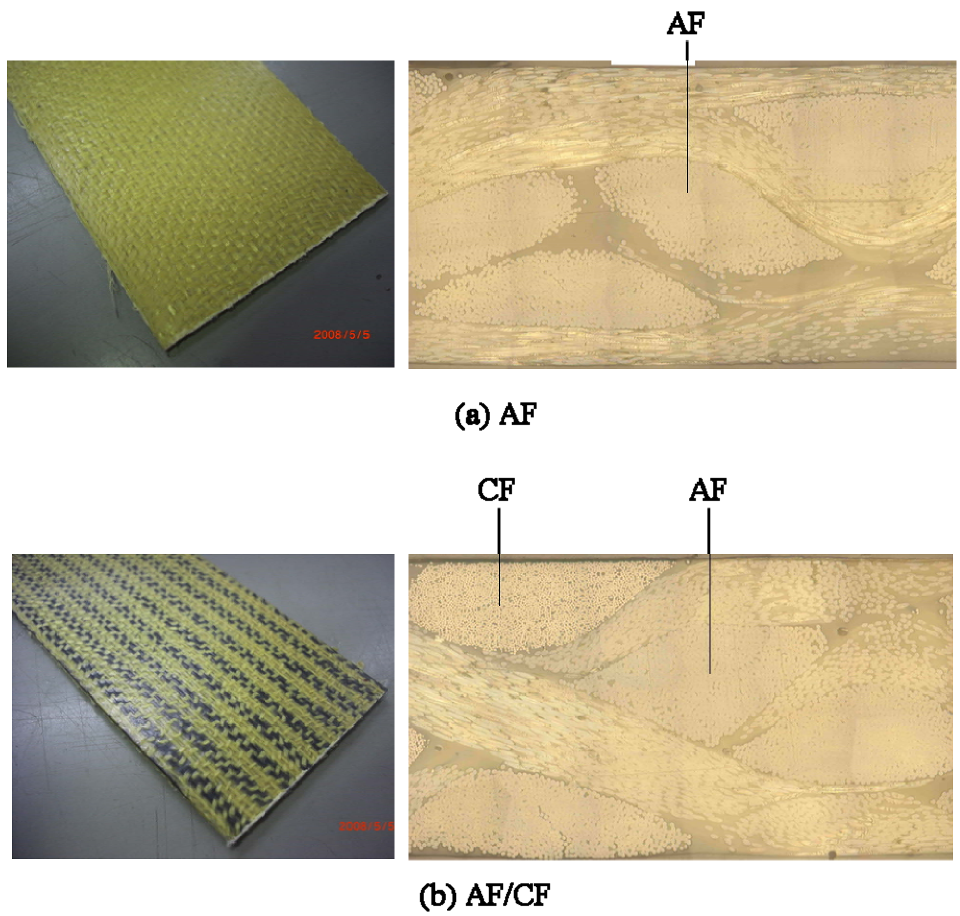


Fig. 3 Photographs of composites and cross sections: (a) AF; (b) CF/AF.

Fig. 5 shows the stress-displacement curves with cumulative AE events. Fig. 6 shows the expanded initial part of tensile stress-displacement curves with cumulative AE events of each specimen. AE generating stress is defined as the stress at which AE signals begin to occur. AE generating stress of CF/AF (105 MPa) became slightly high compared to AF (92 MPa). In the case of CF/AF, the load sharing ratio of the tensile fiber was increased and that of transverse fiber decreased.

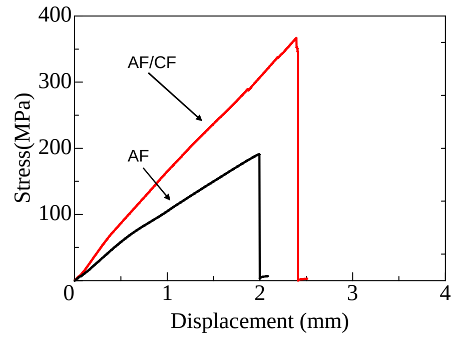


Fig. 4 Stress-displacement curves.

Table 1 Results of tensile tests

	Modulus (GPa)	Strength (MPa)	AE generating stress (MPa)
AF	21.9	215	92
AF/CF	49.3	399	105

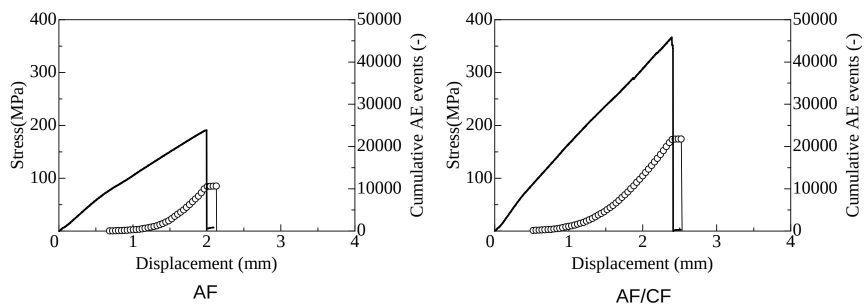


Fig. 5 Stress-displacement curve with cumulative AE events of each specimen.

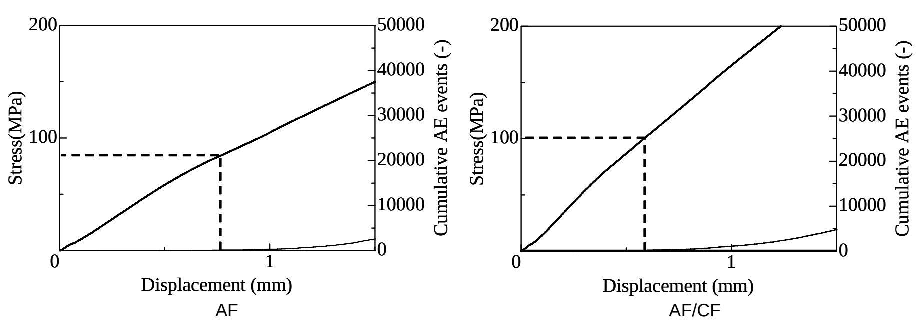


Fig. 6 Expanded initial stress-displacement curve with cumulative AE event of each specimen.

CONCLUSION

In this study, to improve the mechanical properties of composite, fiber hybrid composite was applied into the woven fabric reinforced thermoplastics composite. Micro-braided yarn was used as the solution method to the resin impregnation. Aramid and aramid/carbon woven fabric composite with Micro-braided yarn were fabricated by compression molding with heat. The mechanical properties of composites were investigated by using tensile test with Acoustic emission technique. Tensile modulus and strength of CF/AF were higher than those of AF. In the case of hybrid woven fabric, the load sharing ratio of the tensile fiber was increased and that of transverse fiber decreased. Therefore the initial fracture and final fracture occurrence was restrained.

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