

INTERFACIAL PROPERTIES OF CARBON FIBER REINFORCED THERMOPLASTIC COMPOSITES

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ABSTRACT: Continuous carbon fiber reinforcement thermoplastic composite has many advantages, however, it is difficult to impregnate the thermoplastic resin into reinforcement fiber bundle because of the high melt viscosity. For the solution, Micro-braided-yarn (MBY) was used as intermediate material. MBY was fabricated by braiding matrix resin fiber bundles alongside reinforcement fiber bundles. Since matrix resin fiber bundles are located directly in contact to reinforcement fiber bundle, impregnation performance is distinguished. The melted thermoplastic resin can easily impregnate into the reinforcing fiber bundles. And carbon fiber reinforcement thermoplastic composite plates were molded by hot press molding with various molding conditions. Whereas, sizing agents are a chemical coating agent applied on the surface of the CF and affect interfacial adhesion and impregnation state of CF/PP. In this study, various kinds of CF with different surface treatment and PP were used and interfacial shear strength (IFSS) was measured by micro-droplet test. In addition, effect on the impregnation state of CF/PP was investigated.

KEYWORDS:

Carbon fiber, PP, Maleated PP, interfacial shear strength, impregnation

INTRODUCTION

Fiber reinforced thermoplastic resin composites have a number of advantages such as high fracture toughness, recyclability and possibility to re-melt and reprocess compared with thermo-setting composites. Therefore, the CFRTP is very keen under global environmental issue in which natural resources are effectively used.

Thermoplastics as matrices have high melt viscosity so that it is difficult to impregnate resin into reinforcing fiber bundle in continuous fiber reinforced thermoplastic composites. To overcome this problem, CF/PP Micro-braided yarn was fabricated as a intermediate material by Japanese traditional braiding technique. Micro-braided yarn is fabricated by braiding resin fibers alongside reinforcement fiber. Since resin fibers are located close to reinforcement fiber bundle, impregnation performance of thermoplastics is excellent (1). Moreover, the Micro-braided yarn could be applied for textile technique. The unidirectional composites were fabricated by the Micro-braided yarn and the mechanical properties were investigated. However, CF/PP composites had

a problem as lower interfacial properties. It is considered that interfacial properties in continuous fiber reinforced thermoplastic composites can be characterized by the wetting ability and chemical interaction between fiber and matrix surfaces. Wetting ability would affect resin impregnation state during molding while chemical reaction affects composite strength. Therefore, interface design of CFRTP is very important to obtain materials with improved processability and mechanical performance.

Sizing agents are a chemical coating agent applied on the surface of the CF. The general purpose of the sizing is to protect the fiber from fuzzing and fragmenting during textile processing into a woven or braided preform. Sizing agent also affects the fiber /matrix adhesion.

The objective of this study is to investigate the effect of the sizing agents on the interfacial adhesion and impregnation state. To achieve this objective, various sizing agents were applied on the carbon fiber Moreover, maleated PP was used to improve the interfacial adhesion of the CF to the PP matrix.

Materials

Table 1 presents the CF coated with different sizing agents (Toray Co.,ltd). As matrix resin, PP fiber and PP with maleated PP; MAPP were used (Daiwabo Polytec Co.,ltd).

Table 1 The types of CF.

Grade	Type of sizing agents	Amount of sizing agents (%)	Filament diameter (μm)	Tensile modulus (GPa)	Tensile strength (MPa)
T700SC-12000-50C	5	1.1	6.9	230	4900
T700SC-12000-H0C	H	1.0			
T700SC-12000-31E	3	0.6			
T700SC-12000-60E	6	0.2			

Micro-droplet test

To evaluate interfacial shear strength of the CF/PP interface, the micro-droplet test was employed. The resin fiber was melted by using a hot plate at 220 °C and a small droplet of resin was applied to a single fiber. Micro-droplet test machine HM410 (Tohei Sangyo Co.,Ltd) was used with a fiber pull-out speed of 0.03 mm/min. When the micro-droplet touches the knife edges, the interface is solicited in shear mode. The maximum load F measured before matrix detachment from the fiber is related to the fiber / matrix shear strength. The interfacial shear strength (τ) was calculated by equation 1,

$$\tau = \frac{F}{\pi dl} \quad (1)$$

where F is the maximum load, πd is the fiber circumference, and l is the embedded fiber length. The values of the fiber circumference and embedded length were characterized using microscope images.

Fabrication of unidirectional specimen

CF as the reinforcement fibers was aligned and braided with PP fibers to yield CF/PP MBY by using the braiding technique. The fiber volume fraction (V_f) of CF/PP MBY was adjusted to 40 %. The CF/PP MBY was wound 32 times onto a parallel metallic frame equipped with a spring mechanism to accept thermal shrinkage during molding,

as shown in Fig. 1. The frame was then placed into a pre-heated mold before performing compression molding at 200 °C with a molding pressure of 10 MPa. The molding time was varied at 5, 10, 20, and 40 min. The CF/PP composites were cut along the direction perpendicular to the fiber axis. The cross section of CF/PP composites was polished and observed by using an optical microscope. The regions that were unimpregnated by the resin could be determined from the cross-sectional photographs. The image analysis software Photoshop CS2 (Adobe systems) was used to calculate the unimpregnation ratio. The unimpregnation ratio was calculated by normalizing the unimpregnated area by the fiber bundle area.

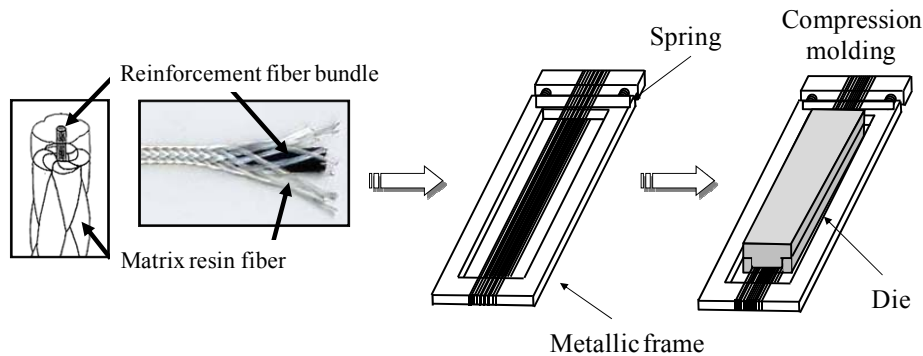


Fig. 1 Fabrication method of unidirectional specimens

Results and Discussion

Fig. 2 shows relationship between interfacial shear strength and sizing content. The interfacial shear strength decreased linearly with increasing the sizing content. Sizing agents inhibited adhesion between CF and PP. Fig. 3 shows interfacial shear strength of CF/PA compared with CF/PP and CF/MAPP. By using MAPP, interfacial shear strength was greatly improved but CF/PA tended to have higher interfacial shear strength compared with CF/PP and CF/MAPP. However, in the case of CF/MAPP and CF/PA, interfacial shear strength also decreased with increasing the sizing content.

Fig. 4 shows the cross-sectional photographs of CF/PP for each molding time with different sizing content. In this figure, the clear circles are the CF bundles surrounded by grey matrix rich regions. Black regions, attributed to unimpregnated areas, were observed inside the fiber bundles. In the case of 1.1%, for the molding time of 5 min, an unimpregnation region in the fiber bundle was observed. The unimpregnation region decreased with the increasing molding time. However, the unimpregnation region did not disappear after molding time of 40 min. In the case of 0.2 %, for the molding time of 5 min, unimpregnation regions in fiber bundle were observed but disappeared in the 10 min molding time sample. Therefore, the impregnation process was achieved in 10 min. Fig. 5 shows the relationship between unimpregnation ratio, sizing content and molding time. Unimpregnation ratio decreased with increasing sizing content and molding time. Therefore, it was clarified that sizing condition affected the impregnation process of CF/PP.

Next, effect of Maleated PP on the impregnation state was investigated. Fig. 6 shows the cross-sectional photographs of CF/PP and CF/MAPP for each molding time. In the case of CF/MAPP, bigger unimpregnated regions were observed compared with CF/PP. Therefore, it was clarified that CF/MAPP had higher interfacial shear strength but matrix resin did not impregnate the fiber bundles. Then, to clarify the wetting ability, contact angle was investigated. Fig. 7 shows photographs of contact angle of CF/PP. The contact angle of CF/MAPP was higher than that one of CF/PP. It indicated that the wetting ability became lower by using maleated PP so that CF/MAPP had poor impregnation state.

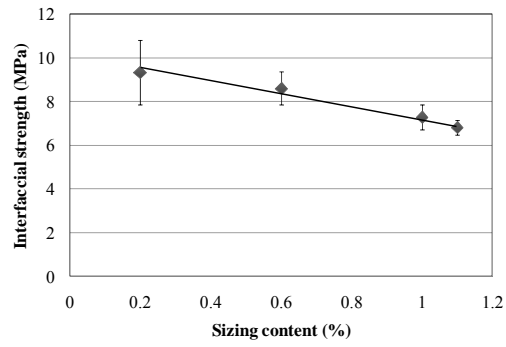


Fig. 2 Relationship between interfacial shear strength and sizing content.

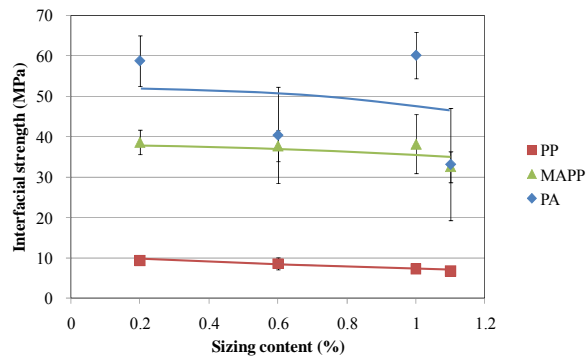


Fig. 3 Relationship between interfacial shear strength and sizing content.

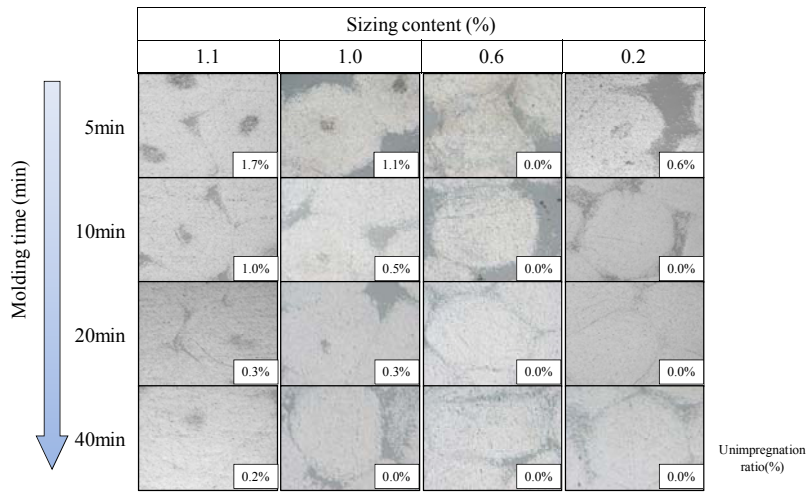


Fig. 4 Cross-sectional photographs of CF/PP.

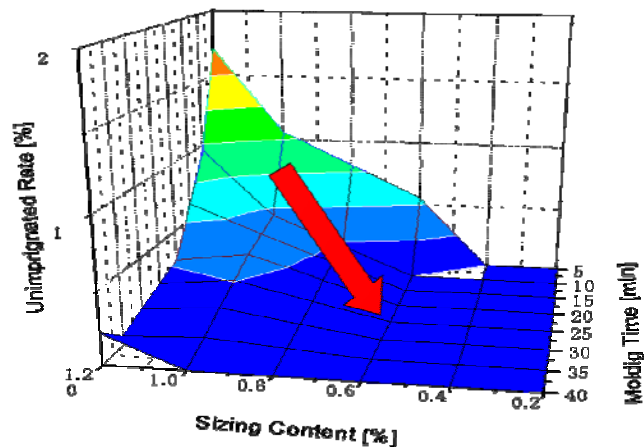


Fig. 5 Relationship between unimpregnation ratio, sizing content and molding time.

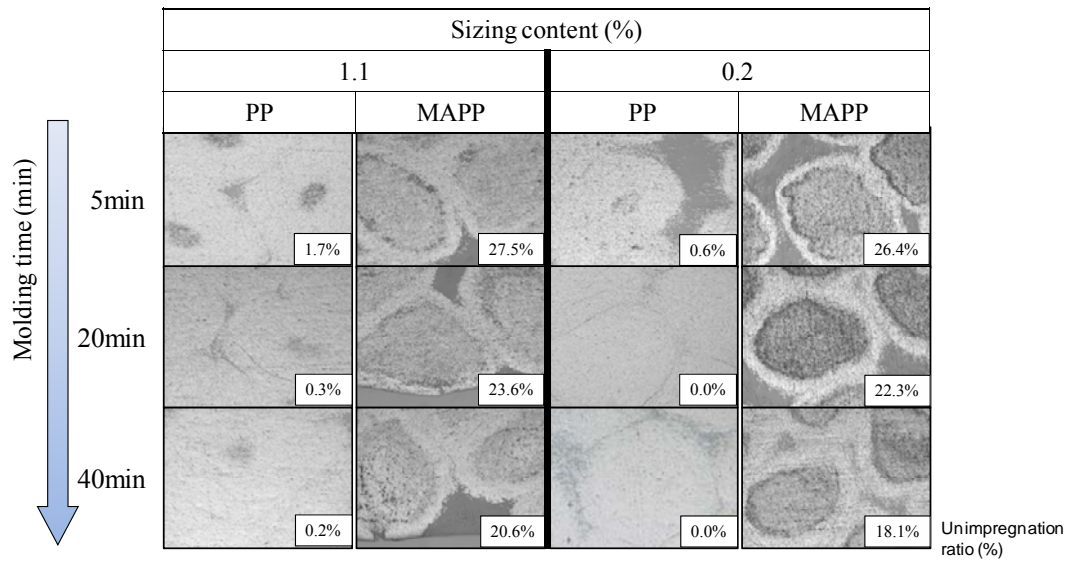


Fig. 6 Cross-sectional photographs of CF/PP and CF/MAPP.

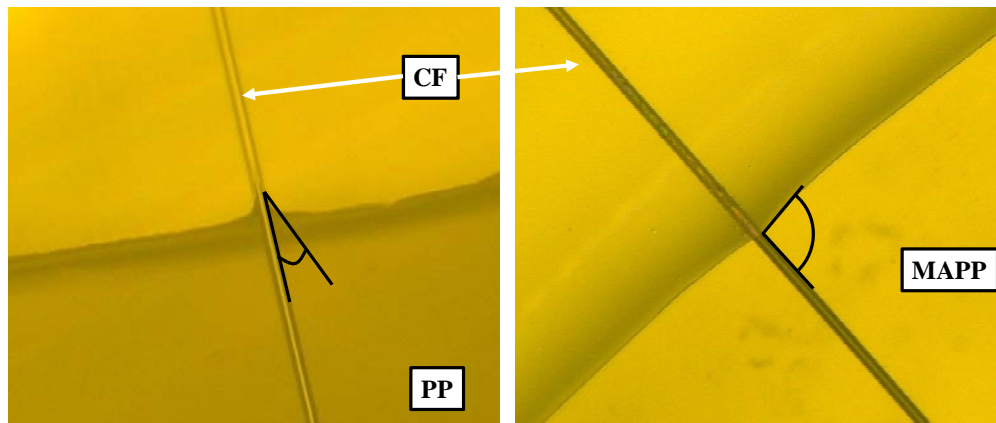


Fig. 7 Photographs of contact angle.

CONCLUSIONS:

In this study, the effect of the sizing agents on the interfacial adhesion and impregnation state was investigated. Moreover, maleated PP was used to improve the interfacial adhesion of the CF to the PP matrix. The results obtained can be concluded as follows:

It was clarified that interfacial shear strength of CF/PP decreased with increasing amount of sizing agents because sizing agents inhibited adhesion of CF/PP. Moreover unimpregnation region increased with increasing amount of sizing agents.

By using MAPP, interfacial adhesion was improved, but CF/MAPP had poor impregnation state compared with CF/PP because of poor wetting ability.

REFERENCES

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