NOVEL PREFORM WITH SELF-BONDING LAYERS

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Keywords: Self-bonding, Preform, RTM, Composites, Interlaminar performance

ABSTRACT

A novel preform with self-bonding layers used for resin transfer molding (RTM) molding laminated composites is introduced. In this study, the preform, usually also called reinforcement fabric using for composites, contains two parts—satin weave fabric with carbon fiber and silk net with hot-melt nylon. The preform is prepared with 5 different content (2%, 4%, 6%,8% and 10%) of hot-melt nylon silk. The short-beam method is conducted to evaluate the interlaminar performance of composites with the preform in 3 different temperatures (room temperature, 45℃ and 65℃).

1 INTRODUCTION

With the development of advanced composites processing technology, low cost of composites processing is increasingly popular. In low cost forming technology, liquid molding technology represented by RTM molding process is the mainstream of the current development. With the promotion and application of RTM technology, it is found that simplifying procedure of layers and assembly can facilitate the RTM process. And it can be gained more low-cost spaces in a certain sense [1]. Resin matrix laminated composites are used the most in industry. Reinforced fabric is likely to occur friction and sliding between layers while molded in the mould. It is caused the phenomenon of fabric wrinkling or uneven in layer depth. So it is very critical to strengthen the reinforced fabric fabrics preliminarily. Tackified fabrics refer to dry fluffy fabric preformed with special tackified materials. And the fabric keeps the shape of the needed effectively and ensures the structure of the fabric unchanged in the process of molding [2, 3]. Traditionally, special tackifiers matched with resin, including solution and powder, will be coated onto the surface of fabric to get performs. This method may due to uneven bonding between fabrics caused by uneven coating degrees the solution or powder on the fabric surface. So a preform with self-bonding characteristics is studied. It seems that a kind of bonding surface upper connects with the base fabric bottom in the preform. Satin weave fabric with carbon fiber and silk net with hot-melt nylon are chose in the research. The bonding surface with hot-melt nylon silk net can be evenly dispersed in the base fabric with carbon fiber satin weave fabric. So after heat treatment, the fabric has the self-bonding characteristics, and can guarantee the hot-melt nylon silk net can be distributed uniformly between layers.

2 PREFORM PREPARATION

The preform contains two parts—satin weave fabric with carbon fiber and silk net with hot-melt nylon. The satin weave fabric with carbon fiber is provided by Institute of Textile Composites, Tianjin Polytechnic University. The silk net with hot-melt nylon is prepared with hot-melt nylon silk. The areal density of carbon fiber satin weave fabric is 320g/m^2. The content of hot-melt nylon silk is defined as the ratio of areal density between hot-melt nylon silk and carbon fiber satin weave fabric. According to 5 different contents (2%, 4%, 6%, 8% and 10%) of hot-melt nylon silk, the silk net with hot-melt nylon is prepared by the way similar to plain weave fabric. The preform is prepared by putting the silk net between two layers of satin fabric with heated and pressed. Fig.1 is the schematic diagram that shows the relative position of the hot-melt nylon silk net and carbon fiber satin weave fabric. The preform includes 6 layers of carbon fiber satin weave fabric and 5 layers of hot-melt nylon silk net. The layer order of carbon fiber satin weave fabric is [90, 0, 90, 0, 90, 0]. The direction of 0°is parallel to the warp direction, and the direction of 90° is perpendicular to the warp direction. The advantage of the preform is that the preform has self-bonding characteristics and it is convenient to be pushed in the mould and injected.

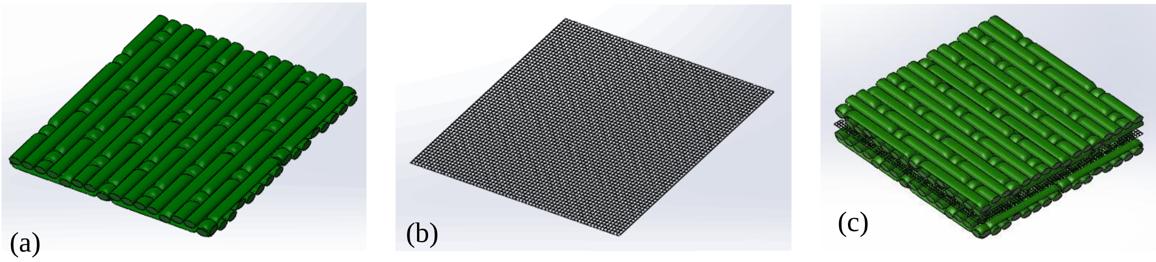


Fig.1: The schematic diagram of (a) satin weave fabric; (b) hot-melt nylon silk net; (c) the relative position of the hot-melt nylon silk net and carbon fiber satin weave fabric.

3 EXPERIMENTAL

3.1 Sample preparation

The preform is cured by RTM process to prepare laminated composites. Short-beam method is proposed to determine the interlaminar shear strength (ILSS) of the carbon fiber reinforced laminated composites (Reference standard: ISO 14130: 1997, Fiber-reinforced plastics composites-Determination of apparent interlaminar shear strength by short-beam method). The interlaminar shear failure resistance is referred to as the ILSS [4,5]. According to the reference standard, the size of the samples is 20mm×10mm×2mm. Samples are taken along the same privileged direction. The apparent ILSS of short-beam shear test of composites is given by the following equation according to the reference standard:

$$\tau_M = \frac{3}{4} \times \frac{F}{bh} \tag{1}$$

where τ_M is apparent ILSS, F is the first peak load in the short-beam shear test, b and h is the average measured width and thickness of the specimen, respectively. In order to calculate correctly, width and thickness of every specimen are measured to meet the requirements of the reference standard.

3.2 Experiment

Experimental equipments of a mechanical testing machine and a calorstat are used in the test. Becausethe experimental temperatures include 45℃ and 65℃ besides the room temperature, the function of the calorstat is making the experimental temperature constant. The short-beam shear test at 45℃ and 65℃ also need refer to the standard: GB/T 9979-2005, Guide rule of test for mechanical properties of fiber-reinforced plastics at elevated and reduced temperature. In the short-beam shear test, the span-to-thickness ratio is 5 and the test speed is 1 mm/min. The deflection and load value is obtained by using the recording devices of the testing machine. The average apparent ILSS values are reported by equation (1). Moreover, the surface morphology of the shear plane is also observed after the short-beam shear test.

4 RESULT AND DISCUSSION

Table 1 shows the apparent ILSS values of the carbon fiber reinforced laminated composites. To make the trend of the apparent ILSS values more intuitive, the line diagram is drawn. Fig.2 (1) shows the trend of the apparent ILSS values with different content of hot-melt nylon silk at same experimental temperature. Fig.2 (2) shows the trend of the apparent ILSS values with different experimental temperature under same content of hot-melt nylon silk.

Fig.2 illustrates clearly the trend of the apparent ILSS values. From Fig.2 (1), we can see that the overall trend of the apparent ILSS values is declining with different content of hot-melt nylon silk at same experimental temperature. But at experimental temperatures of room temperature, the apparent ILSS values of composites with 2% of hot-melt nylon silk is higher 1.87% than the apparent ILSS values of composites without hot-melt nylon silk. The apparent ILSS values of composites with 4%, 6%,8% and 10% of hot-melt nylon silk is lower 2.99%, 4.68%, 6.67% and 26.49% than the apparent ILSS values of composites without hot-melt nylon silk, respectively. At experimental temperatures of

45℃, the apparent ILSS values of composites with 2%, 4%, 6%,8% and 10% of hot-melt nylon silk is lower 2.87%, 8.61%, 15.50%, 15.92% and 31.37% than the apparent ILSS values of composites without hot-melt nylon silk, respectively. At experimental temperatures of 65℃, the apparent ILSS values of composites with 2%, 4%, 6%,8% and 10% of hot-melt nylon silk is lower 5.15%, 12.49%, 20.97%, 25.30% and 29.11% than the apparent ILSS values of composites without hot-melt nylon silk, respectively. In the contrast above, we can see that at experimental temperatures of room temperature, the apparent ILSS values of composites is improved 1.87% when the content of hot-melt nylon silk is 2%, and the apparent ILSS values of composites is reduced within 10% when the content of hot-melt nylon silk is 4%, 6% and 8%. At experimental temperatures of 45℃, the apparent ILSS values of composites is reduced within 10% when the content of hot-melt nylon silk is 2% and 4%. At experimental temperatures of 65℃, the apparent ILSS values of composites is reduced within 10% when the content of hot-melt nylon silk is 2%. It is concluded that the content of hot-melt nylon silk influences the interlaminar performance of composites. And the more the content of hot-melt nylon silk is, the bigger the influence at the interlaminar performance of composites is. At room temperature, which is not affected by the high temperature, a small amount of hot-melt nylon silk can have a function of toughening to improve the interlaminar performance [6,7]. The higher content of hot-melt nylon silk can affect the interfacial adhesion between the matrix and the enhanced perform to reduce the interlaminar performance.

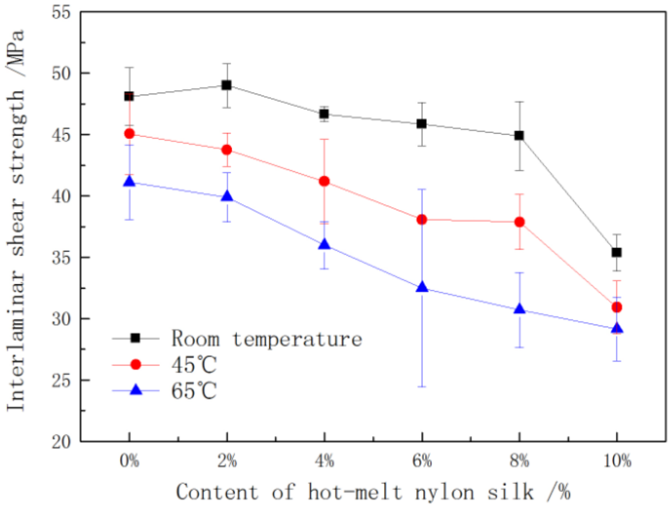
From Fig.2 (2), we can see that the overall trend of the apparent ILSS values is also declining with different experimental temperature under same content of hot-melt nylon silk. The trend of the apparent ILSS values of composites with hot-melt nylon silk is similar with the trend of the apparent ILSS values of composites without hot-melt nylon silk at different experimental temperature. When the content of hot-melt nylon silk is 0%, the apparent ILSS values of composites at experimental temperature of 45℃ and 65℃ is lower 6.34% and 14.53% than the apparent ILSS values of composites at experimental temperatures of room temperature, respectively. When the content of hot-melt nylon silk is 2%, the apparent ILSS values of composites at experimental temperature of 45℃ and 65℃ is lower 10.69% and 20.41% than the apparent ILSS values of composites at experimental temperatures of room temperature, respectively. When the content of hot-melt nylon silk is 4%, the apparent ILSS values of composites at experimental temperature of 45℃ and 65℃ is lower 11.76% and 22.89% than the apparent ILSS values of composites at experimental temperatures of room temperature, respectively. When the content of hot-melt nylon silk is 6%, the apparent ILSS values of composites at experimental temperature of 45℃ and 65℃ is lower 16.97% and 29.14% than the apparent ILSS values of composites at experimental temperatures of room temperature, respectively. When the content of hot-melt nylon silk is 8%, the apparent ILSS values of composites at experimental temperature of 45℃ and 65℃ is lower 15.62% and 31.59% than the apparent ILSS values of composites at experimental temperatures of room temperature, respectively. When the content of hot-melt nylon silk is 10%, the apparent ILSS values of composites at experimental temperature of 45℃ and 65℃ is lower 12.56% and 17.58% than the apparent ILSS values of composites at experimental temperatures of room temperature, respectively. In the contrast above, we can see that in the case of containing hot-melt nylon silk, the apparent ILSS values of composites at experimental temperature of 45℃ and 65℃ is lower over 10% than the apparent ILSS values of composites at experimental temperatures of room temperature. It is concluded that the experimental temperatures influences the interlaminar performance of composites. And the higher the experimental temperature is, the bigger the influence at the interlaminar performance of composites is. When the experimental temperature is 45℃ and 65℃, hot-melt nylon silk inside perform is affected by the temperature, which affect the interfacial adhesion between the matrix and the enhanced perform to reduce the interlaminar performance.

Fig.3 shows the microscope photographs of fracture morphology of typical specimens with different content of hot-melt nylon silk after test at different experimental temperatures. From the picture in Fig.3, we can see that failure of specimens usually occurs in the position of pressure head and support and crack grows along the interface between layers. The failure mode is mostly single layer shear mode or multi-layer shear mode. This, to some extent, shows that crack growth along the interface between layers can be affected by the hot-melt nylon silk net between layers.

Temperature (℃)	Content of hot-melt nylon silk (%)					
	0%	2%	4%	6%	8%	10%
Room temperature	48.104	49.002	46.664	45.854	44.894	35.362
45℃	45.055	43.764	41.175	38.073	37.880	30.922
65℃	41.116	39.000	35.982	32.494	30.713	29.147

Table 1: The apparent ILSS values (unit: Mpa).

(1)



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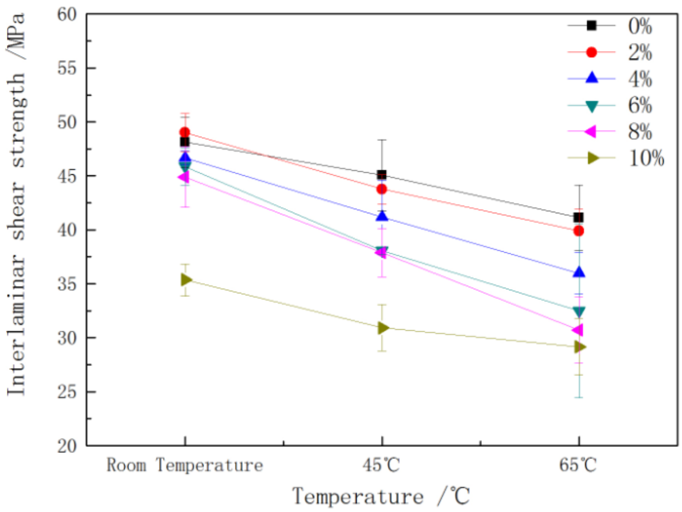
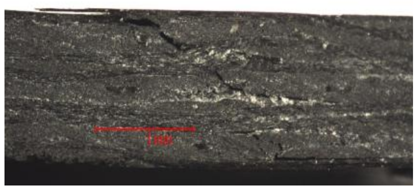


Fig.2: The trend of the apparent ILSS values (1) with different content of hot-melt nylon silk at same experimental temperature (2) with different experimental temperature under same content of hot-melt nylon silk

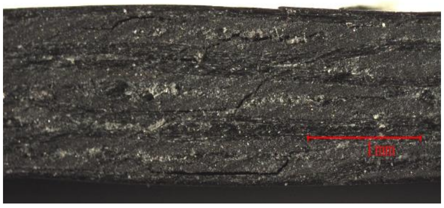
(1)

(a) 0%

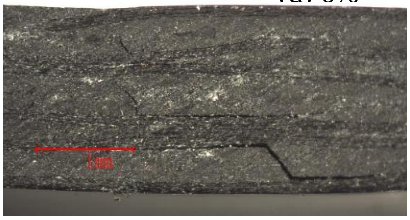
(b) 2%



(c) 4%



(d) 6%



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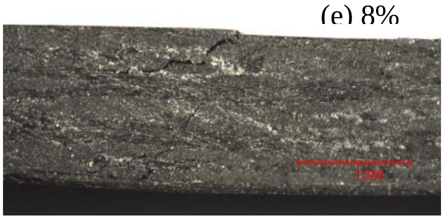
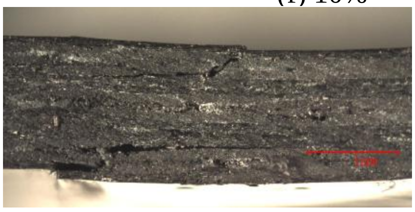
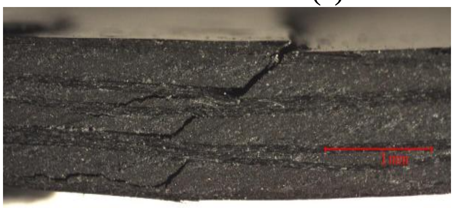


(f) 10%



(2)

(a) 0%



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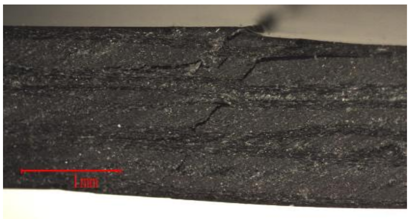

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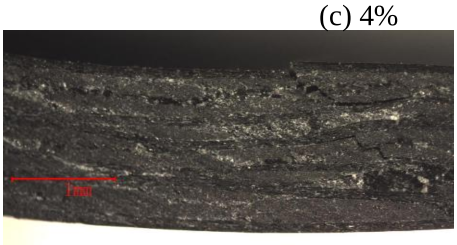

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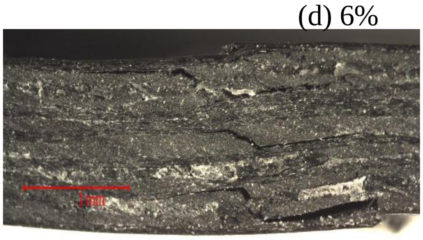

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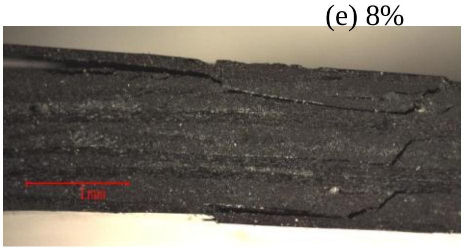

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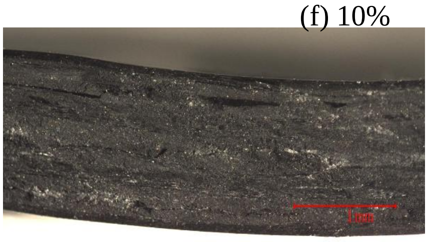
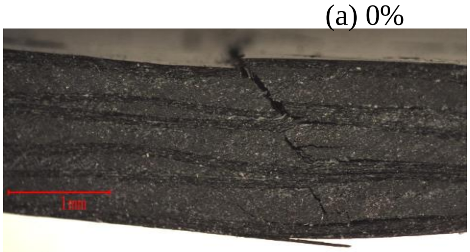


(3)

(a) 0%



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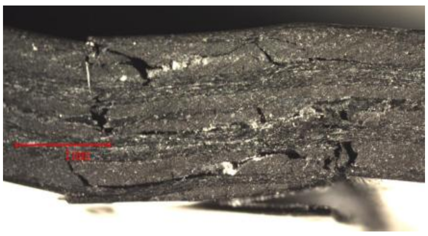
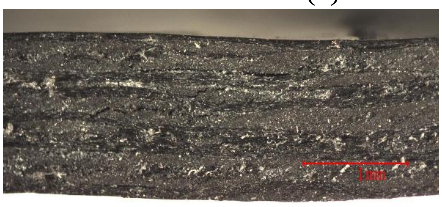


(c) 4%

(d) 6%



(e) 8% (f) 10%

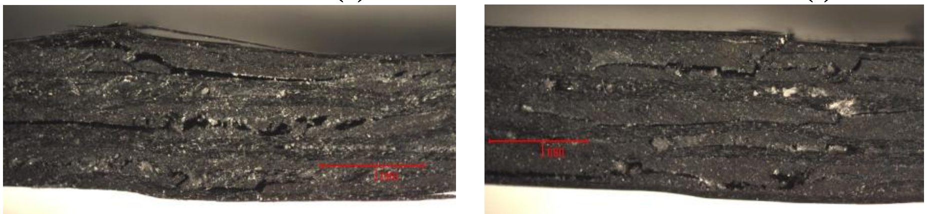


Fig.3: Microscope photographs of fracture morphology of typical specimens with different content of hot-melt nylon silk (1) Room temperature (2) 45℃ (3) 65℃

5 CONCLUSION

The reinforced fabric with self-bonding characteristics can be used for RTM molding composites. Through heated and pressed, the fabric has self-bonding characteristics. The different layers of fabric can be bonded together each other into a final preform. It's convenient to be pushed in the mould and injected. At experimental temperatures of room temperature, the apparent ILSS value of composites with the preform is improved 1.87% when the content of hot-melt nylon silk is 2%. But at other experimental temperatures or under other content of hot-melt nylon silk, the apparent ILSS value of composites is lower than the apparent ILSS value of composites at experimental temperatures of room temperature without hot-melt nylon silk. It is found that the fabric with self-bonding characteristics is an effective reinforced fabric.And we can use the preform with a small amount of hot-melt nylon silk at room temperature.

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