EVALUATION OF RESIN IMPREGNATION PROCESS IN TEXTILE FABRICS

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ABSTRACT: 3-D hollow knitted fabrics consist of two surface knitted fabrics and two knitted fabrics are connected by the pile yarns using warp knitting technology. The 3-D hollow knitted fabrics would be fabricated in the LCM processes such as RTM and the permeability is important parameters used especially in these molding methods. The 3-D hollow knitted fabrics have anisotropy structure in x, y, z directions and these structures can be designed by changing knitting parameters such as fineness of fiber bundle and the density. In consequence, the permeability is changed according to the structure. In this study, the permeability of 3-D hollow glass knitted fabrics with different knitting structure was investigated.

KEYWORDS: *Permeability, Textile composite, Textile structure*

INTRODUCTION

Generally, knitted fabrics are classified into two categories, i.e. weft and warp knitted fabrics. By using warp knitting technology, useful reinforcement configurations are available. One of these examples is multi axial warp knitted fabric known as non-crimp fabric. Another reinforcement configuration is the 3-D hollow knitted fabrics as shown in Fig.1. 3-D hollow knitted fabrics consist of two surface knitted fabrics and two knitted fabrics are connected by the pile yarns to form a 3-D hollow structure in which the surface and rear surface layers are interconnected. After molding, 3-D hollow composite with sandwich structure is obtained as shown in Fig.2.

This 3-D hollow knitted fabric has some advantages. Generally, textile composites such as plain woven fabric composite are stacked as laminates in order to acquire a specific thickness. However, by using the 3-D hollow knitted fabric, the thickness can be controlled by the height of the pile yarns. Moreover the sandwich structure in composites formed from these fabrics would provide excellent bending properties as well as light weight.

Currently, the types of fibers available for a 3-D knitting machine are limited. So far, polyester and nylon fibers are commonly used for commercial productions of 3-D hollow knitted fabrics. In this study 3-D hollow knitted fabric made by glass fiber was newly developed.

It is supposed that the 3-D hollow knitted fabrics would be fabricated in the LCM processes such as RTM. The permeability is important parameters used especially in these molding methods. These fabrics have anisotropy structure in x, y directions and these structures can be designed by changing knitting parameters such as fineness of fiber bundle and the density. In consequence, the permeability is changed according to the structure. In this study, the permeability of 3-D hollow glass knitted fabrics with different knitting structure was investigated.

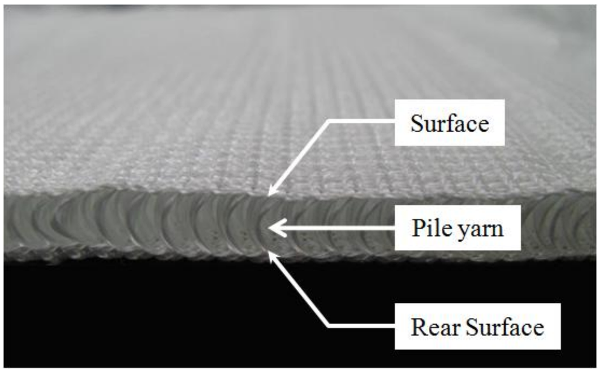

Fig.1 3-D hollow knitted fabric before resin impregnation

Fig.2 3-D hollow knitted fabric after resin impregnation

MATERIALS

Six types of 3-D hollow knitted fabrics were prepared as summarized in Table.1. These fabrics had different warp density and fineness of pile yarns, so that resulted weight per area was different. Here, 1/2 or 1/4 of pile yarn means 2 or 4 fiber bundles with 675 tex were used in one pile yarn. In the case of 1/2 and 1/4, pile yarn has 1350 tex and 2700 tex, respectively. Therefore, under the same warp density, weight per area was bigger in 1/4.

Table 1 Types of 3-D hollow knitted fabric structure.

	Warp density (/inch)	Fineness of pile yarns	Weight (g/m^2)
185E-1/2 (KNE 185E(12-1/2-10-6.5))	6.5	1/2	1850
215E-1/2 (KNE 215E(12-1/2-10-7.2))	7.2	1/2	2150
270E-1/2 (KNE 270E(12-1/2-10-9.0))	9.0	1/2	2700
270E-1/4 (KNE 270E(12-1/4-10-6.5))	6.5	1/4	2700
310E-1/4 (KNE 310E(12-1/4-10-7.2))	7.2	1/4	3100
345E-1/4 (KNE 345E(12-1/4-10-8.3))	8.3	1/4	3450

EXPERIMENTS

A schematic of the experimental setup is shown in Fig.3. The 3-D hollow knitted fabrics were placed on acrylic plate covered by a plastic bag and sealed at the edges with tacky tape. A vacuum pump evacuated the air from the edge and pulled fluid into the center of preform. Unsaturated polyester resin (RIGORAC 150HRBQNTNW;

Showa Highpolymer Co., Ltd., Japan) was used for the experimental fluid. The progressions of the flow front along the top surface of the preform were recorded with a video camera. Hence, at every instant of time, the shape and diameter of the flow in the top plane as well as the amount of fluid in the preform and the elapsed time were obtained.

Constitutive equation for permeation flow is expressed by Darcy's law as shown in equation (1).

$$v_x = -\frac{k_{xx}}{\mu}\frac{\partial p}{\partial x}, v_y = -\frac{k_{yy}}{\mu}\frac{\partial p}{\partial y} \quad (1)$$

where k*xx*, k*yy* were permeability in *x*, *y* direction, ν is infiltration rate[m/s], μ is viscosity[Pa・ s], dp/dx is pressure gradient. Here, fluid velocity follows equation of continuity and the pressure distribution was expressed with equation (2)

$$p = p_0 \frac{\ln(r/r_f)}{\ln(r_i/r_f)} \quad (2)$$

where r_f is the flow-front radius for x direction. r_0 is radius of injection tube which inject fluid into acrylic plate. According to these equations, relationship between the length of flow-front in x direction and times was expressed with equation (3):

$$\frac{r^2}{2}\ln\frac{r_0}{r} + \frac{1}{4}(r^2 - r_0{}^2) = -\frac{k_{xx}}{\mu\phi} p_0 t \quad (3)$$

According to equation (3), the value of k*xx* can be calculated by measuring r at each time. φ means void ratio calculated using V*f*.

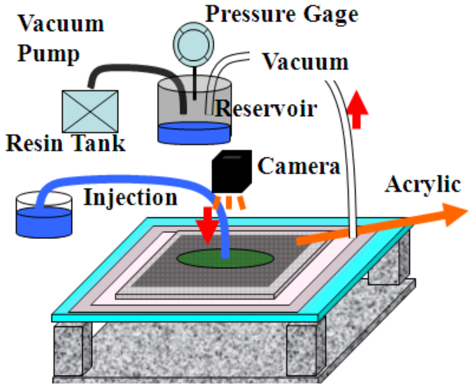

Fig.3 Experimental equipment.

RESULTS

Fig.4 shows the behavior of the resin impregnation during testing. In the surface, the shape of injected resin was an ellipse. The permeability was measured by distance which was length of the major axis of an ellipse for x axis and y axis.

Fig.5 shows relationship between the permeability for x axis and y axis, k*xx*, k*yy* and weight per area. The dotted line expressed k*xx* and straight line express results of k*yy*. The tendency was different according to the density of pile yarn. The coefficient of permeability was decreased with increasing weight per area in the case of 1/2 condition. In the case of 1/4 condition, the coefficient of permeability was constant regardless of the weight per area. Under same weight condition with different fineness of pile yarn, permeability of 270E-1/2 was higher than that of 270E-1/4.Further investigation for relationship between knitting structure and the coefficient of permeability would be needed.

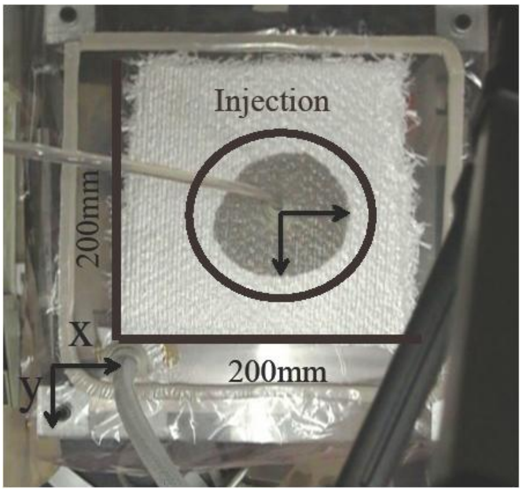

Fig.4 Resin impregnation during testing

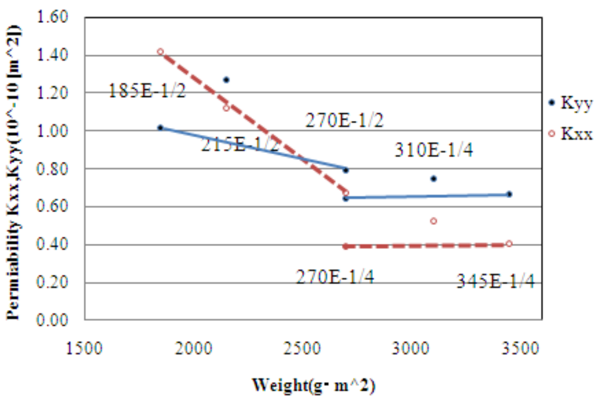

Fig.5 Relationship between permeability and weight.

CONCLUSION

The permeability of six type 3-D hollow knitted fabrics with different weight per area was measured. The coefficient of permeability was decreased with increasing weight per area. However, when the amount of pile yarn was changed, the tendency was changed. The coefficient of permeability was constant regardless of weight per area in case that number of pile yarn was increased.

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