고분자 수지 이송 성형에서 브레이드 프리폼의 두께방향 투과율 계수 측정

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Out-of-Permeability Measurement of the Braided Preform in Resin Transfer Molding

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Abstract

In Resin transfer molding (RTM), composite parts are produced by impregnation of a dry reinforcement with liquid matrix resin. Permeability is a key issue in this process. For thin parts, the resin flow in the thickness direction can be neglected. Therefore thin parts are considered as two-dimensional composites. However the resin flow through the thickness is important to thicker parts and we have to consider out-of-plane permeability. This work discusses a method to measure out-of-plane permeability. The flow rate and pressure drop across the porous media were measured. Also one dimensional form of Darcy's law is applied to calculate the out-of-plane permeability of various preforms. The flow is injected uniformly into layers of the preform. And a circular fiber mat with 6cm diameter was cut and flattened from cylindrical mandrel

Key Words: Out-of-permeability measurement, RTM(Resin Transfer Molding.), Braided Preform

기호설명

K : Permeability tensor of the porous medium
Q : Volume flow rate (m^3/s)
μ : Newtonian viscosity of the fluid
ΔP : the pressure difference between top and bottom position

1. Introduction

Resin transfer molding (RTM) is a very efficient composite manufacturing process and has gained industrial acceptance. In RTM, a fiber preform is placed in a mold cavity. The mold is then closed, and resin is injected into the cavity to impregnate the preform. After the mold is filled with the resin, inlets are closed. Finally, the resin cures to form the final composite part. Therefore the flow behavior is important factor of resin transfer molding and can be very complicated because of different fiber orientations and stacking sequences. For evaluating the flow behavior, Darcy's law is used.

$$\bar{u} = -\frac{K}{\mu}\nabla P \qquad (1)$$

where $\bar{u}$: Darcy's velocity vector
μ : Newtonian viscosity of the fluid
∇P : pressure gradient vector
K : permeability tensor of the porous medium

Recently, the permeability of assemblies of fibers has been a special issue, because the reliable knowledge of the variation in permeability with respect to a fiber preform is essential for the successful application of computer-aided engineering principles.

In this study, we measured permeability in

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the out-of-plane direction and compared the experimental data with simulation results.

2. Theoretical background

To calculate the out-of-plane permeability, one dimensional form of Darcy's law is written by following form.

$$Q = \frac{KA}{\mu} \triangle P \tag{2}$$

where Q : flow rate

$\frac{dP}{dz}$: pressure gradient in the flow direction

A : cross-sectional area

Because the measured permeability is composed of permeability of permeable wall and preform, series model was adopted in this study. The model can be written as

$$\triangle P_t = \triangle P_p + \triangle P_w \tag{3}$$

$$Q_t = Q_p = Q_w \tag{4}$$

where ΔP_t : total pressure difference between the inlet and the outlet position

ΔP_p and ΔP_w : pressure difference across preform or permeable wall

Q_t, Q_p, Q_w : total flow rate, flow through the preform and permeable wall

Then,

$$\frac{Q_t \mu l_t}{K_t A_t} = \frac{Q_p \mu l_p}{K_p A_p} + \frac{Q_w \mu l_w}{K_w A_w} \tag{5}$$

$$\frac{l_t}{K_t} = \frac{a l_p}{K_p} + \frac{l_w}{K_w} \tag{6}$$

where K_t : total permeability

K_p : permeability of the preform

K_w : permeability of the permeable wall

l_t : total length

l_p : length of the preform

l_w : length of the permeable wall

a : area ratio, A_t/A_p

Total permeability and permeability of the permeable wall were measured and permeability of the preform can be obtained by using equation (6).

3. Experiments

3.1 Preparation of braided preform

Multi-axial braided performs were produced by using a 3-D circular braiding machine which consists of 12×48 carriers. In this study, braided preform is made by using 48×7 carriers as shown in Fig.1. The carrier of braiding machine was moved by piston drived compressed air mode. Braided preforms were made of E-glass roving.

3.2 Out-of-Permeability measurement

Permeability measurements in the out-of-plane direction were carried out using a one-dimensional channel flow apparatus under the constant pressure. The transverse-plane permeability measurement setup (Fig. 2) is assembled in forms of a pair of concentric cylinders, of which thickness can be controlled. Pressure was measured at the inlet and the outlet of the mold. A circular fiber mat with 6cm diameter was cut from cylindrical mandrel(80mm diameter). Two parallel permeable walls were placed into the mold and the sandwiched preform layers were placed between permeable walls. In order to accurately determine the out-of-plane permeability, the thickness of the preform layers maintained to be large a bit.

The transverse flow was achieved by injecting the fluid through a central 5mm diameter gate. The fluid flowed through the preform layers uniformly. Silicone oil(DC 200F) was used as injecting fluid and viscosity is $100cs(9.7\times10^{-2}Pa\cdot s)$.

Numerical simulation results were obtained in our previous study and we compared experimental data with simulation results

Fig.1. Braided preform used for experiment

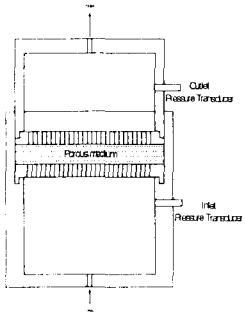

Fig.2. Schematic diagram of the trans-plane permeability measurement device

4. Results

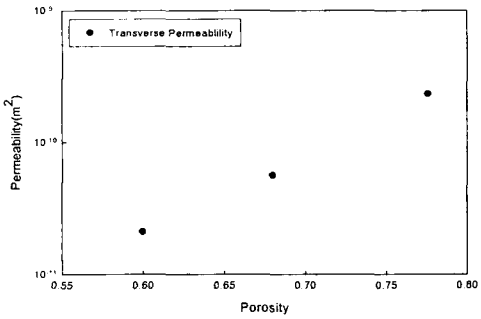

Fig. 3. Out-of-plane permeability of one layer braided preform with respect to the porosity

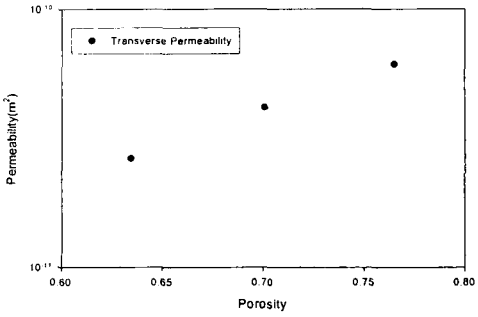

Fig. 4. Out-of-plane permeability of two layers braided preform with respect to the porosity

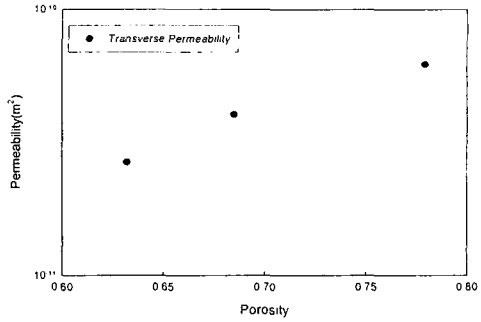

Fig. 5. Out-of-plane permeability of three layers braided preform with respect to the porosity

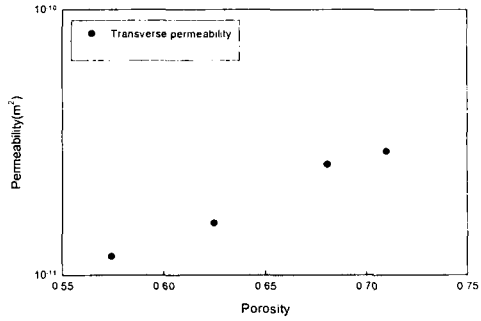

Fig. 6. Out-of-plane permeability of four layers braided preform with respect to the porosity

5. Conclusion

Measurement method for out-of-plane permeability was proposed and permeability was measured for various preforms. From results, it can be stated that out-of-plane permeability is strongly dependent on the variations of the number of preform layers and porosity.

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