COMPARISON OF IN-PLANE PERMEABILITY BETWEEN FLAX AND GLASS STITCHED FABRICS

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ABSTRACT: This study deals with processing plant fiber composites by the way of Resin Transfer Molding. In the present work, measurements of in-plane permeability of flax preforms are obtained and discussed. Two types of flax preforms are prepared with stacks of a stitched unidirectional fabric on one side and a stitched biaxial +45/-45 fabric on the other side. The originality and interest of both fabrics consist in their composition drawn on untwisted flax fibers. Permeability values have been measured under unsaturated and saturated conditions in the two principal directions for the biaxial +45/-45 fabric and in the longitudinal direction for the unidirectional fabric. Results are compared with values on a stitched biaxial +45/-45 glass fabric with the same stitching and same areal weight than the flax biaxial +45/-45 fabric and an industrial unidirectional glass fabric.
Results show that in-plane saturated permeability values for biaxial +45/-45 flax fabric are between five and seven times lower than for biaxial +45/-45 glass fabric at the same volume fraction of fibers. In-plane saturated permeability for unidirectional flax fabric is at least 3.3 times lower than glass one. For both types of fabrics, the higher the volume fraction of fibers is, the lower the difference between glass and flax fabrics is.

KEYWORDS: Plant fiber, In-plane permeability, flax fabrics, stitched fabrics

INTRODUCTION

Nowadays renewable resources offer a solution to replace petroleum products. In this context natural fibers are an interesting reinforcement for thermosetting composite materials. For example glass fibers can be substituted by flax fibers in polyester composites because specific mechanical properties of composites are close especially rigidity [1]. Composite materials made with flax fibers and a thermosetting resin can be processed with Liquid composite Molding (LCM) techniques. For theses process we need to characterize the preform. One of the most important characteristic concerning the preform during LCM process is its permeability. This paper deals with in-plane permeability determined experimentally with a device that gives both unsatured and satured permeability values. With this device we characterize unidirectional and biaxial flax perform as a function of the volume fraction of fibers. Results are compared with similar structures of preforms made with glass fabrics and tested with the same device. This comparison avoids critics on permeability measured with different sets-up and shows new perspectives on the ability of LCM techniques used with plant fibers.

MATERIALS AND METHODS

Materials

A biaxial flax fabric (CRST, France) with an areal weight of 500g/m² is elaborated with two perpendicular layers of flax stitched by a cotton yarn with a 45 degree angle. The stitching density is about 3.1 stitches/cm^2. The fabric is non-woven and is called biaxial +45/-45 fabric in the following (Fig. 1a).
An unidirectional fabric is produced in the same way (CSRT, France) from a single layer of flax stitched by a cotton yarn with a 90 degree angle. Its areal weight is 180g/m² and stitching density is about 2.6 stitches/cm^2 (Fig. 1b).

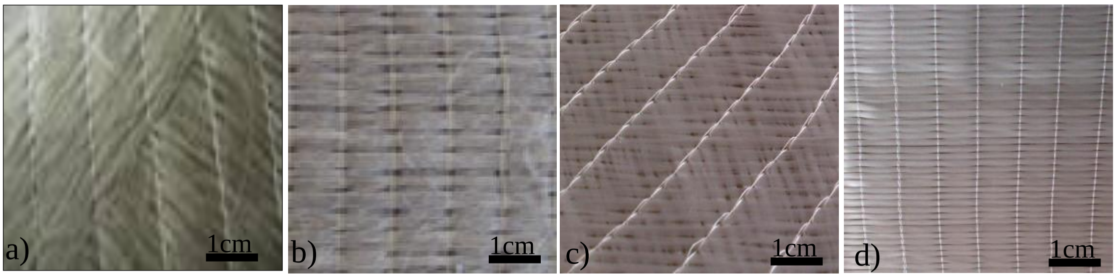

Fig. 1 Biaxial (a) and unidirectionnal (b) flax fabrics; biaxial (c) and unidirectionnal (d) glass fabrics

Both fabrics are constituted of traditional french dew-retted, stripped and combed flax fibers. Interest for these fabrics arises from the fact that flax fibers are as straight as possible inside. Usually flax fibers are spinned in threads inside clothing textiles. Dedicated fabrics for composites also exist: for example tests have been done with fabrics involving low twisted flax yarns [2]. Another interest of this biaxial +45/-45 fabric lies in the fact that a glass biaxial fabric has been elaborated in the same way than the flax one. The glass fabric has an equivalent areal weight of the flax one: 500 g/m^2. As a matter of fact the glass fabric is thinner than the flax one in its relaxed state.
Comparison for unidirectional flax and glass fabrics is established with the help of a previous study on permeability of an unidirectional stitched glass fabrics. Bizet *and al.* [3] give a detailed description of this fabric whose major characteristics are: areal weight of 646 g/m^2; yarns of 2000 aligned fibers; average diameter of fibers of 17.4 µm; stitching density of 4.9 stitches/cm^2.
Permeability experiments are performed with a silicon oil: Rhodorsil 47V100 (from Rhodia). Oil viscosity is equal to 0.1 Pa.s at 25°C. Viscosity value is corrected as a function of the temperature during experiments

Methods

Permeability is determined from Darcy's law. For unsaturated permeability determination, Darcy's law is integrated according to the method used by Luthy and Ermanni [4]:

$$x_f{}^2(t) = \frac{2K_{unsat}}{\phi\mu}\Delta P.t \quad (1)$$

where ΔP is the difference of pressure between the input and the output of the set-up (a fixed value of 1.0 bar is chosen in all our experiments), x_f, the liquid front position as a function of the delay t, Φ, the porosity accessed from the weight of the preform and μ, the dynamic viscosity.

During the second step of the experiment, saturated permeability is obtained by measurement of velocity flow Q for various differences of pressure ΔP (between 0.6 and 2.4 bars in our experiments):

$$K_{sat} = \frac{Q.L.\mu}{\Delta P.A} \quad (2)$$

Device

Permeability is characterized with a planar rectangular rigid mould where injection takes place from one side to the other. Dimensions of all preforms used are the following: length between 30.0 cm and 50.0 cm; width 10.0 cm; thickness between 1.5 mm and 3.85 mm as a function of the desired volume fraction of fibers. Different volume fractions of fibers are accessed in the device by varying the number of plies in the preform (between 2 and 8) or by varying the thickness of the mould.

Unsatured permeability is determined by using a camera to follow the propagation of the fluid in the preform thanks to the glass on the top of the mould. The front position x_f is extracted by image analysis with Aphelion software (ADCIS). Satured permeability is obtained by weighing the output fluid.

Biaxial preforms are always oriented with half of the fibers along the direction of the flow. Unidirectional preforms are oriented with fibers along the direction of the flow.

RESULTS

Fig. 2 gives the permeability values obtained for the four different preforms in unsaturated and saturated conditions. Three values are recorded for each preform and these values are fitted by a power law. For all preforms unsaturated and saturated permeabilities decrease when the volume fraction of fibers increase. For the same volume fraction of fibers, both unsaturated and saturated permeabilities are classified from the higher to the lower: glass UD; glass biaxial; flax UD; flax biaxial.

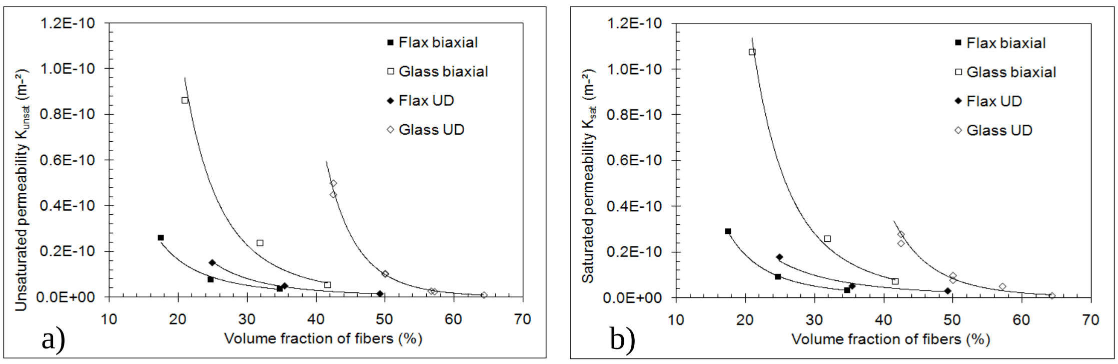

Fig. 2 Permeability results: unsatured (a) and satured (b) values

DISCUSSION

As showed in Fig. 3, permeability of the biaxial glass fabrics is between 3.7 and 7.2 times higher than the biaxial flax fabrics in unsaturated and saturated conditions. This ratio decreases with the volume fraction of fibers in the range of our observations. The unidirectional glass fabrics give saturated permeability values at least 3.3 times higher than UD flax one. The ratio also decreases with the volume fraction of fibers. Compared to glass fabrics, injections like RTM with flax preforms become easier at high volume fractions of fibers although permeabilities remain lower than glass ones.

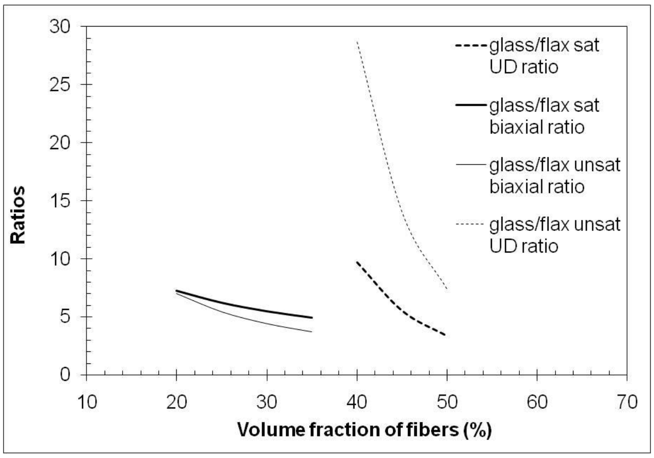

Fig. 3 Ratios of unsaturated and saturated permeabilities between glass and flax

As biaxial +45/-45 fabric is made of two perpendicular layers of unidirectional fabric, saturated permeability of biaxial fabric $K_{biaxial}$ should be interpreted with a classical mixing law of the saturated UD permeabilities along the fibers, $K_{//}$, and perpendicular to the fibers, $K_{\perp}$:

$$K_{biaxial} = 0.5K_{//} + 0.5K_{\perp} \tag{3}$$

Permeability $K_{\perp}$ has then been measured at three volume fraction of fibers and fitted by a power law (Fig. 4) as it has been done on Fig. 2a ("Flax UD") for $K_{//}$.

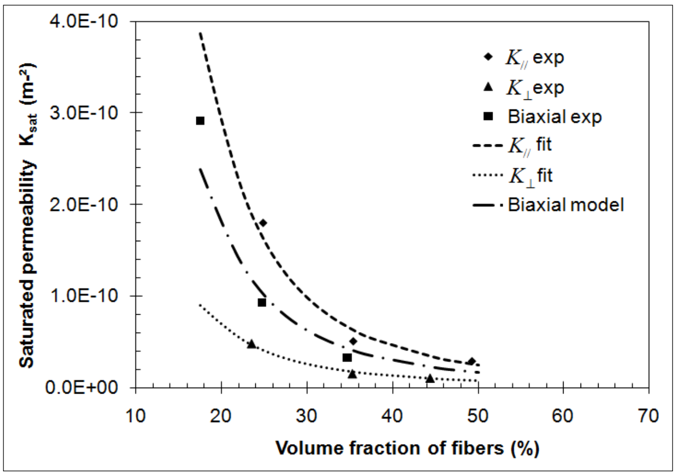

Fig. 4 Saturated biaxial permeability: comparison between model and measurements

Fig. 4 finally shows comparison of saturated biaxial permeability between the measurements and the model based on UD permeability values. $K_{biaxial}$ is obtained from $K_{\perp}$ and $K_{//}$ fits by power's laws and use of Eqn. 3. Our experimental results are in good agreement with this model considering that flax UD fabric differs from the biaxial one at different points of view: areal weight, stitching, etc.

CONCLUSIONS

In-plane permeability is always better for a glass preform compared to the flax preform of the same type. This result is available for the two types of preforms studied in this work: unidirectional and biaxial. The best glass-to-flax ratio is observed for unidirectional preforms with saturated permeability at a high volume fraction of fibers: it gives 3.3. At lower volume fraction of fibers, this ratio increases. The same result is observed for the biaxial preforms, starting from a ratio of 3.7 at the highest volume fraction of fibers. A simple mixing law with permeability values of the unidirectional fabrics has been applied to interpret saturated permeability values of the biaxial fabrics. This model works well and could be used further for prediction.
This work will be extended by interpretation of the difference between glass and flax performs permeabilities. The two major hypotheses concern the flow inside the preforms and the microstructure of the preforms. The characteristics of flow will be studied using capillary measurements (e.g. surface tension) and the microstructure will be examined in terms of heterogeneity of pores inside the plies and between plies. Results of these both studies may lead to modify flax preforms in a way that their in-plane permeability can be competitive with glass preforms of the same type.

REFERENCES

1. E. Bodros, I. Pillin, N. Montrelay and C. Baley, "Could biopolymers reinforced by randomly scattered flax fibre be used in structural applications?", *Composites Science and Technology,* Vol. 67, Issues 3-4, pp. 462-470 (2007).

2. S. Goutianos, T. Peijs, B. Nystrom and M. Skrifvars, "Development of Flax Fibre based Textile Reinforcements for Composite Applications", Applied Composite Materials, Vol. 13, no. 4, pp. 199-215 (2006).

3. L. Bizet, J. Bréard, G. Bouquet, J.-P. Jernot, M. Gomina, "Interpretation of permeability in a unidirectional non-crimp stitched preform by geometrical description of the porosity", Proc. of the 7th International Conference on Flow Processes Composite Molding FPCM7, Newark (Delaware), pp. 379-384, July 7-9 (2004).

4. T. Luthy, P. Ermanni, "Linear direct current sensing system for flow monitoring in Liquid Composite Moulding", Composites Part A : applied science and manufacturing, Vol.33, Issue 3, pp. 385-397 (2002).