Calculation of permeability of preforms with channels

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The paper proposes a simple analytical model for calculation of permeability of preforms, consisting of fibrous layers with "channels" or "gaps" in them. This geometry is characteristic for non-crimp fabrics (NCF), where the channels are created by fibres distortions, caused by the stitching, and for dry tape laying (DTL) preforms, where the gaps can be caused by not-that-precise tape placement or created artificially to enhance the preform permeability. The model is applied to these two types of preforms and is validated against experimental data.

1 Introduction

The idea of representation of the pores in textile laminates as a system of straight channels, which allows easy calculation of its permeability has been exploited for a decade now [1-4]. In a recent paper [5] the formulae for channel permeability are revisited and consistent formulae for intra- and inter-bundle permeability are derived. These formulae are summarised in Table 1. The present paper investigates the application of these formulae to non-crimp fabrics (NCF) and dry tape laying (DTL) preforms.

Table 1 Intra- and inter-bundle permeability [5]

Permeability of a bundle	*Permeability of a channel*
$K_{t1} = \frac{R_f^2}{4c_1}\frac{(1-Vf)^3}{Vf^2}$; $K_{t2} = R_f^2 c_2\left[\left(\frac{Vf_{max}}{Vf}\right)^{1/2} - 1\right]^{5/2}$	$K_g = \frac{2D_h^2}{c}$; $D_h = \frac{2wh}{w+h}$; $c = 56 \cdot R^{0.17}$; $R = \begin{cases} \frac{h}{2w}, 2w < h \\ \frac{2w}{h}, h < 2w \end{cases}$
$R_f^2/4c_1=5.69\cdot10^{-12} m^2$; $c_2R_f^2=27.49\cdot10^{-14} m^2$; $V_{fmax}=0.91$	w, h – channel width and height

The permeability of a ply in the fibre direction is calculated as a weighted (by the bundle and gap wodth) sum of the bundle and channels (gaps) permeability, and the permeability of a laminate – a weighted (by the ply thickness) sum of plies permeability, with the tensors rotated to the global coordinate system.

2 NCF

NCF is a laminate of fibrous plies, with unidirectional arrangement of the fibres distorted by the stitching yarn. The parameters of the modelled fabric, as modelled by *WiseTex* [6, 7] are shown in Figure 1a. The results of the modelling of permeability in comparison with the permeability data for different NCFs, collected in [3] are shown in Figure 1b.

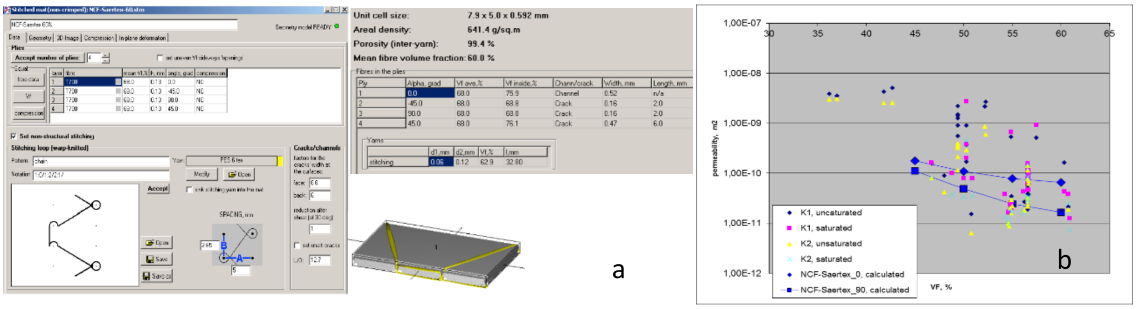


Figure 1 Parameters of the modelled NCF (WiseTex model, a) and results of the permeability calculation (b)

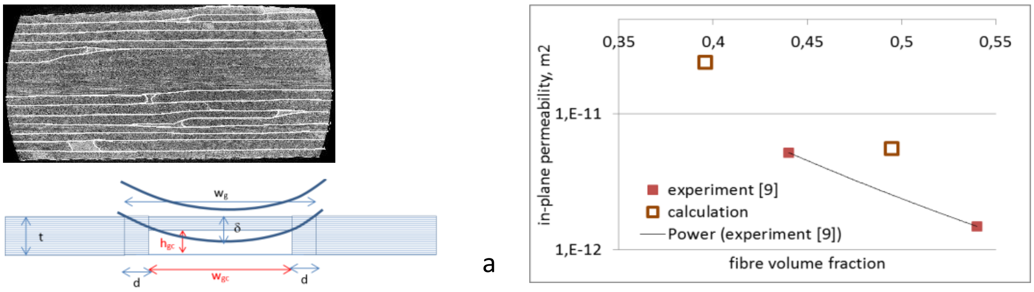
The channel model well represents the trend of the permeability for the bulk of the data. In analysing the results in Figure 2b one has to take into account that the experiments shown were not done in accordance with the results of the benchmark exercise and hence the outliers should be most probably discarded.

3 DTL

For DTL laminates the gaps in the layers can be partially closed by bending of the overlying layers [8]. Figure 2a shows the scheme for the gap closing. To calculate bending δ a simple model of bending of the upper layer of the width *w* over a gap with the width w_g at the applied pressure *p* is used (see notations in Figure 2a):

$$\delta = \min(\frac{5pww_g^4}{384B}, t); B = N_f E_f \frac{\pi d_f^4}{64}; h_{gc} = t - \delta + \delta \frac{w_{gc}}{3w_g}$$

where *B* is the bending stiffness of a bundle of N_f fibres with diameter d_f and Young modulus E_f. Calculations with formulae of Table 1 for experimental data in [9] for permeability of DTL preforms are shown in Figure 2b. The prediction error lies within two times overestimation of the permeability



b

Figure 2 A scheme for calculation of the gap closing (a) and the calculation results (b)

4 Conclusion

The channel permeability model for NCF and DTL preforms gives rough estimation of permeability which can be used for preliminary parametric studies.

5 Acknowledgement

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