



PREDICTION OF AIR PERMEABILITY USING A FINITE ELEMENT METHOD



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Introduction

Air permeability is one of the most important parameters in the study of thermo-physiological comfort of fabrics; it plays an important role for their thermal insulation and it is mainly influenced by the fabric structure and by fibres properties.

Air permeability measures how easily a fabric allows the air passage through it; it can be evaluated using an Air Permeability Tester according to the UNI EN ISO 9237 test standard.

In the last years some computational methods were proposed in order to predict the air permeability properties of textile fabrics. [1]

This work was aimed at estimating air permeability of different plain weave fabrics using COMSOL Multiphysics®; the main goal is to develop a virtual process that allows the prediction of air permeability of any fabric without realizing a sample.

Computational methods

For this work, nine different fabric structures were analyzed, whose air permeability has been measured in the literature [2].

All fabrics were made of cotton and both warp and weft yarns had the same linear density (17x2 tex); one single yarn density, namely 22 ends/cm for warp and 15 picks/cm for weft yarns, was analyzed, except for the plain weave, for which also 22/20 density was simulated. The fabrics characteristics are reported in Table 1.

N°	Weave type	Set density warp/weft	Measured warp density	Measured weft density	Measured permeability [mm/s]
1	Plain weave (PL)	22/15	21	15	2391.67
2	Plain weave (PL)	22/20	21	20	1571.67
3	Basket weave (BW)	22/15	21	15	3065
4	Filling rib 4/2 (R4/2)	22/15	20	15	3491.67
5	Warp rib 2/4 (R2/4)	22/15	22	14	3288.33
6	Twill 1/3 (T1/3)	22/15	22	15	3505.83
7	Broken twill 1/3 (BT1/3)	22/15	21.5	15	3501.67
8	Twill 2/2 (T2/2)	22/15	21	15	3016.25
9	Broken twill 2/2 (BT2/2)	22/15	21	15	3169.17
10	Crossed twill (CT)	22/15	21	15	3465.83

Table 1 – Fabrics characteristics

The fabric geometry was created in TexGen, an open-source software developed by the University of Nottingham for modelling plain and knitted structures of textile fabrics. The structures were then exported in a step file format and subsequently imported into COMSOL Multiphysics®.

An area including four interstices between yarns was simulated (Figure 1 shows one of the structures with its mesh). Geometric parameters were calculated using the lenticular model developed by Hearle [3].

This model allows to describe the deformed geometry of yarns and fabrics using the basic construction parameters, namely warp and weft density, yarn linear density and fibres material.

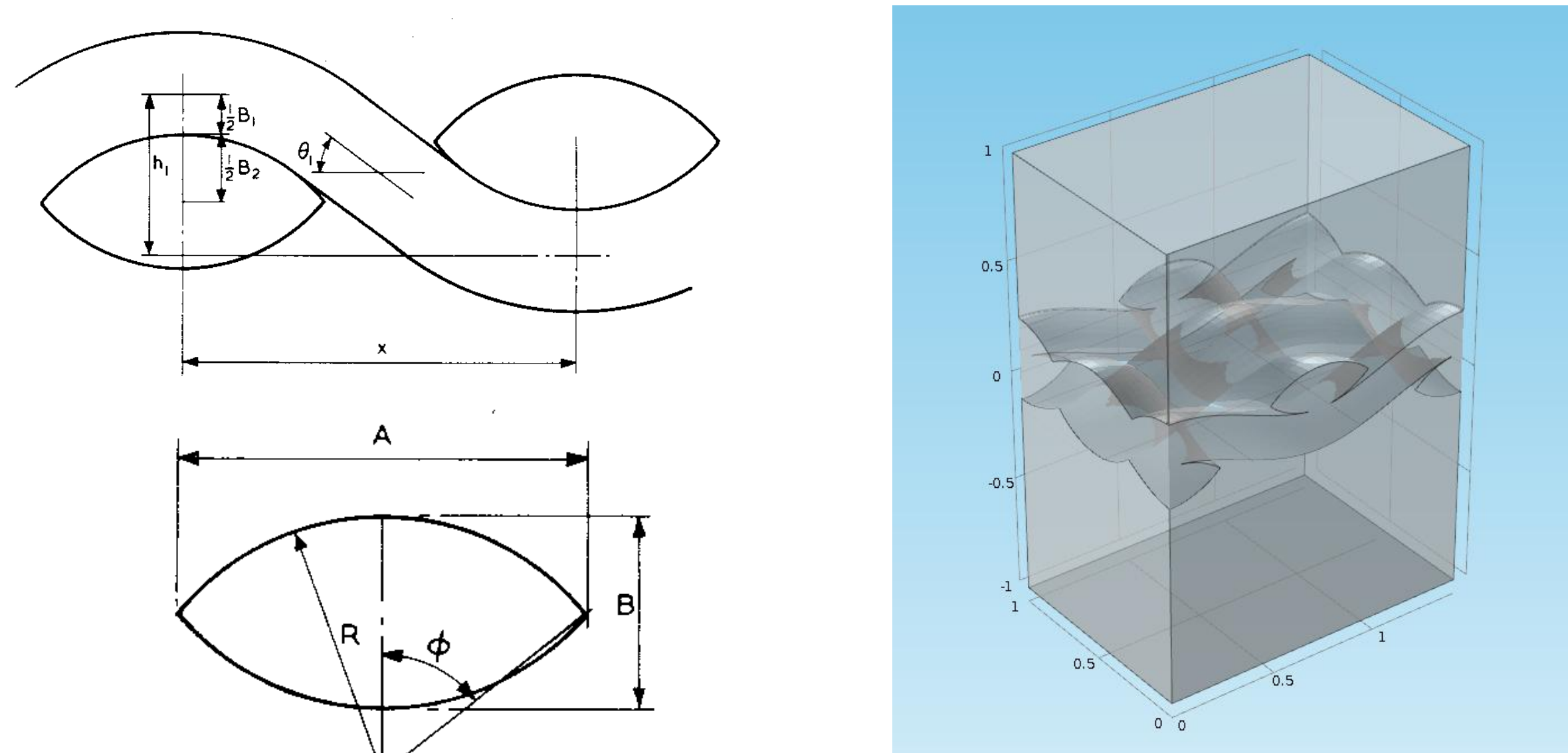


Figure 1 – Fabrics modeling

Computational methods

The Free and Porous Media Flow interface was set in COMSOL Multiphysics®; this allows to use Navier-Stokes equation for simulating the air free volume through yarns and the Brinkman equation for simulating the air flow inside yarns between the fibres (yarns were considered as a porous medium).

The set of equations that has been used is [5] [6]:

$$\rho(u \cdot \nabla) = \nabla \cdot \left[-pI + \mu(\nabla u + (\nabla u)^T) - \frac{2}{3}\mu(\nabla \cdot u)I \right] + F$$

$$\nabla \cdot (\rho u) = 0$$

$$\frac{\rho}{\varepsilon_p} \left((u \cdot \nabla) \frac{u}{\varepsilon_p} \right) = \nabla \cdot \left[-pI + \frac{\mu}{\varepsilon_p} (\nabla u + (\nabla u)^T) - \frac{2\mu}{3\varepsilon_p} (\nabla \cdot u)I \right] - \left(\mu k^{-1} + \beta_F |u| + \frac{Q_{br}}{\varepsilon_p^2} \right) u + F$$

$$\nabla \cdot (\rho u) = Q_{br}$$

As boundary conditions, the inlet pressure was set to 200 Pa and the outlet pressure to atmospheric pressure.

Results

The agreement between the literature data and the simulations results were good, with a maximum error of about 3%.

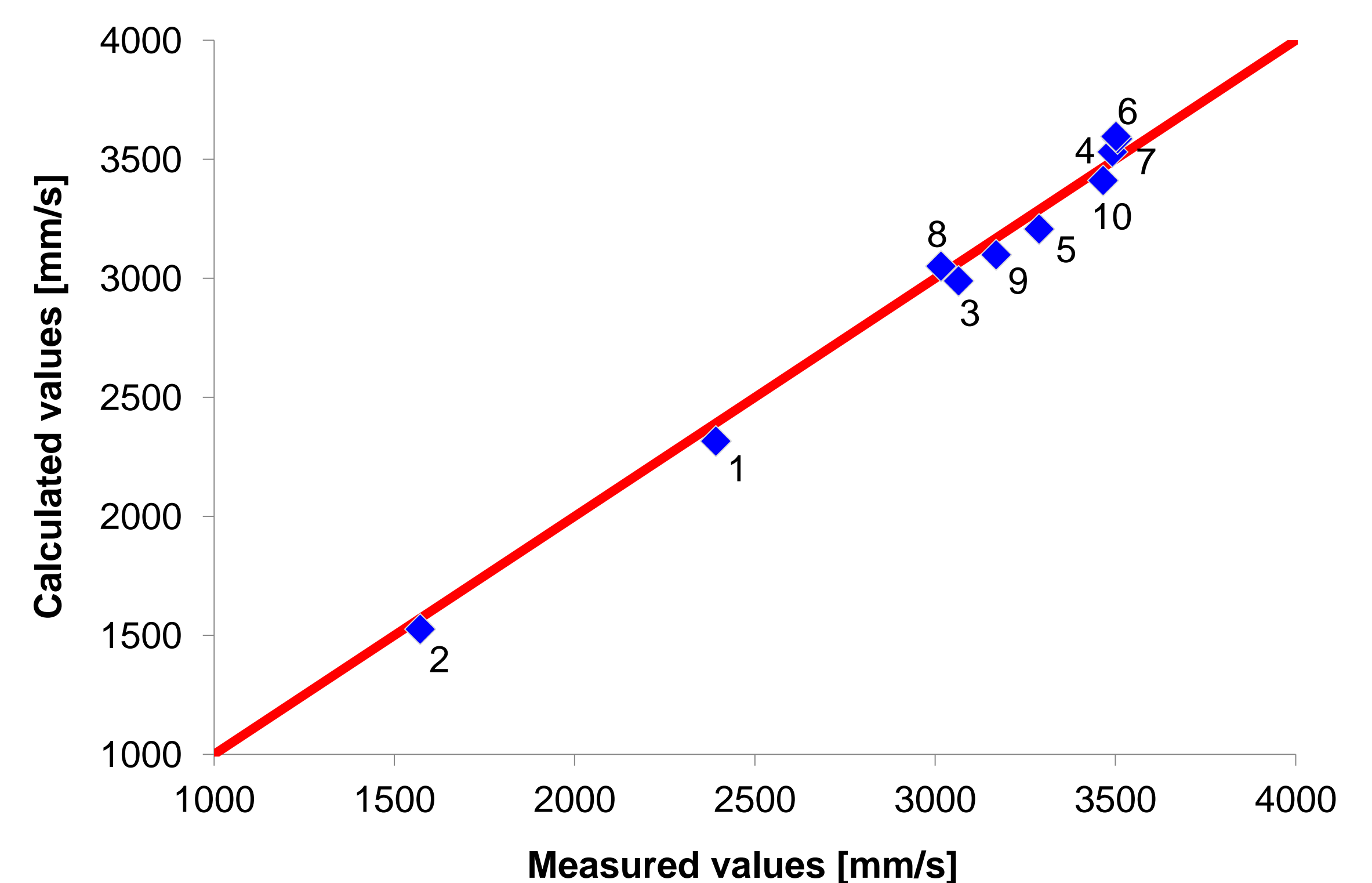


Figure 2 – Parity plot

Conclusion

This work confirms that air permeability of different woven fabrics can be predicted with good accuracy, from the basic design parameters of any fabric.

This approach can lead to a cost reduction as far as sample development is concerned as simulation can be used as a screening tool for fabric selection.

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References

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