QUANTITATIVE TRANSVERSAL PERMEABILITY TESTING - CHALLENGES AND ENHANCEMENTS

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Introduction

For the production of large CFRP parts, the usage of infusion or injection methods is becoming more and more popular. Aiming for a high efficient process it is common to reduce the flow length. In these cases, the matrix is distributed as fast as possible above or below the stack of fabrics. The infusion of the textiles is done in the shortest possible length – through thickness impregnation. The relevant parameter to characterise the flow process is the transversal permeability. This value is essential for both, simulation as well as optimisation of the impregnation process. Although numerous methods for transversal (through-thickness) permeability testing have been developed and used [1-3], none has been adopted as industry standard so far.

The published work is showing the challenges that have been identified as well as different contributions to enhance the existing methods towards more reliable experimental results.

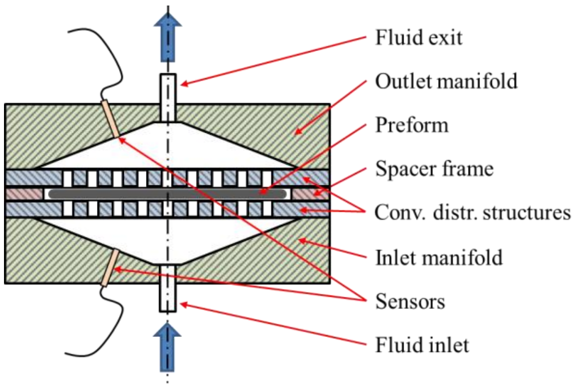

Figure 1: *Conventional transversal permeability equipment*

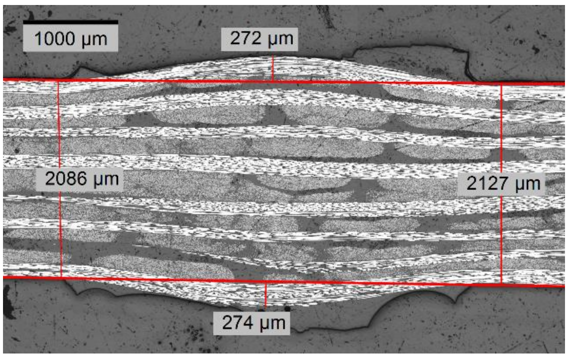

Figure 2: *Undulation at holes*

State of the art

A well-known and widespread way for transversal permeability testing is the saturated method with constant cavity height. The test specimen (preform) is loaded to the predefined fibre volume fraction V_f. A test fluid is injected using a constant fluid pressure until the test specimen is fully saturated. By detecting the flow rate $\dot{Q}$ and the driving pressure difference $\Delta\bar{p}$ the transversal permeability K_{33} can be calculated according to $K_{33} = \dot{Q}\,\mu\, l / A\,\Delta\bar{p}$. The cavity bounds usually consist of a spacer frame providing the height l and the upper and lower distribution structures made from metal plates with a pattern of equidistant holes (conventional distribution structures). These structures are thought to distribute the fluid flow the way that a homogeneous flow profile establishes within the preform while the necessary compression force provides the desired V_f throughout the preform. A schematic sketch of this conventional saturated method for transversal permeability testing is shown in Figure 1.

Challenge of quantitative transversal permeability testing

One of the dominating parameters for permeability testing is the precise knowledge about the cavity height. For typical Non Crimp Fabrics (NCF) a 5% offset of the cavity height is resulting in a permeability variation of up to 60%. It therefore is essential to detect the cavity height throughout the whole experimental work.

Especially when testing low permeability specimens race tracking at the edges can affect the results.

Another challenge is related to the use of metal plates with a pattern of equidistant holes as distribution structures. Previous studies have shown that these conventional distribution structures cannot provide a homogenous flow profile and V_f [4]. When compression force is applied on the textile, the outermost layers undulate into the holes changing the flow resistance locally. In Figure 2 a cured sample is presented showing the intended thickness of ~2,1mm in the flange area and an increased thickness (+26%) at the area of the hole. Therefore, the permeability results depend on the design of the used distribution structures.

Enhancements for quantitative transversal permeability testing

By using a conventional testing machine, an infinitely variable cavity height is achieved. The stiffness correction is integrated in the closed loop control of the testing machine and a video extensometer is used to guarantee the constant cavity height during the test.

To ensure a homogenous V_f and therefore a uniform flow profile, a sintered metal distribution structure is used on both sides of the preform. The high permeable sinter structure is able to distribute the fluid at the whole area of the test specimen without allowing the fibre textile to undulate.

Race tracking is avoided by separating the affected fluid flow at the edges from the unaffected fluid flow at the centre of the tested specimen. Schematic sketches are presented in Figure 3 and Figure 4.

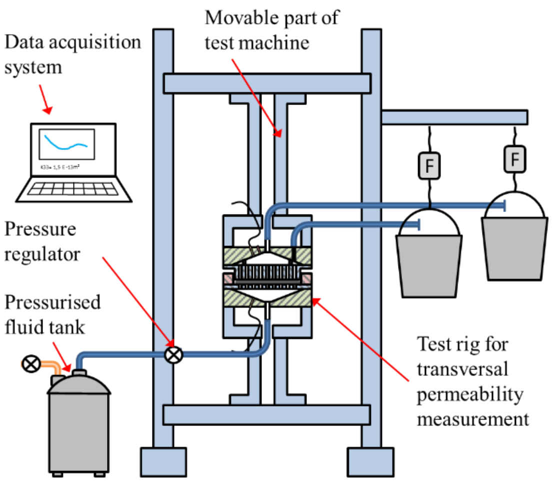

Figure 3: *Schematic of the machine setup*

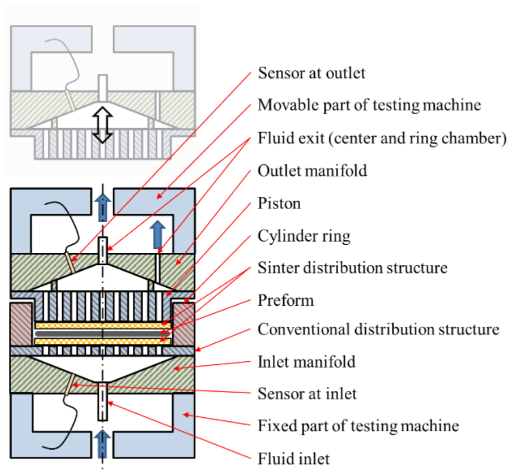

Figure 4: *Enhanced transversal permeability test rig*

Tests and validation

Several tests have been done to validate the enhancements on the method and equipment including tests with and without the sinter metal distribution structure as well as tests with intentionally placed gaps at the edges of the samples to exaggerate race tracking effects.

Results

Results of the tests with gaps at the edges of the samples show a significantly higher volume flow around the edges but no increasing value at the centre region of the sample. The concept of separating the affected and the unaffected area was therefore proven successfully.

For the tests with and without the sintered metal distribution structures it was found that a difference occurs but the effect is smaller than expected. At the areas of the holes a locally lower V_f and consequently a higher permeability occurs resulting in a locally lower flow resistance. The overall volume flow is therefore expected to increase. This effect is limited to a fraction of the preform area (cumulated area of the holes). At the area in between, test fluid is not able to intrude the preform and consequently not the whole preform area is equally exchanging fluid transversally, resulting in a reduced overall volume flow. Both effects depend on the used textiles and on the design of the conventional distribution structures influencing the final permeability value in opposite directions and since might almost cancel out.

Acknowledgements

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