PHYSICAL ATTRIBUTES AND PROCESSABILITY OF MULTIAXIAL AND WOVEN REINFORCEMENT FABRICS IN CASE OF VACUUM INFUSION

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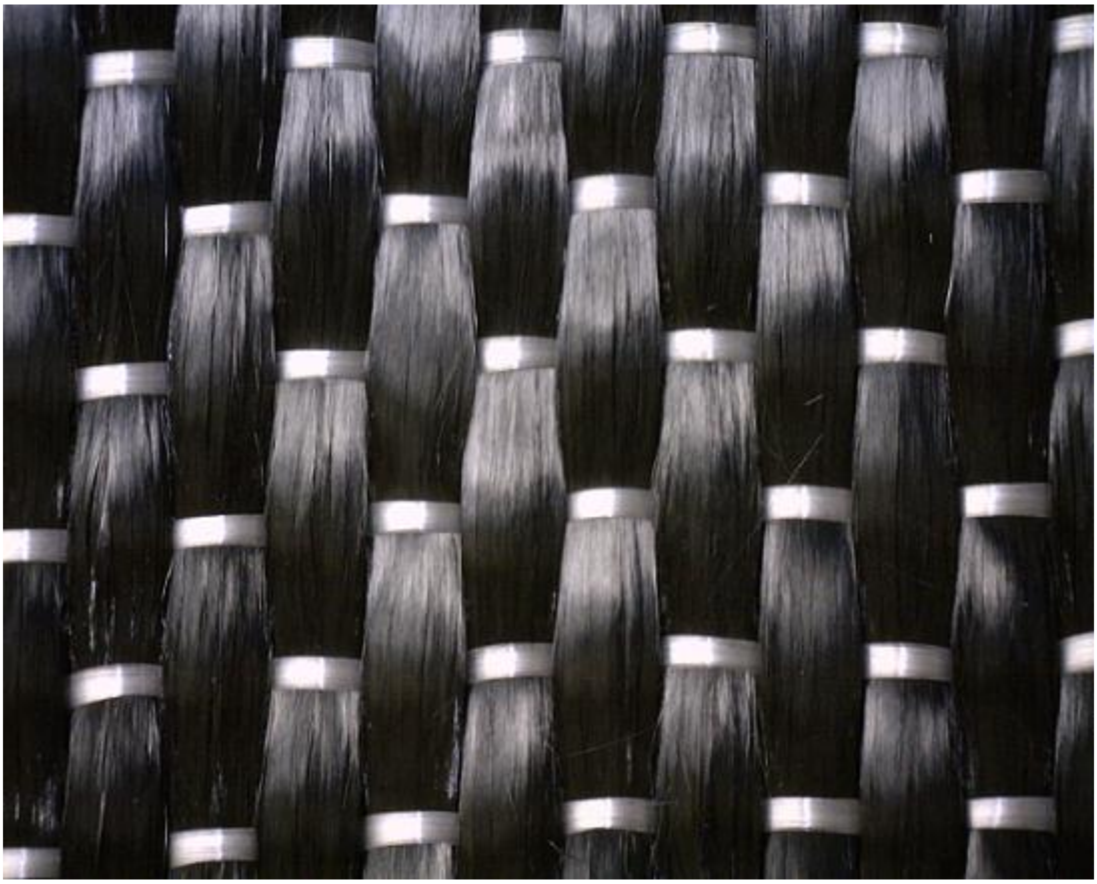


Physical attributes and processability of multiaxial and woven Reinforcement fabrics In case of Vacuum infusion

Abstract:

The study presents experiments made in the laboratory of Formax UK Ltd. via ERASMUS internship.

Multiaxial and woven reinforcement textiles were inspected in the matter of physical performance, permeability and drape. The study gives answer to the customer requests, in order to engineer the desired fabric.

Basic points of the study:

- *Description of the making of composite panels/components*
- *Set-up of multiaxial reinforcement fabrics*
- *Set-up of multiaxial woven fabrics*
- *Description of Vacuum Infusion*
- *Fabric behavior under Vacuum Infusion in respect to the pressure drop and permeability*
- *Mechanical properties of various textiles*
- *Drape/Conformability of the fabrics*
- *Geometrical attributes of the cured panels*
- *Optimized attributes of the cured particles by engineering of the fabric*
- *Other methods to develop easier handling or special requests by customer*

Keywords:

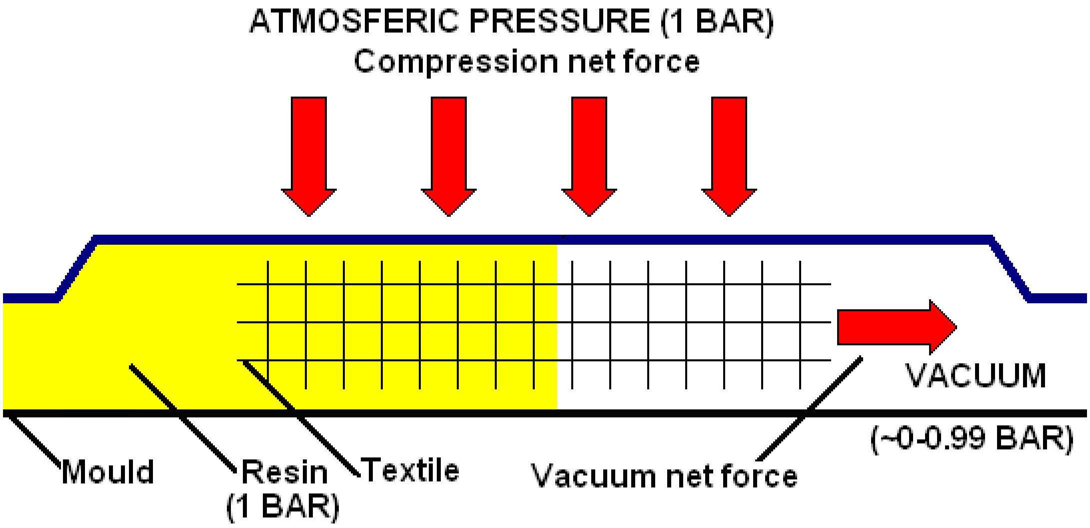
Reinforcement textiles, conformability, processability, mechanical properties

INTRODUCTION

The experiments were held at Formax UK Ltd., which is a reinforced textile manufacturing company. It purchases mainly three reinforcement fibre types: Carbon, glass (mostly E-glass) and aramid (also known as Kevlar). The company takes the fibers and makes woven or multiaxial textiles in many different form and for different applications due to the customer request.. The customers then make frequent feedbacks to the company, so Formax can optimize the textiles to improve the manufacturing performance.

Three important applications are the most important regarding reinforcement textiles: mechanical properties, processability and conformability. The crucial point is knowing the tradeoffs of the fabrics, optimizing them for the proper usage.

Making of composites by Vacuum Infusion (VI)



During the Vacuum Infusion (VI) the fabric is set in a closed system, where resin is pulled through the fabric using the net force of pressure difference – created by a vacuum pump. The resin flows through the pores, connects the fibers, so after the curing, the end product will be strong, but light in weight. The component is then used in car production, marine applications, aerospace structures or in the making of wind turbine blades.
The main question however is how quick the procedure last, and how much excess resin can be allowed in the final product.

The graph shows that by increasing the pressure difference between the vacuum side and the resin (atmospheric) side not just creates greater resin suction, but it does increase the compression to the fibers. It means that the pores become more tight, packed, but the pores become smaller as well. A perfect, 1 bar pressure difference means 10 ton mass per square meter. However, pressure increase still fastens the permeability to a greater extent.

Used textiles

The textiles used in this experiment are all made of 12k carbon rowings, which equals to 300g areal weight per square meters. The textiles are also unidirectional (UD), which means the fibers are oriented in one direction.

— <u>Woven fabrics:</u>

The woven textiles include the combination of the carbon warp and a type of weft. The most common types are heat-set and glass wovens.

The heat-set warps are thermoplastic stitches which can melt in higher temperature. The heat-set woven fabrics are treated in a laminator in order to melt the stitches, which bounds the fibers together.

Glass woven fabrics use a thicker (i.e. 68 tex) warp. Thermoplastic stitches are also used, but only side warps – this prevents the fabric from falling apart after the manufacture. Since there are actually no friction between the fibers – except on the sides – the fabric has high conformability, but inconsistent mechanical properties.

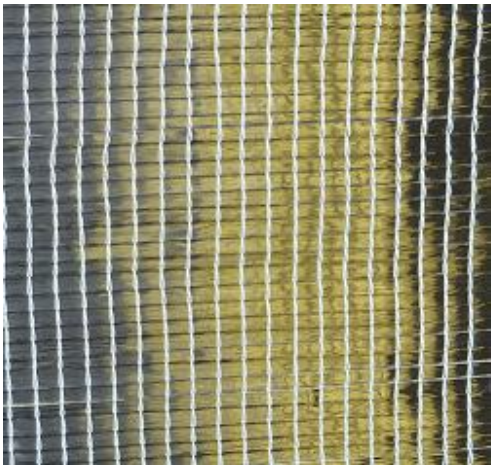
24tex linear density weft heat-set woven 68tex linear density weft glass woven

— **Stitched (multiaxial) fabrics**

Multiaxial fabrics include one or more layers of fibers oriented at specific directions, and are stitched together using various methods.

“0” textiles are oriented at the production’s direction, the same direction of the stitches. Therefore, more layers, usually +45/-45 are used, but with low density. Unidirectional fibers have usually 90-95% one axial fibers.

“90” textiles are oriented perpendicular to the direction of production. Therefore, they do not need additional fibers other than the stitches to secure them. However, the size of the rowings in the fabric are very inconsistent.



Stitched unidirectional fabric, 0 direction Stitched unidirectional fabric, 90 direction

Permeability

Permeability depends on the pore system of a fabric. The more pores exist, the faster the fill time will be. However, having pores decreases the Fiber Volume Fraction. The component must likely be heavier and thicker, because of the excess resin in it.

By the type of the manufacturing, the pore system can be engineered. The study categorizes the permeability types by type. Starting with the tight packed, woven structure, high fiber content can be archived, if the weft is a lighter fiber (i.e. 24 tex polyester stitch). As the weft gets thicker, more pores are created – but the dimensions grow as well. Multiaxial fibers have even quicker fill time, because their pore system is connected.

The key is to find an optional permeability to an optional FVF.

Conformability

Mostly known as drape or drape-ability. The textiles as two dimensional fabrics are often processed in moulds that have complex shapes. In that case, the fabric cannot follow the lines of the mould, leaving unreinforced parts, which are more likely to be rigid and exposed to damage.

The conformability of a textile on one side depends greatly on the areal mass of the fabric. The thicker the layer the harder to form. Also, the construction of the fabric is crucial. For example, a fabric, that has two layers each +45 and -45 degree to the stitching (direction of procession) is more likely to drape than a 0/90 fabric. The first has no fiber at the stitches' direction, while the latter cannot stretch enough.

Mechanical properties

The mechanical properties are most commonly regarded as the Fiber Volume Fraction (FVF) content of the finished, cured composite.

Fiber Volume Fraction in textile production means the density of fibers packed next to each other. If the fibers are separated, then gaps are created, which are known as pores. Therefore the end product will be thicker and heavier thanks to the resin filling up the space.

However, if a customer switches to a high FVF product, the thickness of the cured composite can be highly reduced. This can be bad news for the bending strength, because it depends on the thickness factor. Thickness factor means that the bending strength is exponential to the thickness: The thicker the component, the harder to bend. This is why it is hazardous for technologies which does not use thickness-enhancing parts (i.e. sandwich- structures).

Also, the denser fabrics are less likely to be processed easy

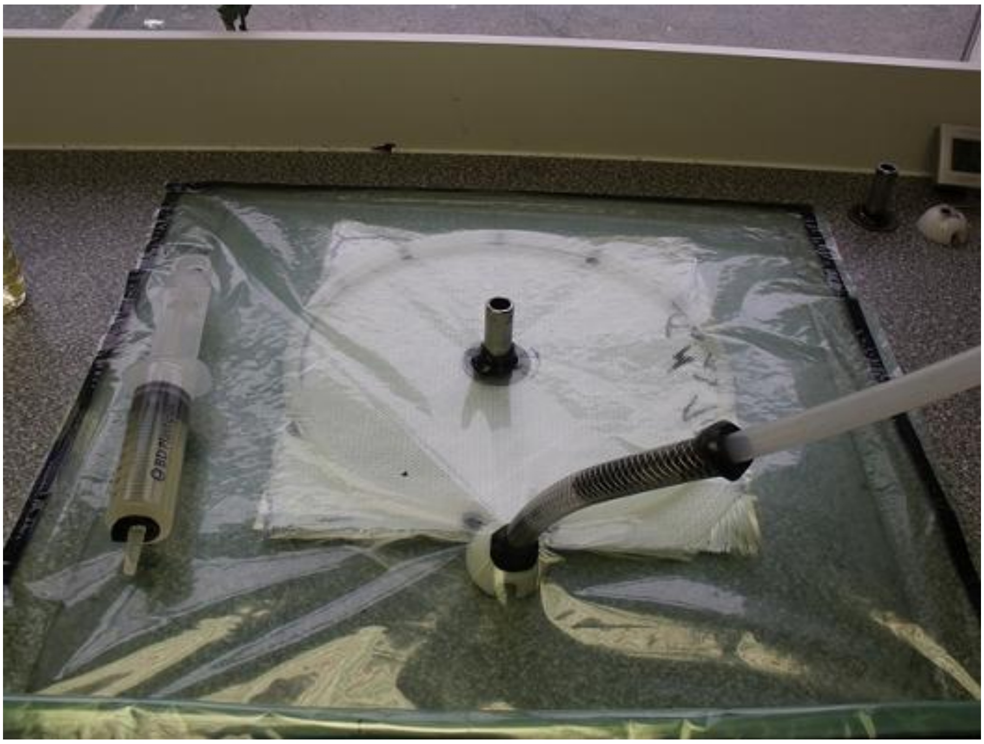
The experiments for mechanical properties of unidirectional carbon textiles will be published by Formax at November 10, 2011. This paper is yet to contain, but it will be updated by the conference.

- EXPERIMENTAL

Permeability

The permeability of unidirectional (one way) textiles were tested by radial in-plane infusion.

All the textiles are made with 12k carbon rowings, which creates a textile of 300g mass per square meter. The tests for the permeability are comparative experiments where single layers were infused, registered and compared .



The "envelope" setup

The picture shows a setup for the radial infusion. The setup creates a vacuum-stable area where liquid is infused from the center inlet to the outlet – the latter is connected to a spiral tube. During the infusion the liquid flow front would give us the information on polar permeability. The only difference made compared to the original setup was the use of airtight seal on one side. Therefore the fabrics could be quickly tested, and replaced. Besides anything but monitoring the vacuum leaks, the setup needs no modifications, and enables a great number of permeability tests in short time.
This setup is unofficially called the "envelope".

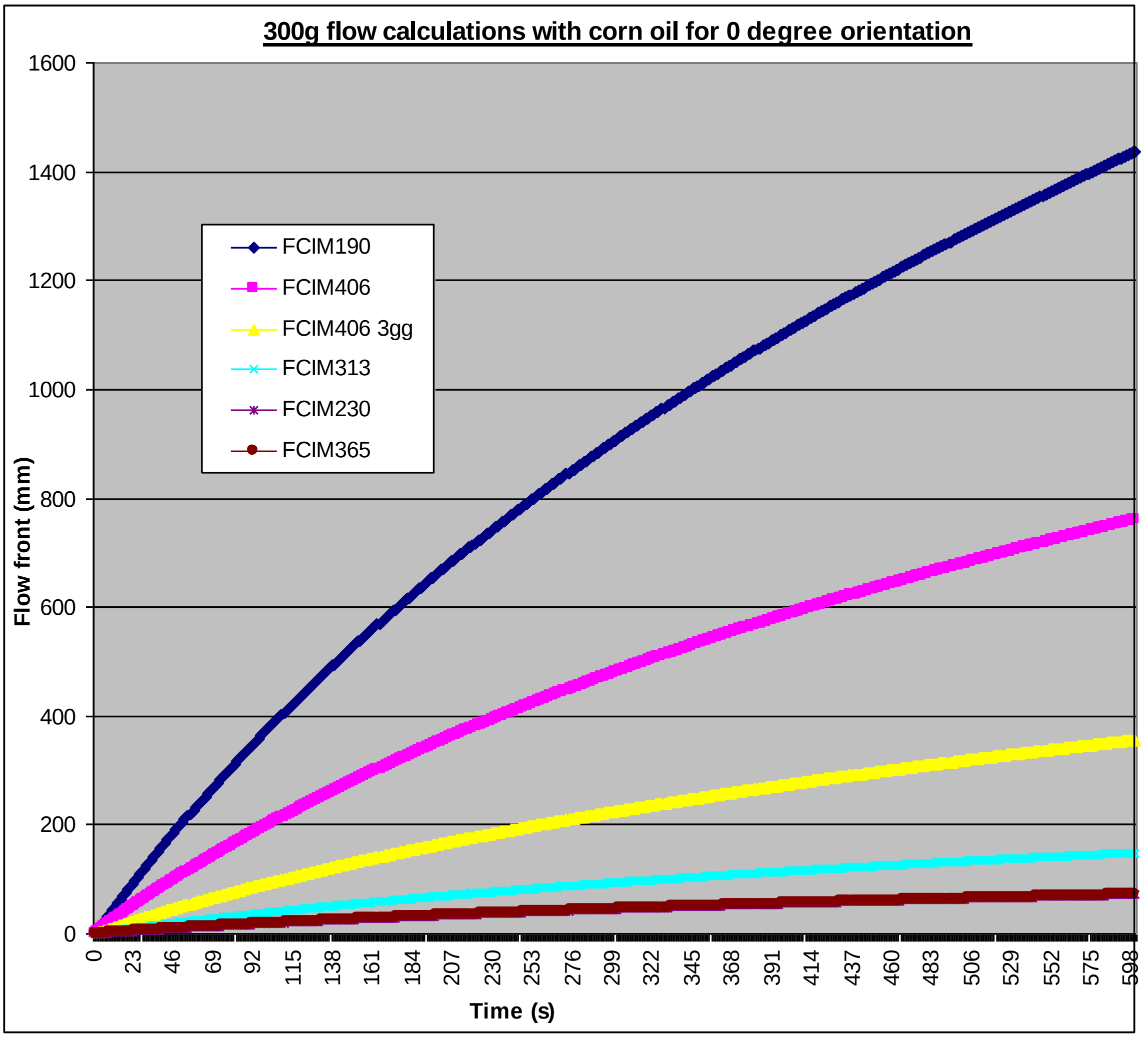
The used liquid for the tests was corn oil because of the handling, lower viscosity (quicker fill, more tests) and price. However, because of it is oil, absolute permeability cannot be determined, but calculated.

In the table, vacuum level means the drop between the inlet and the outlet – the change is modified by the pore system of the textiles. The Vacuum Level does not only represents the net force of infusion, but also modifies the net force of the vacuum foil, and so the compression of the fibers.

- RESULTS

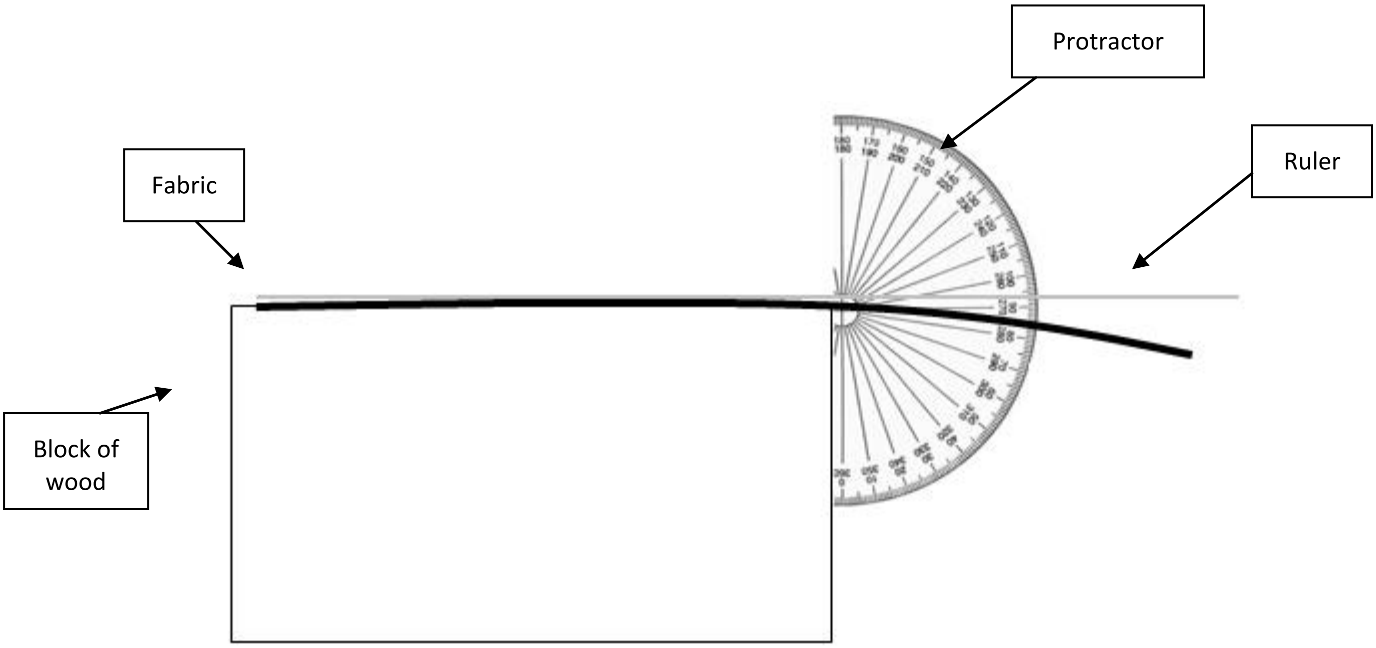
Results for the speed of the fill time:

Code	Fabric construction	0 orientation	90 orientation	Vacuum level (bar)	Note
FCIM190 6gg	C12k, 300g, 90, Multiaxial	100%	100%	0.6	90 oriented fibers, 6 stitch rows per inch, 2.5mm stitches
FCIM406 6gg	C12k, 300g, 0, Multiaxial	53%	55%	0.5	6 stitch rows per inch, Tricot 2.5mm stitches
FCIM406 3gg	C12k, 300g, 0, Multiaxial	25%	35%	0.4	3 stitch rows per inch, Tricot 2.5mm stitches
FCIM313	C12k, 300g, 0, Glass Woven	10%	18%	0.25	Woven,68 tex glass weft 1 weft every cm
FCIM230	C12k, 300g, 0, UD Woven	5%	11%	0.2	Woven, 24 tex thermoset weft 1 weft every cm
FCIM365	C12k, 300g, 0, UD Woven	5%	10%	0.15	Woven, 24 tex thermoset weft 1 weft every 2cm



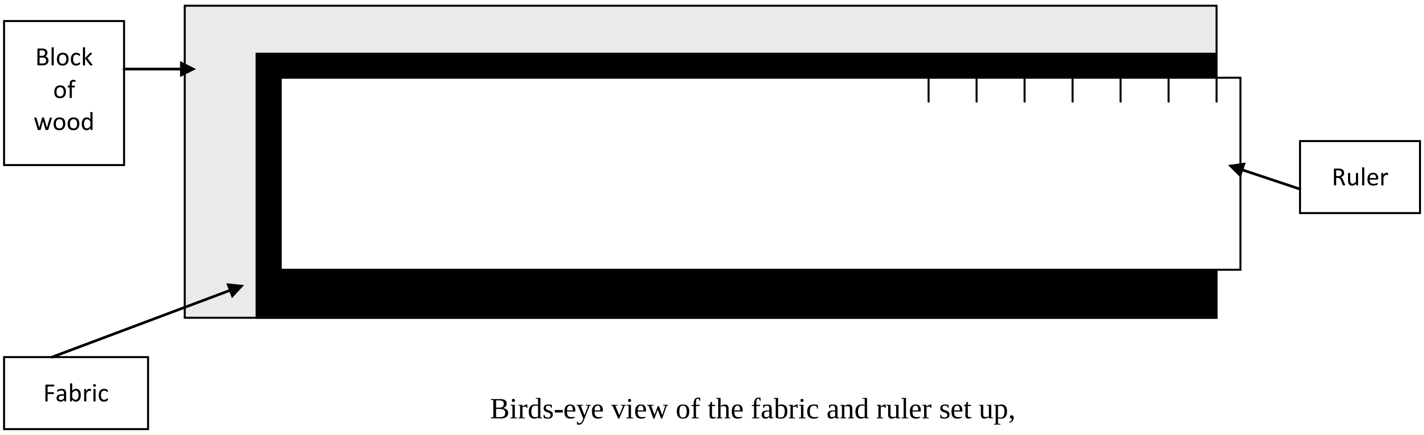
Conformability test method

Three 50x200mm samples are cut out of the fabric that are going to be tested in three different orientations; 0, 90 and +/-45 degrees. Testing drape in these directions will give an overall value.



Drape tester setup

The samples will be placed on the top of the block of wood (see Figure One), and a ruler placed on top, with 0mm at the end of the fabric (see Figure Two). The fabric will then be pushed along the wood until the 100mm calibration is in line with the edge of the wood. The ruler will then be removed (while still keeping weight on the fabric still placed on the wood). From this, the fabric will have bent off the edge of the wood.



Birds-eye view of the fabric and ruler set up,
on top of the wooden block.

The drape can then be calculated by looking at the fabric from the same level, and seeing where on the protractor the fabric falls to. The degree is measured where the fabric passes the calibrations on the equipment.

Carbon drape:

Fabric	Information	Angle of drape (°)			
		0 direction	90 direction	45 direction - Bottom of twist	45 direction – Top of twist
FCIM190	C12k, 300g, 90, Multiaxial	**88**	**1**	**50**	**75**
FCIM406 6gg	C12k, 300g, 0, Multiaxial	**83**	**0**	**15**	**44**
FCIM406 3gg	C12k, 300g, 0, Multiaxial	**88**	**0**	**28**	**56**
FCIM313	C12k, 300g, 0, Glass Woven	**83**	**4**	**8**	**42**
FCIM230	C12k, 300g, 0, UD Woven	**90**	**1**	**47**	**70**
FCIM365	C12k, 300g, 0, UD Woven	**90**	**2**	**50**	**80**

- DISCUSSION

Permeability

The 90 orientation textile had the greatest pore system, following the two stitched fabrics with more stitch rows. Among the wovens, the faster fill is related to the thickness of the warp.

Conformability

The unidirectional textiles show little variety in the term of drape in 0 and 90. The variety is greater at +45 and -45, but

Mechanical experiments will be updated

- CONCLUSIONS

Permeability

The pore system seems to be connected in the multiaxial products, creating more run-ins, which are raising the vacuum level and thus the net force pulling the resin. The study also shows that increasing the number of stitches from 3 to 6 doubles the permeability. It means the stitches create more spaces between tows. The woven textiles seem to have minimal pores between the warps, therefore blocking the flow of air and liquid.

Drape

The table shows that UD textiles has great conformability at 90, but not at 0 angle. The variety between the +45 and -45 orientations are significant, however, relations between structure and drape have not been found. Further tests are needed.

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