Impregnated Fibre Bundle Test - IFBT

Methodology of uses

2015

CELC

Introduction

This method is based on ISO 10618. This is a standard to determine properties of fibres and fibre bundles or yarns, like they behave in composites. Therefore the results of this test are more of direct use for composite applications, compared to fibre properties obtained via single fibre testing.

Recommendations for sample preparation

One sample preparation method is proposed hereunder, however other methods may also be applied. The resulting sample should have :

- a resin volume content of at least 30%
- a good orientation of the fibres
- a limited porosity <2%

It is important that a suitable resin is used. The best is to use a resin which is well known by the user and from which the properties are well known. Recommended properties are:

- Young's modulus: 2 < E <3 GPa
- failure strain larger than 4%
- curing temperature < 125°C
- it is recommended to choose a fast curing resin to avoid long curing cycles that may cause fibre degradation

Note: Please mention any deviation from the guidelines and recommendations in the yarn/roving data sheet.

STEP-BY-STEP GUIDELINES FOR THE MANUNFACTURING OF IMPREGNATED FIBRE BUNDLE TEST (IFBT) SAMPLES

Step 1: Clean the mould with acetone or ethanol and prepare all necessary material: the fibres, the vacuum bagging film, the resin, a release agent (preferably in spray form). Don't forget to degas the resin on beforehand.

Step 2: Fibre (or yarn) bundle preparation

Take a bunch of fibres (or yarns) with the correct weight, with a length of about 25cm. The fibres (or yarns) should be pre-dried for 24h at 60°C. The final length should be 25cm. The use of spacers is recommended to obtains a regular cross-section.

The calculation of the volume fraction can be done in the following way (according to the ISO 14127:2008 standard):

$$v_f = \frac{m_f / \rho_f}{V_c} \quad \text{(Eq.1)}$$

$$m_f = v_f * V_c * \rho_f$$

where,
m_f = mass of the fibres
v_f = fibre volume fraction of fibres
V_c = volume of composite
ρ_f = density of the fibres = 1,45 g/cm^3

Hence, if we target a fibre volume fraction of 40%, the calculation of the necessary amount of fibres/yarns (mass m_f in grams) for a 2 mm thick,10 mm wide sample and 250 mm long is:

m_f= 0,4 * (0,2*1*25) cm^3*1,45 g/cm^3= 2,9 g of fibres are needed

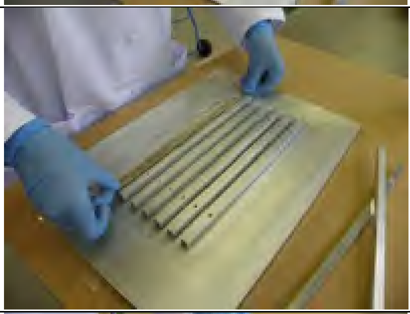
For the volume of the composite sample V_c: one should try to obtain samples with a thickness of 2 mm , a width of 10mm and a length of 250 mm.

A second method can be used to determine the fibre volume fraction after manufacturing. Using the weight of the fibre and the weight of the composite, it is possible to calculate the fibre volume fraction (Eq.2) with the hypothesis that there is no porosity.

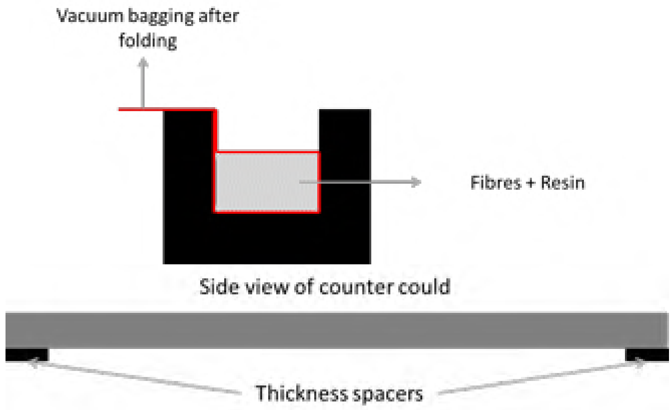
$$V_f(\%) = \frac{\frac{m_f}{\rho_f}}{\frac{m_f}{\rho_f}+\frac{m_c-m_f}{\rho_{res}}} x\ 100 \qquad \text{(Eq. 1)}$$

Where ρ_{res} is the density of the resin (in g/cm^3), m_f is the mass (in grams) of the fibres and m_c is the mass of the impregnated bundle.

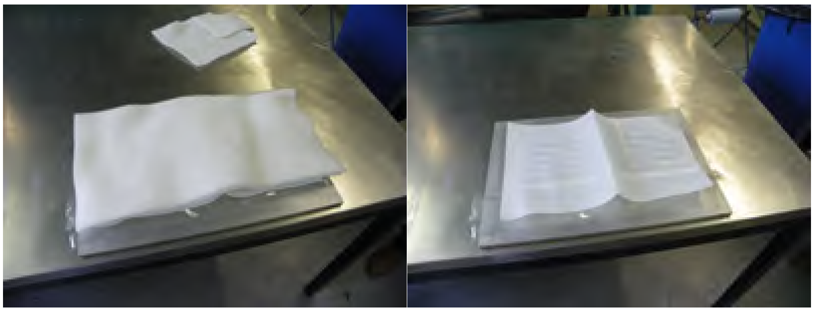
At least 10 samples should be prepared and at least 6 of them should be successfully tested to get a reliable average value of the properties.

	**Step 3:** Place the vacuum bag on top of the mould previously coated with release agent
	**Step 4:** Put a small line (or thread) of resin on the film
	**Step 5:** Place the fibres on top of the resin thread
	**Step 6:** Push the fibre down in the cavities of the mould

Step 7: Add more resin on top of the fibres to thoroughly soak them. It is best to put slightly more resin to avoid dry areas

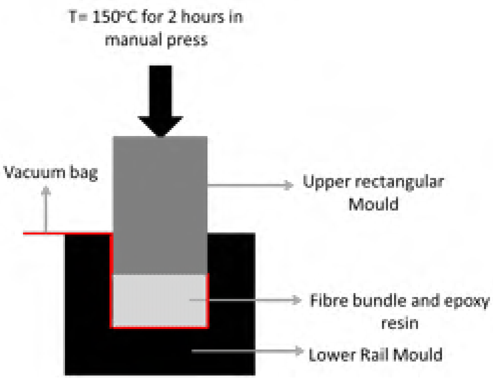


Step 8: Fold the vacuum film and place the counter mould; insert the spacers at the extremities in order to guarantee a constant thickness



Step 9: Place a Teflon film on top of the mould as well as 2 layers of breather. The Teflon film is added to avoid any contact with the breather.

The breather will allow the pressure to be equally distributed on the complete surface of the counter-mould once in the press. Equal pressure = a more even thickness



Step 10: Pre-heat the press and place
the complete mould package inside. Close the press and apply the curing cycle needed for resin system chosen. In this example, we cure the sample at 150 °C for 2 hours.

Once the curing cycle is complete, turn down the heating and let the sample cool down inside the press (and under pressure) in order to avoid warping of the sample due to temperature gradient. Once at room temperature, de-mould the samples

Side view of the mould once closed

The final sample will have
Thickness = according to the used spacer thickness
Width= 10mm
Length= 250 mm

Bad sample:
varying width,
non-straight fibres

Good Sample

***Don’t test sample with irregular cross-section. This will lead to unreliable results.

CALCULATION OF THE PROPERTIES

1- Determination of the composite tensile properties

The calculation of the modulus is made according to the ISO 527 for tensile testing and ISO14125 for flexural testing. The differences from the standard are that:

- E_1: the stiffness calculated between 0 and 0,1% strain
- E_2: the stiffness calculated between 0,3 and 0,5 % strain
- The strength at maximum strain
  → only samples which break in between the grips are valid
- The failure strain in %

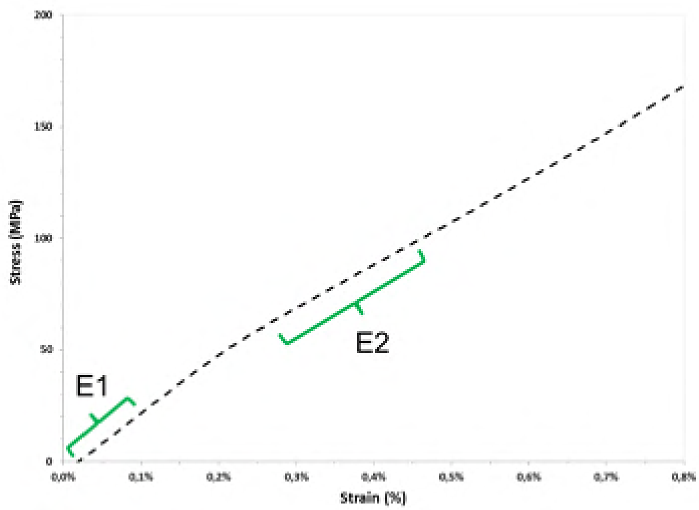


Figure 1: Zone where E1 and E2 should be calculated

The reason for calculating 2 values for the stiffness is that there can be a decrease in stiffness around 0.2% strain; the amount of decrease depends on the type of preform. It is important to mention both values, because both values can be relevant for design purposes.

Example of table to report of sample properties

	Mass of fibre m_f(g)	Mass of composite m_c(g)	Size of sample (mm)			Actual V_f in impregnated roving/yarn*	***E₁***:*Tensile modulus (GPa) between 0 and 0,1% strain*	***E₂***:*Tensile modulus (GPa) between 0,3 and 0,5% strain*	*Tensile strength σ_f (MPa)*	*Failure strain ε (%)*
			Length (mm)	Width (mm)	Thickness (mm)					
Sample 1										
Sample 2										
Sample 3										
Sample 4										
Sample 5										
Sample 6										
Sample 7										
Sample 8										
Sample 9										
Sample 10										
Average										
Stdev										

2- Back-calculated fibre/yarns properties

For the roving/yarn data sheets, the Impregnated Fibre Bundle Test (IFBT) has to be used. Please see separate guidelines for IFBT sample manufacturing and testing, also provided by CELC. From the measured composite properties on this "impregnated fibre bundle", the following properties can be back-calculated:

- From an **impregnated roving** (having no twist!), the properties of **flax <u>fibres</u>**, as they are present and behave in a composite, can be determined
- From an **impregnated bundle of yarns** (having a certain twist), the properties of **(twisted) flax <u>yarns</u>**, as they are present and behave in a composite, can be determined

The back calculation the fibre/yarn properties is performed using the following formulas:

$$E_f = \frac{E_C - E_m * (1 - V_f)}{V_f}$$

$$\sigma_f = \frac{\sigma_C - \sigma_m * (1 - V_f)}{V_f}$$

Where,

- E_f is the modulus of the fibre,
- E_m is the modulus of the matrix and
- Vf is the fibre volume fraction,
- σ_f is the strength of the fibre
- σ_m is the stress in the matrix at the failure strain which can calculated assuming elastic deformation of the matrix: $\sigma_m = E_m \times \varepsilon_c$.
  **moduli are given in GPa, strengths in MPa*

Because two composite moduli have to be measured (E_1 and E_2), two fibre moduli can be calculated: $\mathbf{E_{f1}}$ and $\mathbf{E_{f2}}$.

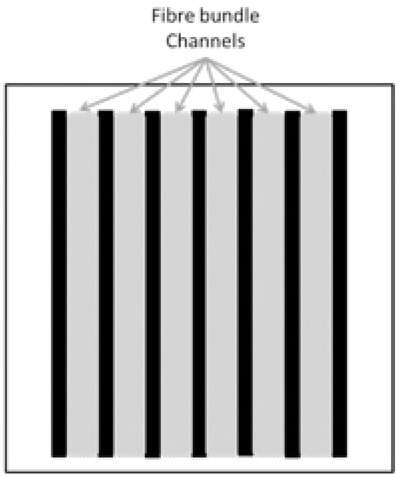
Example of table to report of dry yarn/roving properties

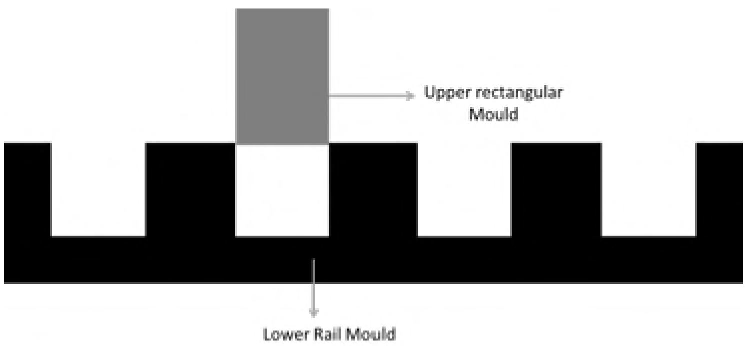
	E_{f1}: *Tensile modulus (GPa) between 0 and 0,1% strain*	***E_{f2}***:*Ttensile modulus (GPa) between 0,3 and 0,5% strain*	*Tensile strength σ_f (MPa)*
Sample 1			
Sample 2			
Sample 3			
Sample 4			
Sample 5			
Sample 6			
Sample 7			
Sample 8			
Sample 9			
Sample 10			
Average Stdev			

APPENDIX A: THE MOULDS

Mould I

Multiple channels structure





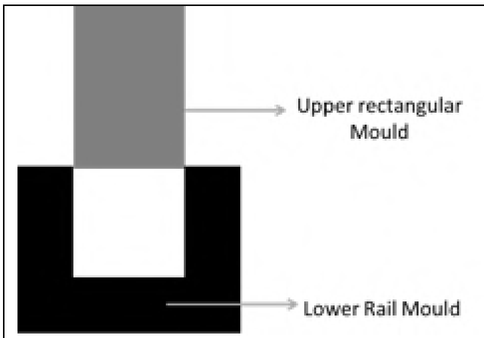
Material : Steel or aluminum

Channel dimensions : 10 mm x 250 mm

Counter-mould dimensions : 9 mm x 300 mm

Mould II

Individual U-bars



Material : Aluminium profiles

Channel dimensions : 10 mm x 250 mm

Counter-mould dimensions : 8 mm x 300 mm