Experimental analysis of the strain in a woven fabric during a shear test

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ABSTRACT: In plane shear behaviour of textile performs is the most studied mechanical property because this mode of deformation is necessary for forming on double curvature surfaces. The mechanical behaviour which results is complex and specific considering the possibilities of relative movements between yarns and fibres. Two principal tests are used: the hinged framework or ‘‘picture frame’’ and the tensile test at 45° or ‘‘bias test’’. But the results are different because of different shear frame sizes. It is necessary to define a quantity characteristic of shear behaviour, independent of the measurement device, and that allows comparing two fabrics and the measures obtained by two laboratories on the same fabric. An experimental device is proposed which enables to measure the strain and tension during a picture frame test or a bias test. The analysis of the results on sample of different size is proposed in this paper.

Key words: Fabrics/textiles; Textile composites; Mechanical properties; Non-linear behavior; In plane shear behaviour.

1 INTRODUCTION

The woven reinforcements used in composites are composed of yarns or tows made up themselves of thousands of small carbon, glass or aramid … fibres. The warp and weft yarns are joined by weaving. The mechanical behaviour which results is complex and specific considering the possibilities of relative movements between yarns and fibres. All rigidities of such a woven reinforcement are low compared to those of tension in the warp and weft directions [1].
The mechanical model must take this specificity into account and be as simple as possible. Shear is the main strain mode that gives to the fabric its formability. Even if the shear rigidity is low in front of tensions, the increase in shear rigidity with the angle between warp and weft yarns especially when this shear angle becomes large has to be defined to model accurately the mechanical behaviour.
In the present work shear tests are carried out on a composite woven reinforcements: a Twintex® plain weave of composed of glass fibres (60%) and polypropylene fibres (40%)
Two principal devices are used: the hinged framework or "picture frame" and the tensile test at 45° or "bias test"[2]. These have proved themselves to be difficult to realise, especially dispersion on different test have been observed [3,4].
It is shown in this paper that with respect of certain test criterion, the intrinsic shear behaviour of the fabrics can be obtained with a very good consistency between different tests. In order to compare the different results of Picture Frame and Bias Test, the couple C on a normalised unit cell created by in the plan shearing γ was used [1,5].

2 CRITERION OF GOOD PROGRESS OF THE TEST

2.1 Good positioning of the lug

The comparison between two tests is presented hereafter. For the first one, the border of the aluminium lug coincides with the axis of the framework (1st case), and for the other the border of the aluminium lug is exceeded of 2mm with the axis (2nd case).
First of all, the figure 1 presents the angle between

warps and wefts measured by an optical method. The results show that we obtain similar values of the real angles in the two tests.

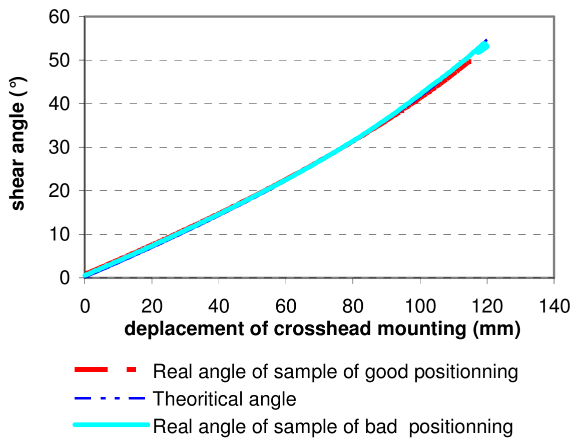

Fig1: Real angles measured by optical method of the two tests

In the figure 2 the torque C according to shear angle with the two tests is plotted.

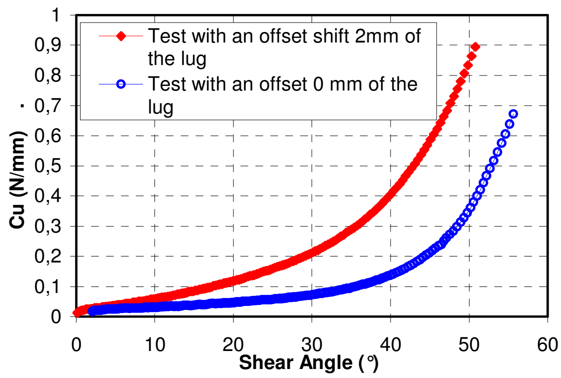

Fig2. Picture Frame test with different offset of the lug

The shear rigidity in the second case is much more important than the first case.

It is well known that the positioning of the lug in the picture frame test influences the tensions and consequently to the shear behaviour [6].

Fig 3, 4 plot tensions in the yarns according to shear angle γ. It enables to explain easily this phenomenon. Tensions appear earlier in the yarns which cause the increase in the shear rigidity. Since the tensile rigidity is very high in front of the shear one, and the positioning of the sample is not perfect, small longitudinal deformations are involved, and tension increases widely. The results of the picture frame test are highly affected.

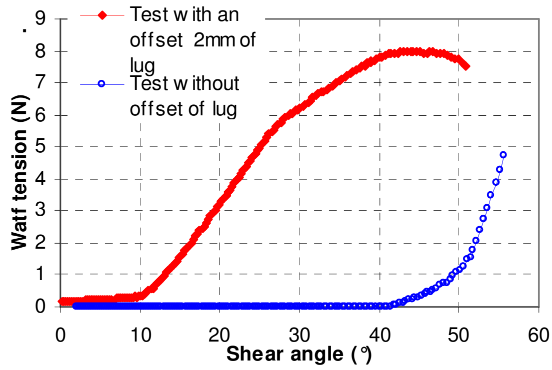

Fig3: Warp tensions

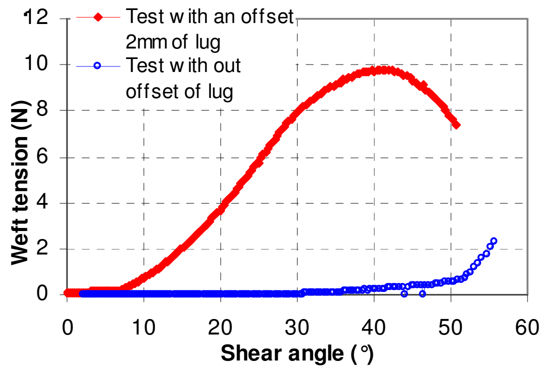

Fig4: Weft tensions

A possible explanation for theses tensions can be found in the geometry on a mesoscopic scale (i.e. the scale of the unit woven cell) and in the woven nature of the reinforcement. If the distance from one edge to the other of the picture frame is constant during the test, the yarn has a slightly higher length because it is undulated because of weaving. When the shear kinematics is prescribed to the fabric, the contact with nearby yarns tends to create an in plane undulation of the yarns. Taking into account the clamping of the yarns in the rigid bars of the framework and the strong tension rigidity of the yarns, it results a tension in the yarns. If the border of the lug is exceeded the axis of the framework, the length of the fabrics play in the test is shorter. The strains on the fabrics are higher thus, the tensions increases widely. The conclusion is that the measure of the tensions during the test is a good criterion for the positioning of the sample.

2.2 *Initial value of the angle between warp and weft yarn.*

Fig 5 and 6 shows the results of the couple C on 5 samples of Picture Frame. Angles in the figure 6 are measured by the optical method, and we compared with the theoretical angles which are calculated from the movement of the framework [7]. These 5 tests have been selected so that the tensions in the yarns remain low. The positioning of the aluminium lug is then verified. The repeatability of these tests is fairly good except for one curve. Although, when the angle between the yarns is not strictly 90°, we see dispersions on the results.

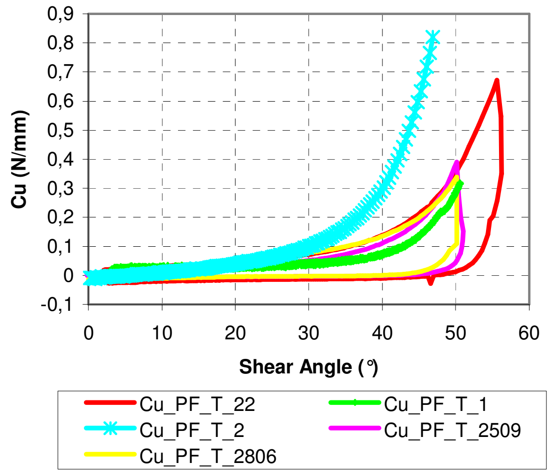

Fig5 Results of Cu with different specimens

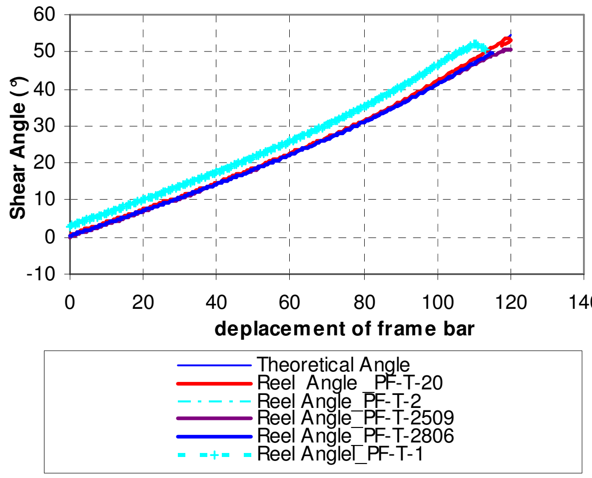

Fig 6. Offset of the initial angle between arms

As a conclusion, it can be noticed that if the initial angle between the arms of the framework is 90°, dispersions of the values are small. On the other hand, with a small offset of 3° of the initial angle of the framework, dispersions are important.

In order to obtain a good repeatability on a Picture frame test, it is necessary to follow the two criteria below:

a. Tensions during the test have to remain low especially in the first part of the test (pure shear test).

b. The arms of the framework and the two yarns networks must be regulated perpendicularly. A small offset of 3° can cause a dispersion of 20% on the results. We have seen how to ensure a good repeatability on different samples of different sizes for a Picture Frame test. We have to compare now these results with bias test results.

3 COMPARISON THE RESULTS OF THE PICTURE FRAME WITH THE BIAS TEST

The first advantage of the Bias Test with respect to the picture frame lies in its simplicity of implementation [8]. In addition the yarns of the central zone in pure shear are free at their ends. Consequently the Bias Test is a pure shear test.

To highlight the influence of the tensions in tests of Picture Frame, we carried out the tests with tensions brought back to zero. The fact to keep the tensions to zero during the test of Picture frame reduces the rigidity of the corp structure of material and make it is similar to that of the bias test.

On the figure 7, it appears the curves of shear torque Cu of different sample from Picture Frame and Bias Test. We have here the results of 3 samples with small tensions of different dimensions: 200x200mm of width and 180x180 mm of width, 2 sample of dimension 200mmx200mm with the tensions brought back to zero and 3 of Bias Test with various dimensions: 80mmx160mm, 80mmx230mm and 115x230mm. The results show a very good consistency between a “normal Picture Frame” Test and Bias Test and a very good consistency between the picture frame test with tensions put to zero and Bias Test.

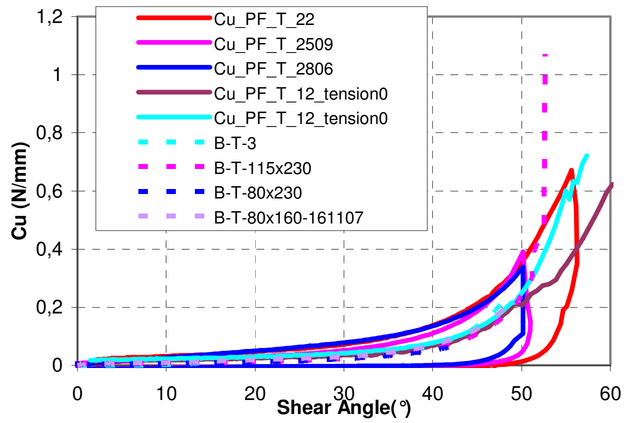

Fig7: Shear Torque

The conclusion is that if the two previously defined criterions are respected (angle at the initial state, tension during the test), results are repeatable and consistent for different samples of different sizes and with results of bias test. The curves obtained can be used as the intrinsic shear behaviour of the fabric.

4 STRAIN IN THE SHEAR TESTS

On the figure below, the results of the strain of yarns according to shear angle were presented. These strains were calculated by methods of follow-up of markers, by using the tasks marked on the sample by a software Deftac 2D. Basing on the displacement of these markers, we can obtain the strains on a macroscopic or microscopic scale.

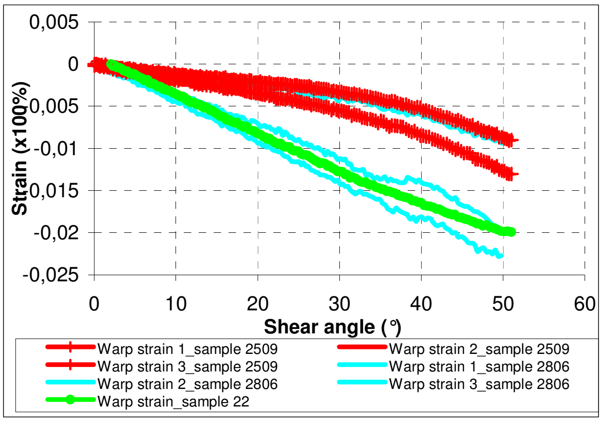

Fig8. Warp strain

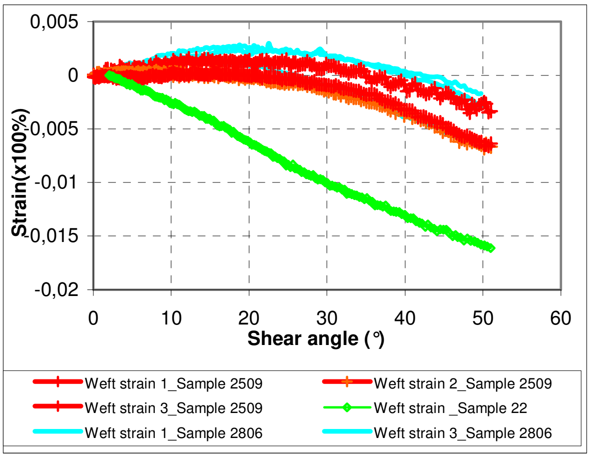

Fig9. Weft strain

It is noted that the strains are not homogeneous on 3 samples tested. It shows here again how difficult it is to perform a full homogeneous pure shear test. Nevertheless, strains in the yarn direction appear to be negative, this can be explained by an increase of undulation at high shear angle.

5 CONCLUSIONS

The instrumented device used in this paper allowed us to understand much more clearly the problem that can be encountered during a Picture Frame Test.
The control and verification of 2 criterions
-Tensions during the test
-Optical measurements of the angle
ensure a good repeatability of the test.
The results between different tests on different samples of different size are consistent. The optical measurements seem also show the finite increase of the undulation during shear. The influence of this longitudinal strain in font of shear will have to be taken into account in forming simulation.

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