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# Experimental analysis of in plane shear behaviour of woven composite reinforcements. Influence of tensions.

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**Abstract.** Two tests are mainly used to identify the shear behavior of fabrics. The "picture frame" which uses a lozenge framework made of four rigid and articulated bars and the "bias test" which is a tensile test on a sample with initially a 45° angle between the yarns and the edges. The picture frame test is the more commonly used because the whole specimen is theoretically in a pure shear state. Nevertheless the absence of tension in the woven reinforcement supposes a perfect alignment of fibres and positioning of the clamping point with regards to the framework articulations. In addition, it is often necessary in practice to impose an initial tension which is not quantified and whose consequences are ignored in the classical picture frame test. An experimental device making it possible to measure the tensions during the test is carried out. Different types of tests on different fabrics have been performed. Results presented here concern a twintex fabric that has been selected for a shear benchmark. Thanks to this device, it is shown that tensions play an important role in plane shear behaviour.

**Keywords:** Fabric, Textile, Shear behaviour, Picture frame, Tension.

**PACS:** 81.70.-q, 81.70.Bt, 62.20.-x

## PICTURE FRAME WITH TENSION MEASUREMENTS

### Standard Measurements of Shear Behavior

The experimental analysis of in plane shear behaviour of textile performs has been the subject of many works probably because it is the principal deformation mode of these woven fabrics. Among many we can cite [1-7]. Two principal devices are used: the hinged framework or "picture frame" and the tensile test at 45° or "bias test".

A benchmark carried out by different laboratories on identical woven composite fabrics led to large discrepancy between the results especially for those obtained via the picture frame test [1]. This tends to show that this test is not completely controlled. A practical difficulty in this test resides in the need for the strict positioning of yarn clampings on the straight line that joins to articulations of the frame. If the ends of the yarns are not clamped on this straight line, the kinematics imposed to the specimen

does not correspond to pure shear, the yarns are stretched and are thus subjected to spurious tensions. It is necessary to scrupulously respect this alignment [.

The significant difference between the response to the different picture frame tests and to the bias tests can also be explained by the boundary conditions on the fabric. In the first case the yarns are clamped on the rigid bars of the framework whereas for the bias test they are free. It is supposed that taking into account the geometry and kinematics of the picture frame the tensions remain small during the test. This aspect is questionable especially because a small tensile strain of the yarns leads to significant strain energies taking into account the much larger tensile rigidity in comparison to that of shearing. An other point concerns the assumption made in most experimental and simulation works that consists in assuming that the effort  $F_{sh}$  (or the in plane shear stress) only depends on the shear angle  $\gamma$ . In order to measure the warp and weft tensions during a picture frame test and to analyse the consequences of these tensions on the shear stiffness, a specific device is proposed.

### **Assumptions And Results Format**

Even though it was shown that the results of shear tests are modified when the test is repeated on the same specimen and that some cycles are necessary before obtaining a stabilized value. Nevertheless, since it is the behaviour during forming which interests us, we will always consider the first cycle of loading in present work, as it is the case in a forming process.

In this work a new experimental device is implemented which makes it possible to measure the tensions in a fabric during a shear test. This device will show that, as opposed to the classically used assumptions, the shear stiffness varies with the tensions. In addition it will be seen that the classical "picture frame" test used as pure shear test may cause tensions in the yarns of the fabric depending on the limit conditions imposed near the picture frame arms. The tests presented in the present paper are carried out on two composite woven reinforcements: a Twintex<sup>®</sup> plain weave composed of glass fibres (60%) and polypropylene fibres (40%) (743g/m<sup>2</sup>) [1]. In the present work,  $F_{sh}$  will be used, to give the results of the different tests.  $F_{sh}$  is normalized from the frame load using:

$$F_{sh} = \frac{F_{norm}}{2 \cos(\alpha/2)}, \text{ with } F_{norm} = \frac{F_c L_{frame}}{L_{fab}^2} \quad (1)$$

where  $L_{frame}$  and  $L_{fab}$  are the lengths of the side of the picture frame and of the sample respectively [1,4].  $\alpha = \pi/2 - \gamma$  is the angle between the two bars connected at of top of the picture frame.

### **Picture Frame With Tension**

Devices for measurement and adjustment of the tension are added to a picture frame in the warp and weft directions. (Fig. 1). In each direction the yarns are fixed on a system which is connected to the picture frame by a load sensor on one end and by an adjustment on the other end. So it is possible to measure the warp and weft tensions during the test and to adjust the initial tensions. Possibly, by stopping the test, warp

and weft tensions can be set to given values. The shear angle can be calculated from the frame displacement or be measured by optics measurements. The values of angles provided in the present work will be the average values measured by optical measures in the useful zone of the specimen. The load sensors added on the frame measure the load at right angles to the rigid bar. The yarns do not remain perpendicular to the bars during the test (Fig. 1). It is thus necessary to correct the values measured by the sensors to obtain the tensions in the yarns. The tension in the yarn is obtained from the measure of the sensor by:

$$T_{\text{yarn}} = \frac{F_{\text{sensor}}}{\cos(\gamma)} \quad (2)$$

This device will first enable to analyze the influence of a initial tensions on the shear rigidity of a woven reinforcement. Then in the second time the evolution of the tension will be analyzed during a shear test. Finally tests for which the tension will be set to zero during all the tests will be performed.

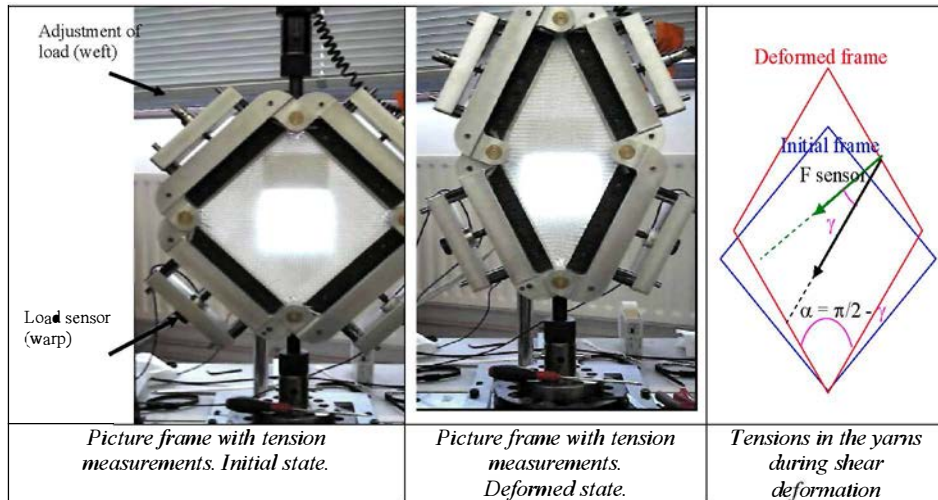


FIGURE 1. The new picture frame with tension measurements.

## RESULTS OBTAINED

### Influence Of The Initial Tension On Shear Stiffness

Fig. 2 shows the shear loads obtained in the case of the Plain Weave fabric for initial tensions equal to 0, 10 and 20 N per yarn. These results show that the shear load is increased by the tension in the yarns especially in the first part of the shear curve (small and medium shear angles). For a 25° shear angle, the ratio between the shear load of a test without initial tension and with an initial tension equal to 20 N is close to 2. This result is not surprising because the shear rigidity is for a part due to frictions

between the yarns (especially in the first part of the curve). When increasing the tension in the yarns, the weaving brings a transverse compressive force and consequently the friction loads and consequently the shear stiffness increases. For large shear angles, the shear load is less affected by the initial tensions. The initial tensions are applied for a null shear angle and their influence on the tension state after a large shear is less important.

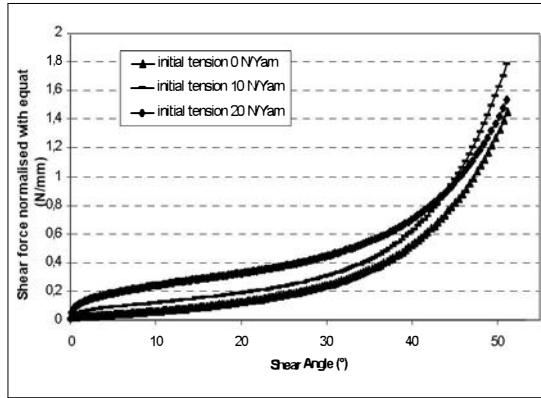


FIGURE 2. Shear load curves for different initial tensions.

### Yarn Tension During The Picture Frame Test

Although the yarn tensions are null at the beginning of the test, they increase in a significant way during the test. Such a picture frame shear test is thus not strictly a pure shear test since fairly important yarn tensions are superimposed. A possible explanation for these 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 [5]. Although the distance from one edge to the other of the picture frame is constant during the test, the yarn length increases slightly. The boundary conditions and the need for the strict positioning of yarn clampings can induce tension. 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. It can be noted that the tension in the yarns remains null in the first part of the shear test (Fig. 3). This is reasonable since it as been shown [7] that, in the first part of the shear test, the yarns undergo a rigid body rotation and are not in contact with their neighbours. The tension in the yarns only increases starting from the beginning of the side contacts

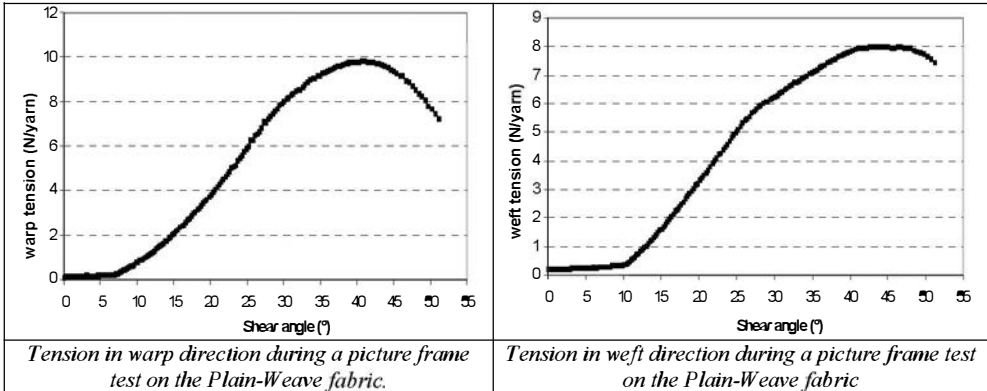


FIGURE 3. Tension during the picture frame test on the Plain-Weave fabric.

### Comparison between picture frame tests and bias test

The test carried out in the present section consists to maintain the tensions very near a zero value. Fig. 4 shows the comparison between the shear curve obtained in this case with that obtained with a standard picture frame test i.e. without relaxing the tension during the test and the bias test. The results obtained by setting the tension to zero in the picture frame test are rather close to those obtained by the bias test. This is explained by the fact that tensions in the bias test are null or very small because the ends of yarns of the sheared zone are free. This test clearly shows the significant consequences of the tensions in a standard picture frame test. Other tests on other fabrics have been performed that lead to the same type of results.

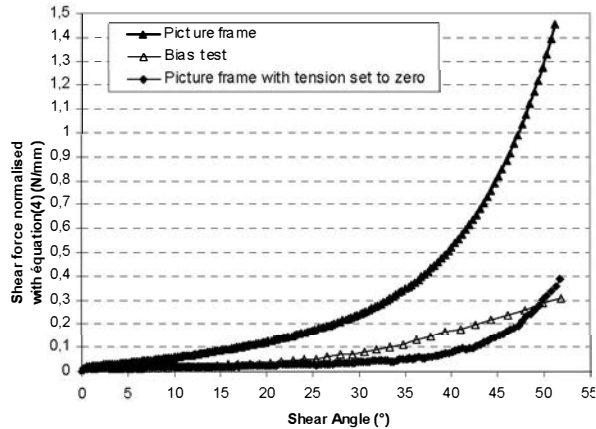


FIGURE 4. Picture frame test with tensions equal to zero on the Plain Weave fabric. Comparison with standard picture frame and bias test.

## CONCLUSION

A new experimental device makes it possible to measure the tensions in the warp and weft directions during a picture frame shear test. The first results show that the tensions which generally are not taken into account play a significant role in shear behaviour. When the initial tensions vary, the obtained shear loads in the first part of the test increase with the initial tension. The measurement of the tensions during a picture frame shear test shows that those tensions may not remain null during the test. It has been shown that the tensions influence significantly the picture frame results and can explain the differences observed between the different picture frame tests (benchmark) and the differences between the bias test results and the standard picture frame results. The real coupling between shear and tension behaviour has then to be further investigated and maybe taken into account in the finite elements computations of fabric forming [8]. Especially when the forming processes uses tools, especially blank holders, because the tensions can become significant.

## ACKNOWLEDGMENTS

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