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DETERMINATION OF SHEAR PROPERTIES AND YARN PULL-OUT BEHAVIOR OF TEXTILES BY NOVEL APPARATUS

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Abstract:

In our department a novel apparatus, that can be mounted on almost any kind of universal load machine, has been developed that makes possible to investigate both the shear properties of sheet-like materials and to carry out yarn pull-out tests on woven textiles. The main idea of the gripping unit was to fix two parallel edges of a rectangular test sample and to induce the shearing deformation amongst the symmetry line. A simple pretension system, working with a metal spring, makes available to generate and maintain a transversal preload. The clamps can move in this transversal direction according to the horizontal pretension and the vertical shear force induced by displacement. Therefore the transversal yarns of the specimen have constant length and almost pure shearing takes place. The transversal preload and the clamping distance can be adjusted easily in a wide range and therefore various textiles can be tested. In this paper the apparatus and the related simple test method is introduced as well as the accuracy and reproducibility of the test results.

Keywords:

Shear properties, Deformation, Plain weave, Fabric reinforcement

1 INTRODUCTION

At human environmental textiles and at composite reinforcements it is necessary to know their various mechanical properties in order to be able to design complex structures. In the first case the textile has to suit to the shape of the body or adequate draping properties are required for the appropriate optical performance. At composite reinforcements the textile has to conform the shape of the mould. In all these cases, besides the good handling possibilities, appropriate shear properties, flexibility and the role of the friction between the fiber bundles have high importance and these things also influence one another [1-3].

The method has to be simple and rapid to fit the requirements of the industry. There are widely-known methods making available to determine the shear properties of woven textiles, but these are either complicated or the stress state, generated by the test method, is not ideal [4-5].

Maybe the most simple method is when the woven textile sample is tested by tensile tester in bias direction (the weft and warp yarns are located in directions ±45° to the axis of pulling) [4]. As the endings of the yarns are not constrained in the shear zone, therefore the shear state is appropriate, but complex. The problem is with the determination of the location of the pure-shearing zone and as the shear deformation is calculated from the strain of the whole sample it is hard to obtain precise results. The method can be further improved by image processing as Domskiené and Strazdiené [6]; Al-Gaadi and Halász [7] demonstrated. This method is more precise but maybe too complex for industrial purposes.

The other widespread method when the textile sample is fixed to a picture frame that has knuckle-joints in their corners. The two opposite corners of the frame are displaced thus the square becomes a rhomb and the textile is sheared. The method is simple but not precise and stress state is not ideal close to the clamping bars hence the yarns are bended [6-7]. The Kawabata's Evaluation System for Fabrics (KES-FB) [8] can also be used for determining the shear properties of textiles. At this method two parallel sides of an oblong textile sample are clamped and one of them is moved to shear the textile. The distance of the parallel clamps changes during the test as its initial value is determined by a transversal pretension. The system is precise and the experiment can be carried out rapidly. The pretension is generated by a rotating drum and the requisite displacement is calculated from torque measurements that requires additional electronic control devices. The apparatus can only be used for this kind of experiments exclusively.

In our study the aim was to design and construct an apparatus that makes possible to combine the simplicity of the above-mentioned methods and the precision of the KES-FB system in order to determine the shear properties of textiles. A simple construction was designed that makes possible to maintain transversal pretension of the textile during the tests akin to the KES-FB shearing system.

The pretension is applied by clearly mechanical ways during tests leading to a simple, easy-to-build, symmetrical construction. There is no need for a whole device dedicated to only shear experiments as the apparatus can be mounted on almost any kind of universal load machine. With the apparatus the tests can be carried out rapidly and the evaluation of the results can be done with the aid of the software of the load machine. Moreover the apparatus can be used for yarn pull-out tests. The repeatability of the results in case of both yarn pull-out and shear tests are demonstrated in this paper through an example of a glass fiber plain weave reinforcement.

2 EXPERIMENTAL

2.1 Applied materials

A glass fibre plain weave (1/1) fabric was chosen for the measurements because it is widely used in engineering constructions as composite reinforcements. Krossglass (Poland) STR 022-250-110 type fabric was applied having an areal density of 250 ± 15 g/m^2 and a yarn density of 5/cm in both warp and weft directions. For the tests the gripping distance (width) was chosen to be 2x50 mm (symmetrical setup) and the length of the sample was 200 mm.

2.2 Apparatus design

The schematic draft of the apparatus can be seen in Figure 1. The experimental setup is symmetrical meaning that there are two clamps at the edges and one in the middle. Two parallel edges of an oblong test sample (Figure 1:1) are clamped (Figure 1:2A) and the deformation is induced amongst the symmetry line. Different middle clamps (Figure 1:2B) can be mounted — at the symmetry line — for yarn pull-out and for shear tests. To achieve a simple but precise construction the pretension is induced by a long spring (Figure 1:5) having linear characteristics. The two clamps can move during the test due to the vertical force generated by the testing device and the horizontal forces of the pretension spring. The spring has to be stretched (ΔX) by two simple gears until reaching a desired length related to 20 N tensile force. The spring was calibrated by a simple tensile test and the length related to this force is determined. At this displacement a strong (0.24 mm diameter) high performance polyethylene (HPPE) fishing line (Figure 1: 6) was then fixed to the hooks at the ends of the spring in an elongated state limiting the maximum strain and pretension. This yarn ensures that the spring can only be stretched by the adjustment gears (Figure 1: ΔX) until reaching the strain related to 20 N.

This simple pretension system makes available to generate and maintain a transversal force with an accuracy of approximately ±0.5% (at a preload of 20 N and 1 mm displacement of the grippers) avoiding the application of complementary electronics. As shear modulus is determined at small shear deformations the pretension induced by the spring can be considered constant from the viewpoint of the tests.

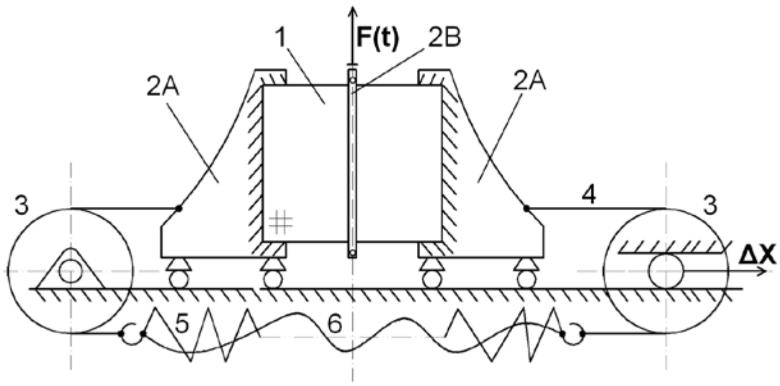

Figure 1: The schematics of the designed apparatus. 1: textile specimen, 2A: side clamps, 2B: middle clamp 3: rollers with bearing, 4: rope, 5: pretensioning steel spring, 6: strain limiting yarn

The deformation of the textile test sample at shear test can be seen in Figure 2. According to the construction, during the shear tests the transversal yarns of the specimen have approximately constant length and almost pure shearing takes place. The half-gripping distance (X_0) is the distance between the central and the outer clamps. This Y_0 distance also identical with the length of the horizontal yarns between the clamps. When displacement is induced (Figure 2B) the length of the horizontal yarn remains the same but the clamps come closer to each other (X(t)) due to the pretension. As the side clamps can be fixed at any positions it also makes possible to carry out tests with constant gripping distance.

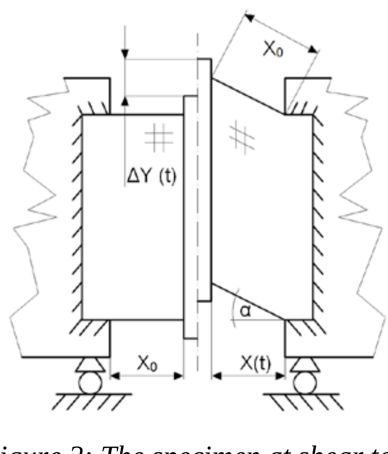

Figure 2: The specimen at shear test.

The steel pretension spring was designed to have a maximum loaded length of 291 mm, while the unloaded state is only 119 mm long including the 12 mm size hooks at both ends.

2.3 Test parameters

Both the shear properties and the yarn-pull out behavior was determined to demonstrate the applicability of the device. The apparatus was mounted on a Zwick Z005 type universal load machine and the speed of the crosshead was set to 10 mm/min. The shear force was measured by a sensor having a measuring range of 20 N and a resolution of 1 mN. The shear tests were carried out with 20 N pretension force, i.e. 1 N/cm (related to sample width) induced by the spring. The shear angle range was ±8° and a whole shear cycle was investigated. Samples were investigated in 0° and 45°directions. The yarn pull-out tests were carried out with a crosshead speed of 20 mm/min and weft yarns were pulled out.

3 RESULTS AND DISCUSSION

The apparatus was designed then manufactured. The apparatus mounted on Zwick Z005 (Germany) type load machine can be seen in Figure 3. The whole apparatus can be tilted to a horizontal position around the motherboard after removing two fixing bolts (Figure 3: 7). Then the clamps (Figure 3: 3A&B). can be fixed at any position by a locking lever (in the back side) in order to ensure their appropriate distance (2x50 mm). At this point the textile specimen can be fixed to the grippers in a horizontal position. Both grippers have a rough surface (sanding paper) at one side and soft rubber on the other side to avoid slipping of the specimen. The two sides can be pressed together by screws. After the specimen is well-fixed, the apparatus can be tilted back to operating position then fixed by the shafts. Then the locking levers can be loosened, therefore the side clamps can move free. The pretension can be applied (Figure 3: 5-6) by shortening the rope until reaching the sufficient strain of the spring. The central clamping unit is then fixed depending on which test (yarn pull-out or shear) is destined to be carried out.

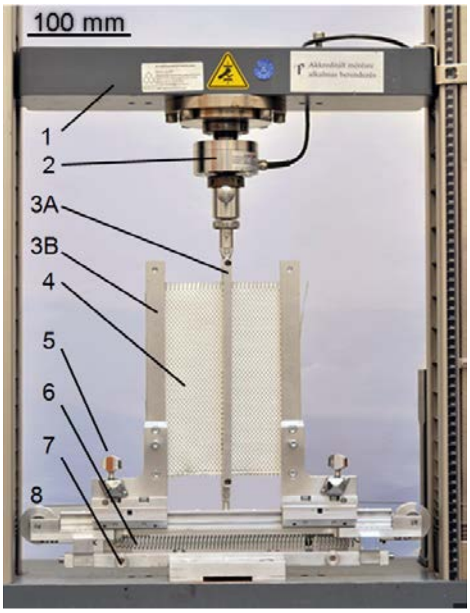

Figure 3: Apparatus for determining shear properties of textiles at yarn pull-out test. 1: Crosshead, 2: force sensor, 3A: middle clamping unit connected to the crosshead of the tensile tester, 3B: side clamps, 4: test specimen, 5: gears for adjusting pretension, 6: pretension spring, 7: fixing bolts, 8: rollers with bearings

The results of the shear tests can be seen in Figure 4. Only the first hysteresis cycle is introduced, the second and third cycle overlapped the curves well, confirming the reproducibility of the tests and that no irreversible deformations are applied on the test samples. The test in 45°cutting direction resulted in approximately ten times higher shear moduli and stresses as well. After the initial section the characteristics of the diagrams are different. While the 0° sample resulted a hysteresis with almost straight and parallel lines between -6°and +6° the behaviour of the 45° cut sample is more complex. At the bias (45°) sample the curves are not parallel indicating that shearing behavior is angle-dependent. At this sample wrinkles are formed what can also be followed by the shear characteristics.

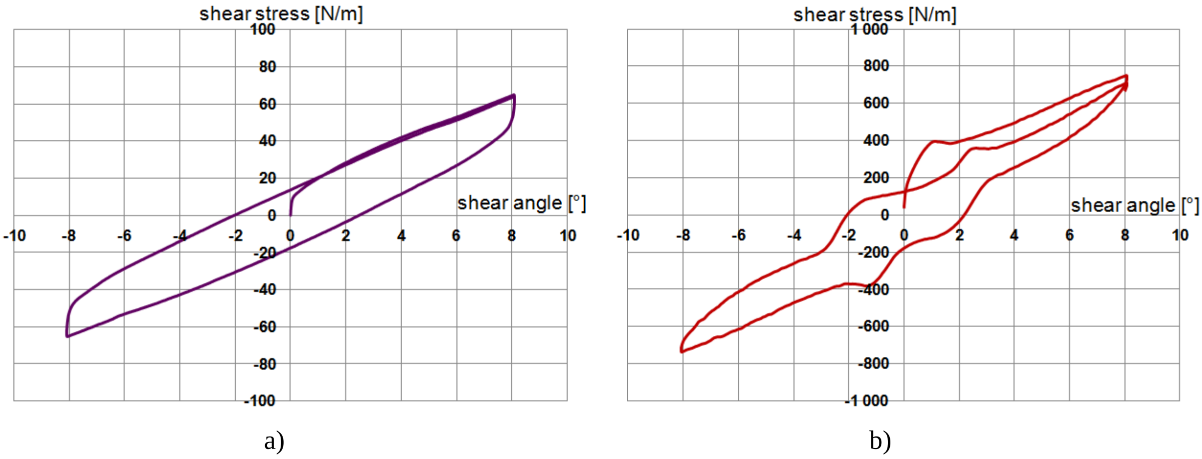

Figure 4: Shear test results. a) 0°direction, b) 45°direction

Some of the preliminary results of the yarn pull-out tests are demonstrated in Figure 5. The roving which was in the middle was slightly pulled out by hand to be able to grip it. Therefore the pull-out length was slightly different in each case leading to different initial force values. Apart of this the curves have similar characteristics. The periodical nature of the yarn pull-out originated from the intersections of rovings can clearly be observed.

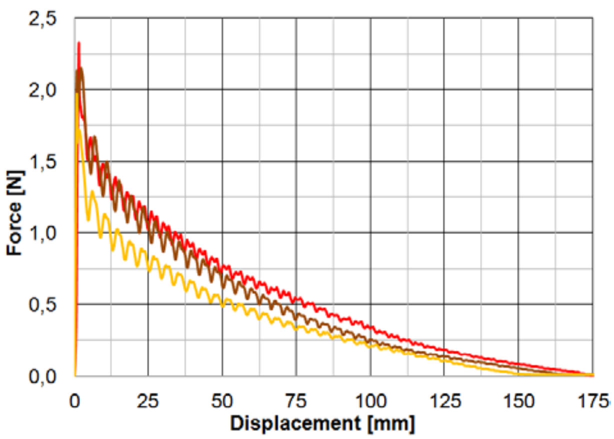

Figure 5: Brief results of the yarn pull-out tests [9]

4 CONCLUSIONS

A simple apparatus for determining shear properties of various textiles has been developed. The apparatus can be mounted on almost any kind of universal load machine depending on the motherboard. The test arrangement is quite similar to the KES-FB system but instead of using supplementary electronics the pretension is generated by a steel spring in order to regulate the stress-state. The simple system makes available to have a pretension typically in a ±0.5% range during tests. As the clamps can be fixed at any positions it also makes possible to carry out tests with constant gripping distance. The pretension and the distance of the clamps can be adjusted moreover various middle clamps can be applied.

The main advantage of the device is that besides the good repeatability, cost-effectiveness, and appropriate stress state the tests can be carried out rapidly. The software of the load machine can be used for the evaluation.

The repeatability of the tests were confirmed by shear and yarn pull-out tests on glass fiber plain weave fabrics. The results revealed that the device can be used for both yarn pull-out and shear tests as the deviations of the recorded values are low. Our next goal is to analyse and compare the results with that of other widely used measuring methods.

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