APPARATUS FOR MEASURING THE SHEAR PROPERTIES OF REINFORCEMENTS

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Abstract

An apparatus has been developed at our department that makes possible both to investigate the shear properties of sheet-like materials and to carry out yarn pull-out tests on woven textiles. The apparatus can be mounted on almost any kind of universal tensile testing machine. The transversal preload and the clamping distance can be adjusted easily in a wide range and therefore various textiles can be tested. In our study a plain weave glass fabric reinforcement was chosen to demonstrate the precision, flexibility and feasibility of the apparatus in case of both yarn pull-out and shear tests.

Key words: *glass fibre, shear properties, deformation, plain weave, fabric reinforcement*

Introduction

For technical textiles and at composite reinforcements it is necessary to know their various mechanical properties in order to be able to design complex structures. It can be seen that nowadays many non-conventional test methods have been appeared [1-3]. Maybe the most simple method is when the woven textile is tested by tensile tester and the weft and warp yarns are located in directions ±45° to the axis of pulling. As the endings of the yarns are not constrained in the shear zone, therefore the shear state is appropriate, but complex. The local deformation is generally analyzed by image processing methods [4-5]. The other simple and widespread method when the textile sample is fixed to a square frame that has knuckle-joints in the 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 as the stress state is not ideal close to the clamping bars [6]. The Kawabata's Evaluation System for Fabrics (KES-FB) [3,7] allows to carry out the shear tests on textiles (KES-FB1). At this method two parallel sides of a textile sample are clamped and one side 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 but more complicated compared to the others as the pretension is generated by a rotating drum. The requisite displacement is calculated from torque measurements that requires additional apparatus.
In this study our 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 figured out that allows transversal pretension of the textile and therefore a stress state akin to the KES-FB is realized. A symmetrical setup was chosen and the pretension is applied by clearly mechanical ways during tests. The apparatus can be mounted on almost any kind of universal tensile testing machine and moreover its design also makes possible to be used for yarn pull-out tests. The repeatability of the results, the flexibility and the feasibility of the apparatus in case of both yarn pull-out and shear tests are demonstrated in this paper.

Experimental

The experimental setup is symmetrical meaning that the distance of the central gripping device is the same from both clamps. Only the middle clamp is different for yarn pull-out and for shear test and can easily be changed.

The main idea of the gripping unit was to fix two parallel edges of a test sample and to induce the deformation amongst the symmetry line (Figure 1). As a simple but precise construction was aimed at, the pretension is induced by a long spring having linear characteristics. The two clamps can move free during the test due to the vertical force generated by the testing device and the horizontal forces of the pretension spring (Figure 1: 3). The spring can be stretched (ΔX) until a desired length since a thin rope (Figure 3: 4) does not allow to stretch it anymore. 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). As shear modulus is determined at small deformations the spring force can be considered constant.

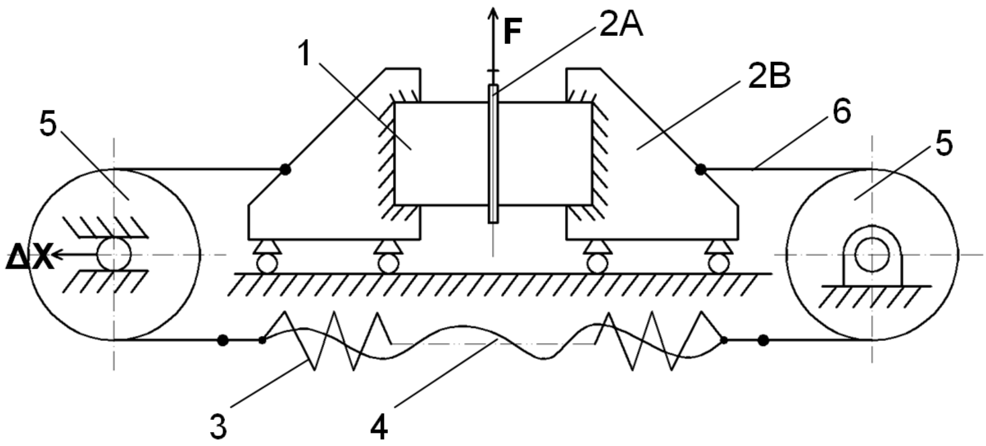

Figure 1. The schematic draft of the apparatus. 1: textile specimen, 2A & 2B: grippers, 3: steel spring, 4: HOPE yarn, 5: rollers with bearing, 6: rope

The deformation of the textile test sample can be seen in Figure 2. Due 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 (Y_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 (Y_1) due to the pretension.

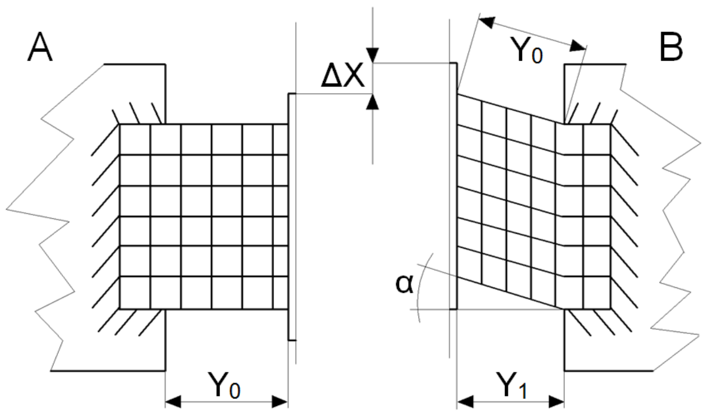

Figure 2. The specimen at shear test. A: before test, B: deformation during test

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

to be 20 N or 1 N/cm in other words, as 20 cm wide samples are designated to be measured. To ensure this force the manufactured spring was calibrated and a simple method was applied. The spring was gripped to the Zwick Z005 universal tensile tester and the crosshead was moved until reaching 20 N force. At this displacement a strong (0.24 mm diameter) high performance polyethylene (HPPE) fishing line was applied to tightly link the two ends of the spring. This yarn ensured that the spring can only be stretched by the adjustment gears until reaching the strain related to 20 N.
For the measurements a glass fibre plain weave (1/1) fabric was chosen since it is widely used in engineering constructions as composite reinforcements. Krossglass (Poland) STR 022-250-110 type fabric 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 half gripping distance (Y_0) was chosen to be 50 mm and 200 x 150 mm (weft x warp) samples were cut. Both yarn pull-out and shear tests were carried out.

Results and Discussion

The apparatus mounted on a Zwick Z005 (Germany) type tensile tester can be seen in Figure 3A. Gripping the sample is easy. The whole apparatus can be rotated to a horizontal position around the motherboard after removing two fixing bolts (Figure 3B). Then the clamps can be fixed at any position by a locking lever in order to ensure their distance (2x50 mm in our case). At this point the textile specimen can be fixed to the grippers in a horizontal position (Figure 3C). 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 to operating position and fixed. As the adequate gripping distance is ensured by the textile specimen the locking levers can be loosened, therefore the clamps can move free. The pretension can be applied (Figure 3A: 6) by shortening the rope until reaching the sufficient strain of the spring. As the clamps can be fixed at any positions it also makes possible to carry out tests with constant gripping distance. In such case the locking levers should not be loosened. The central clamping unit is then fixed depending on which test (yarn pull-out or shear) is destined to be carried out.

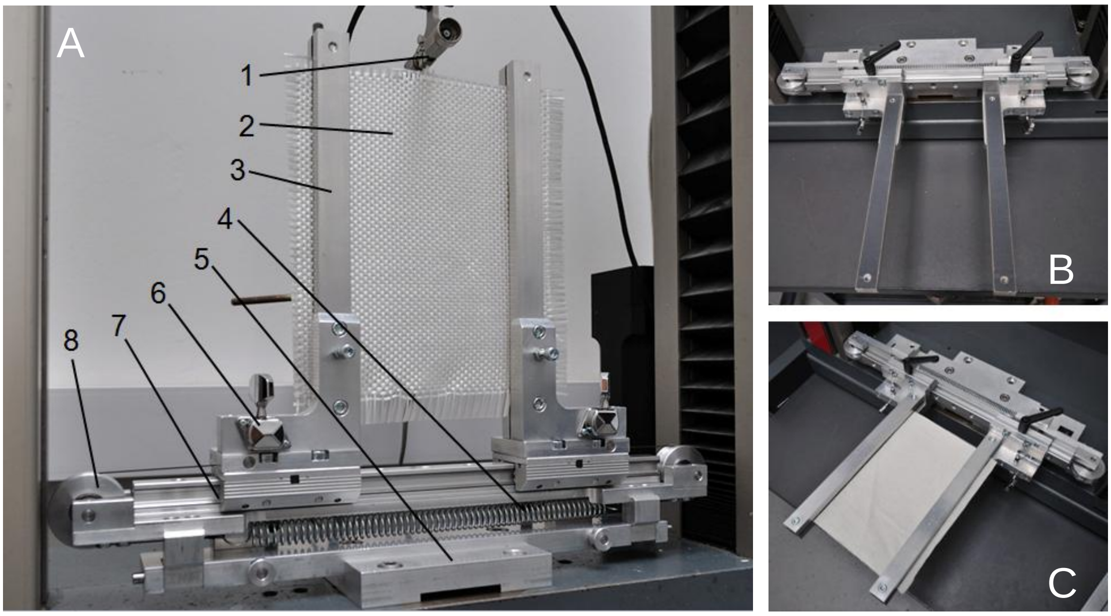

Figure 3. Apparatus for determining shear properties of textiles at yarn pull-out test. A: beginning of test, B: tilted to horizontal position, C: specimen gripping, 1: clamping unit connected to the crosshead of the tensile tester, 2: test specimen, 3: clamps, 4: pretension spring, 5: motherboard, 6: gears for adjusting pretension, 7: linear bearing, 8: rollers with bearings

Both the shear properties and the yarn-pull out behavior was determined to demonstrate the applicability of the device. Figures 4A and 4B demonstrate the deformation of the test samples cut in 0° (warp) and 45°directions, respectively. It can be seen that wrinkles appeared in the case of the latter sample. At different directions, such as 15°and 30°assymetrical wrinkles appeared showing asymmetrical strain state and the distances of the clamps were different at left and right side, accordingly.

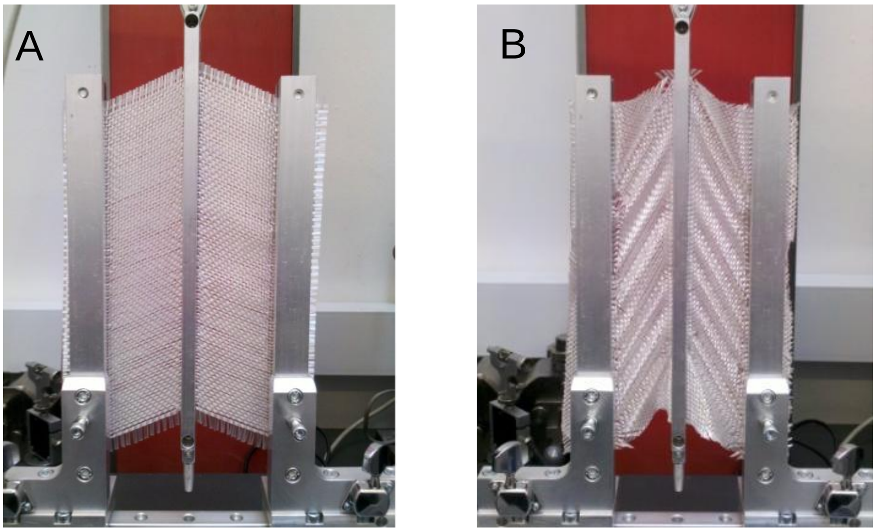

Figure 4. Deformation of the sample at shear test. A: 0°direction, B: 45°direction

The shear stress diagrams can be seen in Figure 5. The test in 45°cutting direction resulted in higher shear moduli and stresses as well. After the initial section the diagrams are near-linear before reaching 10°angle in both cases. The deviations are quite low indicating that the apparatus gives reproducible results. At the diagonal (45°) sample the curves are not smooth indicating that at some points sticking friction (stick-slip) blocked the free displacement of the rovings on one another.

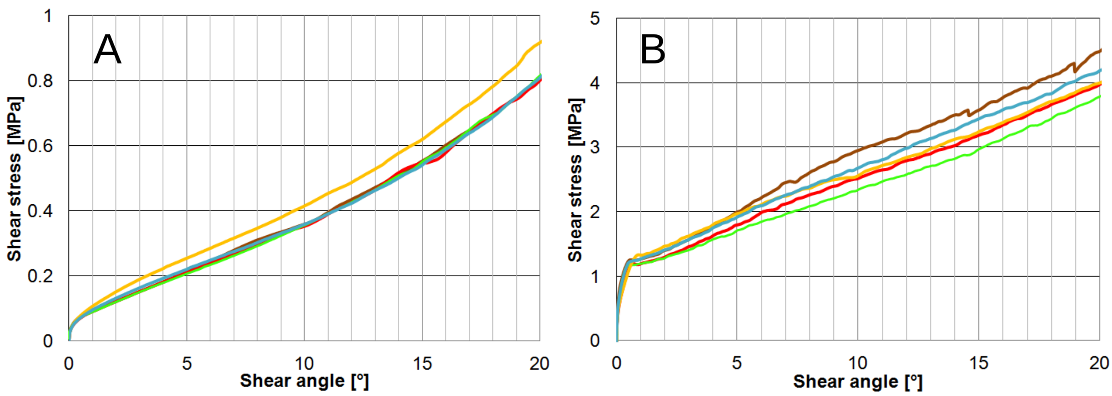

Figure 5. Shear diagrams measured with the aid of the designed apparatus. Samples cut at: A: 0°direction B: 45°direction

Some of the results of the yarn pull-out tests are shown in Figure 6. At this test one roving is slightly pulled out by hand to be able to grip it. Therefore the pull-out length was slightly different in each case. 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.

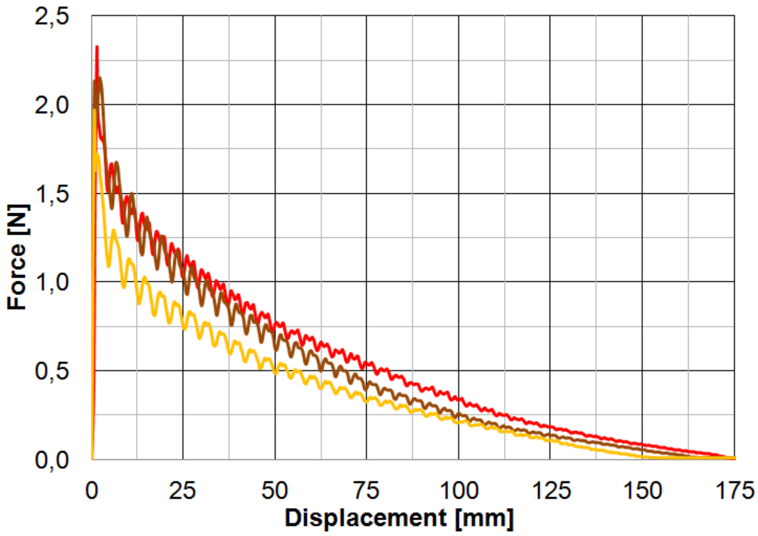

Figure 6. Brief results of the yarn pull-out tests

Conclusion

A simple apparatus was designed and built for the investigation of shear properties of various textiles. The test method is akin to KES-FB system, but a symmetrical arrangement is applied and it makes possible to carry out yarn pull-out tests with the same apparatus. The sample undergoes a pretension during the tests that is generated by a steel spring in order to regulate the stress-state. As the clamps can be fixed at any positions it also makes possible to carry out tests with constant gripping distance.
The pretension, the distance of the clamps can be adjusted and various central clamps can be applied, therefore different sheet-like textiles in different sizes can be tested. In our study a plain weave glass fabric reinforcement was chosen for the experiments. The results demonstrated that the device can be used for both yarn pull-out and shear tests as the deviations of the recorded values are low.

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