TEXTEST® – MULTIAXIAL PLANAR TESTING EQUIPMENT

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Abstract: The mechanical and fatigue behaviour of materials under multiaxial loading is determinant to characterize, improve and predict the performance, durability and failure of anisotropic structures. To replicate these conditions and assess, in a more realistic way, the behaviour of these structures under combined stresses, a multiaxial testing machine – TexTest – was designed and manufactured.
The equipment is able to perform tensile and fatigue testing on 4 axes at 45°, on a force range varying from 10 N to 10 kN/axis and at a testing speed adjusted from 5 to 500 mm/min. Besides pre-defined testing procedures the equipment can be programmed to meet specific testing conditions.

Keywords: Tensile testing, Fatigue testing, Multiaxial testing, TexTest®.

1. Introduction

Tensile and fatigue testing is one of the most important quality control assessment methods used for product certification of materials for technical applications, such as geotextiles and textile-based composites. In addition this data is extensively used in the design of products and also sometimes applied on component life assessment.
However, so far this data is mainly based on uniaxial or biaxial testing which leads to an insufficient characterization of the mechanical and fatigue behaviour of anisotropic (directionally-dependent) structures when simultaneously subjected to multidirectional stresses.
To overcome these limitations and to achieve a better understanding of the behaviour of 2D complex structures under combined stresses, a multiaxial force planar system – *TexTest* – was investigated, designed and developed.

2. Equipment specifications

Designed to evaluate the mechanical behaviour and performance of materials with planar structures, such as fabrics, composites and laminates, the testing system *TexTest* is able to perform tensile, compression and fatigue testing on 4 mobile axis at 45° (2 directions per axis), on a force range up to 10 kN/axis. Besides pre-defined testing procedures, the equipment can be programmed to different testing conditions, namely:

Pre-load;
Testing speed;
Maximum elongation;
Maximum load;
Number of cycles on fatigue testing.

The jaws displacement range varies from 260 to 700 mm and speed can be adjusted between 5 and 500 mm/min, with a 0,1 mm displacement resolution.
This equipment is actually capable of performing 3 types of tests:

- *Breaking test*: a test consisting in applying an increasing load to the specimen up to collapse;
- *Constant Load test*: the specimen is subjected to a constant reference load during a preset period of time, in order to follow the material and structure behaviour under these conditions. Collapse is not reached;
- *Fatigue test*: the specimen is subjected to a number of cycles of a predefined multiaxial elongation.

In table 1 the technical characteristics of the equipment are presented.

Table 1- Technical characteristics

Pre-load (N)	Min: 10	Max: 10k
Testing speed (mm/min)	Min: 5	Max: 500
Distance between jaws (mm)	Min: 260	Max: 700
Type of Test	CRE (Constant Rate of Extension)	
	CRL (Constant Rate of Load)	
	Fatigue Test	
Precision Class	OIML R 65	0,5
EQUIPMENT DIMENSION	Diameter (mm)	3020

3. Textest design

The equipment was designed with an octagonal prismatic central block (in grey in figure 1), where 8 platforms (in blue in figure 1) are rigidly attached in a radial orientation. Each platform is the bed for an "arm", responsible for applying a force and displacement to one of the 8 jaws where the sample specimen is attached.

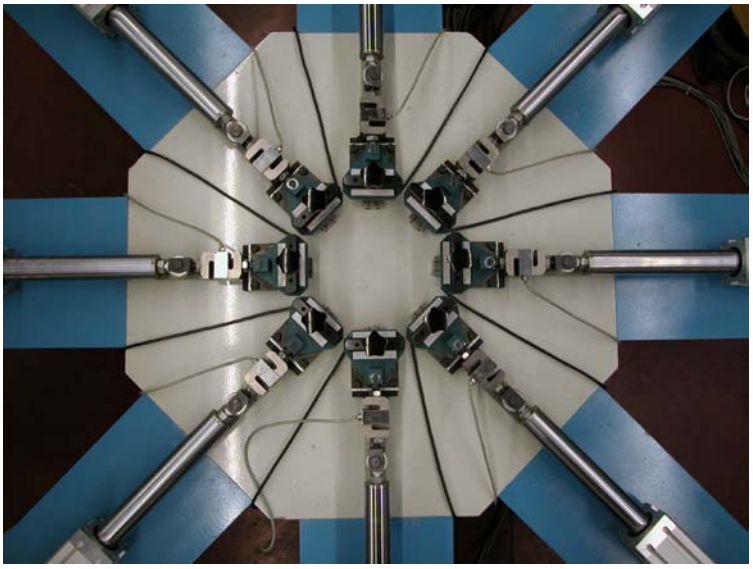


Fig. 1 - Top view of TexTest equipment

Each one of these 8 "arms" is made up of an electric actuator with speed reducer, coupled to a linear drive, in series with a load cell and a gripping jaw.
The rotational movement of the motor is converted into linear displacement of the jaw. A geared motor is responsible for low speed rotary motion and high torque, which is turned into linear displacement and force applied to the jaw. The main advantage of this mechanical solution is an overall axial alignment of the linear drive with the applied force, thus eliminating any undesirable bending moments.
The load cell is the transducer that converts the physical value of the force applied to the test specimen into an electric signal that can be digitalized and acquired by the data acquisition system incorporated in the computer controlled system. As it can only work under uniaxial stress, a pivoted coupling was provided.
The jaw is responsible for grabbing the test specimen by friction, therefore eliminating any slipping from the jaw. The gripping load is applied by a manually driven screw handle, therefore simplifying the design and eliminating any need for pneumatic pressure or complex and heavy electric actuators. In the interest of cleanliness, hydraulics has always been ruled out.
A slide carriage supports each jaw that can travel along a linear dry bearing, responsible for the correct alignment of the test specimen displacement. The complete equipment is represented in figure 2.

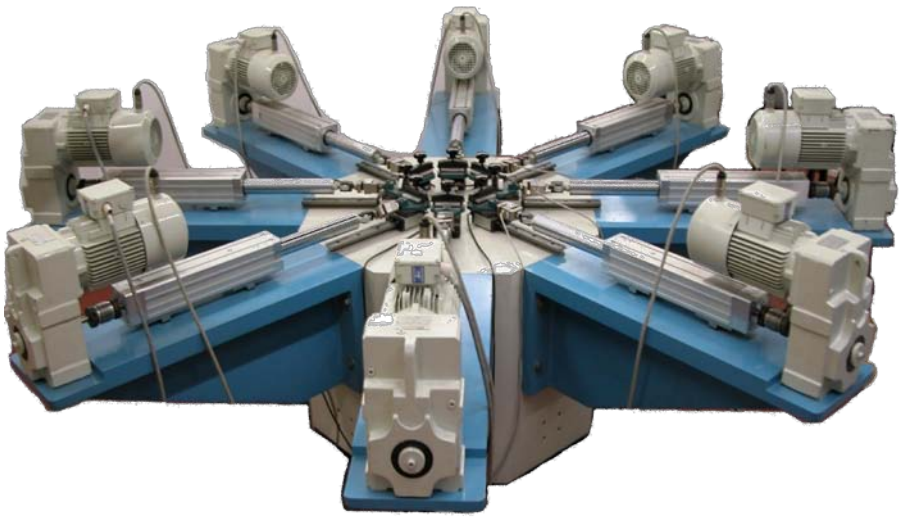


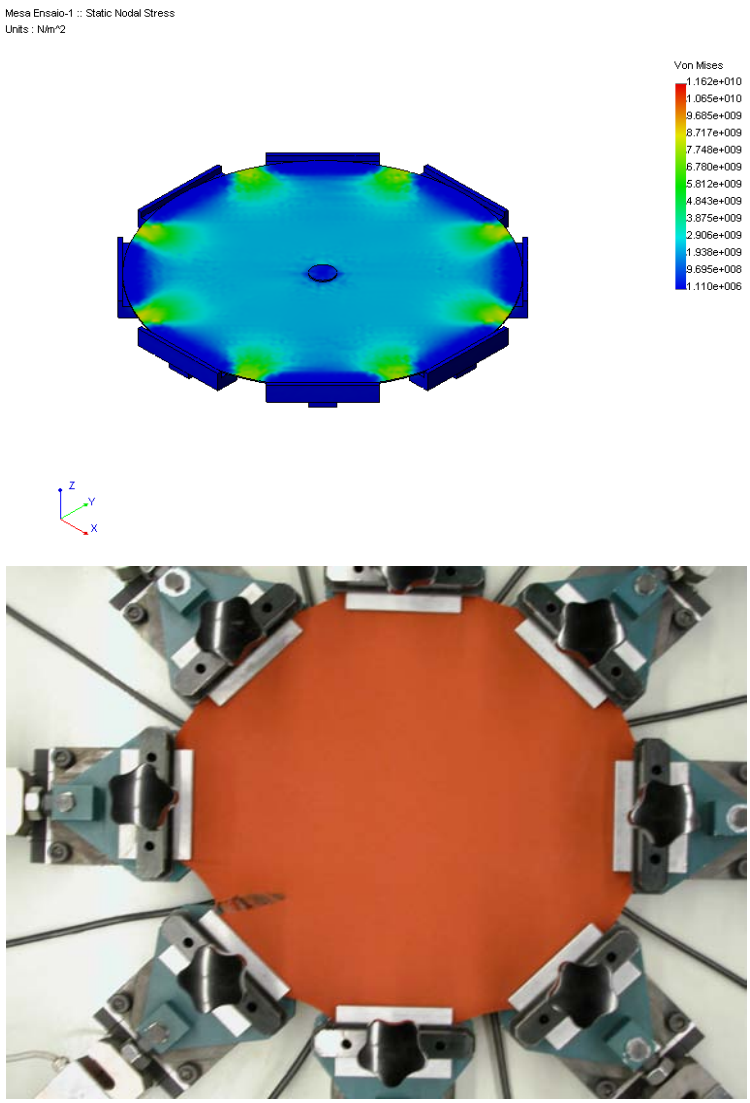
Fig. 2 - TexTest multiaxial testing equipment

3. Test procedure and method

Due to the functional characteristics of the *TexTest* equipment, uniaxial and multiaxial tests (biaxial included) can be carried out either by using the available standard methods (such as in uniaxial testing) or the developed testing procedures and methods specified for this equipment. In the establishment of test conditions, the parameters that were considered to most influence the validity of the test were the shape and dimensions of the test specimens and the design and face coating of the jaws. Figure 3 shows the distribution of forces on the round test specimen selected for multiaxial testing and the corresponding view on the machine. A similar study was carried out to determine the adequate shape of the test specimen for the biaxial testing. A cruciform shape led to the best results.

The reliability and precision of the test method was also determined.

Tests reproducibility has been calculated to assess data homogeneity. The statistical analysis that was carried out demonstrated that for a significance level of 5%, the measurement data obtained with the *TexTest* equipment is reproducible.



4. TEXTEST results

Several sets of tests were performed on a 2D woven fabric material in order to assess, for the different types of tests (CRE, CRL, Cyclic testing), the performance behaviour of an anisotropic material under different stress conditions.

The evaluation of material strength and elongation under uniaxial loading was conducted according to standard methods and for multiaxial loading (on 2 and 4 axis) according to the testing methods developed for this equipment. The results of different test typologies obtained under biaxial or multiaxial stress are presented on figures 4, 5 and 6.

All the results are presented in a graphical mode and the values of the measured force, elongation and extension characteristics are also depicted.

These results are also available on a report sheet that includes data regarding testing machine settings (pre-load, testing speed, gauge, elongation and force ranges) and identification headers. These results can also be treated using other statistical software tools.

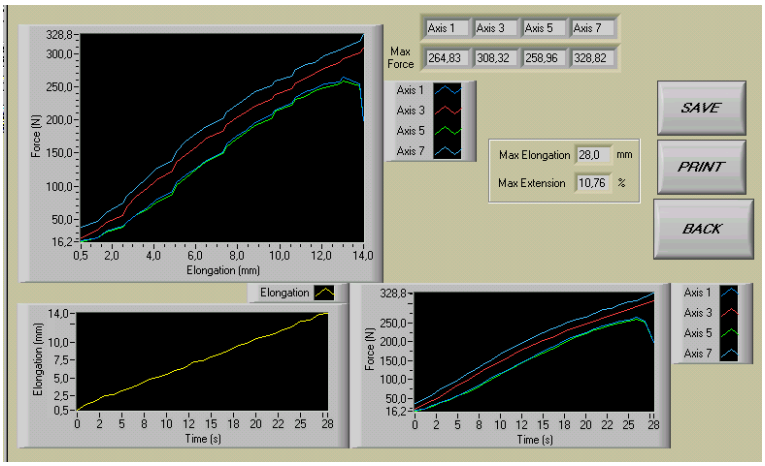


Fig. 4- CRE Breaking test under biaxial loading

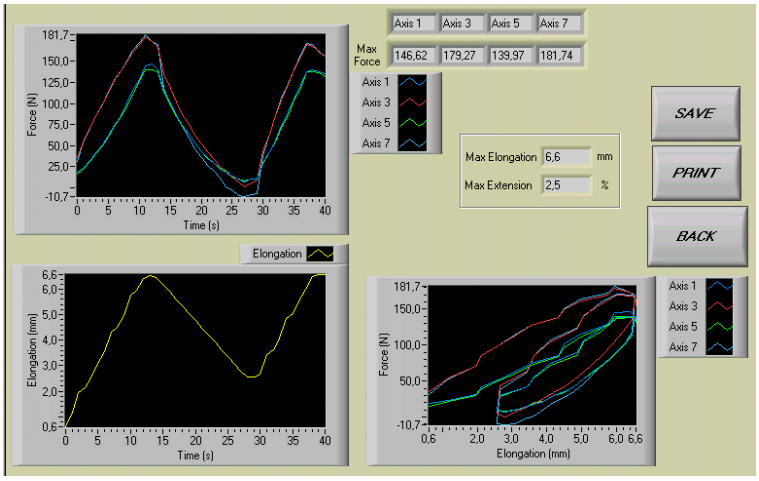


Fig. 5 - Fatigue test: The number of cycles as well as the elongation and force are independently programmable

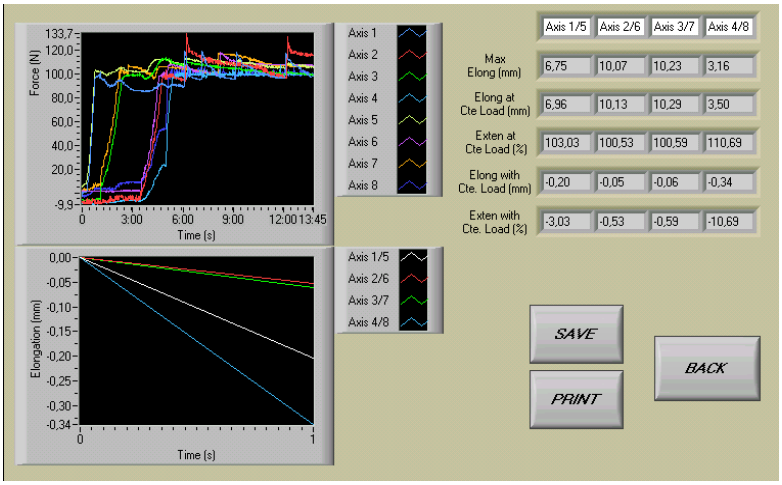


Fig. 6 - CRL Test under multiaxial loading (for the 8 actuators over the 4 axes)

5. Comparative analysis

The ability to characterize, predict and improve, in a more realistic way, the mechanical and fatigue behaviour of 2D materials is the main objective of the *TexTest* equipment.

To study the performance behaviour of the materials under uniaxial or multiaxial (2 and 4 axes) loading, an experiment was designed and a comparative analysis of the measured results was carried out.

Figures 7 and 8 show the forces obtained on the experiment when a Constant Rate of Extension test was performed.

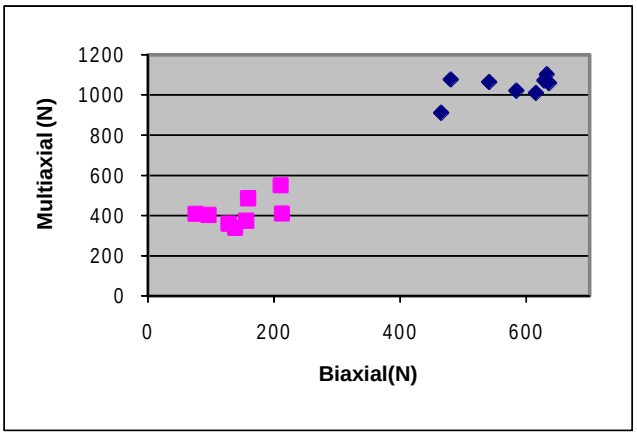


Fig. 7 - Comparison between forces obtained under biaxial and multiaxial (4 axes) stress

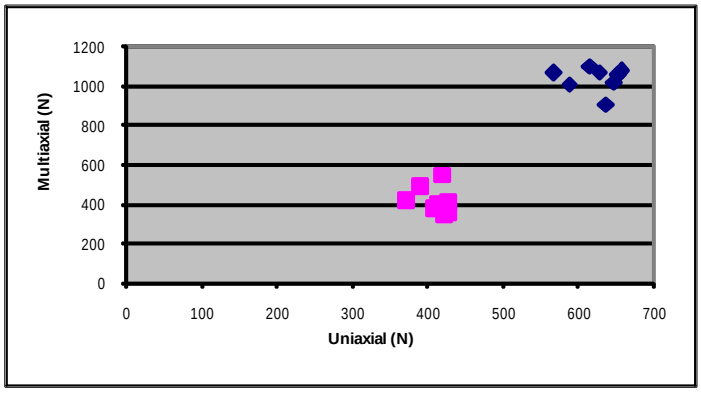


Fig. 8 - Comparison between forces obtained under uniaxial and multiaxial (4 axes) stress

The results obtained clearly show that the mechanical performance of the material varies with the direction of the applied forces and, with this material, the maximum forces are obtained under multiaxial (4 axes) loading. This implies that a re-arrangement of the yarns in the structure may have occurred, changing fabric geometry and leading to a higher resistance to break of the whole structure.

To better understand the mechanical and fatigue behaviour of 2D structures under multiaxial stresses, experiments are being carried out on other materials.

6. Conclusions

The *TexTest* equipment is an innovative product with a number of advantages relatively to the existing testing machines, namely in terms of versatility, as it allows uniaxial, biaxial and multiaxial (4 axes) testing and. Validation tests already carried out proved the reliability of the equipment, test reproducibility and repeatability.

The *TexTest* multiaxial planar testing system, test methodologies and procedures are particularly useful in the following situations:

- Design and development of new 2D anisotropic structures with a controlled degree of anisotropy, enhanced characteristics and performance under multiaxial forces;
- Quality control of fabrics (multiaxial or traditional textiles).

So far, the fabrics strength to multiaxial loading is measured by “bursting tests” which doesn’t allow the convenient simulation of planar multiaxial test conditions.

7. Bibliography

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