DRAPETEST
Automatic Drapability Tester
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The behavior of standard- and non-crimp fabrics in forming and draping is of importance in any production process of non-flat, fabric-reinforced composite parts. As automation of such production processes progresses, drapability and the detection of defects during draping like gaps, loops, or wrinkles become even more important.

DRAPESTEST, a new automatic drapability tester, allows to automatically characterize drapability and the formation of defects during draping and forming. The tester combines the measurement of the force, which is required for forming, with an optical analysis of small-scale defects such as gaps and loops by means of image analysis. An optional triangulation sensor can determine large-scale defects such as wrinkles.

As a standardized simulation of the draping process a flat circular sample of the fabric to be tested is deformed at its center by means of a motor-driven piston. A camera with an appropriate illumination inspects the sample at several elevation steps while the sample is rotated in order to inspect a maximum percentage of its surface. In the same manner the sample is scanned by the optional triangulation sensor.

A Windows® PC is connected to the instrument via USB. It is used for parameterization and control of the test, the image analysis, as well as for the evaluation, storage, and display of the measured data.

DRAPESTEST is suited for fabrics made of glass, Carbon, Aramid, and similar materials. It is based on an earlier development by SAERTEX, a leading producer of non-crimp fabrics, and proved its function and the relevance of results in practice. Image analysis technology developed at the Faserinstitut Bremen (FIBRE) allows the automatic detection of faults.
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Function Principle

DRAPETEST is based on an idea and earlier prototype produced by SAERTEX, a leading producer of non-crimp (engineered) fabrics. As a standardized simulation of the draping process a flat circular sample of the fabric to be tested is deformed at its center from below by means of a motor-driven calotte having a ball-shaped top. The sample is held back by means of a clamping ring and a membrane system which is subject to controlled air pressure. All surfaces in contact with the sample have a surface coating with a low coefficient of friction, so that varying the pressure allows to cover a wide range of retaining forces and the sample will not be damaged. The tester is connected to a standard Windows® PC for setting test conditions and for data acquisition and storage. Test conditions can be stored in parameter sets, which contain all information about the test, the evaluation, and the form of the protocol to be generated. The number of different parameter sets is unlimited.

Sample diameter can vary from 310 mm to 330 mm, the latter being recommended as at this size the sample will still be completely inside of the retaining mechanism up to an elevation of about 90 mm. Samples having a thickness of up to about 4 mm can be clamped with the standard clamping ring. Clamping rings for thicker samples can be manufactured.

A force transducer inside the calotte measures the force which is required to form the sample. Since force is subject to relaxation to a certain extent both maximum- and average force at each elevation level are stored. The calotte drive has a maximum elevation of 100 mm allowing a strong deformation of the sample, if required. Elevation steps are freely programmable in the parameter set in tens of a millimeter. A test could e.g. contain the elevations 0, 20, 40, 60, 75, 85, 95 mm.

Figure 1: Principle arrangement of the sample, calotte, and clamping ring at elevations 0 mm, 40 mm, and 80 mm.

In contrast to the original prototype by SAERTEX, the new tester is equipped with additional optical detection of the defects arising during forming:

A high-resolution camera with an appropriate illumination inspects the sample for fine-scale defects, such as gaps and changes in fiber orientation. The picture quality thus has to allow resolving the individual fibers. The image field has a size of about 30 mm x 40 mm. In order to inspect a maximum percentage of the surface the camera can be positioned in three axis and the sample can rotate by more than 360 degrees.
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The angle range to be inspected as well as the number of pictures to be taken around can again be defined within the parameter set. A slight overlap of the pictures is recommended.

Since the camera can take a 2-dimensional picture of the sample only, an additional laser-triangulation sensor is used in order to define the surface morphology of the sample before and after forming. The sample is rotated while the laser sensor scans the sample continuously. In this way DRAPETEST detects large-scale defects such as wrinkles and plies.

Figure 2: Arrangement of detail camera (left), overhead camera (top), and laser-triangulation sensor (right) over the sample at an elevation of 40 mm.

A second, medium-resolution camera (overhead camera) takes pictures of the sample before and after the test. At this stage one picture is taken each, with the calotte still at maximum elevation and with the calotte back to elevation 0 mm. This allows evaluating the retraction of a sample in the different orientations after having been draped into a form.

A complete drapability test on the instrument comprises the following steps

1. Take the clamping ring out.
2. Insert the circular sample. The line of the laser triangulation sensor is projected onto the sample in order to ease the proper orientation of the sample.
3. Press the green control button to take an overhead picture.
4. Insert the clamping ring and close the locking knobs.
5. Press the green control button in order to establish the clamping pressure and start testing.
6. DRAPETEST starts running taking the programmed detail pictures while rotating the sample. When all detail pictures are taken, the sample is rotated again for scanning the surface with the triangulation sensor.

Step 6 is repeated for all other programmed elevation steps. The tester indicates when testing at all elevation steps is completed.

7. Take the clamping ring out.
8. Press the green control button in order to take the second overhead picture.
9. Press the green button to drive the calotte down and take the final overhead picture.
10. Take the sample out.

A typical test with several elevation steps takes between 5 and 15 minutes per sample.
Figure 3: Realization of DRAPESTEST. All interactions with the tester during testing are controlled by the control keys on the tester.
Results

The primary result of the basic instrument is the force measured by the force transducer inside the calotte. This force is composed of the force required to form the sample and the force it needs to pull the sample out of the clamping ring.

The below measurements have been carried out on a glass-fiber non-crimp fabric with a tricot warp-knit binding. Measuring force/elevation-curves as shown in Figure 4 at different pressure levels shall allow to distinguish between the forming and the friction properties.

![Graph showing average values of measured force vs calotte elevation](image)

**Figure 4:** Average values of the force measured by the force transducer at different elevations for two similar samples. The measurement was performed at high clamping pressure.

From the pictures taken by the high-resolution detail camera the image analysis software determines the width, length, and area of gaps, the degree of fiber misalignment, all as functions of the elevation and orientation of the camera towards the sample. Area and volume of wrinkles are measured using the laser-triangulation sensor. With the overhead camera the overall deformation of the original circular shape of the specimen can be measured. From this data a complete description of the drapability of a fabric can be derived. The tester automatically groups the measured areas of gaps and fiber misalignment into three user-definable classes. This gives a very quick impression of the draping effects that result from the deformation of the specimen by the spherical calotte. The classes are defined by the gap width and the degree of misalignment. This can be defined as the intensity of the effect. The extent of the effect would then be the overall area affected by e.g. gaps, independent of the width of the individual gaps. For the sake of brevity only results of the gap and fiber alignment detection are shown here.
Figure 5: Results of the fiber orientation measurement after an elevation of 95 mm at 0° (left picture) and 90° (right picture) orientation relative to the upper fiber layer. Large misalignments are colored red, medium misalignments yellow and small misalignments green. At the 90° position more misalignments have occurred compared to the 0° position. This corresponds to the diagrams in Figure 6.

The following illustrations show the average of five repetitions of the same experiments; with a greater fiber misalignment at the 90° position where the fibers of the upper layer run perpendicularly to the curvature of the hemisphere.

Figure 6: Fiber misalignment at two different orientations and various elevation levels.
The data for the gap width distribution are even more interesting. Gaps are already present in the flat specimen due to binding yarn. At 0 mm elevation the gap width distribution is equal at the 0° and at the 90° position. Any difference is solely due to manufacturing tolerances. When the specimen is deformed, the gaps at the 0° position slowly close, while the gaps at the 90° position are opened wide. This can be traced back to the straightening of the fibers at the 0° position while the fibers at the 90° position fan out to cover the increased area of the hemispherical surface compared to the flat plane.

Figure 7: Results of the gap detection after an elevation of 95 mm at 0° and 90° position. Wide gaps are colored red, medium gaps yellow and narrow gaps green. At the 90° position more wide gaps have occurred compared to the 0° position. This corresponds to the diagram in Figure 8

Figure 8: Gap width distribution at different orientations and various elevation levels.
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Although image analysis on carbon fiber fabrics is tough because of the high reflectivity of carbon fibers, the detection of gaps and misalignments works well for these specimens, too.

Figure 9: Results of the classification of misalignment (left picture) and gaps in a carbon fiber NCF

For the misalignment classification in woven fabrics the image analysis works similar as for NCF. For the gap classification, it detects the largest diagonal line as the gap width.

Figure 10: Results of the classification of fiber misalignment (left picture) and gaps in a glass fiber woven fabric.

The laser-triangulation sensor delivers data, which – after filtering – can be used to generate a 3D model of the specimen and/or false color images. A statistical evaluation of the elevation at a given radius of the sample can used to describe the unevenness of the sample.
Figure 11: 3D-model and false color image generated from data of the laser-triangulation sensor taken on a carbon fiber sample.

The pictures from the overhead camera also show the general deformation of the round specimen. This deformation occurs because the different fiber alignments in the non-crimp fabrics are pulled in different directions once the specimen is deformed. This deformation of the sample can be quantified by means of the image analysis software, too.

Figure 12: Deformation of specimen for glass (left picture) and carbon as documented in pictures of the overhead camera. The right hand picture also shows results of the image analysis software: The red line follows the specimen contour; the yellow circle describes a circle with the same area as the specimen.

Conclusion and Outlook

The quantitative results of the DRAPETEST using digital image analysis and laser triangulation can lead to reproducible and detailed descriptions of the drapability of reinforcement fabrics. The data can be used as input for numerical simulations or to verify existing material models. The existence of a standardized testing method and equipment will also simplify the communication between researchers, designers and manufacturers. This could lead to an international harmonization of drapability testing.

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**Technical data**

- Sample diameter: 310 - 330 mm;
- Maximum elevation (path of piston): 100 mm;
- Mains supply: 230 V, 50 (60) Hz, current requirement less than 2 A;
- Lacquer finish: RAL 9006/5002;
- Dimensions: height 820 mm, width 620 mm, depth 680 mm;
- Weight: approx. 70 kg;

The above technical contents can be subject to changes by Textechno.