ROUND – ROBIN FORMABILITY STUDY

Glass/polypropylene woven fabrics: shear diagrams and full field strain measurements

CORRECTED REPORT

Tzvetelina Stoilova
Stepan Lomov

Leuven, August 2005
Abstract

This report presents results of measuring shear properties of three types of glass/polypropylene fabrics (balanced and unbalanced fabrics, plain and twill 2/2 weaves). Picture frame tests are performed together with full field strain mapping (Aramis system).
LIST OF FIGURES

Figure 2.1. Fabric 1 ................................................................. 7
Figure 2.2. Fabric 2 ................................................................. 8
Figure 2.3. Fabric 3 ................................................................. 8
Figure 2.4. Shear diagram – Fabric 1. Error! Bookmark not defined.
Figure 2.5. Shear diagram – Fabric 2 Error! Bookmark not defined.
Figure 2.6. Shear diagram – Fabric 3 Error! Bookmark not defined.
Figure 2.7. Comparison of the shear diagrams – 1st cycle................................. 9
Figure 4.1. Picture frame test (Fabric 1, sample 4/ 2nd cycle) ............................ 13
Figure 4.2 “Bad” diagrams. Fabric 1................................................................. 14
Figure 4.3 Shear diagram of Fabric 1, as measured by the picture frame. The error has show standard deviation ................................................................. 14
Figure 4.4. Shear strain field. Fabric 1, sample # 4, cycle 2. See Figure 4.5 for the maximum and minimum values of the strain in each image. ............................................. 15
Figure 4.5. Typical dependency of the shear angle of the fabric on the shear angle of the frame, Fabric 1, sample # 4, cycle 2....................... Error! Bookmark not defined.
Figure 4.6. Average shear angle of the fabric vs shear angle of the frame (all the samples) and the correction equation. Fabric 1................................. Error! Bookmark not defined.
Figure 4.7 Shear diagram of the Fabric 1 after correction....... Error! Bookmark not defined.
Figure 5.1. Picture frame test (Fabric 2, sample 4/ 2nd cycle) ............................ 16
Figure 5.2 Shear diagram of Fabric 2, as measured by the picture frame. The error has show standard deviation ................................................................. 17
Figure 5.3. Shear strain field. Fabric 2, sample # 9, cycle 2. See Figure 5.4 for the maximum and minimum values of the strain in each image. ............................................. 18
Figure 5.4. Typical dependency of the shear angle of the fabric on the shear angle of the frame, Fabric 2, sample #9, cycle 2................. Error! Bookmark not defined.
Figure 5.5. Average shear angle of the fabric vs shear angle of the frame (all the samples) and the correction equation. Fabric 2................................. Error! Bookmark not defined.
Figure 5.6 Shear diagram of the Fabric 2 after correction....... Error! Bookmark not defined.
Figure 5.1. Picture frame test (Fabric 3, sample 4/ 2nd cycle) ............................ 19
Figure 5.2 Shear diagram of Fabric 3, as measured by the picture frame. The error has show standard deviation ................................................................. 20
Figure 6.3. Shear strain field. Fabric 3, sample #2, cycle 2. See Figure 5.4 for the maximum and minimum values of the strain in each image. ............................................. 21
Figure 5.4. Typical dependency of the shear angle of the fabric on the shear angle of the frame, Fabric 3, sample #2, cycle 2......................... Error! Bookmark not defined.
Figure 5.5. Average shear angle of the fabric vs shear angle of the frame (all the samples) and the correction equation. Fabric 3................................. Error! Bookmark not defined.
Figure 5.6 Shear diagram of the Fabric 3 after correction....... Error! Bookmark not defined.
LIST OF TABLES

Table 2.1 Parameters of the fabrics ................................................................. 7
Table 3.1 Shear angle: Calculated with (3.3) and with (3.4).... Error! Bookmark not defined.
1 INTRODUCTION

The work reported in this document, is a part of a round-robin deformability study of glass/PP fabrics, initiated at the ESAFORM 2002 conference in Krakow. This report describes measurements of the shear behaviour of woven fabrics produced by Saint-Gobain. The fabrics are woven with commingled yarns, which contain glass/PP in relation 60/40, in twill and plain weave.

For the full characterisation of the fabrics see the accompanying report:


The measurement program included:

- Tensile test on the Instron 4467 machine at 20 mm/min
- Simultaneous registration of the strain field on the Aramis system.

The tests were performed by Tzvetelina Stoilova – Marie Curie Fellow (from Technical University of Sofia, Bulgaria) at the department MTM with the help of Prof. Stepan Lomov.

Strain mapping process on Aramis system – 2 D full-field registration of shear strain on the samples and processing of the data was explained by Sergey Kondratiev. Setup of the machine was prepared Kris Van de Staey and Bart Pelgrims.

This report contains corrected:

1. Data processing according to:

Picture frame. Description of the device. Experimental technique. CORRECTED REPORT // S.V.Lomov, Dept MTM, KULeuven, August 2005

2. ARAMIS data processing
2 SUMMARY

2.1 Fabrics

Table 2.1 Parameters of the fabrics

<table>
<thead>
<tr>
<th></th>
<th>Fabric 1</th>
<th>Fabric 2</th>
<th>Fabric 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer’s style</td>
<td>TPECU53XXX</td>
<td>TPEET44XXX</td>
<td>TPEET22XXX</td>
</tr>
<tr>
<td>Yarns</td>
<td>Glass/PP</td>
<td>Glass/PP</td>
<td>Glass/PP</td>
</tr>
<tr>
<td>Fibre diameter, µm</td>
<td>21</td>
<td>18.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Weave</td>
<td>Twill 2/2</td>
<td>Twill 2/2</td>
<td>Plain</td>
</tr>
<tr>
<td>Areal density, g/sq. m</td>
<td>1816</td>
<td>1485</td>
<td>743</td>
</tr>
<tr>
<td>Yarns linear density, tex</td>
<td>2x2400</td>
<td>1870 warp</td>
<td>1870</td>
</tr>
<tr>
<td></td>
<td>2x1870 weft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picks/ends count, yarn/cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warp</td>
<td>2.63</td>
<td>4.08</td>
<td>1.91</td>
</tr>
<tr>
<td>Weft</td>
<td>0.76</td>
<td>1.88</td>
<td>1.90</td>
</tr>
<tr>
<td>Yarn width in the fabric, mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warp</td>
<td>5.44 ± 0.76*</td>
<td>3.24 ± 0.214*</td>
<td>4.18±0.14*</td>
</tr>
<tr>
<td>Weft</td>
<td>7.16 ± 0.42*</td>
<td>4.64±0.40*</td>
<td>4.22± 0.15*</td>
</tr>
</tbody>
</table>

* standard deviation

Figure 2.1. Fabric 1
Figure 2.2. Fabric 2

Figure 2.3. Fabric 3
2.2 Shear diagrams

![Shear diagrams](image)

*Figure 2.4. Comparison of the shear diagrams – 1st cycle*
3 EXPERIMENTAL ROUTINE AND DATA PROCESSING

3.1 Instron and the picture frame

Experimental technique of picture frame measurements is described in the report:

Picture frame. Description of the device. Experimental routine / S.V.Lomov,
Department MTM, K.U.Leuven, July 2003

Test speed was 20 mm/min. Only “good” tests were used for data processing. Experiments were carried on to get at least three valid registrations of the shear curve for each fabric type. Three shear cycles were registered.

It was not possible to measure pretension of the fabric, as proposed in this report, because of difficulties with marking the surface of the fabrics with a sufficient precision.

The data processing gives shear diagrams “shear force – shear angle of the picture frame”. These were further processed into diagrams “shear force – average shear angle of the fabric” using the results of strain mapping.

3.2 Strain mapping

2D full field measurement was performed using Aramis system.

3.2.1 Parameters of the Aramis strain processing

Facet step 11 pix
Facet size 13 pix = 9.3 mm
1 pix 0.71 mm

3.2.2 Data measured by Aramis and true shear angle

The ARAMIS® software (http://www.gom.com/) analyses the sequence of grey scale images of the deforming sample and calculates the strain field on it’s surface. 2D registration (one camera, image size 1280x1024 pixels) was used in the measurements; a limited number of tests were registered in the 3D stereoscopic regime. Because of the inherent texture of the fabric surface, there was no need to use speckle painting of the sample, normally recommended for ARAMIS measurements. Image capturing and processing leads to a certain noise in the final strain field, which is estimated not to exceed 0.2% of the strain. 60 images (one per second) were normally captured in each test.

The ARAMIS provides positions of the corners of the deforming facets, initially square and “glued” to the fabric surface (Fig. 3.1). Based on these data, the local shear angle of the fabric is calculated:

\[ \gamma = \frac{\pi}{2} - \alpha_{ACBD} \]

where \( \alpha_{ACBD} \) is the angle between diagonals AC and BD of the facet, which represents the angle between the yarns, as the diagonals in the initial configuration go along the yarns.

The dotted line in Fig. 3.1c shows the yarn path, which is close to the normal to the frame side near the gripping (line 1). Line 3, connecting the points of gripping of the yarn, is parallel to the frame side. Hence, local shear angle of the fabric, defined by the yarn direction (line 2), should be larger then the angle of the frame.
The results are given in Fig. 3.2. It shows the difference between local shear angle of the fabric and the corresponding shear angle of the frame: averaged over the central part of the sample, standard deviation, minimum and maximum value over this area.

The average shear angle of the fabric is very close to the frame shear. The difference is less than 2° for one of the glass/PP fabrics, and reaches 4…5° at 30…35° frame shear for the other two glass/PP fabrics. The larger difference in the latter case can be explained by the much higher linear density of the yarns, which increases the deviating effect of the rigid clamping. The measured local shear angle of the fabric is always higher then the shear of the frame (drop of the curves at the end should be attributed to error in the measurements after onset of wrinkling), as it is expected.

For the glass/PP fabric the scatter of the local shear angle is large: the difference between the maximum and minimum local angles reaches 10° at the frame shear 20° and increases fast. However, the standard deviation is still small (less then few degrees). The very high and very low values occurring in several spots of the image (increasing the maximum and decreasing the minimum) may be explained by the coarse structure of the fabric.
Fig. 3.2 Difference of the local shear angle of the fabric and shear angle of the frame. Error bars indicate standard deviation in five tests.
4 Details of the tests. Fabric 1.

4.1 Picture frame test

Figure 4.1. Picture frame test (Fabric 1, sample 4/2nd cycle)

Full set of the images is on the CD.
 Remarks:

- Fabric #1 has big thickness, it is the thickest of the three fabrics. The mounting of it on the frame was not easy, because the structure of the fabric is not balanced and it is very difficult to position it on the frame. No problems were encountered with the with clamping on the frame.
- Some of the tests resulted in “bad” diagrams (Figure 4.2). These were not used for the final data processing.
- No wrinkling was detected up to 36° of the frame shear. The locking angle $\cos^{-1}(w/p)$, where $w$ is the yarn width, $p$ is the yarn spacing is different for warp and weft: 22° and 57° correspondingly. The average of 39° corresponds to the observed onset of the wrinkling.

4.2 Strain mapping

Figure 4.4 shows typical results of the strain field registration.
Figure 4.4. Shear strain field. Fabric 1, sample # 4, cycle 2. See Error! Reference source not found. for the maximum and minimum values of the strain in each image.
5 DETAILS OF THE TESTS. FABRIC 2.

5.1 Picture frame test

Figure 5.1. Picture frame test (Fabric 2, sample 4/ 2\textsuperscript{nd} cycle)

Full set of the images is on the CD.
Figure 5.2 Shear diagram of Fabric 2, as measured by the picture frame. The error bars show standard deviation.

Remarks:

- Fabric # 2 is thick but there were not any problems with the mounting and clamping of the samples on the frame.
- No “bad” tests were encountered.
- The onset of wrinkling was detected at 16°…38° of the frame shear (different tests). The locking angle $\text{acos}(w/p)$, where $w$ is the yarn width, $p$ is the yarn spacing is different for warp and weft: 25° and 29° correspondingly. The average of 27° corresponds to the observed onset of the wrinkling.

5.2 Strain mapping

Figure 5.3 shows typical results of the strain field registration.
Figure 5.3. Shear strain field. Fabric 2, sample # 9, cycle 2. See Error! Reference source not found. for the maximum and minimum values of the strain in each image.

Full set of the images is on the CD.
6 DETAILS OF THE TESTS. FABRIC 3.

6.1 Picture frame test

Figure 6.1. Picture frame test (Fabric 3, sample 4/ 2nd cycle)

Full set of the images is on the CD.
Figure 6.2 Shear diagram of Fabric 3, as measured by the picture frame. The error bars show standard deviation.

Remarks:

- Fabric # 3 is the thinnest of the three fabrics. The mounting of the sample and clamping was easy.
- No “bad” tests were encountered.
- The onset of wrinkling was detected at 27…36° of the frame shear (different tests). The locking angle $\cos(w/p)$, where $w$ is the yarn width, $p$ is the yarn spacing is different for warp and weft: 26° and 24° correspondingly. The average of 25° corresponds to the observed onset of the wrinkling.

6.2 Strain mapping

Figure 6.3 shows typical results of the strain field registration. The scale shows von Mises technical strain, which is proportional to the local shear angle (see 3.2).
Figure 6.3. Shear strain field. Fabric 3, sample #2, cycle 2. See Reference source not found. for the maximum and minimum values of the strain in each image.

Full set of the images is on the CD.

<table>
<thead>
<tr>
<th>CD</th>
<th>Folder / subfolder</th>
<th>file</th>
<th>content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric # 1</td>
<td></td>
<td>F1.xls</td>
<td>Shear diagrams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>results</td>
<td>Instron results</td>
</tr>
<tr>
<td>Aramis</td>
<td></td>
<td>Mises F1.xls</td>
<td>Distribution of shear angle</td>
</tr>
<tr>
<td>Strain – mapping files</td>
<td></td>
<td></td>
<td>Aramis project files</td>
</tr>
<tr>
<td>images</td>
<td></td>
<td></td>
<td>Images by CCD camera</td>
</tr>
<tr>
<td>projects</td>
<td></td>
<td></td>
<td>Aramis project data</td>
</tr>
<tr>
<td>results</td>
<td></td>
<td></td>
<td>Field von Mises strain</td>
</tr>
<tr>
<td>Photos</td>
<td></td>
<td></td>
<td>Scanned pictures of fabric</td>
</tr>
<tr>
<td>Fabric # 2</td>
<td></td>
<td></td>
<td>The same</td>
</tr>
<tr>
<td>Fabric # 3</td>
<td></td>
<td></td>
<td>The same</td>
</tr>
</tbody>
</table>