Objective evaluation of steel fibre knitted fabric for automotive glass moulds

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Acknowledgments and publications

The presentation give an overview of work performed in collaboration between Bekaert and KU Leuven in 2009 – 2014

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1. Introduction. Objective evaluation of HRSM?
2. Experimental characterisation of steel knitted fabric deformability
3. Fabric thickness variation, sheet pretension and the glass quality
4. Oxidation influence
5. Conclusions and outlook
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Quality of the Heat Resistant Separation Material

- fibre production
- spinning
- knitting
- mould preparation
- glass quality
- glass production
Objective evaluation of fabric hand (Kawabata, 1970s)

Shear

Bending

Surface roughness

Compression

KES-F

Hand Values

Mechanical Parameter

Suit Appearance

Three Basic Components of Tailorability
Draping of composite reinforcements

Internal architecture of the reinforcement

Production

Deformation resistance and change of geometry

Compr. Shear Tension Bending

Drapeability and formability

local defects and micro-macro modelling
Mechanical characterisation of the fabric

Shear angle, °

Shear force, N/mm

Force [N/mm]

Elong [%]

0

0.002

0.004

0.006

0.008

0.01

0.012

0.014

1:5

1:2

1:1

2:1

5:1

0

0.005

0.01

0.015

0.02

0.025

0.03

0.035

0.04

0.045

0.05

0.055

0.06
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Biaxial tension

Bi-axial strain – load diagram
Shear: picture frame
Draping tests

Digital Image Correlation measurement: strains on the cloth surface
Finite elements simulation of draping

material model based on the deformability measurements
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Compression after biaxial tension and shear
Compression diagrams

After shearing

After biaxial pre-tension
Compressibility of the pre-tensed fabric

![Graph showing thickness vs. deformation for different fabrics and deformations.](image-url)

- **Steel fibres knitted fabric**
- **Thickness for 100kPa**

Data points for:
- Free x Free
- 10x10
- 10x0, 20x0
- 0x10, 0x20
- 5deg, 10deg, 15deg, 25deg

**Variables:**
- Deformation (5x5, 10x10, 15x15)
- Thickness (0.40 to 0.65 mm)

**Legend:**
- Different colors represent different deformation levels.
Test of the formed glass quality

cloth without pre-strain
cloth after 10% - 10% strain
Glass quality is higher for the pre-strained fabric

Possible reasons:

1. Sagging of the cloth if not pre-strained
2. The pre-strained cloth is less compressible, hence the cloth thickness variations are lower
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4. Oxidation influence

Steel fibres are affected by oxidation...

before oxidation

after $T^\circ$ exposure: 24 h in 650°C;
... changing the friction ...

friction measurement device @ TU Lodz

\[ \mu_{st} = \frac{1}{\alpha} (\ln P_1 - \ln P_0) \]

\[ \mu_{k} = \frac{1}{\alpha} (\ln P_2 - \ln P_0) \]

preload

sliding yarn

testing diagram
... and bending resistance of the yarns and tension of the cloth

\[
C_g I = \frac{F_x \cdot L^2}{z I} \cdot 10^{-2}; \quad C_g II = \frac{F_x \cdot L^2}{z II} \cdot 10^{-2} \quad [\mu N \cdot m^2]
\]

\[
C_g = C_g II + \frac{(C_g I - C_g II)(x II - 3)}{x II - x I} \quad [\mu N \cdot m^2]
\]
# Bending and friction

<table>
<thead>
<tr>
<th></th>
<th>Static friction coefficient</th>
<th>Kinetic friction coefficient</th>
<th>Static friction force (cN)</th>
<th>Kinetic friction force (cN)</th>
<th>Bending rigidity (μN·m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonoxidized</td>
<td>0.135 ± 0.004</td>
<td>0.110 ± 0.003</td>
<td>165 ± 6.8</td>
<td>122 ± 4.3</td>
<td>0.079 ± 0.015</td>
</tr>
<tr>
<td>oxidized</td>
<td>0.286 ± 0.021</td>
<td>0.213 ± 0.025</td>
<td>703 ± 120</td>
<td>373 ± 86</td>
<td>0.115 ± 0.007</td>
</tr>
<tr>
<td>Increase by</td>
<td>113%</td>
<td>93%</td>
<td>326%</td>
<td>205%</td>
<td>44%</td>
</tr>
</tbody>
</table>

The scatter shows standard deviation in 10 tests.

![Friction graphs for not-oxidized and oxidized yarn](image)
Biaxial tension

After oxidation:

- strength is retained
- deformation at low force increases significantly
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Conclusions and outlook

1. We have formulated the Cloth Objective Evaluation Approach for analysis of the links between the textile manufacturing process of HRSM, conditions for mounting of the fabric on the mould, and the glass quality.
2. The proposed testing procedure includes biaxial tension, shear (picture frame), and compression tests.
3. The experimental procedure has been validated as a tool for identification of material laws, necessary for finite element draping simulations.
4. Pre-straining of the cloth is favourable for the glass quality.
5. After the cloth exposure to high T°, the change of the surface properties (friction coefficient) and the tensile response makes the conditions of the fabric/glass interaction more severe.

Bekaert and KU Leuven invite new collaborations for continuation of this research direction, especially among the glass specialists.