Virtual Textiles and Textile Composites: WiseTex software

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[www.composites-kuleuven.be](http://www.composites-kuleuven.be)
Main publications


Contents

1. History and current status of WiseTex
2. Open data formats and scripting
3. Micromechanics and transformation into FE models
4. Conclusion: multi-scale integration
1. History and current status of WiseTex

2. Open data formats and scripting

3. Micromechanics and transformation into FE models

4. Conclusion: multi-scale integration
Integration of simulation tools for textile composites

Internal architecture of the reinforcement

Production

Deformation resistance and change of geometry
- Compr.
- Shear
- Tension
- Bending

Permeability

Performance

Mechanical properties and damage

Drapeability and formability

Impregnation

Structural analysis
WiseTex: Virtual textiles/composites

Internal geometry: textile unit cell

- WiseTex
- LamTex
- WeftKnit

Woven (2D and 3D)
Weft-knits
Braids
Laminates
NCF

Virtual reality

Meso-FE

WiseTex -> Abaqus
WiseTex -> Ansys (FETex)
SACOM MeshTex

Composite micromechanics (fast stiffness calculations)

TexComp

Permeability

Virtual reality

FlowTex
## WiseTex pre-history

<table>
<thead>
<tr>
<th>Year</th>
<th>St-Petersburg</th>
<th>Leuven</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>preliminary models</td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>CETKA – DOS</td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>CETKA – Windows</td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>3D coding algorithm</td>
<td>Preliminary models</td>
</tr>
<tr>
<td>1996</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td></td>
<td>PhD Gommers</td>
</tr>
<tr>
<td>1998</td>
<td>CETKA 3.1 “true 3D” textiles</td>
<td>PhD Vandeurzen</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td>FlexComp; TC3D</td>
</tr>
<tr>
<td>2000</td>
<td>CETKA-KUL</td>
<td></td>
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</tbody>
</table>
## WiseTex history

<table>
<thead>
<tr>
<th>Vers.</th>
<th>WiseTex</th>
<th>auxiliaries</th>
<th>external collaborators</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1.1</td>
<td>Geometrical models weaves and braids</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>1.5</td>
<td>Compression; NCF</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>2.2</td>
<td>In-plane; <strong>LamTex</strong>; <strong>WeftKnit</strong> (M. Moesen)</td>
<td><strong>TexComp</strong> (G. Huysmans)</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td></td>
<td>T. Peeters; T. Mikolanda</td>
</tr>
<tr>
<td>2004</td>
<td>2.4</td>
<td><strong>FETex</strong> (S. Kondratiev) <strong>VRTex</strong></td>
<td>FlowTex 1.0: LB</td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td><strong>MeshTex</strong> conceived</td>
<td>M. Zako</td>
</tr>
<tr>
<td>2006</td>
<td>2.5</td>
<td>New braids; Fibre distribution (V.E. Koissin)</td>
<td><strong>FE manual</strong> (D.S. Ivanov) Link to <strong>TexGen</strong></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>FlowTex 2.0: FD</td>
<td>B. Verleye et al; M. Griebel</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td><strong>MeshTex</strong> current</td>
<td>M. Zako et al</td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>integration <strong>SYSPLY</strong></td>
<td>P. de Luka et al</td>
</tr>
<tr>
<td>2012</td>
<td>3.0</td>
<td>XML; command line</td>
<td>integration <strong>DIGIMAT</strong> Ch. Hanh et al</td>
</tr>
<tr>
<td>2013</td>
<td>3.1</td>
<td>Fast voxelisation</td>
<td>FlowTex 3.0; <strong>Abaqus</strong> exchange script</td>
</tr>
<tr>
<td>2013</td>
<td>3.2</td>
<td>Distance fabrics</td>
<td><strong>Abaqus</strong>: EE (A. Tabatabaei)</td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td>integration <strong>NX Open</strong></td>
</tr>
</tbody>
</table>
WiseTex worldwide

licenses, 2016:
- industrial (15)
- university (39)
1. History and current status of WiseTex

2. Open data formats and scripting

3. Micromechanics and transformation into FE models

4. Conclusion: multi-scale integration
Data flow for textile composites

Specifications and measurements

Textile processing model

Textile data (TEX)

Textile deformations (DEF)

Specifications and measurements

Composite processing model

MLTP

Geometrical model (GEO)

Permeability model

Micromechanical model

meso-FE

Thermal, electromagnetic etc models

Meso-level textile geometry preprocessor

... ... ... ... ...
WiseTex: data open to a user

WiseTex 3.0+
- open XML input and output formats

New possibilities:
- easy integration:
  - upstream, with user-defined process models (e.g., braiding process)
  - downstream, with user-defined models of composite (e.g. meso-FE)

WiseTex or custom software
- open XML input and output formats
- "command line" version

New possibilities:
- easy integration:
  - upstream, with user-defined process models (e.g., braiding process)
  - downstream, with user-defined models of composite (e.g. meso-FE)

XML: textile data
XML: fabric geometry
custom software
WiseTex: scripting

WiseTex 3.0+
- open XML input and output formats
- "command line" version

New possibilities:

**easy integration:**
- upstream, with user-defined process models (e.g., braiding process)
- downstream, with user-defined models of composite (e.g., meso-FE)

**scripting:**
- parametric studies
- look-up tables (e.g., shear angle)

```
command line script

\TexCompCL "W-Hexcel\W-Hexcel-45.wfa" "HUN_matrix.xml" "W-Hexcel\W-Hexcel-45_stiff.csv" /n1
\TexCompCL "W-Hexcel\W-Hexcel-50.wfa" "HUN_matrix.xml" "W-Hexcel\W-Hexcel-50_stiff.csv" /n1
\TexCompCL "W-Hexcel\W-Hexcel-55.wfa" "HUN_matrix.xml" "W-Hexcel\W-Hexcel-55_stiff.csv" /n1
\TexCompCL "W-Hexcel\W-Hexcel-60.wfa" "HUN_matrix.xml" "W-Hexcel\W-Hexcel-60_stiff.csv" /n1
```

XML: textile data
XML: fabric geometry

WiseTex or custom software

custom software
WiseTex workflow

1. Define the textile data
2. Build the **geometrical model**
3. Control the resulting parameters

After that you can ...

... in WiseTex
- **compress** the fabric
- **shear** the fabric
- apply **biaxial tension** to the fabric

In all these cases:
- deformation – force response is calculated
- the **deformed fabric** can be stored

... in TexComp
- calculate **stiffness** matrix of the composite

... in FlowTex
- calculate **permeability** of the fabric

... in VRTex
- **visualise** the fabric

... using the WiseTex – Abaqus converting Python script or FETex
- create an **Abaqus or ANSYS model** of the unit cell

... using software of our partners
- create SACOM, NX Open, LS Dyna or TexGen models
### Example: 3D fabrics for fan blades

<table>
<thead>
<tr>
<th>Industrial partner</th>
<th>Snecma, France</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Problem</strong></td>
<td>Optimisation of the reinforcement structure of 3D reinforced composite fan blades</td>
</tr>
<tr>
<td><strong>Project description</strong></td>
<td>Development of methods and software tools for prediction of mechanical properties of 3D angle interlock composites</td>
</tr>
<tr>
<td><strong>Team</strong></td>
<td>G. Perie (Snecma – PhD student @ KU Leuven), S. V. Lomov</td>
</tr>
<tr>
<td><strong>Years</strong></td>
<td>2005 – 2008</td>
</tr>
<tr>
<td><strong>Main innovation</strong></td>
<td>Software tools, used by Snecma for design of the fan blades</td>
</tr>
</tbody>
</table>
1. History and current status of WiseTex
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Meso: method of inclusions (1)

Matrix data

\[ E_{11} = V_f E'_{11} + (1 - V_f) E_m \]
\[ E_{22} = E_{33} = \frac{E_m}{1 - \sqrt{V_f} \left( 1 - \frac{E_m}{E_{22}'} \right)} \]
\[ G_{12} = G_{13} = \frac{G_m}{1 - \sqrt{V_f} \left( 1 - \frac{G_m}{G_{12}'} \right)} \]
\[ G_{23} = \frac{G_m}{1 - \sqrt{V_f} \left( 1 - \frac{G_m}{G_{23}'} \right)} \]

\[ \nu_{12} = \nu_{13} = V_f \nu'_{12} + (1 - V_f) \nu_m \]
\[ \nu_{23} = \frac{E_{22}}{2G_{23}} - 1 \]

Chamis’ model
Meso: Method of inclusions (2)

\[
C^C = \left[ c_m C^m + \langle c_s C^s A^s \rangle \right] \left[ c_m I + \langle c_s A^s \rangle \right]^{-1}
\]

stiffness in local coordinate system

example: glass/epoxy woven stiffness vs shear angle

Syncoglas R420 bias coordinates 12

![Graph showing stiffness vs shear angle for glass/epoxy woven composites](attachment:image.png)
Models of textile geometry and deformability:

- woven 2D and 3D
- braided bi- and triaxial
- knitted

Predictive models of composites mechanics:

Homogenisation of stiffness of textile composite, based on the method of inclusions:

any textile reinforcement described by WiseTex, including deformed (sheared, compressed, tensed)
Road map for meso-FE modelling

- Geometric modeller
- Geometry corrector
- Meshing
- Assign material properties
- Boundary conditions
- FE solver, postprocessor
- Homogenisation
- Damage analysis
Interpenetration of yarn volumes
MeshTex and SACOM

WiseTex, K.U. Leuven

MeshTex, Osaka University

WISETEX
- Geometric modeller
- Geometry corrector
- Meshing
- Assign material properties
- Boundary conditions

MESHTEX

SACOM, VISUAL SACOM
- FE solver, postprocessor
- Homogenisation
- Damage analysis
I. Composite geometry definition

- woven (2D and 3D)
- braids
- laminates
- weft-knits
- NCF

Fast analytical homogenization

Macro-level properties

Stiffness

II. FE-based homogenization

Homogenization

\[ C^H_{ijkl} = \frac{(\sigma_{ij})}{\epsilon_{kl}} \delta_{ij} \delta_{kl} + \frac{(\sigma_{ij})}{2\kappa_e} \delta_{ik} \delta_{jk} \delta_{ij} - 1 \]

Macro-level properties

Stiffness

Strength

Damage

Material data (orientations, ...)

Constraints (PBC, ...)

\[ u(x) = \bar{e}x + \tilde{u}(x) \]

ORAS

III. FE preprocessing

FE solutions
## Mesh superposition

<table>
<thead>
<tr>
<th>Publication</th>
<th>Term and FE software used</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish, 1992</td>
<td>s-element</td>
<td></td>
</tr>
<tr>
<td>Zako et al, 2005</td>
<td>M3 method (SACOM)</td>
<td></td>
</tr>
<tr>
<td>Jiang et al, 2008</td>
<td>Domain superposition (ANSYS)</td>
<td></td>
</tr>
<tr>
<td>Iarve et al, 2009</td>
<td>Independent mesh (own software)</td>
<td></td>
</tr>
<tr>
<td>Tabatabaei et al, 2014</td>
<td>Embedded elements (Abaqus)</td>
<td></td>
</tr>
</tbody>
</table>
Example: 3D woven fabric, mesh

FULL (continuous meshes)

Embedded elements
Example: woven laminate, shear
1. History and current status of WiseTex
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Multi-level structural analysis

Forming

Local deformation parameters (thickness, shear...)

Local stiffness $[Q]$

WiseTex

Internal geometry

FE analysis

Stress/strain fields

TexComp
Multi-level permeability analysis

Filling simulation

Processing parameters

Process model

Local reinforcement deformation

Local permeability $[K]$
## WiseTex use in software of third parties

<table>
<thead>
<tr>
<th>year</th>
<th>software</th>
<th>company</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>TexGen</td>
<td>U Nottingham</td>
<td>File format transformation WiseTex &lt;-&gt; TexGen</td>
</tr>
<tr>
<td>2008</td>
<td>MeshTex</td>
<td>U Osaka</td>
<td>Transformation of WiseTex models in FE, solution with damage and multi-level modelling (M³)</td>
</tr>
<tr>
<td></td>
<td>SACOM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>SYSPLY</td>
<td>ESI Group</td>
<td>WiseTex/TexComp routines for local stiffness calculation in macro-modelling, linked to forming</td>
</tr>
<tr>
<td>2012</td>
<td>Digimat</td>
<td>eXstream</td>
<td>WiseTex algorithms for textile geometry used inside Digimat</td>
</tr>
<tr>
<td>2013</td>
<td>TexMind</td>
<td>TexMind (DE)</td>
<td>WiseTex XML format of textile geometry used as one of TexMind formats</td>
</tr>
<tr>
<td>2015 (pilot)</td>
<td>NX Open</td>
<td>Siemens</td>
<td>WiseTex/TexComp used for micromechanical calculations and to create geometrical models of textiles for FE modelling</td>
</tr>
</tbody>
</table>