The University of Nottingham

TexGen – an 'Open Source' story

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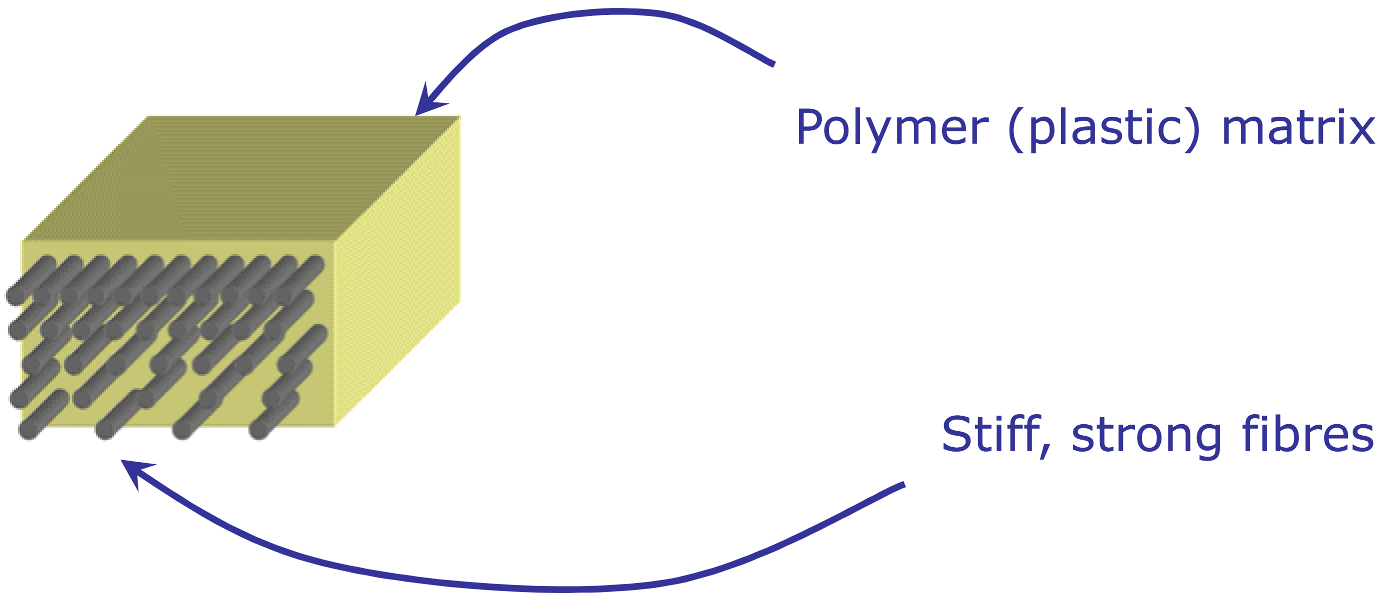
Overview

- (Short) background of textile composite materials
- Introduction to TexGen:
  - Purpose & background
  - Evolution
- Rationale:
  - Improved implementation
  - Decision to go open source
- Outcomes (and incomes!)
- Useful links

Background

Composites are materials formed by combining two materials. Our group's interest is in **fibre reinforced polymer composites**. These materials are often referred to colloquially using names such as 'fibreglass', 'carbon fibre' and 'Kevlar'.

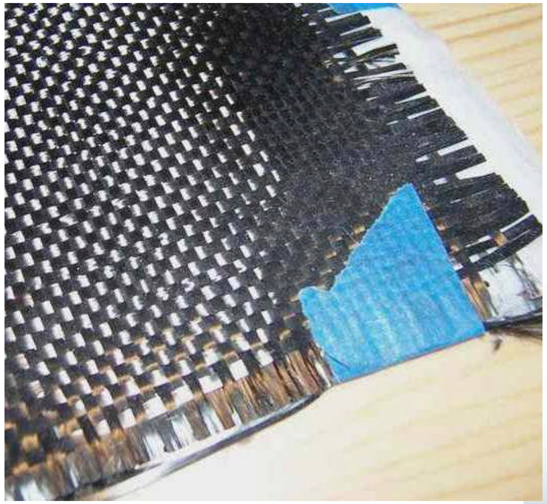
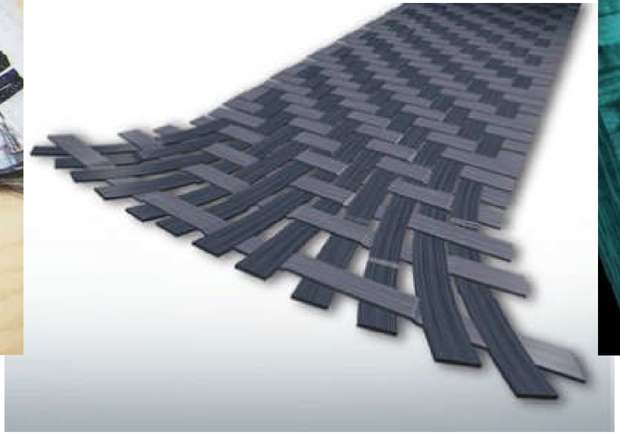
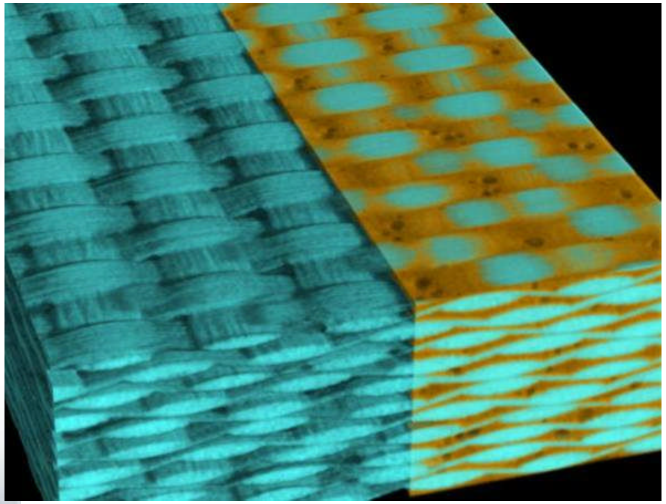


Applications

Engineering composites are valued for their high stiffness- and strength-to-weight ratios. They are often expensive compared with metals, so tend to be used in high-value, high-performance situations.

Textile composites

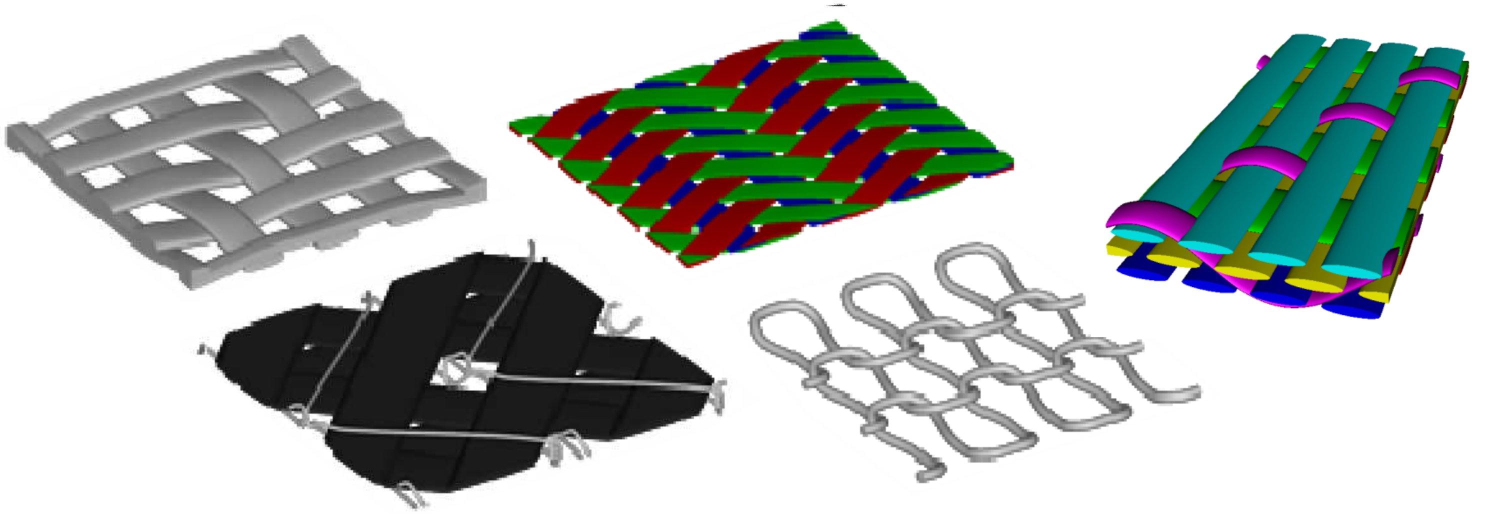
For manufacturing reasons, it is often useful to supply the reinforcement fibres in the form of a textile. Each yarn typically comprises several thousand fibres.

To understand the behaviour of the material, we need to consider the structure of the textile.

TexGen Purpose & Background

To understand the behaviour of the material, we need to consider the structure of the textile. Our in-house textile CAD modeller, TexGen, is used to generate geometric models of the textiles and their composites.



These models are used for analysis of manufacturing processes, mechanics, heat transfer etc.

TexGen Evolution

1998

TexGen development begins c. 1998 via an EPSRC project (Long & Rudd). Dr. François Robitaille & Ben Souter work on the initial algorithms and implementation of v1.

Martin Sherburn begins 3rd year project with François in 2002 and decides to re-write the TexGen application as v2.

2003

Martin begins PhD (EPSRC funded) studying textile geometry in 2003 under supervision of Robitaille/Jones & Long.

Wout Ruijter begins PhD (EPSRC funded, Jones & Long) in 2004 studying textile composite mechanics.

c.2006 Wout and Martin agree with supervisors that TexGen should be re-implemented as a platform-independent code following an open source model. **Public release of v3 2006.**

Wout leaves 2007; Martin leaves 2008; Louise Brown joins 2009.

2009

2009: Even with a gap in developer support, the code is still accessible, in use and has some level of support.

Rationale – why re-implement?

- Although a capable package, TexGen v2 was **never intended to be extended by multiple developers**. There was no version management, no formal code documentation and no clear code design. Adding a new feature would sometimes break an existing feature.

- Because of its use of MFC (Microsoft Foundation Classes), it was written such that it **was completely tied to MS Windows**. ☹

- Geometry export was provided by the ACIS libraries, for which our **licence prohibited redistribution**.

- v3 was designed carefully **before** it was implemented, and the implementation was done in an accessible way.

Rationale – why re-implement?

v3 is:

Modular

- **Core functionality is in the core module**, graphics are in a renderer module; if not using visualisation, the renderer doesn't need to be built.

Platform independent

- Since it is written in standard C++, it can be run under **Windows, Linux and most/any operating systems** which are supported by the CMake build system.
Hence it can be used on the HPC.

Extensible

- There is a documented programmer interface to the code and the design of the **object-oriented structure reflects the physical problem** (e.g. weave styles derived from the main weave class).

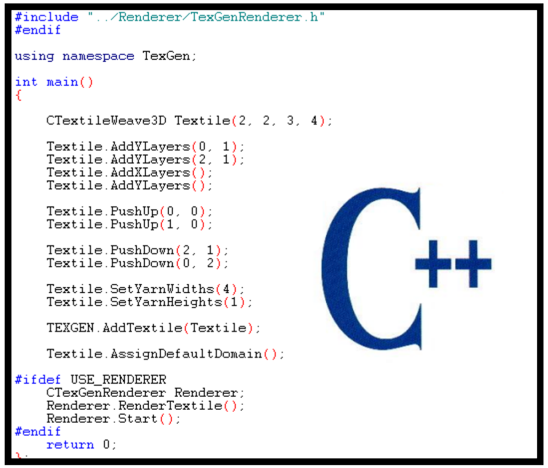
Flexible

- TexGen can be used **through a GUI, driven by Python scripts or linked as a library to C++ programs**.

Rationale – why re-implement?

Benefits of having an API (programming interface):

- TexGen functions can be called from within other programs.
- Many tasks can be automated 'easily' using Python interface.
- Python interface allows integration with other packages which have their own Python functionality (notably for us, **Abaqus CAE**).
- **Python interface also allows specific functionality (e.g. commercially sensitive research) to be developed separately from the main build.**
- TexGen models can be built parametrically and interrogated 'on-the-fly' to determine local fibre distribution, orientations etc.



```
#include "../Renderer/TexGenRenderer.h"
#endif

using namespace TexGen;

int main()
{

    CTextileWeave3D Textile(2, 2, 3, 4);

    Textile.AddYLayers(0, 1);
    Textile.AddYLayers(2, 1);
    Textile.AddXLayers();
    Textile.AddYLayers();

    Textile.PushUp(0, 0);
    Textile.PushUp(1, 0);

    Textile.PushDown(2, 1);
    Textile.PushDown(0, 2);

    Textile.SetYarnWidths(4);
    Textile.SetYarnHeights(1);

    TEXGEN.AddTextile(Textile);

    Textile.AssignDefaultDomain();

#ifdef USE_RENDERER
    CTexGenRenderer Renderer;
    Renderer.RenderTextile();
    Renderer.Start();
#endif
    return 0;
```


```
fibreDistributionWarp = CFibreDistributionConst (calculateFibreArea(tex=texWarp, fibreDens
fibreDistributionWeft = CFibreDistributionConst (calculateFibreArea(tex=texWeft, fibreDens
fibreDistributionBinder = CFibreDistributionConst (calculateFibreArea(tex=texBinder, fibreI


# Generate warp yarns
totalLengthWarpmm = 0
for warpLayer in range(numWarpLayers):
    yarn  = CYarn()
    x1 = offset[0]
    x2 = x1 + numWeftsPerLayer*spacingWeft
    y = offset[1]
    z = offset[2] + warpLayer*(nominalHeightWarp + nominalHeightWeft)
    node1pos = XYZ(x1, y, z)
    node2pos = XYZ(x2, y, z)
    node1 = CNode(node1pos)
    node2 = CNode(node2pos)
    yarn.AddNode(node1)
    yarn.AddNode(node2)
    yarn.AssignInterpolation(CInterpolationBezier())
    yarn.AssignSection(sectionWarp)
    yarn.AssignFibreDistribution(fibreDistributionWarp)
    # Set the resolution of the surface mesh
    yarn.SetResolution(resolutionSlaves1, resolutionSection)
    # Add the repeats to the yarn
    yarn.AddRepeat(XYZ((x2-x1), 0, 0))
    yarn.AddRepeat(XYZ(0, spacingWarp, 0))
    # Add the yarn to the textile
    Textile.AddYarn(yarn)
    totalLengthWarpmm += yarn.GetYarnLength()
totalLengthWarpmm *= numWarpsPerLayer
```

Rationale – why not commercialise?

- TexGen would be of relatively limited commercial value (comparatively small customer base).
- **Commercial customers would expect support.**
- Casual use does not occur.
- All development has to be undertaken in-house.
- If code is commercialised in conjunction with a company this will inhibit research collaborations with their competitors.

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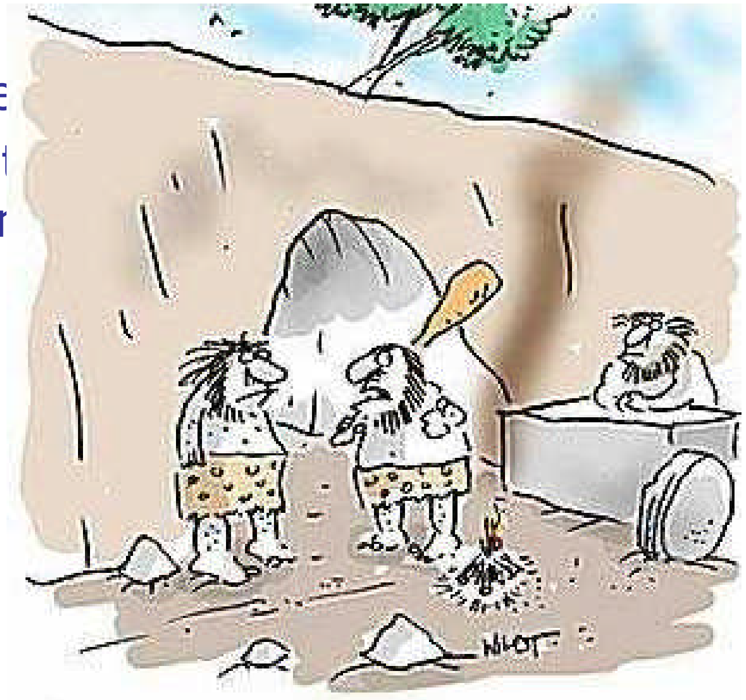


"After fire and the wheel, it was only logical to invent the patent attorney."

Rationale – why open source?

Aside: what is open source?

TexGen is released under the GNU General Public License. In short, this means that copyright is retained, but that others are free to download and redistribute the code. They may modify it, providing that this is clearly indicated.

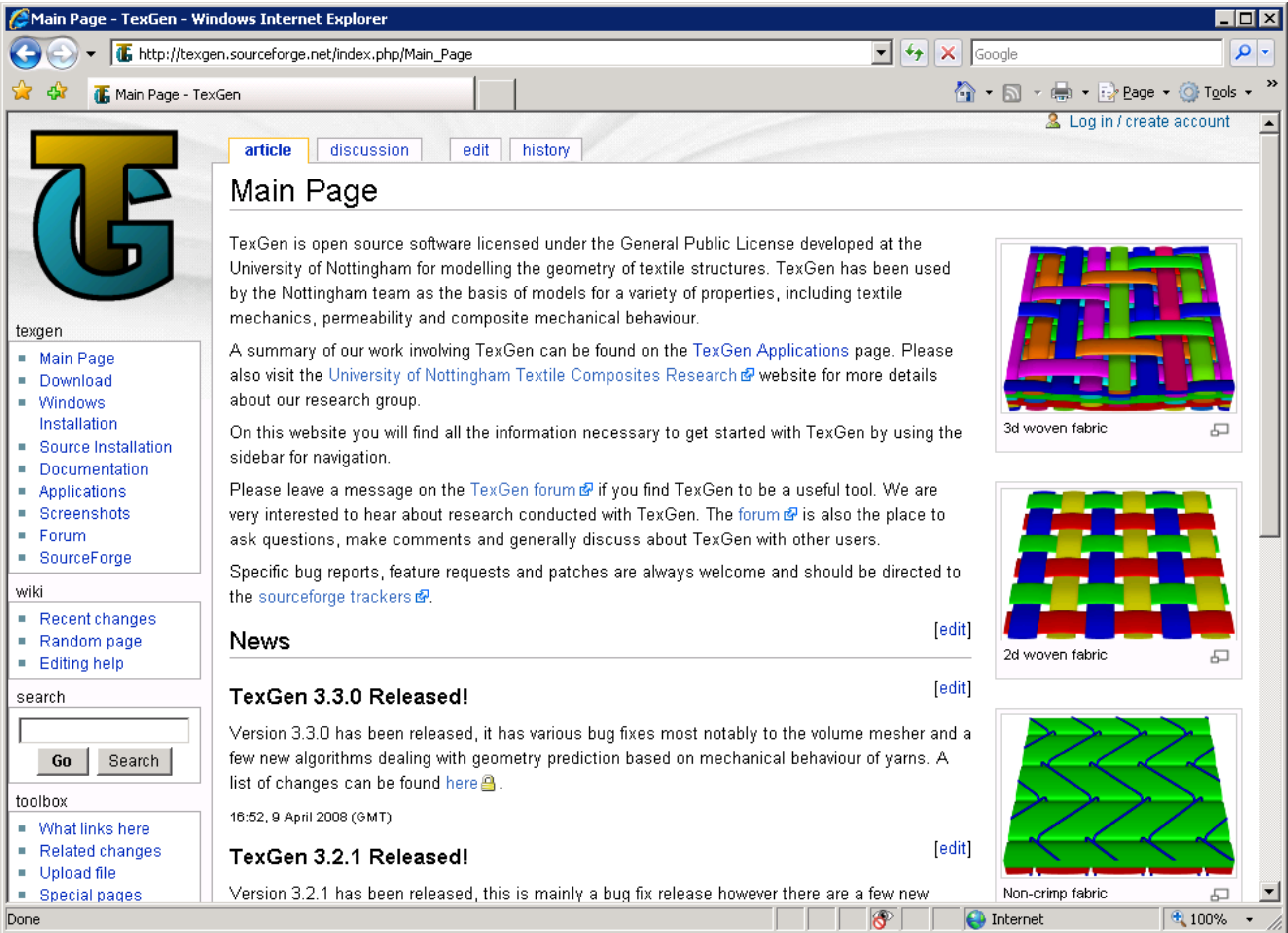
```
/*============================================================================
TexGen: Geometric textile modeller.
Copyright (C) 2006 Martin Sherburn

This program is free software; you can redistribute it and/or
modify it under the terms of the GNU General Public License
as published by the Free Software Foundation; either version 2
of the License, or (at your option) any later version.

This program is distributed in the hope that it will be useful,
but WITHOUT ANY WARRANTY; without even the implied warranty of
MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
GNU General Public License for more details.

You should have received a copy of the GNU General Public License
along with this program; if not, write to the Free Software
Foundation, Inc., 51 Franklin Street, Fifth Floor, Boston, MA  02110-1301, USA.
============================================================================*/
```

Rationale – why open source?

- **People can download TexGen and use it for free.**
- TexGen is a tool to facilitate research rather than a piece of research in itself (although many algorithms are novel). Once algorithms are published, there is no reason to withhold the implementation.
- Opening the code to scrutiny gives a better level of both knowledge transfer and verification.
- **Giving open access to the code encourages third-party use/ citation.**
- People can use it in more flexible and clever ways because they understand it more clearly.
- Third parties can develop their own extensions, which can be incorporated into the code.
- **Casual use can lead to collaboration.**
- **IPR issues are simplified since everyone knows that TexGen is open.**

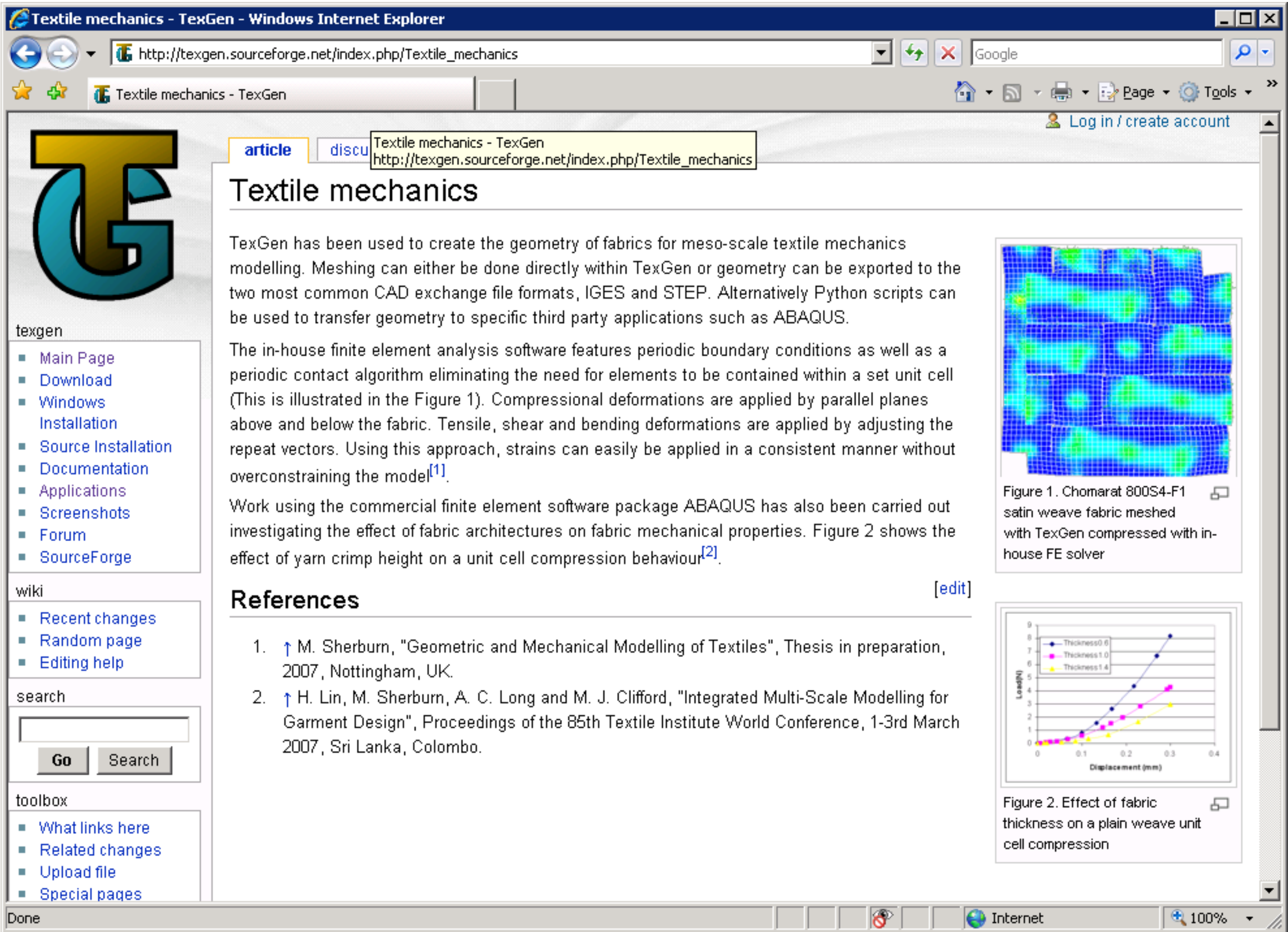
TexGen – the outsider's view

Wiki-based (community maintainable) user documentation including instructions for compiling under different operating systems, tutorials etc.



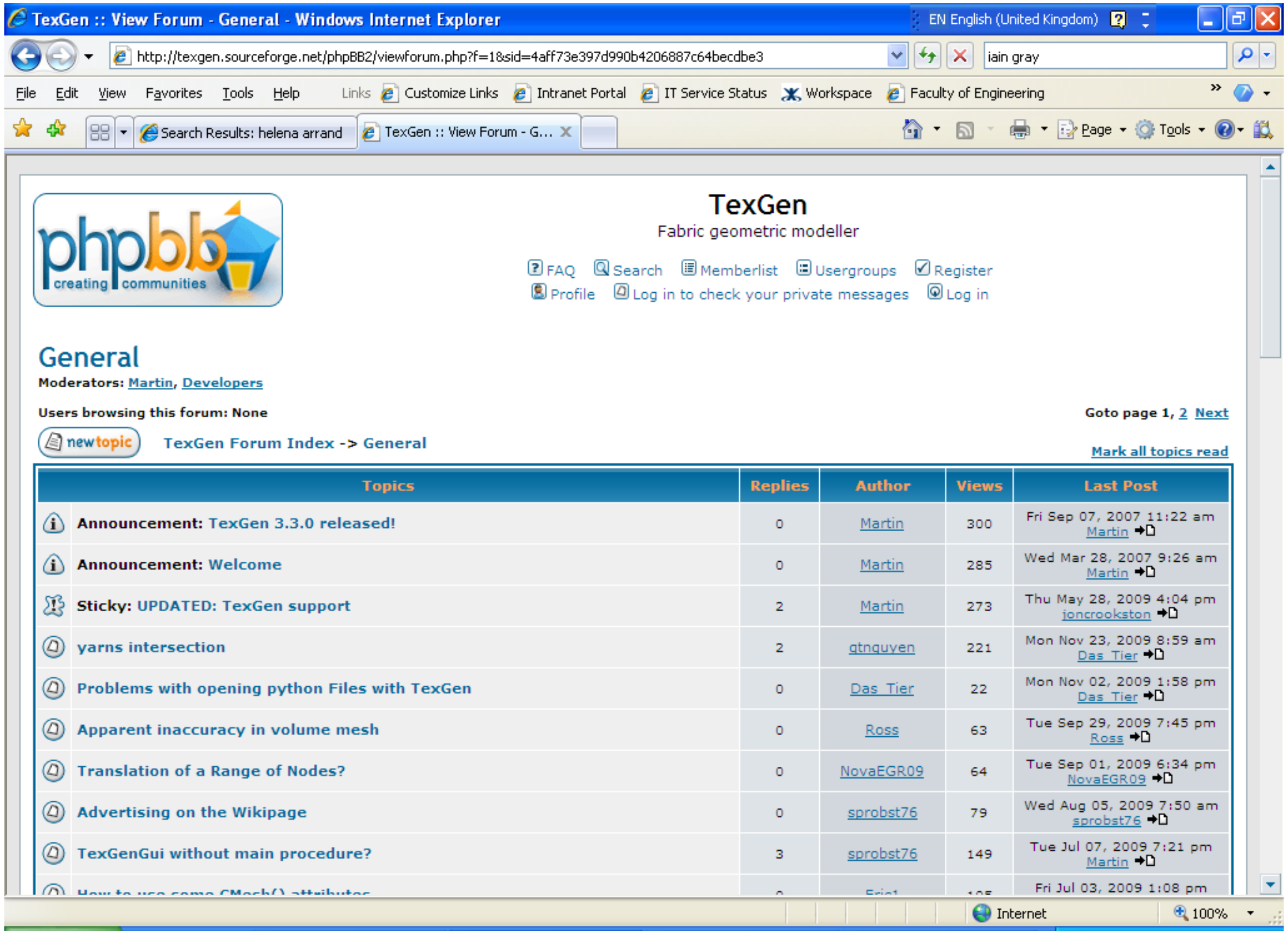
TexGen – the outsider's view

Applications of TexGen are documented with references.



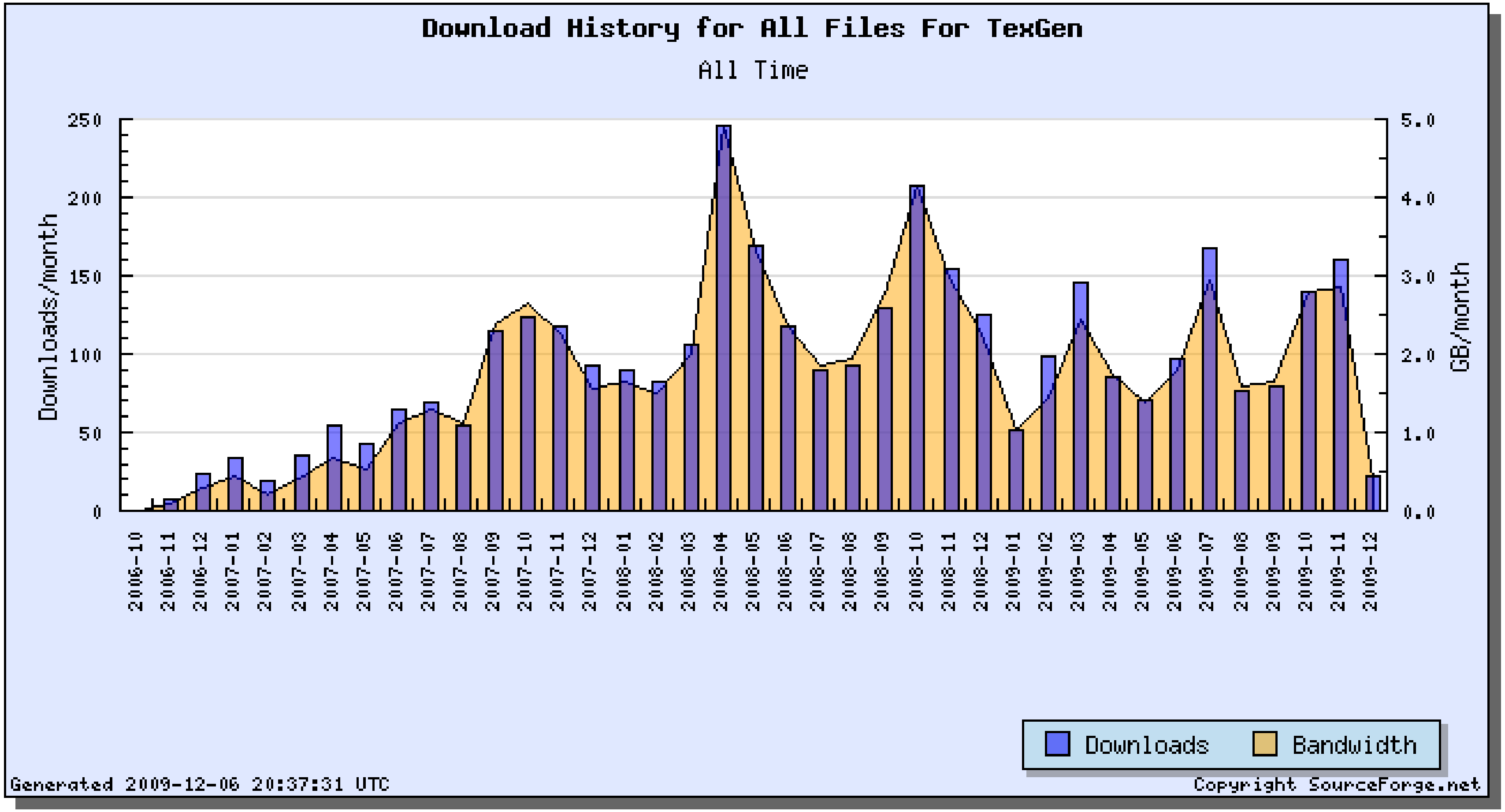
TexGen – the outsider's view

A discussion forum enables questions to be answered and new functionality requirements to be determined (47 registered users as at 4/12/09).



A success story?

In total, there have been over 3,588 downloads from Sourceforge & 550,000+ hits (6/12/09).



A success story?

There are known users at:

- Akron Uni (Cheng) – impact modelling for braided composites
- Bristol Uni (Hallett) – unit cell FEA using embedded element approach
- Delaware Uni (Simacek) – fabric compaction modelling
- FEA Ltd (Irving) – unit cell models for thermal shrinkage in Lusas
- Federal-Mogul SPG (Teal) – thermal modelling of textiles
- Grenoble Uni (Orgeas) – flow of power law fluids through textiles
- Heimbach Ireland (O'Brien) – visualisation of multi-layer textiles for paper making
- IIT Delhi (Das) – flow modelling for 3D textiles
- Imperial College (Robinson) – unit cell mechanics FEA (EPSRC bid)
- Leuven (Lomov/Verleye) – comparative predictions with WiseTex for permeability
- Manchester Uni (Hanspal/ Jetavat) – flow through filtration fabrics/ textile design
- NRC Canada (Hind) – composite thermal conductivity
- Oxford Uni (Gerlach) – impact modelling for 3D composites
- Ottawa Uni (Robitaille) – heat transfer modelling and medical textiles
- Rolls Royce (McMillan) – unit cell mechanical properties (RAE Fellowship)
- Sigmatex (Murray) – visualisation for multi-layer textiles
- Texas A&M Uni (Whitcomb) – textile composite mechanics
- Ulster Uni (McIlhagger/Quinn) – unit cell modelling and visualisation
- Unilever (Lee) – models for textile mechanics and fabric softness
- WM Gore (Zhang) – mechanical behaviour of GoreTex fabrics

A success story?

Related projects include:

Jan 2007 – Jun 2010 Multi-Scale Integrated Modelling for High Performance Flexible Materials

Investigators: M J Clifford, A C Long

Funding body: DTI Technology Programme (TP/5/MAT/6/I/H0558C)

Partners: Unilever, OCF, Croda Chemicals, ScotCad Textiles, Carrington Career & Workwear, Hield Brothers, Airbags International, Technitex Faraday, University of Manchester, Heriot-Watt University

Research grant: £318k (total project value £1,703k)

Feb 2008 – Feb 2011 Advanced Composite Truss Structures (ACTS)

Investigators: A C Long

Funding body: DTI Technology Programme (TP/8/MAT/6/I/Q1505D)

Partners: Bentley Motors, Airbus UK, Carr Reinforcements, Composite Integration, Network Rail, NP Aerospace, Pipex, QinetiQ, Tony Gee & Partners, Oxford Brookes University

Research grant: £213k (total project value £1,821k)

All in all, **approximately £1m research income** can be largely attributed to this initiative.

A success story?

Platform: Textile Composites - Engineering Science and its Applications - Windows Internet Explorer

http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/F02911X/1

EPSRC
Engineering and Physical Sciences Research Council

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Details of Grant

EPSRC Reference:	EP/F02911X/1				
Title:	Platform: Textile Composites - Engineering Science and its Applications				
Principal Investigator:	Professor AC Long				
Other Investigators:	Dr R Brooks	Dr MJ Clifford	Dr M Johnson		
	Dr IA Jones	Dr SJ Pickering	Professor CD Rudd		
	Dr CA Scotchford	Dr G Walker	Professor NA Warrior		
Researcher Co-investigator:					
Project Partner:					
Department:	Sch of Mech Materials Manuf Eng Mgt				
Organisation:	University of Nottingham				
Scheme:	Platform Grants				
Starts:	01 February 2009	Ends:	31 January 2013	Value (£):	863,232
EPSRC Research Topic Classifications:	Biomaterials	Composites: Processing			
	Engineering of Matrs/Props/Test: Mechanical	Theoretical Materials Science			
EPSRC Industrial Sector Classifications:	Aerospace and Defence	Manufacturing			
	Healthcare				
Related Grants:					
Panel History:	Panel Date	Panel Name	Outcome		
	29 Oct 2007	Platforms Panel October 2007	Announced		

Summary

Done | Internet | 100%

For reference

TexGen:

http://texgen.sourceforge.net/

GNU (public licence):

http://www.gnu.org/

Trac (a wiki-derived software project management tool):

http://trac.edgewall.org/

Subversion (version control):

http://subversion.tigris.org/

Doxygen (documentation generator):

http://www.doxygen.org/