INTRODUCTION

Integrated Tool for Simulation of Textile Composites

Funding: European (6th RTD Framework Programme)
Duration: Mar 2005 - Aug 2008
Status: Complete with results
Total project cost: €3,894,097
EU contribution: €2,619,913

Call for proposal: FP6-2003-AERO-1
CORDIS RCN: 75789

Background & policy context:

Textile preforming of composites offers the potential of significant cost savings in comparison to prepreg (pre-impregnated) tape layering. To enable engineers to make use of dry fibre textiles, reliable simulation tools and design principles are needed. In contrast to conventional, unidirectional reinforced composites, textile reinforcement results in 3D fibre architectures so that standard analysis procedures, like 2D rules of mixture and laminate theory, are no longer valid. It is also important to consider the manufacturing processes since they have a strong influence on the textile properties.

To fulfil the objectives within a limited time (and cost) scale, the linking and integration of different stand-alone solutions in the tool chain is proposed, thus creating an open flexible interface for fluent data exchange and communication.

The main benefit is to users of textile composites. ITOOL can set up a standard for testing, modelling and simulation, thus responding to market demands. A further impact of the enhanced simulation capabilities will be a reduction of at least 20% in necessary testing effort, as well as a lead-time reduction of more than 15%.

Objectives:

The technical approach of ITOOL is a simulation along the process line in a virtual manufacturing chain, which incorporates the preform manufacturing, draping and impregnation process followed by the external loading of the finished component.

The scientific objective of ITOOL is to close the gap between missing knowledge and proved advantages of dry fibre textiles by developing an adequate integrated simulation tool for textile preforming technologies including braiding, advanced engineering textiles, weaving and stitching. Reliable simulation tools and design methods provide the enabling prerequisites for an increased use of these materials in aerospace and other industries.

From the technical point of view, a special focus will be on 3D reinforcements by the use of structural stitching to improve mechanical properties of composites in the thickness direction (damage tolerance +80%, fracture toughness +75%, weight specific energy absorption +75%).

By achieving the objectives mentioned above, ITOOL could provide the basis of a standard for the design, analysis and testing of textile preformed composites in Europe.

Methodology:

As there are already stand-alone solutions for several parts of the simulation in use, the approach of ITOOL is mainly the linking and integration of these tools to ensure a fluid interaction and data interchange. This approach will enable a flexible and adaptable solution, which may be extended by the user to include alternative technologies.
The materials used in the project, especially the ones that will be used for a set of validation examples, will be characterised. The relevant data will be stored in a database structure allowing the user to access the properties they will need.

The mechanical behaviour will be analysed on three different approximation levels called 3M (micro / meso / macro) mechanics:

- on the microscale, the different constituents are always modelled separately
- on the mesoscale, fibre and matrix properties are homogenised locally
- on a macro level, the micro or mesoscale models are homogenised in a coarser way to lower the computational effort.

The processes used in production and handling of textile preforms will be evaluated and appropriate models will be developed to predict their influence on the properties of the preform materials. The draping and infiltration behaviour of textile preforms will be the focus of this subtask.

Static stress and failure models will be developed to predict macroscopic structural deformation, stress and failure of textile-reinforced structures. Global analysis methods, which compute structural behaviour under external loads, will be provided. The developed tools will address static stress, quasi-static failure, crash and dynamic impact computations.

The proof for this integration concept will be performed for different application fields of textile-preformed composites in aerospace: typical stiffened skin sections, integral joining technologies and a braided propeller fan. The evaluation also includes the interface and the related flow of data as a measure of the quality of results in comparison to tests.

In parallel to the development of the integrated simulation tool, the second aspect of the project is to build up physical understanding of the behaviour of textile preformed composites to increase their usage. Therefore, design rules for the use of dry fibre textiles will be extracted and made easily available for the design engineer as a guideline.

**Parent Programmes:**
[FP6-AERO-1.1 - Strengthening competitiveness](#)

**Institute type:** Public institution

**Institute name:** European Commission

**Funding type:** Public (EU)

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Key Results:

Degree to which the objectives were reached:

- **Objective: reliable simulation tools and design principles**
  
  Within the ITOOL project it was chosen to use integrate existing and newly developed tools which have been extensively tested against experimental benchmark cases. Also within the project a large amount of effort was put into experimental work for validation purposes.

- **Objective: simulation along the process line with a virtual manufacturing chain**
  
  Taking into account the prediction of textile deformations during draping processes and linking the results from there simulations to predictions or permeability and mechanical properties a simulation along the process line is established. Moreover the tools are organised in such a way that other features that have not been taken into account during the project can easily be integrated.

- **Objective: development of an adequate integrated simulation tool**
  
  The integration of the existing and newly developed tools have led to reliable simulation tools and design principles which are able to handle composites reinforced with 3d fibre architectures. The linking and integration of exiting tools ensures a fluent interaction and data interchange with minimum friction and without critical data loss. Furthermore a graphical user interface is developed to minimise user interference.

- **Objective: consider braiding, weaving and stitching technologies**
  
  The performance of textiles and textile reinforced composites is analysed on three different approximation levels called 3M (micro / meso / macro) mechanics. This approach enables to consider many different kinds of textile architectures as all of them can be assembled from the basic building blocks. Newly developed tools enable geometrical and mechanical descriptions of braiding, advanced engineering textiles, weaving and stitching textile preforming technologies.

- **Objective: improve properties in the thickness direction with stitching technologies**
  
  Different though thickness reinforcement technologies where investigated. New modeling tools are developed that enable the analysis of such materials. Via optimisation algorithms ideal stitching configurations could be determined. These results where experimentally validated.

- **Objective: proof for this integration concept and benefit of cost and effort**

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Other results

Whereas the technologies for the manufacturing of textile reinforced composite parts have been continuously improved in the past, flexible and qualitative methods for the analysis of these materials and their parts are difficult to find if yet not been developed. Within the ITOOL project a multi-level approach for the simulation of different aspects of textile reinforced composite material is developed.

Detailed geometrical models that represent 3D fibre architectures are developed and are used as a base to generate finite element models that enable the analysis of infiltration and draping processes as
well as detailed analysis of the mechanical performance including failure, damage and high strain rate behaviours. Advanced homogenisation methods are adapted to predict average properties that can be used for part analysis.

The developments in work package 5 have lead to a first integration of different existing tools by the development of the data transfer protocols and the material data base (DataTool). These techniques enable a fluent communication between the previously existing tools.

Many of the features developed in the project have been validated against experimental investigations on industrial validation examples. For most of these features good compliance was obtained.

Basic structural elements as well as key manufacturing methods are identified and design guidelines and rules of thumb are set-up based on their evaluation. The know-how and obtained experience during the project was collected in a document that is intended for possible standardisation of textile reinforced composite features.

The cost benefit analysis described in task 6.4 has shown that the ITOOL approach is effective in terms of costs and effort and hence it is proven that further developments of the ITOOL features are definitely worth while.

**Readiness**

The list of exploitable results that were obtained within the ITOOL project is as follows:

- Exploitable result 1: Effect of stitching on permeability.
- Exploitable result 2: Numerical prediction of permeability.
- Exploitable result 4: Data Exchange Procedure.
- Exploitable result 5: Composite Material Data Manager.
- Exploitable result 6: Numerical prediction bird impact.
- Exploitable result 7: Multi-level modelling approach for textile reinforcement of aeronautic structures.
- Exploitable result 8: New modules for WiseTex.
- Exploitable result 9: Draping model for textiles.
- Exploitable result 10: New and enhanced damage models for textile composites.
- Exploitable result 11: Dynamic characterisation of textile composites.
- Exploitable result 12: Out of plain mechanical properties.
- Exploitable result 13: Design procedures.

Documents:

- [Publishable_Activity_Report.pdf](file://localhost/home/documents/Publishable_Activity_Report.pdf) (Final report)

**STRIA Roadmaps:** Vehicle design and manufacturing

**Transport mode:** Air transport

**Transport sectors:** Passenger transport, Freight transport

**Transport policies:** Societal/Economic issues

**Geo-spatial type:** Infrastructure Node