



COST 526

**“Automatic Process Optimization in Materials Technology”  
(APOMAT)**

**Half-Yearly Report**

To be sent to [V.Tesch@access.rwth-aachen.de](mailto:V.Tesch@access.rwth-aachen.de) until **February 28, 2004**

<b>1. Reporting Period</b>	<b>1.7.2003 – 31.12.2003</b>
Project title	Optimisation of properties and dimensional stability of composites by controlled fibre placement
Project leader	Dr. Martyn Wakeman
Organization	Laboratoire de Technologie des Composites et Polymères (LTC) Ecole Polytechnique Fédérale de Lausanne (EPFL) CH-1015 Lausanne, Switzerland
Main collaborators involved	Dr. Niklas Jansson, Dr. Martyn Wakeman

**2. Funding Situation**

Amount of money received specifically for COST	62 000 CHF	kEuros (received 2002-06-24)
Other resources partially used for the project		kEuros

**3. International Collaboration**

(mention group and type of work done in collaboration during the reporting period)

Participation in the Working Group Meeting in Krakow + project progress report

- YES  
 NO

**4. Industry participation**

(mention name of companies and work done in collaboration during the whole project)

The project will to some extent be carried out in collaboration with DaimlerChrysler, Research and Technology, Ulm, Germany

<b>5. Meetings, visits, exchange of scientists, short-term scientific missions</b>	<b>Location, date</b>

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**6. Progress within the reporting period**  
(Not exceeding 3 pages, including tables and figures)

The aim of this research project is to develop the techniques and tools necessary to optimise the amount, material and location of the tow in order to reach the maximum mechanical performance in relation to weight or cost of structures manufactured by using integrated processing. One important building block includes the development and validation of finite element modelling strategies to allow efficient but accurate stress and stiffness analysis of fibre-tow reinforced thermoplastic structures. Efficient and accurate finite element analysis forms the basis and is a prerequisite for a subsequent successful coupling with the to-be developed optimisation tools and routines.

As a starting point detailed 3D finite element analyses have been performed and shown to compare favourably with available experimental data. However, one conclusion that can be drawn from the results of the detailed 3D modelling is that the effects of stable cracking in the matrix (experimental observation) and the non-fatal transverse failure of the tow (from the simulations) are very hard to incorporate in a finite element analysis. That means that the advantage of a good resolution of the stress state in the detailed 3D models is counteracted by the inability to model the progressive damage occurring in the structure. Hence, in an attempt to decrease the complexity and computational cost of the finite element models substantially with only a minor loss of accuracy, 2D models have been developed.

Within the reporting period, two different 2-D models have been developed and tested, the beam and the composite shell model. In both models, the matrix is represented by shell elements whereas the tow is modelled either by beam elements or composite shell elements. In the latter, the area covered by tow is meshed with layered shell elements where the tow is an orthotropic layer in the middle with matrix layers top and bottom. The models has been evaluated in both tension and flexure against a detailed 3-D analysis and against experimental data.

The first main conclusion that can be drawn from the comparison between experiments and simulations is that the modelling of the compressive behaviour need further attention. In the 3-point flexure test, compressive failure is predicted to occur already at a mid-point deformation of 7-8 mm. However, in the microscopy examinations of the flexure specimens, no signs of buckling failure could be found even for a maximum displacement of 16.5 mm. The second conclusion is that the results from the 2-D models compare favourably with the ones from the 3-D model. Hence, it is fully viable to use the more effective 2-D models for the optimisation simulations.

**7. List of publications**  
a) Published

Below are publications that have been generated within the IPPC project, which as mentioned, is related to the APOMAT project:

MECHANICAL ANALYSIS OF MULTI-MATERIAL COMPOSITES MANUFACTURED BY INTEGRATED PROCESSING

P.-O. Hagstrand, M. D. Wakeman, F. Bonjour, P.-E. Bourban and J.-A. E. Månson

*Proceedings of SAMPE 2002*

Long Beach, California, USA, May 12-16 2002.

COST MODELLING OF A NOVEL INTEGRATED COMPOSITE MANUFACTURING CELL FOR INTEGRATED COMPOSITE PROCESSING

M.D. Wakeman, F. Bonjour, P.-E. Bourban, P.-O. Hagstrand, J.-A. E. Månson

*Proceedings of the 23<sup>rd</sup> International SAMPE Europe Conference*

Paris, France, April 9-11 2002.

ROBOTIC TOW PLACEMENT FOR LOCAL REINFORCEMENT OF GLASS MAT THERMOPLASTICS (GMTs)

M. D. Wakeman, P.-O. Hagstrand, F. Bonjour, P.-E. Bourban and J.-A. E. Månson

*Composites Part A*. 33 1199-1208 (2002)

MECHANICAL ANALYSIS OF THERMOPLASTIC POLYMERS REINFORCED WITH ROBOTICALLY PLACED CONTINUOUS FIBRE TOWS

P.-O. Hagstrand, N. Jansson, M. D. Wakeman, F. Bonjour and J.-A. E. Månson

*Proceedings of the 14<sup>th</sup> International Conference on Composite Materials (ICCM-14)*

San Diego, California, USA, July 14-18 2003.

b) Submitted for publications

c) In preparation

FINITE ELEMENT MODELLING AND TESTING OF A GENERIC TOW REINFORCED STRUCTURE

N.E. Jansson, P.-O. Hagstrand, M. D. Wakeman, J.-A. Månson

To be submitted to *Composites part B: Engineering* (Elsevier)