Appendix D

Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

GARTEUR
Action Group Proposal

RTM-MATERIAL PROPERTIES DURING CURING

GARTEUR EG 28

GoR Meeting 9-10 October 2006

Introduction (1)

- **Why GARTEUR cooperation on "RTM-material properties during curing" ?**
  - Increased use of RTM production process
  - Thick RTM components are used for highly loaded details
  - For primary structures high quality and reproducibility is necessary

- **Status on current RTM process**
  - Applied temperature – time cure cycle not related to component geometry
  - No simulation models for polymerisation shrinkage and/or thermal stresses including the effect of exothermal reactions
  - For high quality RTM components there is a need for process (curing) simulation to minimise the formation of cure related defects

Introduction (2)

- **Objectives for AG**
  - Gain insight in the shrinkage behaviour of RTM resins and RTM composites
  - Develop numerical models
  - Define an experimental test to verify numerical prediction models
  - Develop a non destructive acoustic emission test to monitor cure related defects

- **EG 28 activities**
  - 2004 — Preliminary meeting + draft proposal issue 1 Suspended because of lack of funding
  - July 2006 — EG 28 meeting to make an inventory for interest to start an Action Group for the period 2007 – 2009
  - October 2006 — Proposal for Action Group submitted

WP1 Specifications

- **Specifications and agreement on:**
  - RTM-resins — One tough and one brittle system (RTM6)
  - RTM-fibres — HTA carbon fibre in square fabric
  - RTM-production process
    - Lay-up
    - Thickness
    - Resin ring injection
    - Thermocouples
    - Etc.
  - Input-data needed for numerical models
  - Methodology of deriving required data

- **Participants: All**

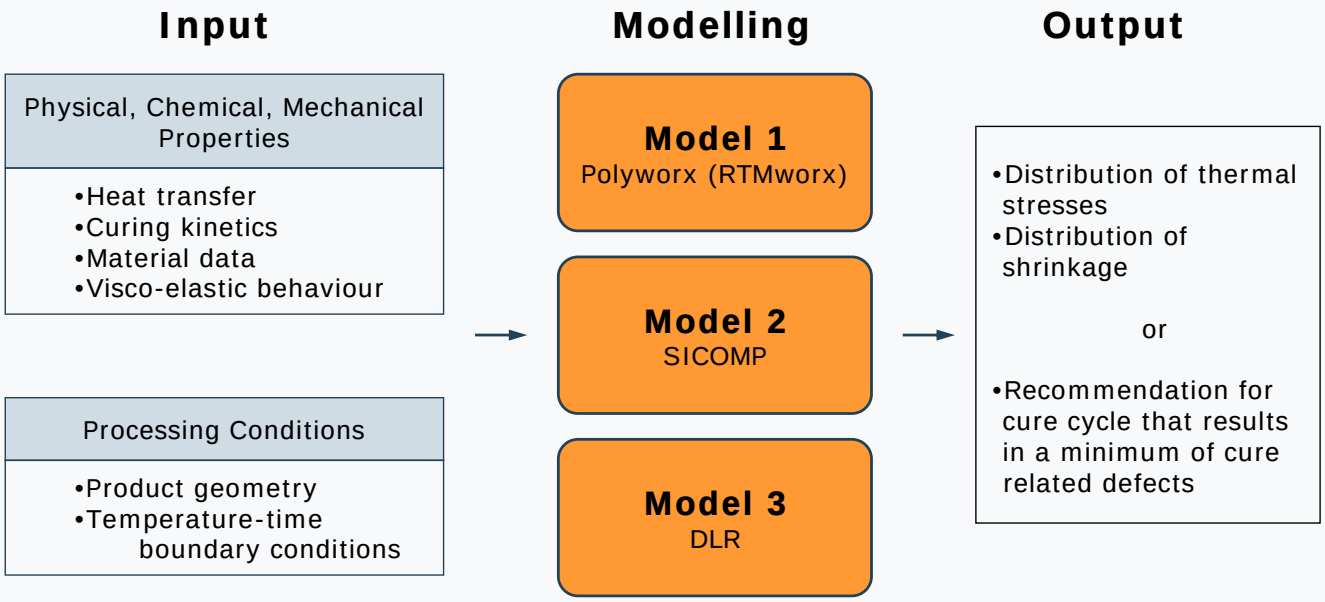
WP2 Resin-material properties

- **Experiments to determine mechanical and thermal resin properties as a function of the degree of curing**
  - Mechanical properties
    - Young's modulus
    - Shear modules
    - Creep behaviour
    - Volumetric shrinkage (density)
  - Thermal properties
    - Degree of curing as function of time and temperature
    - Heat transfer behaviour: specific heat and thermal conductivity
    - Glass transition temperature as function of degree of cure
- **Results will be input for WP4 Numerical Modelling**
- **Participants : CIRA,DLR, QinetiQ, UT**

WP3 Cure-related-defects detection techniques

- **Validation of cure-related-defects detection techniques**
  - Investigation of the correlation between acoustic emission and the occurrence of micro cracks.
    - Manufacturing of RTM samples
    - Registration of temperature, heat flow, pressure and acoustic emission during manufacturing
    - After manufacturing, curing stresses will be measured by Röntgen-diffraction
    - Cross sections will be made to determine the amount of micro-cracks
- **Results will be input for WP4 Numerical Modelling and WP5 Validation**
- **Participants: INTA,NLR, UT**

WP4 Numerical Modelling



- **Participants: DLR, Polyworx, SICOMP**

WP5 Validation

- **Validation of numerical models**
  - For each numerical model, 4 RTM samples will be manufactured
    - Tough resin system minimal cure related defects
    - Tough resin system maximal cure related defects
    - Brittle resin system minimal cure related defects
    - Brittle resin system maximal cure related defects
  - All samples will be monitored during fabrication as in WP3
  - All samples will be tested after manufacturing to determine physical properties
    - Micro-cracks
    - Curing stresses
    - Strength
    - Stiffness
    - Etc.
- **Results could be used for further optimization of Numerical Models (Not part of this AG)**
- **Participants: CIRA,INTA,NLR, UT**

Prospective Partners

Company		PoC	WP1 Specs	WP2 Resin Material Properties	WP3 Detection Techniques	WP4 Numerical Models	WP5 Validation	Involvement
1 **SICOMP**	S	Magnus Svanberg	•			•		Active participation
2 **CIRA**	I	Felice De Nicola	•	•			•	Active participation
3 **QinetiQ**	GB	Graeme Stringer	•	•				Support in mechanical and some physical-chemical testing
4 **INTA**	E	José Maria Pintado	•		•		•	Support in mechanical and some physical-chemical testing
5 **DLR**	D	Markus Kleineberg	•	•		•		Active participation
6 **UT**	NL	Remco Akkerman	•	•	•		•	Active participation
7 **Polyworx**	NL	Arjen Korevaar	•			•		Active participation
8 **NLR**	NL	Chris Groenendijk Walter 't Hart	•		•		•	Active participation

Time table

Work Package	Year 1				Year 2				Year 3			
WP1 Specifications (Kick-off Feb 2007)	■	■										
WP2 Resin-material properties			■	■	■	■						
WP3 Cure-related-defects detection techniques			■	■	■	■						
WP4 Numerical models					■	■	■	■				
WP5 Validation									■	■	■	■

Resources

Partner	Man Months	Computing costs [k€]	Other costs [k€]
CIRA	10-12		15
DLR	9	50	18
INTA	?		
NLR	12		20
Polyworx	3		7
QinetiQ	?		
SICOMP	5		7
University of Twente	5		7