DEVELOPMENT OF COMPOSITE PARTS WITH RTM PROCESS BASED ON NEW HIGH FLUIDITY THERMOPLASTIC POLYMERS

G. Orange[1*], E. Bessard[2], J. Breard[3], L. Bizet[3], J.L. Bailleul[4], S. Comas-Cardona[5], Ch. Binetruy[5], Ph. Boisse[6] , M. Gomina[7]

[1] *Research and Innovation Centre Lyon, Solvay, F69192 Saint Fons, France.*
**Corresponding author's e-mail: gilles.orange@solvay.com*
[2] *Centre de Recherche, CTeC Hutchinson, F45120 Chalette sur Loing, France.*
[3] *Laboratoire Ondes et Milieux Complexes, CNRS-Université Le Havre, F76600 Le Havre, France.*
[4] *Laboratoire Thermocinétique Nantes, CNRS-Université Polytech Nantes, F44306 Nantes, France.*
[5] *Research Institute in Civil Engineering, Ecole Centrale Nantes, F44321Nantes, France.*
[6] *Laboratoire Mécanique des Contacts et Structures, INSA Lyon, F69621 Villeurbanne, France.*
[7] *Laboratoire Cristallographie et Science des Matériaux, CNRS-ENSICAEN, F14050 Caen, France.*

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Introduction

The inability to produce parts of complex geometry at controlled cost prevents the use of thermoplastic composite materials for application in medium to large series, despite the major advantages of these materials as their low environmental impact and their good mechanical behaviour. Among the different manufacturing processes of composite structures, the liquid impregnation at low pressure of a dry preform placed in a mould (Liquid Composite Moulding) presents a major interest in the production of parts with complex geometry (non-developable surfaces) with the possibility of integrated functions. A R&D Consortium ('Tapas-LCM') has been set up between industrial and academic partners to develop a new process based on LCM and new high fluidity thermoplastic polymers.

RTM : High fluidity TP polymers, associated with high permeability reinforcement

Reactive RTM has been extensively studied, but some problems inherent to polymerization are not yet solved [1]. New thermoplastic polymers based on polyamide chemistry (aliphatic and semi-aromatic) with low viscosity have been especially developed as an alternative. Main characteristics of high fluidity PA (PA66) are listed in Table 1.

Table 1: *Main characteristics of the new high fluidity Polyamide (PA66)at RH0.*

	Viscosity (Pa.s)	Tm (°C)	Tc (°C)	Xc (%)	E (GPa)
Standard PA66	225	265	216	40	3.0
PA66 HF	65	262	220	40	3.0
New PA66 HF	15	256	227	30	4.2
PA66 SHF	5	262	222	38	3.2

Two permeability models taking into account the pore structure at macro and micro-scales were used to estimate the in-plane permeability (Kx, Ky). These models were employed to design a new enhanced permeability fabric. First results show the technical feasibility of RTM process based on high fluidity thermoplastic polymers (15 Pa.s) with a complete impregnation (void content < 1.5%) at low injection pressure ($\Delta P < 1.5$ MPa) : see Fig. 1. Fiber contents are between 50 and 60 vol.%, leading to structural composites. The improvement of the process cycle time at low void content relies on both preform permeability (K : from 10^{-10} to 10^{-9} m^2) and polymer characteristics (viscosity $\eta < 20$ Pa.s, wetting angle $\theta < 75°$) [2]. In a second time, the process cycle time can be significantly reduced by using compression [3].

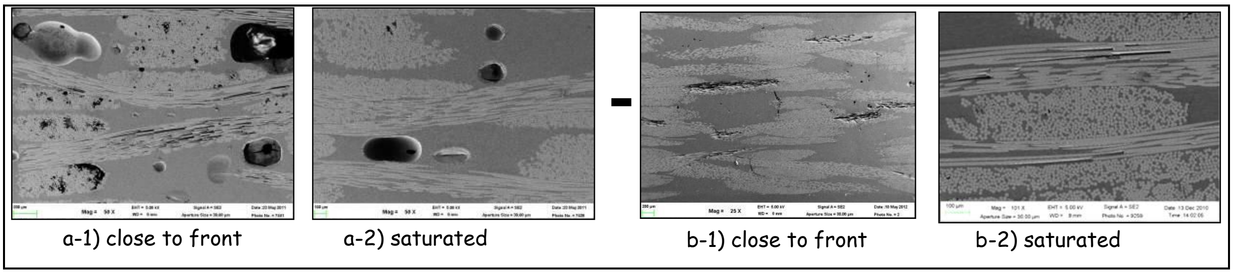

Figure 1: *Microstructure of RTM plates obtained from low viscosity PA66 and Injectex glass preform (55 vol. % fibre ; ΔP < 15 bars) : a) high fluidity PA66 (50 < η < 75 Pa.s) ; b) new high fluidity PA66 (5 < η < 20 Pa.s)*

Laminate TP composite consolidation

Medium to high Tg semi-crystalline polymers are required for semi-structural to structural applications. The crystallization of polymers between the equilibrium melting temperature of crystals and the glass transition temperature is controlled by the confinement (inter/ intra mesh) and the cooling down rate. Standard and flash DSC are used to analyze the isothermal crystallization kinetics in a large temperature range. Global shrinkage (crystallization and thermal shrinkage) is estimated at 4.5%, from PVT measurements. This shrinkage leads to large residual stresses in the consolidated composite parts.

RTM TP process : from plates to 3D functional parts

Woven reinforcements undergo very large in-plane shear strain to obtain double curved preforms. Based on 'frame' geometry, simulation is developed at meso-scale from the mechanical characteristics of reinforcement as in-plane tensile, shear or bias tests (see Fig. 2).

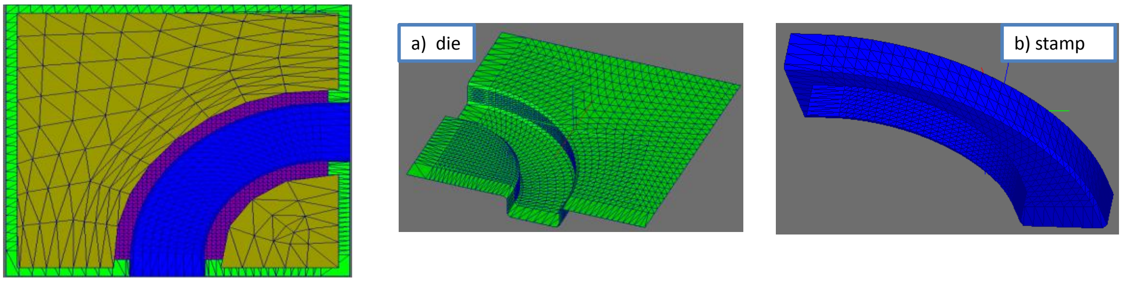

Figure 2: *Simulation of frame forming from high permeability woven reinforcement (Abaqus, PlasFibre)*

The preform permeability values can be estimated from the geometry of the deformed ply stacking.

These first experiments show it is possible to produce complex composite part for structural application through RTM process from high fluidity TP polymers (η < 20 Pa.s) and high permeability drapable woven reinforcements ($K > 5.10^{-10}$ m^2).

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