Flow Processes in Composite Materials

RTM Process Analysis and On-Line Characterisation
E Ruiz, V Achim (Ecole Polytechnique of Montreal)
Resin Transfer Molding (RTM) is a widely used manufacturing technique of composite parts. Selecting the adequate manufacturing conditions (i.e. temperature, pressure and resin formulation) is often a tricky decision mainly based on user’s ‘know-how’. In this study, a software has been developed for helping process engineers in the proper selection of such critical parameters. The software is also coupled to a data acquisition system allowing quick identification of key material properties. (C2:1)

Experimental Investigation of through the Thickness Temperature Gradients in Thick Composite during Infusion Process
M Gascons, J Vives, N Blanco (Univ de Girona) K5 Matthys (Brunel Univ) P Simacek, SG Advani (Univ of Delaware)
Deformation on composite parts, due to stresses built up during curing, is an important manufacturing problem for parts under a flexible tooling system. Such issues are usually addressed by modifying the component shape after experimental prototyping. This study focuses on flow process and curing strategy instead to reduce residual stress. (C2:2)

The RTM-Light Manufacturing Process: Experimentation and Modelling
O MacLaren, JM Gan, C Hickey, S Bickerton, PA Kelly (Univ of Auckland)
A study was carried out to investigate key aspects of the RTM-Light process, in particular the effect of mould flexibility on process times, cavity thickness and pressure distributions. A simulation of RTM-Light was developed using an iterative coupling procedure to solve the fluid-mould interaction problem. Excellent agreement was obtained between experimental and numerical results. (C2:3)

Optimal Flow Behaviour Formulation Based on Homotopy Maps and Configuration Spaces for LCM Process Design
N Montés, F Sánchez, A Falcó (Univ CEU Cardenal Herrera)
This paper proposes a mathematical formulation for the optimal flow behaviour in LCM processes, based on different optimal criterions. It is based on a class of homotopy maps and the use of Flow Pattern Configuration Spaces in order to characterize an idealized resin mould filling behaviour. (C2:4)

Development of Computer Controlled Flow Manipulation for Vacuum Infusion Processes
JB Alms, JL Glancey, SG Advani (Univ of Delaware)
A computer controlled gantry system has been constructed to deploy a rigid vacuum chamber to automate the Vacuum Induced Preform Relaxation (VIPR) process. To introduce active control, the gantry system is combined with a liquid injection molding test bed with several resin injection ports, vents, and flow sensors to automate flow control in VARTM. (C2:5)

Analytical Permeability Modelling for 3D Woven Reinforcements
A Endruweit, AC Long (Univ of Nottingham)
This study deals with the analytical modelling and experimental characterisation of the permeabilities (in-plane and through-thickness) for examples of 3D woven carbon fibre reinforcements, relates them to the specific textile architectures and compares them quantitatively with the properties of examples for commercial 2D carbon fibre reinforcements. (C2:6)
Full Characterization of a Stitched Twill Weave Textile by Unsaturated 2-D and 3-D Permeability Measurements
G Rieber, P Mitschang (Institut für Verbundwerkstoffe GmbH)
In this paper the influence of stitching seams on the 2-D and 3-D permeability are presented. The 2-D measurements are conducted with lineal capacitive sensors; the 3-D measurements are conducted by ultrasound. The paper will reveal the significant influence of the stitching seam distance on the permeability values K1, K2, and K3, the orientation angle of the flow front ellipse, and the anisotropy. (C2:7)

Biot Coefficients of Unidirectional Fibre Packed Assemblies: Theoretical and Experimental
T Tran, S Comas-Cardona, NE Abriak, C Binetruy (Ecole des Mines de Douai)
The present paper aims at predicting the Biot coefficients for perfectly straight unidirectional fibre assemblies using different micromechanical methods. An experimental procedure is also detailed and applied to rubber fibre assemblies. The theoretical and experimental Biot coefficient results are compared and show a good agreement. (C2:8)

A Study on the Determination of Stochastic Reinforcement Permeability in Constant Injection Pressure Conditions
PCT Gonçalves, NC Correia (INEGI)
We report two effects in permeability measurement: the error introduced by assuming constant injection pressure and the evolution of permeability dispersion with volume fraction. For the first, we proposed a simple modelling approach. For the second, our results showed a reduction in the dispersion with higher fibre volume fractions, which we believe is due to the reduction of the variability of the size of the pores of the reinforcement. (C2:9)

A Thermomechanical Constitutive Model for Fibrous Reinforcements
JJ Cheng, PA Kelly, S Bickerton (Univ of Auckland)
A thermomechanical model for the response of fibrous reinforcements, as occur in Liquid Composite Moulding processes, to compaction is presented. Rate-dependent non-linear inelastic behaviour as well as rate-independent permanent deformation are incorporated into the model. Fibre bending and frictional sliding are accounted for. The model is validated against experimental compaction data. (C2:10)

Compaction Response of Fibre Reinforcements Depending on Processing Temperature
S Aranda, F Klunker, G Ziegmann (TU Clausthal)
The compaction behaviour of textile reinforcements in Liquid Composite Moulding must be considered for the design and optimization of those closed mould manufacturing processes. The deformation of the reinforcement during preforming and processing is affecting important processing and final product characteristics. The influence of the heating treatment on fibre reinforcement deformation is studied in the present work. (C2:10A)

Nano-Composites: From Reology to Forming Process Simulation
F Chinesta, A Ma, M Mackley, E Cueto (EADS)
This paper is concerned with the rheological modeling of untreated Carbon Nanotubes (CNTs) suspended within an epoxy resin and its application in nanocomposites forming processes. A new model named the “Aggregation/Orientation” (AO) model was developed to describe the experimental findings. However, it predicts an “affine” orientation of the tubes with the fluid deformation that is not observed experimentally. (C2:11)
Flow of Carbon Nanoparticle Loaded Epoxy Resin in Liquid Moulding
EF Reia da Costa, AA Skordos, IK Partridge (Cranfield Univ) A Rezai (BAE Systems)
The Resin Transfer Moulding of carbon and glass epoxy composites containing carbon nanoparticles is studied. Different types of carbon particles and dispersion processes are investigated. The work focuses on the influence of nanoparticles on flow, the filtration of the nanofiller, and the potential of incorporating these effects in process models. (C2:12)

Compression Moulding of SMC: Coupling Between the Flow and Local Void Contents
NEJ Olsson, TS Lundström (Luleå Univ of Technology) K Olofsson (Swerea Sicomp AB)
During compression moulding of sheet moulding compound (SMC), voids are formed that can deteriorate the properties of the final product. Here, experimental work and CFD-simulations have been carried out in order to increase the knowledge of the SMC compression moulding behaviour which highly affects the quality of the final products. (C2:13)

Resin Infusion of Sandwich Structures - Core/Skin Interactions and Void Formation
RK Cullen, SM Grove, J Summerscales (Univ of Plymouth)
This paper presents results of experimental and modelling work exploring aspects of fibre, core and resin interaction during the infusion process. In particular we observe the nature of regions of flow front convergence in areas containing various types of core, such as wood, sealed wood and closed cell foam. Data on comparative resin absorption for the various cores are presented. (C2:14)

Modelling the Consolidation of Partially Impregnated Prepregs
M Wysocki (Swerea Sicomp AB) S Toll, R Larsson (Chalmers Univ of Tech)
A finite element model is developed to solve consolidation problems for composites manufacturing. The model is developed from a generic two-phase continuum theory allowing for coupling between the solid and fluid responses. The code is applied to a case study consisting of consolidation of a hat stringer to evaluate nonlinear effects. (C2:15)

Monitoring the Liquid Resin Infusion (LRI) Manufacturing Process under Industrial Environment using Distributed Sensors
P Wang, J Molimard, S Drapier, A Vautrin (Ecole des mines de Saint Etienne) P Henrat (Hexcel Corporation SAS)
In the present paper, a novel direct approach to detect the resin flow front during the LRI process under industrial environment is proposed. To detect the resin flow more accurately and verify the results which are deduced from indirect micro-thermocouples measurements, optical fibre sensors based on Fresnel reflection are utilized. (C2:16)

Permeability Prediction in Fibrous Porous Media with Complex 3D Architectures
WR Hwang, JF Wang, HL Liu (Gyeongsang National Univ)
A 3D finite-element scheme combined with fictitious-domain/mortar-element method is presented to investigate the permeability of fibrous porous medium using a representative tri-periodic domain. The current scheme has been verified by comparison with existing literatures and employed to predict permeability of fibrous porous medium with various complicated 3D architectures. (IC2:1)

Parameters Affecting Mechanical Properties of Composite Manufactured by Liquid Resin Infusion (LRI)
A Njionhou Kepnang, F Berthet, B Castanie (Univ de Toulouse)
The properties of composites made by Liquid Resin Infusion (LRI) process depend on those of components used and the process parameters. To understand this relationship, an experimental plan is proposed. The results show the effects of processing parameters on the thickness, ultimate tensile and compressive strengths of LRI composites laminate. (IC2:2)

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