New Materials and Out-of-Autoclave Manufacturing Technologies for Aircraft Structures

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The majority of high performance composite structures are manufactured in autoclaves. Autoclave processing of composites uses primarily pre-impregnated unidirectional fibers or fabrics (prepregs) that are cured at 180°C and consolidated with 6 atm of pressure. A large database of design allowables for autoclave prepregs is available and accessible to product designers. This well established process requires high infrastructure investment for autoclaves as well as high recurring tooling costs. The maximum component size is limited by the size of available autoclaves. Alternative processing methods need to be investigated in order to reduce production costs and broaden the supply base of composite structures. This presentation addresses the application of a relatively new class of composite materials using out-of-autoclave (OOA) technologies. The advantages of OOA processes include substantially lower infrastructure, tooling, and overall manufacturing costs. However, current OOA processes give poorer component quality and material properties, which has limited their application. The presentation outlines recent works on the characterization of OOA prepregs. The physics of air evacuation, void nucleation, resin infiltration and pressure evolution is presented, and how all this depends on prepreg material architecture, bagging conditions, location of vacuum ports, temperature and vacuum application, size, lay-up, and shape of the component.

Furthermore, the presentation will present recent research results on the processing of carbon nanotube modified epoxy resins. Carbon nanotubes have been added to composite laminates to improve their mechanical, thermal, and electrical properties and also provide a structural component with multifunctional properties. Most of these efforts were to improve matrix dominated properties, i.e. interlaminar reinforcement to improve delamination resistance. These studies showed an increase in fracture toughness even at low-carbon nanotube content. In this presentation, the effect of carbon nanotubes on the Mode I and Mode II interlaminar properties of carbon fibre reinforced composites will be presented. The importance of dispersion stability during cure will also be discussed.
Biography and research interests

Dr. Pascal Hubert (Ph.D. Metals and Materials Engineering, The University of British Columbia) holds a Canada Research Chair (Tier II) in Advanced Composite Materials. He is an associate professor at McGill University in the Department of Mechanical Engineering since September 2002. Before coming back to Canada, Dr. Hubert was leading the process modelling research at the Advanced Material and Processes Branch at NASA Langley Research Center in Hampton, VA. Dr. Hubert is a co-founder and director of Convergent Manufacturing Technologies Inc., a university spin-off company specialized in software development for composites process simulation. At McGill University, Dr. Hubert research focuses on the processing and performance of composite materials. His research activities include:

- **Process Modelling of Polymer Composites**: Processing models are developed in order to understand and optimize the manufacturing of composite materials. These models use the finite element method and simulate the physical phenomena found during the processing of polymer composite materials (i.e. thermal, chemical, flow and residual stress development).

- **Investigation of Processing-Performance Relationship**: The design of composite structures is intimately linked to the processing cycle used. It is critical to understand the relationship between processing and the performance (mechanical, surface finish) of the final composite part.

- **Development of Polymer Nanocomposites**: This new class of composite materials consists of polymers reinforced with particles a few nanometres in size (e.g. carbon nanotubes, nanoclays). The properties of these composite materials are predicted using new numerical approaches that combine molecular dynamics and continuum mechanics.

- **Development of Polymer Composites Characterization Techniques**: In order to apply process modelling, numerous material properties must be measured. The resin curing behaviour is correlated with other changes in other properties (e.g. viscosity, cure shrinkage, elastic modulus). Fibre preforms used in composite materials are also characterized to obtain the permeability and compaction as a function of fibre architecture and volume fraction.