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HOMOGENISATION OF COMPACTION BEHAVIOUR AND PERMEABILITY FOR MULTI-LAYERED COMPOSITE STRUCTURES MANUFACTURED VIA LCM PROCESSES.

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Modern composite structures make use of the possibilities offered by composite materials to add stiffness and strength only where they are needed and in the direction required. This ability to tailor material properties to the needs of the structure have led to significant weight reductions; they have also allowed one to develop new architectures and design shapes, as composites materials are usually formed at the same time as the part they form.

The Liquid Composite Moulding (LCM) family of processes, comprising RTM, CRTM, RTMLight and Resin Infusion VARTM, involves the placement of dry fibrous reinforcement into a mould and then, after closing the mould, injection of liquid resin to impregnate the reinforcement before resin-cure. LCM processes have a number of advantages over other processes; these include control over harmful volatiles, the ability to achieve high and consistent final fibre volume fraction (V_f) and their potential for automation, greatly reducing labour costs [1, 2].

During manufacture with an LCM process, the operator typically has little control. Successful process development by trial and error, on the other hand, requires experience and can be time consuming and expensive. Reduction of development costs requires a good understanding of the process physics, and can benefit from development of an accurate simulation tool. Significant effort has been placed into establishment of RTM and CRTM simulations that accurately predict process outcomes, such as fill time, flow front advancement and dry spot formation [3, 4].

SimLCM is a simulation software developed at the University of Auckland to simulate LCM processes. Incorporation of the compaction behaviour of the fibrous reinforcement into the simulation allows for calculation of the tooling forces. Modelling of the reinforcement compaction also allows one to calculate the changes in permeability which occur during compaction, which is necessary for providing accurate simulation of the CRTM process. To determine the compaction and permeability behaviour, a set of experimental characterisation is required. Experimental procedures for reinforcement characterisation were devised and presented in [5-8] and [8, 9], respectively, for the compaction and permeability. Using these characterisation techniques, a material database can be constructed for the range of fibrous reinforcements used by a manufacturer. However, in a real composite structure, the laminate is seldom composed of only one type of reinforcement across the thickness of the part. Each different fabric within a laminate will exhibit different compaction behaviour; this makes , itdifficult to determine the fibre volume fractions and permeabilities of a laminate at any given mould thickness. Characterising the response of every possible layup would be costly and ineffective. Taking into account the reinforcement orientation and shear, induced by the draping of a flat fabric onto a complex geometry, further complicates matters .

In this paper, a method is proposed whereby the known compaction and permeability responses of the individual fibrous layers are homogeneised to produce material properties for the complete laminate. This technique is based on the assumption that the compaction stress on the reinforcement is homogeneous through the thickness of the layup.

A preprocessing module for SimLCM has been developed to handle complex preform and draping induced shear effects on the compaction and permeability of the reinforcements. The preform definition and draping analysis is performed using the Composites Modeler for Abaqus developed by Simulayt; this information is then transferred into SimLCM along with the compaction and permeability data of the reinforcements being used, from the material database constructed from the characterisation experiments. Details of the technique will be presented in this paper as well as a case study of a composite structure presenting the simulation of the fabrication process and comparing it to experimental results.

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