Combining process simulation and sensing for optimised composites manufacturing

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Introduction

Liquid composite moulding of advanced composites is a closed manufacturing process which rarely allows the operator to know what is happening in the mould e.g. during filling until resin emerges from the outlet gates or not even this if the mould is in an oven. The introduction of non-intrusive or through-the-laminate sensors that would signal when resin arrives at a specific location or at an outlet gate would help considerably the operator at the production floor but also during the development stage to identify and to check the repeatability of the process. On the other hand, flow simulation tools which are used extensively in the simulation of the filling stage is a powerful tool for the mould design and the optimisation of the filling stage as long as they are fed with the right parameters including the well-known permeability tensor. Since the first use of the Darcy law in the simulation of the resin flow through fibre preforms, the calculation of the permeability tensor has been one of the most challenging steps to achieve accurate results. However, only recently some researchers focused on the calculation of these parameters through the combination of flow simulations and experimental data.

Identifying the appropriate model parameters

In this work a more generalised approach will be developed for the automatic calculation of the important process parameters by matching computer simulations and process measurements through an error-minimisation algorithm. The target is to use this method not only when many experimental data are available and limited process variability is expected such as in a lab-scale experimental set-up's but also at industrial applications where measurements are limited and process variability may be high. Today this task is done manually trying to match computer simulations with the times the resin exits the cavity.
RTM-worx software has been used for the filling simulation based on the popular Darcy law:

$$\vec{\mathrm{u}} = -\frac{1}{\mu}\overline{\overline{K}}\vec{\nabla}p \tag{1}$$

where $\vec{u}$ is resin's velocity vector, μ is the fluid viscosity, p the resin pressure and $\overline{K}$ is the permeability tensor.
A very important advantage of RTM-worx is that it can be included into an optimisation loop using the unique SALT language developed by Polyworx.
Although resin's viscosity may remain constant throughout the filling stage the permeability tensor may vary by an unknown factor not only throughout the cavity but also from one injection to the other. For this reason a robust optimisation tool and strategy have been developed to cope efficiently with the potential lack of data.
For the resin monitoring the Optiflow system from Synthesites have been used. Although during production limited number of durable resin arrival sensors will be used, during the

process development phase an additional number of flexible sensors can be added in order to improve considerably the volume of experimental data and help the identification algorithm find the appropriate process parameters.

In fig.1 the identification procedure is depicted: the flow simulation starts with a first approximate of the process parameters, solves the Darcy equation and compares the calculated resin arrival times to the experimental ones. Based on the difference between them the identification algorithm calculates new parameters that potentially will minimise this difference. The identification loop continues until this difference drops below a given threshold.

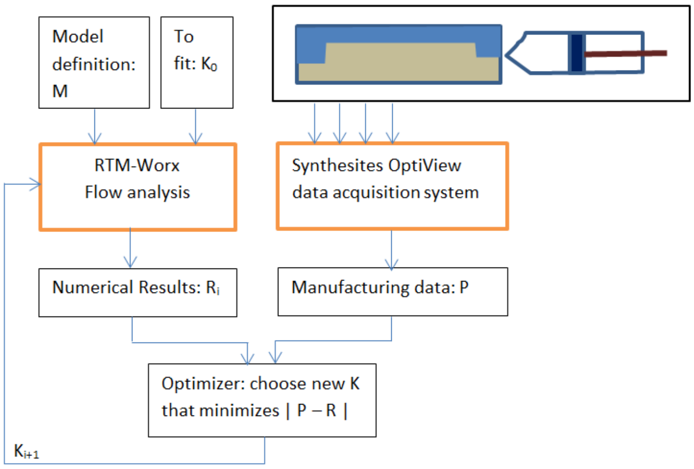

Figure 1: *Overview of the model identification procedure.*

Conclusions- Next Steps

An automated procedure for the accurate modelling of the filling stage for liquid composite moulding process is being developed, combining computer simulation and process monitoring tools in an intelligent environment. Next steps are the finalisation of the algorithms and their implementation to realistic applications in order to benchmark and optimise the performance of the algorithms.

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