Abstract

Within Fibre Reinforced Plastics (FRP) manufacturing technologies, Liquid Composite Moulding (LCM) describes a group of cost efficient processes that provide an outstanding variety of possibilities for the manufacture of parts of virtually any size and complexity. In addition to the classic pressure supported Resin Transfer Moulding (RTM) process, techniques such as the VARTM (Vacuum Assisted RTM), the ARTM (Advanced RTM) and the SCRIMP® (Seeman Composite Resin Infusion Molding Process) are well established. Each of the different techniques utilizes the same method – a thermoset resin is injected into a mould containing the reinforcement. The impregnation of the reinforcing structure by a resin in a closed mould permits the combination of a wide range of matrix systems and reinforcing materials. With the gelation and curing of the resin after the completed injection, the finished part is ready to be demoulded.

The overall process is influenced by many parameters including:

- the reinforcing structure,
- the viscosity and curing properties of the thermoset resin,
- the position of inlet and outlet,
- the pressure distribution throughout the mould and
- the geometry and size of the part.

Though the process chain has to be analysed as one – from the raw materials to the finished part – the key step within that chain is the injection and impregnation of the porous reinforcing structure within the closed mould. An inherent property of any porous material characterized by its ability to let a fluid flow through under the driving force of a pressure gradient, is the material's permeability. Because it controls the propagation velocity of the resin system in the mould, the permeability of the reinforcing material is crucial for both understanding and modeling the RTM-process. Consequently, measurement and determination of the flow front propagation is necessary to further the development of the LCM-process and to maximize high volume productions while maintaining overall quality and process control.

The importance of the reinforcing structure and the effects on the RTM-process make it clear that a separate evaluation of key characteristics such as permeability is the best way to understand the process. As such, characterizing the permeability of fibre structures can offer valuable information about the general design of the preform structure as well as the preform structure's influence on permeability alterations.

Though the importance of an online control of the in-mould flow propagation processes is recognized as an important tool, existing efforts to describe and control the flow front position on a continuous basis have severe problems. Apart from others, the high temperatures and pressures occurring, the thermosetting materials and their chemistry, as well as the high geometrical complexity of moulds are issues to be taken into account during the development of new mould integrated sensor systems.

A customized Capacitive Condensator Reading System (CCRS) provides the ability to incorporate the above features with a continuous online determination of the flow-front position in closed moulds. The condensator is integrated within the mould surface and is able to measure the spreading of the resin by the differentiation of the complex dielectric constant of air and resin. This system resolves the particularly difficult problem of gathering data concerning the permeability of conductive fabrics (i.e. of carbon fibre fabrics), which cannot be measured by a standard capacity sensor. Investigation and experimental work lead to the result that (although exhibiting a 'Faraday's cage') by using an insulated sensor and a newly developed and customized electronic data acquisition system the propagation of a fluid can be determined.

As a result, the newly developed capacitive sensor system allows the online determination of the flow front propagation of liquid systems in both non electric conducting and conducting reinforcing structures throughout the injection processes in closed moulds. When compared to existing measurement methods, the benefits of the Capacitive Condensator Reading System are:

- online continuous determination of flow front propagation,
- online data acquisition for permeability calculations,
- online fibre volume fraction control,
- online cavity height control,
- online curing documentation

and the ability to

- allow high volume fractions and injection pressures,
- withstand high tool and resin temperatures,
- allow any geometry within the tool.

With the understanding that the process chain is a complex production cycle with its various interacting elements and the possibility to document these completely in an overall quality and process control, the realization of the potentials of the LCM-technologies will perform even more outstanding manufacturing possibilities for high quality and high volume productions in the future.