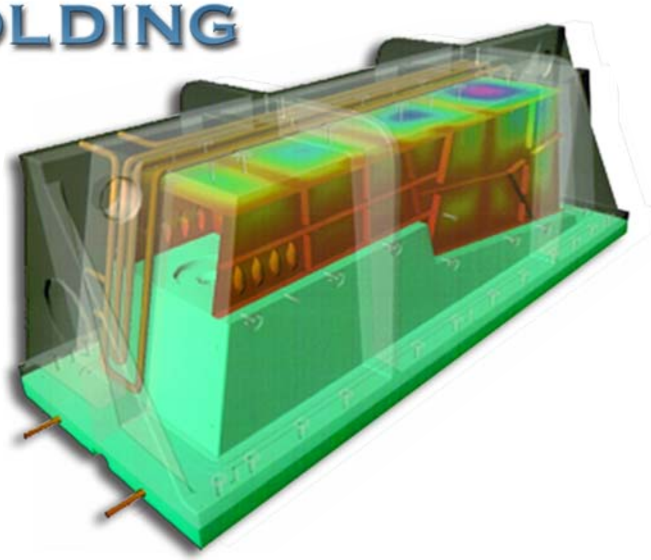
University of Delaware Center for Composite Materials
CompositeTechBrief

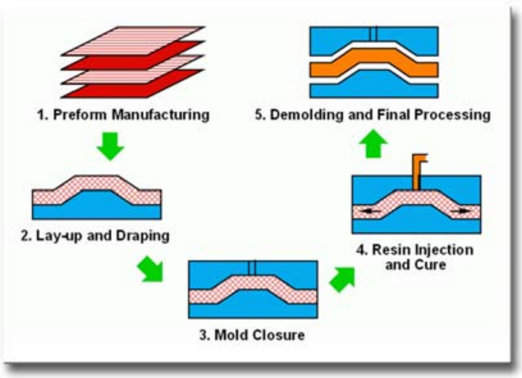
Resin Transfer Molding



Overview

A polymeric composite consists of reinforcements and a matrix to hold the reinforcements and to transfer the load. The reinforcements are usually glass, aramid or carbon fibers and the matrix is a thermoplastic or thermoset polymer. The Liquid Composite Molding (LCM) refers to a number of processes that use liquid resin to impregnate the stationary fibrous preform. The variation of this process that is of a particular interest is Resin Transfer Molding (RTM).

During the RTM Process, the preform is placed into the mold cavity, the mold is closed and the resin is injected into the cavity under pressure. Once the liquid resin fills the mold cavity, it cures, during which the resin hardens due to the formation of polymeric network forming the matrix of the composite, allowing the part to be de-molded. Note that the mold walls are considered rigid and preform is stationary during the injection. This technique is well known and has been traditionally applied to moderately large parts in various applications. It allows one to obtain even very complex neat-shape parts with good surface finish, in many cases at reasonable production rates. Careful process design is needed to obtain a repeatable high quality product.

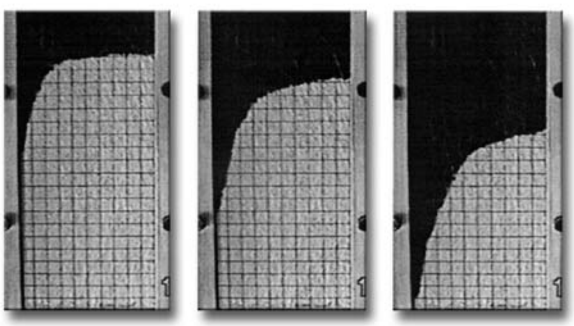


Process Challenges

The complexity of each stage will depend on the mold shape, preform architecture and, obviously, the design of the mold. The mold shape and preform architecture would be dictated primarily by the part design. The design details of the mold, such as gate and vent locations, runners for resin and similar factors, can be adjusted for the ease of manufacturing only as long as the design criteria are satisfied. The ability to take advantage of this fact and design a fast, reliable and cheap process depends on our understanding of the RTM process and the ability to model it by analytical or numerical means.

Preforming and Race Tracking

Preform architecture and type is generally prescribed by the part design. In most cases, it consists of layers of woven fibrous material, precut to proper shape and draped over the bottom part of the mold. The draping often results in the shearing deformation of the original preform. Then, as the mold is closed, preform is deformed further by compaction. To a significant degree, these deformations are understood and can be predicted by available tools. Their effects are two-fold: (i) Design specifications such as fiber volume fraction and elastic moduli change and (ii) Resin flow in subsequent phase is significantly influenced. The preform cutting process is prone to minor deviations from the desired shape, and so is the preform placement in the mold. This introduces potential variability, a particular process



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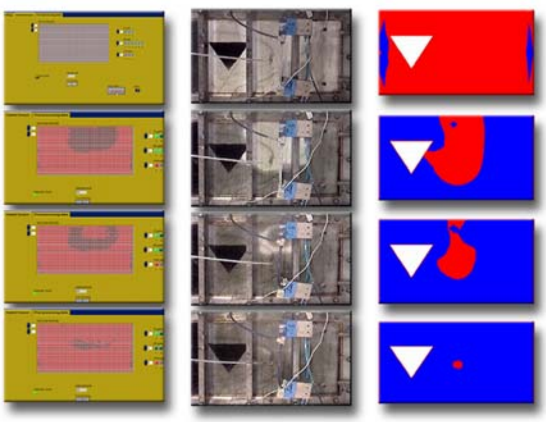
feature of all LCM processes. The gaps between mold and preform may serve as channels of low resistance (racetracking channels) by resin. Their presence-or absence-may significantly alter the subsequent filling stage of the process, lowering part quality or increasing number of rejected parts. The variability can be accounted for and various passive- and active-control schemes were examined, implemented and tested to reduce or eliminate this problem.

Resin Injection Stage

The resin is injected into a closed mold through a gate or gates. The location of the gate plays a key role in governing the flow dynamics of the resin. The dynamics decide if the



resin will displace all the air and fill up the empty space in the mold or if certain regions will remain unfilled with resin. The unfilled regions are known as voids or dry spots. They are undesirable as their existence results usually in rejection of the manufactured part. The number and position of the gates also dictate how fast the filling process can be completed which is also important as reduction in filling time translates into lower cycle time and better production efficiency. As one cannot visualize the resin flow inside the closed and non-transparent mold, the incorrect placement of the gate is usually uncovered by detection of voids in the manufactured part. Remachining to relocate the gate can be expensive in both money and time. Thus, most of the process design, most importantly the gate and vent locations to let the displaced air out, should be accomplished before mold construction. Simulation tools, such as LIMS (Liquid Injection Molding Simulation) from University of Delaware that can predict the movement of the resin inside a closed mold can be used for this purpose.

The crucial data needed for this simulation is the resin permeability, which quantifies the preform's resistance to flow. This is a second order tensor, depending on the preform architecture and deformation as stated above. To establish permeability values, experiments must be conducted as the predictions based on analytic models are still quite inaccurate. Depending on which permeability components are needed one must choose a proper experimental setup. The number of experiments to be performed may be high, especially if preform shearing and compaction is to be included in the study. To alleviate this problem, one might use setup allowing continuous measurement while changing the preform compaction (and thus fiber volume fraction).

Cure and De-molding

After successful filling, the resin is allowed to cure, either at room temperature or by the means of heating elements within the mold. The curing reaction is exothermic and substantial amount of heat may be generated during curing, non-uniformly elevating the system temperature. The temperature and degree of cure during the reaction are very important. Non-uniform temperature field generally results in residual stress and/or deformation (warp) of the finished part. Numerical modeling may be used to determine in advance whether this is likely to happen. The issue then may be addressed by several means, like stacking sequence of the preform layers or careful temperature control during curing stage.

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