Recent innovations in equipment, resin chemistry and mould building methods have elevated the LRTM process to a whole new level, one that not only offers a very practical moulding technology, but is now also being recognized as a “green” process.

The “green” advantage does not only refer to the clear reduction in VOC emissions associated with the closed-mould LRTM process. Resin materials suppliers have released bio-based resin systems which are based on various soy bean formulations, such as Ashland Chemical’s Envirez™ resins. The new Envirez resins are proving to be ideal for the LRTM and vacuum infusion moulding processes, offering low viscosity, excellent wet-out of fibres, and enhanced surface finish. These resins cure well in ambient-temperature tooling or can be accelerated with temperature-condition tooling.

Beyond resins there are solvent replacements such as Acrastrip™ which further the green advantage by eliminating acetone needed to flush injection equipment.

Material suppliers have made enormous commitments to bringing in ecologically-responsible resins and now these efforts are bearing fruit in support of the LRTM and vacuum infusion processes worldwide.

Efforts to conquer the process challenges of RTM and LRTM have been the focus of JHM Technologies (Fenton, Michigan, USA) since their inception in 1992. JHM Technologies has been recognized as one of the world leader in manufacturing and supply of state-of-the-art LRTM injection equipment, along with training classes on mould building and moulding process methods. Their development team is keenly focused on refining the LRTM process to enhance productivity and the quality of each moulding produced. They have developed a full line of LRTM injection systems which offer low-cost automation, thus eliminating the reliance on operator skills.

Background
Historically, the conventional RTM process relies on a central injection point with a “diverging” resin flow path towards the vents located at the outer extremities of the mould cavity. In contrast, the LRTM process takes advantage of a “converging” flow path beginning with a perimeter resin feed circumventing the mould cavity in a converging route to the vent located typically in the centre of the mould cavity. In addition, LRTM utilizes cavity vacuum which typically eliminates half of the atmosphere within the mould cavity prior to the injection process and is completed by a perimeter flange under high vacuum which holds the upper and lower mould halves together during injection and cure.

The “converging” resin flow path combined with balanced cavity and clamping flange vacuum eliminate the primary challenge faced by the conventional RTM process, which is plagued with flowing resin that “race tracks” around the outer perimeter of the fibre, leaving behind excessive laminate voids and occasional dry fibre.

In LRTM, the use of vacuum as a means to retain the mould halves eliminates the need for capital equipment such as presses or excessive mould structure and weight to counteract internal cavity pressure needed for conventional RTM. This has opened the door for moderate-size moulds to be handled by hand with one or two operators, making the LRTM process convenient and practical for even the small moulder.

Even with a lighter LRTM tooling structure and the elimination of clamping presses, several challenges still remained to be overcome, as described below.

Refinements
With these initial advantages of the LRTM process and moulds in play, the challenge of controlling the resin injection feed was enhanced since now the moulds are lighter in structure and there are no hydraulic presses to maintain closure. To meet this
JHM Technologies identified the precise control factors in mould building methods which can prevent the usual inaccuracies that come with composite tool building. By using a proprietary combination of mould lamination materials and methods, JHM Technologies has developed and now teaches moulders how to build tooling offering cross-section thickness accuracy well within ±0.15mm in all areas of the moulding. This level of mould accuracy is critical to the repeatable control of the moulding process and the quality of the mouldings produced. Having an accurate mould is crucial, yet there are two additional pillars of success in the process, i.e. fibre loading and controlling the injection pressure/flow rate.

**Fibre loading**
Loading the fibre in the mould is an aspect of the LRTM process that relies on the operator. It is not practical to add automation to the fibre loading process, and we must rely on the operator to manage the critical fibre placement step. While some preform technologies are available in the market, preforms are not practical for the vast majority of moulders due to capital cost or part geometry.

It is worth pointing out that fibre loading is an area that is often neglected by those offering technical support for the LRTM process. In fact, the most ingrained false idea circulating in the industry is that mould closure will "push the fibres into the details of the part cavity". This is totally wrong and works against many moulding applications. The truth is that mould closure at best can only pull the fibre tightly into the inner radii of the geometry, thus leaving fibre voids in the outer radii and providing a path for the resin to race track, which defeats all efforts to achieve uniform or accurate mould cavity calibration. The solution is to teach the operators techniques to fill the tight radii with fibre before loading the nominal fibre and to "over-stretch" the nominal fibre in the Z plane or vertical walls to make certain that the fibre properly fits the mould cavity before the mould is closed.

When the mould is uniformly filled with fibre in all areas and has consistent cavity calibration, it is possible to achieve uniform resistance to the leading edge of the resin flow towards the exit vents. Providing resistance to the leading edge of the resin flow creates a "plow" effect that compresses the remaining atmosphere in the mould, causing it to naturally flee...
The Infuser series of injection systems offered by JHM Technologies provides a level of automation that focuses on the resin flow rate, with an upper limit set point for pressure. Each mould has a specific programmed recipe which automatically controls the flow rate, the upper pressure limit, the resin injection temperature, the catalyst ratio, and the precise volume of resin as prescribed in the bill of materials. Furthermore, the recipe selection is fully automatic through the use of RFID tags. The operator simply sets the RFID tag connected to the mould on the remote control/RFID reader of the Infuser injection system. With the RFID tag on the reader, the operator simply presses the “Start” button on the remote control and the Infuser automatically fills the mould with precise flow rate, pressure, temperature, and volume control. The level of automation found in the Infuser series of LRTM injection systems is priced competitively with non-automated equipment in the market. Moreover, the features of the Infuser injection system pay for the equipment with material savings when compared with the competitive injection system.

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Successful LRTM moulding

The LRTM mould cavity must be calibrated with accuracy, and then loaded with fibre that uniformly fills all of the part geometry especially in the radii. The operator has to make sure that the fibre is stretched in the vertical plane, not relying on mould closure to position the fibre into the part details. The injection system must control the process so the operator does not need to make any adjustments.

Providing the needed injection control

The typical LRTM injection equipment in the market has little to no control of the resin injection process. Generally, the operator is left to count pump strokes or to decide to stop the injection process based on watching the resin as it begins to vent the mould. Equipment manufacturers, who have added controls to their injection systems, typically have some form of predetermined counter (PDC) to halt the resin injection when the mould is filled. Yet this type of system relies on the operator to adjust the “counts” as needed for each mould. In many cases, the operator decides on the volume needed to fill the mould and the value entered into the PDC is not based on the resin volume specified in the bill of materials for each moulding. In addition to the PDC, some equipment suppliers have added pressure sensing devices to prevent the injection from over-pressurizing the mould during the injection process.

The actual injection control requirements are far different from what are offered by most equipment suppliers. First, it must be understood that pressure alone is not the answer to the injection process control issue. Pressure must remain as a “governing factor” or “upper limit”, it cannot act as the sole control. This can be quickly understood when the surface area factor is applied to the injection pressure. For instance, just one PSI of pressure over one square foot (144 square inches) will provide 144 pounds of lifting force. Considering the fact that most LRTM tools only weigh about 4 pounds per square foot of laminate area, it is easy to understand how very little pressure can open the mould to cause a thick cavity cross-section and loss of resin flow path control.

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Fig. 3: Operator placing the RFID tag on the remote control reader and pressing the “green” start button.

Fig. 4: Infuser PRG - fully automatic LRTM injection system.

Fig. 5: JHM LRTM Training includes “hands on” moulding demonstrations.