

# HOW TO MAKE A CHOICE BETWEEN LIQUID COMPOSITE MOLDING PROCESSES?

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**SUMMARY:** With the growing demand of composite industry for consistency, quality, productivity, economy and ecological friendliness, more and more production plants are converting to Liquid Composite Molding (LCM) processes. Before converting, “beginners” and experienced people have to make a choice for the process to use according to specifications for their part. With the wide range of processes and the number of parameters to take into account (technical and economical), the choice is tricky and usually empirical. The purpose of this study – based on a worldwide database of industrial examples – is to give advises and simple tools to give an orientation for any new project. We focused our study on main processes found in the industry: vacuum infusion, RTM light, RTM Eco, CCBM, RTM and press molding. Taking into account process parameters, raw material availability, production cost **before** is a way to reduce development time and to start production in an efficient way.

**KEYWORDS:** Liquid Composite Molding (LCM), process selection, vacuum infusion, RTM, CCBM, press molding

## INTRODUCTION

The huge number of Liquid Composite Molding Processes acronyms – at least three to four dozen of processes very similar patented or not – is representative of the challenge to find the most appropriate process. Among others closed mold processes, we can quote: VI, VRTM, VARTM, VIM, VIP, VARI, CCBM, CVI, SCRIMP, VEC<sup>TM</sup>, PRESTOVAC, etc.

Process differences are mainly based on:

- the use of rigid tool, semi-flexible tool or flexible tool,
- the use of consumable, flow media,
- the use of high injection pressure, low injection pressure or no pressure,
- the use of vacuum assistance or not,
- the use of peripheral, linear or central injection,
- the use of automation or not,
- etc.

A few years ago, many industrial composite plants were using only ONE type of closed mold process to produce their different parts. This process was adapted to most of part produced but it could lead to technical and economical issues when the process was not adapted to a specific part.

More and more industrial plants try to convert their production lines to processes adapted to each type of part. In the same workshop, you can find different processes for different parts. Benefits are substantial: improvement of quality, increase of integrated functions, optimization of production, reduction of labor, reduction of production costs, etc.

## **FAMILIES OF PROCESS**

We classified main processes in three main families. These families are representative of LCM processes found in industrial production workshops in the world. For each family, we give a simple generic definition, typical applications of the process and we specify advantages and limits.

### **Vacuum Infusion**

Definition: Impregnation under vacuum of a dry structural reinforcement with liquid resin between a rigid mold and a flexible counter-mold (membrane).

Applications: Windmill Blade and Nacelle, Boat Hull, Industrial parts

Advantages:

- Moderate investment
- Ability to produce large parts
- Sandwich construction
- High % of reinforcement
- Large possibility of shapes (even part with undercut)
- Small series

Limitations:

- Importance of Know how
- Risk of vacuum breaking in case of leaking (waste part)
- Loss of consumable (20% of the material)
- Only one smooth side

### **RTM light, RTM Eco and Closed Cavity Bag Molding (CCBM)**

Definition: Injection under low pressure of liquid resin through a dry non-structural reinforcement with assistance of vacuum between a lightweight rigid mold and a lightweight counter-mold.

Applications: Transportation (Truck, Bus, Car), Boat Deck, Covers, Industrial parts

Advantages:

- Regularity in production
- Ideal for small & medium sized productions
- Sandwich-construction
- Smooth, glossy surfaces
- Small to Large parts
- Quick and easy manufacturing of tooling

Limitations:

- Vacuum pump and injection machine are necessary
- 2 molds are needed: male and female
- Importance of know-how

### **RTM and Press Molding**

Definition : Injection under high pressure of liquid resin through a dry structural or non-structural reinforcement between a heavy rigid mold and a heavy rigid counter-mold.

Applications : Transportation (Truck, Bus, and Car), Structural parts, Industrial parts

Advantages :

- High rate of production
- Easy to control
- Ideal for medium to large series of small to medium parts
- Possibility to produce structural parts
- High level of consistency
- Dimensional Stability

Limitations:

- Need a press or lifting facilities.
- Cost of the equipment (male and female mold + injection machine).
- Precision of molds.
- Importance of Know-how.

## **PROCESS CHOICE**

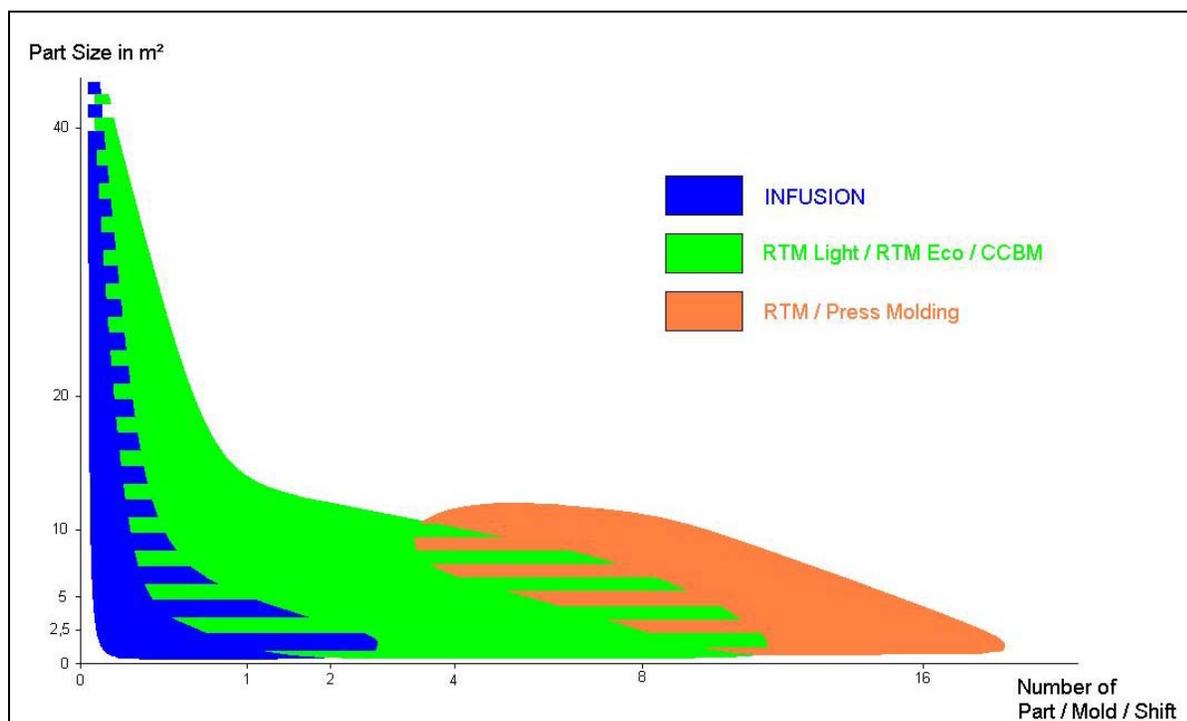
To define the best process, most important parameters to take into account are :

- **Part size**
- **Function integrated** (cosmetic, sandwich, insert, structural reinforcement, weight, chemical, fire and thermal resistance...)
- **Scale production** (Total number of part and production rate)
- **Investment + Production cost**

From definition of the part with specifications to the industrial production, the selection of the process and production method should follow this kind of specific procedure :

- 1) Check specifications of the part (size, geometry, mechanical, chemical and thermal performances or structural design, scale production, production rate, price indications...)
- 2) Define most suitable Family of process according to size of the part and production rate. Due to economical and technical reasons, it's impossible to produce any part with any process. For example, a 30m<sup>2</sup> part can't be produced reasonably by RTM or Press Molding due to limit in size of a press and investment related. The following Fig. 1 shows possibilities to use LCM Process according to part size and production rate (Parts per mold per shift to be produced).

Table 1 Part size as a function of production rate



- 3) Define precisely integrated functions of the part including :
  - Number of cosmetic surfaces (0, 1 or 2)
  - Sandwich construction area or not
  - Mechanical performances to achieve : Structural or not, Crash, Vibration...
  - Chemical resistance : Osmosis, Salt, Oil, Gas, Concrete, Acid...
  - Thermal resistance : Level of Temperature to achieve
  - Fire resistance : Standard to match
  - Thermal insulation : Level of Insulation to achieve
  - etc.

All LCM processes are able to obtain at least one cosmetic surface. For two cosmetic surfaces, Vacuum Infusion and CCBM must be rejected.

The use of sandwich construction and insert in the laminate is tricky with Press Molding.

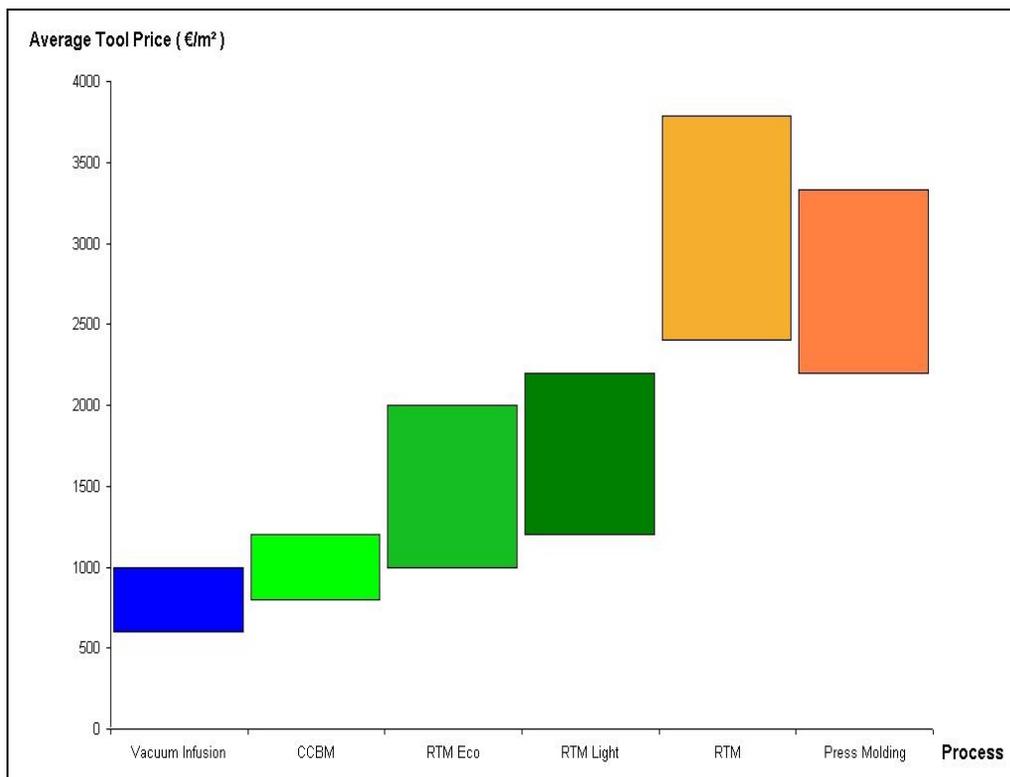
Vacuum Infusion, RTM and Press Molding are appropriate to production of Structural parts but local structural reinforcement can also be added in RTM light and RTM Eco molds.

Part with chemical and thermal resistance can be obtained with all processes because these functions are mainly linked to raw material (chemical properties and HDT of resin, special reinforcement...). But tools must be adapted to get the best results from raw material ; for example, high HDT can be matched only with high curing temperature.

Fire resistance can be obtained with specific resin formulation usually with high filler content or high viscosity. Vacuum Infusion is not really suitable for this kind of application.

- 4) Check investment parameters according to total number of part to produce and production rate. Cost of tool can differ significantly from a process to another. Indicative tool cost range per m<sup>2</sup> is given for each process in Table 2.

Table 2 Indicative average tool price



These prices don't take into account the cost of a press, lifting facility nor cost of consumable goods. Even if average investment for Vacuum Infusion or CCBM is lower than for other processes, use of consumable goods (vacuum bag, tacky tape, tubes, resin bucket, peel ply, flow media, etc.) or replacement of membrane are needed. Final production cost can be affected.

Similar part specifications can also lead to different investment approaches: invest in one heavy rigid tool like RTM and Press molding or invest in multiple economical light-weight tools like RTM Eco or RTM light to get the same production rate.

- 5) Define lay-up and resin. According to previous observations, lay-up of reinforcement, sandwich core and thickness of the part should be determined. Resin type, catalyst system and curing conditions should also be fixed. Raw material selection will end after complete industrial trials. Most of raw material suppliers develop specialty material for any kind of process. To take into account their possibilities, they should be involved from the beginning of the development step of the project.
- 6) Check composite properties and injection / infusion parameters on a reduced scale tool. With the use of a simple tool, most of parameters can be checked easily in “real life” conditions. This kind of tool is also really useful to find the appropriate injection/infusion strategy according to reinforcement sequence and resin used. These tools can be a support for the employees training period before starting industrial trials.

Fig. 1 shows a linear lab tool to simulate RTM Light / Eco and CCBM. Fig. 2 shows a linear flat infusion tool to make comparative infusion tests and check infusion strategy. Table 3 shows an example of comparative reinforcement sequences flow rate



Fig. 1 RTM light / ECO and CCBM linear tool.

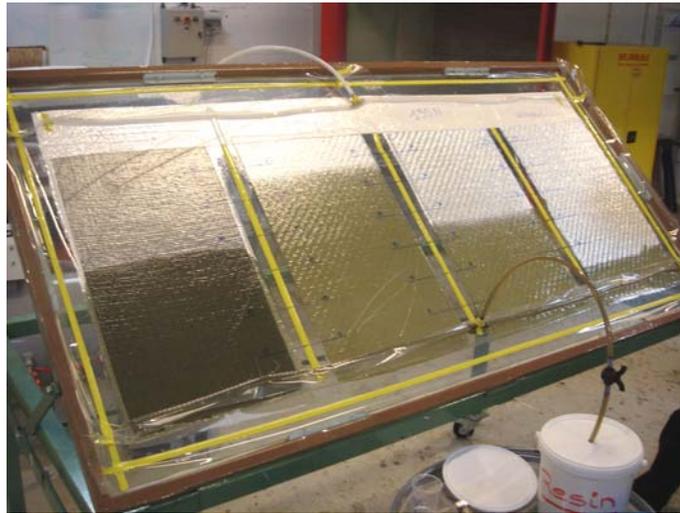
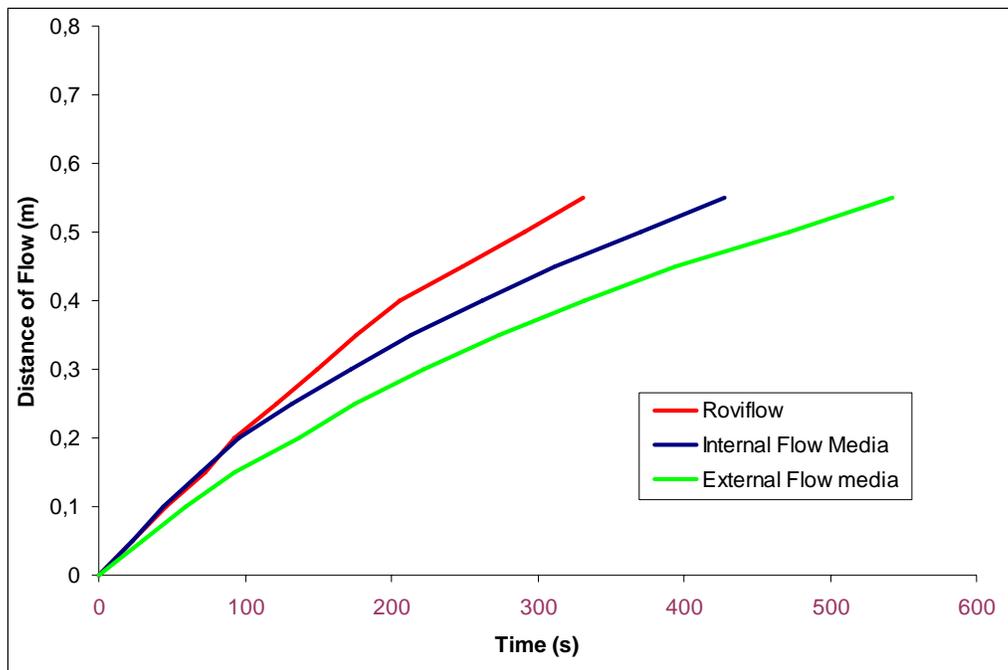


Fig. 2 Infusion flat tool.

- 7) Start building of tools according to previous technical results and economical decision. Peripheral equipment (vacuum network, injection pump, lifting facility, cutting equipment, resin stock, ancillaries...) must be integrated in the production workshop.
- 8) Organize first trials with new tool and then industrial trials on significant quantities. These trials are fundamental to get reliable figures about cycle time, workshop organization, traceability of the part, etc.

Table 3 Example of comparative flow rates



- 9) If previous results are OK, industrial production and optimization can start.

## **CONCLUSIONS**

This study was based on a huge number of applications around the world. More or less, every production workshop developed its own specific process to fit to the part. Change in the process from one to the other is usually small but it can improve significantly the quality of the part produced. These advises are only general development rules for any transfer of technology. They are given to synthesize a way of thinking when a process choice has to be made.

LCM processes make a technical and economical link between Open Mold processes (Hand Lay Up and Spray Up) and high volume processes (SMC, BMC, etc.). With the strong current trend to reduce VOC emissions, LCM processes will continue to grow significantly in the future.