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## Caracterización del proceso CRTM aplicado al refuerzo de una puerta

### RESUMEN

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#### Palabras clave:

Advanced RTM

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La industria automovilística ya se beneficia en cierta medida de los composites desde hace varias décadas, sobre todo para aplicaciones estructurales no primarias. Tecnologías como GMT, LFT o SMC se utilizan para fabricar componentes del interior, piezas funcionales o piezas de carrocería, con estándares de productividad y precios muy competitivos. Pero a pesar de estas aplicaciones exitosas, su expansión a piezas más estructurales no es posible por las limitadas propiedades de los materiales y en gran medida porque los procesos e instalaciones de fabricación actuales no están preparados para la fabricación en masa.

Cuando se pretende fabricar piezas con elevados contenidos en fibra y/o piezas de grandes dimensiones, el incremento del contenido en fibra disminuye la permeabilidad de la preforma, necesitando mayores tiempos de llenado, y generando problemas de impregnación y elevados contenidos en poros. A fin de resolver estos inconvenientes asociados al RTM convencional se han explorado diferentes alternativas: aumentar la presión de inyección, inyectar por múltiples entradas o reducir la viscosidad de la resina entre otras. Una de las más prometedoras es la combinación del RTM con la compresión, denominada CRTM (Compression RTM). A diferencia del RTM convencional, el molde se mantiene parcialmente abierto en la fase de inyección, generando un espacio no ocupado por las fibras que ejerce de camino preferente de flujo para la resina sin necesidad de penetrar en la preforma.

El objetivo del proyecto ha sido caracterizar del proceso CRTM y aplicar este conocimiento en la fabricación de un refuerzo lateral de puerta.

## Characterization of the CRTM process applicated to a door reinforcement

### ABSTRACT

#### Keywords:

Advanced RTM

CFRP

The automotive industry has benefited to some extent from composites for several decades, especially for non-primary structural applications. Technologies such as GMT, LFT or SMC are used to manufacture interior components, functional parts or body parts, with productivity standards and very competitive prices. But despite these successful applications, their expansion to more structural parts is not possible because of the limited properties of the materials and largely because the current manufacturing processes and facilities are not ready for mass manufacturing.

When it is intended to manufacture pieces with high fiber contents and / or large pieces, the increase in fiber content decreases the permeability of the preform, necessitating longer filling times, and generating impregnation problems and high pore contents. In order to solve these drawbacks associated with conventional RTM, different alternatives have been explored: increasing the injection pressure, injecting through multiple entries or reducing the viscosity of the resin among others. One of the most promising is the combination of RTM and compression, called CRTM (Compression RTM). Comparing with conventional RTM, the mold remains partially open in the injection phase, generating a space not occupied by the fibers that exerts a preferred flow path for the resin without having to penetrate the preform.

The objective of the project has been to characterize the CRTM process and apply this knowledge in the manufacture of a side door reinforcement.

# 1 Introducción

The main project drivers, have been CO<sub>2</sub> emission restrictions and the potentiality of composite materials(CFRP) for saving weight and improve other characteristics like; impact energy dissipation, specific stiffness and strength and fatigue resistance [1-2].

Project challenges have been to get a competitive manufacturing process and installation that will be able to get short cycle time, good quality, repeatability and high automation level. Finally, the process should be validated with a real part; in this case, a door reinforcement.

## 2 RTM variants. Cost analysis comparison

The starting point of the project was to analyze with a real case study and using simulation like tool, the cost of this process compared with other RTM variants [3].

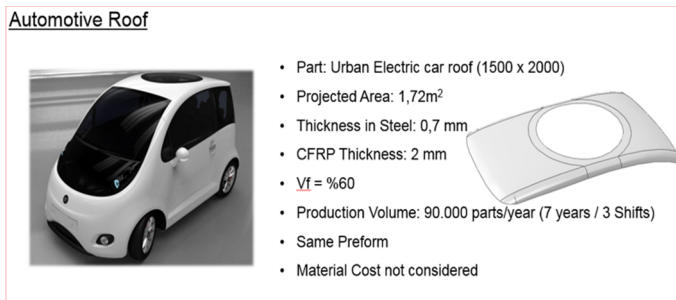


Figure 1. Case Study.

Mold filling simulations have been carried out using PAM-RTM software. The number of injection gates affects the filling time and is a key issue when optimizing the RTM process. However, as the aim was to compare the RTM variants, a single injection point for CRTM, and 4 inlet points for the RTM and HP-RTM have been set. The positions of the injection points, however, have been optimized in order to reduce the filling time as much as possible.

Process	Injection pressure (bar)
RTM	15
HP-RTM	70
CRTM	1

Figure 2. Injection pressure

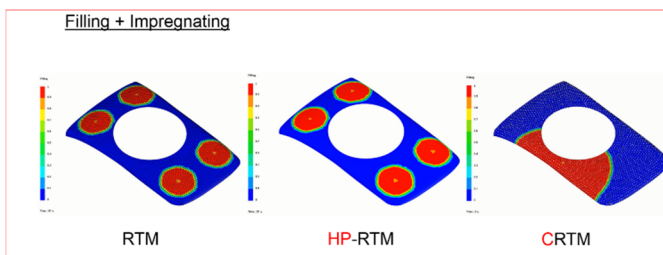


Figure 3. Filling and impregnation in each variant.

The cost of the presses, the injection machine, the molds, the robots and the occupied plant area are reported in the shown

table. The cost of the presses for each RTM variant is calculated using the clamping force and if parallelism control is needed or not. Press speeds are considered to be the same for all processes, as there's no influence when working with a close mould.

The final roof costs, with the main contributions factors, are summarized in the shown table. Taking the CRTM as reference, roof cost manufactured by HP-RTM is 2.5 times higher, and RTM one 5 times. The equipment and tooling costs, and specially the number of units, are the most relevant contributors, since they represent approximately the 90% of the total cost at the three studied RTM variants. Otherwise, the number of presses has a direct effect on the cell area, so the incidence could be stated as high as 94%. From the energy-efficient point of view CRTM is also the best, while RTM is the less competitive.

Process	RELATIVE TOTAL COST (per part)
RTM	4,7
HP-RTM	2,2
CRTM	1,0

Figure 4. Cost comparison of each process equipment.

As a conclusion, we can say that:

- CRTM is the fastest process.
- Investment level is the lowest.
- Bigger Plant area for RTM and HP-RTM than for CRTM.
- Part cost considering investment payback and energy consumption in CRTM is much lower.
- CRTM has limitations for complex geometrical parts.

## 3 CRTM process characterization

Fagor Arrasate wanted to do a depth analysis of the CRTM process and take a more fundamental knowledge of the physics of impregnation: the compression impregnation step leads to an interaction of the preform compressibility and the flow front which is usually not considered in conventional RTM. The thickness of the gap on the preform during injection or mold closure strategy during compression must be carefully selected according to the objective (minimize the filling time or reduce the closing force) [4-7]. Therefore, to develop this innovative process it is necessary to use a holistic approach encompassing both mold design and configuration of the press, an understanding of variable preform compaction by the through-thickness flow front using advanced experimental techniques (materials characterization, process control and monitoring parameters) and robust computational models [8].

The material that has been used:

- Epoxy (XB 3585 / Aradur 3475, HUNSTMAN)
- Biaxial fabric (HPT 610 C090, 50k, SGL)
- Binder (Araldite LT 3366 BD)



### 3.1 Injection stage

By simulation and experimental analysis there have been studied the next parameters:

- Resin viscosity
- Preform permeability
- Gap thickness
- Injection pressure
- Injection flow-rate
- Injected resin volume

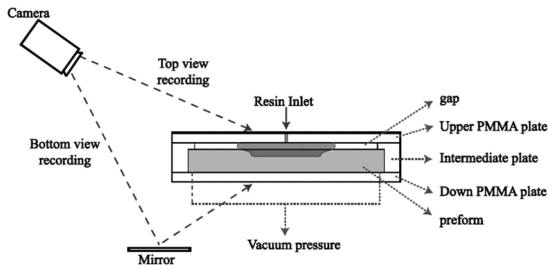


Figure 5. Injection test bench.

After several trials, we can say that there are two injection patterns:

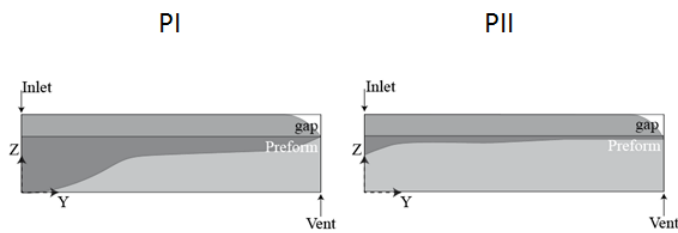


Figure 6. Two impregnation patterns.

At the first one there is a bottom impregnation and at the second one there isn't.

The main conclusion obtained from these characterizations is that resin distribution depends mainly on:

- Gap thickness.
- Permeability of the preform through thickness.

### 3.2 Compression stage

By simulation and experimental analysis there have been studied the next parameters:

- Initial resin distribution.
- Compression speed.
- Compression pressure.

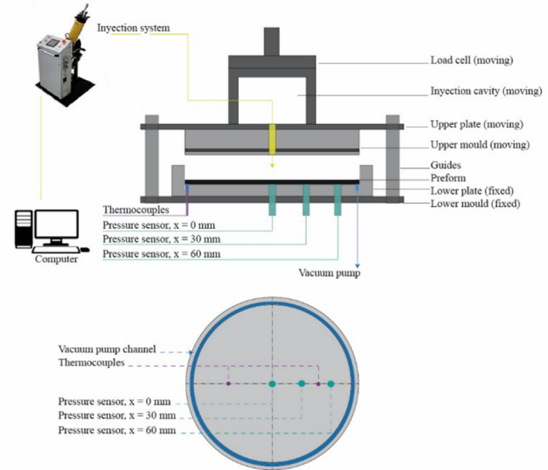


Figure 7. Compression test bench.

The main conclusion obtained from these characterizations is that Compression time and loads depends mainly on:

- Resin volume.
- Speed control of the compression phase.

The stroke of the gap should be done as fast as possible in order to save time but at the stroke of the preform you can't save so much time so, as the force is bigger, not worth to go so fast.

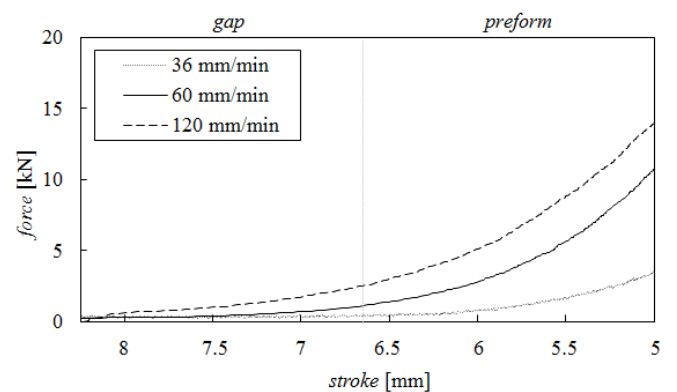
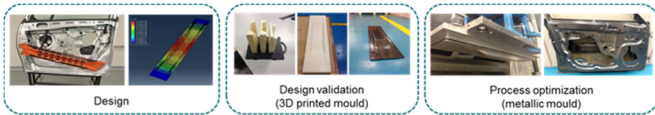


Figure 8. Compression force vs speed.

## 4 Door reinforcement

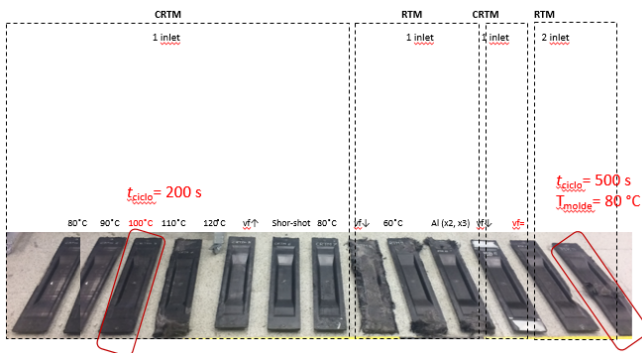
An anti-intrusion bar has been designed and manufactured for the door of a car. It is a type demonstrator, not a real component, which nevertheless has almost all the geometric characteristics of an actual component of this type. The design process was carried out based on finite elements and the manufacturing process was also designed using the PAM-RTM software. In addition, a prototype was developed before launching the fabrication of the metal mold, using a mold made in 3D printing.





**Figure 9.** Anti-intrusion bar designing process.

Once the mold was manufactured, different filling strategies were analyzed; both by RTM and CRTM. At the next figure, it can be seen that for this case and with the available resources, it was not possible to fill the mold using traditional RTM either because of the low permeability of the preform or because of the appearance of preferential filling paths that prevented the impregnation of certain areas of the mold. In contrast, using CRTM and using different strategies, the mold was adequately filled.



**Figure 10.** Anti-intrusion trials with different strategies.

## 5 New press and cell for Advanced CRTM

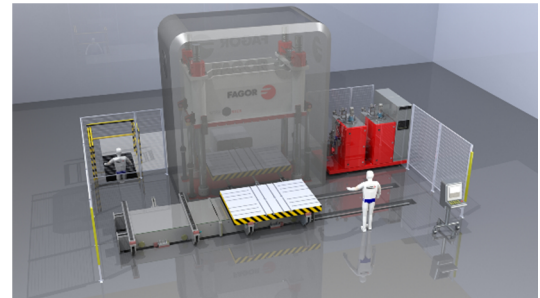
A new press architecture has been developed adjusted for composite processes and with a specific control system customized for CRTM process. Other characteristics of the press are:

- Reduced Height.
- Integrated Parallelism Control.
- Bolster Deformation Control.
- Rapid Closing Speed of the Slide.
- Short Pressure Build up Time.
- Reduced Energy Consumption.



**Figure 11.** New press architecture.

In addition, and in order to prepare a complete solution for manufacturing parts in CRTM, Fagor Arrasate has defined a manufacturing cell.



**Figure 12.** CRTM manufacturing cell.

## 6 Conclusions

- CRTM is the most suitable manufacturing process from cost, energy consumption and cycle time point of view.
- Specific CRTM process knowledge has been developed and has been implemented in our press and cell control.
- A tight cell solution has been defined for CRTM.

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