NEW MOLDABLE AND WATER SOLUBLE CORES FOR HOLLOW COMPOSITE AUTOMOTIVE PARTS

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Abstract

A variety of techniques may be used to create fiber-reinforced parts around a sandwiched core. Pre-formed PU foam or special structural foams are often used to form this core. In spite of its use in a wide range of applications the process of removing such a core from the finished moulded component is difficult and costly, if it is indeed possible at all. At Persico R&D we have focused on a new class of water soluble polymers. Combining our expertise in two fields that of creating tooling for composite components and that of advanced Rotational Molding, we have succeeded in producing molded cores which are water soluble with an efficient industrial process. Cores may be moulded by rotomolding or injection moulding, depending on geometry and number of parts per annum required. This paper illustrates the current process from Persico.

Background

An important trend in nowadays industry aiming for lightweights is the usage of composites in producing tube-like and toroidal components for motorbikes, cars, trucks and other sectors. Different techniques may be used to form fiber-reinforced elements around a specific core that normally remains sandwiched in the parts, and is often made by foamed-PU or special structural foams suitable for thermoforming, CNC-machining and other production process.

Plastic cores have a long tradition and their usage has started long before their use in premium cars and electric vehicles. They help achieving high stiffness and lightweight design. Typical components with these structural characteristics, with medium/high production rates, are Truck Roofs. They often consist of glass fiber RTM sandwiching a lightweight plastic core produced from PU foam. It is worth noting that in this application the core does not need to be mechanically strong being the overall stiffness of the roof assured by the special geometry of the various sections of the part along with the distribution of the glass layers reinforcement. During the press-curing process, the PU core has to withstand a molding pressure in the typical range of 3 to 6 bar (30-60 MPa) and temperatures of 70-80 °C.

Over the past 20 years PERSICO has participated to the development of several Roofs for Tier1 and OEM costumers, with production volumes in the range of 30.000 – 70.000 Roofs/y; sometime this level of productivity requests multiple tools for both PU core and RTM roofs and even presses with PERSICO shuttle systems for RTM [1]. Figure 1 shows a typical dome-shaped roof and a TERENZO (a trade name of Persico) shuttle press line. Around the hatch area there is a ring of PU incorporated, designed to create the required local rigidity and to sustain possible loads due to snow.

Automotive structural parts can also benefit from hollow moldings that incorporate cores of many diverse materials. Typically, current applications use cores molded from PU foam, rotomolded from PE or machined from special foams. These special foam cores can in some cases be soluble (washable) after the composite part is formed.

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During the curing process for the composite using autoclave, press or simple vacuum, the core must withstand the external forces created. It must also withstand the temperatures of curing and guarantee thermal and mechanical stability including creep [2] throughout the curing cycle. Molded and machined cores offer a continuous support for the fiber layers avoiding the weak spots sometimes created with honeycomb fillers. This helps avoid additional fiber reinforcement.

Figure 1: Left, Large truck roofs made in RTM with more than 8m² of visible surface and over 50 kg of mass are produced with the usage of foamed PU cores. Right, presses with shuttle systems allow production rate of n.2 roof/h.

In the automotive sector, components with highly demanding structural characteristics, still with medium/high production rates, are frame elements needed in the car body-in-white, like pillars, front-ends and other structural parts. To produce these kind of parts it is necessary considering cores sandwiched between carbon-reinforced layers. Often the cores assume tubular or even toroidal shapes with the usage of more sophisticated epoxy HP-RTM. Analogous PU or rotomolded PE cores are normally used in producing hollow structural parts obtained by autoclave, vacuum or compression-molding of carbon-based prepregs materials. It is important to remember that, generally, the core itself does not presents peculiar structural properties.

The main problem with core foams consists in creating the required geometry. Specialized high-end foams e.g. those based for example on polyvinyl chloride (PVC) compounds only are available in form of sheets in standard dimensions and thickness. This means that the final geometry has to be created by either CNC machining or thermoforming, both processes being time-consuming and costly with, in most of cases, a large amount of scrapped material. These manufacturing procedures are therefore economically valid for relatively small production batches. On the other side polyurethane (PU) can be foamed directly in the RIM mold in the final geometry with relatively inexpensive method. Whereas PU (polyurethane) can be foamed directly in the RIM process mold to the required geometry relatively inexpensively. The down side is that PU cores is that they are not optimal for high pressure RTM or prepreg compression moulding which are widely used even for high volume production.
In addition, according to the current status of the art molded cores do remain inside the components and installed on the final vehicles or, instead, are mechanically removed with a difficult and costly process, with the risk of damages on the composite components.

So the goal of the research activity started in early 2015 was to find a new polymer suitable for the industrial production of cores with the following aims:

- To perform better in high pressure moulding.
- To be economically viable for medium/high volume production.
- To be soluble for easy removal when required.

In the following paragraph we will present PERSICO’s original results targeting above goals; according to our aims, cores are moldable to guarantee fast & cheap production of complex geometries but also washable allowing in such a way easy removal form the final part.

**PERSICO way to molded cores**

The activity done at PERSICO R&D has been mainly conducted through the milestones described in the next steps. Some of the details of our studies are not totally disclosed for protecting our intellectual properties but are available under NDA [3].

**Step 1: Identifying the right polymer**

We devoted our efforts in qualifying a moldable & water soluble polymer suitable for both injection and rotational molding.

This goal is dictated by simple manufacturing considerations. If the polymer is suitable for rotational moulding it would enable the production of large, complex cores, using relatively cheap and quick to produce tooling for low/medium production volumes. Medium/high volume productions may be instead covered by injection molding production process.

Our tests allowed us to selected a specific water soluble polymer (based on polyvinyl-resins) which offers additional properties:

- an easy-way to be transformed in powder for rotomolding,
- proper filling of core shapes with complex geometry,
- low economic impact on core production.

Samples of PERSICO rotomolded hollow cores are freely available upon request [3].

**Step 2: Identifying the right rotomolding process**

What is important in the rotational molding of this polymer is the accurate and repeatable control of the molding process. Machinery was required that was capable of high productivity with fine control of the polymer temperature and thickness within the tool in a similar way that you would expect in the modern injection molding process. Persico has developed and markets the Smart rotomolding machine which offers this control. The Smart machine has DTH (direct tool Heating) with independent temperature control for up to 24 separate zones in the tool.
The Smart technology system uses a mold specifically designed for the machine with specific temperature controlled sections. This allows the production of cores that meet exacting requirements in local thickness requirements. It can for example vary the thickness of the core from 6mm to 9mm in critical areas. The full capabilities of the Smart technology are documented elsewhere see recent reference [4].

Step 3: Sample test – rotomolded spherical core

To test a typical sample of a soluble core we produced a molded polymer core to enable production of a carbon-fiber sphere. The rotational molded core (yellow sphere) is shown in fig 3A. This core was then tested in the moulding process in the autoclave and compression moulding. It withstood pressures in the range 4-18 bar with temperatures of 70-120°C. The core may be easily draped (fig 3b). After the curing process the core is still present in the carbon sphere (fig 3C ). The core is then removed by dissolving it in water at 50°C for 80 minutes leaving an empty cavity and a hollow one-piece carbon sphere (fig 3D ). After the washing bath, the carbon sphere does not present any kind of damage on both surfaces.

The level of finishing of the internal surface of the sphere does “copy” the finishing of the rotomolded core; in such a way different level of roughness may be achieved by changing the surface finish of the aluminum tools that produce the core.

Table I summarizes some of the main parameters characterizing the entire process described above. Core production conditions are also reported.
In conclusion we list some of the main benefits of this PERSICO solution for soluble rotomolded cores.

- Moulded cores for low volume parts
- Low operating costs with low material consumption.
- High quality fine geometry or the cores.
- Local thickness variation where required.
- Soluble in water for easy removal when required

When the removal of core is not required, Smart technology allows the production of cores with other thermoplastics material (such as PP, PA6 liquid and powder, XPE, PE, HDPE, PC, etc) still fulfilling above list of features for the cores. In this case the core will remain in place inside the carbon parts forming a sandwich structure with peculiar mechanical features depending form the adopted polymer.
Table I: Parameters for rotomolding a washing processes for EVOH Cores

<table>
<thead>
<tr>
<th>Rotomolding – Core</th>
<th>Curing temperature</th>
<th>Weight</th>
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<tbody>
<tr>
<td>Cycle time on Smart®</td>
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<td>15 min / cavity</td>
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<table>
<thead>
<tr>
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<th>Drying Cycle time</th>
<th>Curing temperature</th>
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</thead>
<tbody>
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<td>30°C</td>
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<tr>
<td>200 min</td>
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**Summary and Next Steps**

In this paper a new class of moldable core has been presented. Our cores are both moldable and soluble in hot water with a cost-effective industrial process.

We also aim to overcame the current limits of our know-how, mainly by investigating the behavior of the new rotomolded core when applied in high-pressure curing processes, like HP-RTM or carbon prepreg. The activity for the last quarter of 2016 and 2017 will be devoted to this kind of investigations and PERSICO is totally open to find industrial partners helping us in exploiting these kinds of applications.

**References**


2. Requests for NDA and samples may be addressed to Angela BERGAMINI, angela.bergamini@persico.com