It Couldn't Be More Hybrid

Thermoplastic-Matrix RTM on the Roof Frame of the Roding Roadster

T-RTM is a hybrid technology. The first plants will shortly be starting production around the world to realize modern lightweight design for volume car models. The potential of this production process is shown by the roof frame of the Roding Roadster R1, which was already presented at K 2016.

The process could hardly be more hybrid. The inserts are made of aluminum and steel, the fibers of carbon and glass, and the manufacturing process combines the advantages of shaping by infiltration pressing (resin transfer molding, RTM) with those of reaction technology and thermoplastic materials (the "T" in T-RTM stands for the thermoplastic matrix). It therefore offers good prerequisites for lightweight design. In T-RTM, a preformed textile semifinished product is infiltrated with a two-component reactive mixture (ε-caprolactam plus activator/catalyst) in a press mold. It is in the form of pellets at room temperature and is melted at above 70 °C before application. It cures in a polymerization reaction (in-situ polymerization) to form polyamide 6 (PA6). In the Roadster roof frame application (**Fig. 1**), curing takes 2 minutes.

The particular advantages of T-RTM can be illustrated by comparing it to disciplines similar to plastics processing. Thanks to its very low viscosity – similar to water – the reactive mixture penetrates into the textile web, often even more easily than polyurethane or epoxy resin, which are used in conventional RTM. That allows longer flow paths and higher fiber-volume contents, even though the cavity pressures can thereby be even lower in some cases. At the KraussMaffei pilot plant in Munich, Germany, experiments were conducted with fiber-volume contents up to 70 %. In addition, PA6 has mechanical properties that make it interesting for structural parts: High notch impact resistance, weldability and recyclability. Moreover, the fracture behavior is more ductile than in the case of thermosets.

Perhaps the biggest unique selling point, however, lies in the possibilities for secondary processing of the part. Unlike thermosets, thermoplastics can often be, e. g., welded and recycled. A product manufactured by T-RTM can additionally be provided with other functions, e. g. by applying stiffening ribs, load-transfer elements or fastening elements in an injection molding process. This allows the advantages of RTM to be effectively combined with those of injection molding.

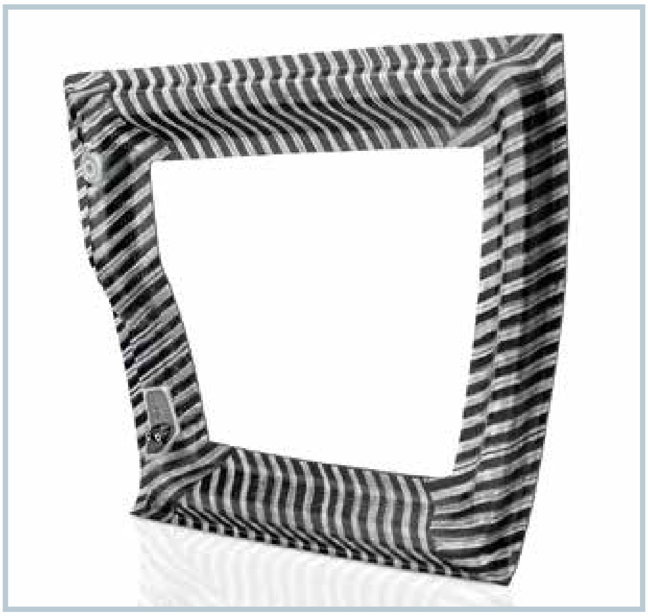

Fig. 1. Fiber hybrid: The roof frame for the Roding Roadster, manufactured by the T-RTM process, was presented at K 2016. It permits the processing of both glass fibers (white) and carbon fibers (black) (© KraussMaffei)

Focus on Series-Capable Production

T-RTM is thus a technically and economically interesting complement to familiar RTM processes, such as high-pressure RTM (HP-RTM) and compression RTM (C-RTM), or wetmolding. However, to realize projects with adequate production volumes in the automotive industry, the plants must be systematically designed for series production. KraussMaffei is the only supplier who can call on experience with over 80 supplied RTM plants, and apply this to T-RTM. For example, 34 HP-RTM plants are in use for a large automotive manufacturer, and T-RTM has already been successfully implemented together with Volkswagen for B-column reinforcement.

As a supplier of complete RTM production systems, KraussMaffei manufactures mold carriers of up to 10,000 kN clamping force, as well as the machines for metering the matrix material, for example the RimStar 8/8 T-RTM (**Fig. 2**) presented at the K show, in which the caprolactam for the Roding Roadster can be melted, supplied, mixed and metered (**Fig. 3**). The system is designed for the high processing temperatures specific to this material, and is thus ideally suited for the in-situ polymerization of ε-caprolactam – the same applies to the MK10-2K heated high-pressure injection mixing head, which can realize the output rates typical of the RTM process.

Fig. 2. The new RimStar 8/8 T-RTM metering system permits automated melting of the caprolactam components (© KraussMaffei)

Part Manufacture – with High Pressure

Material metering is particular important for the efficient series utilization of RTM, for example in three-shift operation. The metering machine must provide the flexibility necessary to produce differently sized parts, while at the same time permitting a reproducible material output. Therefore in the case of T-RTM systems from KraussMaffei, conveying is performed by two in-house-produced metering pumps, operating by the axial piston principle, for each caprolactam component: A small feed pump and a metering pump, which convey the components from here to the mixing head, where the material is mixed by the high-pressure countercurrent injection principle and fed into the mold.

If a filled resin system is used, piston metering is necessary. For this reason, a T-RTM system recently delivered to the Korean Institute for Science and Technology (Kist) has pistons. Since metering pistons only deliver limited output rates, axial piston pumps are appropriate for flexible discharge rates. The material supply can be designed to supply multiple plants, thereby further reducing the production footprint and infrastructure requirement.

For efficient and reliable manufacturing, the pumps, interacting with the mixing head, must be precisely designed to suit the material-specific properties of caprolactam, PU or epoxy resin – as regards, e.g., corrosiveness or viscosity. KraussMaffei has exclusively produced the pumps in house since 2011 (currently around 600 units per year), in order to be able to respond flexibly in terms of equipment and quantities. The pumps, which operate in a wide variety of different material temperature ranges and at viscosities from 4 to 3000 mPa s, are designed individually for the properties of the material to be processed – for example with the appropriate lifetime and resistance to particular materials. »

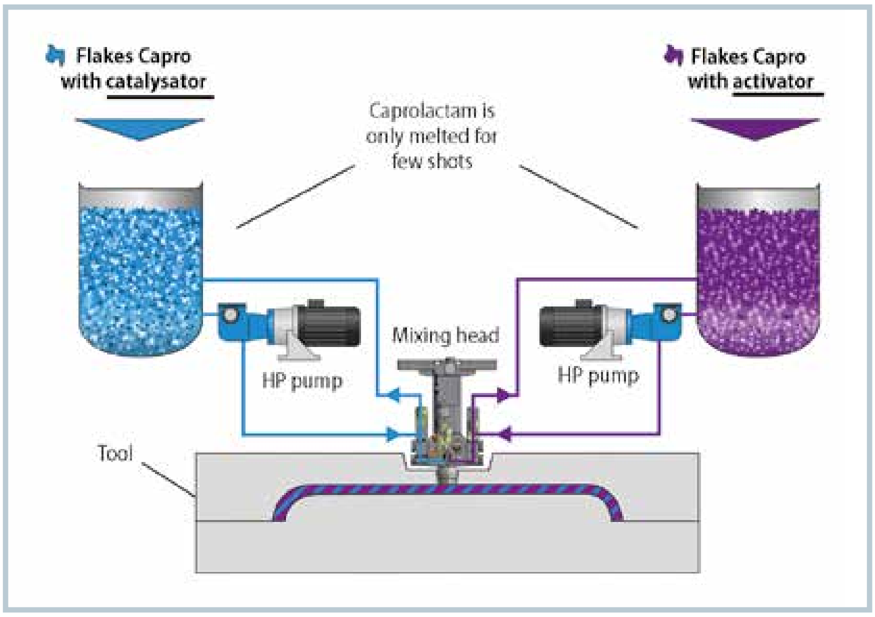

Fig. 3. Automated melting of the caprolactam components: Caprolactam is supplied to the daily tank as flakes and is melted there for just a few shots (© KraussMaffei)

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Fig. 4. Type CFT mold carrier: The compact design permits both precise and compact handling of the T-RTM mold (© KraussMaffei)

Thermoplastic Matrix RTM: An Intrinsically Complex Process

Design know-how is one thing – project experience is another. For projects such as this, KraussMaffei's development team benefits from its very long experience with similar processes. For example, metering systems have been marketed for processing ε-caprolactam into cast polyamide for a good 20 years. This experience, as well as that obtained from HD-RTM, was also successively incorporated into the development of T-RTM. The aim is and remains series-capable production.

For the roof frame of the Roding Roadster, KraussMaffei's team, together with the sports car manufacturer Roding, a specialist in lightweight design, and eight other partners, dealt with a number of challenging issues regarding the inherently complex process. First, four sub-preforms, one with integrated metal inserts, are placed in a positioning gauge, and assembled to form the complete semifinished product, and then the steel-screw insert is riveted. A robot then places a further aluminum insert and the preform in the mold, which is then closed and evacuated (**Fig. 4**). In the next step, the reactive mixture infiltrates the fiber semifinished product, also incorporates the inserts, and cures to form polyamide 6. To join the metal inserts to the matrix system, they had to be pretreated; KraussMaffei specifically commissioned a university project for this purpose. The project partners also studied how the fiber scrims would have to be designed to achieve the necessary stiffness and strength characteristics. The most suitable proved to be a sandwich structure with carbon fiber facings and a mixed carbon fiber (70 %)/glass fiber (30 %) insert that is oriented to the load path. ■