Composite space frame: structural reinforcement for automotive liftgates/tailgates

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Abstract

The space frame is used to reinforce a vehicle's structure. The first applications of this technology in the automobile is for tailgates and liftgates. The Magna Exteriors engineering team, with the help of several machine, material and tool suppliers, combined its unique knowledge of design, materials and processing to address the challenge of reducing weight using composite materials and manufacturing processes. The composite space frame achieves a 10% reduction in mass over the equivalent steel reinforcements, the overall liftgate module achieves a 20% saving in mass compared to the equivalent steel liftgate while meeting all OEM performance requirements.

To date several composite space frame designs have been produced by Magna and have successfully passed all component and vehicle-level testing at multiple OEMs. The first serial production began in 2019 for the 2020 model year Toyota Supra.

1. Innovation drivers

The main drivers were to find a reinforcement that could fulfil the customers' requirements in very difficult packaging situations and kinematic scenarios, coupled with high dimensional stability.

Magna had also previously manufactured a space frame for a liftgate in 2006 using a free-form bent steel tube. This was a low-volume production scenario where 6000 liftgates were produced.
2. Key innovation: winding

The team started with a mind-mapping exercise of possible processes on the market. Many technologies, such as extrusion, blow-molding, etc. were tested for production of the composite space frame. However, no suitable technology was found for producing of the particular space frame desired. Magna would have to have modified existing processes and technology or develop something completely new.

One example is the unique filament-winding technology developed by the team and several partners. The goal of the project was to find technology for placing the roving of glass fiber or any other fiber material on a closed-shaped core with faster cycle times. There was no suitable technology on the market, and Magna had to develop the process itself with external partners. Magna has patents for unique filament-winding machines that are suitable for the requirements of OEMs. It is possible to wind three layers simultaneously with up to 40 rovings per layer. The orientation of rovings is programmable in each position, and as a result, it is possible to also wrap rovings over complex shapes with varying cross-sections. A universal gripper enables winding of different projects with only minor tooling changes.

3. First prototype

During the development stage, it was necessary to develop a part for process verification and mechanical analyses. An L-shaped profiled part was chosen as the best option. This L-shaped profile part was chosen since it served not only as a demonstrator part, but the shape was also suitable for several load case analyses in order to get information about material properties and part structure. It was used as the basis for CAE model tuning as well. By
joining four L-profiles it was possible to obtain a closed-shape space frame. All new possible materials, including polyurethane and epoxy, were tested with this part.

4. Production process
The space-frame production process consists of three main steps. In the first step, the polyurethane foam core is produced. The core has the shape of the final part but with an offset creating a gap for the composite material. In the second step, the core is wound by rovings. In the third step, the fibers are infused with a polyurethane matrix by high-pressure RTM technology.
For production, all the processes were optimized to obtain a competitive overall process for the mass production needed in the automotive sector. For the core, up to 600,000 pieces per year can be produced by one metering unit. Self-clamping molds are used for production without presses.

Filament winding is a fully automated process. The machine was designed to be a universal machine able to run different projects.

For the skin, one press handles up to six molds simultaneously in order to accommodate high-volume production. New material concepts were verified with a focus on foams with low curing times. For the skin, special release agents are used for demolding up to 20 pieces after one application of external release agent to the mold.
5. Competitive impact

This innovation has changed the view of standard rear-door production. It has given room for new design features, more complicated and bolder shapes, and last but not least, reduced weight. Although the competition also offers plastic rear doors, they do not have a continuous load-path reinforcing element such as in our case a composite space frame. Our offering has become much more flexible, providing our end customers much more freedom and customization.

6. Patents

It was known at the time of development that this kind of technology is not on the market anywhere in the world. Several key partners, including VUTS and the Technical University of Liberec helped us develop some elements of the process, which was a key for this particular technology. Every step is automated and the step chain is linked very closely together. The main and key device for laying-up fibrous rovings has been patented worldwide since it includes many process steps, making this device very unique.

Patents include:
- Composite stiffener
- Device for laying-up a composite product with fibrous rovings
- Composite frame of a motor vehicle tail door
- Method for automatic rewinding of fiber strips or fiber strands