Latest trends in SQRTM: upgrading efficiency and cost-effectiveness

SQRTM made aerospace parts have been certified and flying for nearly 2 decades, yet the technology is often misunderstood. This article looks at the process roots and presents the latest trends in the industry.

Today's production challenges, with a need for clear paths to certification, higher rate production with lower energy costs, and a higher level of component integration, make SQRTM (Same Qualified Resin Transfer Moulding) an appealing alternative to the autoclave.

SQRTM, a process that uses toughened prepregs to produce high-quality Carbon Fibre-Reinforced Plastic (CFRP) structures in closed-mould tooling, has been rising in popularity these past several years. JEC Composites Magazine published papers on SQRTM as early as 2011, highlighting a highly-integrated structure produced by the Belgian aerospace company SABCA [1].

What is SQRTM?

SQRTM is very similar to Resin Transfer Moulding (RTM), the main difference being that the mould is filled with prepreg instead of a dry fibre preform. The term "Same Qualified" describes a process that allows customer-qualified prepreg materials to be fabricated in an Out-Of-Autoclave (OOA) process following the same qualified process specification that is approved for autoclave curing. The tool is clamped in a workcell (Figure 1), which consists of a clamping press, a resin injection system, and a control system for regulating heat, pressure, cooling, and time. The clamping press is similar to an RTM setup, while the injection system will usually be smaller given the smaller amount of resin to inject.

In SQRTM (Figure 2), a small amount of pressurised resin is injected in the mould cavity via resin "runners" around the perimeter and edges of the preform in a vacuum-based tool, sealed with an O-ring like in RTM. The injected resin is the same base resin as in the prepreg, sometimes without toughers to increase flow in the case of large parts.

The tool's part-forming cavity is designed and precisely machined so the prepreg laminate will be at the correct fibre volume at the cure temperature. The only free space inside the tool is on the part perimeter, where the resin runners and shallow "gates" between the runners and the composite part edges allow the resin to provide hydrostatic pressure. A key difference with RTM, which also uses injected resin to control hydrostatic pressure for void suppression, is that none of the SQRTM injected resin infiltrates the layup. Instead, the injected resin acts as an "edge dam" to counteract the prepreg resin thermal expansion by providing hydrostatic pressure to the edges of the prepreg laminate. The prepreg and fibre volume are matched so that there is always a resin bleed-out condition. This way, the laminate resin blocks the injected resin from entering the laminate. A photomicrograph of this condition (Figure 3) illustrates the balance of volumes and forces that allow SQRTM to provide high-quality laminates while sealing off the closed mould interior.

Fig. 1: SQRTM/RTM workcell

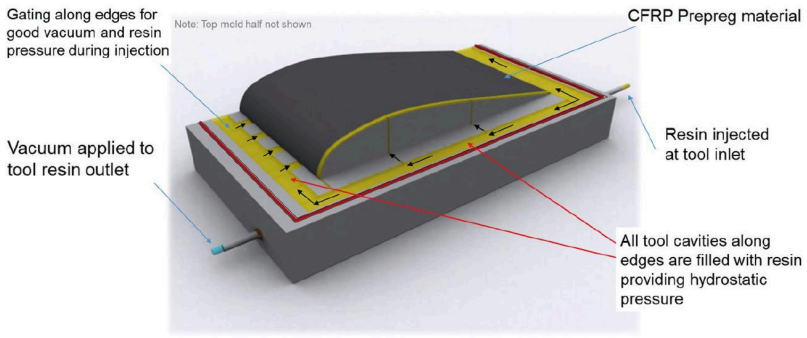

Fig. 2: Schematic of the SQRTM process, where an "edge dam" is created around the part

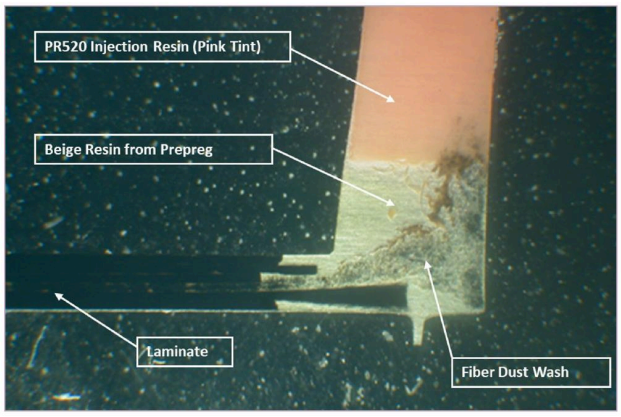

Fig. 3: Concerns of untoughened resin entering the part were answered by injecting pink PR520 resin into a flat panel tool with Toray 3900-2 prepreg; microsections clearly show that no injected resin enters the prepreg laminate

A walk back through time

The market for SQRTM initially came into being because of the difficulty that exists when introducing a new material system to a given customer – specifically when trying to convert an autoclave part design into an OOA process such as RTM. Prepreg is commonly used for aerospace applications, with many established databases used by structural design engineers. Often, the legacy materials and processes continue to be used simply because it would be prohibitively expensive to characterise and qualify a new material system. When the same (already qualified) prepreg material system can be processed in an OOA closed-mould method using the time, temperature, and pressure parameters specified for the autoclave process, the level of effort required to qualify the materials and process is significantly lower than introducing a wholly new material system. Hence the name – same qualified resin transfer moulding. Because SQRTM uses toughened prepregs commonly found on today's aircraft, it can also produce composite structures with higher material allowable than most RTM laminates, particularly in terms of toughness and strength-to-weight ratio.

The accelerated process qualification path was of great importance to early adopters such as the US Air Force. Northrop-Grumman, working for the USAF on the Global Hawk RQ 4B, applied SQRTM to the wingtip extension used to increase performance on the RQ-4B Block 20 as from 2003 (Figure 4). A lower cost was the goal for the part, which was subject to ground damage. Other commercial applications followed with Boeing, initiating work on 787 Dreamliner leading edge slats in 2004, and seeking an improved design more resistant to hail damage than the 777 slats. SQRTM was the process of choice for these properties and was implemented for all 787 leading edge slats. Over 10,000 parts were made and are flying today.

In 2016, Sonaca started applying SQRTM to the Embraer E2 series for the fabrication of inboard flaps after several years of in-house validation [2]. The E-190 and E-195 E2 are now certified and flying with SQRTM parts making large portions of the flaps.

Very highly loaded and integrated primary structures have also been manufactured and tested such as the Sikorsky UH60 SARAP roof demonstrator. The 120-kg structure (2x3 m) is attached to the aircraft gearbox and holds the entire helicopter structure. The demonstrator showed a 56% unit cost reduction and had 80% fewer parts. [3]

Advantages and limitations

The advantages of SQRTM mirror those advantages of RTM:

- design: part integration reduces subsequent assembly steps and fasteners, and thus weight and costs.
- production time: reduced cycle time due to better thermal conductivity of the tooling in a workcell clamping press, while staying within the autoclave process specification.
- high tolerance: the machined

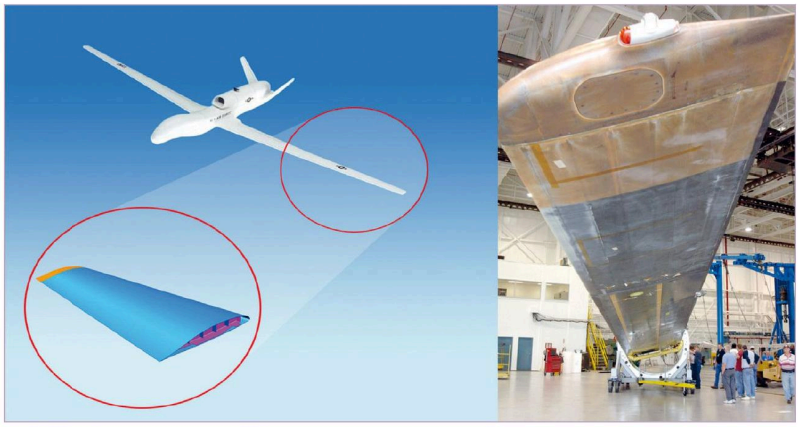

Fig. 4: Global Hawk SQRTM wingtip extension

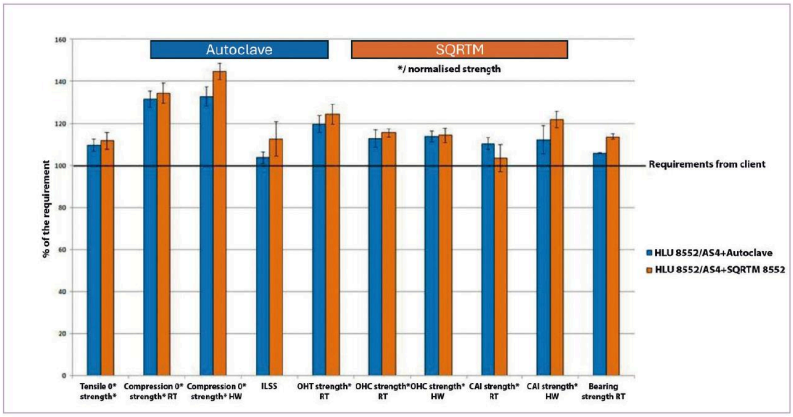

Fig. 5: Comparison of laminates processed by SQRTM and autoclave [4]

metal-matched tooling provides high-tolerance surfaces on all sides of the product.

- accuracy: close control of laminate thickness and fibre volume due to precise tooling tolerances allows lighter-weight structures to be built, while remaining within qualified material specifications.
- assembly costs: ability to provide features on the cured part that can be used for determinant assembly of the finished product, reducing assembly costs.
- performance: high first-pass yields, even with complex geometry.

In addition, the SQRTM process adds advantages drawn from years of autoclave and prepreg development:

- mechanical properties (Figure 5) that usually match or exceed that of autoclave-manufactured test coupons [4] and also exceed RTM mechanical properties;
- ability to use automation methods such as ATL, AFP, and hot-forming solutions.

Despite all these benefits, SQRTM has limitations that typically involve tooling. Managing cure kinetics in large moulds, with thermal gradients and heat history on both the prepreg and injected resin, can become challenging and requires a good understanding and modelling of heat transfer within the tool. The tool cost is often a high initial commitment compared to single-sided autoclave tools. This higher initial tool cost should be compared to a traditional autoclave tooling string, which includes multiple autoclaves, trim fixtures and assembly jigs. The latter can be 1.3 times the cost of an SQRTM tool which may not require such auxiliary tooling and fixtures. In any case, total "tool string" costs need to be understood and compared.

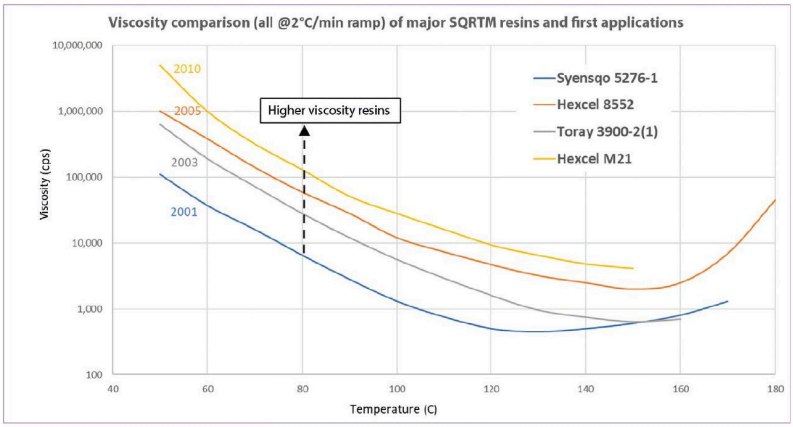

Fig. 6: Viscosity comparison of common SQRTM resins

Current and future trends

SQRTM, with its ability to use existing prepreg databases, offers a more direct path to certification. Mechanical properties from a limited number of SQRTM-fabricated equivalency panels and test coupons are compared to the autoclave-fabricated allowable data to demonstrate SQRTM/autoclave equivalency. This fast and simplified path is especially relevant to the numerous new entrants in advanced air mobility.

Initially, SQRTM used lower-viscosity, easily-injectable resins. Progress in tool designs and experience has allowed the use of tougher (and more viscous) resin systems (Figure 6). This presents many advantages from a certification standpoint and improves the alignment of the injected resin and prepreg resin cure kinematics. These higher-viscosity resins are also more easily available in a thick film form that makes them easier to ship and batch.

As with RTM, function integration is the best way to make the technology highly competitive. Simple stiffened parts can sometimes save money over difficult autoclave components, bringing a high yield and repeatability from the matched tool precision. Additional savings can come from the integration of individual features. While monolithic multicell components have proved successful and cost-effective, partial integration using hybrid solutions is a trend we also see emerging. □

More information:
www.radiuseng.com

References:

[1] JEC Magazine, No62 January-February 2011, Highly Integrated Structure Manufactured in one-shot with prepreg UD tape, C. De Roover and B. Vaneghem, Sabca
[2]] Sampe Journal, July-August 2020: Out-of-Autoclave Process and Automation: A Successful Path to Highly Integrated and Cost Efficient Composite Wing Moveables, T. de Lumley, F. Mathieu
[3] Composite World, August 2010, SQRTM enables net-shape parts
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