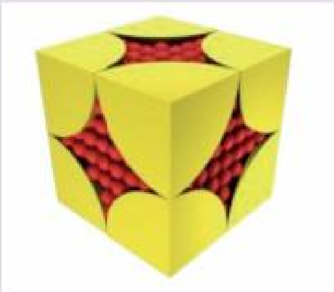

Highly integrated structure manufactured in one-shot with prepreg UD tape

This paper presents a production sequence for a demonstrator of the main landing gear bay for a single-aisle aircraft. The sequence uses efficient, highly automated sequential processes that include prepreg UD tape, automatic tape laying, hot forming, SQRTM and phased-array ultrasonic inspection for the rapid one-shot manufacture of integrated structures. SQRTM is an RTM process adapted to prepreg technology, combining the ad-vantages of RTM with the improved mechanical properties of prepreg UD tape. These processes reduce the assembly steps and the associated costs and results in lighter, better-performing parts.

By

Cédric de Roover, Project Management
Bertrand Vaneghem, Technologies and New products development, SABCA

The existing manufacturing cycle for complex structures is presented in Figure 1.

The first stage of the manufacturing cycle covers the fabrication and inspection of all individual parts. The second stage encompasses assembly and final inspection steps. The part can be mechanically assembled using fasteners or bonded (cobonding or secondary bonding) with the possible need for an additional autoclave cycle.

The means of automation are (1) ply cutting

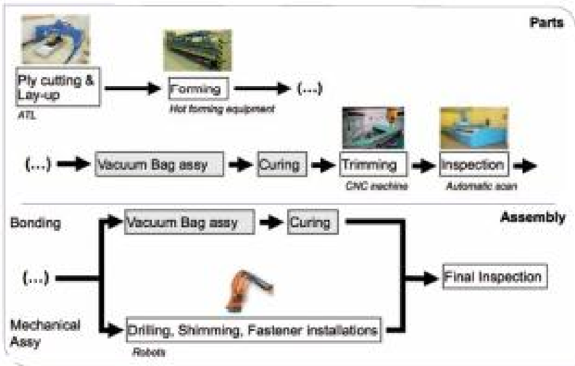

Fig. 1: Existing manufacturing cycle

and lay-up using an automatic tape layer, (2) laminate forming with a hot forming system, (3) trimming with CNC machines, (4)inspection with automatic A- or C-scan equipment, (5) mechanical assembly with robots.

In the existing process, the remaining difficulties are two material-intensive, time-consuming operations: the automation of laminate placement in the curing mould and the vacuum bagging step. These steps could be improved using a closed-mould process such as RTM adapted to prepreg technology (SQRTM). With this process, co-curing is maximized and a complex structure can be produced in a single cure cycle. Steps such as laminate placement in the curing moulds, part demoulding and tool cleaning also offer automation opportunities (Figure 2).

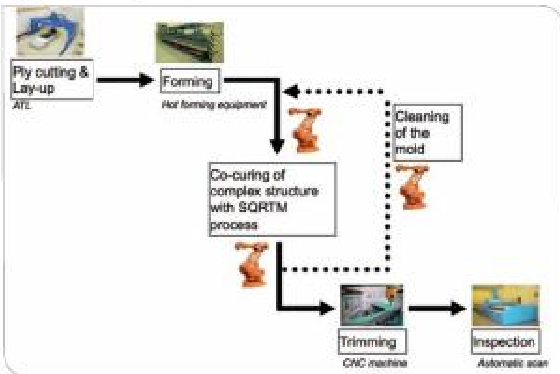

Fig. 2: Automated manufacturing cycle using the SQRTM process

The SQRTM process

SQRTM is an RTM process adapted to prepreg technology. The prepreg is placed in a closed mould and during the cure cycle, a small amount of resin is injected into the cavity through ports positioned around the part to establish hydrostatic pressure on the prepreg [1]. The tool can either be self-clamped and self-heated or heated by a

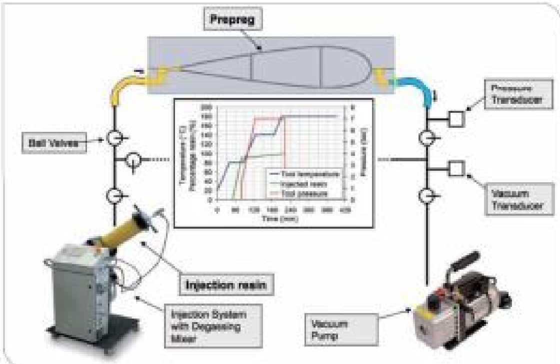

Fig. 3: SQRTM process and equipment

press. The equipment is composed of an injector and a vacuum pump (Figure 3).

The vacuum pump is connected to the mould and to the piston during the resin degassing step. Being a key process parameter, temperature is controlled in the piston, on the piston head, in the injection line and inside the tool. The pressure inside the mould is controlled by the piston. The SQRTM curing cycle, shown in Figure 3, is similar to the standard autoclave curing cycle.

The advantages are the use of qualified prepregs – toughened resins, UD reinforcements, a high level of integration, and tight tolerances [2] – and surface finish according to the moulding process. Disadvantages are a higher tool price and a lower level of flexibility to design changes.

Cost reduction

The left pie chart in Figure 4 shows an example of recurring cost distribution for a complex structure assembled with a standard autoclave process. Cost drivers are materials, clean-room activities (including hot forming, bagging, demoulding and mould cleaning) and final assembly.

Using the SQRTM process results in:
- reduced or, at best, eliminated assembly costs,
- reduced material costs through 1) the elimination or reduced number of fasteners, 2) the reduced amount of tape with thinner junction parts and 3) a significantly reduced amount of process materials,
- reduced clean-room costs due the elimination of the vacuum bagging step,
- reduced trimming costs,
- reduced curing costs through the elimination of the autoclave and shorter cycle time [3, 4].

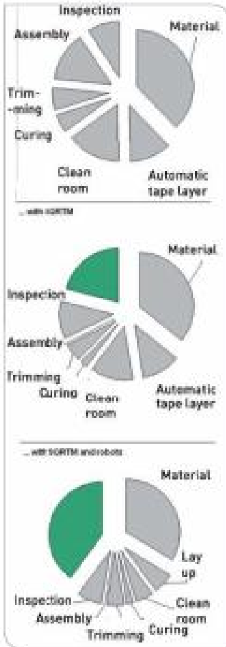

Fig. 4: Example of recurring cost distribution for a complex structure

On the other hand, the inspection could be more complex and time consuming due to highly integrated parts.

The objective of the SQRTM process is to cut recurring costs by about 20%. This level of cost reduction quickly offsets the higher tooling costs, even for small manufacturing batches.

The next stage consists in introducing robots in the process to significantly reduce lay-up, clean-room and inspection activities. RTM process automation can be transferred to

More information ...

Founded in 1920, SABCA is one of the main aerospace companies in Belgium. The company designs, develops and produces major structural assemblies, both metallic and composite, for civil, business and military aircraft as well as European space launchers. The SABCA Group comprises the mother company SABCA with locations in Brussels and Charleroi, and a fully owned subsidiary, SABCA Limburg that specialize in composite manufacturing. Established in 1992, SABCA Limburg specializes in the manufacture of high-tech composite aircraft assemblies based on prepreg technology. The company owns two large automatic tape layers with beds up to 12 m, three autoclaves up to 5.5 m in diameter and 15 m long, a large high-speed 5-axis router, and automatic C- and A-scans.

SQRTM technology. Laminate placement in the curing mould, demoulding, mould and mandrel cleaning are potential new challenges when robotizing the SQRTM process. The next objective of using robots is to reduce recurring costs by about 40%, based on constant material prices.

Demonstrator for the main landing gear bay of a single-aisle aircraft

Figure 5 shows the SQRTM demonstrator, which combines the main structural concepts of the rear bulkhead and pressure floor of a main landing gear bay. It is composed of two beams with local reinforcements and variable sections (up to 9-mm thick), a rib and a stiffened panel with 7 hollow omega stringers. All the parts are made out of prepreg UD tape (HS carbon/epoxy).

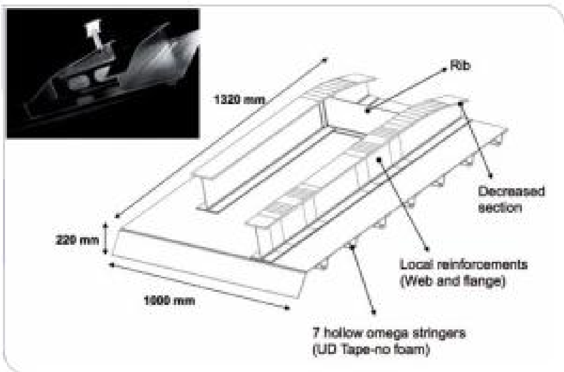

Fig. 5: Single-aisle aircraft main landing gear bay demonstrator

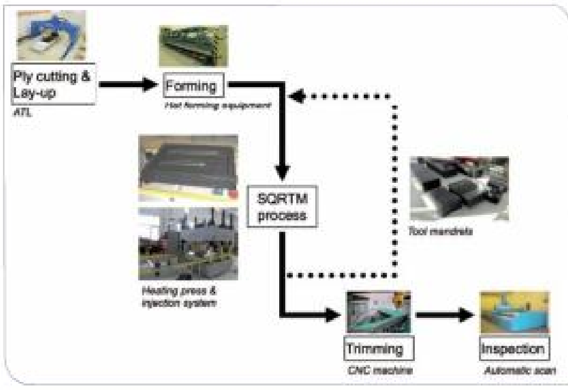

Fig. 6: SQRTM demonstrator manufacturing cycle

The process steps are the same as those presented in Figure 2, without using robots. After the flat lay-up of laminates with the automatic tape layer and hot forming with dedicated equipment (single or double diaphragm), the wet laminates are transferred into the closed mould. The curing mould is placed in the heating press. After curing, the part is demoulded and inspected (Figure 6).

The demonstrator was designed taking into consideration the environmental conditions and the manufacturing sequence. Right from the beginning of the development phase, the concept has to consider the use of prepreg combined with hot forming and closed-mould technologies. This implies a geometric definition enabling forming of laminates and an adequate and efficient assembly sequence of curing-mould mandrels.

A comparison with a similar structure whose parts are cured separately in an autoclave and fastened after individual inspection could give a weight reduction of around 10%. The reasons are: no foam for the stringers, no local reinforcements for bearing capabilities and use of UD tape instead of fabric.

Conclusion

The automated sequential process based on SQRTM technology presented here reduces assembly steps and the associated costs and results in lighter, better-performing parts. The key benefits are the automated manufacturing of integrated structures allowing the production of parts with higher mechanical properties due to prepreg UD products, tighter tolerances and surface finish according to the moulding process. Future investigations will focus on greater automation in combination with fibre placement. ■

More information: www.sabca.be

References

[1] K. Mason, High-Performance Composites, Autoclave quality outside the autoclave, March 2006.

[2] H. P. J. de Vries, Development of generic composite box structures with prepreg preforms and RTM, NLR-TP-2002-019, National Aerospace Laboratory NLR, Amsterdam, January 2002.

[3] B. Morey, Manufacturing Engineering, Processes reduce costs, Vol. 138 No 4, April 2007.

[4] H. G. S. J. Thuis, Development of a composite cargo door for an aircraft, NLRTP- 99434, National Aerospace Laboratory NLR, Amsterdam, October 1999.