ADVANCED MATERIAL AND TOOLING CONCEPT FOR A RTM HELICOPTER FITTING

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ABSTRACT: The VANTEX (Vanishing textile) project introduces a new type of filament made of EMS MS Grilon phenoxy to enhance laminate toughness for RTM components. In this case, a helicopter fitting (usually made of aluminium) has been produced. The component is riveted onto the ground and has two interfaces to load introductions with 20’000N and 2’000N, respectively. In preforming, phenoxy filaments are applied in woven and non-crimped fabrics, as fleece or as sewing thread. Phenoxy replaces binder material and increases the toughness of the final part. Preform structure and injection process are optimized in terms of load introduction and complete wet-out. Due to the geometry of the component, an advanced tooling concept using a mould made of Invar and aluminium, combined with temperature controlled demoulding are applied. The so manufactured components are evaluated in terms of toughness and maximum load introduction. Experimental results show a toughness increases thanks to the use of the phenoxy filament. The required static loads are exceeded by a factor 4.

KEYWORDS: Resin Transfer Moulding RTM, phenoxy, binder, preforming, toughness, Carbon fibre reinforced plastics CFRP

INTRODUCTION

At present, the use of fibre-reinforcing technology in aircraft is expanding very rapidly, with similar trends to be seen in the helicopter business. Besides its advantage of better mechanical properties per unit weight, CFRP is more economical: the technology makes it possible to produce complex components with many functions built into them.

Among other methods of making such components, resin infusion processes are being applied ever more often; and of these, Resin Transfer Moulding and similar processes prove to be especially suitable for aircraft applications.
Plastic structures reinforced with carbon fibres have two chief drawbacks. The first is brittleness, and the second is a potential lack of uniformity because of local concentrations of resin and disturbance to the fibre layout. This article describes a technology for improving the mechanical properties of composite components, which also has advantages in the execution of the process itself.

MATERIALS AND PROCESSES

In Fig. 1, a schematic description of the RTM process, it can be seen that the fabrication of the preform is a preliminary to the injection process itself [1]. The preform is produced, depending on the geometry and technical requirements of the end product, by weaving, braiding, sewing or by forming processes. The preform is then placed in the heated RTM mould for the actual infusion process, whereby a liquid thermosetting resin is injected into the dry preform. The mould cavity fills, the resin system undergoes chemical curing, and when the part is strong enough it is extracted from the mould and tempered.

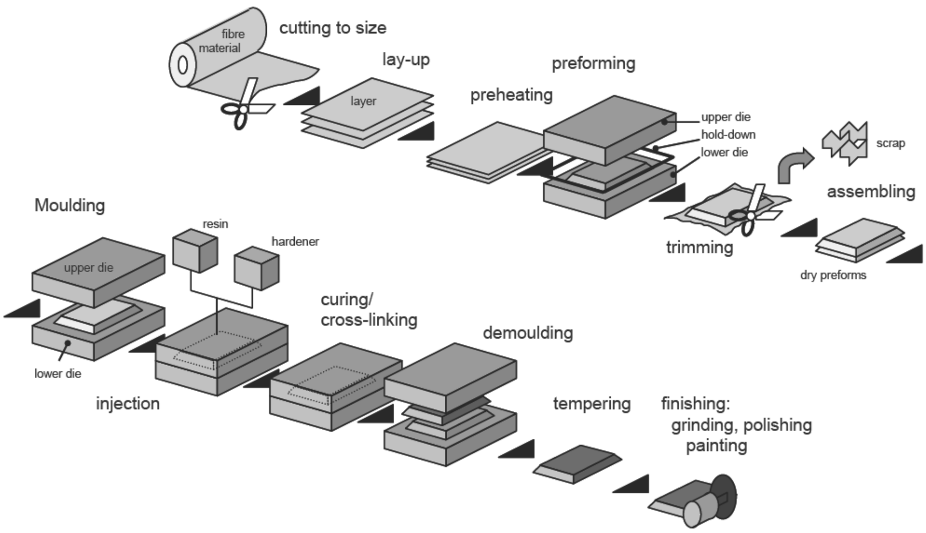

Fig. 1 RTM process (including pre- and postprocessing)

The main advantages of resin transfer moulding are:
- A highly integrated and complex design which results in a lower number of parts and reduced assembly cost;
- Multi-material components may be produced by incorporating metallic parts in the form of inserts;
- Low-investment production facilities;
- Simple material handling (reinforcing fibres & resin systems).

RTM requires a prefabricated dry fibre structure, the preform. This is often stabilised using binder material in powder form or as textile webs with sewn seams. Sometimes considerable amounts of thermoplastic binder may be used in making the preform. GRILON MS is a phenoxy binder yarn developed by EMS-Chemie [2], which can be incorporated into a dry carbon fibre preform for various processes. The subsequent wetting with resin during injection also presents no problems. Care must be taken to ensure that the resin temperature during injection remains below the glass transition temperature of the phenoxy to prevent the latter from dissolving prematurely.

The RTM6 resin is injected at 80°C according to the guidelines set out by its supplier HEXCEL [3], the mould being preheated to 120°C. Since the phenoxy in the preform has a glass transition temperature of about 78°C, it is already molten before injection. As soon as the resin comes into contact with the premelted phenoxy, the latter dissolves in it, increasing the resin's viscosity. This prevents soaking the dry preform in the RTM process as soon as the resin in the preform contains more than 4% by weight of phenoxy. Fig. 2 illustrates schematically the process of dissolution of the phenoxy fibre. The regions shown in beige are those in which the phenoxy diffuses by dissolution. Because of the increase in viscosity the phenoxy-enriched resin can no longer flow freely. Quite the reverse, it tends to stick to the fibres, increasing the flow resistance.

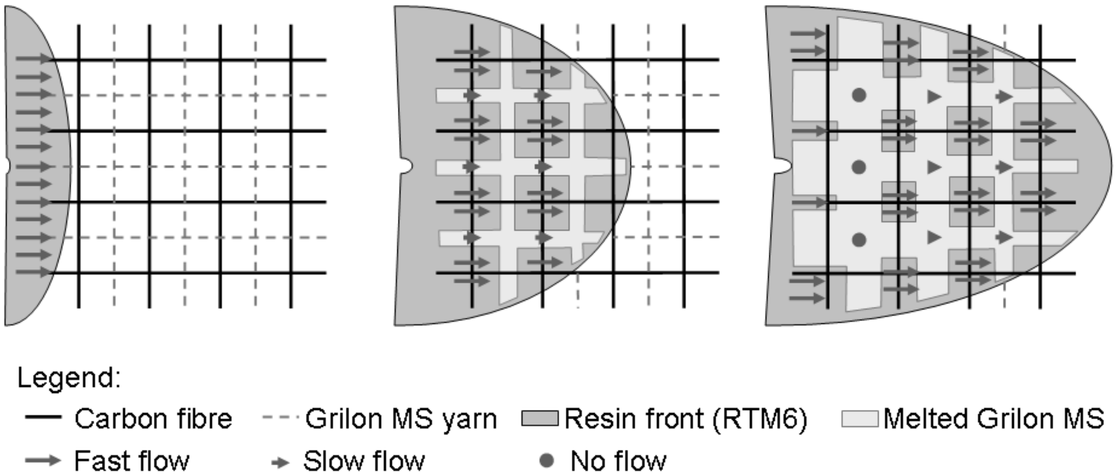

Fig. 2 Increase in flow resistance due to higher viscosity

Using HUNTSMAN's newly developed epoxy resin LME10104 in combination with the phenoxy binder yarn overcomes this disadvantage, as it possesses extremely low viscosity at temperatures below the glass transition temperature of phenoxy.

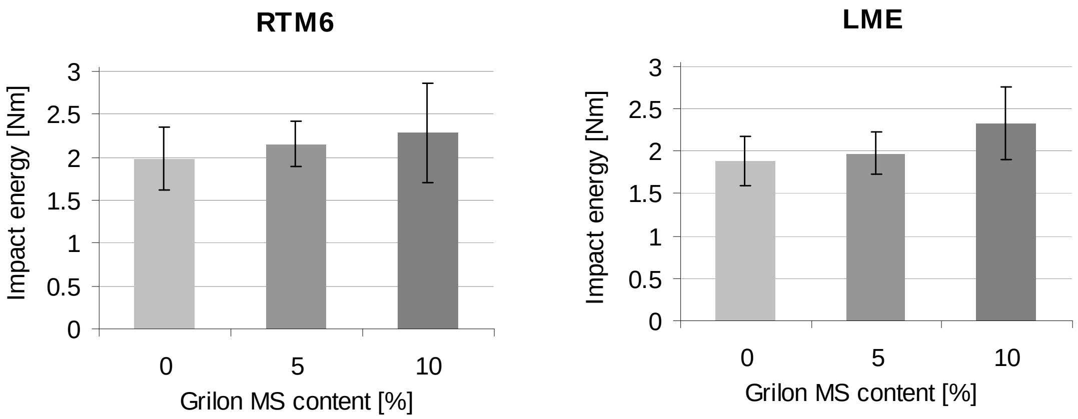

Fig. 3 The effect of phenoxy on the notched-bar impact energy

The effect of phenoxy on impact toughness as measured by the notched bar impact bending test tends to be more pronounced with the LME10104 samples than with those of RTM6. It should be noted that because of the large variances the results are to be used for comparative purposes and not as an indication of absolute values. Despite this, it can be taken that for both resin systems a 10% phenoxy content tends to increase impact toughness by 10-25% (Figure 3).

TOOLING

Using the phenoxy preform, a helicopter fitting from Eurocopter is manufactured. The component is usually made of aluminium; the representation in CFK is shown in Fig. 4, left hand side. The plate is riveted to the substructure and contains two interfaces (both realised as metallic inserts) with load introductions of 20’000N (primary load) and 2’000N (secondary load).

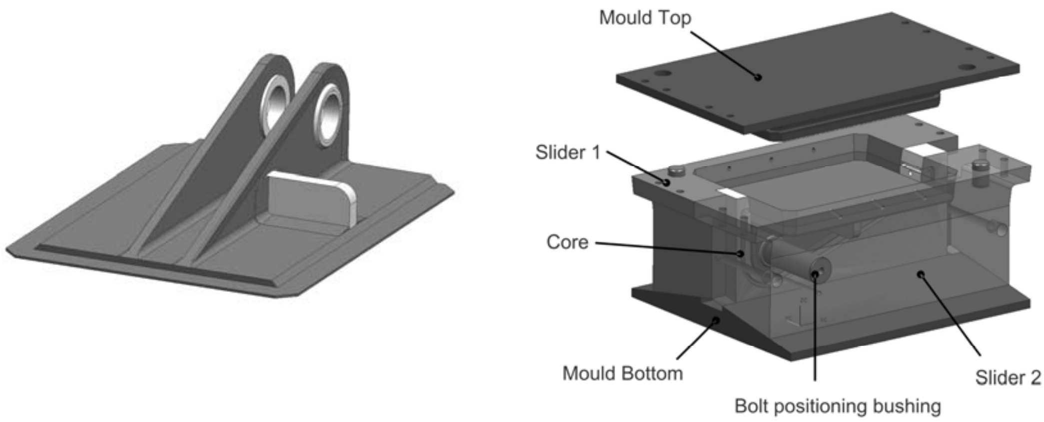

Fig. 4 Helicopter fitting and RTM manufacture tool

The RTM injection strategy has been developed by simulations using myRTM [4] and SLIP [5]: The component is placed upside down inside the tool, with two gates on both circular load introductions (top of bend). Ventilation is realized via flash face around the plate. To be able to demould the component after resin curing, an advanced tooling concept is necessary, as no draft angles are possible due to the design of the part (Fig. 4, right): The two sliders, mould top and bottom are made of Invar – the core is made of PTFE-coted aluminium and design to fit exactly at 180°C (curing temperature). Thus, after the resin curing cycle, the mould is cooled down and the mould top and the bolts are removed, the sliders are moved sideways. Due to the thermal contraction of the aluminium core and its coating, the fitting can be removed with minor effort.

MECHANICAL EVALUATION

To compare the CFK component to its aluminum counterpart, mechanical testing according to the designated load case has been done. Therefore the component was fixed with screws (at original rivet locations) to a stiff steel plate (Fig. 5). In primary load direction the force was applied on a bolt that was going through the aluminum inserts in the two carbon-fiber reinforced ribs. Maximum forces of more than 75'000N were measured in static tests. In the secondary load case the force was introduced in the aluminum rib that is integrated in the carbon fiber reinforced component. Here in the static tests, maximum forces of more than 40'000N were reached. The tests showed good safety factors for static loads compared to the design loads.

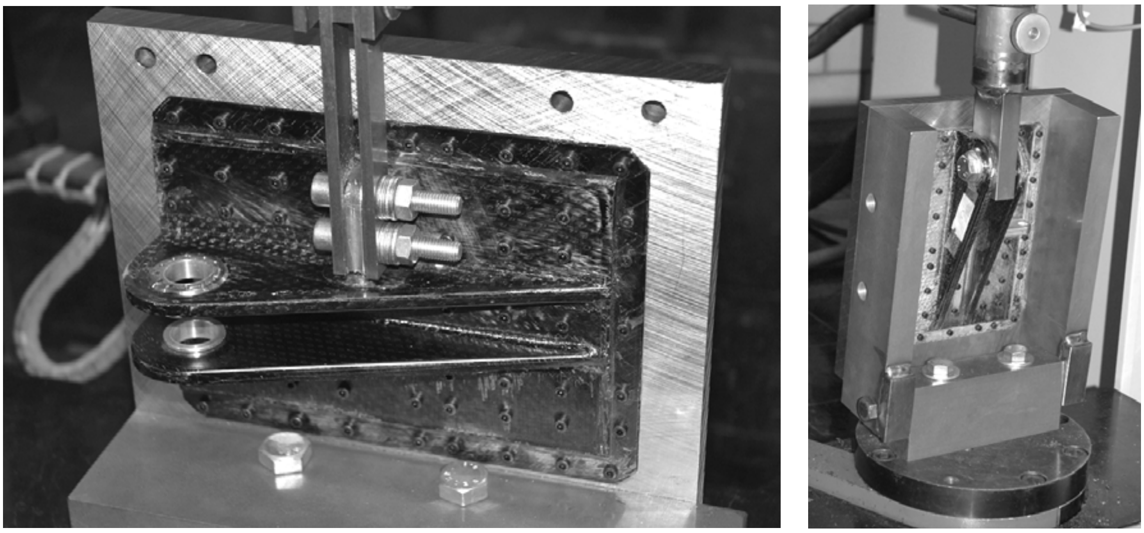

Fig. 5 Mechanical testing in secondary load (left) and primary load direction (right)

CONCLUSIONS

The following points sum up the advantages of phenoxy:
- It is easy to integrate phenoxy into the various textile fabrication processes;
- It replaces binder materials in the production of preforms;
- Using phenoxy with very low viscosity resin systems reduces cycle time;
- Phenoxy improves impact toughness up to 20%;
- Micro-cracks due to sewing threads and resin-rich areas are avoided;
- The new CFK component fulfilled the mechanical requirements, combined with a weight reduction of approx. 40%.

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