EC135 PITCH HORN IN INFUSION TECHNOLOGY

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Abstract

In current dynamic parts on rotorcrafts, such as blades, the prepreg technology has been the primary selected method as the process can be controlled via incoming inspections (material properties) and the complete manufacturing process is easy to be followed via Quality Assurance (QA). To increase the in house created value and process quality validation, a LCM process for a critical part, the pitch horn of the EC135 main rotor blade, has been investigated via the research project PreCarBi and finally serialized. During the serialisation phase, as a prerequisite, the primary functions (transfer of loads and stiffness) of the pitch horn have to be maintained and all the attachment/junction areas must be mirrored to the existing prepreg part. Finally, all the qualification steps of part and materials, as well as the whole new process have to be performed. And in a serialisation phase the stability proven and the process implemented.

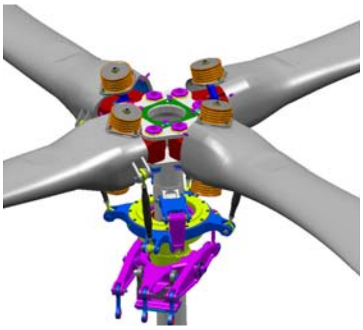


Figure 1: Blade Assembly

Figure 2: Pitch horn Assembly

NOMENCLATURE

QA	Quality Assurance
LCM	Liquid Composite Moulding
PreCarBi	Preimpregnated Carbon Binder Yarn Preform Composites
VAP	Vacuum Assisted Process
VARI	Vacuum Assisted Resin Infusion
DSC	Differential Scanning Calorimeter
RTM	Resin Transfer Moulding
TR	Tailored Reinforcement
CT	Computed Tomography
MAG	Multi Axial Gelege multi axial non- crimp fabrics

1. PRODUCTION PROCESS AND QUALITY STEPS IN THE EXISTING PREPREG PROCESS

In the existing prepreg process the quality of the final part is ensured by the incoming inspection, check of the material properties by standard test specimen to ensure e.g. fibre-volume ratio, DSC measurements as well as mechanical properties such as tensile strength and ILSS values. Those have to correlate to the originally qualified material properties (incl. tolerances) that have been defined and certified during the material qualification. In production the correlation to drawings and manufacturing instruction has to be ensured and checked by QA signature. The curing process is validated by graphical correlation verifying the temperature curve corner points. In case of doubt or printer failure, alternatively checked by DSC measurements, following the necessary authorisation via quality notification. The final part, bonded to the blade, is at last verified via computer tomography for production flaws like lunkers, waves or misalignments.

2. MOTIVATION FOR CHANGING THE PROCESS

The prime motivations for changing the current prepreg process were the new design possibilities infusion based processes offer, as well as the cost reduction and quality increase, by having all the process parameter under one's own control, and to have the option to modify the final parameters of the part. Due to reduced cost for materials (raw fibres and resin) as well as the optimized handling process, a reduction of 43% overall cost (material and labour) was envisaged.

Cost Reduction

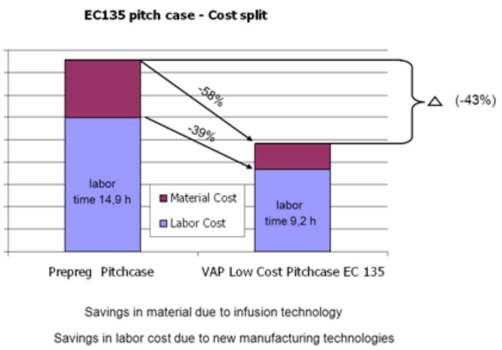


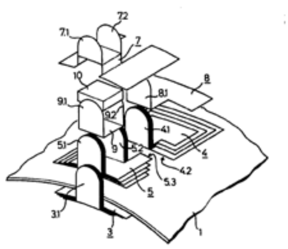
Figure 3: Cost reduction evaluation

A standard T_{100} calculation in this case was critical due to the high variation and uncertainties in this new process. Finally the assumptions have been proven to be correct only by the adaption of the process to the serial setup and beneficial input from in the team integrated operators.

3. DESIGN

To achieve the beneficial process improvements, the design had to be adapted, as a production of the full part is not achievable in one shot due to the pitch horn lever positions which would cause undercuts. The solution is a two phase / part production of levers and pitch horn, finally assembled in a bonding process after the end contour milling of the bonding partners.

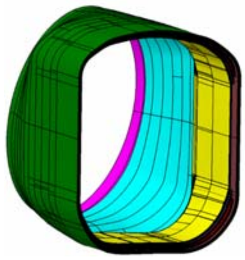
Prepreg one shot design:

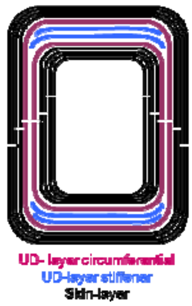


Catia design Schematic layup

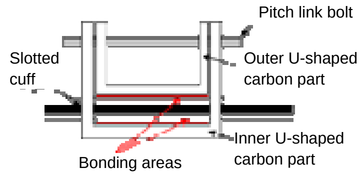
Figure 4: Standard prepreg design

New LCM design:





3D design Cross section layup



Bonding of the U-Profiles

Figure 5: LCM design

Additionally the original low density syntactic core had to be substituted by a dry fibre material, to get the right thickness and stiffness to match with the previous parts properties. In consecutive steps the amount of UD layers was altered. Generally the distance between the inner and outer fabric layers is the key parameter to achieve the final stiffness. The layer length and setup has been verified after a manual calculation (parallel axis theorem) by a FEM analysis.

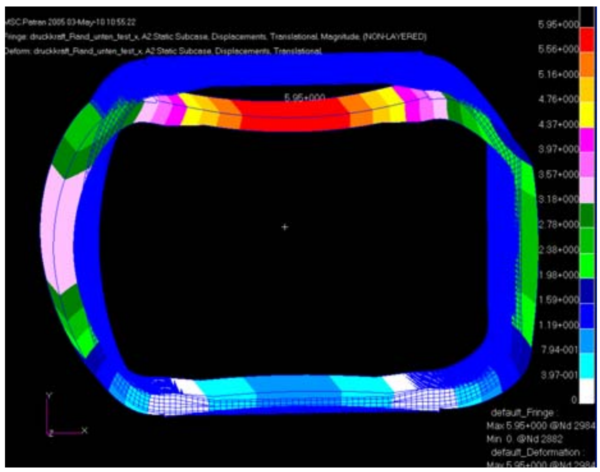


Figure 6: FEM Calculation

And finally proven in the component test.

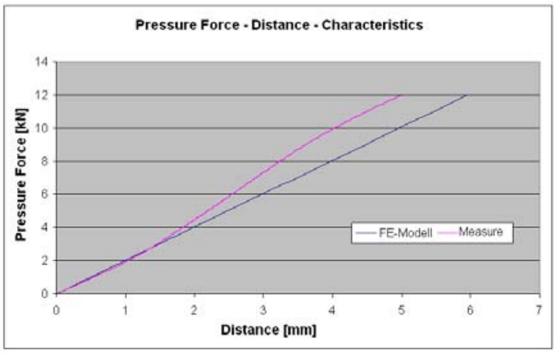


Figure 7: Stiffness Calculation and Measurement

4. GENERAL PROCESS

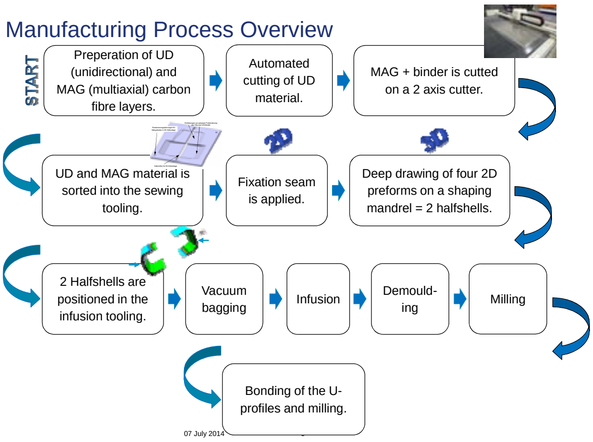


Figure 8: LCM Process overview

According to the manufacturing process a stringent line setup can be arranged adding value to the cost reduction if implied properly.

The following steps have been put in place in a manufacturing line setup.

- Preparation of UD and fabric plies (these could be already bindered material or the binder is applied in an additional process step)
- Automated cutting of the layers according to the drawings
- Binder application to the skin layers if necessary
- Application of the layer setup and fixation of the stack with binder or stitching
- 3D-Preforming of the set by heat application (could be performed on mandrels or already in the RTM setup on the final inner part of the mold)
- Application of the preform in the mould with a vacuum setup
- Injection/Infusion of the part
- Demoulding
- Milling of the part
- Final bonding of the pitch horn levers

5. PREFORMING

The preforming process consists of the application of binder (a thermoplastic web) on cut carbon layers (fabrics and UD tapes), stacking of those layers supported by a template and finally activation of the binder with an IR heating device (see figure below).

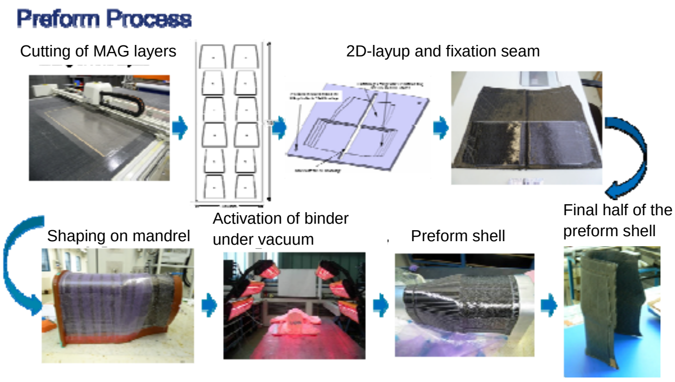


Figure 9: Preforming process

6. INFUSION / INJECTION

For the infusion / injection procedure the preform halves were put in a 3 split mould to obtain the outer contour. The inner shape is achieved by a vacuum process as in the previous prepreg design. Generally LCM processes like VARI, VAP or even, with an inner core, RTM are suitable for this kind of part and requirements. The preferred process depends for example on the intended amount of parts to be produced.

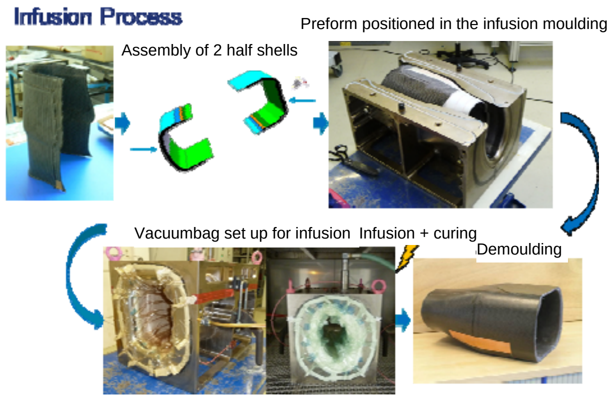


Figure 10: Infusion process

7. BONDING OF CRITICAL PARTS (PROCESS AND DESIGN PATENTED)

For the finalization, the milled parts are bonded in a specific tooling to ensure the perfect fit and the correct position of each attachment or fixation element. The correct bonding is ensured by first, visual inspection, for all the adhesive to excess the bonding area circumferential and second, during the computer tomography, for inner voids.

Additionally a failsafe concept has been chosen and tested (by component test), that if adhesion between cuff and the U-shape levers fails, the form closure geometry of the bonded pitch horn levers offers a second load path that, together with the junction bolt, can carry ultimate loads and functions.

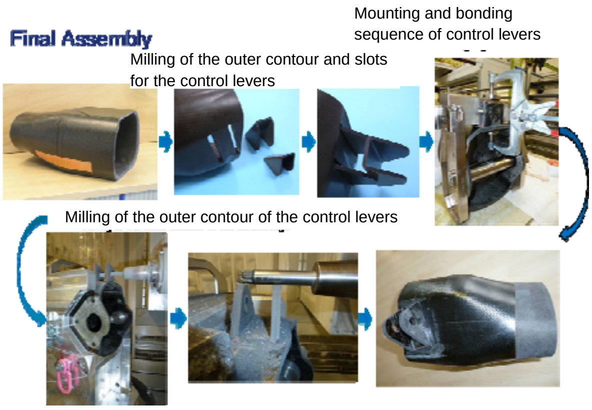


Figure 11: Bonding process

8. QUALIFICATION

Before starting to work with the new material the material properties had to be known and especially the influence of the binder had to be investigated. This was achieved by examining the bonding surface with IR spectrometry, in order to prove the amount of binder in the bonding area and by coupon tests that the mechanical properties are still sufficient. Therefore in a first assumption, to test and design the thickness of the pitch horn with a number of skin and UD layers a stiffness check was chosen. The stiffness had to be mirrored to the existing part and here because of the staggering, the number of layers had to be modified. And finally the static stress analysis has been performed on all functional attachment areas.

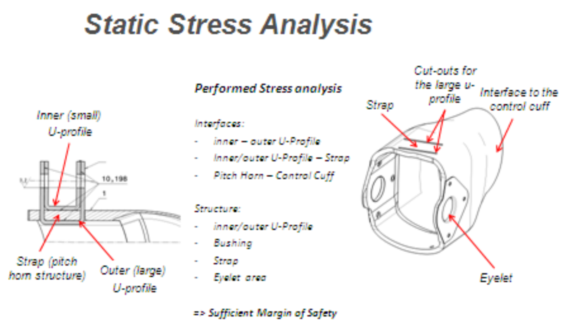


Figure 12: Stress analysis

The final qualification was achieved by two component tests of the pitch horn mounted on the blade. The test consists of all loads combined, like lead lag and flapping motion as well as torsion. The loads applied were in the area of the expected ultimate load values.

Figure 13: Component testing

9. PROCESS STABILIZATION AND CONTROL

To ensure the quality of the part the following steps have been implemented during the production.

General visual inspection

The visual inspection is a 100% inspection of quality characteristics, whose condition can be visually determined. The inspection shall be performed on all parts and components.

For the manufacturing of highly loaded components it shall be especially ensured and documented that the protective films have been removed prior to the component manufacture.

1. Incoming inspection of all selected materials by tensile, Amsler and Schenk specimen
2. Pre-cutting of the MAGs checked via templates (also used for setting up the binder and stacks)
3. Temperature controlled preforming
4. Infusion / vacuum setup checked for correct set up of the sealing
5. Infusion temperature and quantity controlled (via weight scales)

6. Curing cycle checked via temperature and pressure / vacuum print out
7. Visual and geometry check of the part before and after milling

   In particular, attention shall be paid to:

   - Debonding
   - Area with low amount of resin
   - Area with high amount of resin
   - Deformation
   - Delamination
   - Contamination
   - Residues
   - Impacts
   - Forming of radii
   - Ply shifting
   - Pressed out fabric

8. Bonding of the levers checked visually, by a tapping test and by CT inspection
9. General internal check by CT together with the mounted blade
10. Final check by stiffness control stiffness test
11. Periodical component tests

For the stiffness test, the pressure stiffness of the part between the two attachments of the dampers is measured The test is performed in a tensile testing machine with the standard fixation for pitch horns.

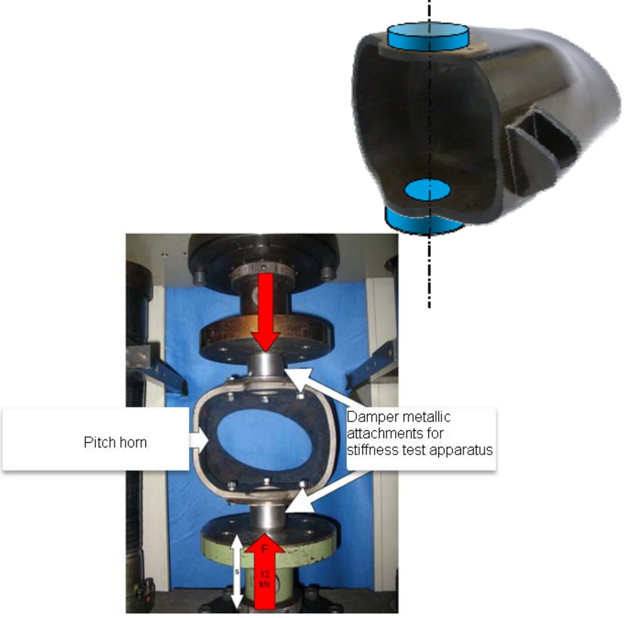


Figure 14: Stiffness testing

Environmental conditions:

- Room temperature

Test-procedure specification:

- 3 times compressive loading with
- F_A=(0…3…0) kN
- Rate of loading: $1^{mm}/_{min}$

Documentation:

- Environmental conditions by test
- Force deflection graph of the loading cycles
- Pitch horn height (measured at damper center)

The process of serialisation is often underestimated. After the prototypes have been produced and the general requirements fulfilled, the design is frozen and any change has to be limited to non FFF (Fit Form Function) changes. In the phase of introduction, a long period of adaption to serial needs and cost optimized process changes took place for the LCM pitch horn, before the final part was tested in component test equipment together with the nearly full blade. Calculations to convince everybody involved in the process qualification for the necessity, the industrial opportunities and the part improvement as well as the functionality of the adaption were necessary.

10. INDUSTRIALIZATION

Industrialization of the part for final serial application was/is done in a series of approx. 25 parts where different improvement and stabilisation methods were tested as well as manufacturing flaws artificially simulated and checked, like uninfilltrated areas, over- and underweight, variations (within the tolerances) of the curing cycles and finally variations in the CT inspections. Those inputs were finalized in the manufacturing instructions as well as the test specifications, and led to a process with the capability to fulfill the cost reduction requirements.

11. POTENTIALS FOR INDUSTRIAL AUTOMATION AND OPTIMIZATION

The current manufacturing process of the pitch horn is a mixture of automated and manual processes with a backlog of manual work. Parts of the infusion process itself are already automated but there are still a lot of other process steps which have a high potential for industrial automation. The manufacturing of the preforms is one of the most important steps in the production chain. With an automated manufacturing process the part can be optimised in terms of quality, process stability and cost optimization. Nevertheless the quality of the part is already very high today.

By use of automated 2D-Stiching machines in combination with a dry fibre cutter (automated lay-up stitching cutting process), linked with a “Pick and Place” or “Pick and Drape”-robot the automation of producing the TRs (Tailored Reinforcement) can be increased a lot.

Also the preparation for the infiltration process is still done manually (e.g. installation of vacuum bag, tubes). Changing the process to a vacuum assisted closed mould low pressure RTM could be one possibility to increase the automation and reduce waste cost due to the absence of additional sealing tapes , foils, etc…

12. ACKNOWLEDGEMENTS

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13. REFERENCES

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