

# INCREASING COMPOSITE HAND-LAYUP REPEATABILITY USING END-END DESIGN AND MANUFACTURE SIMULATION SOFTWARE

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## Introduction

Hand layup is still the dominant forming process for the creation of the widest range of complex geometry and mixed material composite parts. The hand layup process however is still poorly controlled and informed, limiting productivity. Processing and therefore products often vary between laminators [1]. There are a number of material properties which contribute to the repeatability challenges including flexural rigidity, tack, shear stiffness and material variability [2]. In hand layup, the desired output form of a ply over a complex surface is provided to the laminator in a Manufacturing Instruction Sheet (MIS). Ambiguity in the MIS leads to interpretation, and variability between laminators and components, creating difficulty for a true benchmark of time, cost, and quality to be achieved. Variation of skill levels between operators presents a host of repeatability problem particularly where unintuitive complex geometries are considered. Manual layup for complex geometries is therefore conducted by highly experienced and skilled laminators. This work seeks to identify and control factors which affect repeatability by demonstrating a methodology for simulation based composite manufacture process development, improving the standardisation of produced components.

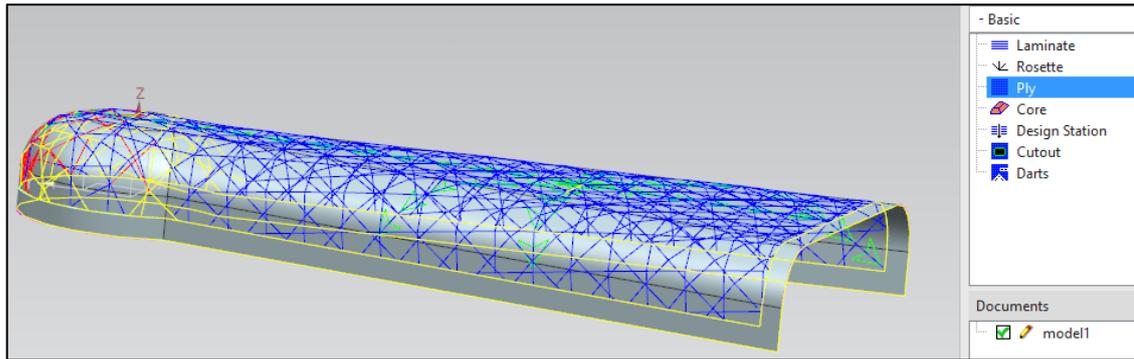
## Composite manufacture Simulation

Commercial digital composite manufacturing tools take a component-based approach to the fabrication of a laminate. The integration of part design and manufacture controlled in a digital environment is termed end-end design.

The traditional technique of hand lay-up involves using more material than required in order to trim to size at a later date and undertaking modifications during the lay-up process which leads to variability and wastage [3]. Digital lay-up manufacture simulation allows for modifications to be defined and controlled in the simulation environment and regulated before being released to the production floor. These iterations can include stress analysis, manufacturability assessment and waste reduction. Digital manufacturing increases process automation reducing the decision-making burden on the operator and streamlining the steps required during the lay-up.

A drone arm (shown in figure 1) is currently manufactured in small batch production. It is assumed that the dimensions, i.e. the length and the width, are fixed. The part is a pre-preg (3K, 2x2 Twill Weave Carbon) 3 ply laminate (0, 45, 0). The current manufacture method is pre-preg hand lay-up. Layup is based on square cut, full-body plies which are modified to conform to the tool surface during layup.

The drone arm CAD model is opened in NX10 (Siemens PLM) and ply boundaries established around the lower face of the arm using 3D lines. The model is directly imported into Fibresim (Siemens PLM). A single ply is applied across the whole part surface as in the current manufacturing method. Material properties are loaded into Fibresim to accurately simulate drape properties. Net producibility assessment is performed on the generated digital ply with results shown in figure 1. A series of iterations of, layup start points, slices and darts are applied based on advice from the laminators to generate a low deformation net. Two further plies are defined using the same method to generate a digital laminate. This is then exported back into NX10 and solved using the Nastran laminate solver to validate mechanical performance and identify stress raisers. An iterative process of ply modification and stress optimisation is made to define an optimum cut plan. The final cut plan is sent to an automated cutting system and also produced as a MIS containing not just ply templates but definitions for the first layup region and ply spreading direction.



**Figure 1:** Net producibility assessment of the drone arm components generated in Fibresim. Critical region (shown red) where fibre must be amended to conform to the lay-up surface.

### Layup assessment

In order to assess the impact of the digital manufacturing data on production repeatability and cycle time a current production line is compared. The manufactured parts from six laminators were measured before and after the implementation of the digitally generated layup templates. 37 samples pre and 35 samples post implementation were manufactured during the test period. Final part weight (after finish grinding) is used as a measure of part consistency. Part weight indicates total material use and resin bleeding. No voids or wrinkles are present in any of the manufactured parts.

**Table 1:** Layup trial results.

	<i>Pre-Implementation</i>	<i>Post-Implementation</i>
StDev Part weight	0.5004	0.3258

### Discussion and Conclusion

The Fibresim digital manufacturing package creates a digital environment for iterative modification and assessment. The ability to perform stress-based analysis for multiple ply cut patterns and overlay regions allows for part optimisation to be achieved quickly. Cutting waste can be reviewed using cut-pattern areas and nesting outputs. The production of a detailed MIS informs laminator layup approach.

Results show that the implementation of end-end digital design and manufacturing optimisation can improve repeatability. Repeatability, shown by part weight deviation, has improved through the standardisation of ply layup and cutting. It was also observed during the trial that the digital tools supported inexperienced laminators in production confidence and part consistency.

While variation still exists within hand layup, part repeatability is shown to be improved by the implementation of digital end-to-end design and manufacturing techniques.

### Acknowledgements

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### References

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