ORIGINAL CONCEPTS OF PLY DROP CONFIGURATIONS FOR IMPROVED MECHANICAL PERFORMANCE IN TAPERED COMPOSITES

E. Kazemi[1], A. Whitehouse[1], E. Greenhalgh[1], S. Pimenta[1], J. Finlayson[2], S. Pinho[1]

[1]Faculty of Engineering, Imperial College London
Exhibition Rd, South Kensington, London SW7 2BU, UK
Email: m.kazemi@imperial.ac.uk
[2]Composites - Structural Systems Design, Rolls-Royce
PO Box 31, Derby, DE24 8BJ, UK

Keywords: Automated fibre placement (AFP), Ply drop, Carbon fibre-reinforced polymer (CFRP), Mechanical performance, Tapered composites.

Abstract

Tapered composites constitute a type of feature that can be easily automated using AFP. These composites are used in several key aero-structural components, such as wings, helicopter rotors and engine fan blades to achieve weight-efficient structural performance and aerodynamic benefits due to experienced loads [1]. Tapered composite laminates exhibit changes in their thickness, achieved by terminating their plies during their manufacturing, commonly referred to as ply drops, Figure 1. One of the optimum manufacturing methods for terminating plies in tapered composites is the AFP.

Although current (conventional) AFP machines have the ability to lay down tapes (containing fibre reinforcements) at any angle to achieve optimum and complex layups, they cannot cut ends of the tapes at specific angles during the layups, see Figure 2. This can result in overlapping materials at the component edges during manufacturing, resulting in extra manufacturing steps and costs for trimming. Moreover, overlapping materials during ply drops in the tapered composites have been reported to suppress the mechanical performance of the structure [1]. Imperial College's AFP machine (Figure 2) is unique in that it can cut tapes at an angle, leading potentially to ply drop configurations that exhibit an improved mechanical performance eventually for fan engine blade manufacturing, Figure 2 (b).

Thus, in this study, we design and introduce original concepts of ply drop configurations that exhibit an enhanced mechanical performance than conventional ply drops in carbon fibre-reinforced polymer (CFRP) composites. After designing and manufacturing CFRP tapered specimens containing new ply drop configurations, we subject them to several mechanical tests (namely tensile and indentation) to evaluate their performance and compare the results to traditional ply drop designs (without angled cuts in their dropped plies region). The results show that the novel design increases the maximum load and displacement at least by 10% and changes the failure mode from undesired compressive failure at the root to desired tensile failure at the location of the ply-drop region.

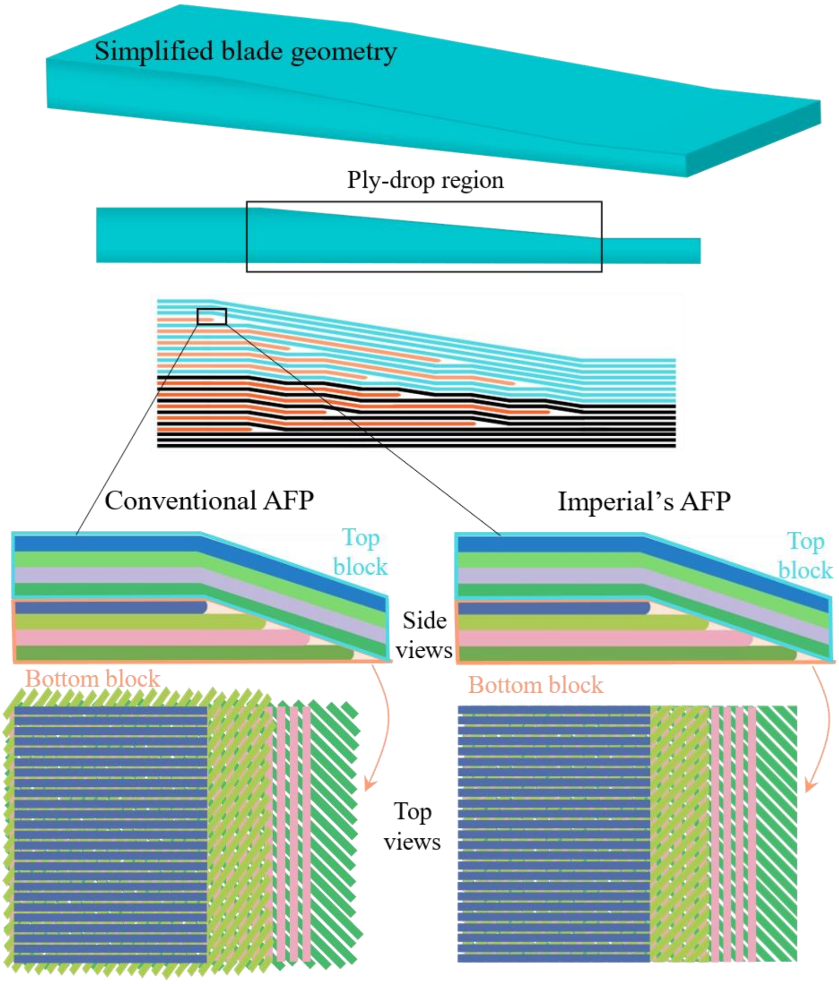
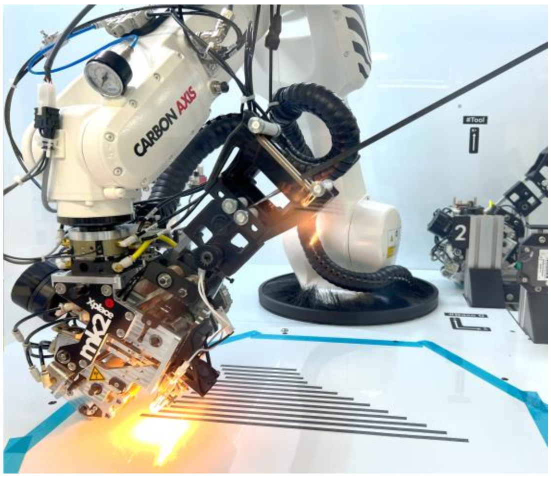
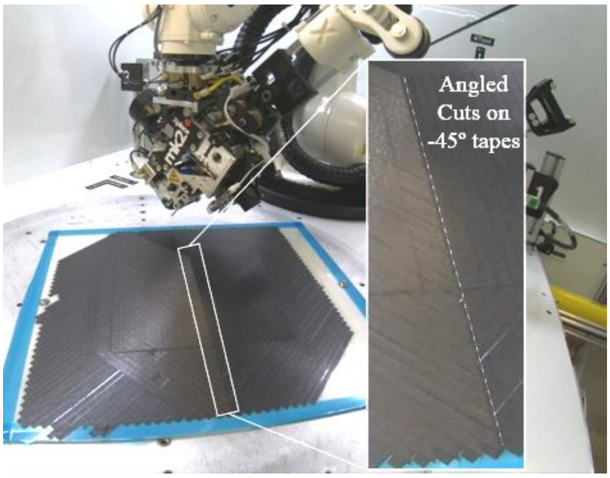


Figure 1: The role of tapes angled cuts during ply drops in tapered composites



(a) Automated fibre placement (AFP) machine



(b) AFP with the feature of angled cuts

Figure 2: Imperial College AFP machine

References

[1] Woigk, W., Zhang, B., Jones, M. I., Kuhtz, M., Hornig, A., Gude, M., & Hallett, S. R. (2021). Effect of saw-tooth ply drops on the mechanical performance of tapered composite laminates. Composite Structures, 272, 114197.