

# RECENT DEVELOPMENTS IN AUTOMATED FIBER PLACEMENT OF THERMOPLASTIC COMPOSITES

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## ABSTRACT

The advantages of in-situ automated fiber placement (AFP) of thermoplastic composites (TPC) are well known and have been widely used in industrial applications for decades. However, acceptance has been slow in aerospace applications due to throughput and quality concerns. Several research efforts in Europe and the US are addressing these concerns and several are focusing on preforming with AFP followed by post consolidation. The ideal process remains in-situ TPC AFP, an additive manufacturing (AM) out-of-autoclave (OoA) process. This paper provides an overview of worldwide research efforts, process physics, and the authors' recent results with synergistic technologies.

## 1. INTRODUCTION

### 1.1 Additive Manufacturing for Composites

Just as the machine tool industry has progressed from manual operations to automated CNC machining centers, the composites industry is moving from hand layup to automated processes. Unlike the machine tool industry that relies on subtractive processes, composites require additive processes. In order to take advantage of the directional strength characteristics of composites the fibers must be placed layer by layer in orientations and patterns that optimize their strength and stiffness for a given application. Additive manufacturing processes for metals and polymers are capable of manufacturing complex structures directly from a 3D CAD model with very little wasted materials. Designers can create a model, "print" it, and have a functional part in minutes. Similar processes are needed for composites.

### 1.2 Automated Fiber Placement

AFP is an additive manufacturing process for composites. There are now many manufacturers of AFP equipment for thermoset composites in production worldwide. The benefits of AFP include:

- Material and labor savings
- Quality improvement
- Accurate fiber placement at any angle
- Automatic debulking

The benefits of AFP are well understood and the technology is now established. We finally have an automated process for composites comparable to CNC workcells for the metalworking industry. However, with thermoset composites there is still a curing step that requires a manual bagging operation and an expensive autoclave cycle. The autoclave is a bottleneck in the

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