ON-THE-FLY PROCESS CONTROL IN AUTOMATED FIBRE PLACEMENT

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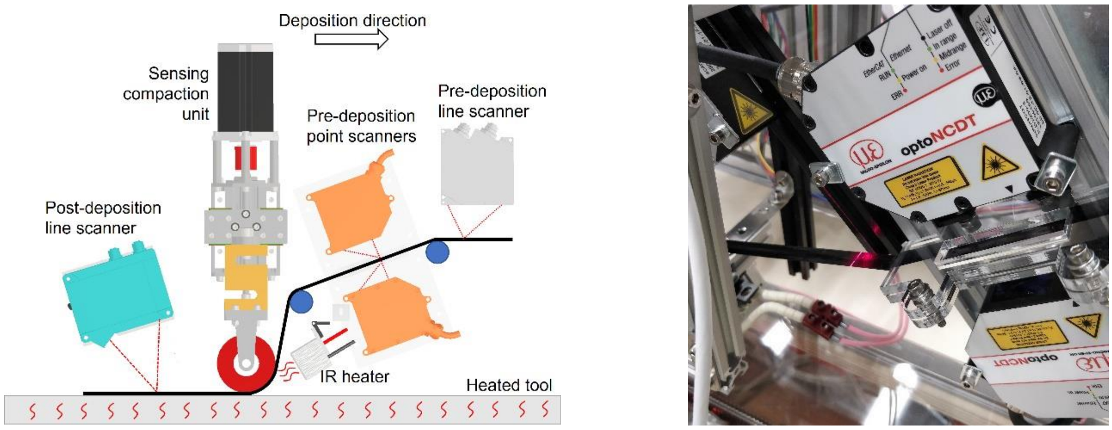
ABSTRACT

Automated Fibre Placement (AFP) technology has been widely recognised as one of the most advanced manufacturing processes for composite structural components across many key industries. Compared to hand lay-up processes, AFP offers considerably higher robustness, repeatability, and productivity, and it is ideally suited for large thin parts with simple geometry [1,2]. As capabilities to process different material systems, process wider tapes and achieve higher process rates are key performance indicators for the most state-of-the-art AFP machines, an intelligent system process control, that makes the machine aware of what it is processing, is in high demand and deserves further exploration.

Current AFP process control has focused on producing defect-free parts with advanced mechanical performance by fibre trajectory design, course monitoring and optimisation of key processing parameters i.e. deposition rate, heating/melting temperature, uniformity of compaction pressure. These parameters are normally determined through averaged off-line material measurements, off-line process condition measurements combined with trial-and-error manufacture iterations, often requiring heavy machine operator intervention with prolonged machine downtime (up to 40%), which makes the cost for AFP and sequential post-processing for large thick parts significantly high [3]. In addition, current process control can be considered as a passive system where in-coming material properties and in-process conditions has no effect on machine actions. While recent advancements have automated defect detection and online quality assurance [4], a lack of real-time material measurements and active process control based on 'live' data during AFP remains. Therefore, deviations between the as-designed and as-manufactured part are inevitable as a-priori determination of 'ideal' processing parameters fail to account for the stochastic nature of the deposited material (i.e. prepreg tape properties and its dimensions).

This research aims to enable on-the-fly fine tuning of the key AFP manufacturing parameters using real-time measurements of both material and active processing conditions. To prove the concept, a novel AFP testbench, named as real-time AFP (RT-AFP), is firstly constructed consisting of multiple sensors to measure material properties and processing conditions in real-time. Figure 1a & b show a schematic of the current design of RT-AFP and pre-deposition sensing unit, respectively. Incoming prepreg material firstly enters pre-deposition sensing region where a laser line sensor and a pair of laser point sensors are located, from which material width and thickness are measured; any defects caused by upstream processing can also be captured. These 'live' sensor data (material dimensional information) and material quality (as a binary indicator) are monitored and fed into a master control system implemented via LabView, which consists of a set of closed-loop controllers that 'tune' the compaction force, temperature and process rate on-the-fly. A post-deposition line scanner simultaneously measures the thickness and width of the material that has been laid down, including current tape(s) and overall thickness of laminate, to confirm the previous intervention from real-time AFP process control. In a class with other online inspection systems, defects detected during deposition can also be measured and assessed by the post-deposition sensor.

Monitoring these key processing variables and up/down stream material dimensions in real-time allows operators to be fully aware of what is going in and out under what conditions during AFP process, which allows 'in-situ' control of incoming material and the key process conditions, the quality and thickness control of the final un-cured laminate may be improved, which provide parts are more closely aligned with design requirements and constraints.



(a) (b)

Figure 1: (a): Schematic of real-time AFP (RT-AFP) testbench; (b): real-time material measurement unit located prior to deposition during AFP process with a pair of point sensors (RHS) and single line sensor (LHS). Note that other processing modules such as material unwinder and feed unit are ignored in (a).

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