University of BRISTOL
Bristol Composites Institute

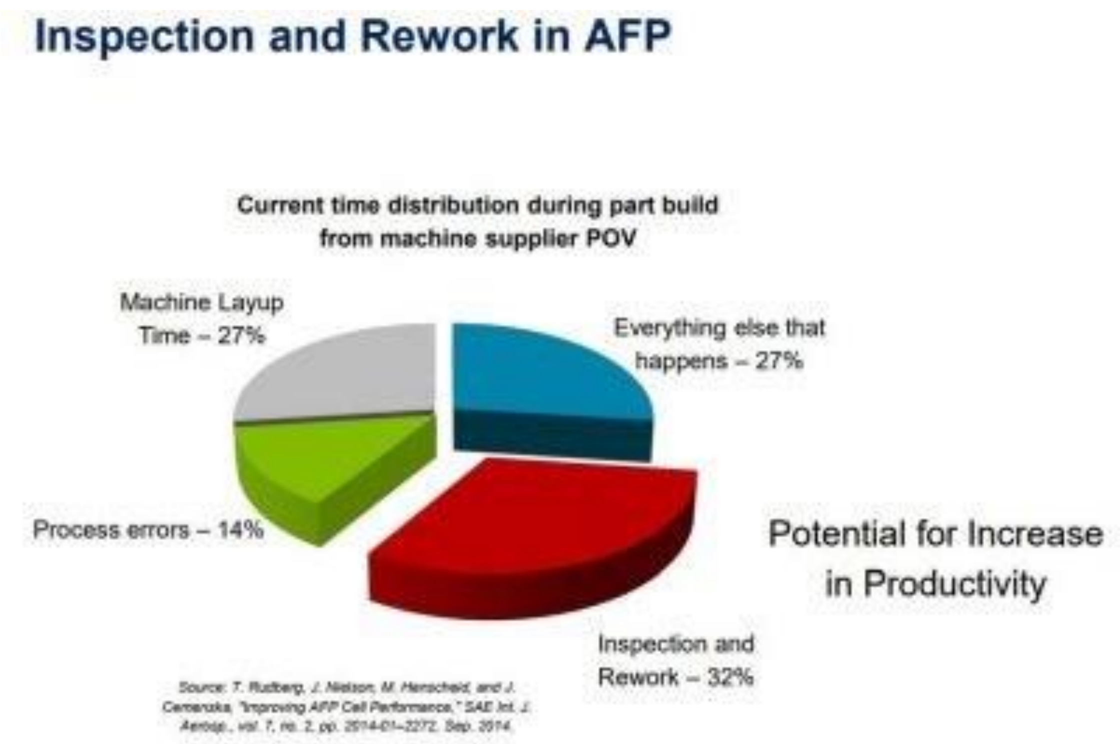
In-situ Defect Detection and Correction using Real-Time Automated Fibre Placement

Iryna Tretiak, Duc Nguyen, Xiaochuan (Ric) Sun, Mario Adrian Valverde, James Kratz

Digitalisation Showcase

06/06/2023

Current Trends and Challenges



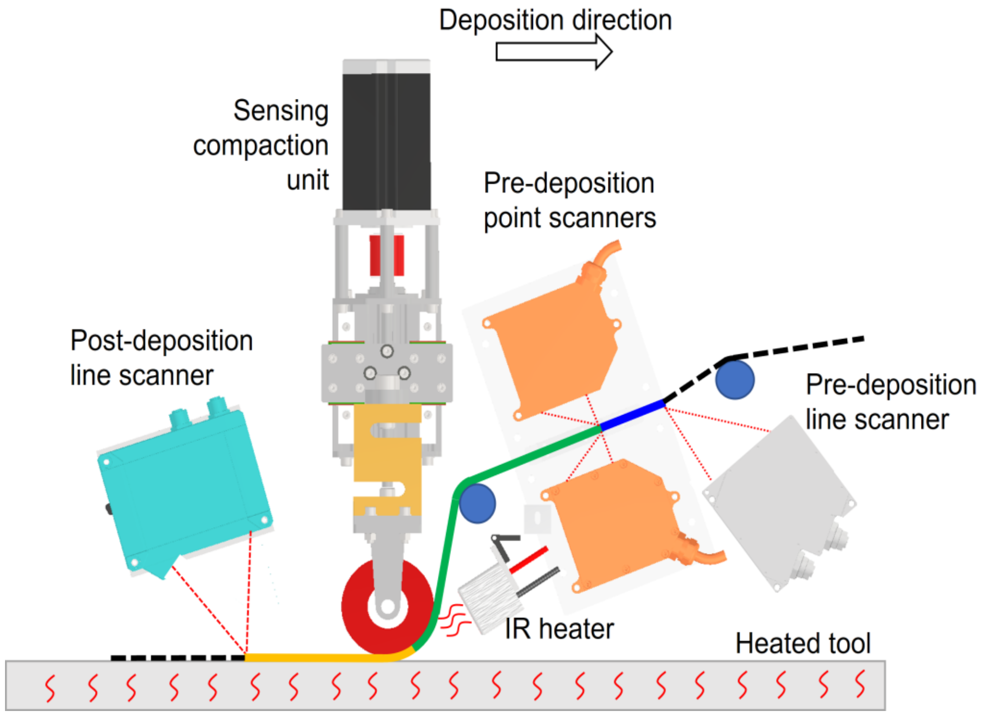
https://www.compositesworld.com/articles/zero-defect-manufacturing-of-composite-parts

The MTorres automated fibre placement head at Airbus applying composite tape to an A350 wing cover tool

Motivation

- Recent move towards industry 4.0
- Global emphasis on sustainability
- Need for less waste and more efficiency in composite manufacturing

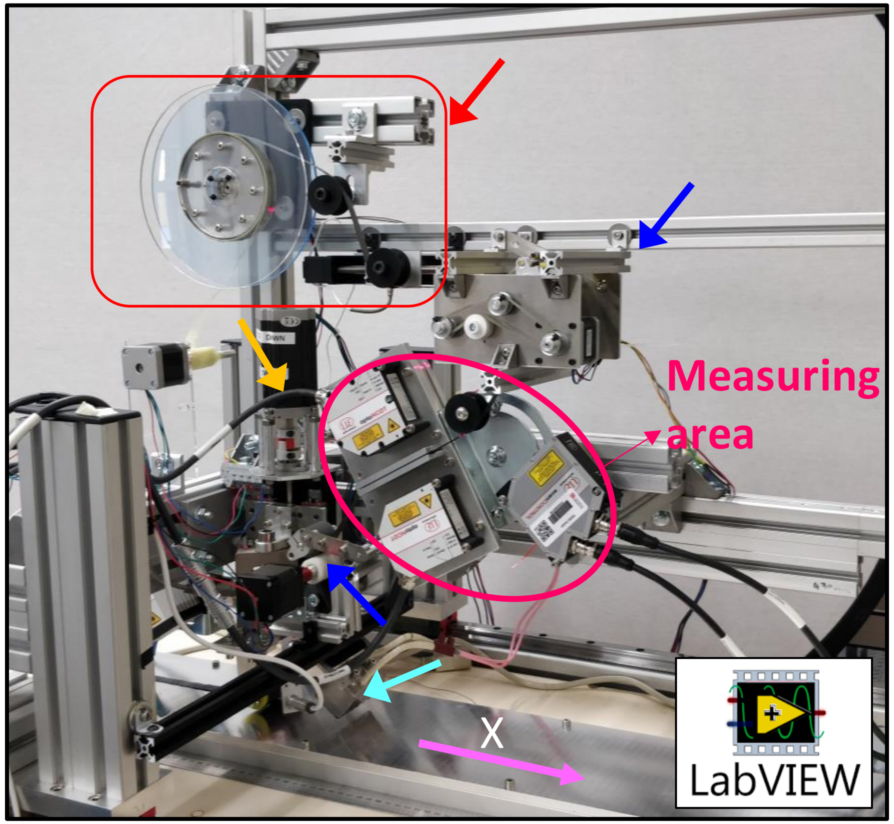
Lab-Scale AFP System Development



Schematic of real-time Automated Fibre Placement (RT-AFP) machine head unit

- Build a research-based lay-up system with sensors to measure and collect material before and after deposition
- Feeds this data to models and actively control the AFP process on-the-fly

RT-AFP Machine Key Components



Real-time AFP prototype: single tow (max. 1 inch) single axis (X) AFP testbench with maximum tested speed of 1m/min

Material Unwinder System: Closed loop tension control including electromagnetic break, dancer load cell and a separate PID tension controller

Material Feed: Feeding units at both the entry and exit of material measurement to minimise additional tension building up

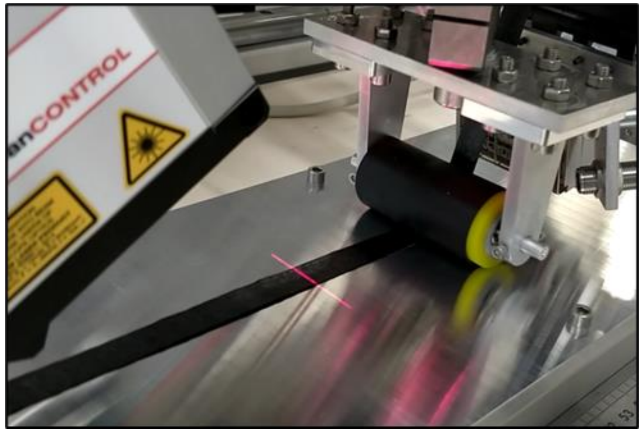
Compaction Sensing Unit: Integration of load cell and linear stage for taking compaction measurement and enabling compaction load on-the-fly tuning, respectively

Material Heating: 300W miniature Infrared heating element

AFP Head Movement: X-axis movement only

AFP Master Control: Implemented via LabVIEW software with multiple NI-DAQ devices (ethernet/serial links) and processed by PC

Material Measurements



Pre-deposition sensors

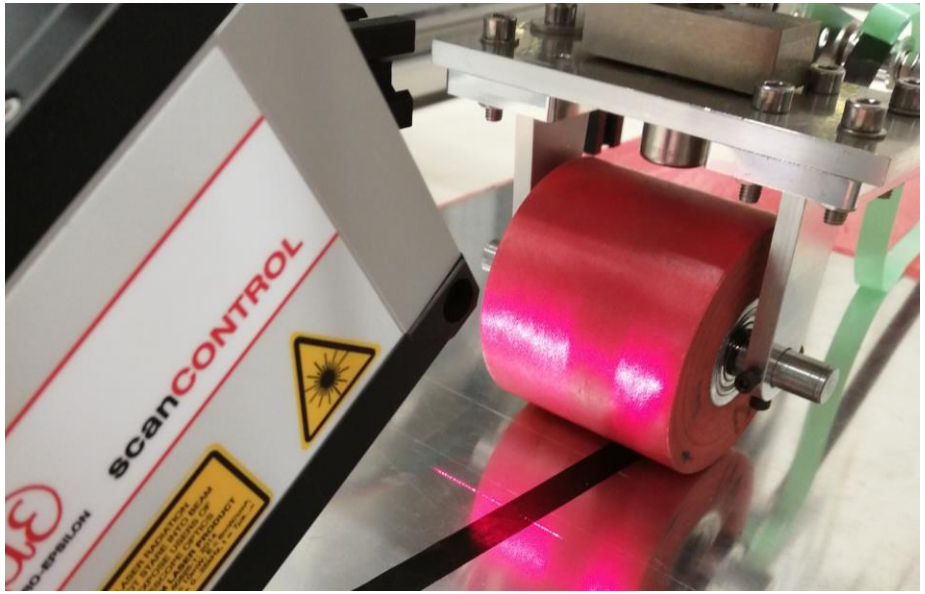
- A pair of laser point sensors
  Resolution 0.3 µm;
  Measuring range 2 mm

- Single laser line scanner:
  Resolution thickness 4 µm;
  Resolution width 1280 pixels per profile

Post- deposition sensor

- Single laser line scanner:
  Resolution thickness 1.5 µm;
  Resolution width 2058 pixels per profile

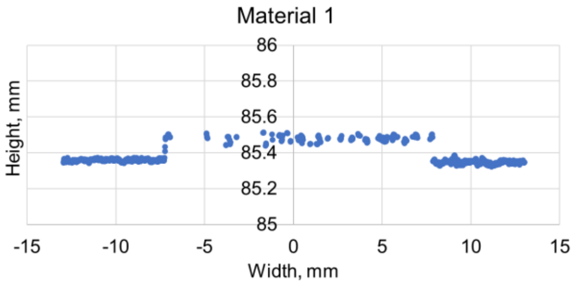
Material Measurements

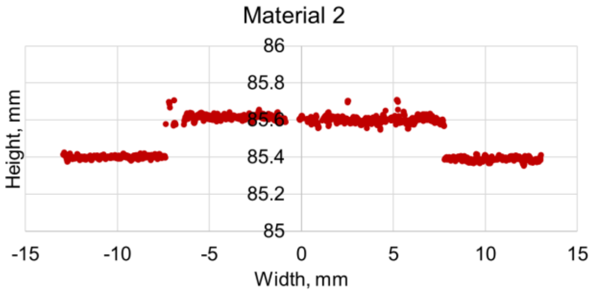


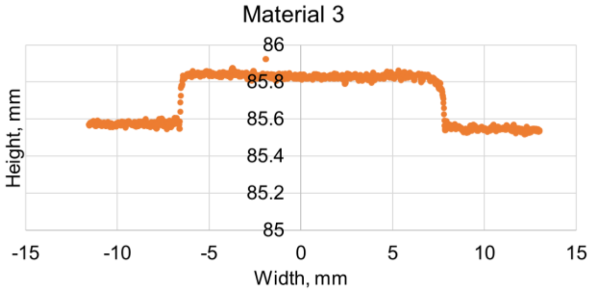
Dimensions of the tape could be measured prior and after deposition.

Investigation of measurement sensitivity to heat, vibration, lighting and material topology.

Results show minimal impact from environmental factors on measurement quality for the materials tested.



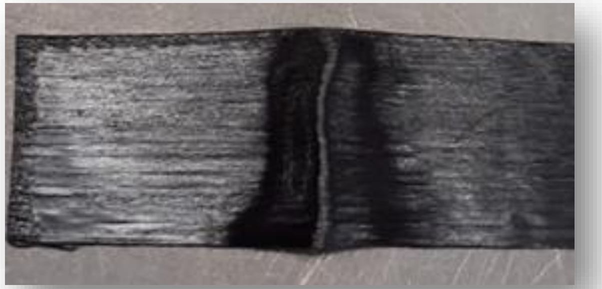


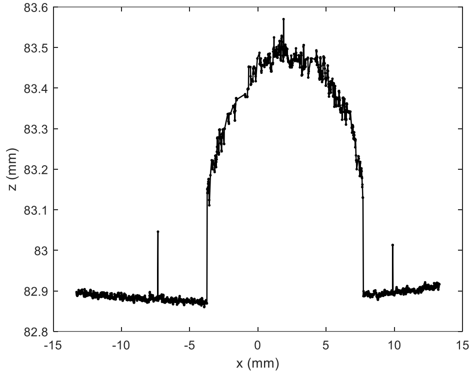


Material	No of points in profile	Line scanner point/profile
Material 1	1067	2048
Material 2	1827	
Material 3	2033	

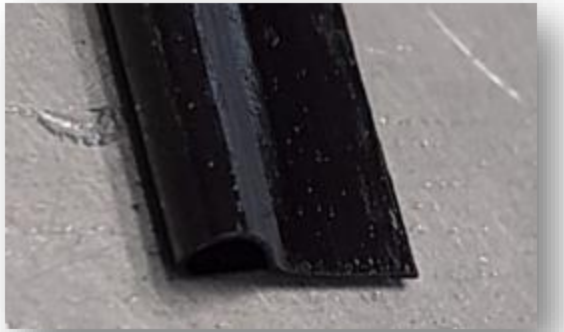
Defect Detection

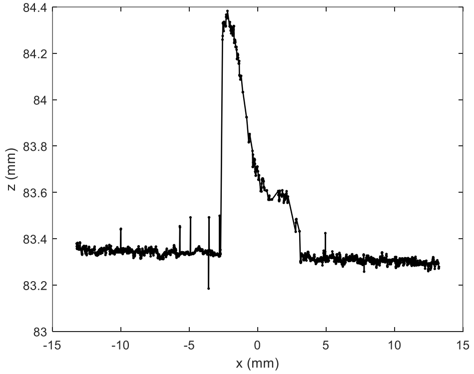
Wrinkle



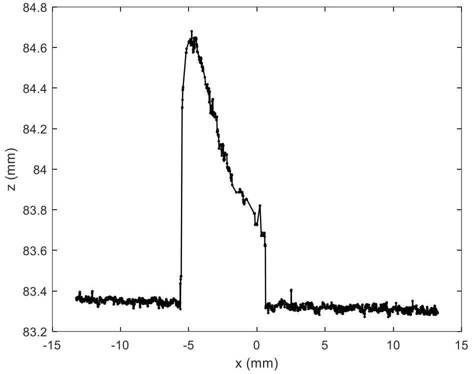


Fold

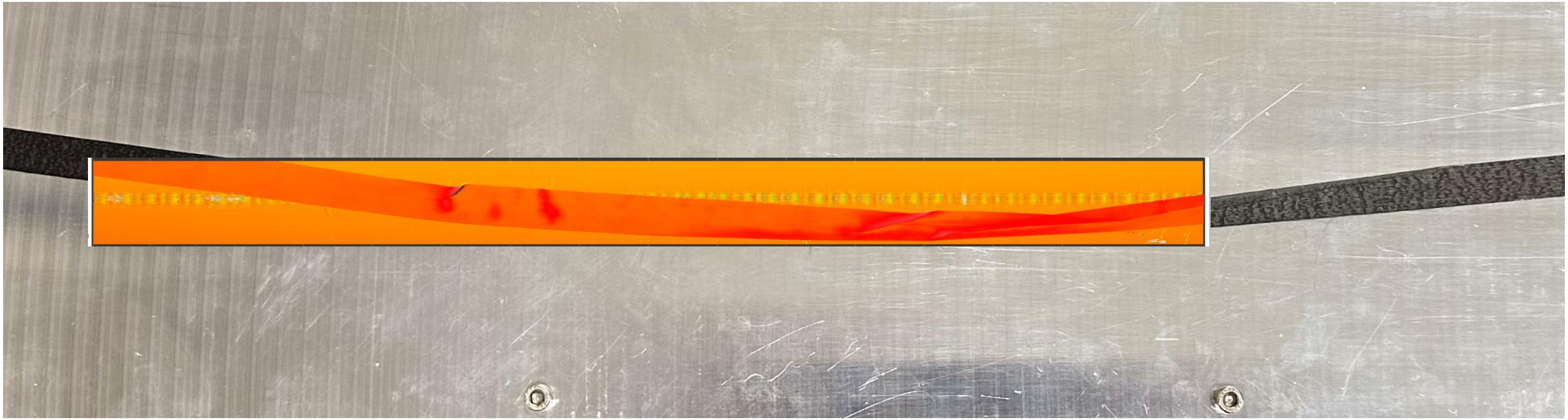




Twist

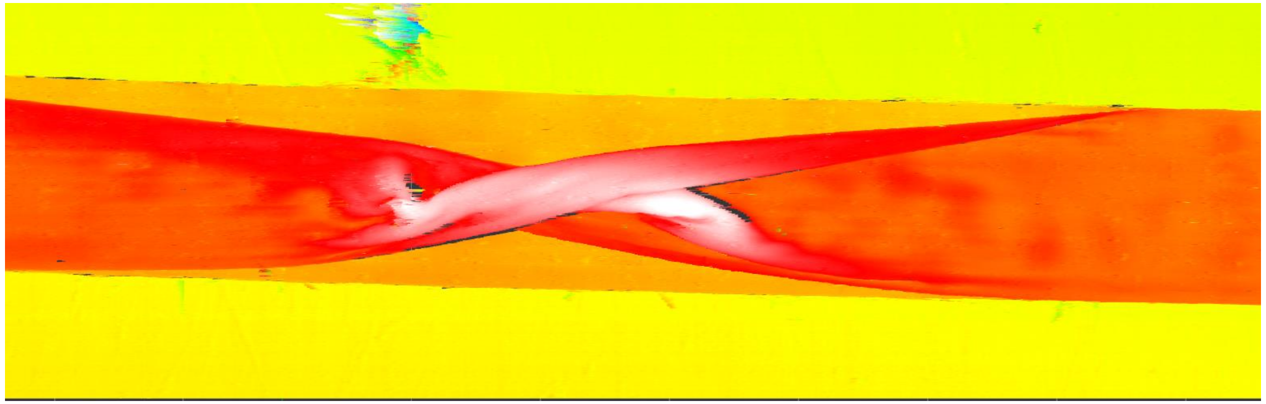


Defect Detection

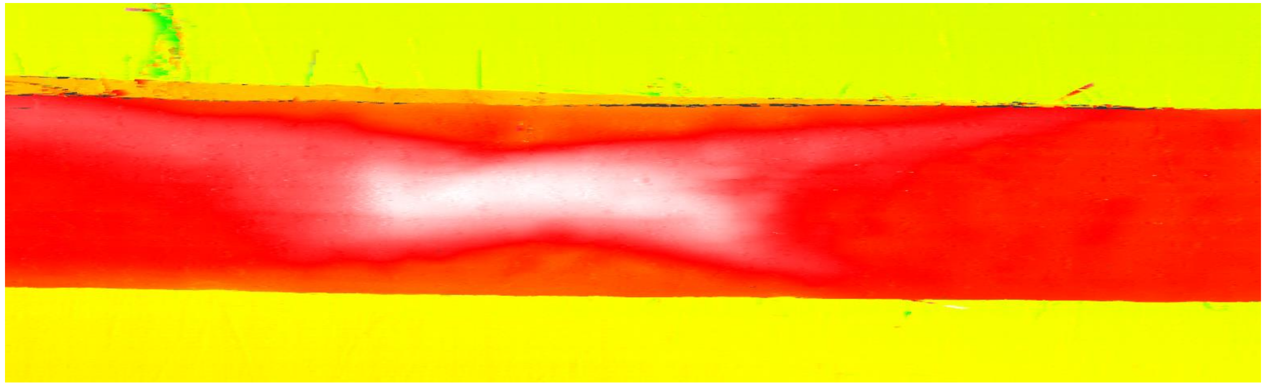


Defect Detection

Ply 2



Ply 3

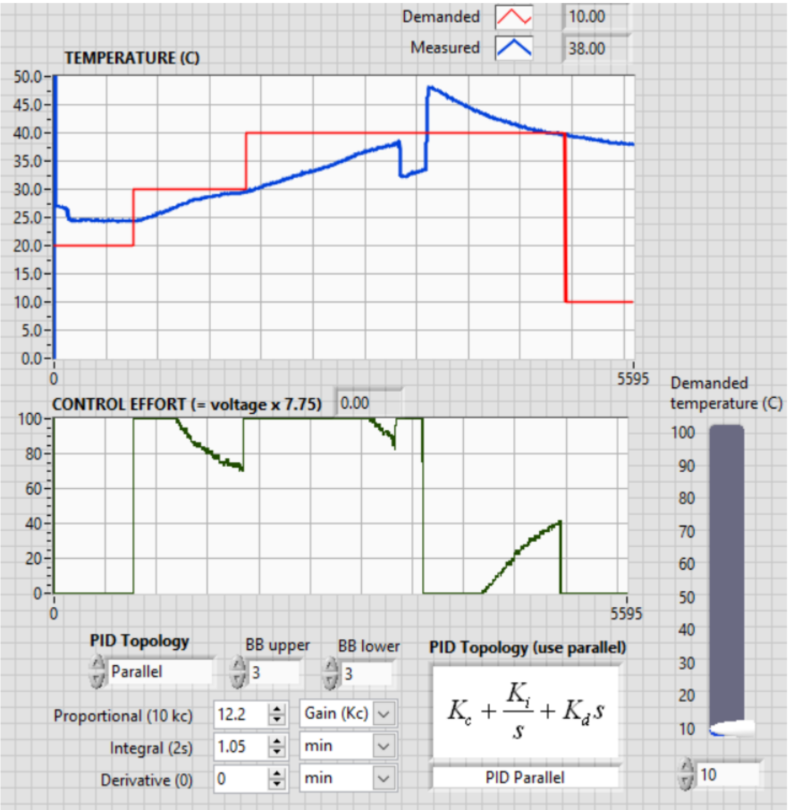


Material Heating

- **External heat source**
  - IR heating element allows for fast and safe heating of deposited tape

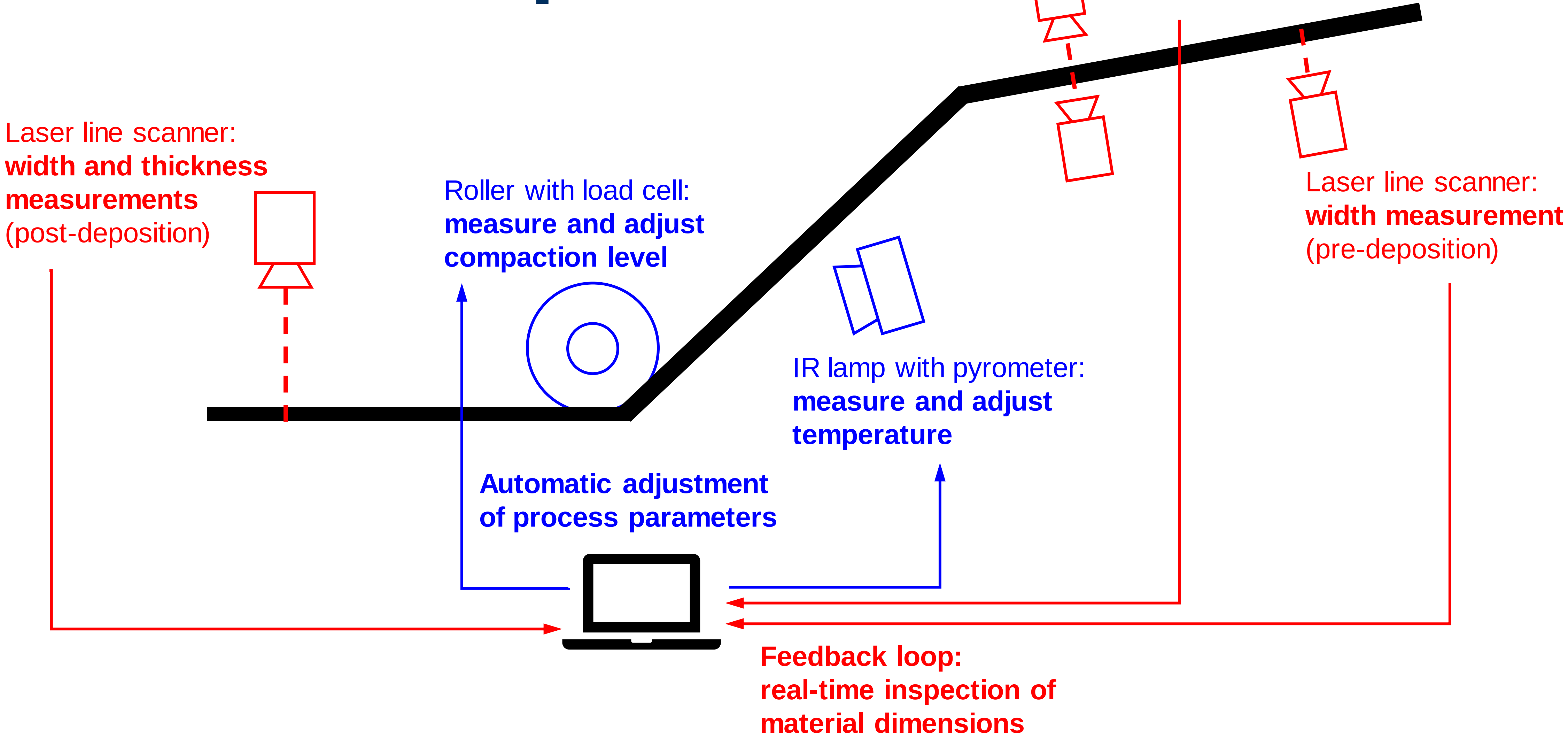
IR lamp heating up deposited tape

- **Real-time PID control of heat lamp power**
  - Developed temperature control using a PID controller
  - Manual or automated setpoint entry based on material measurements and models

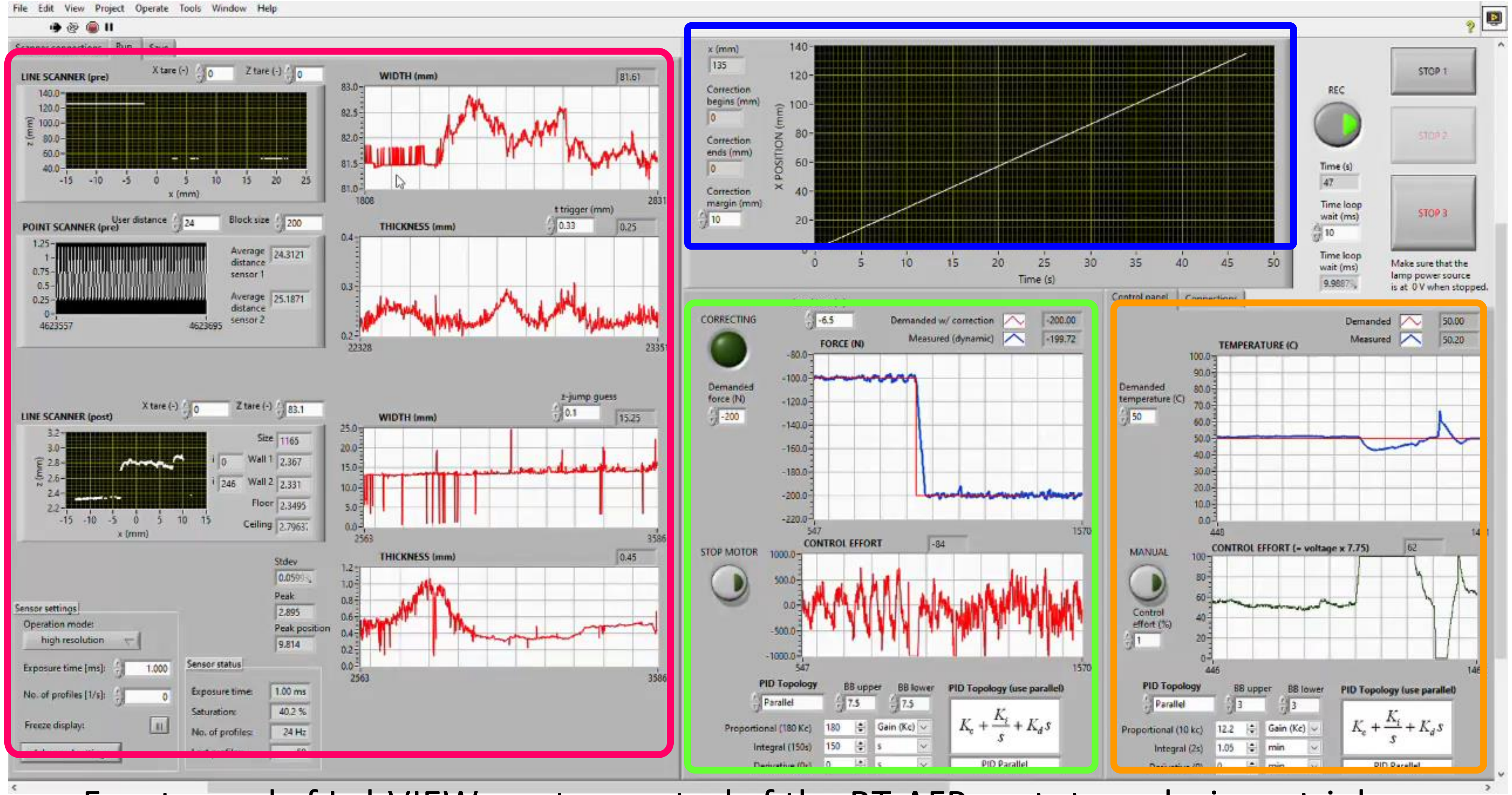


LabVIEW front panel of PID controller showing setpoint and measured values during trial run

RT-AFP Components



Master Control



Front panel of LabVIEW master control of the RT-AFP prototype during a trial run

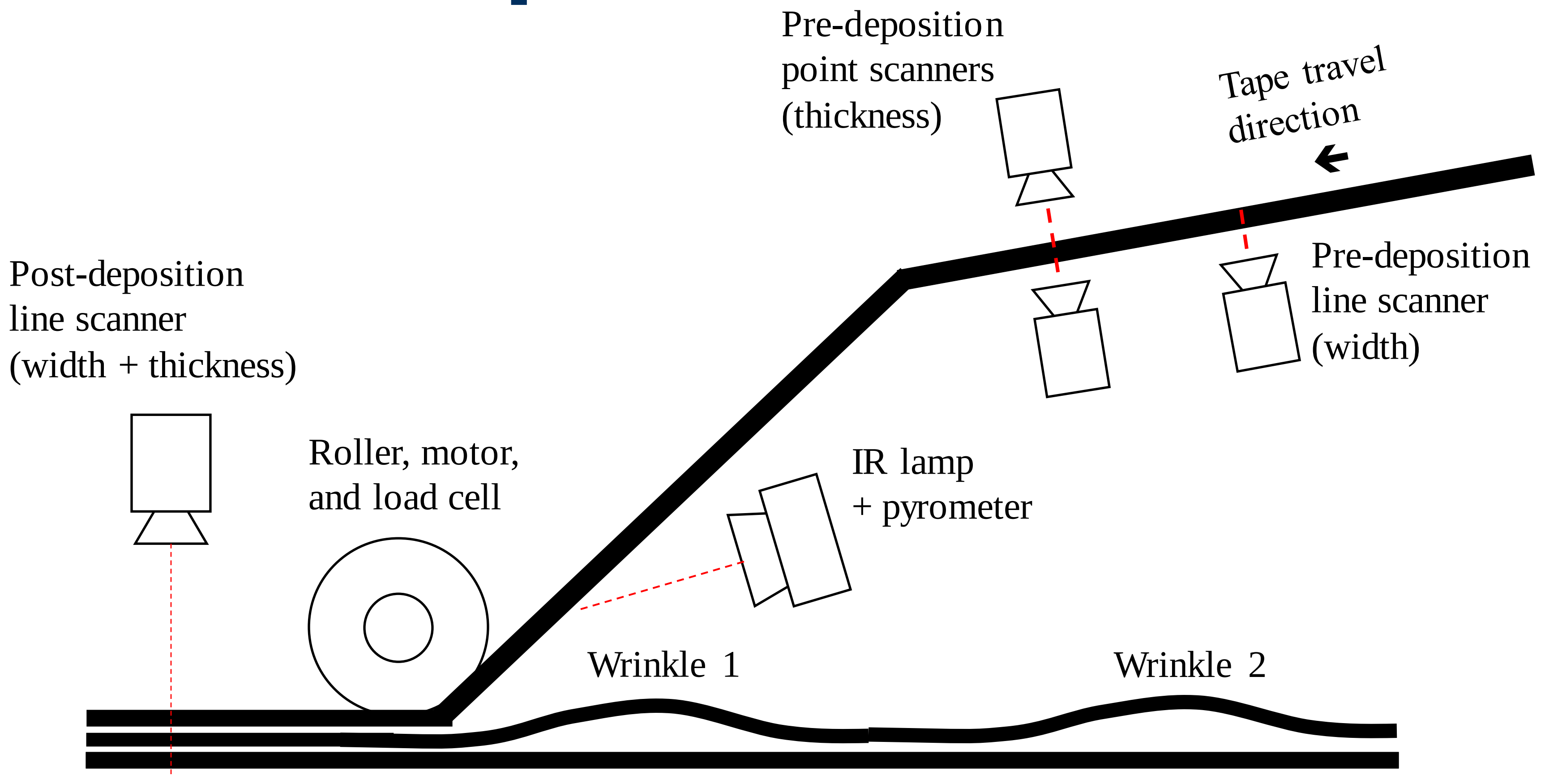
Material measurement

Encoder reading

Control of sensing compaction unit

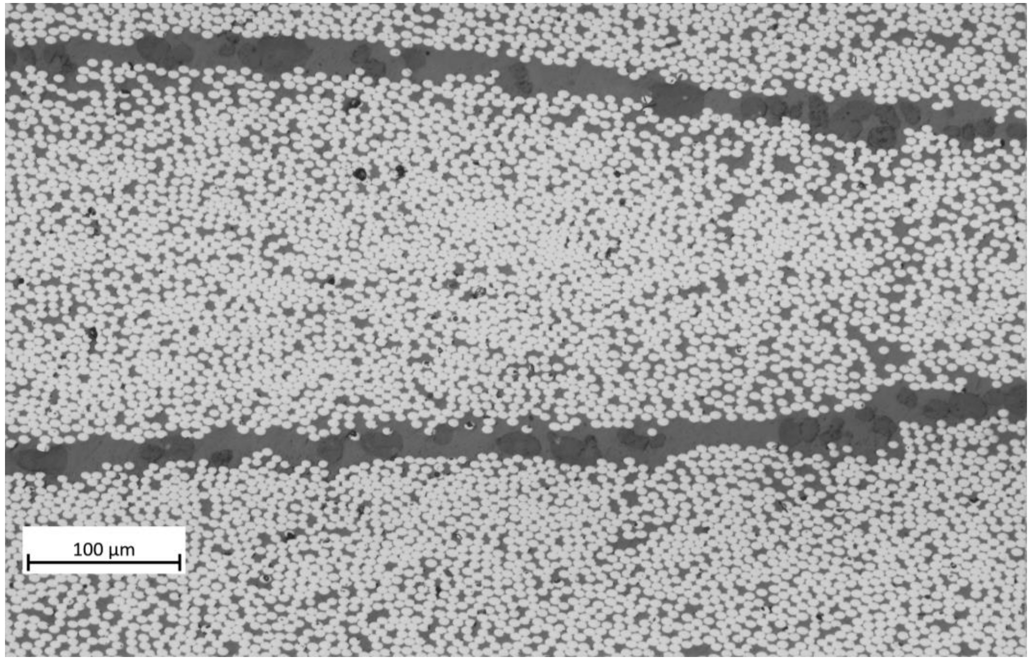
Control of material heating unit

Proof of Concept

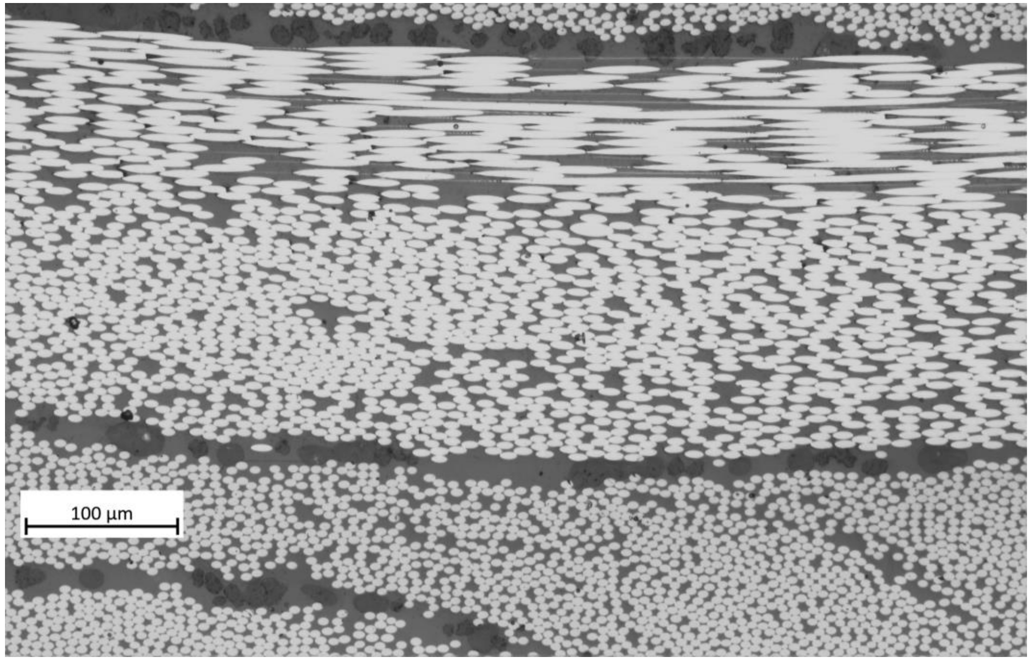


Micrographs

WITH CORRECTION
Uniform fibre orientation



NO CORRECTION
Out-of-plane wrinkle



Reduced strength
due to fibre misalignment

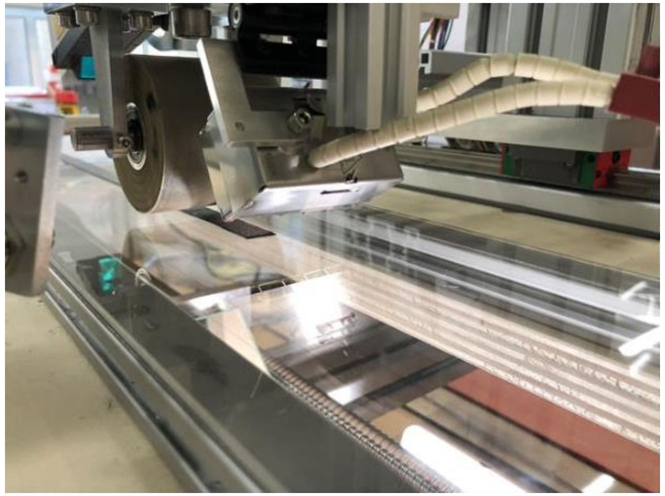
Nguyen, D.H., Sun, X.C., Tretiak, I., Valverde, M.A. and Kratz, J., 2023. Automatic process control of an automated fibre placement machine. *Composites Part A: Applied Science and Manufacturing*, *168*, p.107465.

Future Capabilities

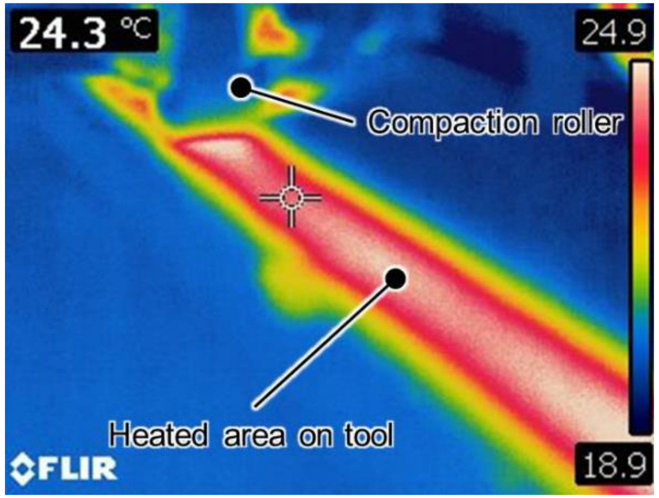
Heated tool

- Bespoke heated aluminium tool was designed to improve first deposition quality by embedded heating elements

- Heated glass tool, which allows for the material behaviour underneath the roller to be captured via the use of a camera



Deposition experiment at test completion



Thermal image glass tool heating up prior to test

Valverde MA, Sun R, Tretiak I, Nguyen D, Kratz J. The Effect of Process Parameters on First Ply Deposition in Automated Fibre Placement. In PROCEEDINGS OF THE AMERICAN SOCIETY FOR COMPOSITES-THIRTY-SEVENTH TECHNICAL CONFERENCE 2022 Sep 21.

Future Developments

- Identification and classification of manufacturing defects using AI
- On-the-fly curing with ply thickness control
- Evaluation of the optimal process parameters for defect correction during manufacturing
- Developing new version of lab-scale AFP with tension control system
- Real-time Automated Fibre Placement control in 2.5D – steering capabilities

Acknowledgements

EPSRC (contract no. EP/S032533/1)

Industrial partners

Hexcel

National Composites Centre

Rolls-Royce

University of BRISTOL
Bristol Composites Institute

Thank You!

iryna.tretiak@bristol.ac.uk

Project PI: James Kratz
james.kratz@bristol.ac.uk