NATIONAL COMPOSITES CENTRE

Numerical Process Simulation of Ultra High-Rate Ply Deposition

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CATAPULT High Value Manufacturing

7 centres of innovation excellence across 17 locations

Matthew Hardman

Engineering Architect at the NCC

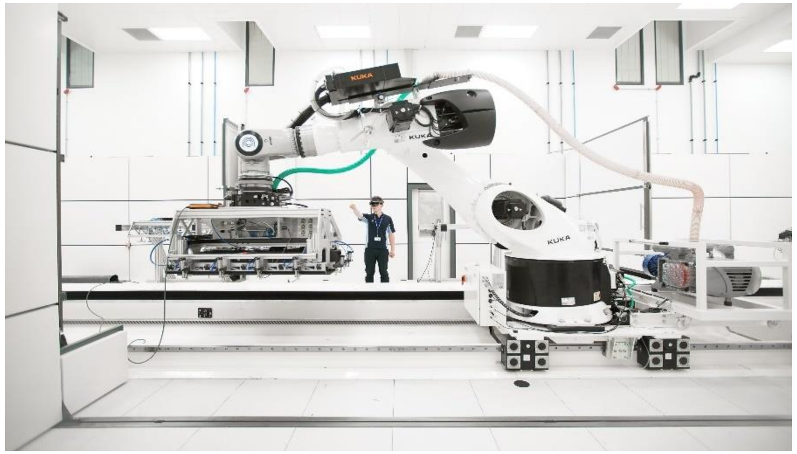
- Technical lead of the Composite Smart Industrial Control (CoSInC) project

Team lead for Automated Layup

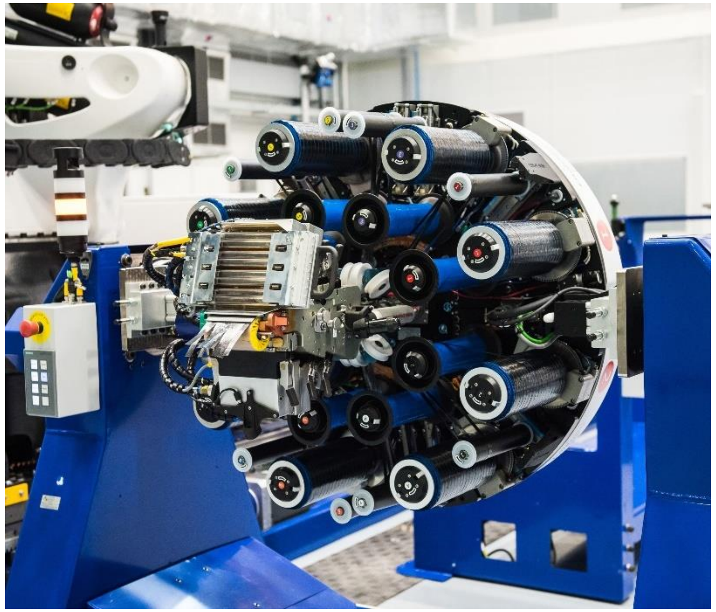
- Automated Fibre Placement,
- Filament Winding, and
- Non-Crimp Fabric deposition

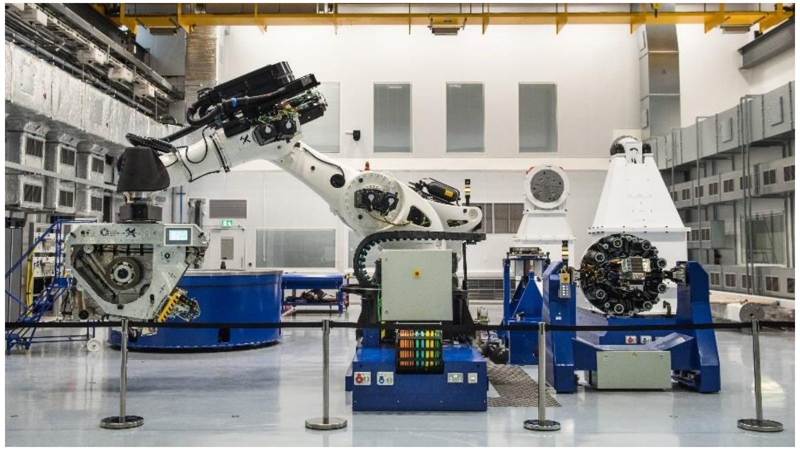
Recent work on

- Ceramic Matrix Composites for high temperature applications,
- Hydrogen storage and delivery,
- Standardisation of AFP process characterisation.



NCC - Europe’s leading composite innovation capability





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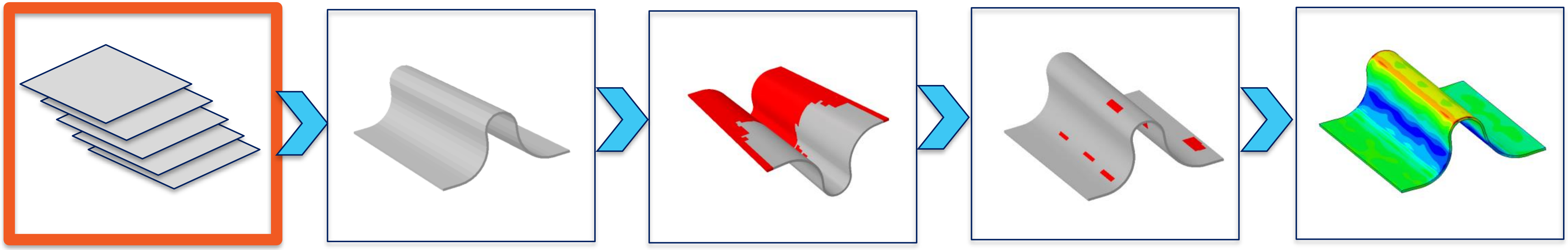
Composite Smart Industrial Control (CoSInC) Overview



Deposition | Forming | Infusion & Cure | Defect Mapping | Virtual Testing

CoSinC is developing manufacturing processes for composites for Aerostructures, by

1. Developing the equipment & processes for deposition, infusion, and cure
2. Delivering validated process simulations:
   a) **Deposition** and forming of dry-fibre Non-Crimp Fabrics
   b) Infusion & Cure
   c) Virtual Testing): As-manufactured mechanical performance, smart DFM & virtual testing
3. Defect mapping: Understanding effect of defects, automatic defect detection and concessions management
4. Virtual Testing: Understanding damage mechanism and mechanical knockdown

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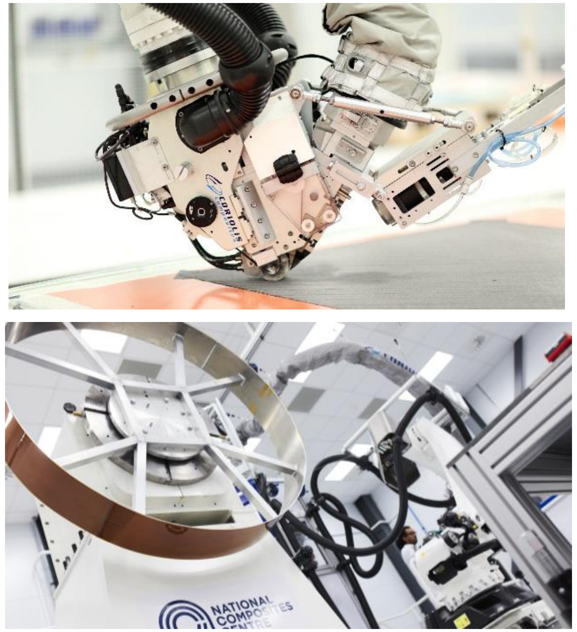
NCC Automated Layup Overview

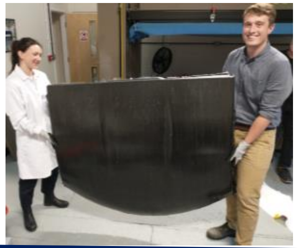
Ultra High-Rate Deposition Cell (UHRDC) - Pilotline

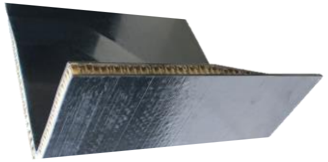
Electroimpact AFP + ATL



Coriolis AFP + FW

Accudyne AFP



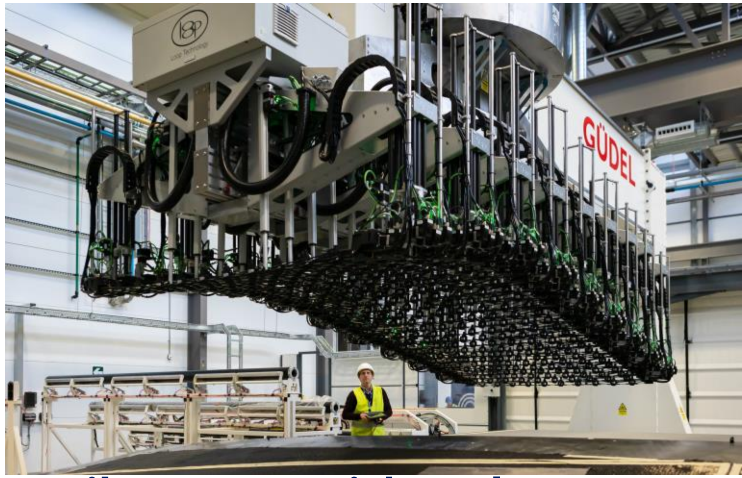


Ultra High Rate Deposition Cell (UHRDC) Overview

- Large working volume: 20 x 5 x 1.8m
- Dry Fabrics and UD tape to 360Kg/hr

- Four independent deposition systems capable of laying over 2D/3D surfaces
  - FibreFORM pick & place
  - 2x fibreROLL roll-up roll-out
  - 1.5” Dry Fibre Placement
  - Ultrasonic knife, kitting system
- Applications:
  - Large Aero structures
  - Process trials for Aero, Energy, and Construction

Ultra-High-Rate deposition cell



FibreFORM (pick & place)


FibreROLL (roll-in roll-out)

Dry fibre placement

bullmer
TRANSLAY TL
Loop Technology

Smart Deposition Simulation: Objectives

- **Support process & equipment development to reach production readiness**

Design for manufacture

- Define cut ply shapes
- Investigation of new parts or modifications to process
- Input to tooling definition

Manufacturing Process Development

- Simulating & shadowing key interactions of FibreROLL system
- Capture key process variables and their impact to accuracy
- Parametric and sensitivity studies

Manufacturing programming optimisation

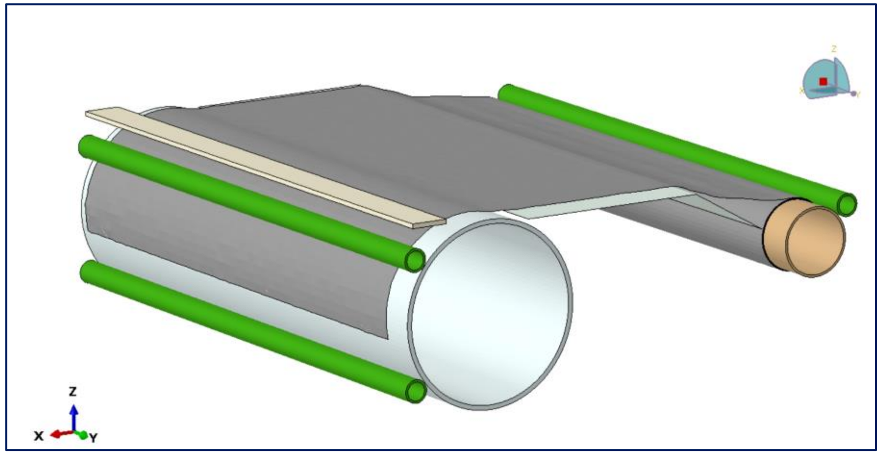
- Overcome programming limitation on path design
- Help to define programming strategy for processing complex ply

FibreROLL Modelling – Input

A Digital Shadow: one-way data flow from machine to process simulations

BECKHOFF TwinCAT

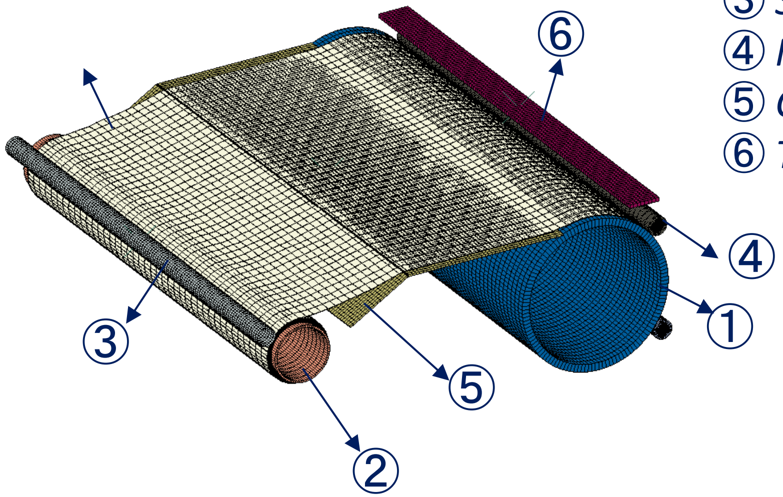
Manufacturing process data → Lightweight & aligned data → *Automated process* → Abaqus Model and boundary conditions



FibreROLL Modelling – Modelling techniques

FibreROLL Modelling

Ply Modelling

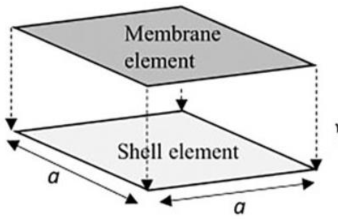


① *Main roller*
② *Storage roller*
③ *Storage pinch roller*
④ *Main pinch rollers*
⑤ *Central tray*
⑥ *Transfer stage*

- Machine parts were modelled with rigid material property
- Rollers and transfer stage were given boundary conditions derived from manufacturing data

Ply Modelling

- User-defined material model using collapsed membrane and shell elements
- Pressure load acting on shell/membrane elements to simulate vacuum cups
- Density and modulus was scaled to reduce computational cost, and hanging pear loop model was used to calibrate modulus and weight



Simulation

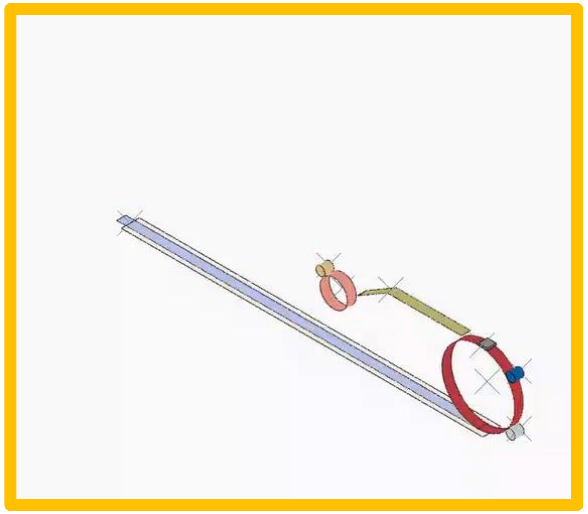
Trial

FibreROLL Modelling – Modelling Strategy

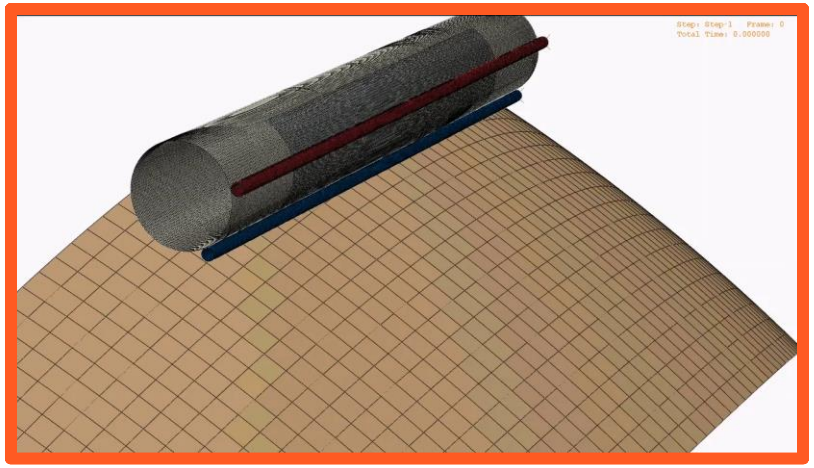
Verification Model
- Feasibility
- Cost
- Data required
- Scalability

Full-size Model
- Bridge gaps between verification model and full model
- Parts are in full size
- Develop script for automated model set-up and results extraction

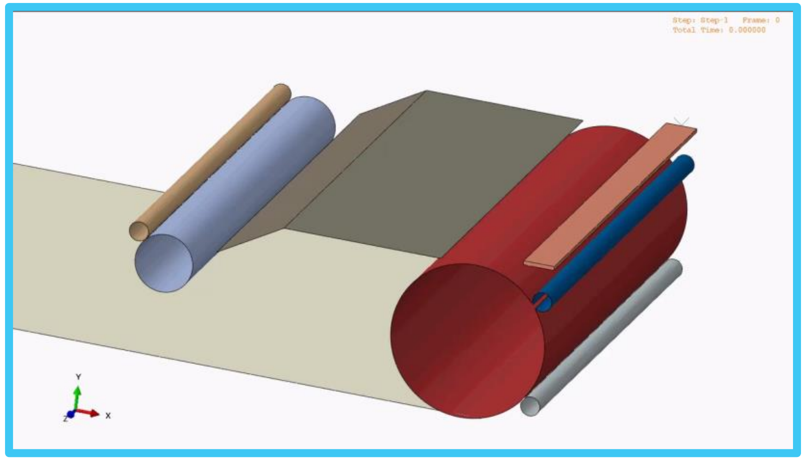
Purpose-built Model



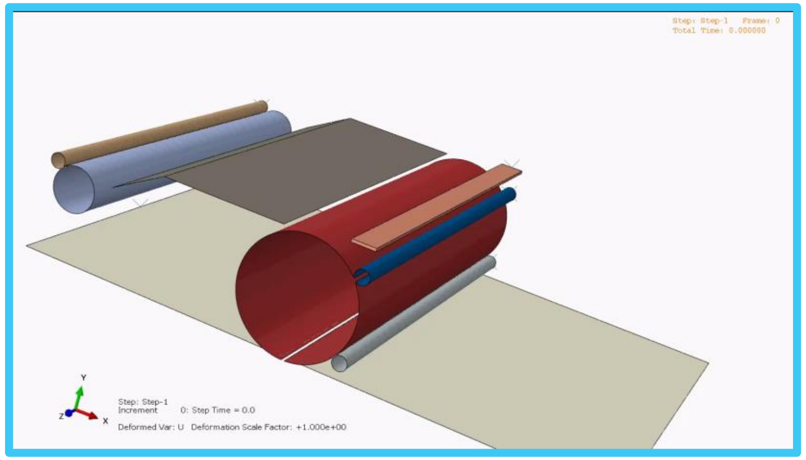
Verification Model (Picking)



Simplified Model



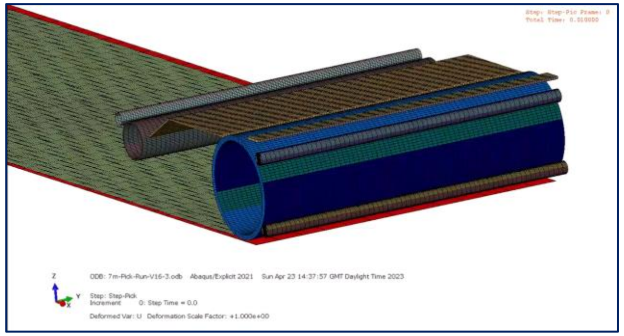
FibreROLL Picking Process ('Dry Run')



FibreROLL Placing Process ('Dry Run')

FibreROLL Modelling – Results

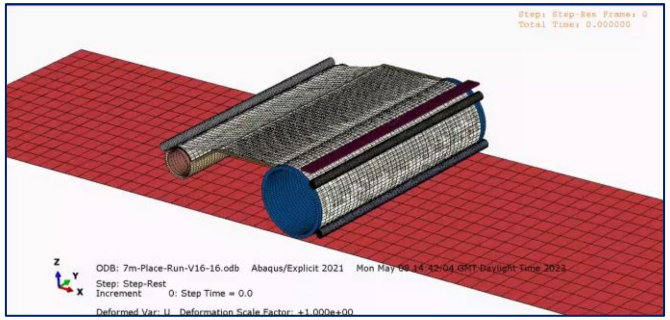
Pick rectangular ply (7 x 1.2 m)



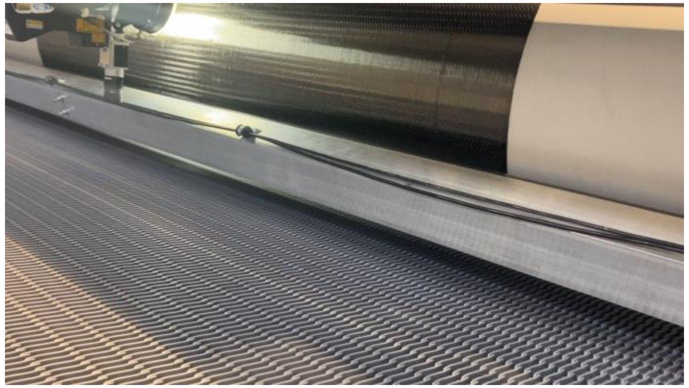
Simulation

Trial

Placing rectangular ply (7 x 1.2 m)

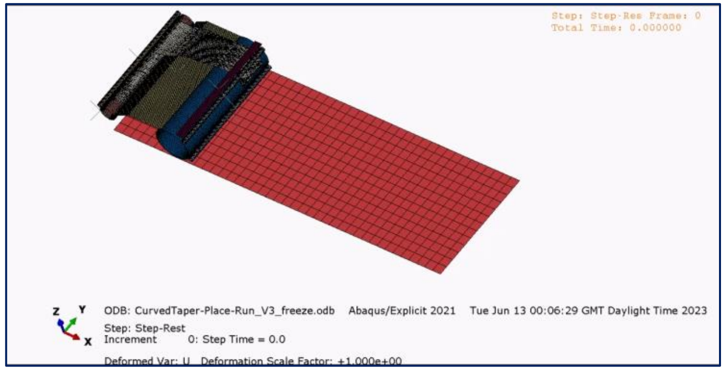


Simulation

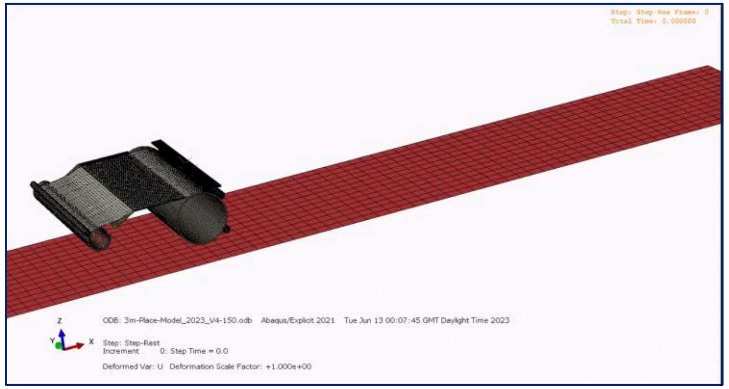


Trial

Placing curve tapered ply (3 x 1.2 m)



Placing over height (150 mm)



FibreROLL Modelling – Summary

- **Process modelling framework** for FibreROLL was developed
- With validated material models, **material deformation and defect formation** during manufacturing process can be captured and reduced
- Process model **integrated with true manufacturing data** shows significant importance when predicting accuracy of ply deposition
- Critical element of **smart process simulation** network where results of deposition simulation can be fed into forming, infusion/curing and virtual testing

Any Questions?

Thanks to our partners

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Thanks to our funding body and customer

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