MODELLING AND SIMULATION OF REINFORCED TAPES BEHAVIOUR FOR FORMING PROCESSES

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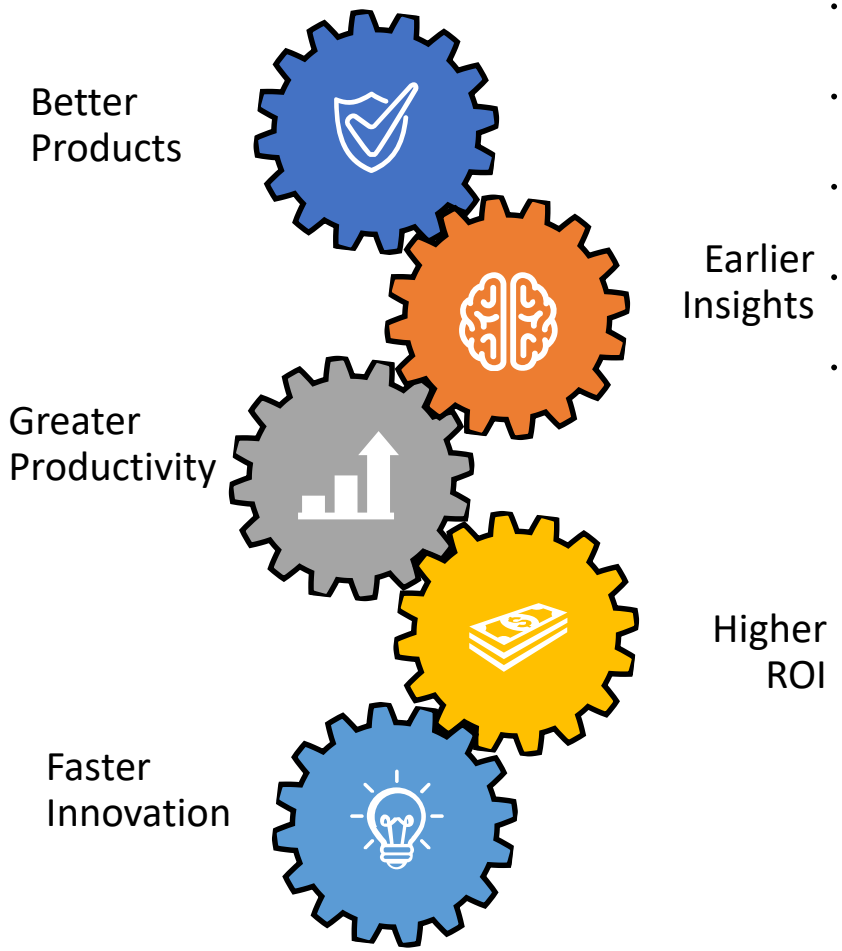
Why we Simulate?

- Modelling of near net shape 2D tape laminates.
- Definition of boundary conditions and process parameters for forming process.

Reduces need for physical prototypes

Reduces costs

Speeds up development process



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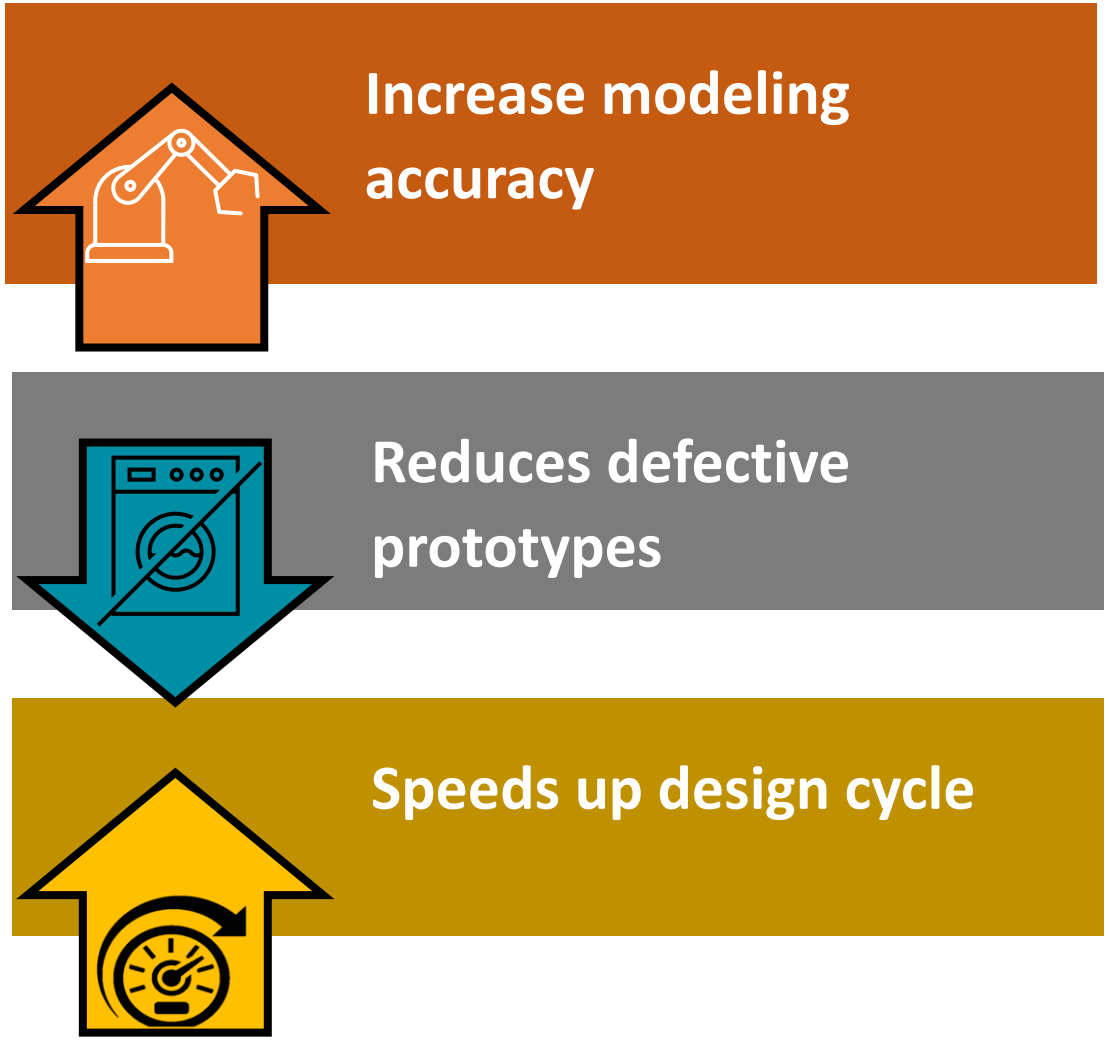
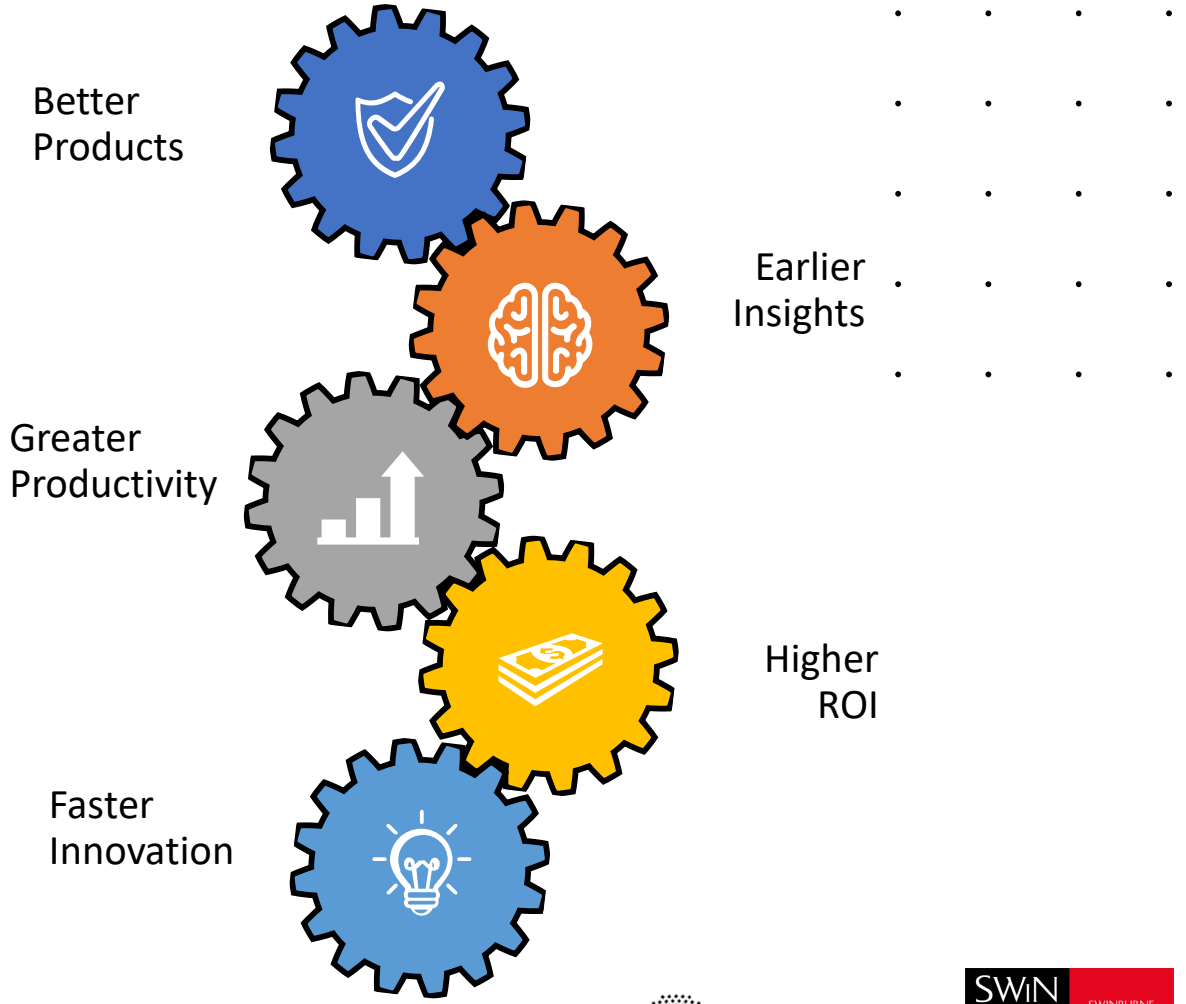
Why we Test it Physically?

- Simulation without a test can lead to some model inaccuracies.
- Performing analyses at the physical level can be relatively simple.





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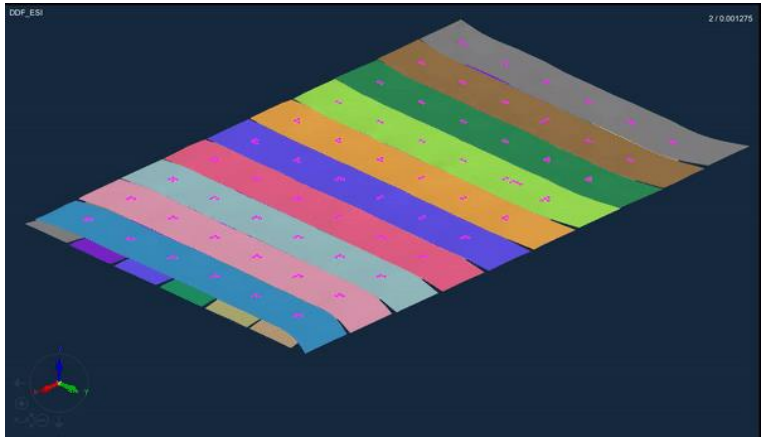
Content

- Research Overview
- Modelling of Tapes
- Simulation of Tapes
- Validation of the Model
- Analysis and Discussion
- Conclusion

Overview

– Modelling and simulation of reinforced tape laminates can aid in supporting the early phase development of defect free formed part.

Forming Simulation for Carbon Fibre Reinforced Tape Laminates

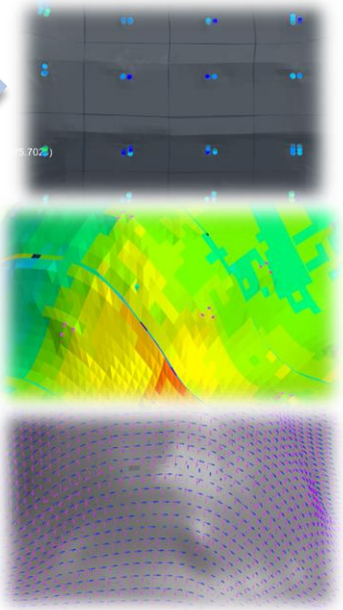


Double Diaphragm Forming Simulation

Forming Experiment for Carbon Fibre Reinforced Tape Laminate

Double Diaphragm Forming Process

Analysis of Tapes behaviour during forming process



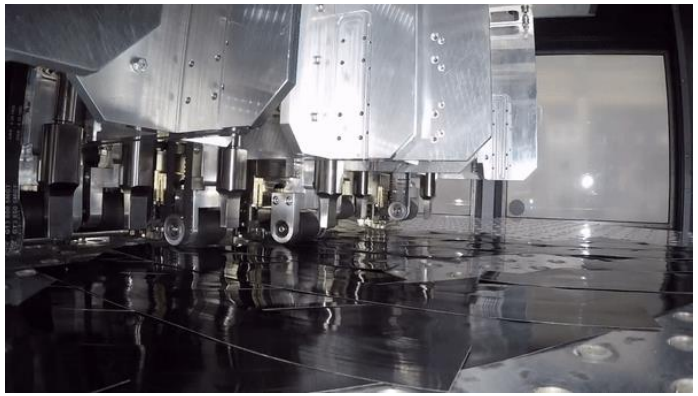
Shear force – Spotweld
Spotweld impact on the forming behaviour

Shear & Fibre Angle
Shear and fibre angle to observe formability

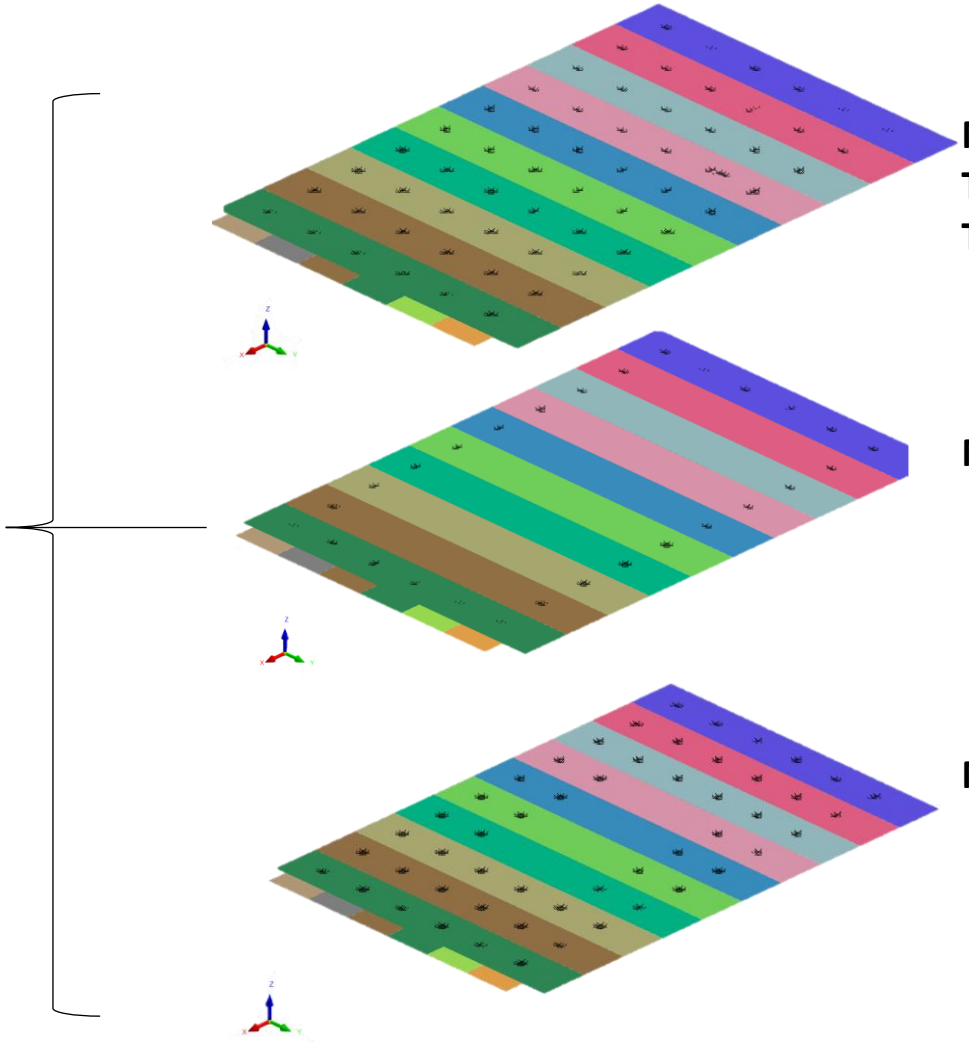
Fibre orientation
Fibre direction depending on the material type

Modelling of Tapes

- Modelling of tapes is according to the Multilayer
- Modelling of spotwelds as per the standards of Multilayer such as the diameters of the spotweld



Multilayer

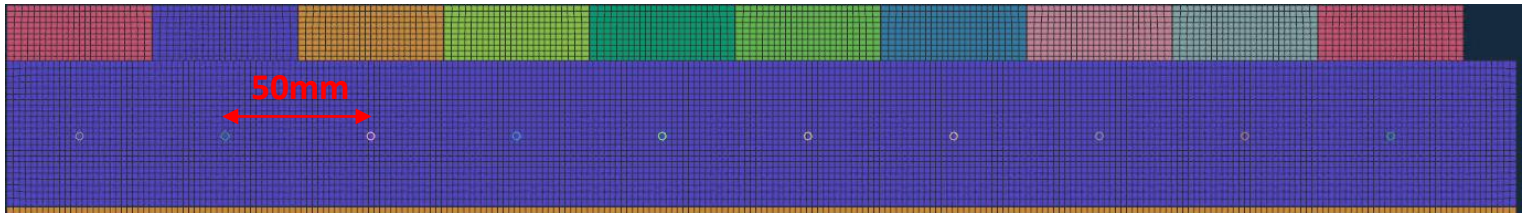


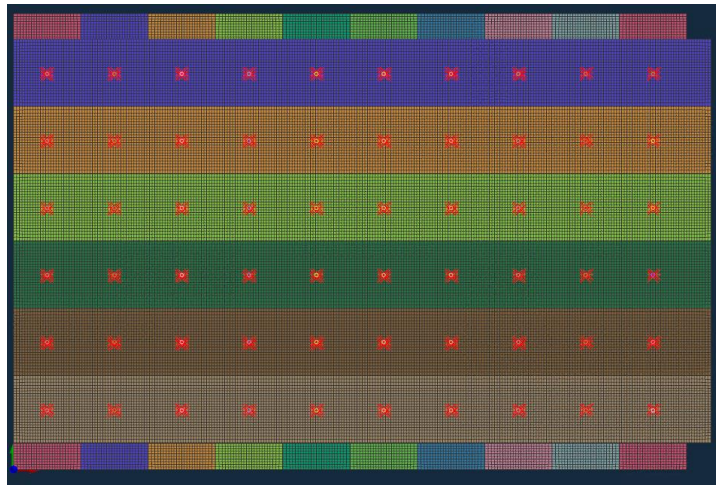
No. of Spotweld: 60
Tape Size: 50 x 300 mm (Qty: 10)
Tape Size: 50 x 500 mm (Qty: 6)

No. of Spotweld: 28

No. of Spotweld: 52

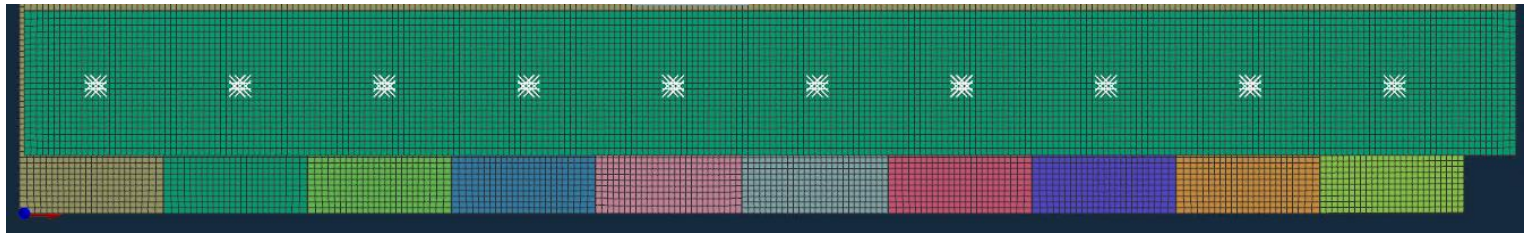
Modelling of Spotwells

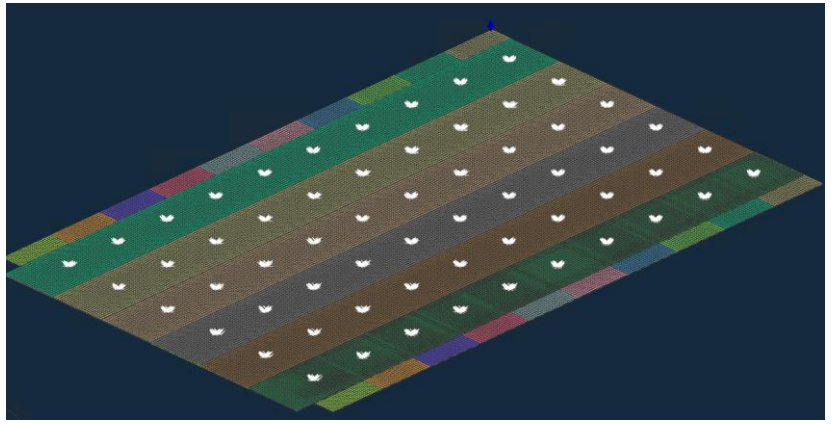




Welding Spots Selected at a uniform Distance

- Multilayer: Welding is done tape by tape for each layer (tape).
- Visual Form: Welding points are selected tape by tape (layer by layer) replicated as Multilayer.





Simulation of Tapes

At Temperature 150°C

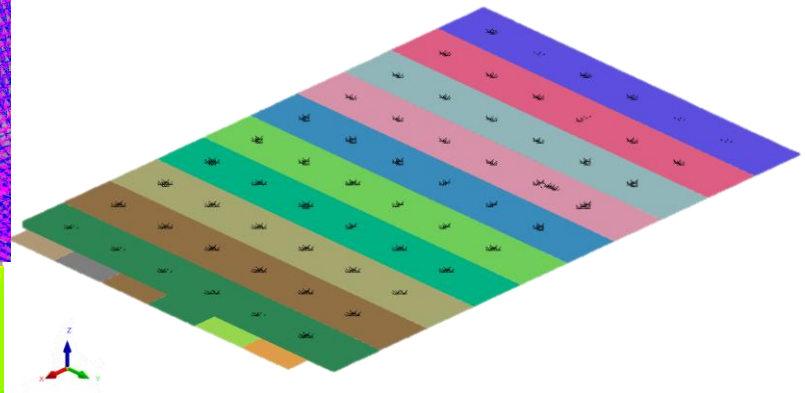
At Temperature 170°C

Shear Angle

Fibre Orientation

Fibre Angle

Shear force – Spotweld



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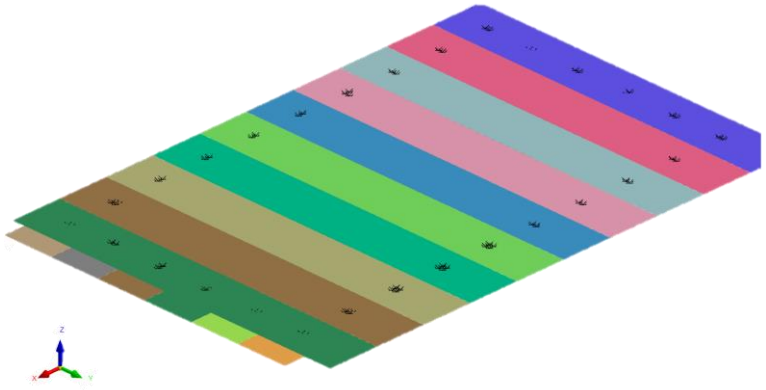

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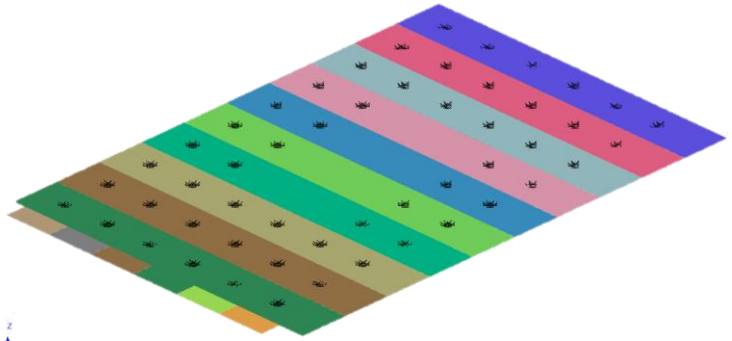

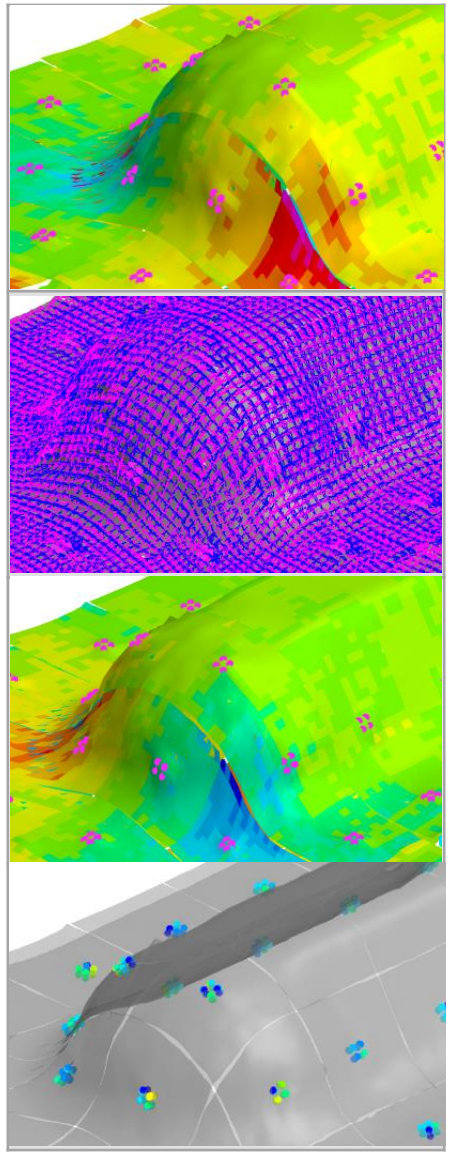

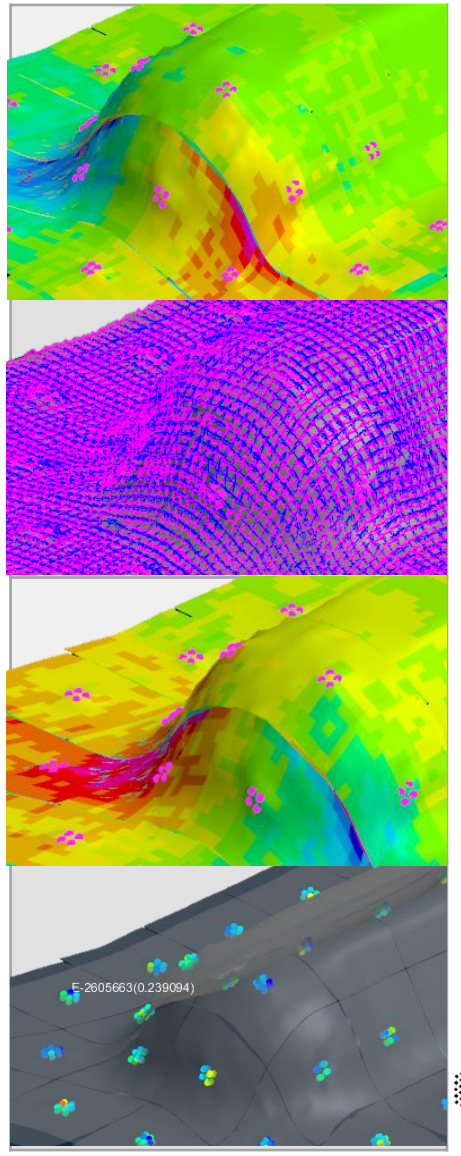

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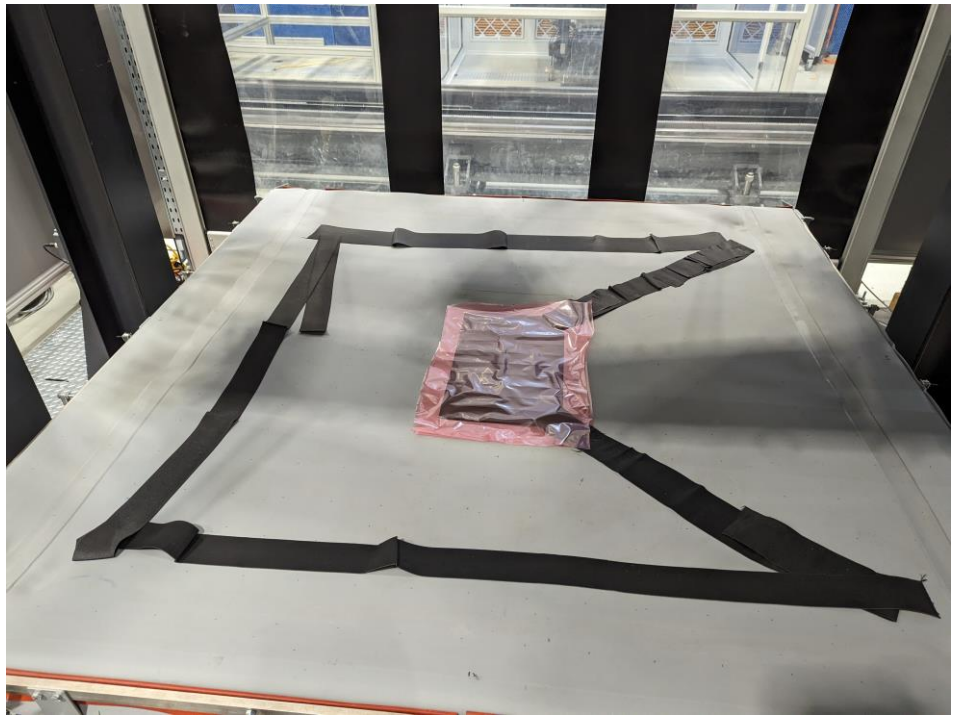
Experimental Setup

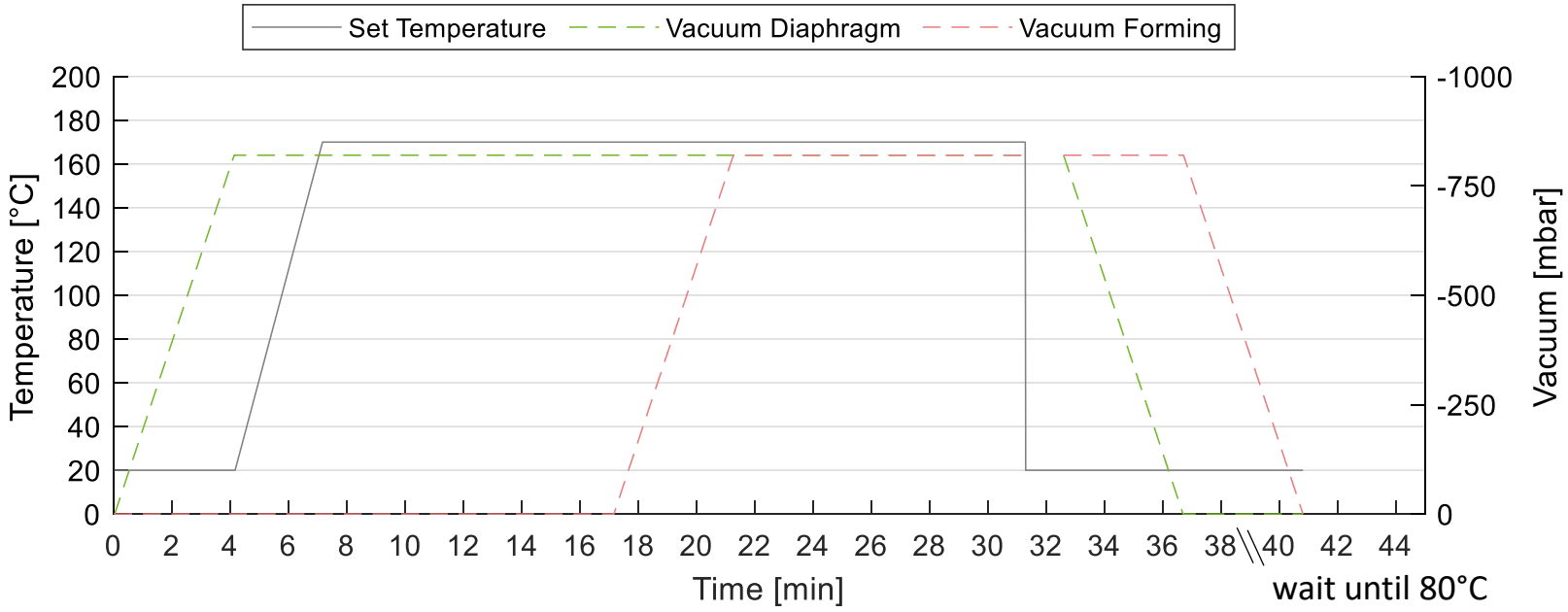
Preheat tool to roughly 70-80°C (only guess, real tool temperature unknown)

- Tool preheated to 70-80°C
- Layup between two vacuum foils to minimise thermoplastic residue on diaphragm
- Set temperature 150°C and 170°C (2 repetitions each)



Experimental Setup

- Place preform between vacuum foil and than between membranes
- Pull Vacuum between Membranes (250mbar/min to –820mbar)
- After reaching vacuum: Turn on IR heaters and preheat preform for 10mins
- Turn on forming vacuum (between lower membrane and tool) (250mbar/min to –820mbar)
- After reaching vacuum: Hold for 10min and turn off IR heaters, turn on fans and air extraction system.
- Let it cool down until 80°, turn off vacuum between membranes (250mbar/min) and take part out
- Turn off vacuum between lower membrane and tool /50mbar/min)



Validation of the Model

- Spotwelds has no significance on developing wrinkles in the actual experimental part.
- Spotwelds are modeled as a rigid body element, that is why it creates additional unwanted stress:

At Temperature 150°C

At Temperature 170°C

Validation of the Model

– Similarly, to the previous case, in simulation model, spotwelds creates unwanted stress that results in generating tape waviness.

At Temperature 150°C

At Temperature 170°C

Validation of the Model

– In this case the Spotwelds are optimised, that result in less formation of induced uncertainties during forming.

At Temperature 150°C

At Temperature 170°C

Analysis and Discussion

Vacuum pull:

- Real Vacuum pull between lower diaphragm and tool different to expected pull in important major forming region due to pump regulator problems
- It can also be seen in the simulation models, where the curve part of the double dome geometry is smooth during forming while the diaphragm changes the conditions.

Springback:

- Good forming behaviour overall
- High springback of the preform
- Possible reasons:
  non-symmetrical layup
  bridging leads to internal stressed built up which are partly released during cool down as explained during simulation model.

Additional Vacuum foil used:

- Silicon spray used on both Vacuum foil sheets facing the preform. This is to minimise sticking of the preform to the vacuum foil.
- The Vacuum foil is being used to minimise sticking of the preform to the diaphragm material, to protect the diaphragm from thermoplastic residue and minimise than change of mechanicaly damaging the diaphragms (by e.g. cutting into them)

Conclusion

At 170°C

- Similar forming results between all weld spot configurations during experiments
- Main defects wrinkles caused by diaphragm and spotwelds in 2 configurations
- Slight flow of matrix, got adhesion between tapes
  Still: Probably higher temperature (and pressure?) necessary for full consolidation
- Weld spots still visible from outside in the simulation model

At 150°C

- Close to lowest possible temperature (tg at 140°C)
- Tapes stick only slighty together. Lift up and sometimes space between tapes visible
- Weld spots still visible from outside and between tapes (When tapes are being pulled apart (if sticking together), weld spots are still clearly connected)
- Forming Quality generally worse than with 170°C (e.g. wrinkles on top side of Doube Dome)
- No major difference between weld spot configurations. (Slightly different wrinkles on side of double dome.
  Might require more detailed analysis to find differences in results.

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Thank you

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