

## TPRC Overmolding

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# AGENDA

## TPRC - Overmolding

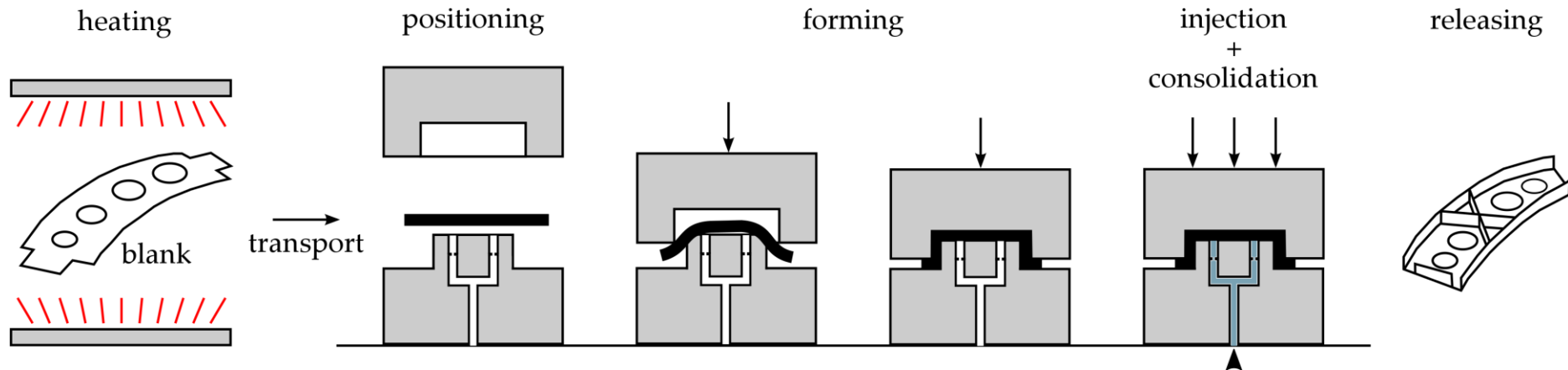
- Introduction
- COMPeTE I project
  - Interface strength
    - Scoping study on structural analysis
  - Warpage behavior
  - Demonstrator manufacturing
- Conclusion & outlook

# OVERMOLDING

## Process overview

### Overmolding = stamp forming + injection molding

- Net shape manufacturing
- Integration of reinforcing ribs/functionality



One-step process: *forming and injection molding combined*

Two-step process: *forming and injection molding separated*

# OVERMOLDING

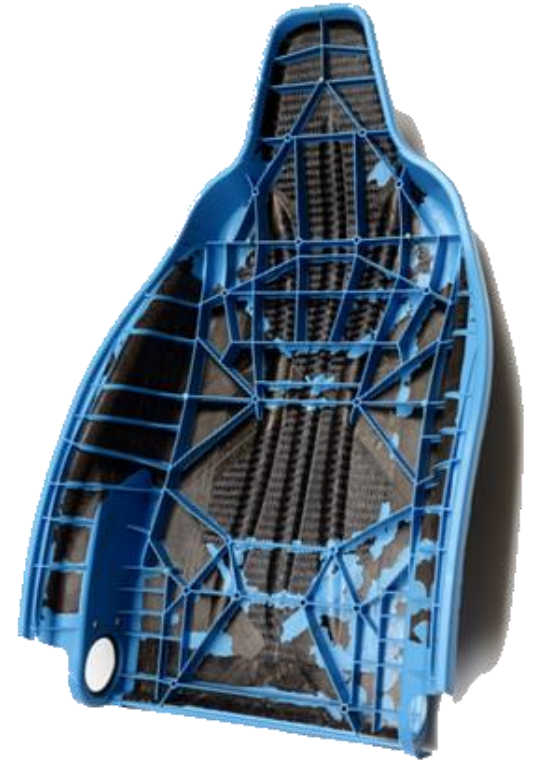
## TPRC – COMPeTE Overmolding

### Challenges for overmolding

- Interface strength
  - Between injected polymer and composite laminate
- Shape distortions
  - Injected polymer + stamp forming

### COMPeTE

- 2 year project (finished) funded by industry
- Develop models and simulation tools, provide guidelines
  - Interface strength & shape distortions



### Materials

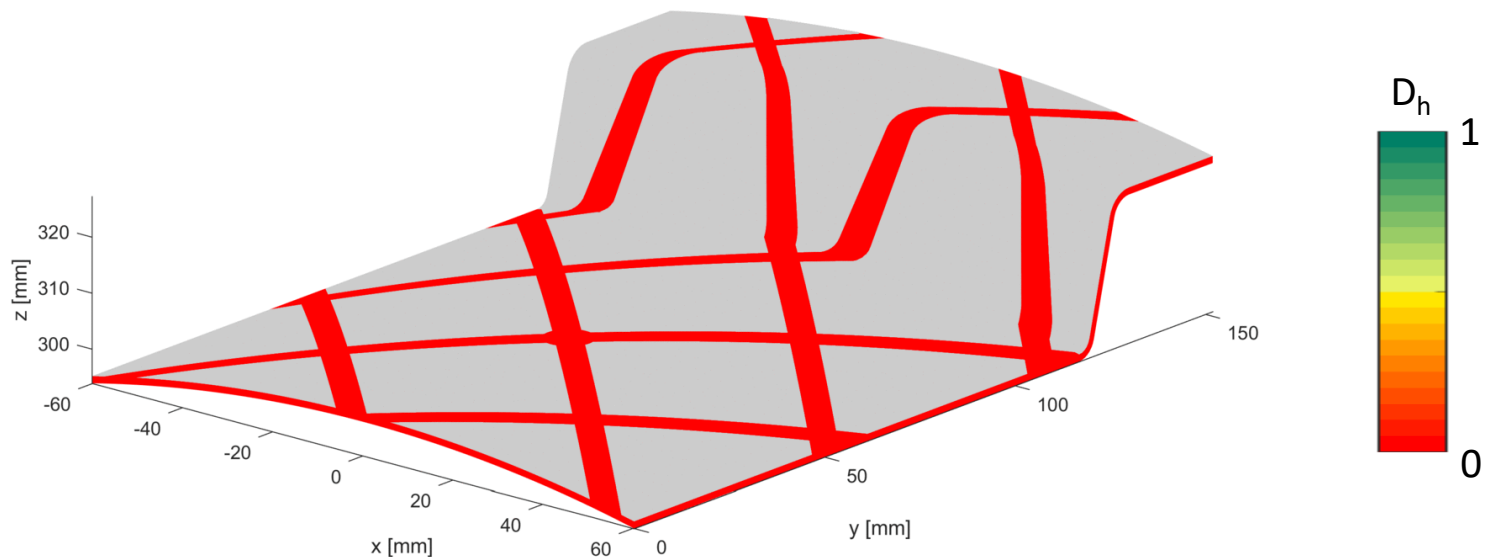
- PA6: BASF B3ZG6 overmolded on TenCate Cetex TC912
- PEEK: Victrex 90HMF40 overmolded on TenCate Cetex TC1225

# Interface strength

# INTERFACE STRENGTH

## Overview

- Develop simulation tool for predicting the interface strength
  - Autodesk Moldflow as basis for thermal simulation
  - Non-isothermal healing model (polymer inter-diffusion & melting behavior)
    - Degree of healing (dimensionless strength value)
    - Validated by using small research geometries



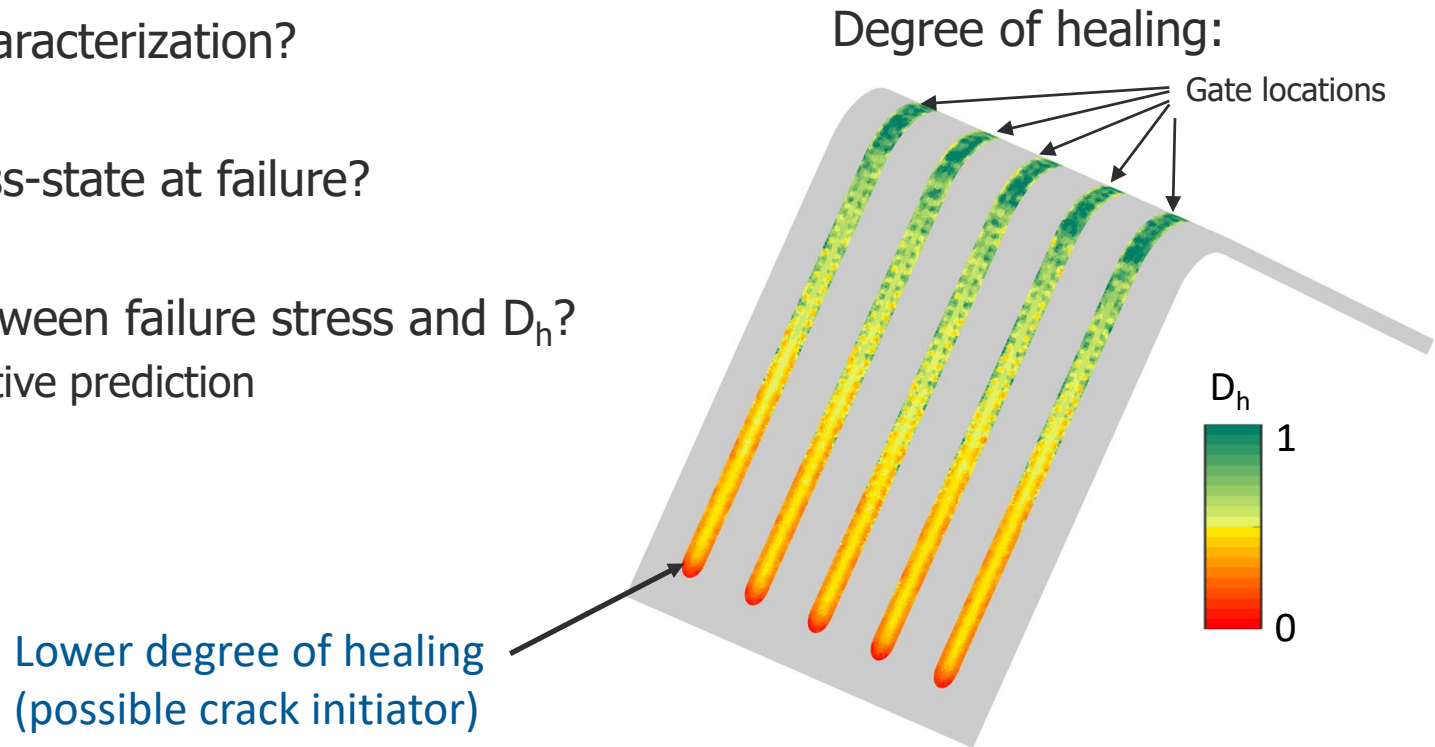
In general: higher temperature gives higher strength

# OVERMOLDING V-SHAPE

Overview – work of master student @ TPRC

## Structural performance

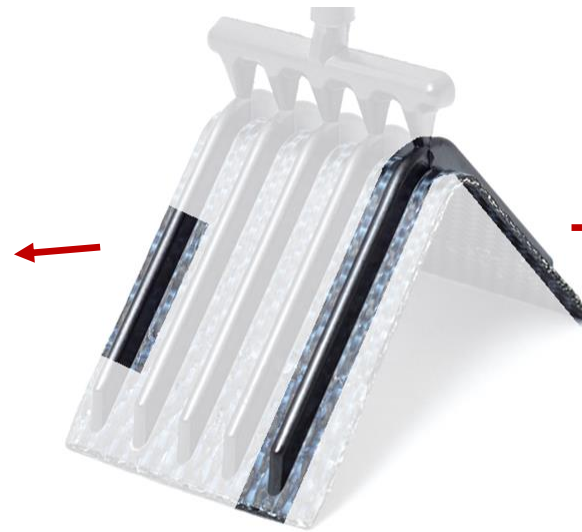
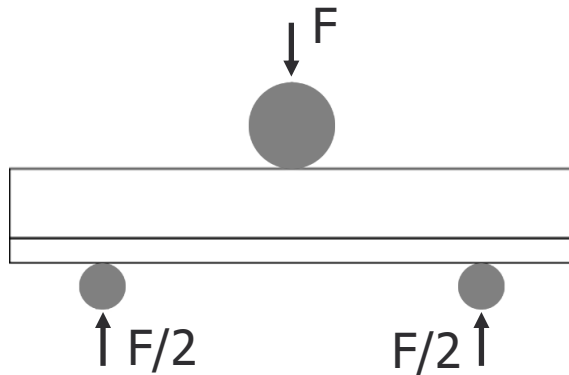
- Healing model (qualitative)
- Strength characterization?
- Critical stress-state at failure?
- Relation between failure stress and  $D_h$ ?
  - Quantitative prediction



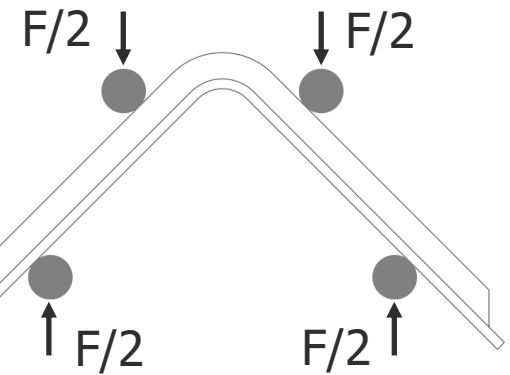
# STRENGTH CHARACTERIZATION

Test methods and failure modes

SBS of a single rib section



4PB of a single rib



Higher strength →

Debonding at the interface followed by rib cracking  
(verified with high speed cam @ 225,000 fps)

Interface and rib failure

(c) Insert and rib failure



# PREDICTING FAILURE

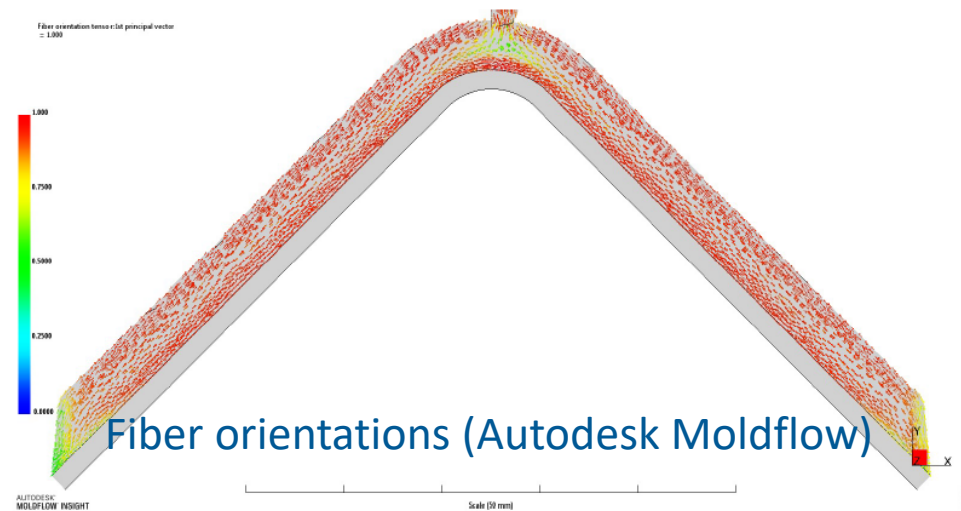
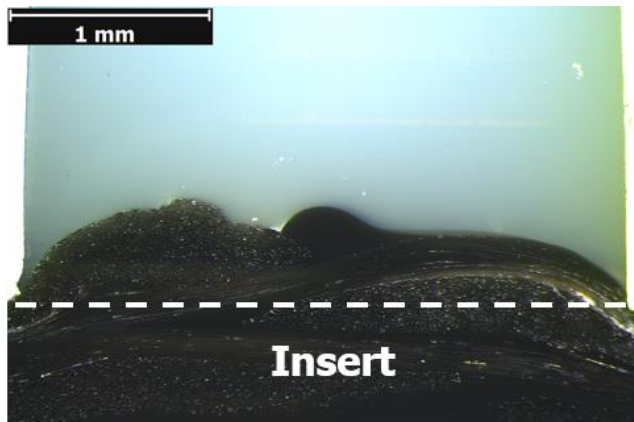
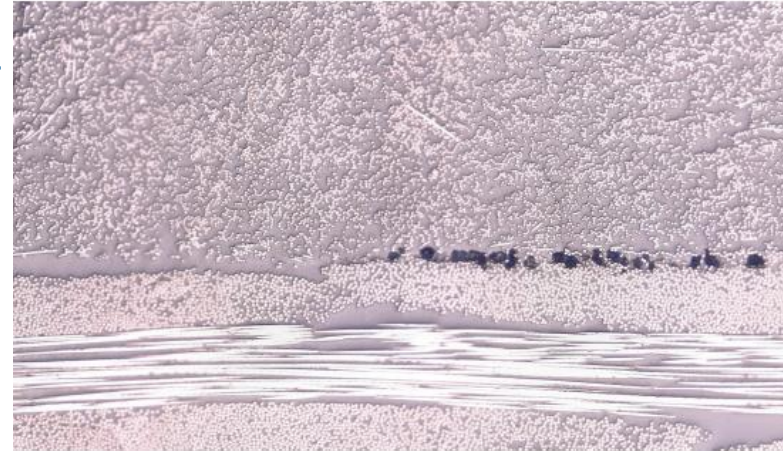
## FEM analysis

### Stress modelling

- Non-homogenous material properties
  - Stress discontinuity at the interface
  - Properties of matrix interface layer
  - Interface 'defects'
  - Fiber orientations

Short fiber  
reinforced  
polymer

Laminate

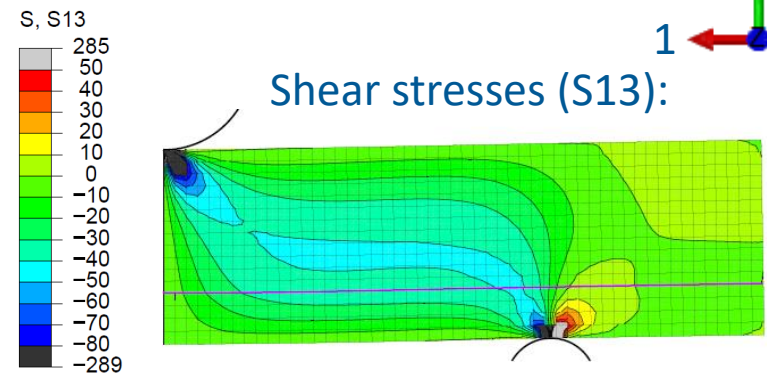
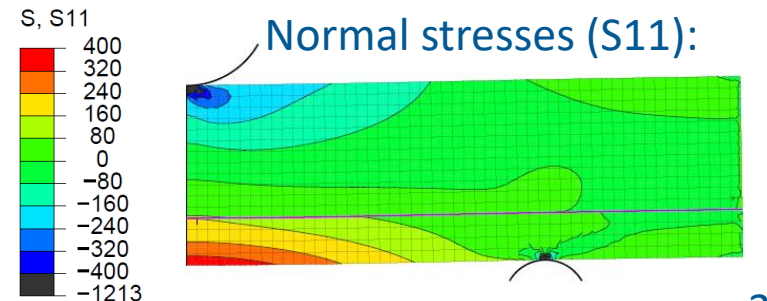
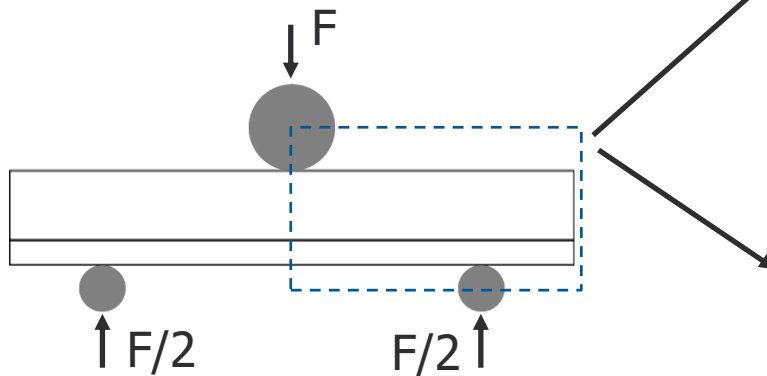


# PREDICTING FAILURE

## FEM analysis

### Stress evaluation

- No pure tensile/compression/shear loading
  - 3D stress state
  - Failure criterion, i.e. Tsai-Hill?



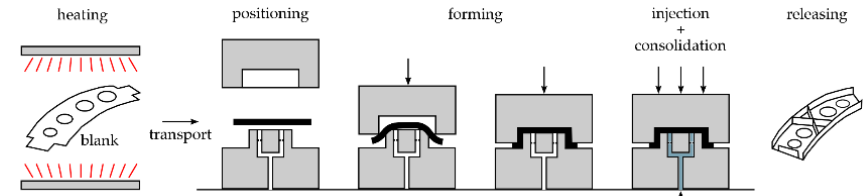
### Ultimate failure strength

- The qualitative degree of healing can be used as a 'knock down' factor for the failure strength
  - A calibration is necessary to have a more quantitative prediction
  - Additional research is necessary → COMPeTE II

# Shape distortions

# SHAPE DISTORTIONS

## Overview



UD CF/PA-6 + PA-6  
cavity height = 4 mm  
laminate thickness = 0.15 mm



material non-symmetry

**warpage**

CTE mismatch

**spring-in**

through-thickness stress distribution

**warpage**

releasing

# SHAPE DISTORTIONS

## Approach

Coupling of software packages:

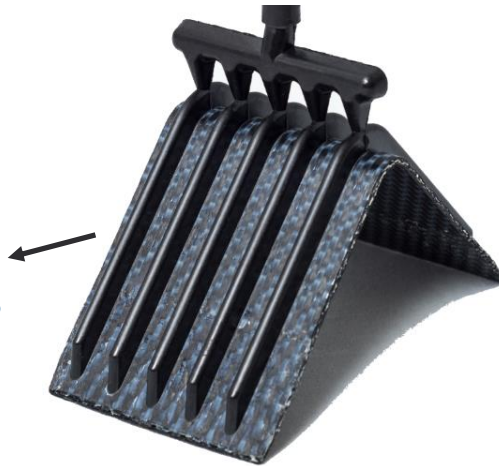


AUTODESK® MOLDFLOW® INSIGHT

Validation: Single curved geometry

Double curved geometry

Scoping study:  
Structural analysis



Demonstrator  
manufacturing

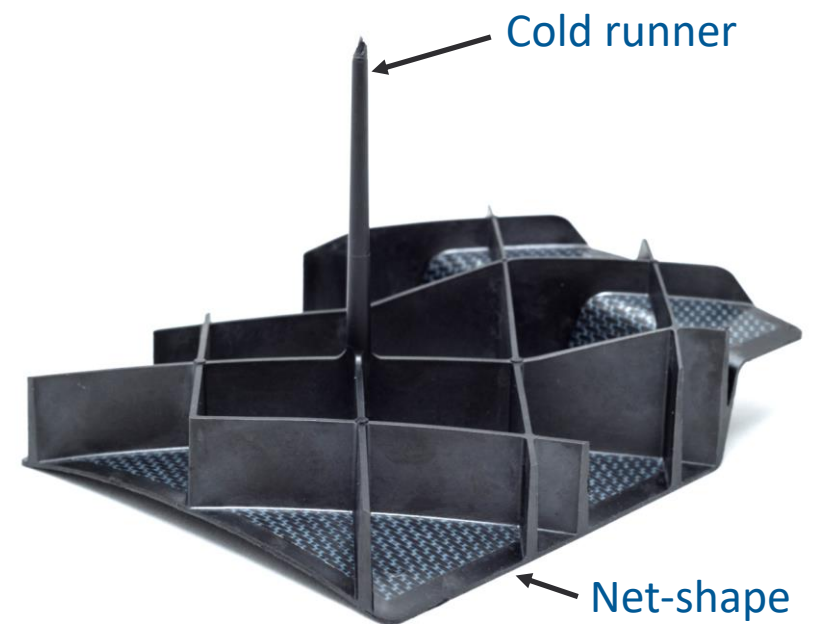
# **Demonstrator manufacturing**



# DEMONSTRATOR MANUFACTURING

## KraussMaffei Overmolding Cell

- Industrial injection molding machine suitable for C/PEEK
  - Equipped with KUKA Robot and Krelus IR oven



# DEMONSTRATOR MANUFACTURING

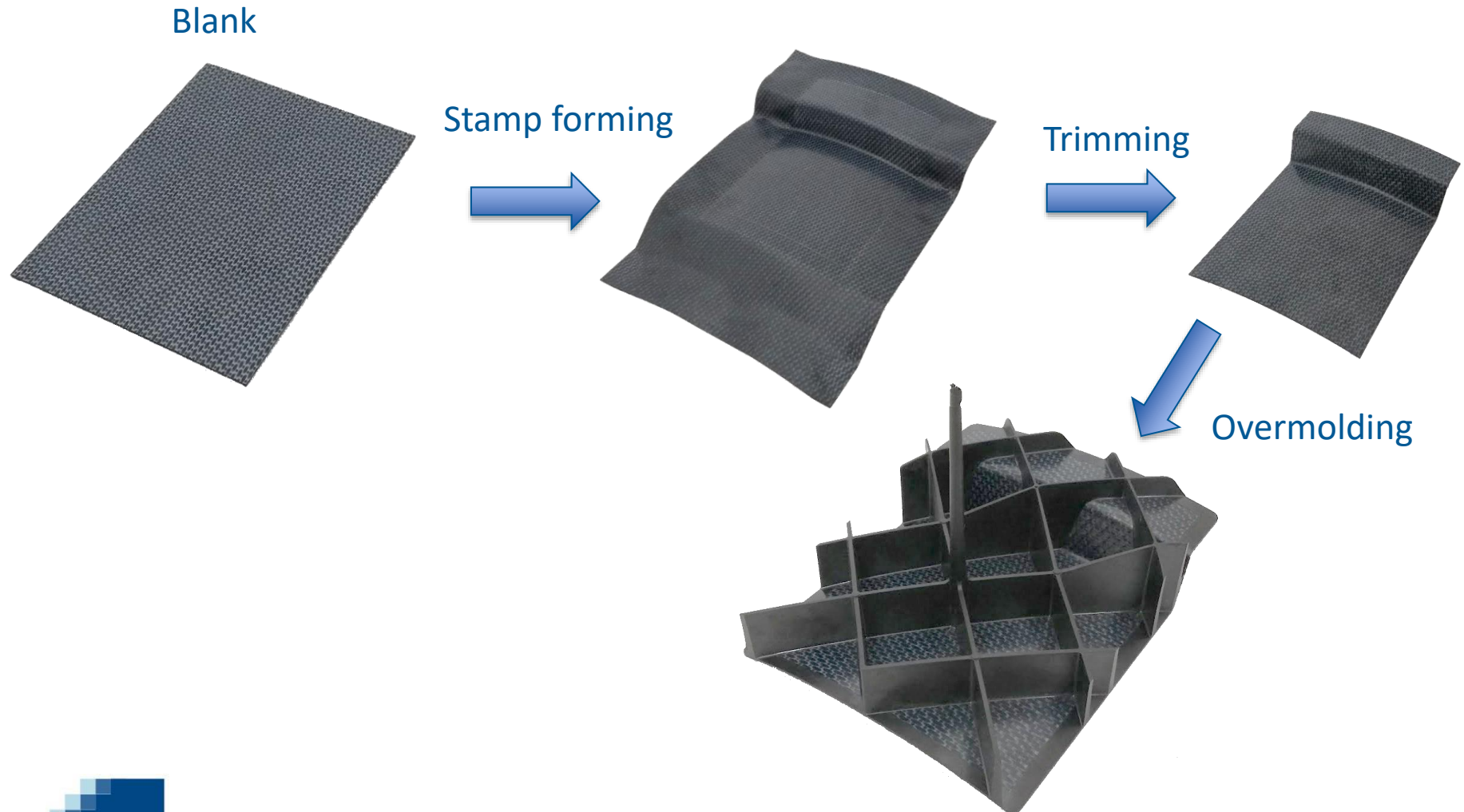
Video of one-step overmolding process





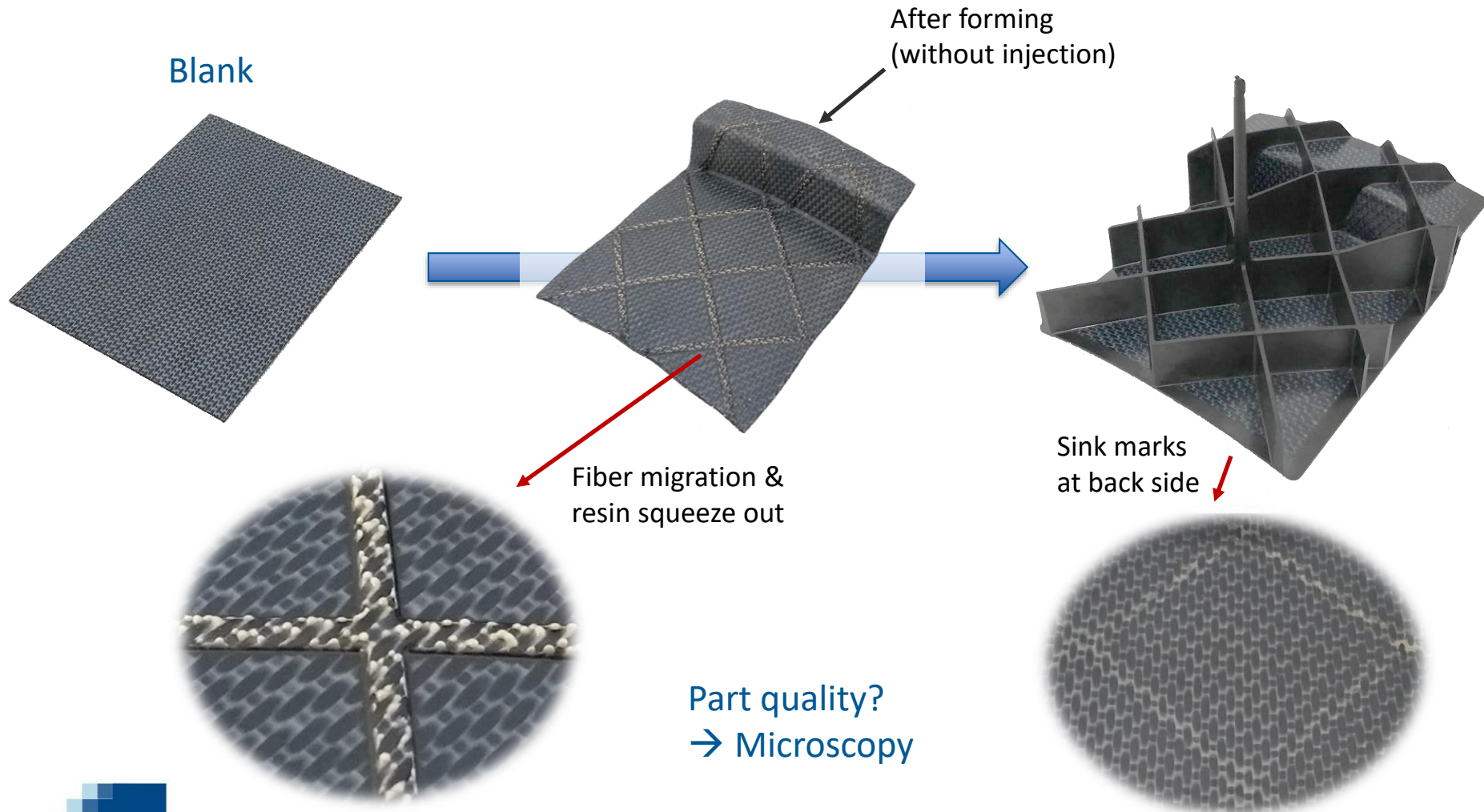
# DEMONSTRATOR MANUFACTURING

Two-step overmolding process



# DEMONSTRATOR MANUFACTURING

One-step overmolding process





# DEMONSTRATOR

Part quality – microscopy cross sections

Overmolding of ribs on a laminate

## Two-step overmolding process



Crack initiator

0.5 mm  
↔

→ Do not use radius

## One-step overmolding process



Fiber migration

→ Influence on laminate performance?

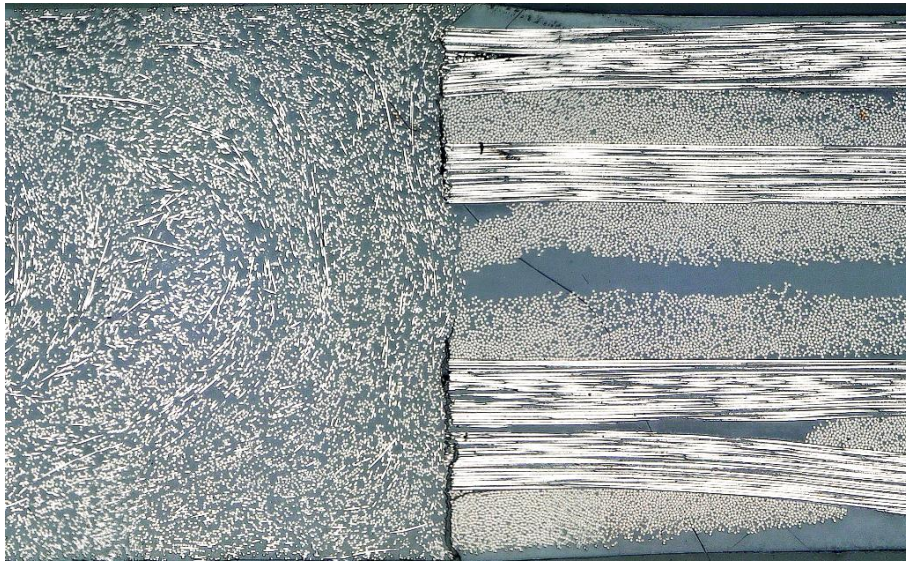


# DEMONSTRATOR

Part quality – microscopy cross sections

Overmolding of laminate edges

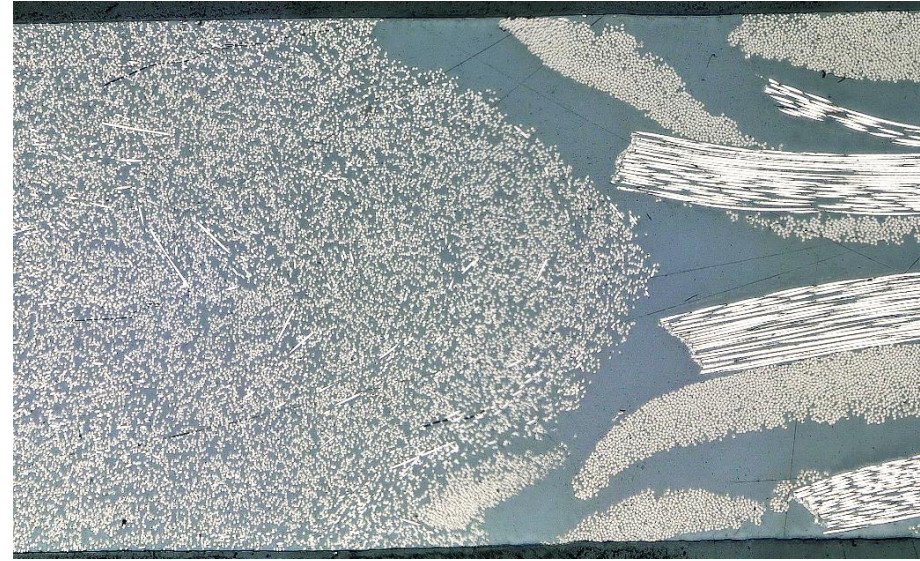
**Two-step overmolding process**



Poor bond strength

0.5 mm

**One-step overmolding process**



Insert penetration

# CONCLUSIONS & OUTLOOK

## Overmolding

- Overmolding is a promising process for thermoplastic composite parts with integrated functionality
- Tools for the prediction of the interface strength and warpage have been developed
- A C/PEEK aerospace demonstrator has been produced in both a one-step and two-step overmolding process
- Work continues on structural modelling of overmolded parts

# OVERMOLDING

## Project Partners

UNIVERSITY OF TWENTE.



**KraussMaffei**

**KISTLER**



ThermoPlastic composites Research Center

Confidential and proprietary

# TPRC

ThermoPlastic composites Research Center

Thank you for your attention.

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