Thermoplastic Injection Overmoulding Using Discrete Reinforcing Elements

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ICCM23, Belfast

Structure of talk

- Introduction
  - The ENACT overmoulding project
  - Fibre orientation in injection moulding
  - Determining fibre orientation distribution (FOD)
- Use of FOD to predict properties
  - Sub-element design, optimisation and manufacture
  - Simulation approach
  - Mechanical testing and results
  - Comparison with prediction, limitations
- Summary and next steps

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Introduction to the ENACT project

- Innovate UK/IACME project
  - Follow on to TOSCAA project
- Overmoulding with discrete reinforcement
  - Small continuous fibre element
  - Not necessarily bridging load introduction points
- Need for improvement in predictive capability
  - Understanding the overmould behaviour – FOD
  - Interface formation and quality
  - Stress management

TOSCAA project demonstrator

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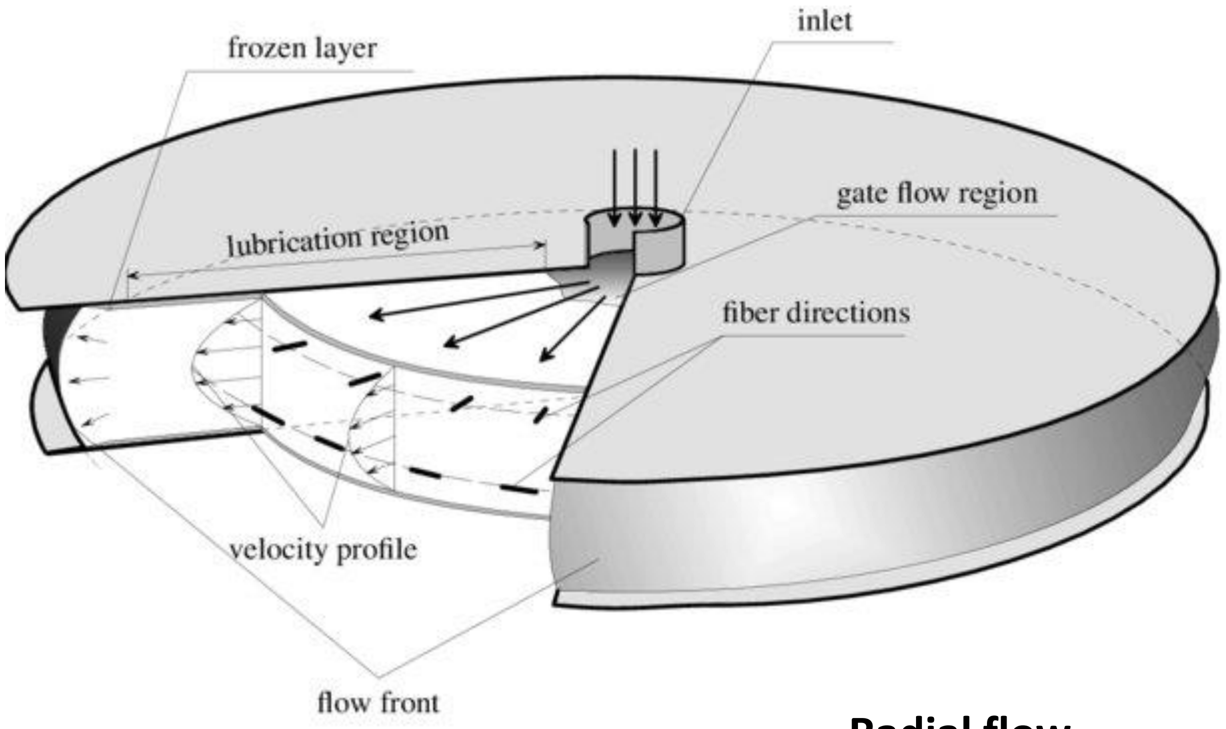
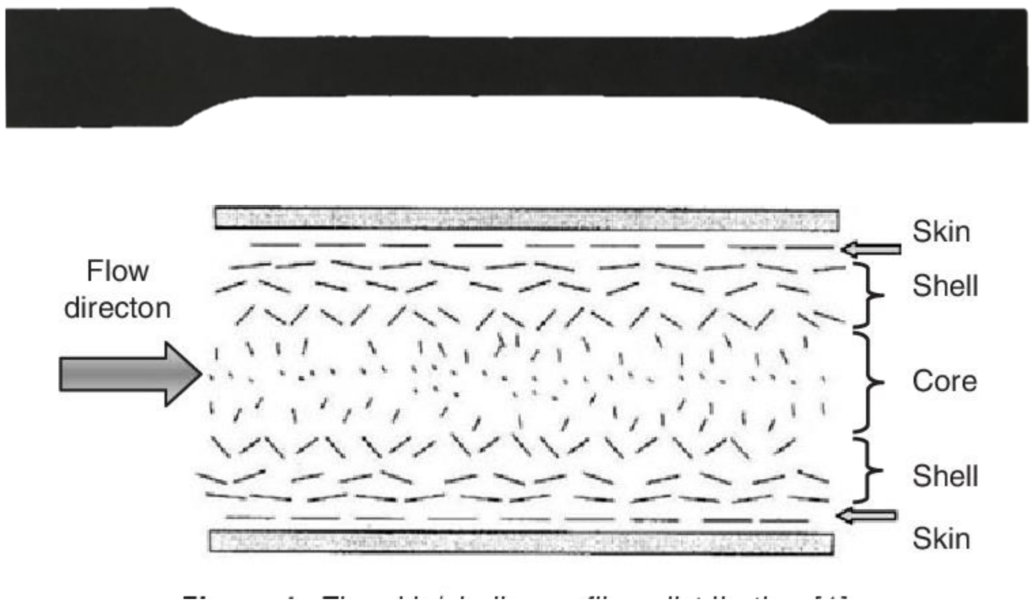
Fibre orientation in injection moulding

- Fibres align with flow – action of shear and stretching
- Results in a complex, five layer fibre orientation





DOI:10.1177/0731684407081352

Radial flow

Axial flow

DOI: 10.1007/s00161-003-0133-5

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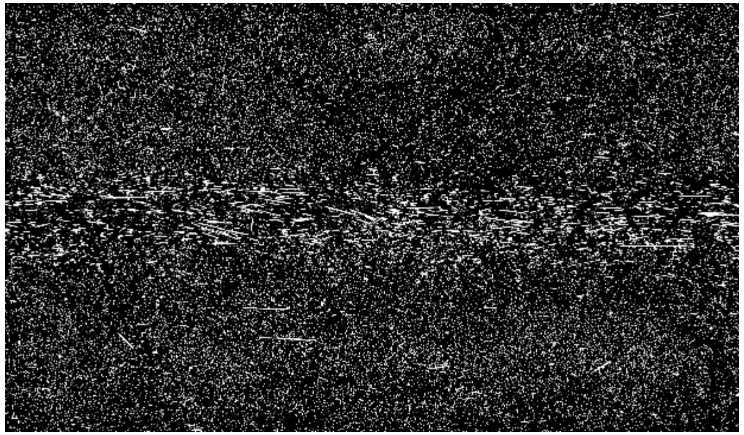
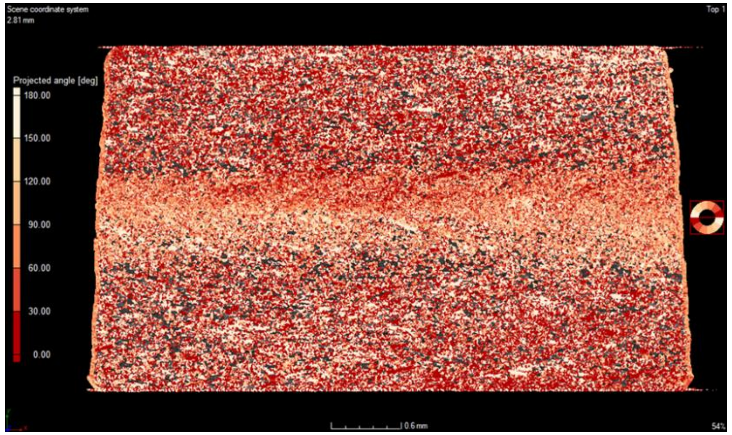
Determining fibre orientation distribution (FOD)

- General methods of capturing fibre orientation distribution

- Eddy Current
  - Large scale
  - Fast
  - Requires conductive fibre
- Microscopy
  - Mid scale
  - Highly skilled
  - Destructive
- MicroCT
  - Small scale
  - Data intensive
  - Expensive





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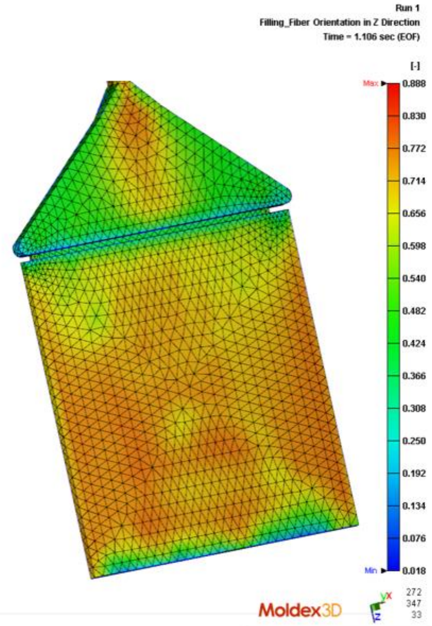
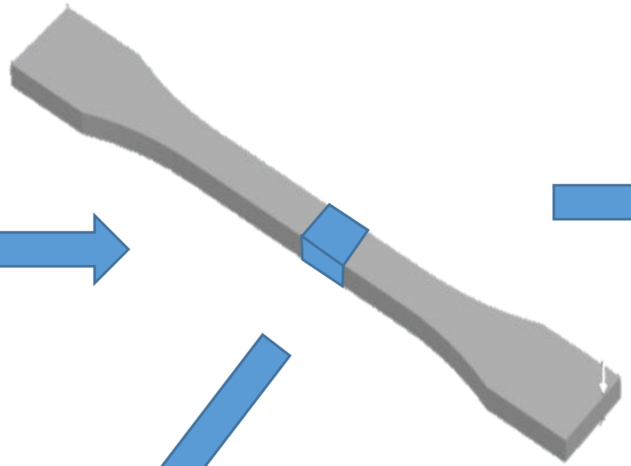
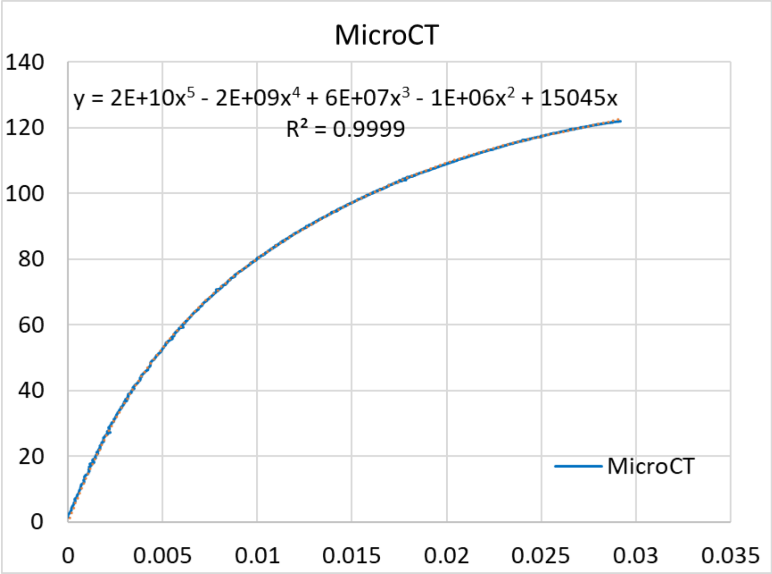
Use of FOD to predict properties



Preferential alignment tool



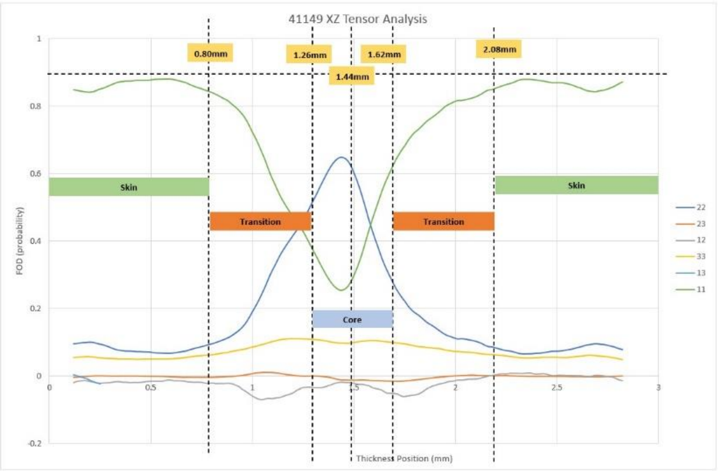
Samples cut at 0, 45, 90 to generate different FODs



Mechanical test data

Digimat

Properties vs FOD mastercurve



FOD captured from microCT

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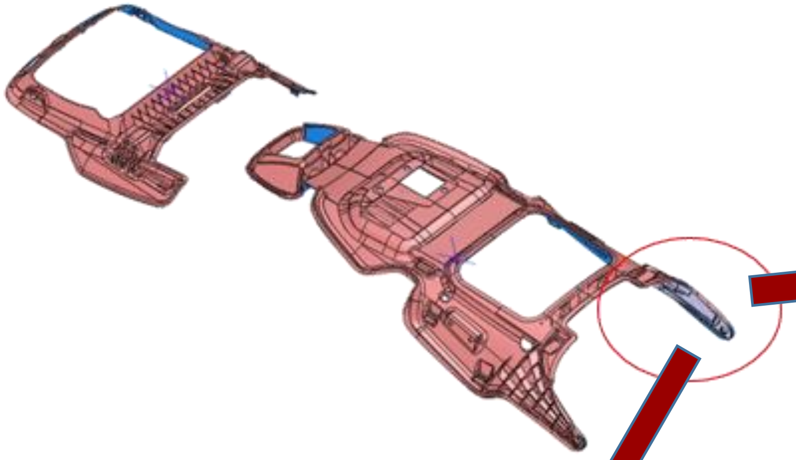
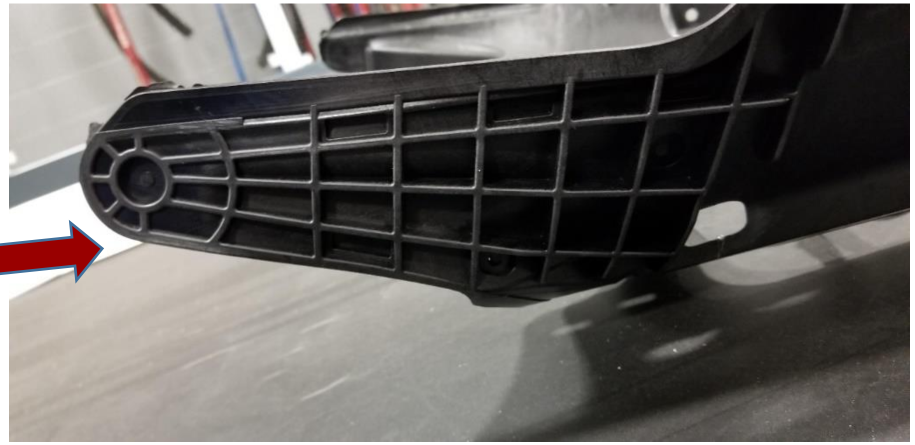
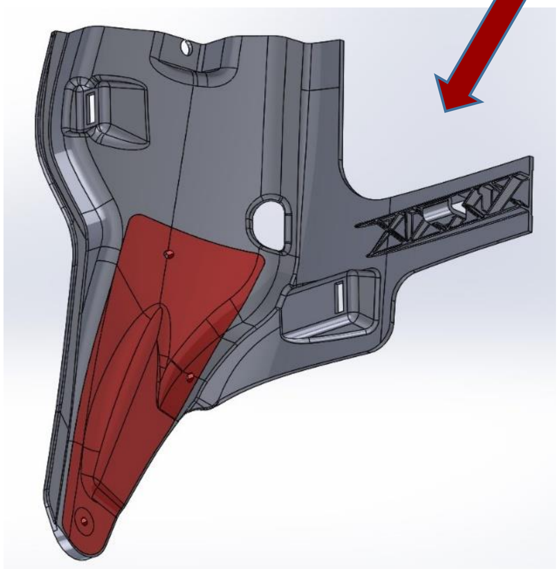
Sub-element design

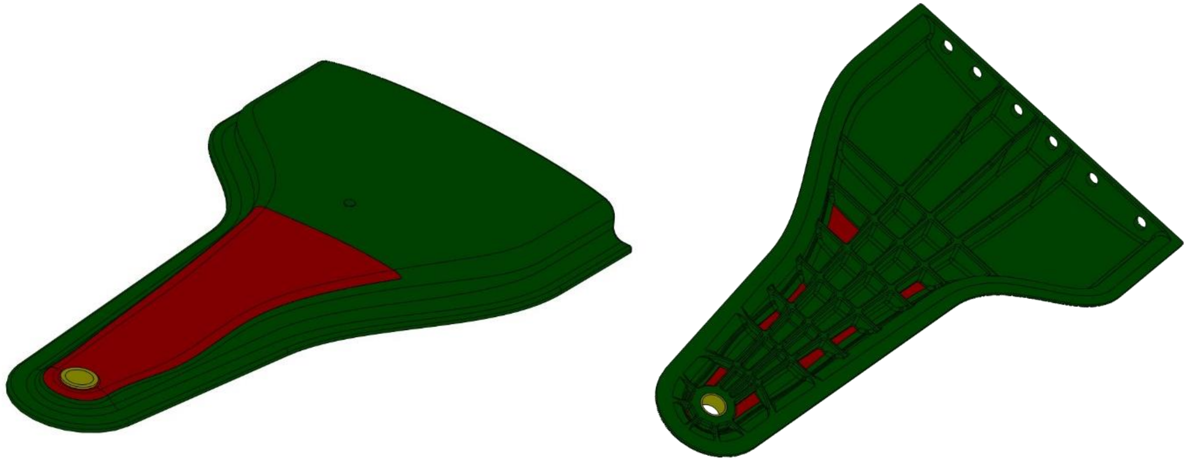




- Red = continuous fibre insert
- Green = overmould



Original geometry



Simplified geometry

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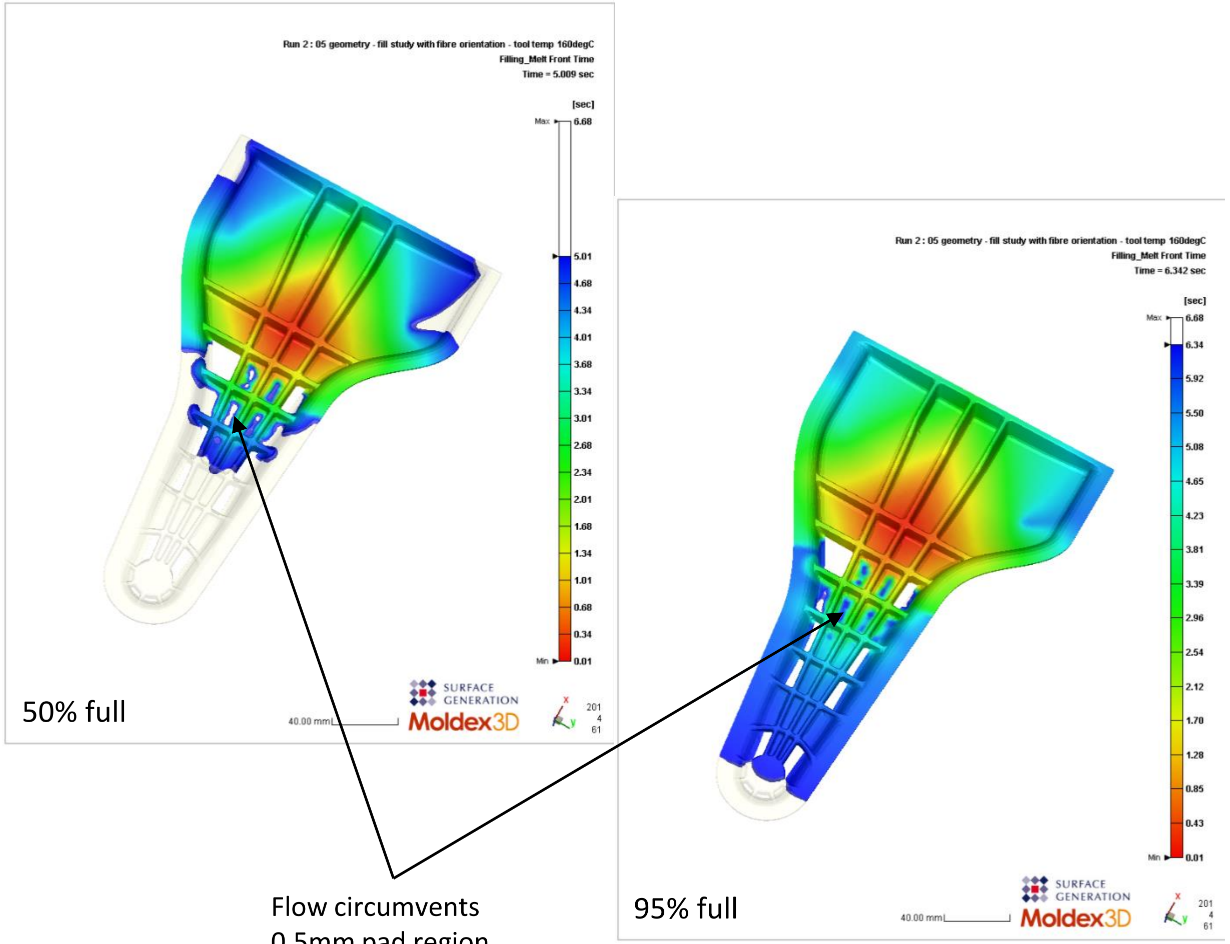
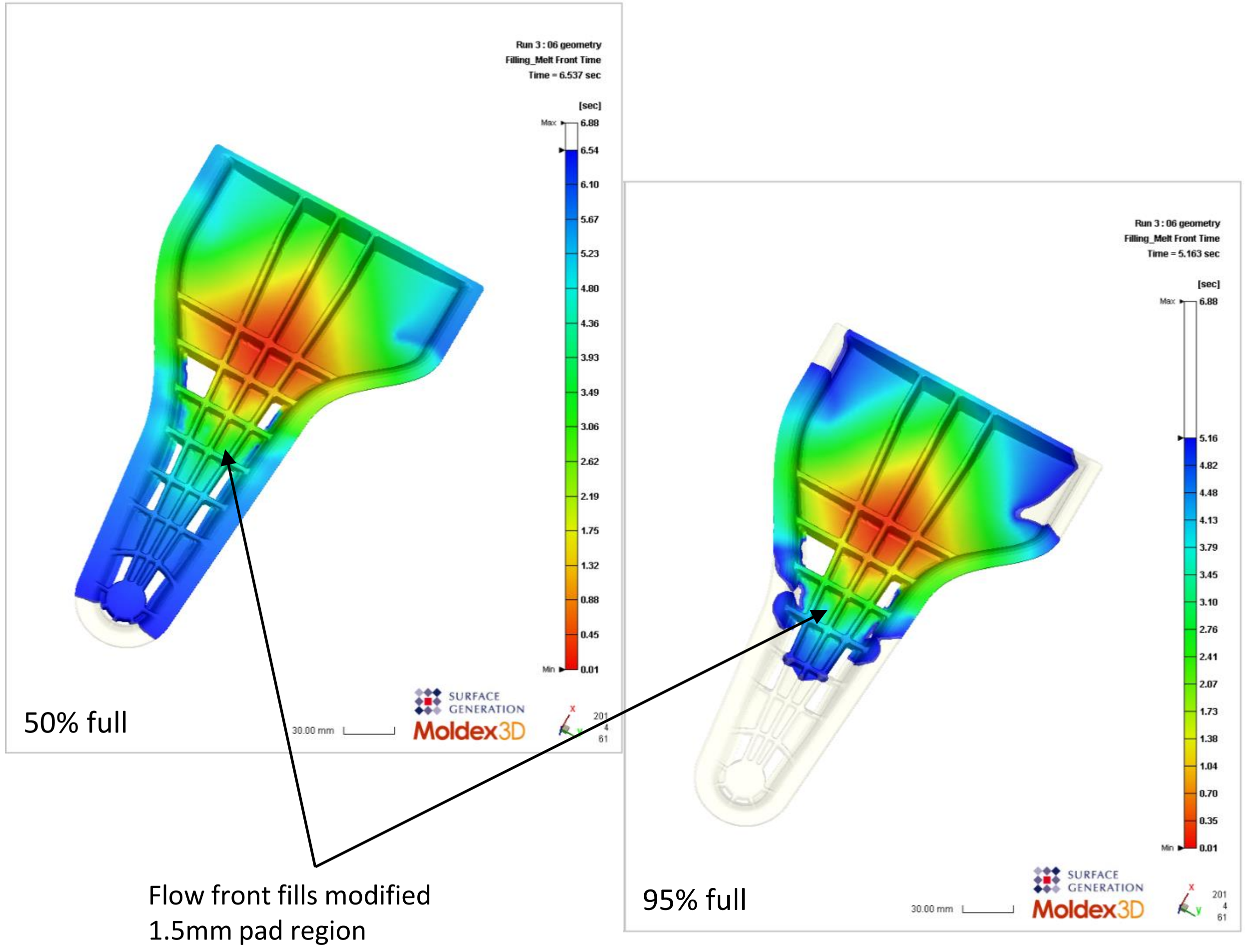
Sub element fill optimisation

0.5mm thickness geometry



Flow circumvents
0.5mm pad region

1.5mm thickness geometry



Flow front fills modified
1.5mm pad region

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Sub element manufacturing

- Insert material:
  - SGL PA6 UD CF tape
  - 45,90,-45,0,0,0,0,0,0,-45,90,45
- Overmoulding material
  - Ultramid B3EG7 (PA6, 35 wt% short glass)
  - Opti-Polymers PA6 CF30 (30wt% short carbon)
- Conditioned to standard atmosphere

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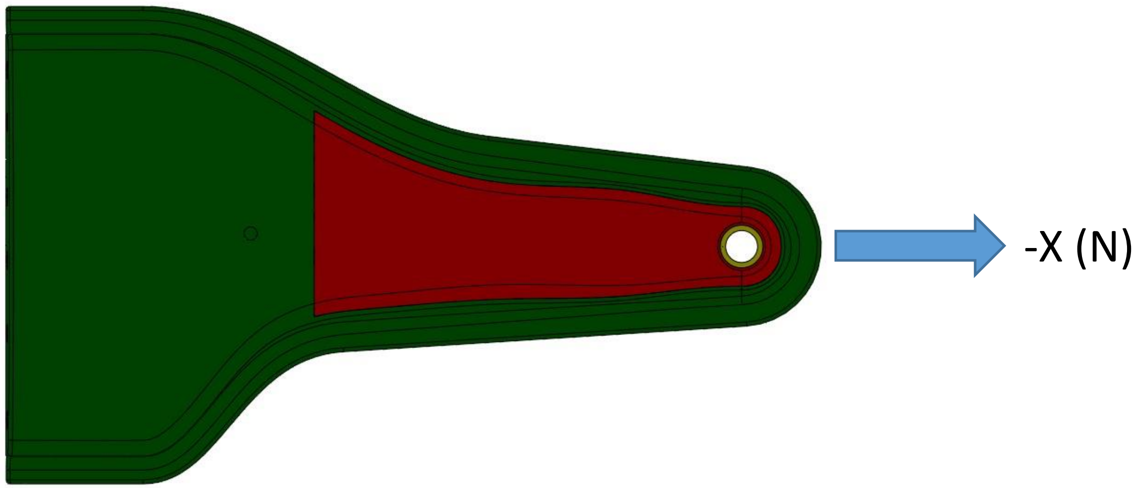
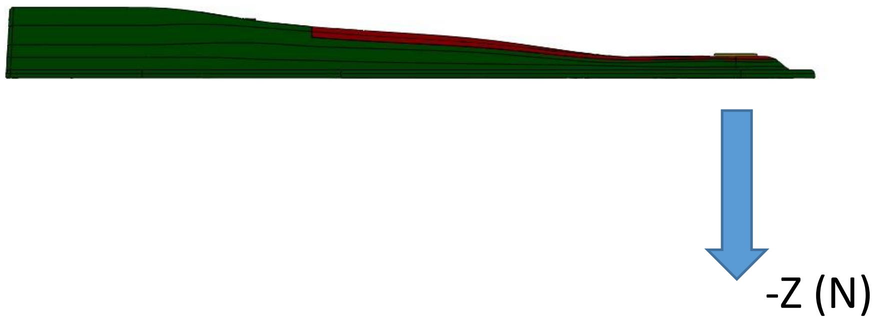
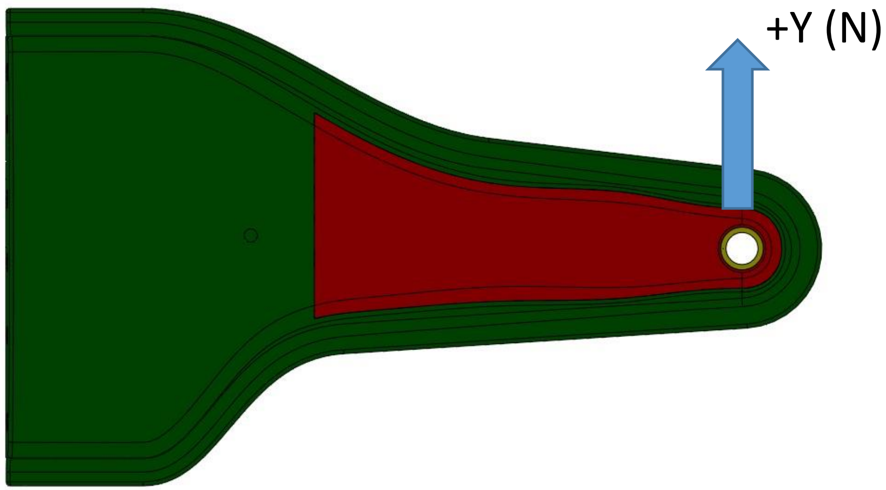
Sub element load cases







Load Case	Description
1	Tension –X
2	Out of plane bending –Z
3	In plane bending +Y

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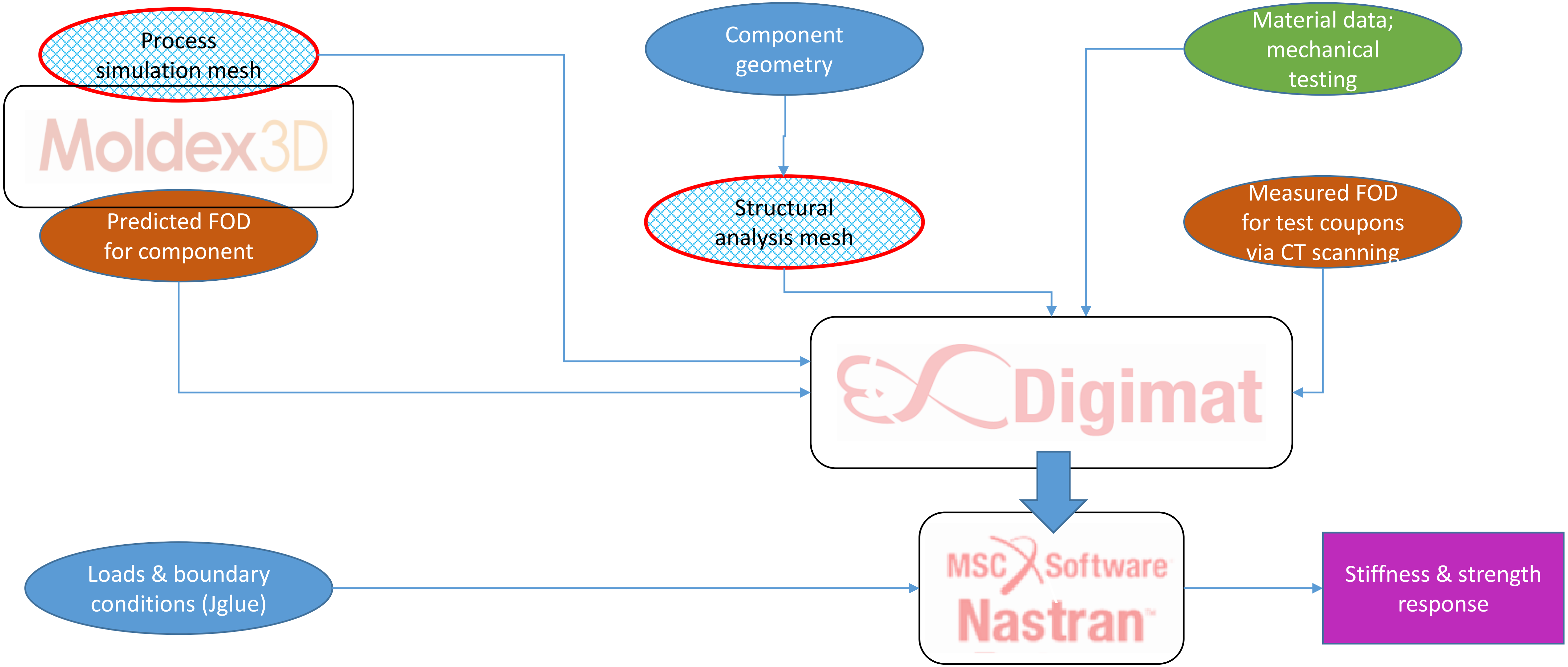
Sub element simulation pathway



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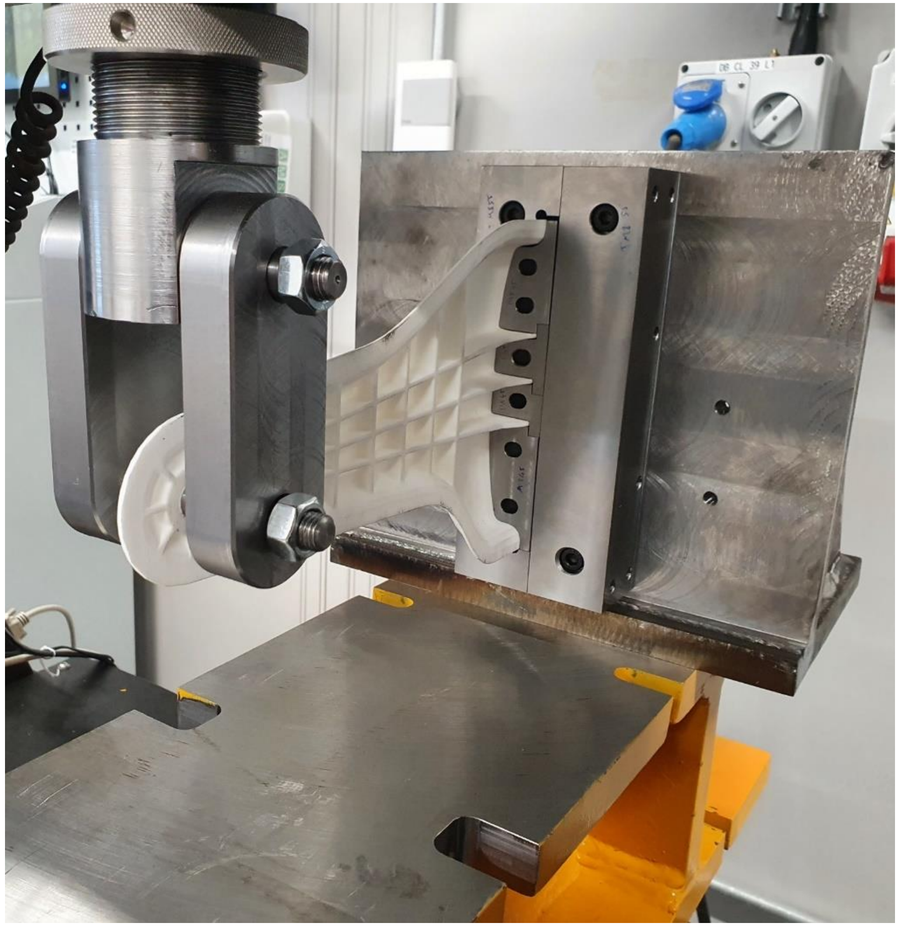
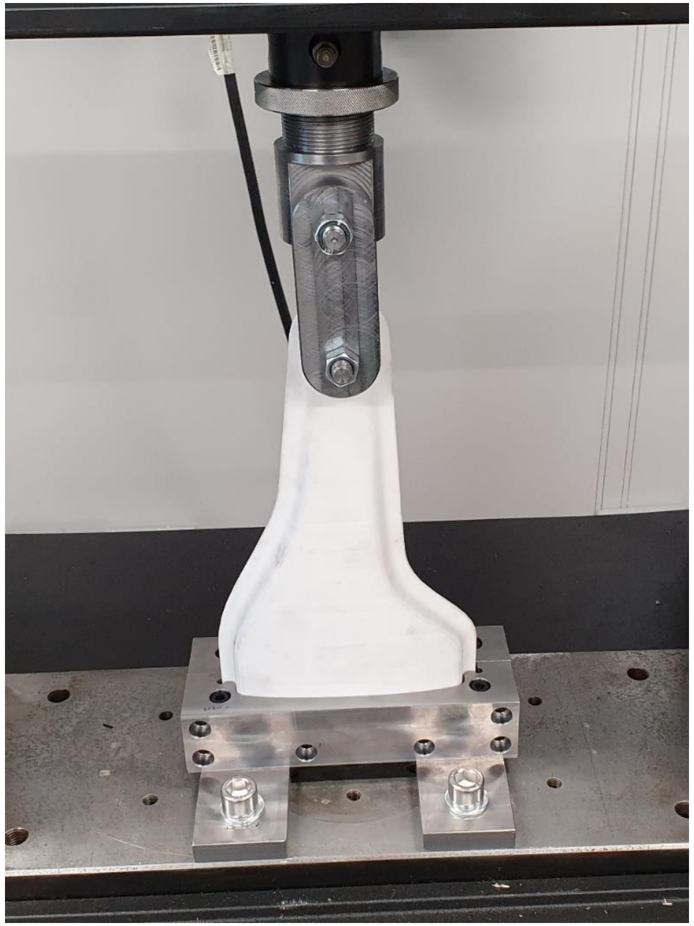
Sub element mechanical testing



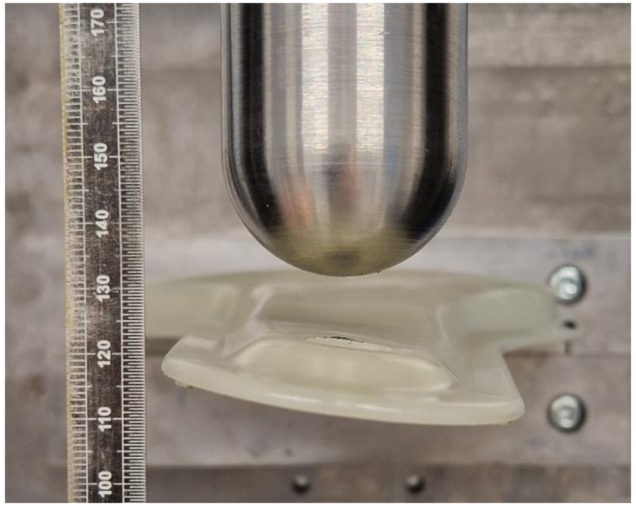
In plane bending

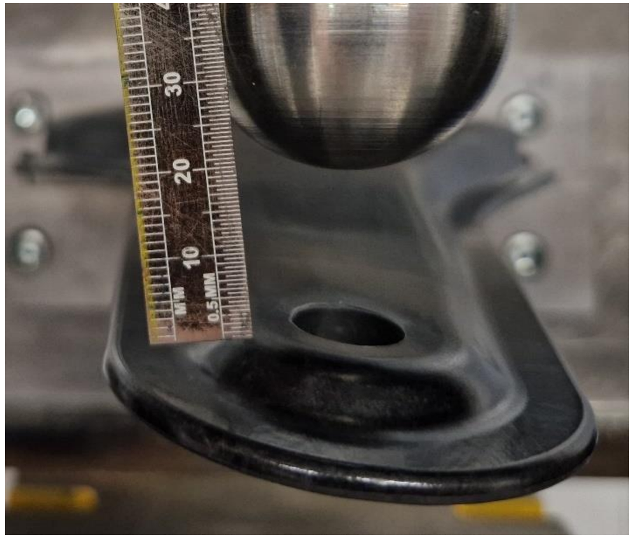
Out of plane bending



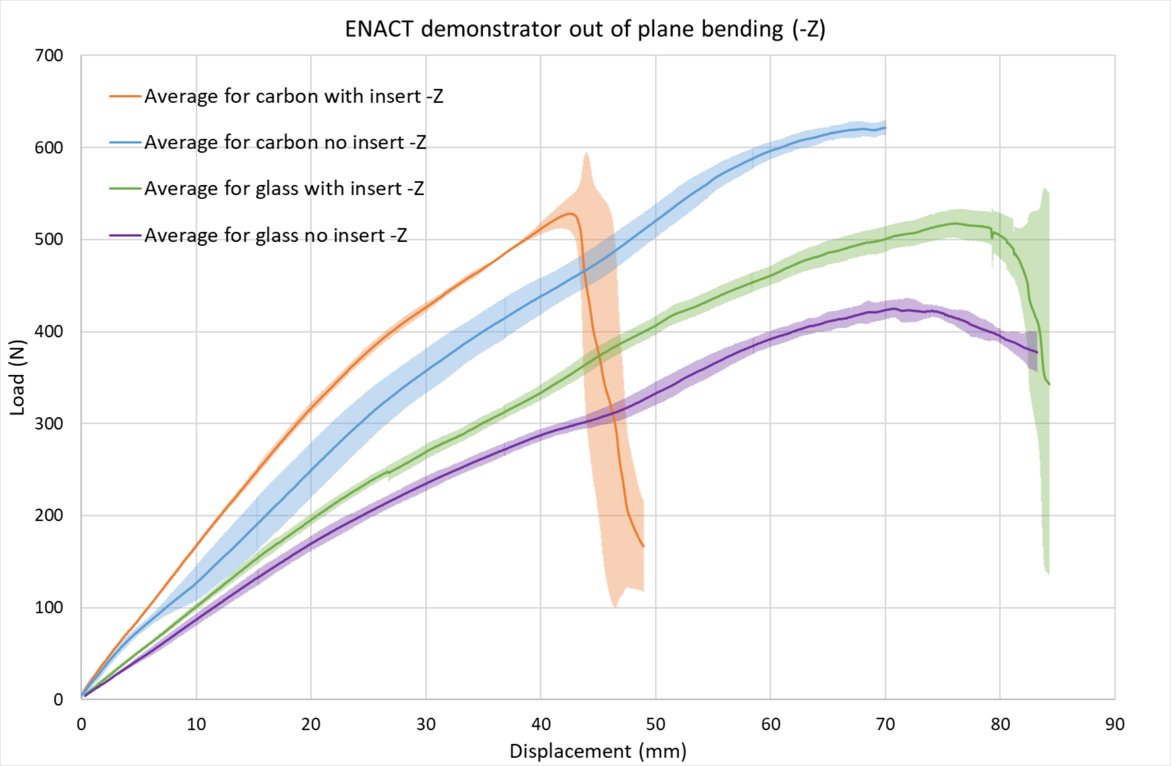
Tensile

Results for out of plane bending (-Z)

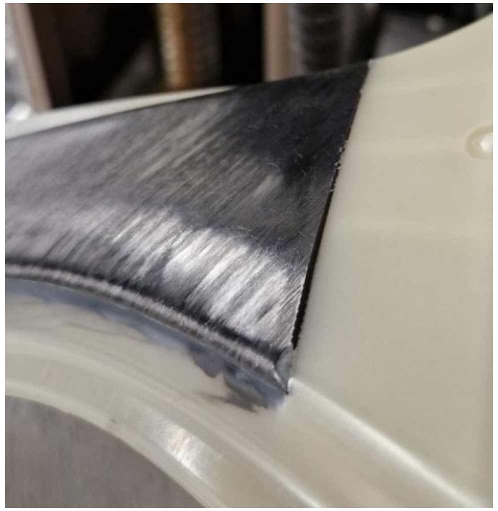




With no insert - no abrupt failure.
Permanent deflection was induced



Failure behaviour was relatively consistent, stiffness increased with insert



With insert - split in the interface appeared on the top face, then the crack proceeded through the overmould

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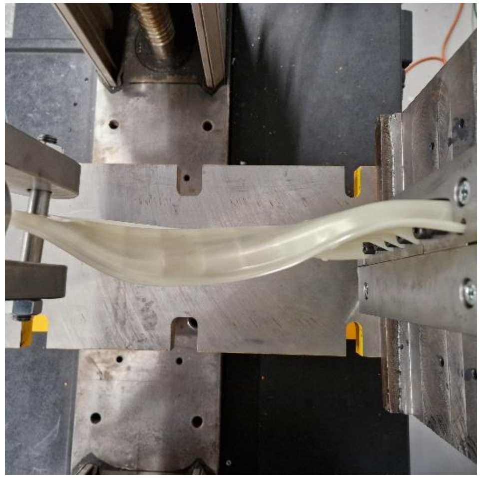
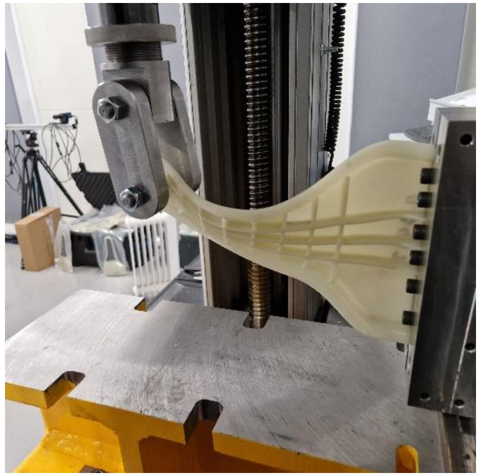
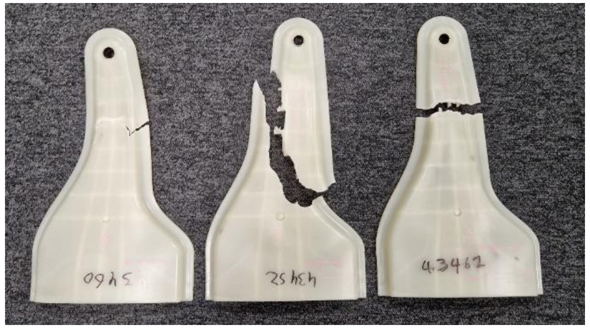
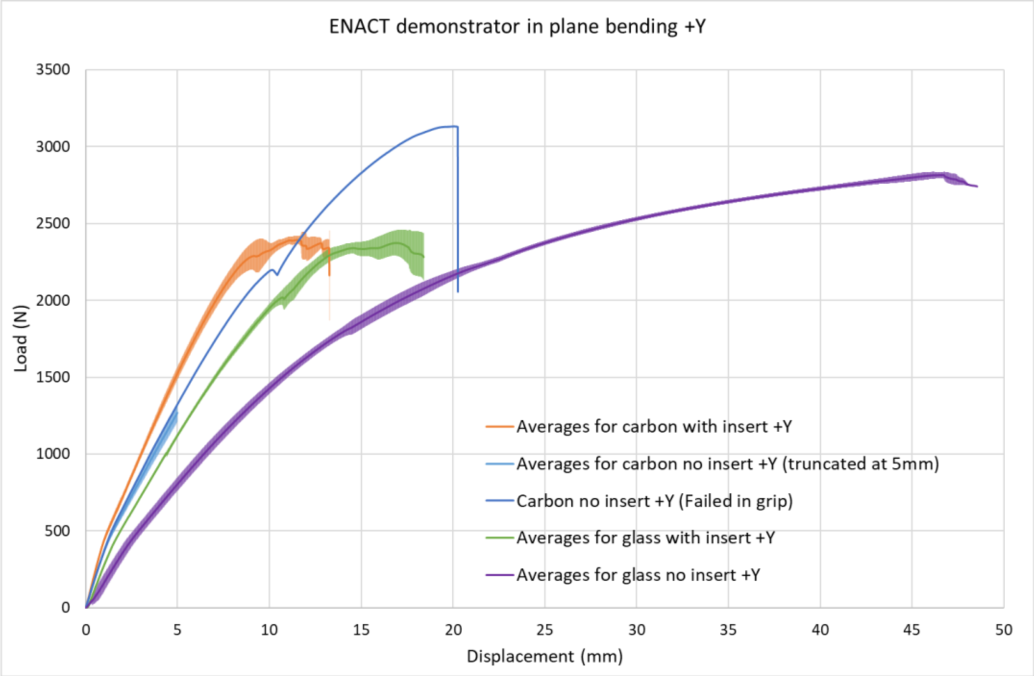
Results for in plane bending (+Y)



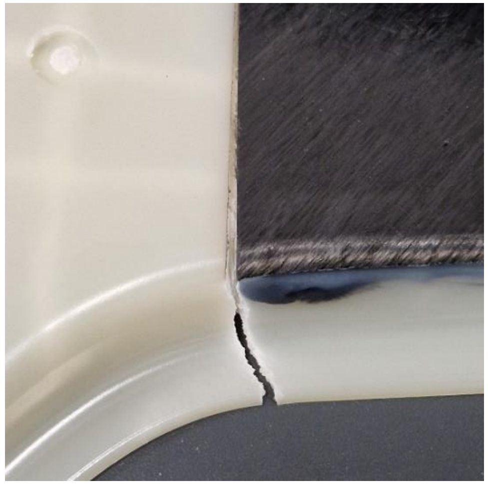




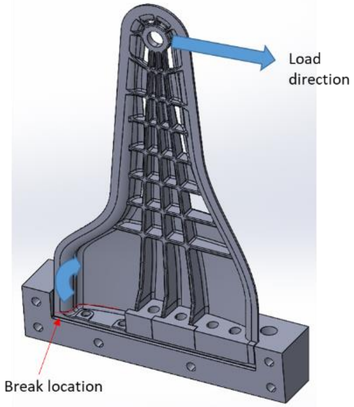
No insert - extreme deformation before abrupt failure for the glass



Failure behaviour was consistent, stiffness increased with insert

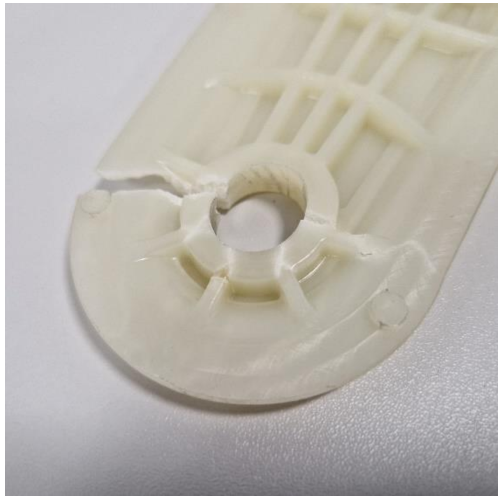


The carbon samples unfortunately broke in the grip

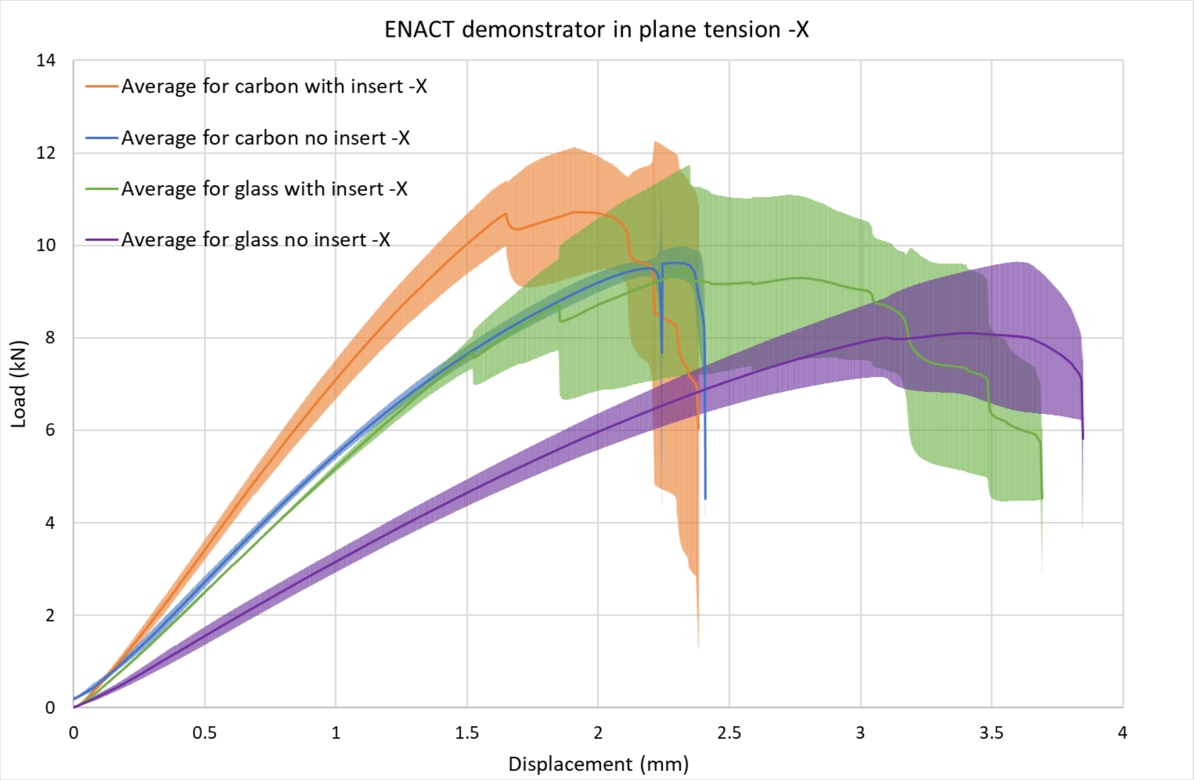


With insert - comparable to out of plane. Split at interface then progression though overmould. Failure at tensile side

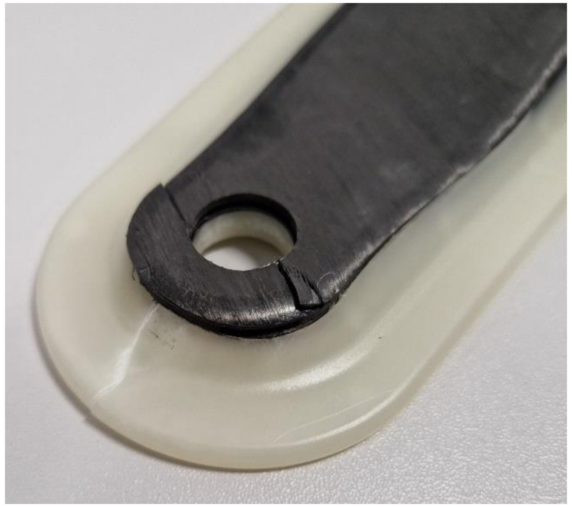
Results for in plane tension (-X)

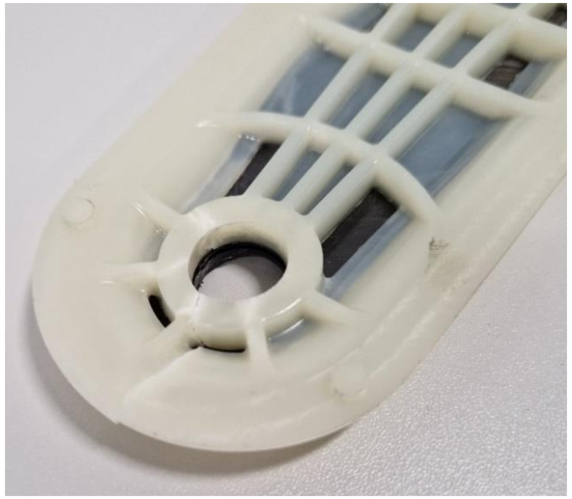


No insert - failure via horizontal crack at hole



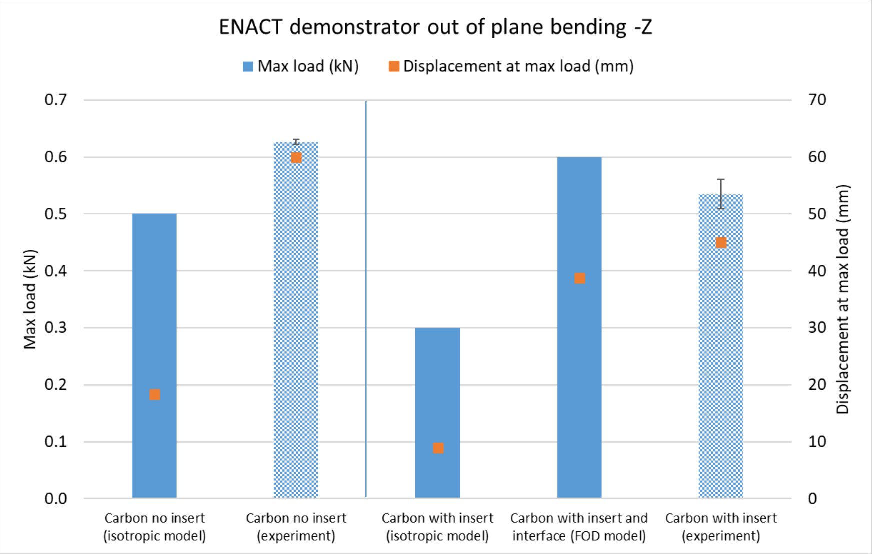
Failure behaviour less consistent during failure, stiffness increased with insert

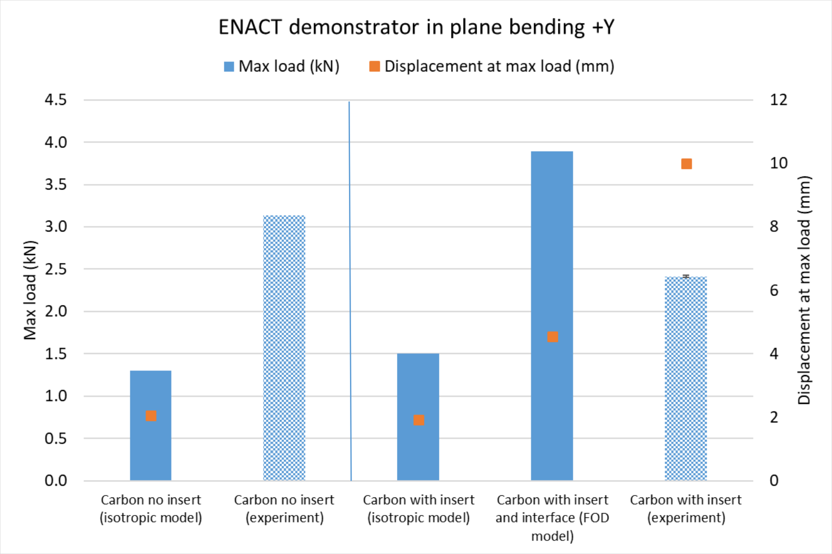


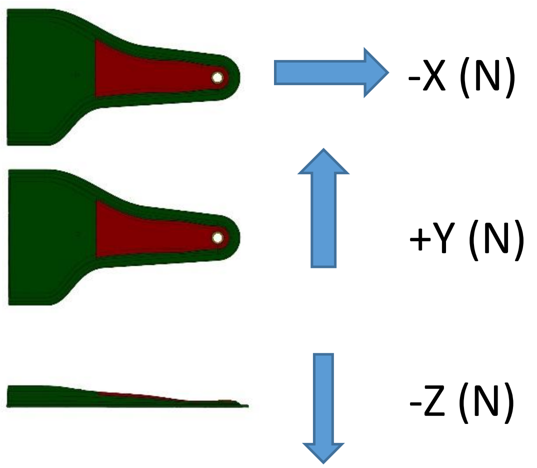


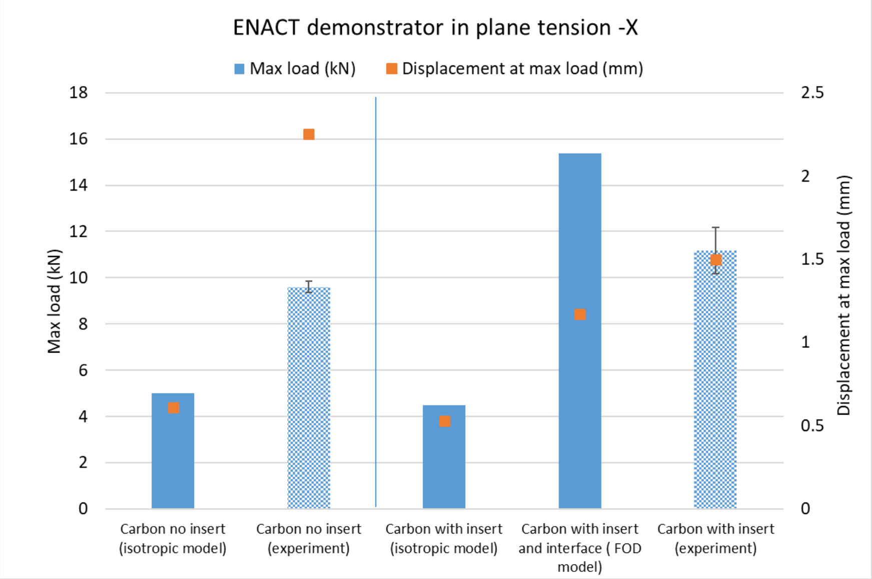
With insert - failure via interlaminar cracking and peel of insert, followed by vertical or horizontal crack

Comparison with model – Maximum load









- Isotropic model significantly underestimates result in each case
- FOD model tends to overestimate result
- Closest result for out of plane (-Z)

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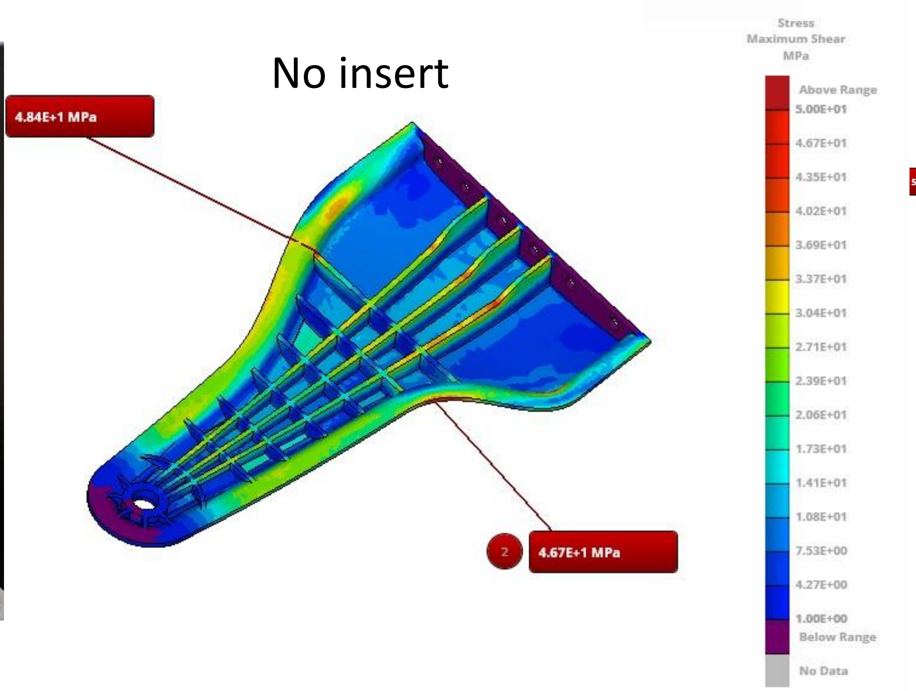
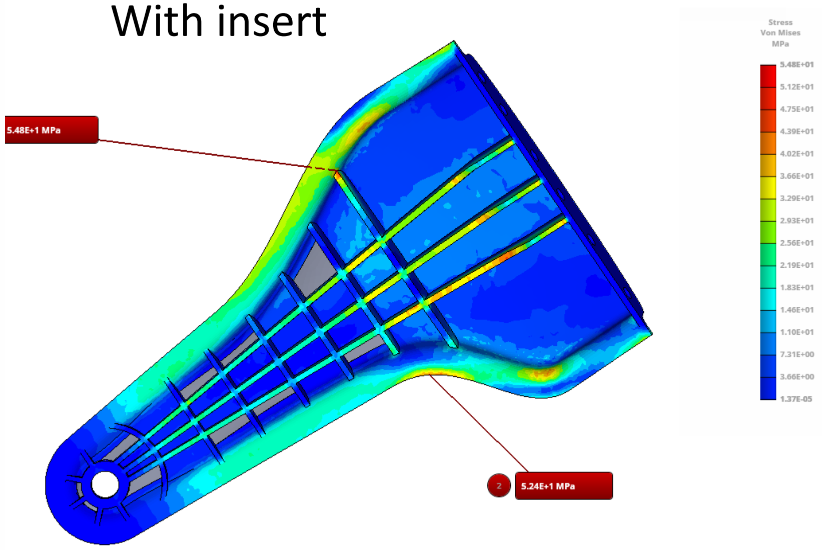
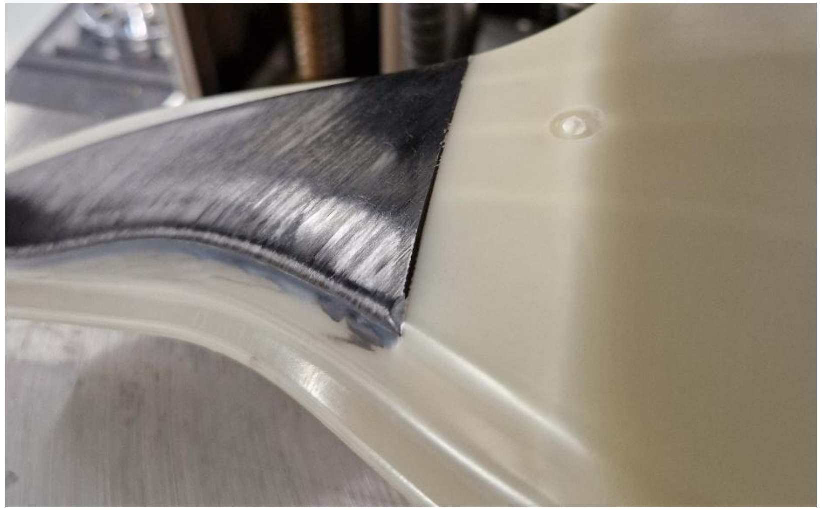
Failure comparison -Z

No insert



With insert





- Complete failure does not occur for the part with no insert
- Highest stress registered in flange, but failure at interface when insert present

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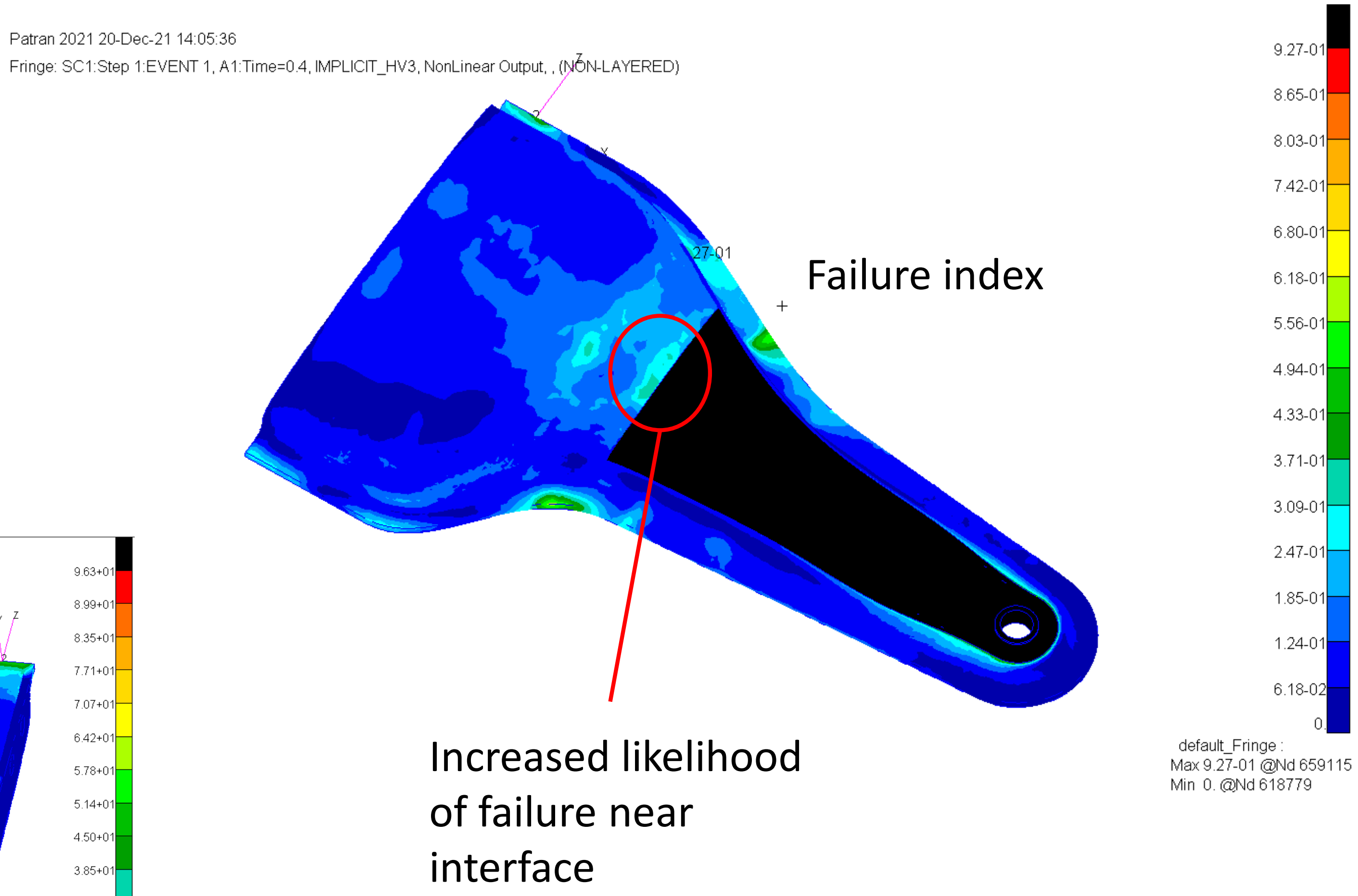
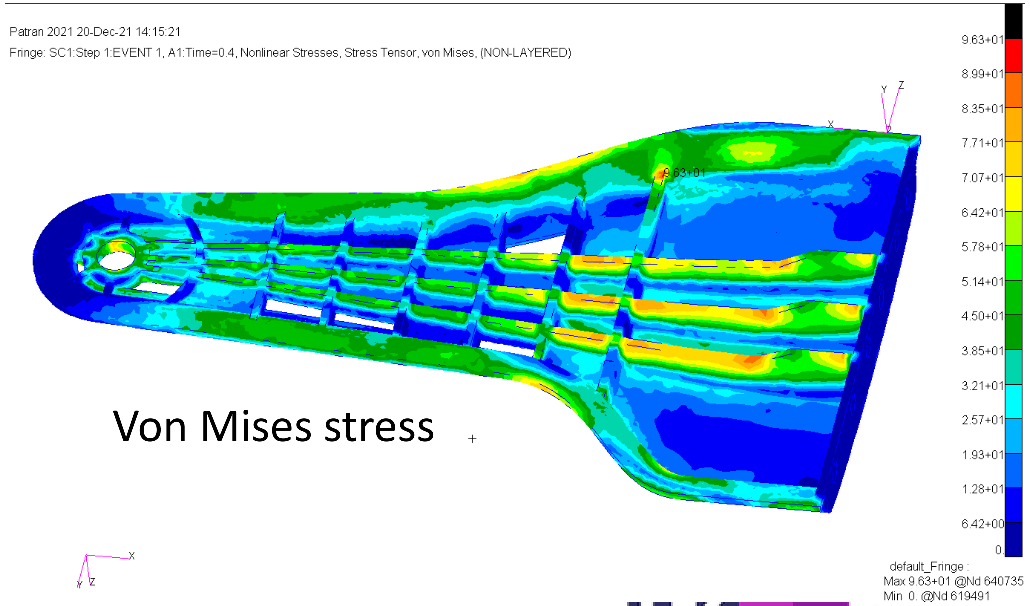
Fully coupled -Z

- The fully coupled model also shows high strains in the flanges
- However, it also captures the failure likely hood near the insert





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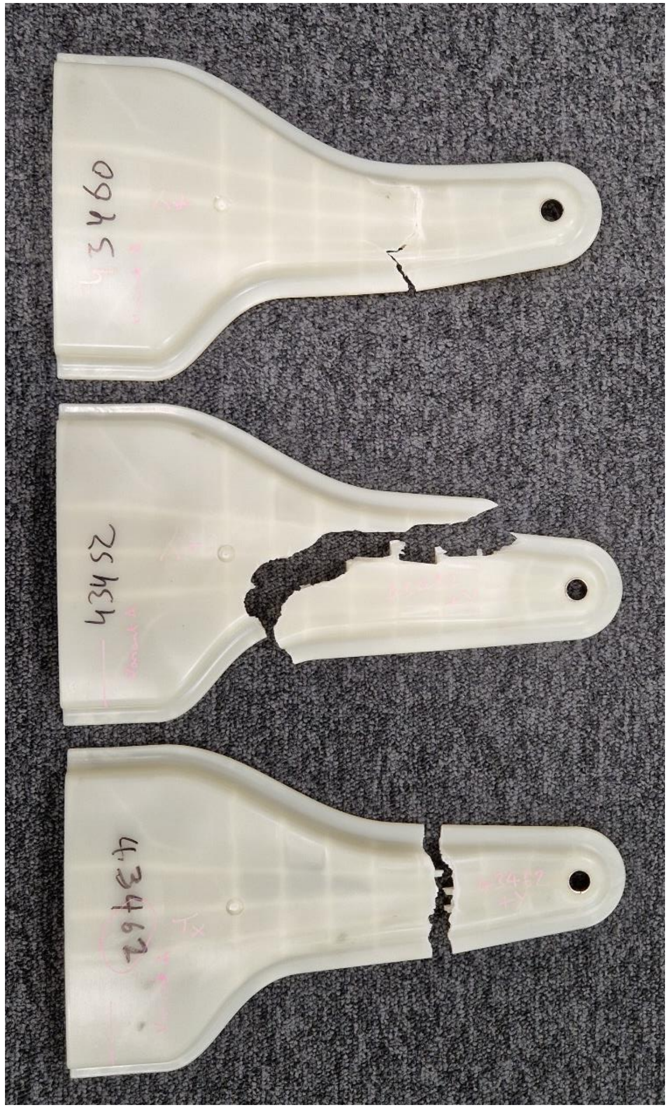
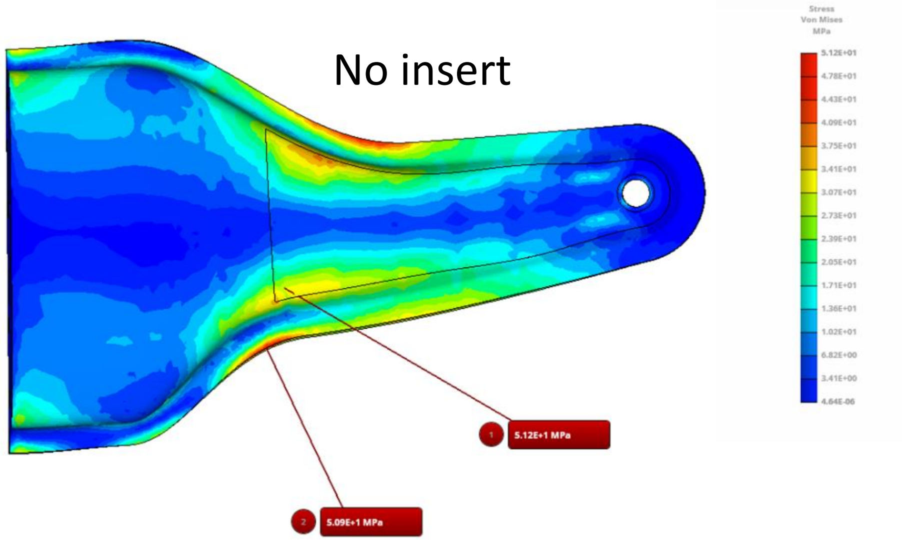
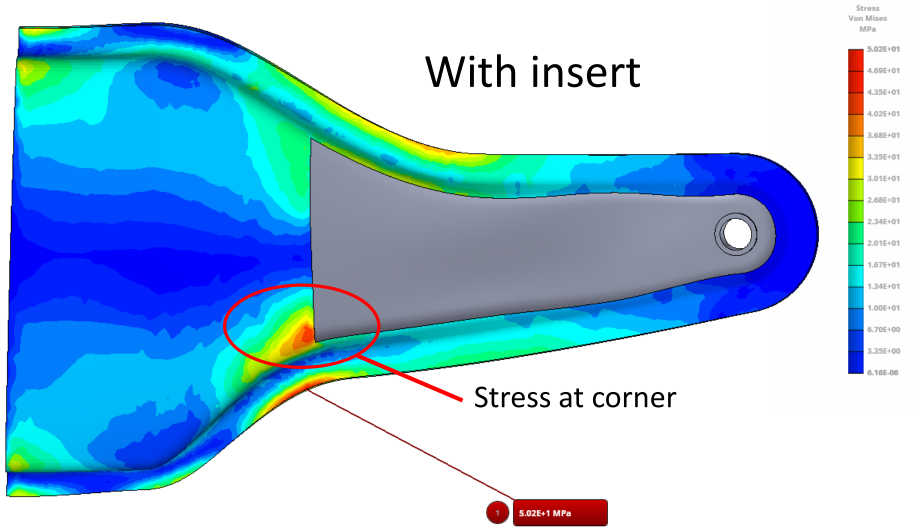
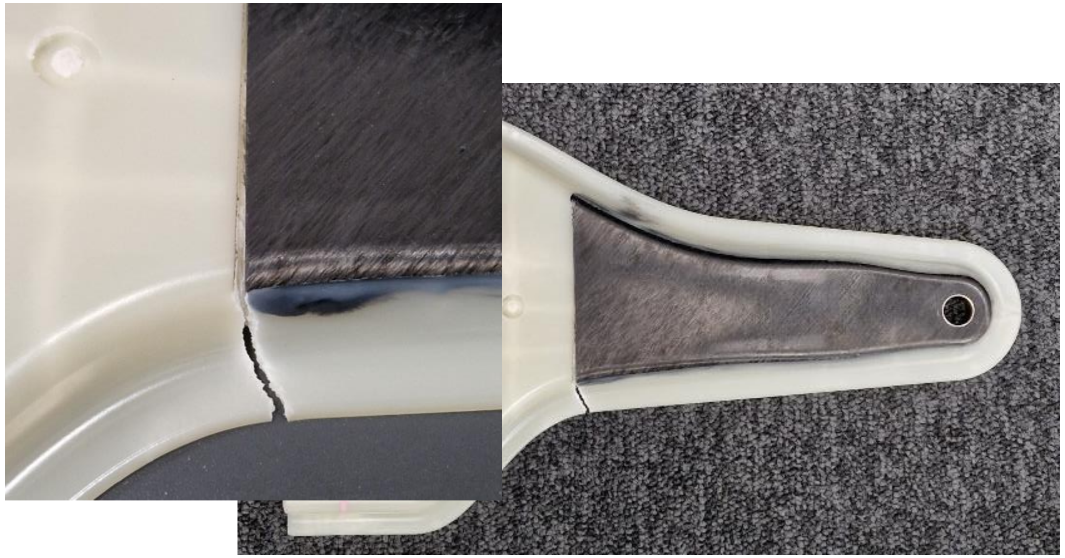
Failure comparison +Y





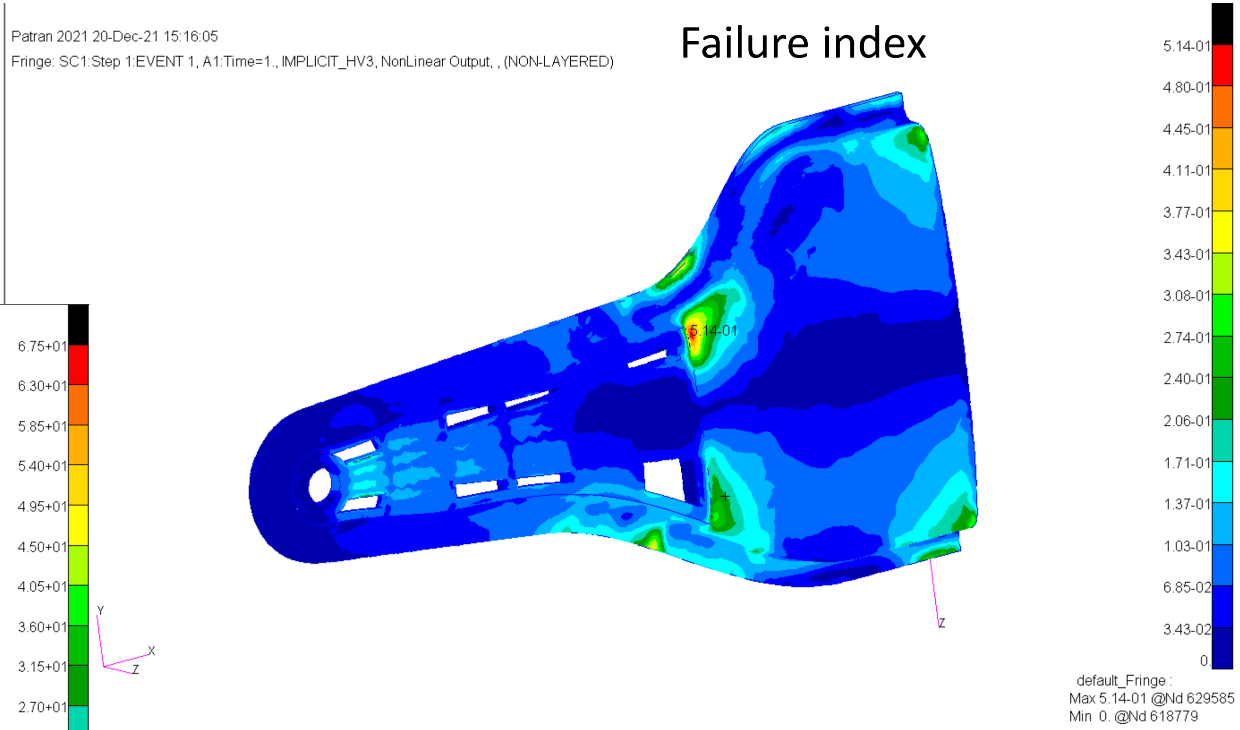


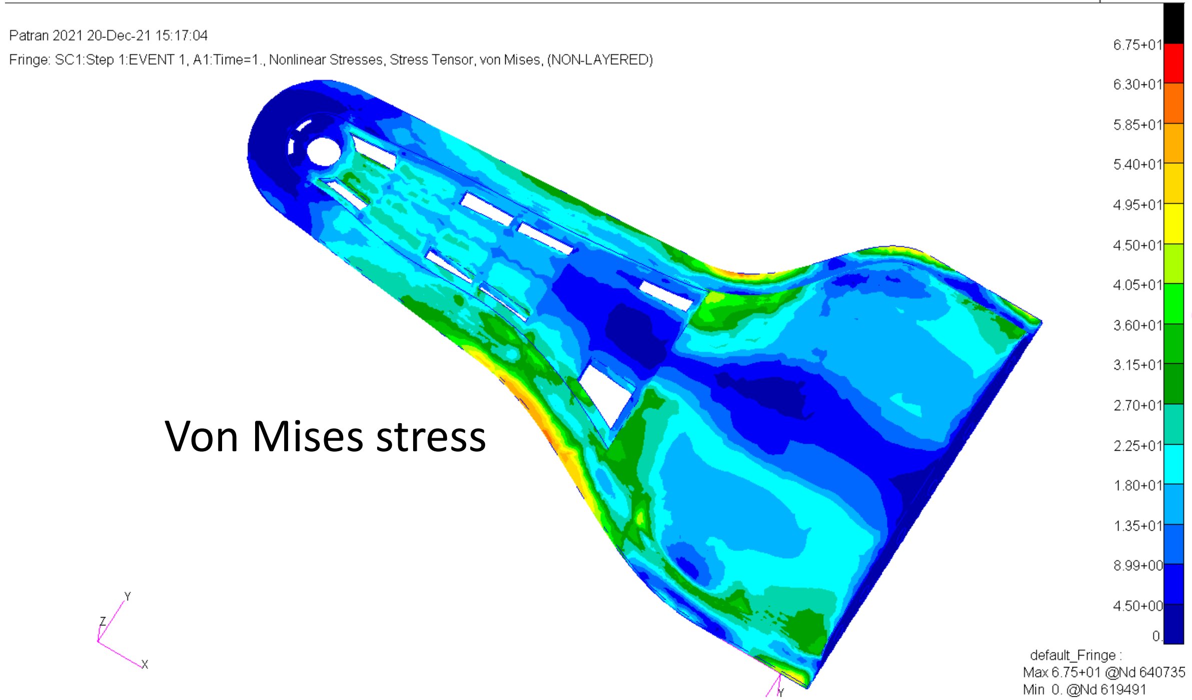
- Failure locations captured in stress plot
- Stress concentration at corner of insert



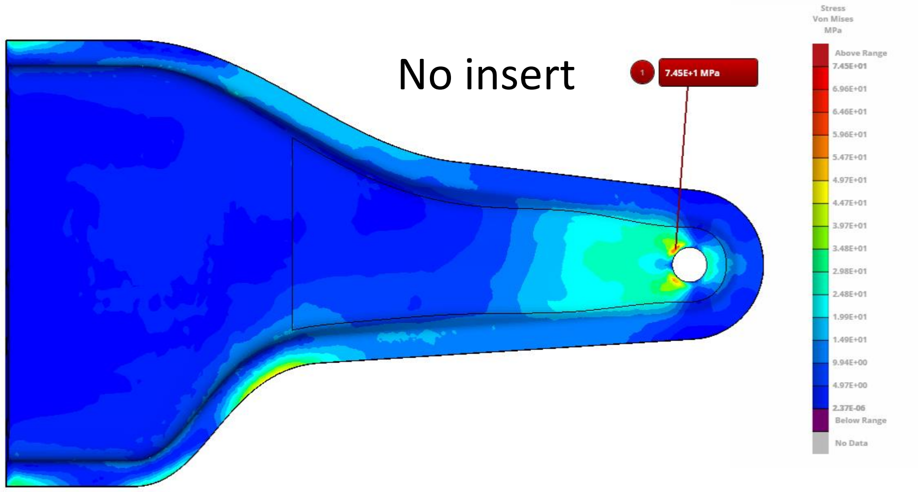
Fully coupled +Y

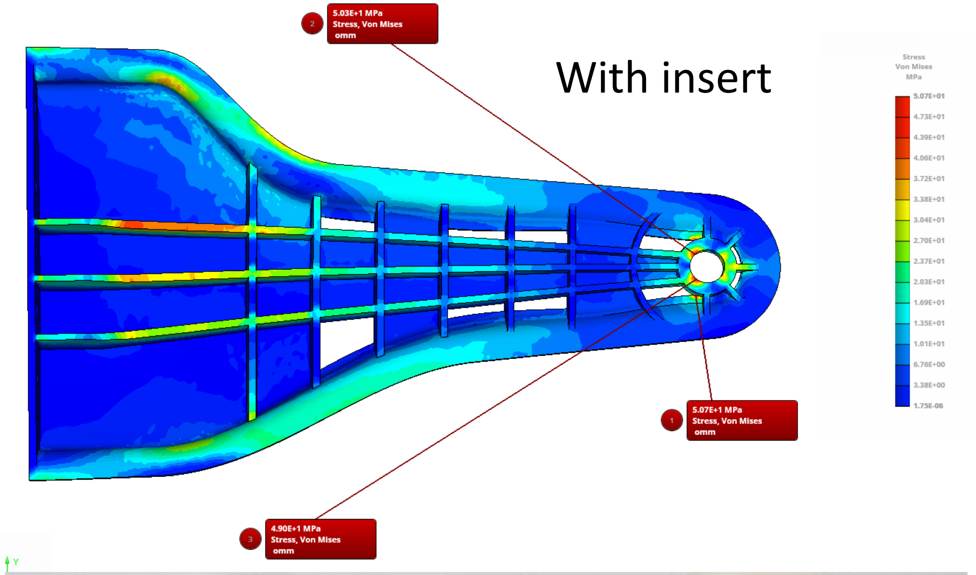
- Stress highest in flanges, however fully coupled model very clearly identifies likely failure at corner of insert





Model comparison -X

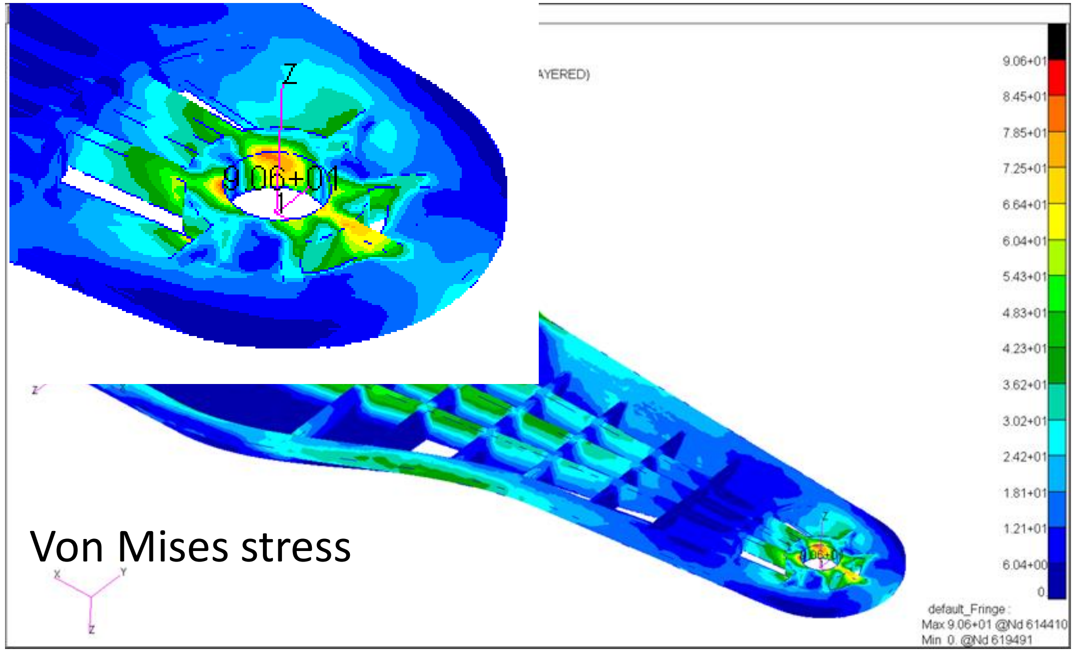


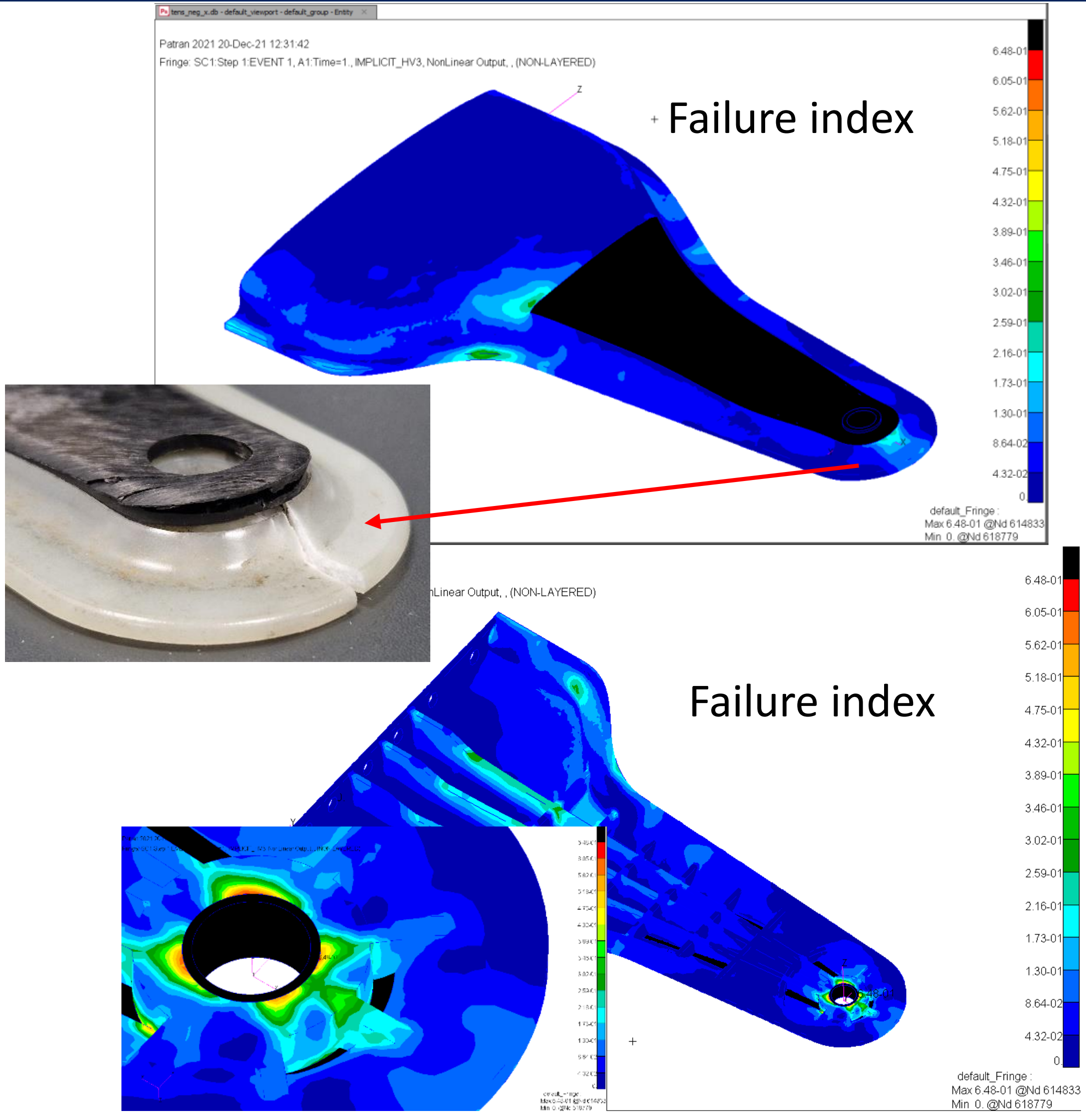


- Failure locations captured in stress plot
- Presence of insert diverts failure path

Fully coupled -X

- Much clearer indication of stress axially from hole
- Identifies insert peel then axial rather than transverse crack as more likely mode of failure





Summary and next steps

- Successfully produced demonstrator with repeatable mechanical behaviour and failure modes
- Successfully integrated software pathway to generate predictive model for mechanical behaviour
- Envelope of properties was captured but fidelity could be improved
- Successfully identified failure locations

- Improve model by:
  - Improving FOD information output from Moldex3D
  - Integrating healing model for interface properties

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