

A Bio-inspired Embedded Composite Stiffener for Improved Damage Tolerance via AFP

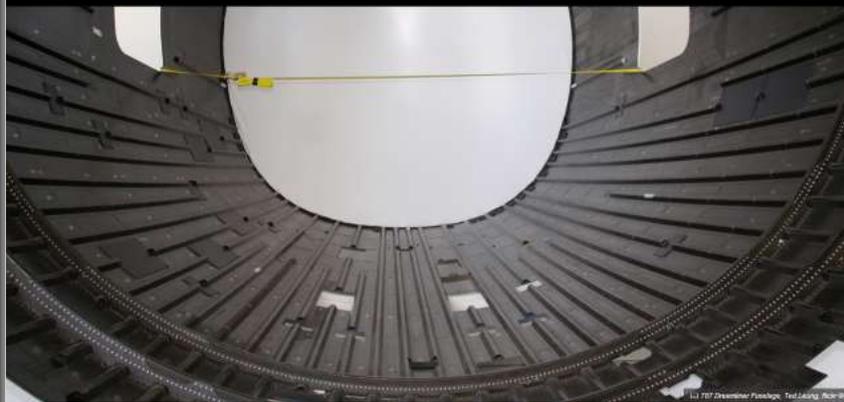
A.D. Whitehouse, Y. Yang, V. Médeau, L. Mencattelli, E. Greenhalgh, S.T. Pinho
Imperial College, Faculty of Engineering

supported by J. Finlayson
Rolls-Royce plc



Outline

Background & Motivation

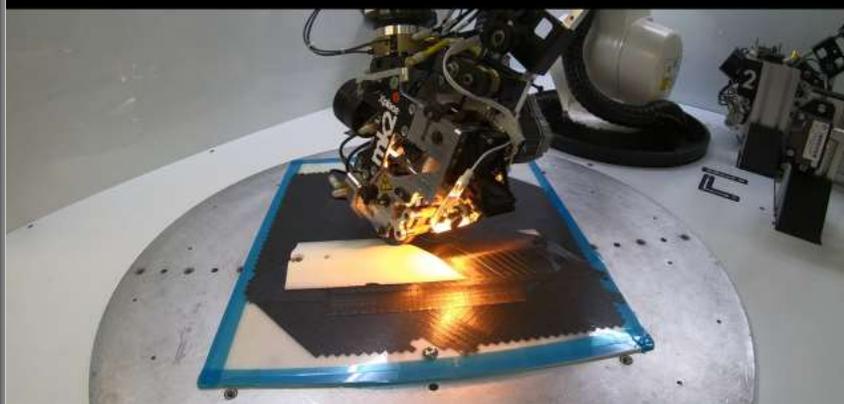


Proposed Concept

Bio-inspired Damage Tolerant Design



Concept Validation



Industrially Relevant Failure Sequence Investigation

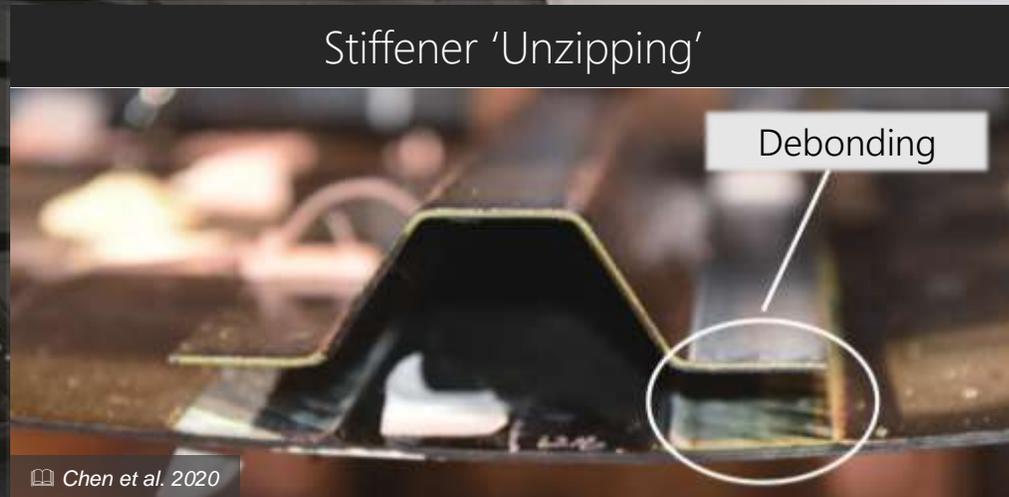


Background & Motivation



Background & Motivation

Stiffener Debonding



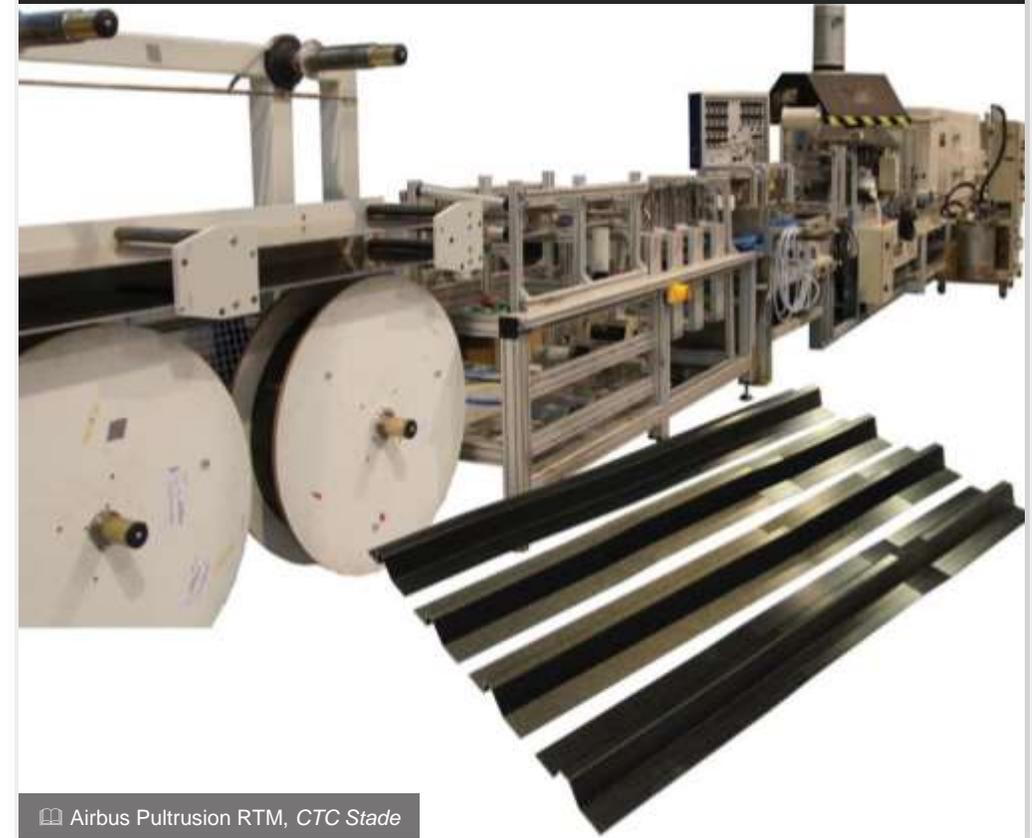
Background & Motivation

Stiffener Manufacture

Automated Fibre Placement (AFP)



Stiffener Manufacture



Proposed Concept

Bio-inspired Damage Tolerant Design



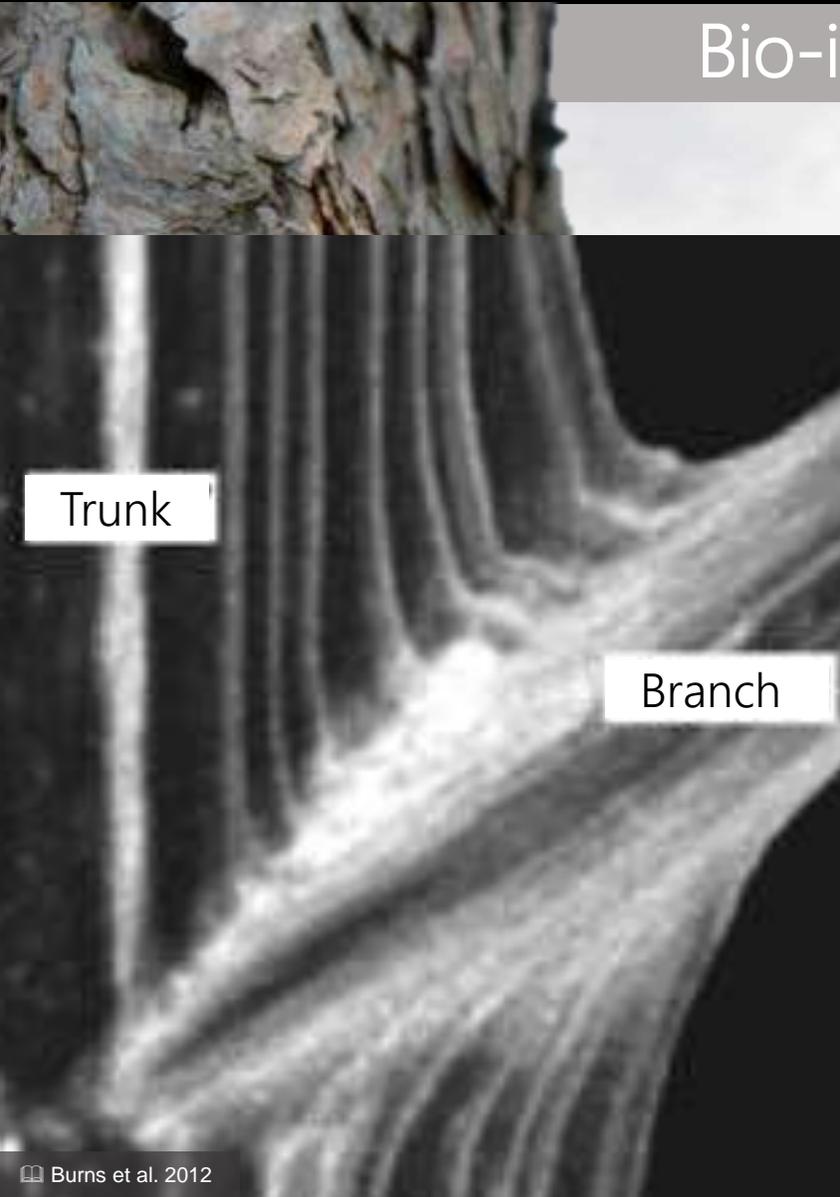
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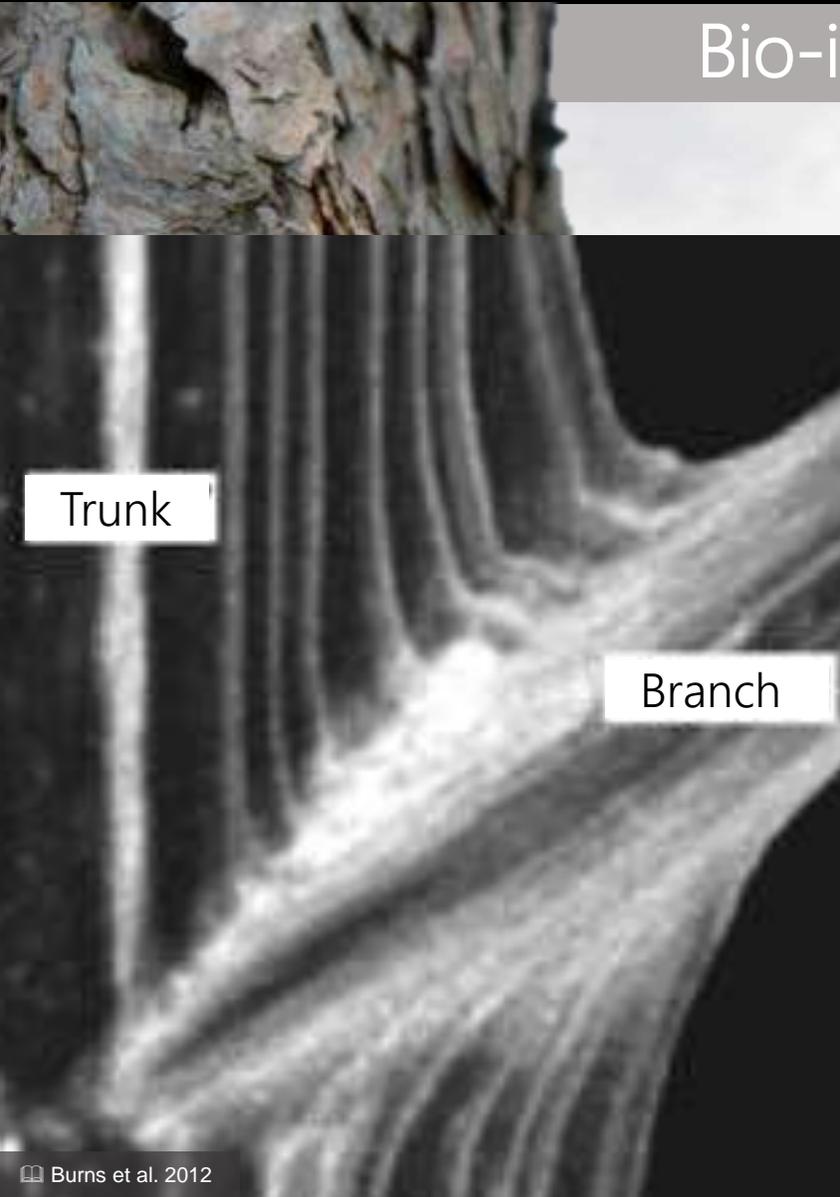
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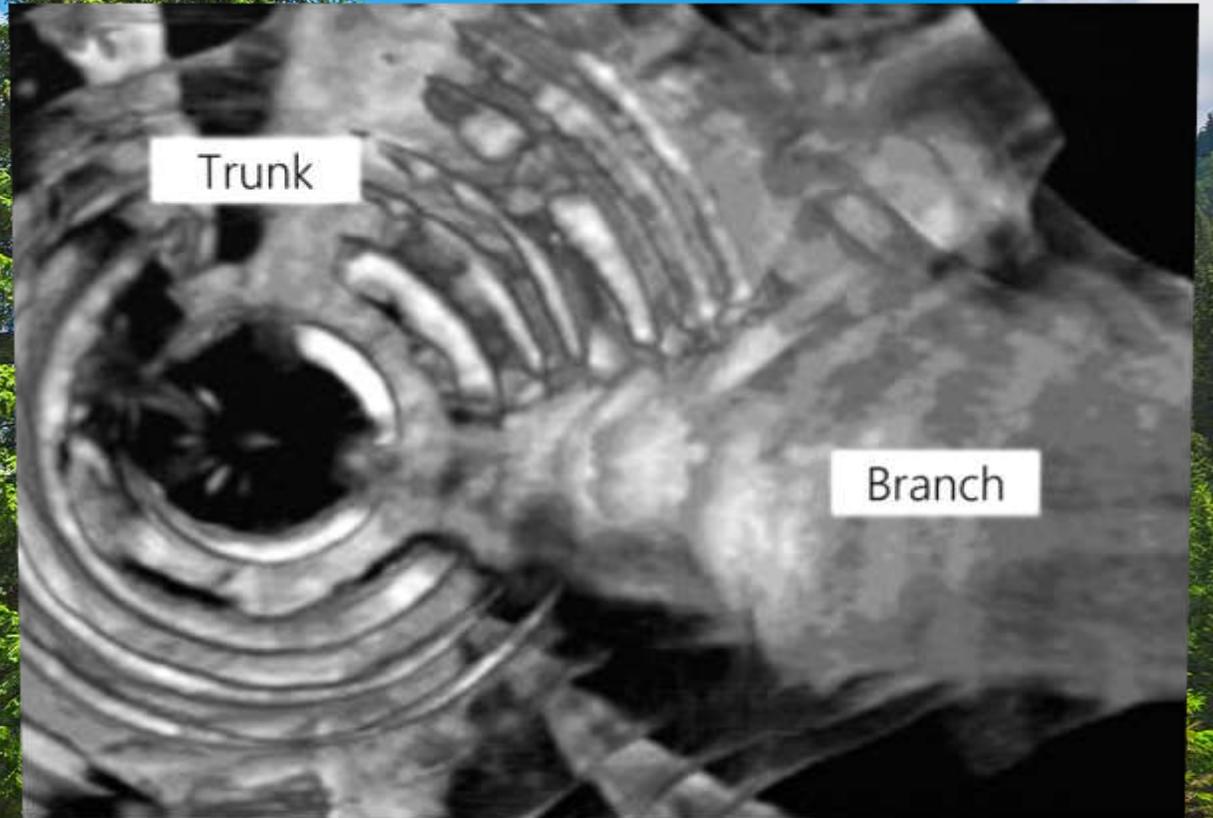
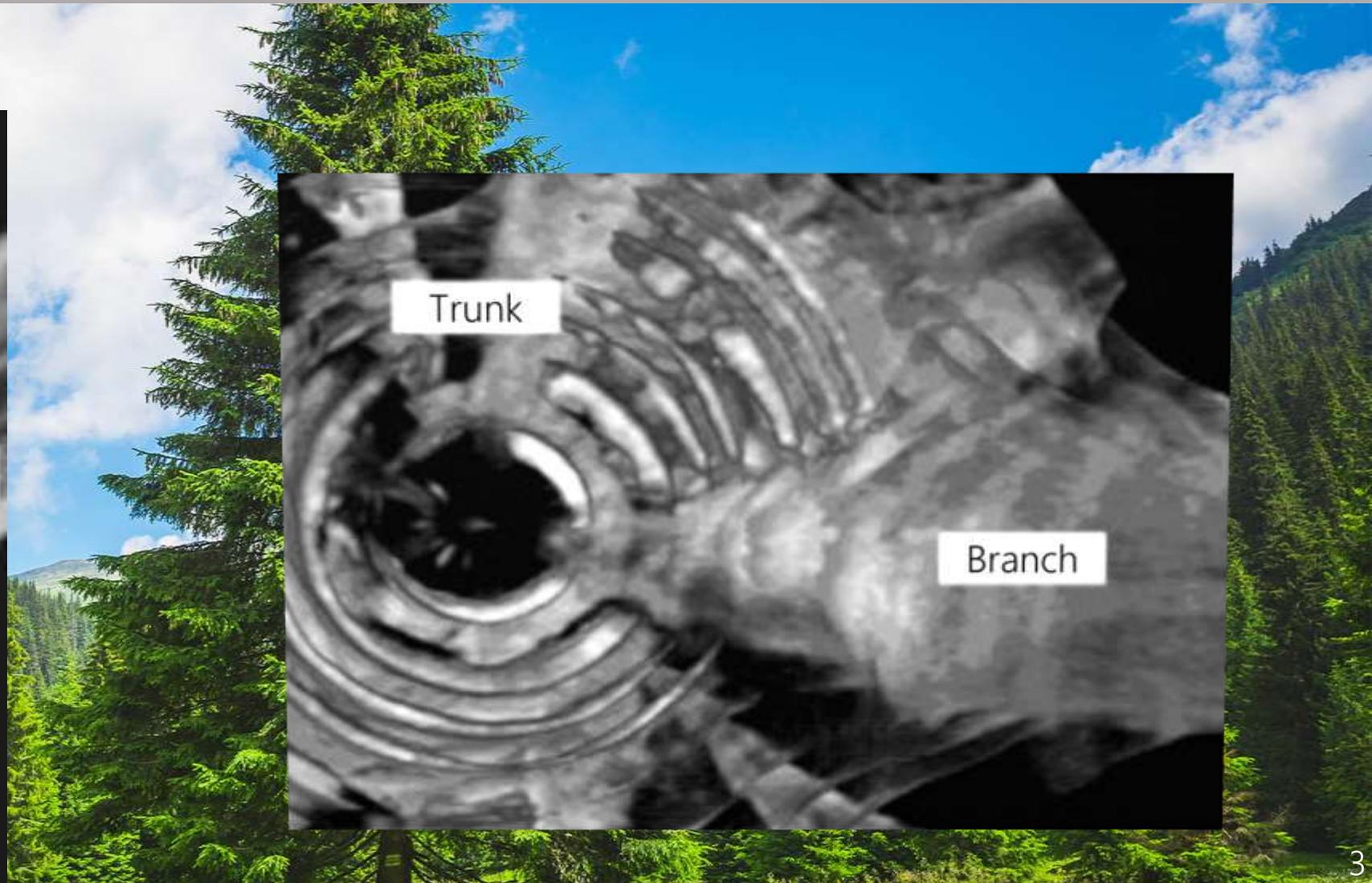
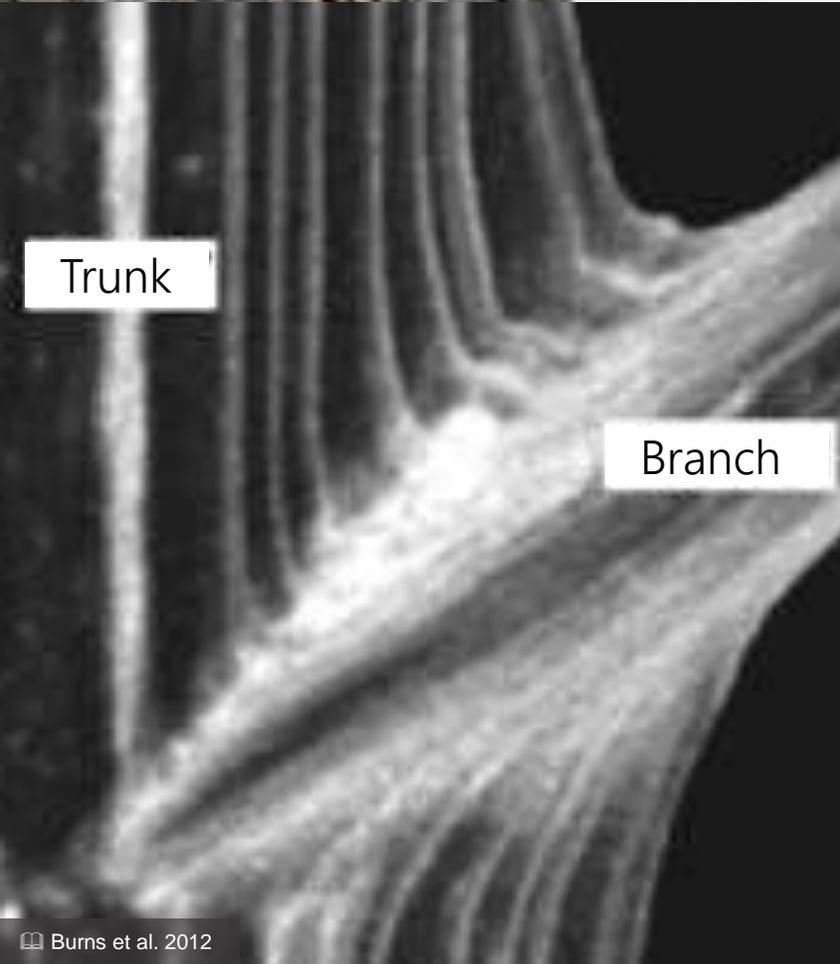
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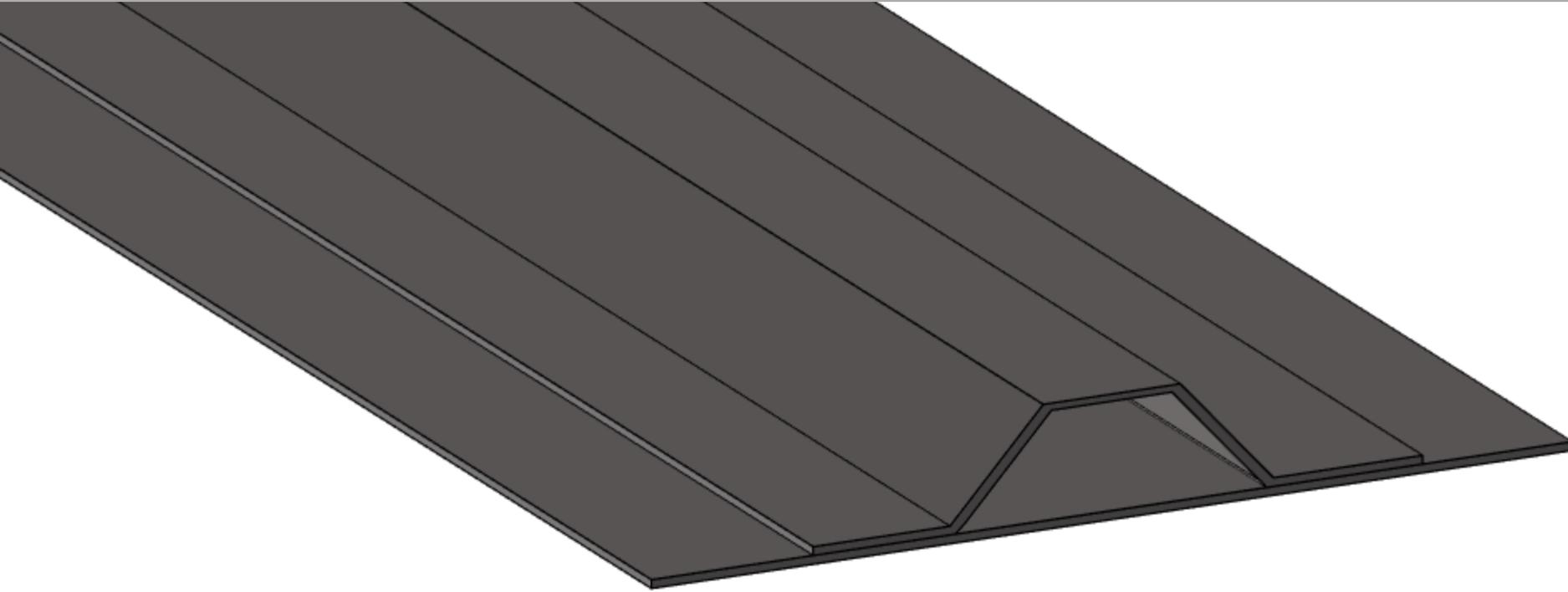
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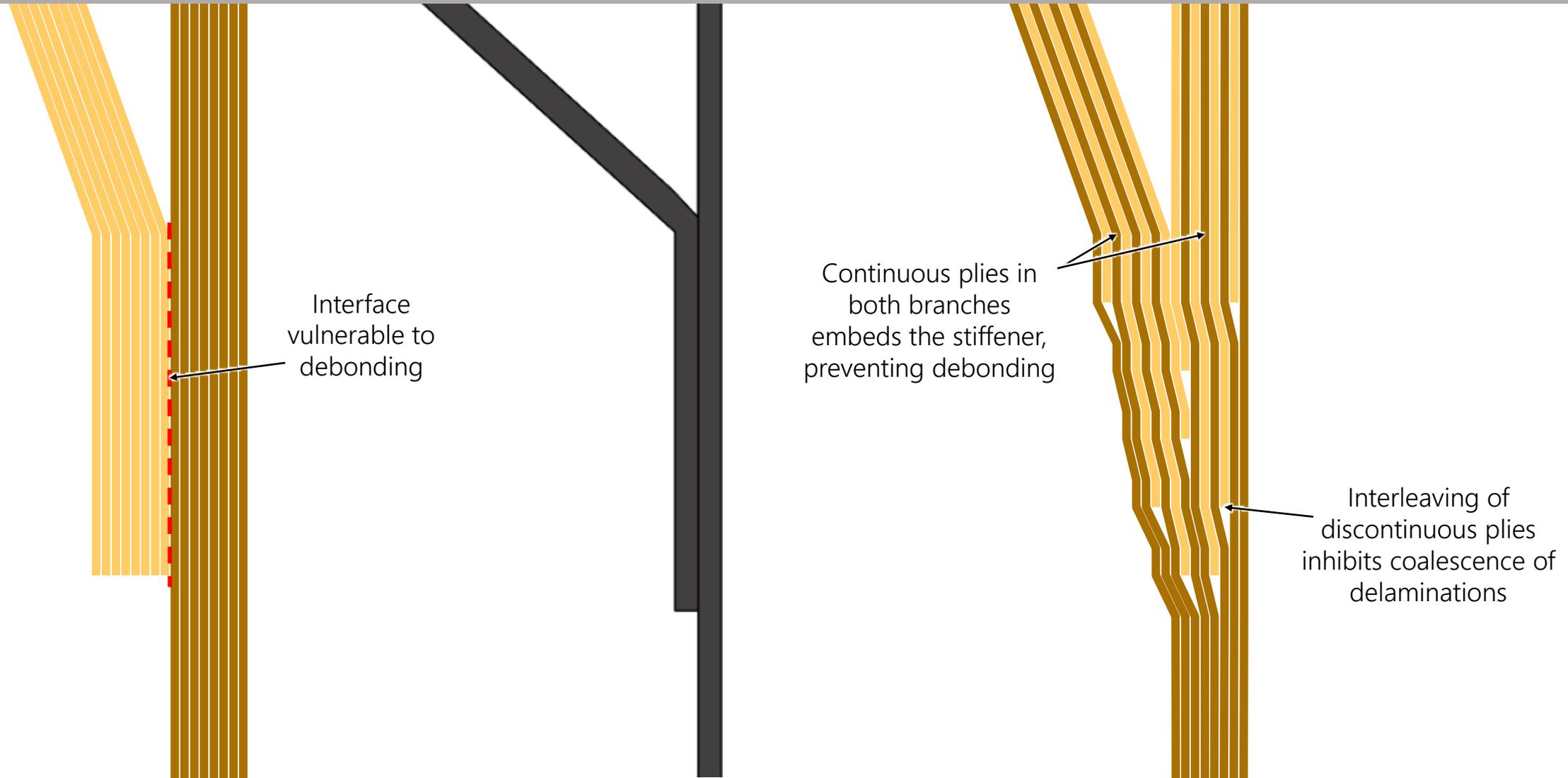
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Bio-inspired Damage Tolerant Design



Proposed Concept

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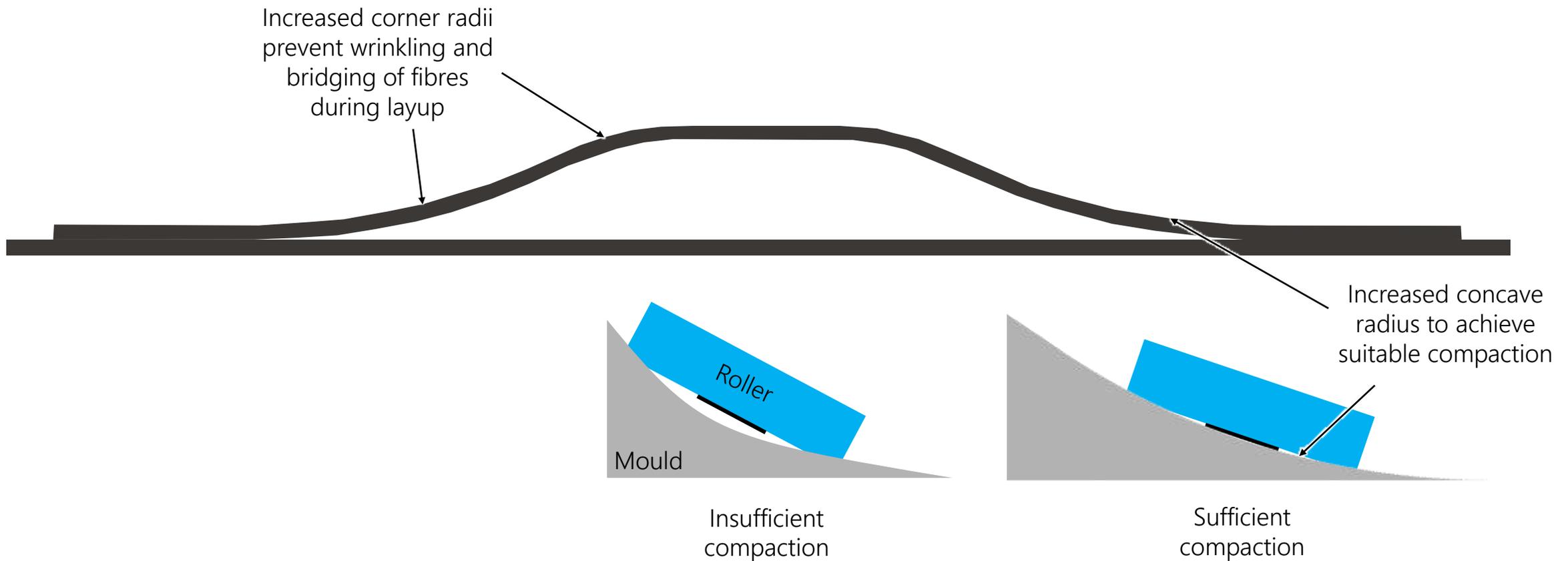
Proposed Concept

Design for AFP Manufacture



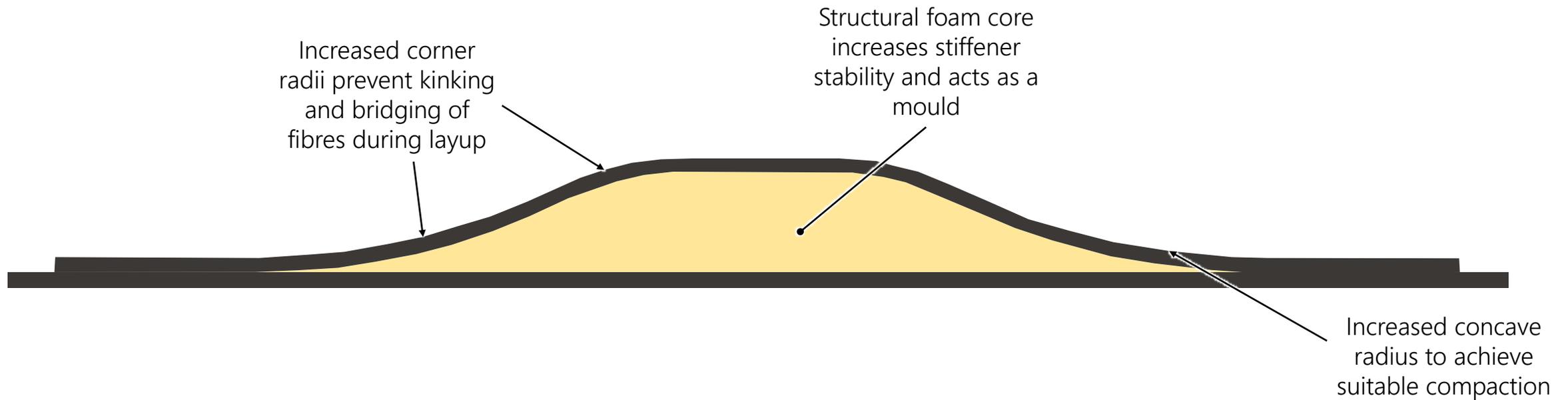
Proposed Concept

Design for AFP Manufacture

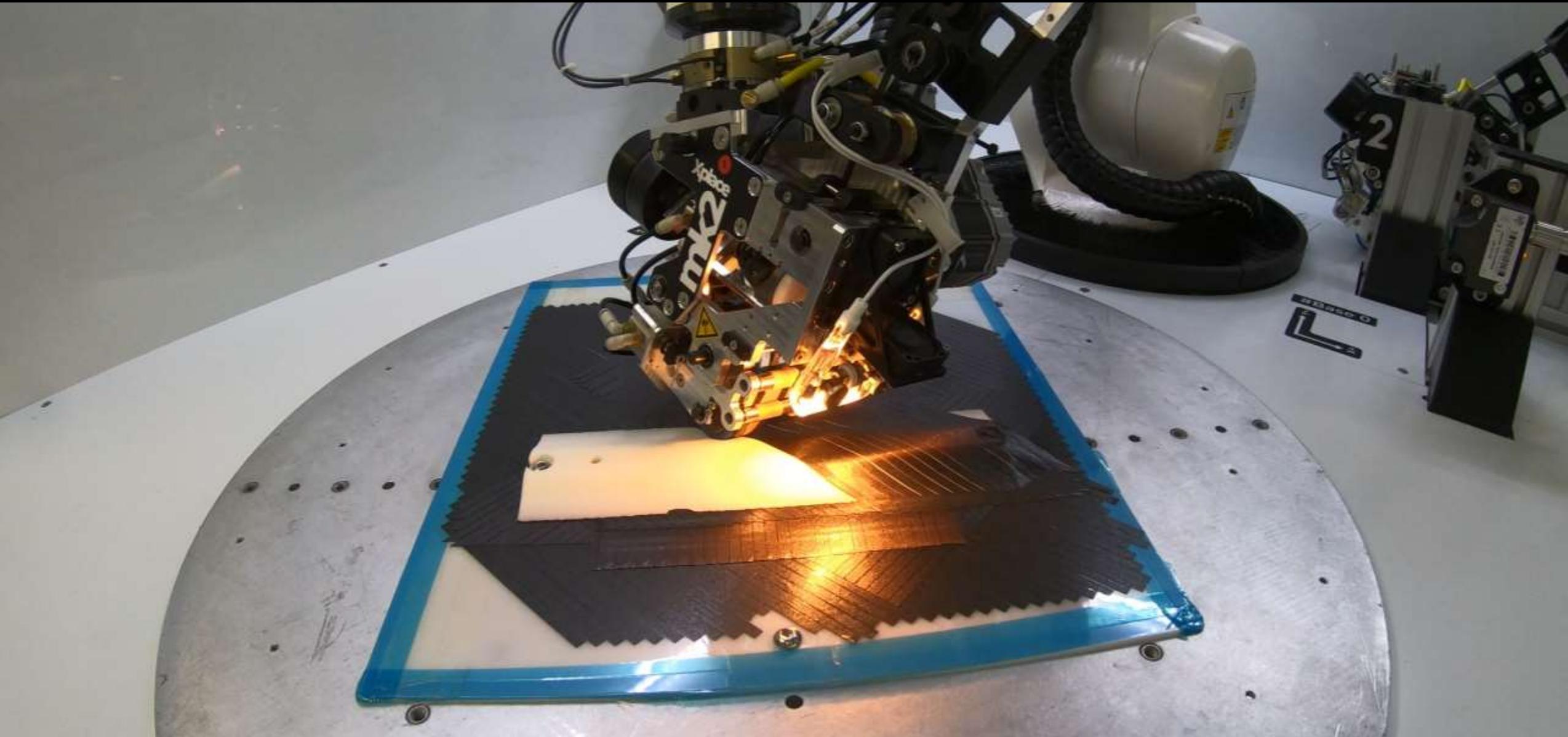


Proposed Concept

Design for AFP Manufacture

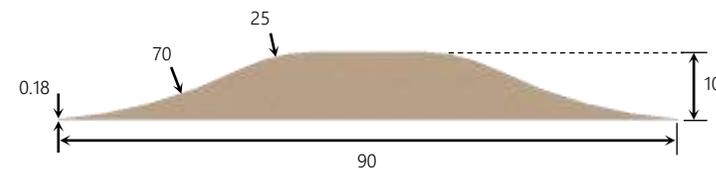
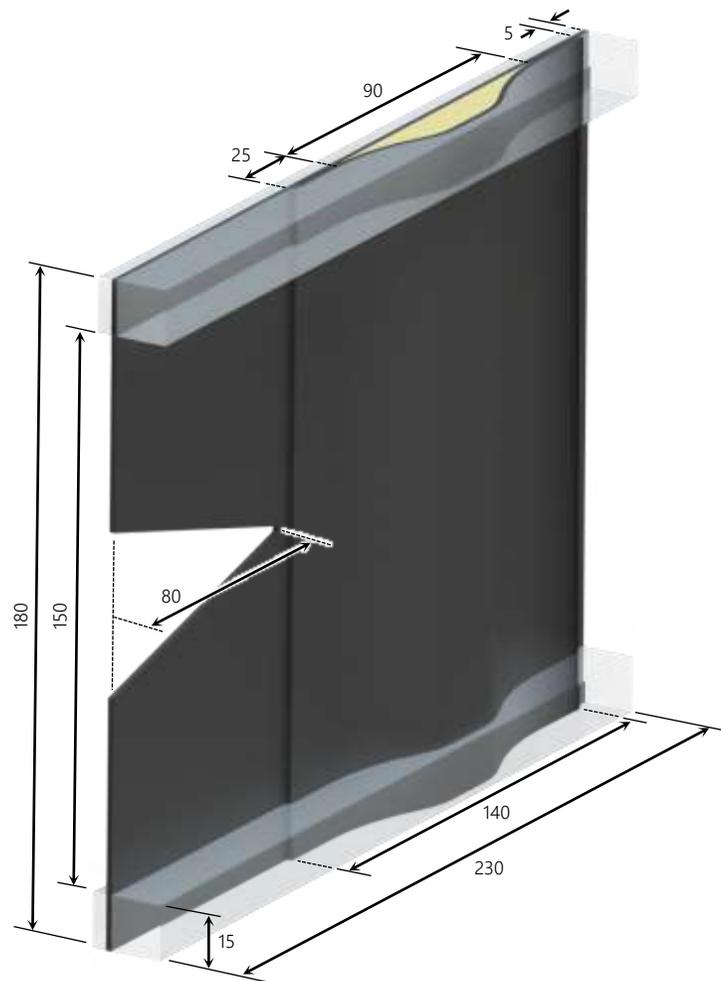


Concept Validation



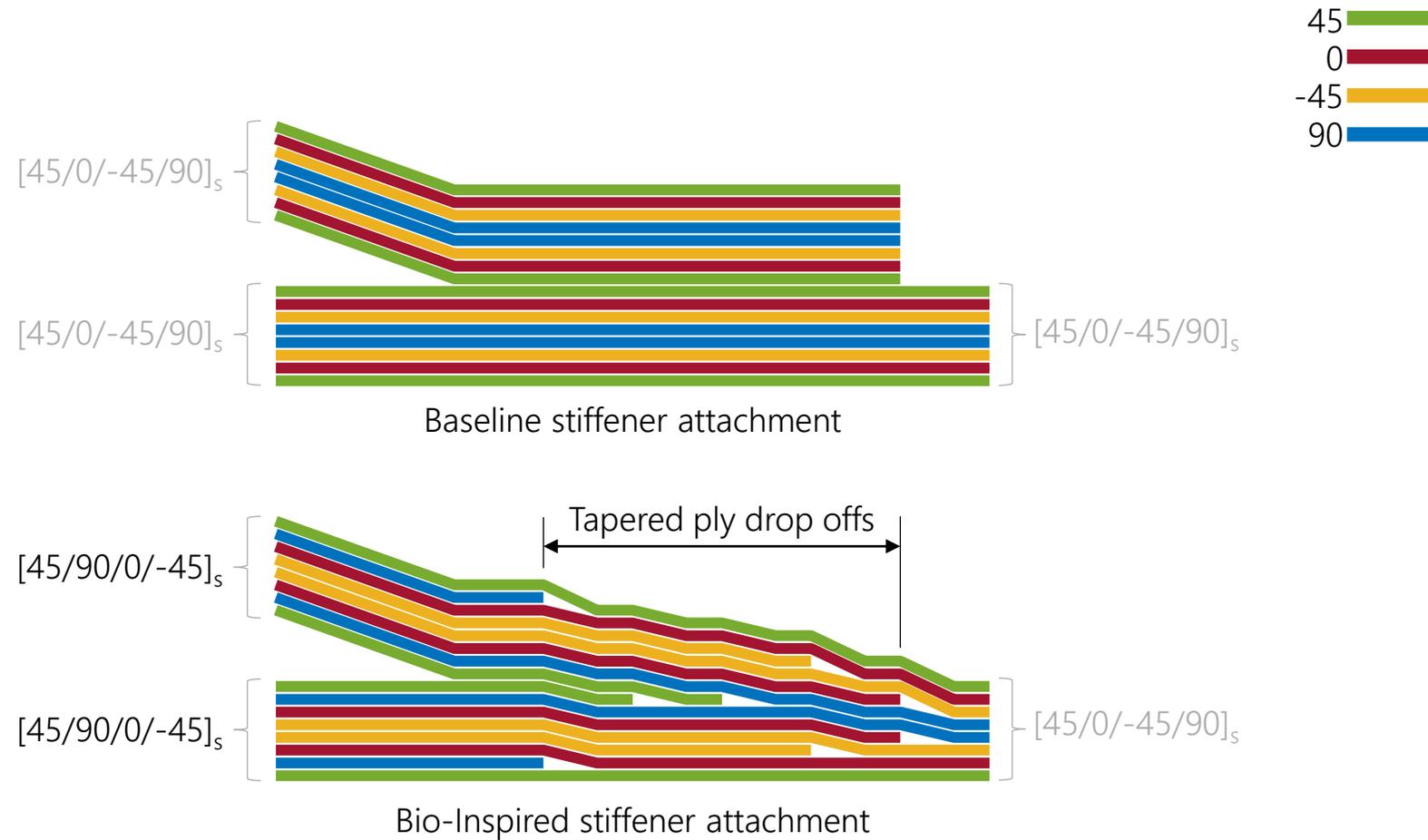
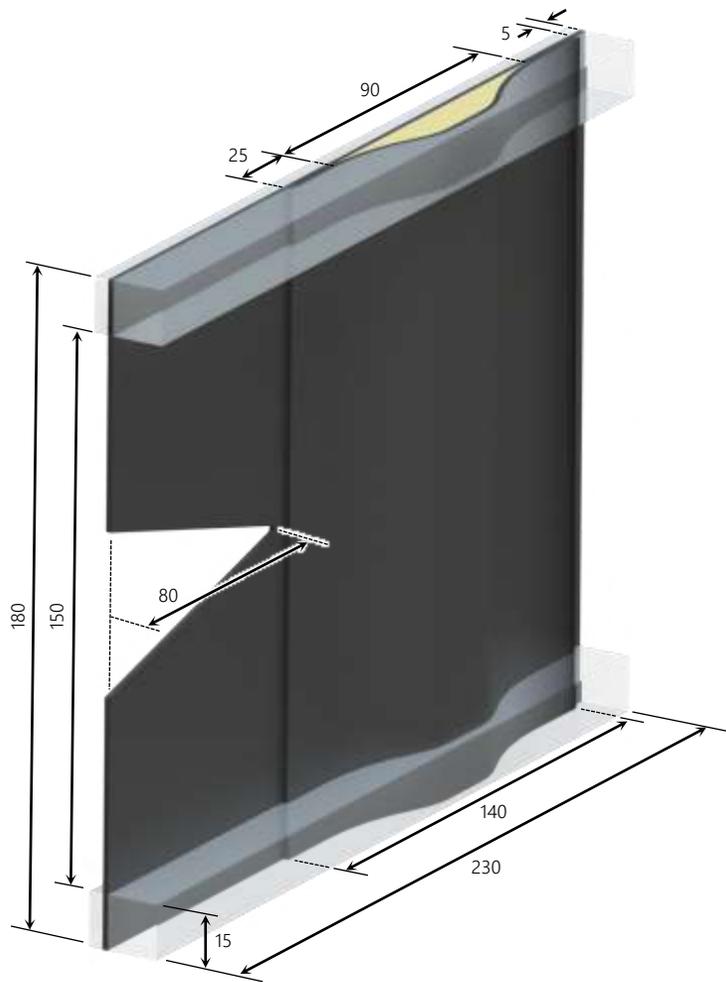
Concept Validation

Prototype Specimen



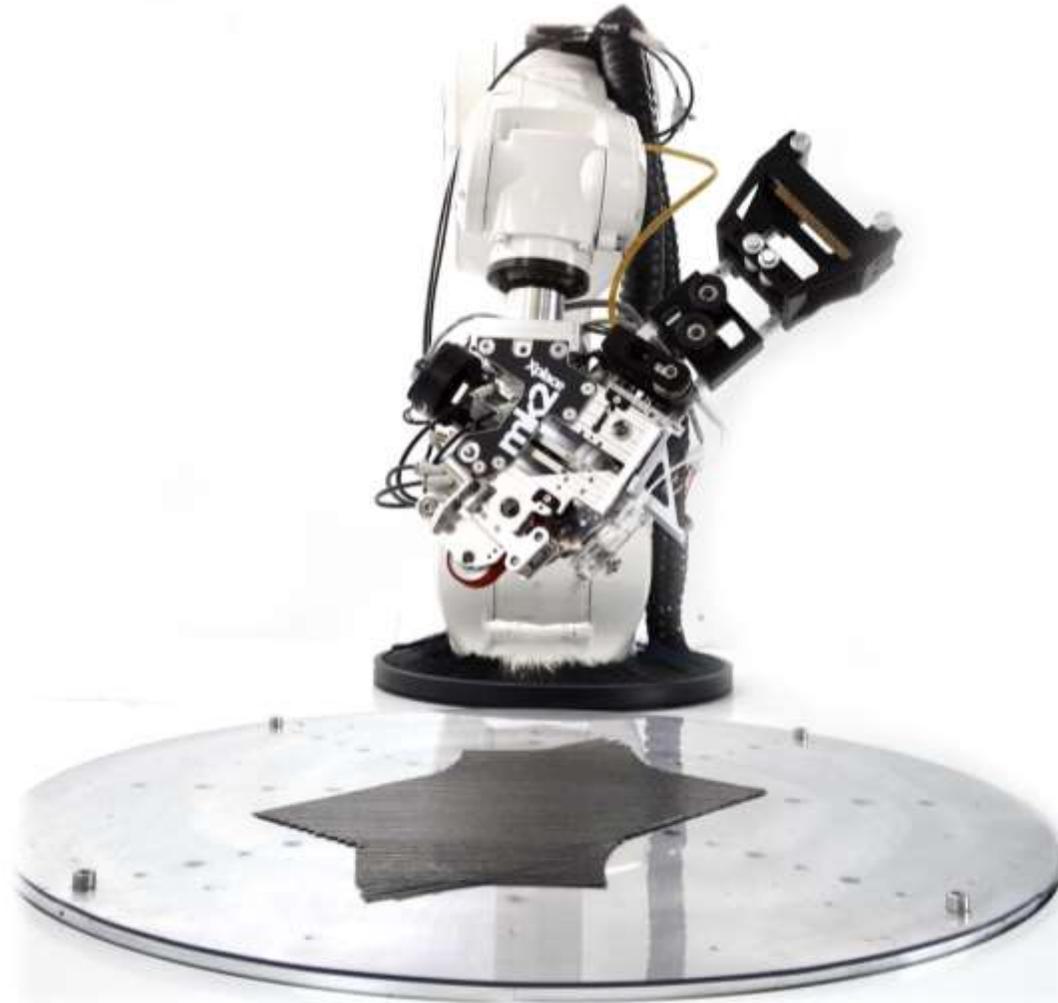
Concept Validation

Prototype Specimen



Concept Validation

Manufacturing Development



Concept Validation

Manufacturing Development



Concept Validation

Manufacturing Results



Baseline

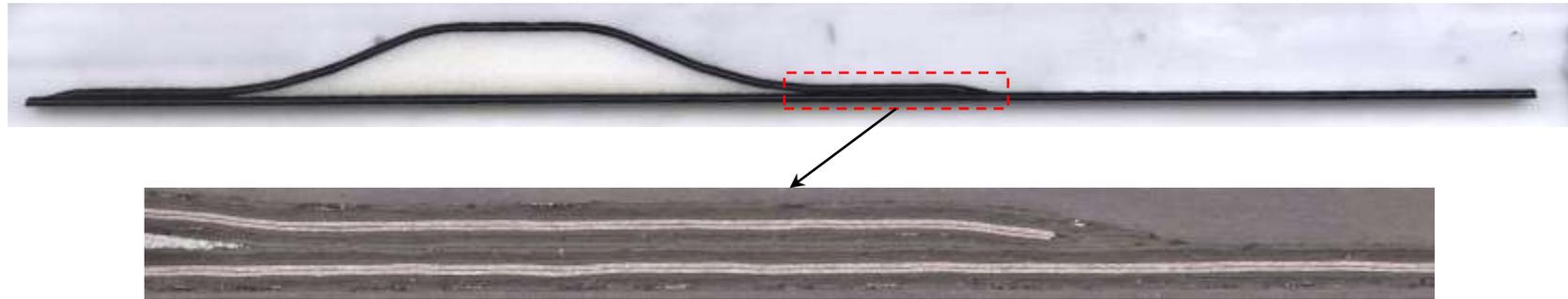


Bio-Inspired

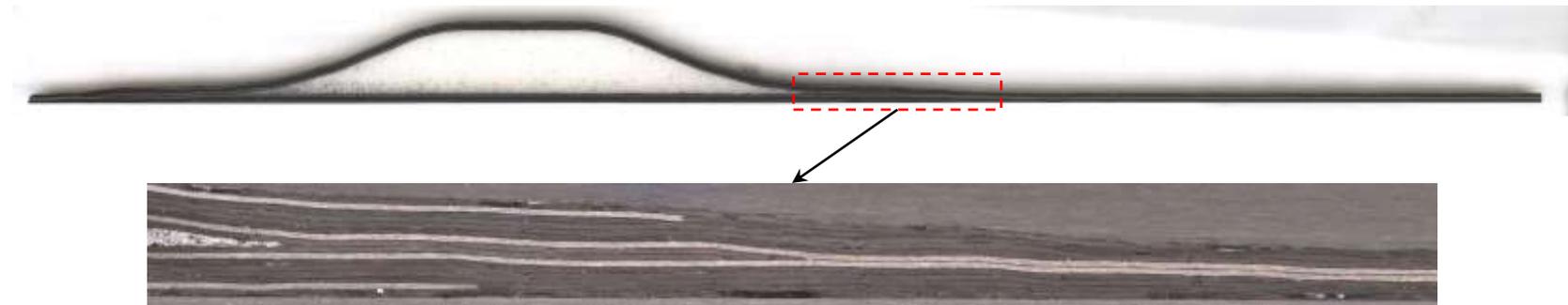
Concept Validation

Manufacturing Results

Baseline

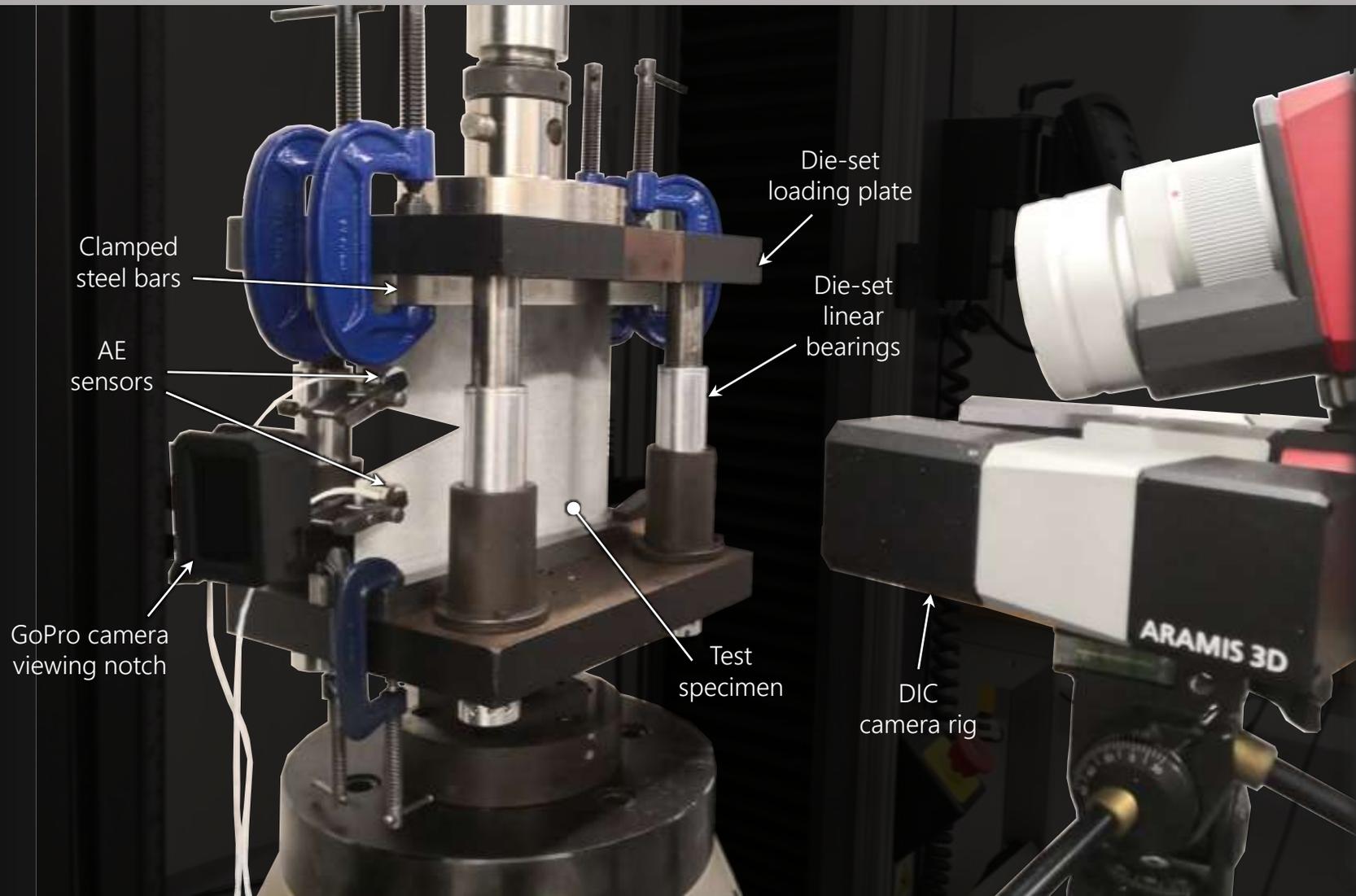


Bio-Inspired



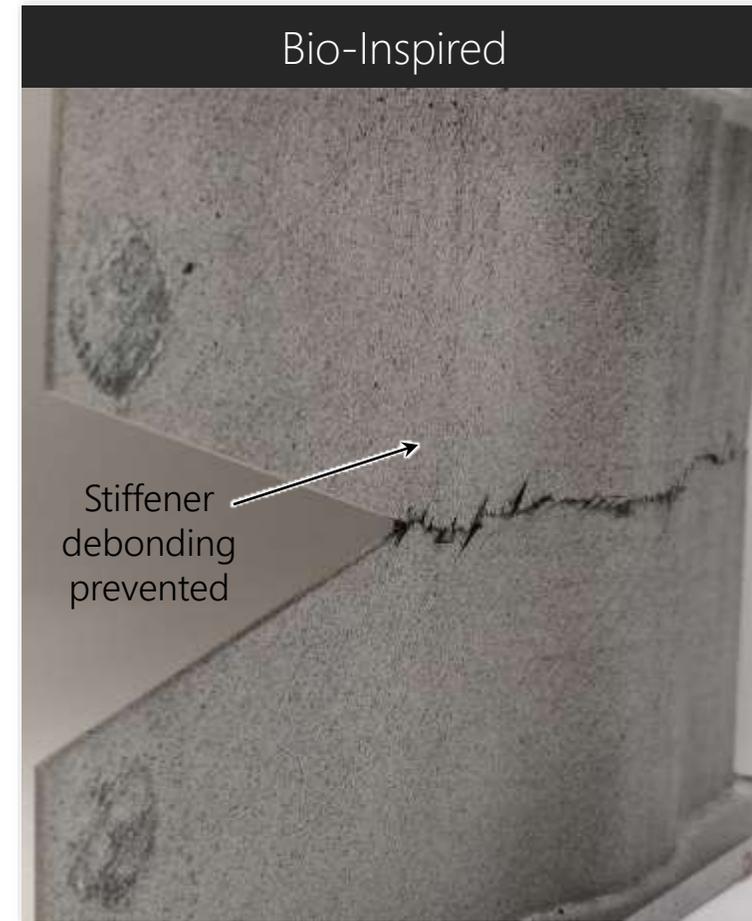
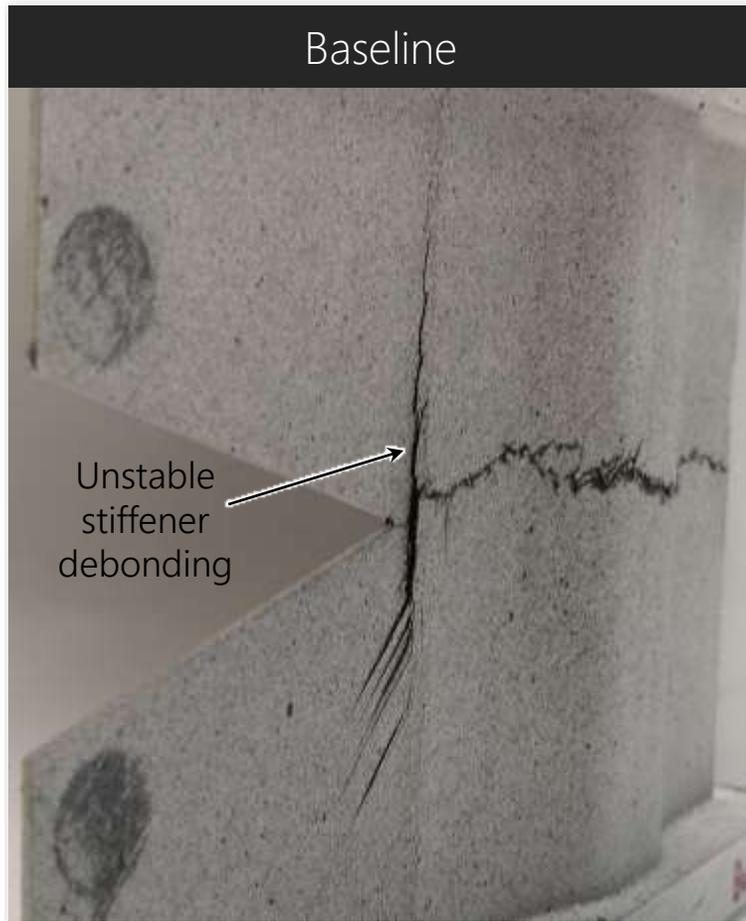
Concept Validation

Testing Setup



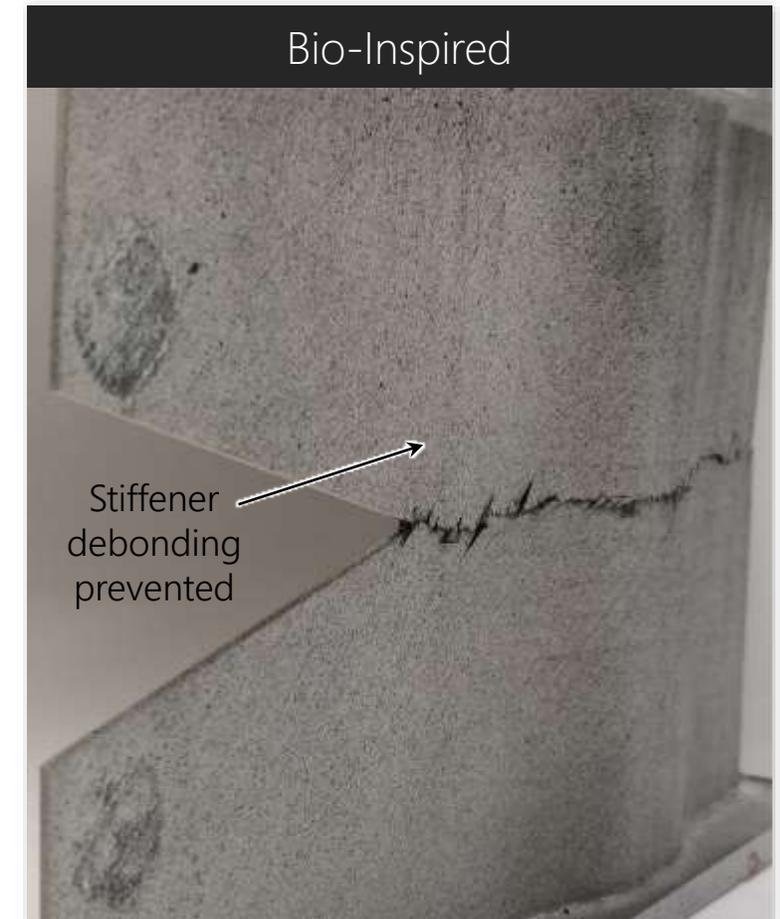
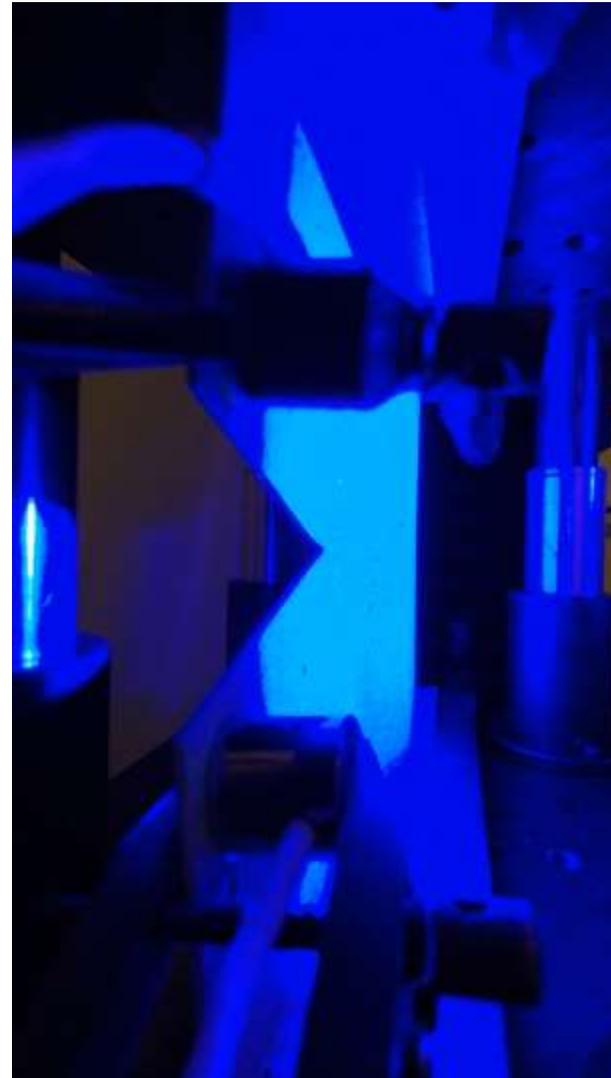
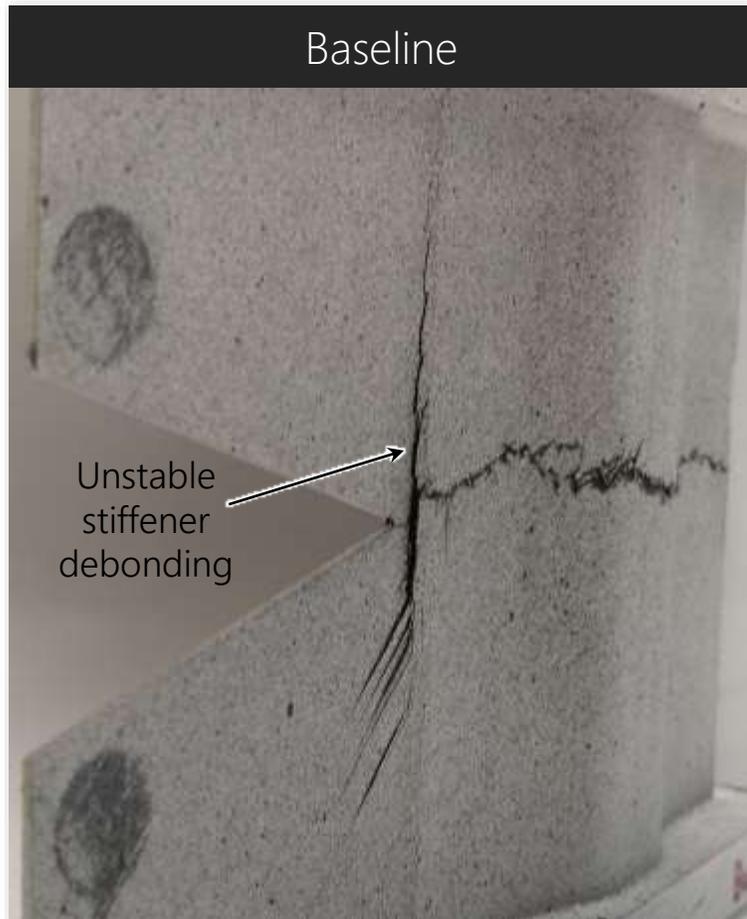
Concept Validation

Testing Results



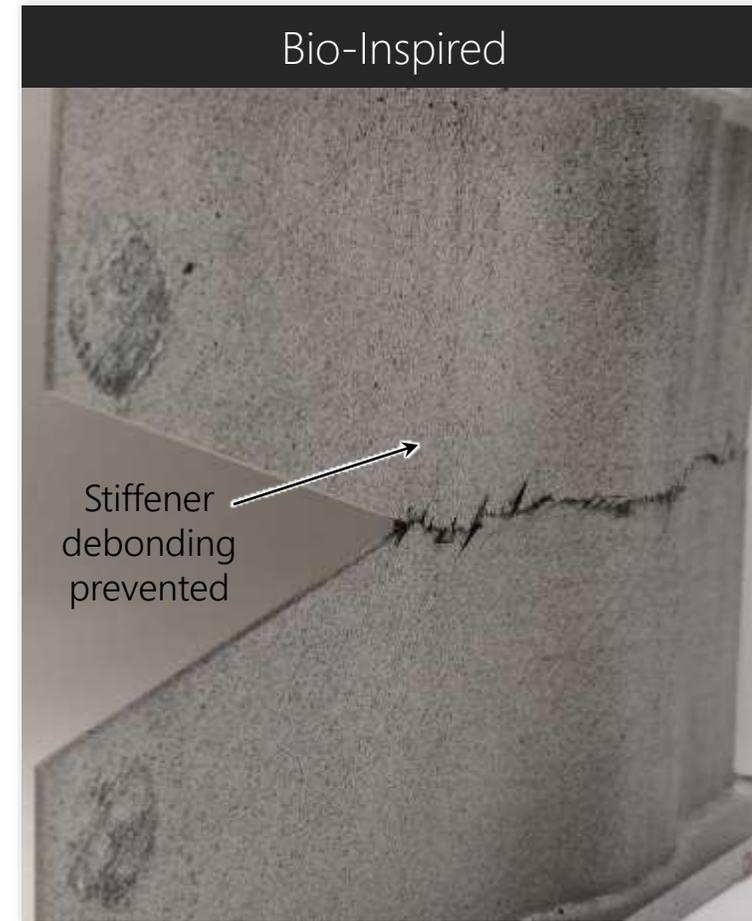
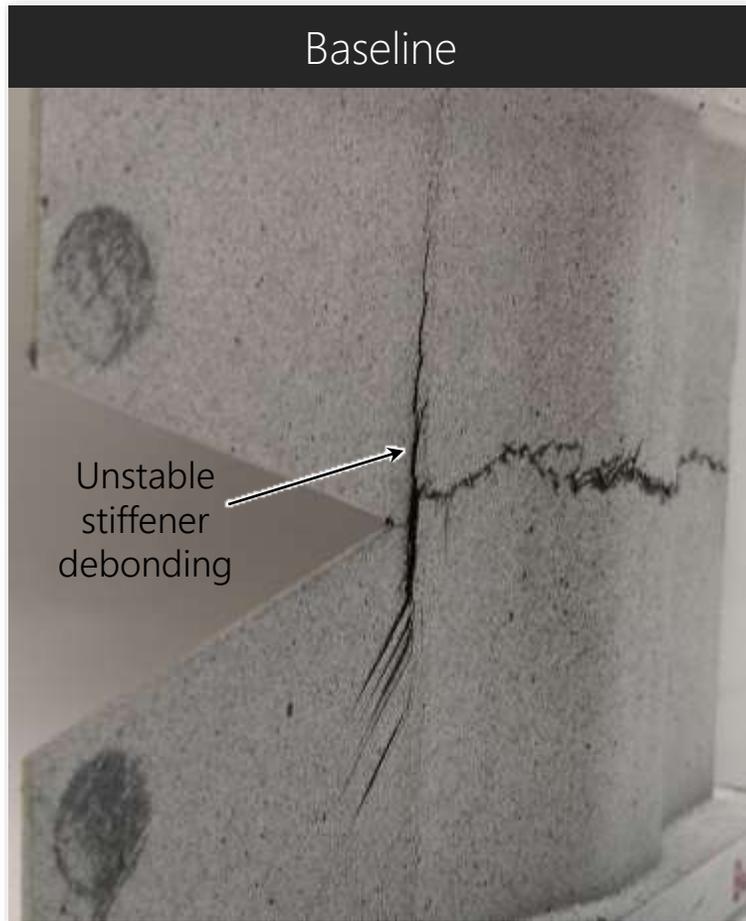
Concept Validation

Testing Results



Concept Validation

Testing Results



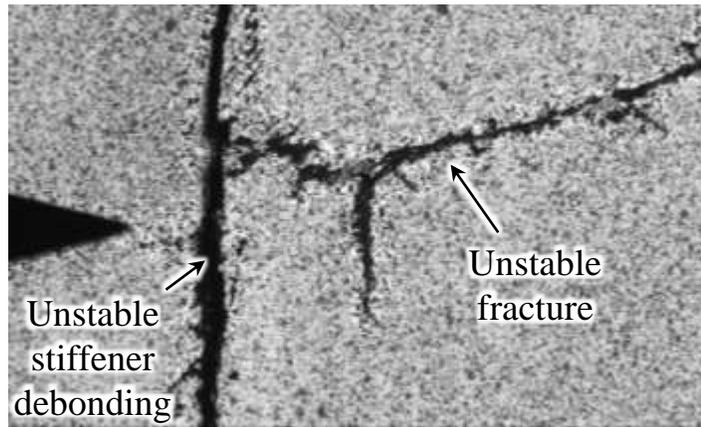
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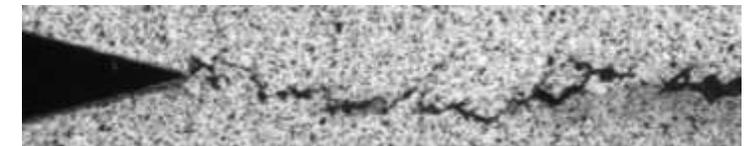
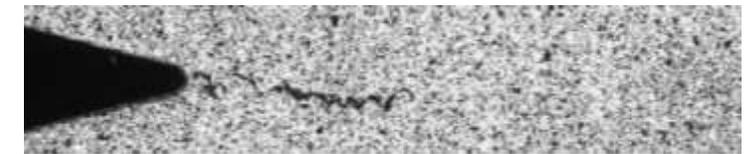
Baseline



Bio-Inspired



Baseline



Time

Bio-Inspired

Industrially Relevant Failure Sequence Investigation



Industrially Relevant Failure Sequence Investigation



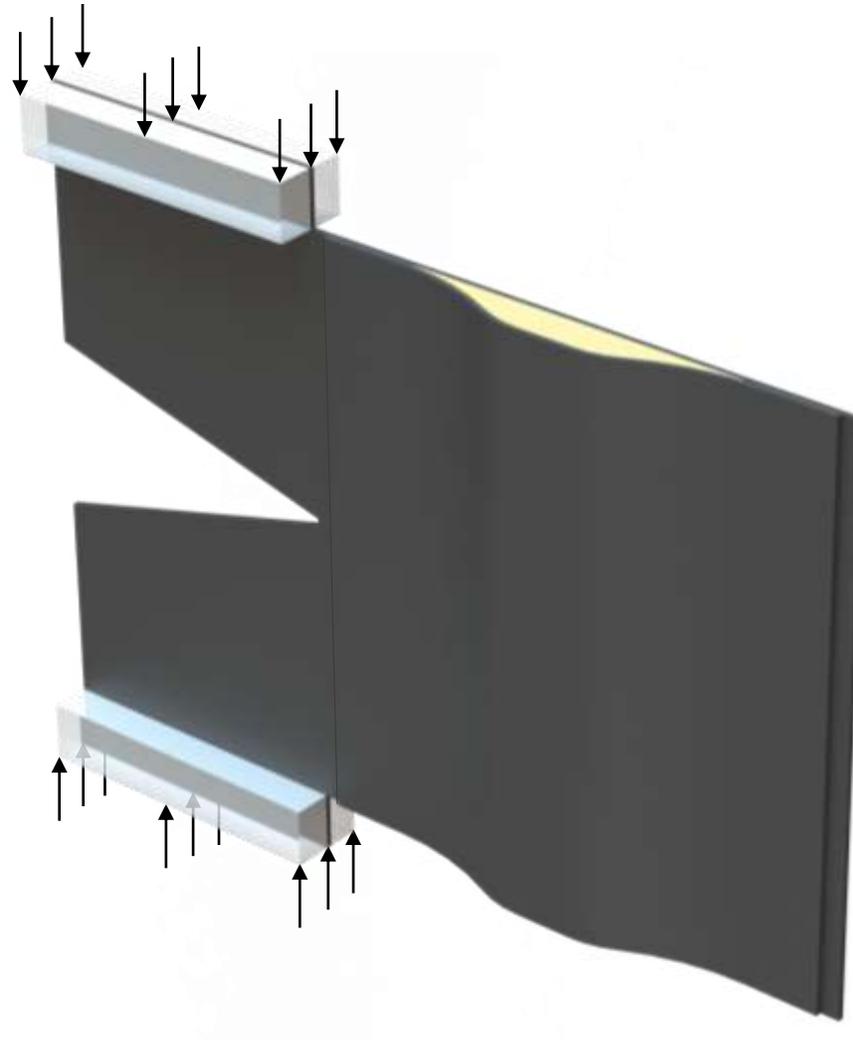
R.O.S.S. Costa et al. 2022

Sequence

1. Skin transfers load to stiffener, which provides support

Industrially Relevant Failure Sequence Investigation

Specimen Design

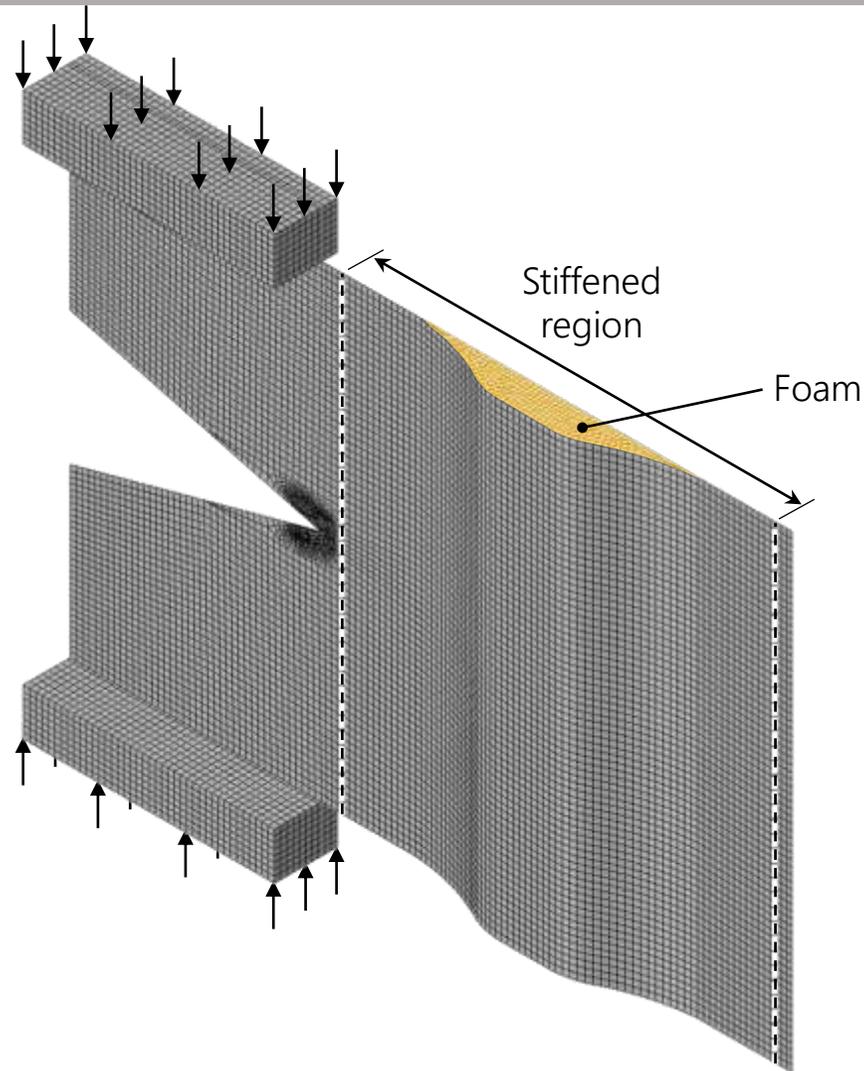


Sequence

1. ✓ Skin transfers load to stiffener, which provides support
2. Local skin instability
3. Translaminar fracture of skin propagates towards stiffener

Industrially Relevant Failure Sequence Investigation

Model Development

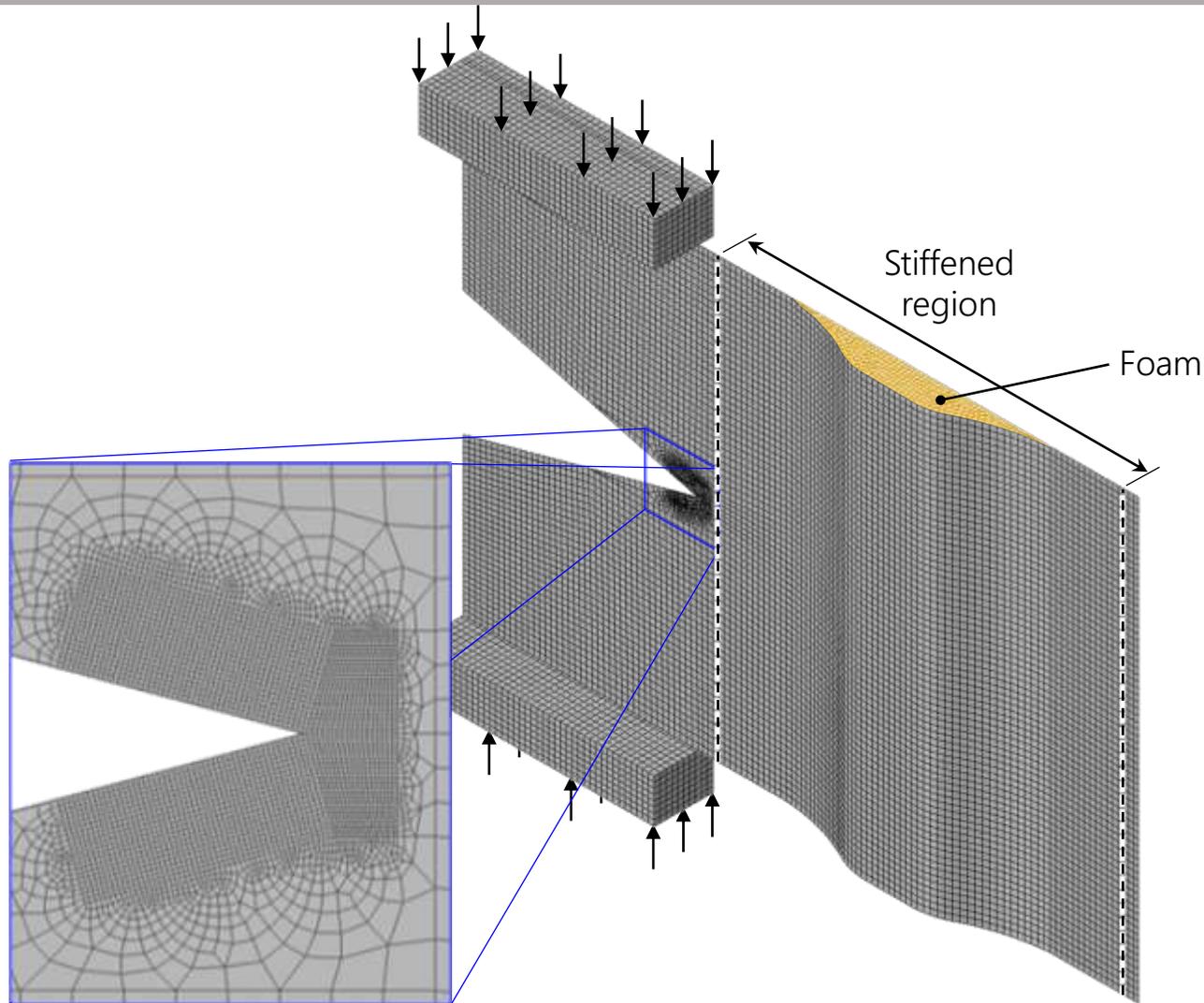


Sequence

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Industrially Relevant Failure Sequence Investigation

Model Development

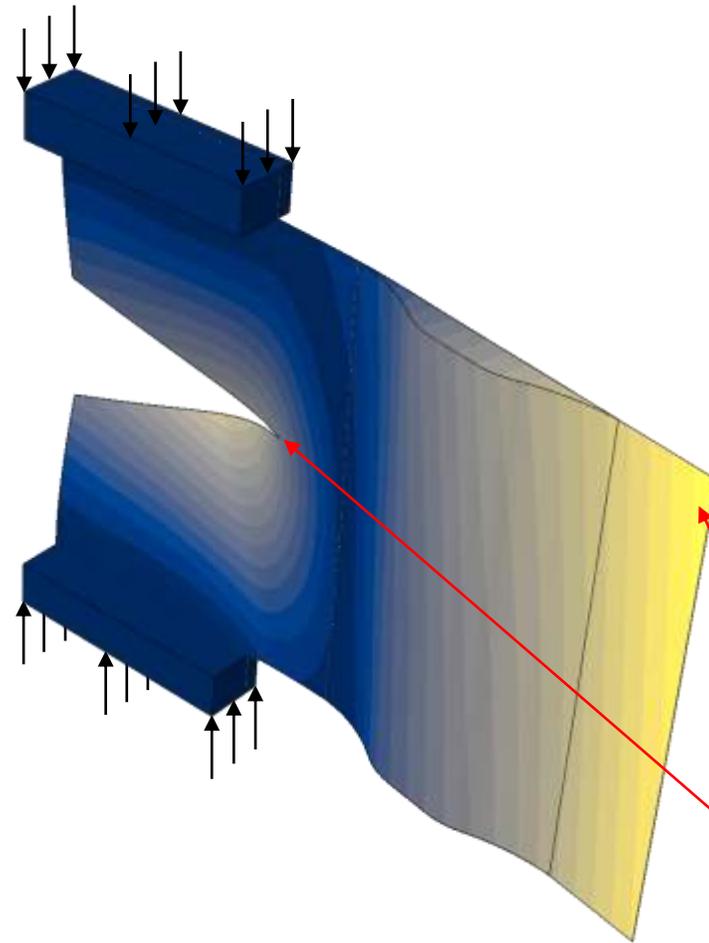


Sequence

1. ✓ Skin transfers load to stiffener, which provides support
2. Local skin instability
3. Translaminar fracture of skin propagates towards stiffener

Industrially Relevant Failure Sequence Investigation

1st Iteration



Sequence

1. ✓ Skin transfers load to stiffener, which provides support
2. ✗ Local skin instability
3. Translaminar fracture of skin propagates towards stiffener

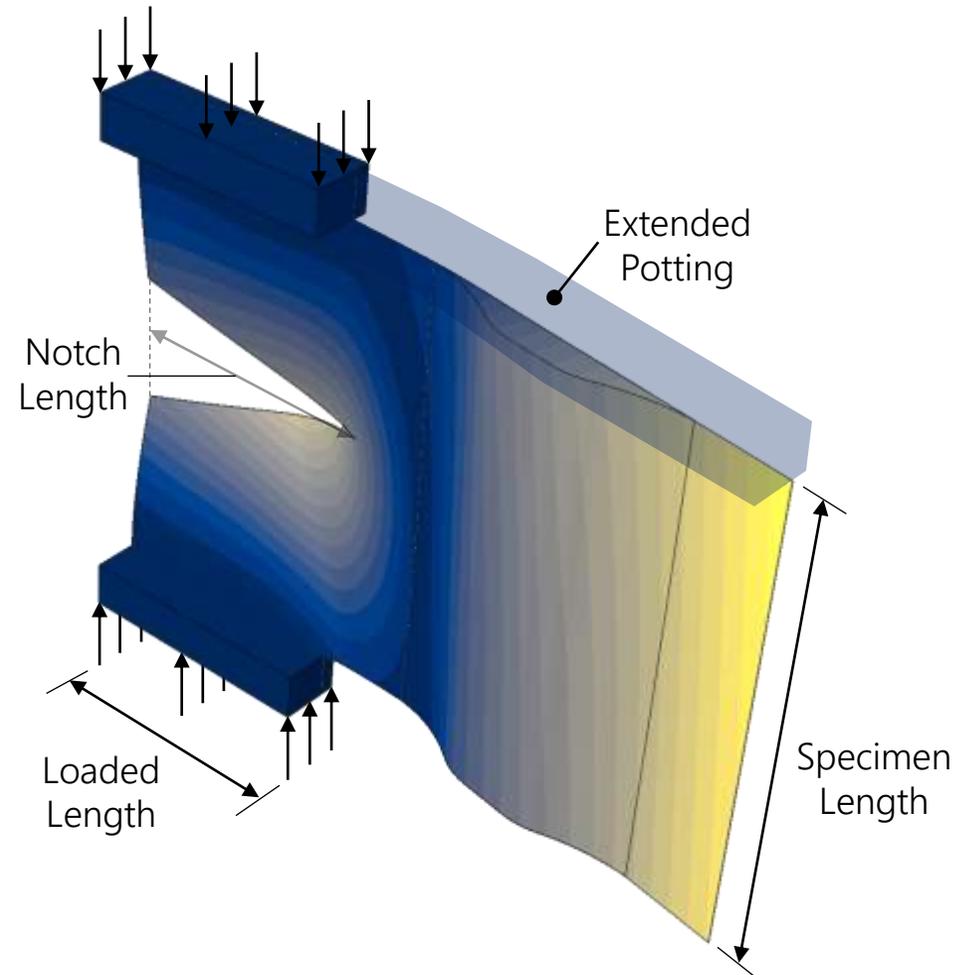
Out-of-plane Buckling: 7.45 kN

Fracture Propagation: 15.4 kN



Industrially Relevant Failure Sequence Investigation

Parametric Study



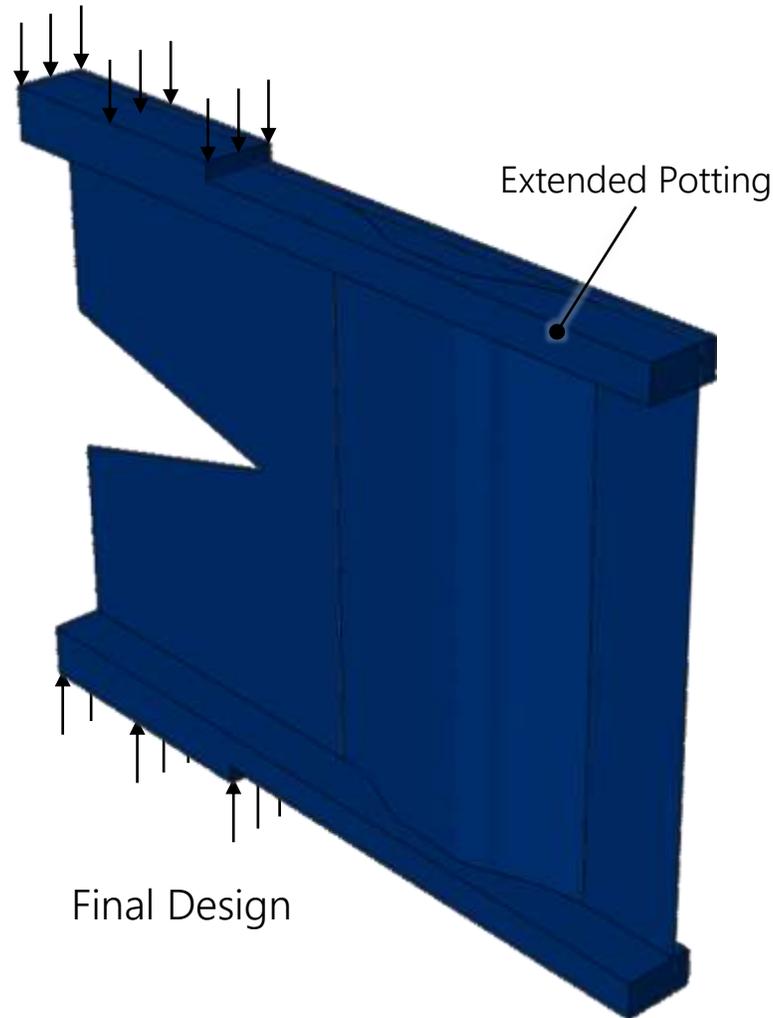
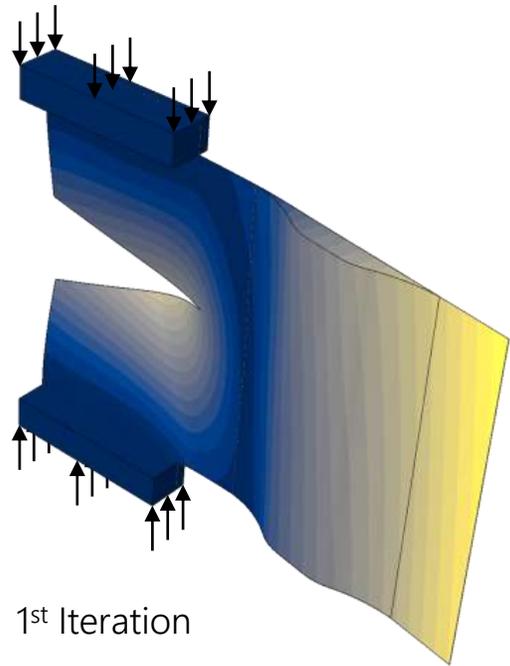
Sequence

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Industrially Relevant Failure Sequence Investigation

Parametric Study Results

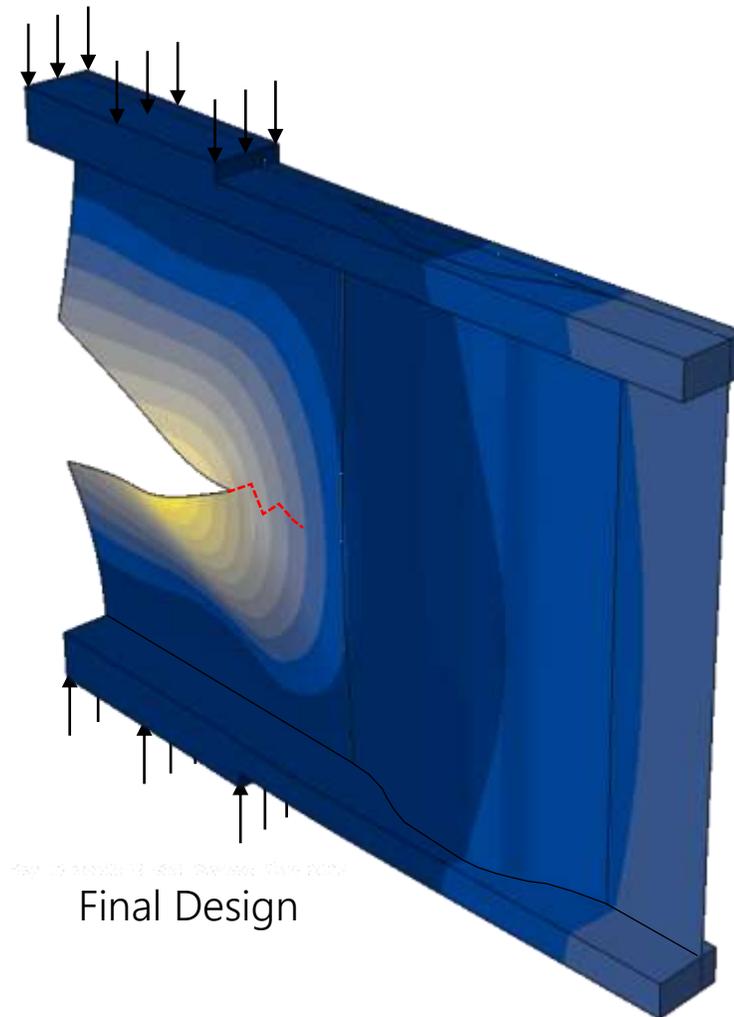
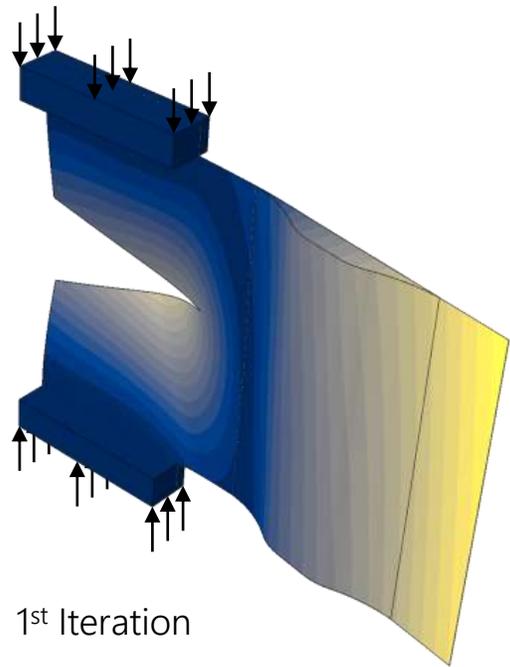


Sequence	
1. ✓	Skin transfers load to stiffener, which provides support
2.	Local skin instability
3.	Translaminar fracture of skin propagates towards stiffener



Industrially Relevant Failure Sequence Investigation

Parametric Study Results

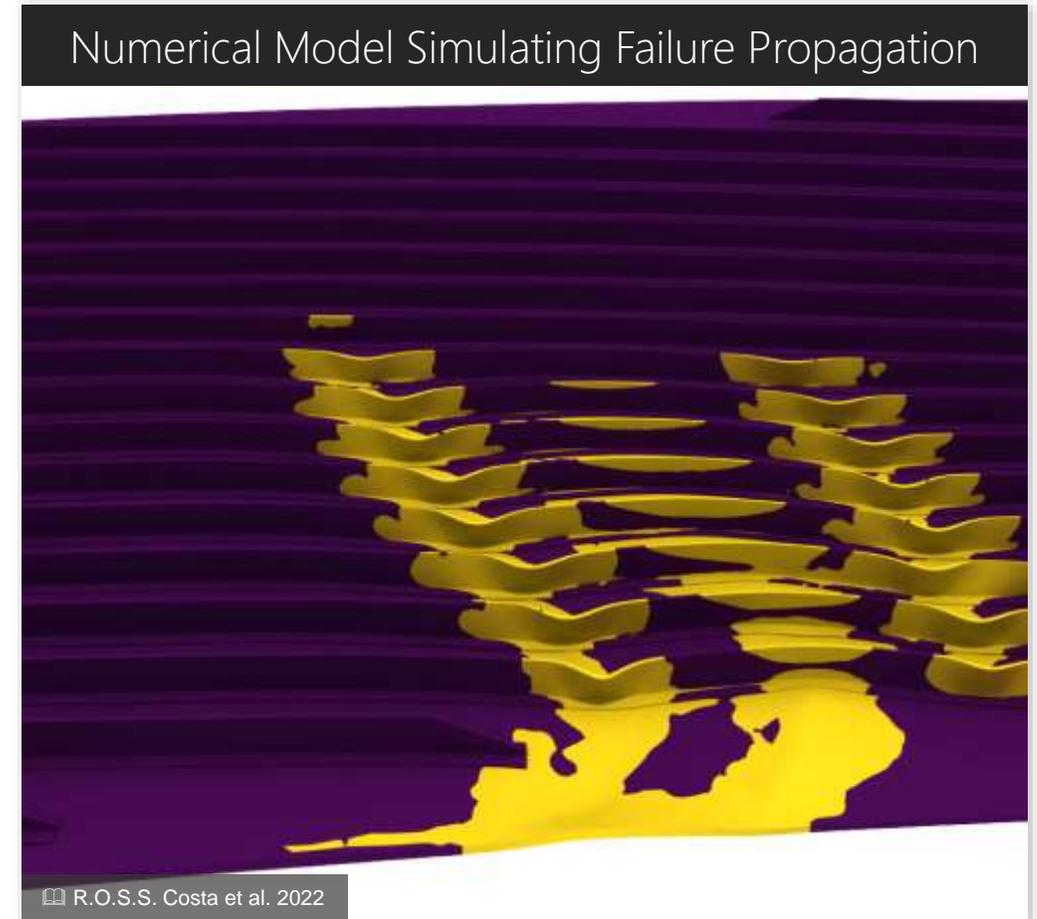
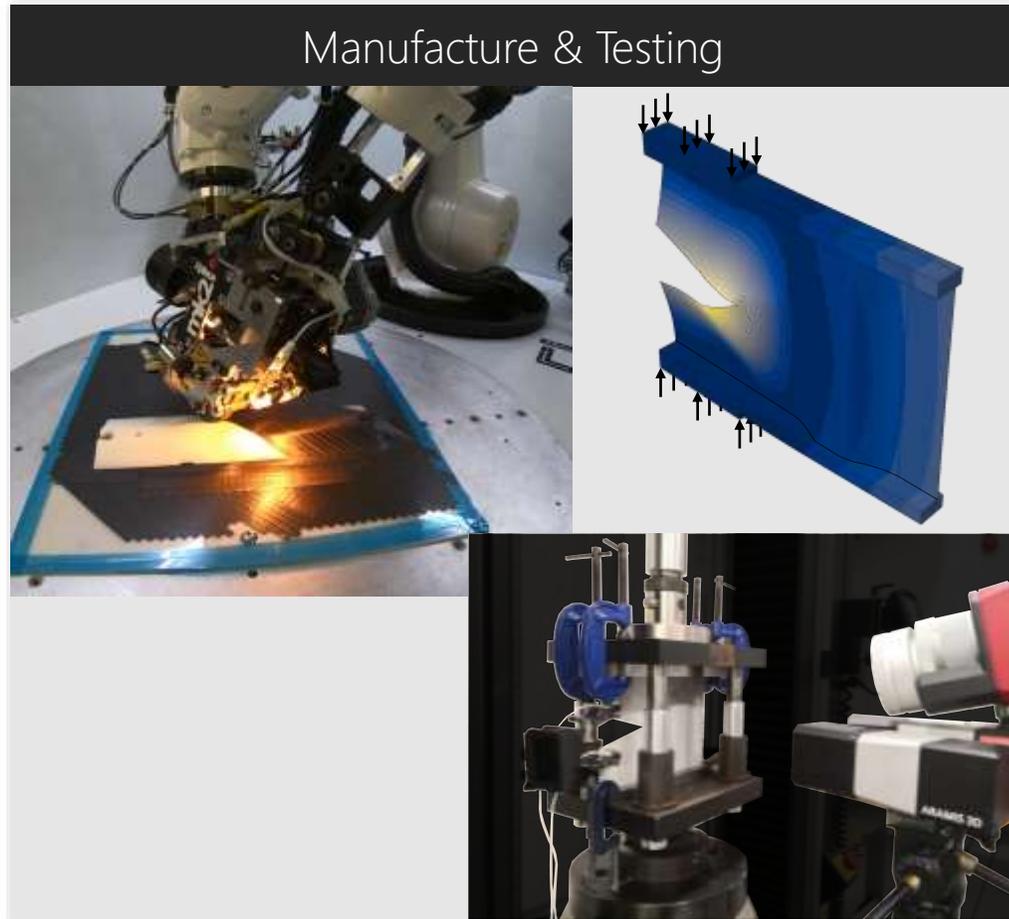


Sequence	
1. ✓	Skin transfers load to stiffener, which provides support
11.9 kN — 2. ✓	Local skin instability
18.5 kN — 3. ✓	Translaminar fracture of skin propagates towards stiffener



Industrially Relevant Failure Sequence Investigation

Next Steps

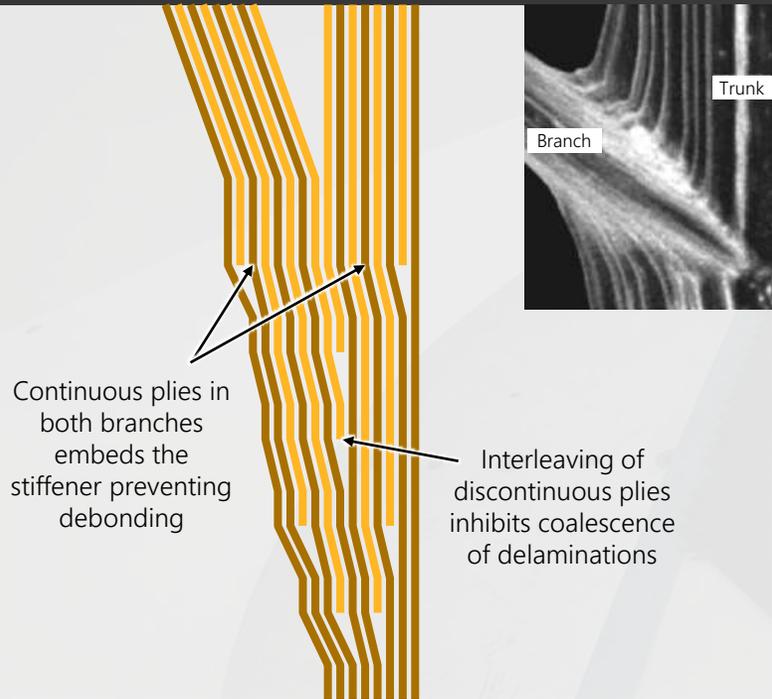


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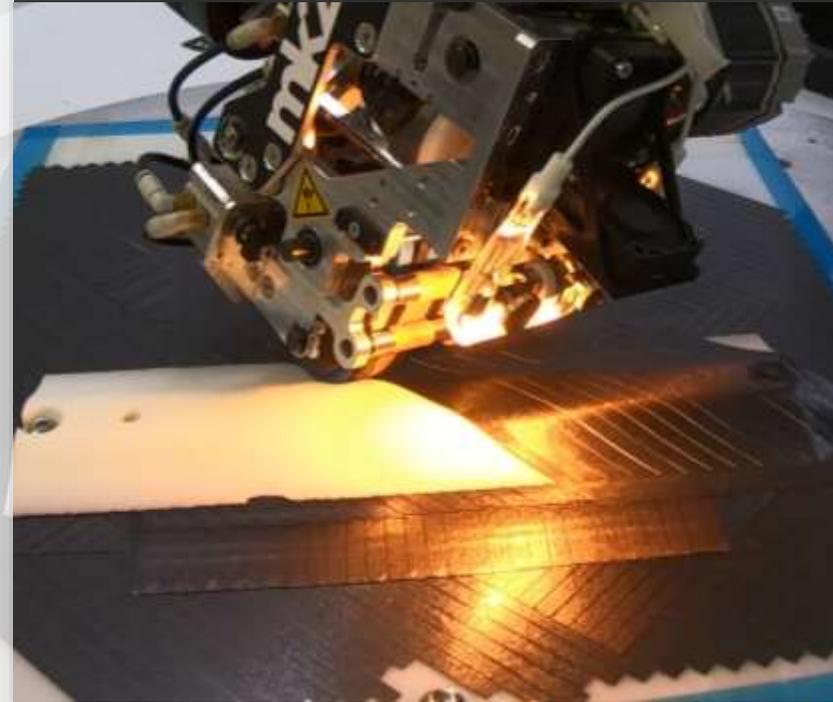
A.D. Whitehouse, Y. Yang, V. Médeau, L. Mencattelli, E. Greenhalgh, S.T. Pinho

CompTest 2023
Girona, Spain
May 31 – June 2

Bio-inspired Concept



Successful Validation



Key Points

- Successful validation of bio-inspired concept:
 - AFP manufacture of composite stiffened panels achieved
 - Experimental testing demonstrated suppressed debonding and stable crack propagation
- Numerical parametric study completed informing current experimental investigation for industrial load case

