ULTRATHIN CARBON FIBRE LAMINATES IN SPACE APPLICATIONS

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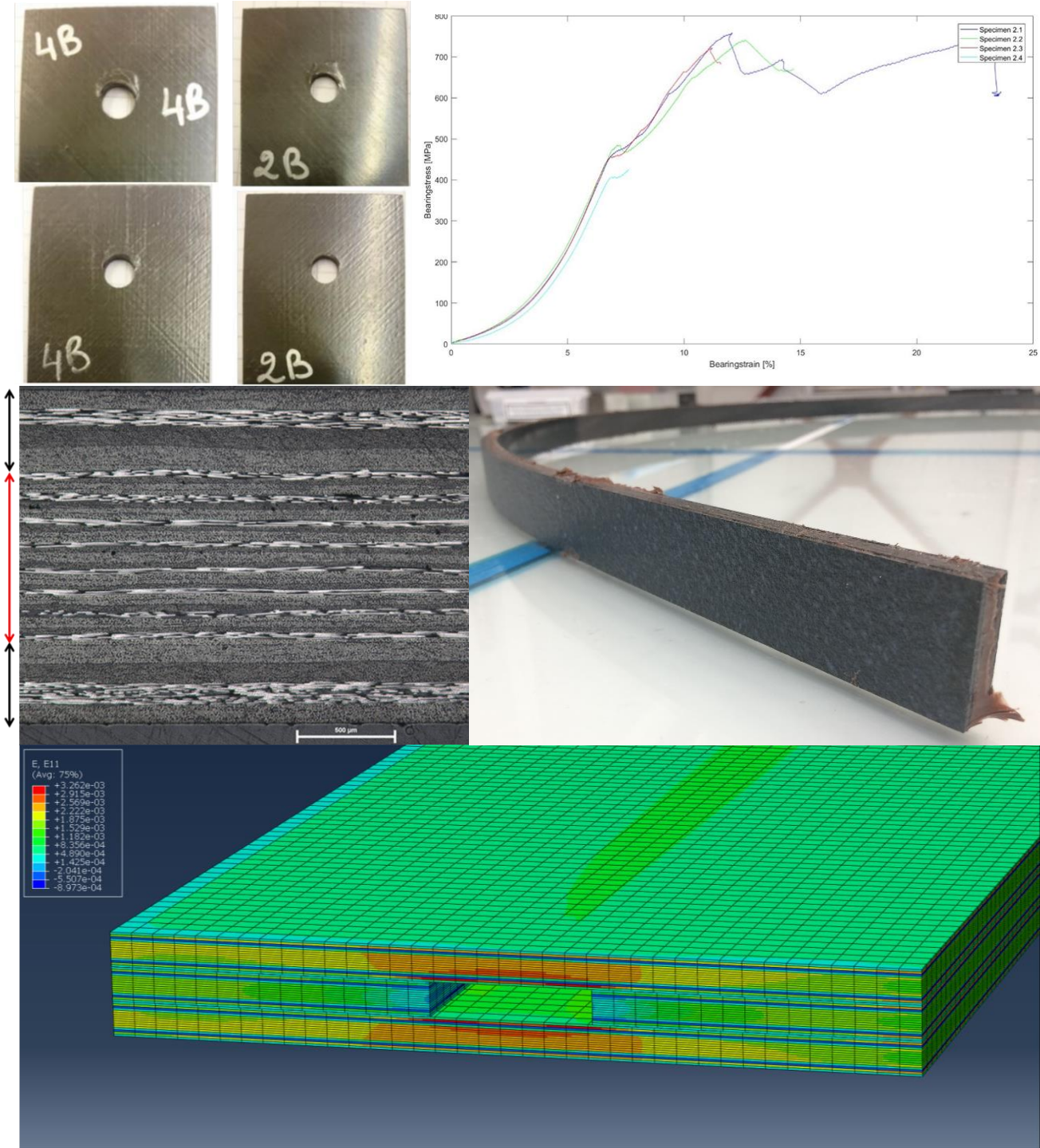
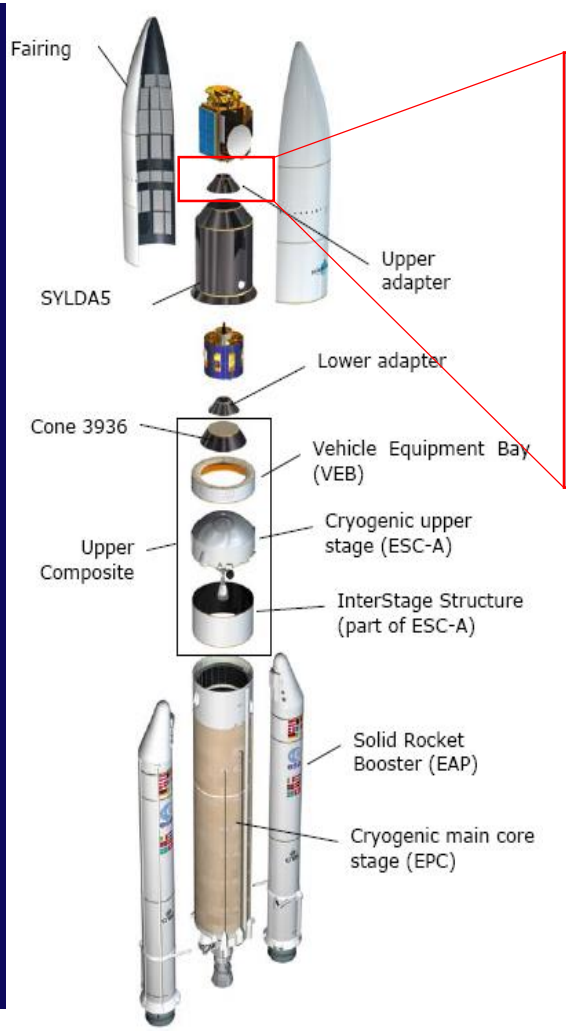
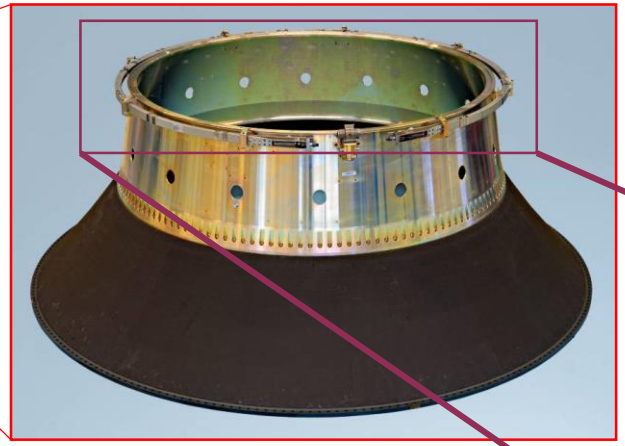
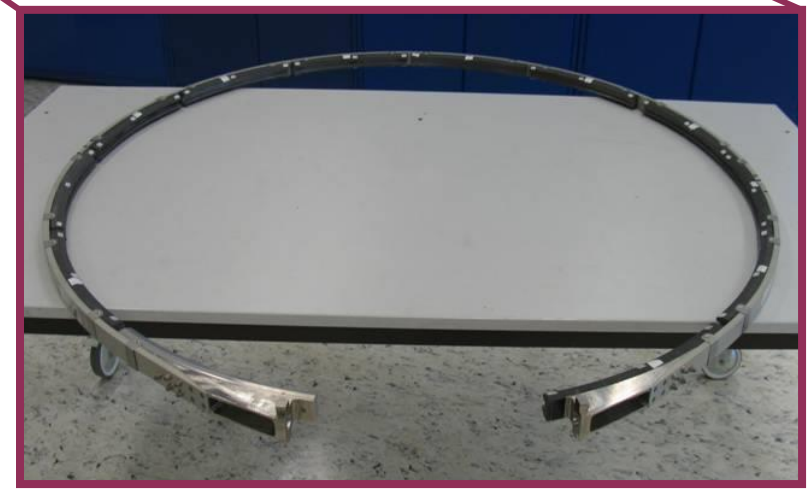


Satellite Separation Systems







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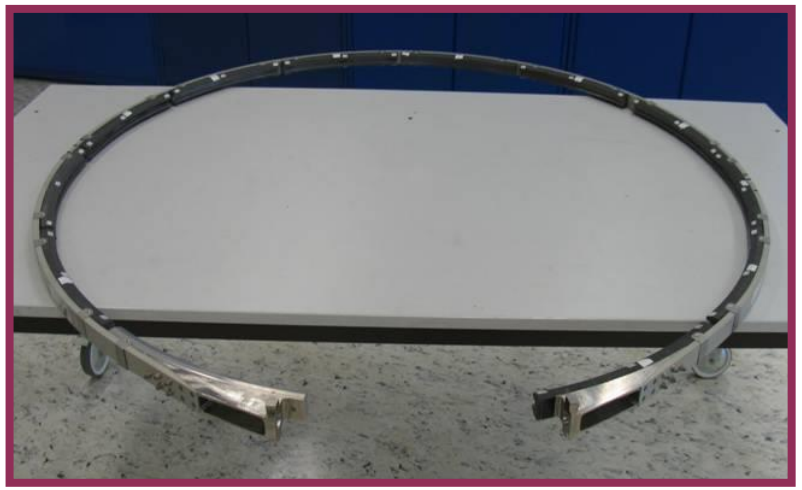
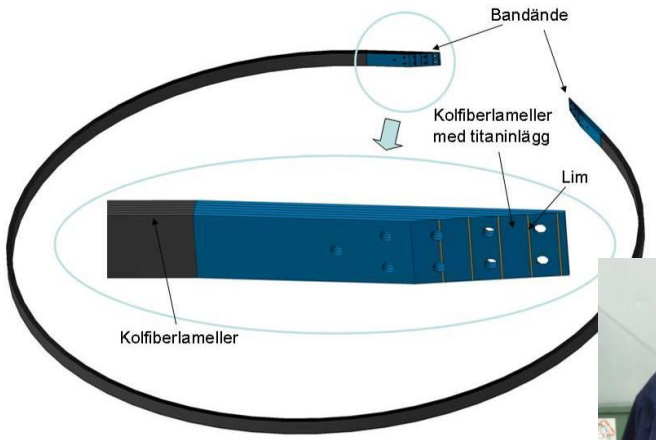




Existing solutions (Al):

- High production costs
- Long lead times
- Weight reduction not possible

Previous composite solutions(KOMET3)

- Bolted joints require hybrid metallic solution
- High reliance on manual labor
- Limited in diameter by length of CF laminates used

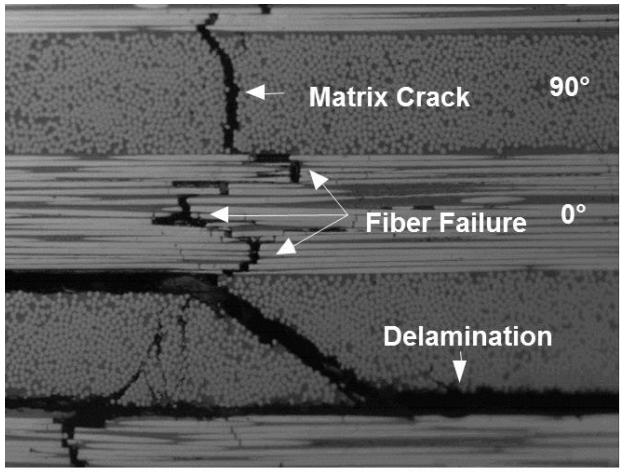
Ultra Thin-Ply Composites- Project Overview

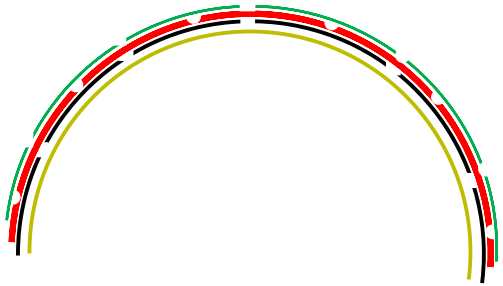
What are thin-ply composites?

- Cured ply thickness < 64µm

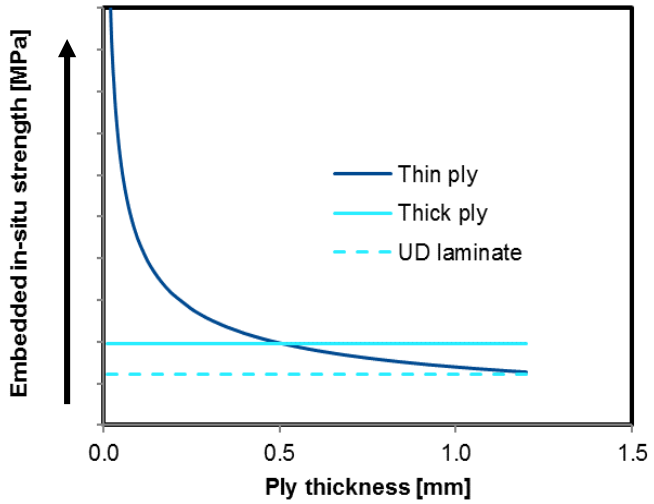
Expected project outcomes:

- Increased margin of safety: thin plies act to arrest crack growth and increase ultimate strength.
- Concepts for modular design: shorter pre-fabricated strips allow multiple diameters to be manufactured.
- Reduced manufacturing cost: combination of the above two leads to reduction in overall costs for composite solution.





In-Situ σ_{U22} vs Ply Thickness



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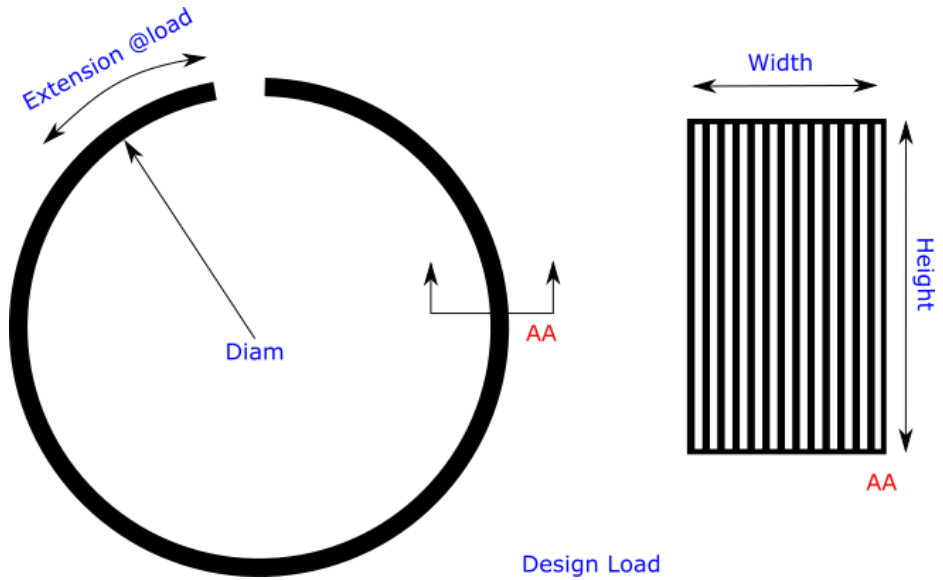
How should we evaluate potential for ultra-thin ply carbon composites?

Case Study: Design a new clamp-band with ultra-thin ply technology

Specification and Requirements

RUAG defined:

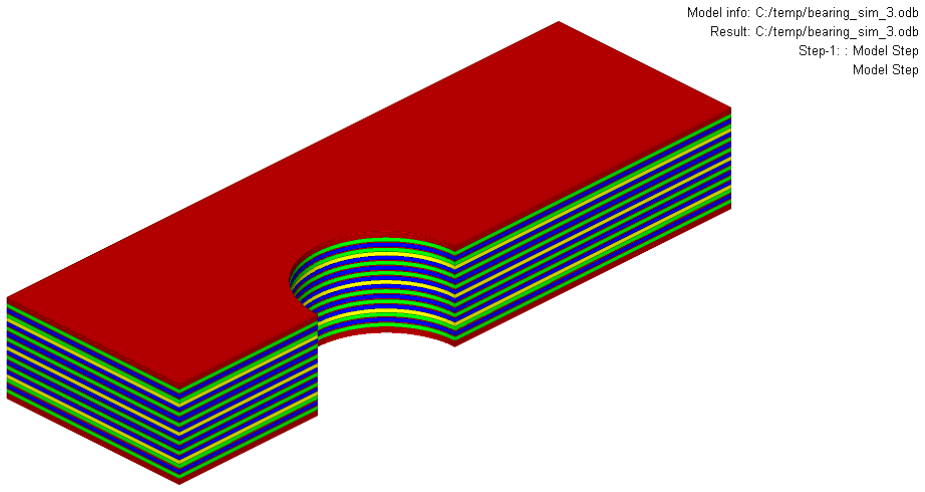
- Typical clamp-band diameters of interest
- Geometric design envelope of clamp band cross-section
- Range of extension at load for proper release
- Design loads applied to clamp band during use

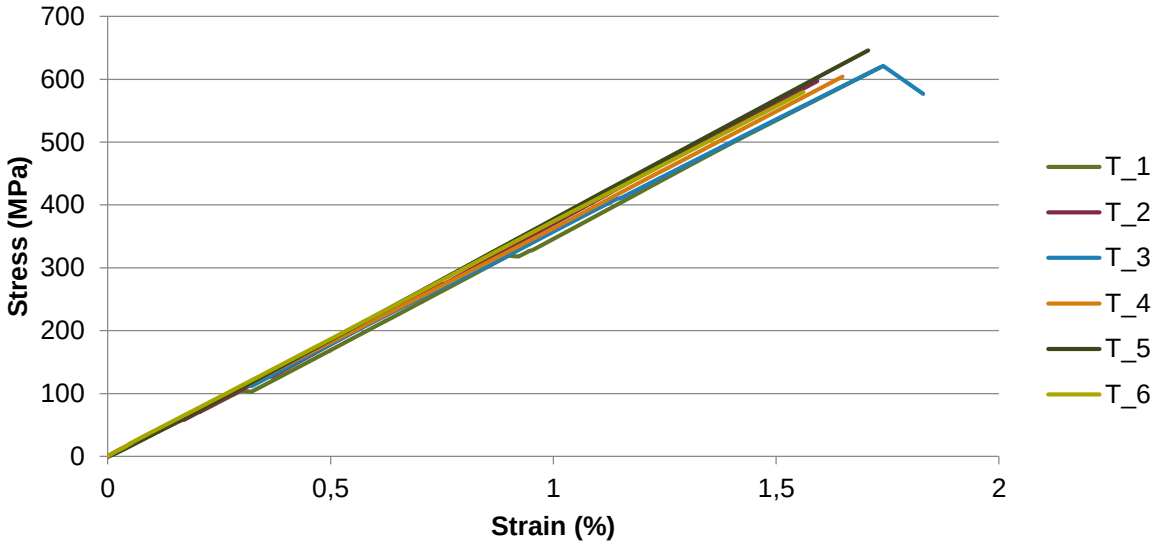


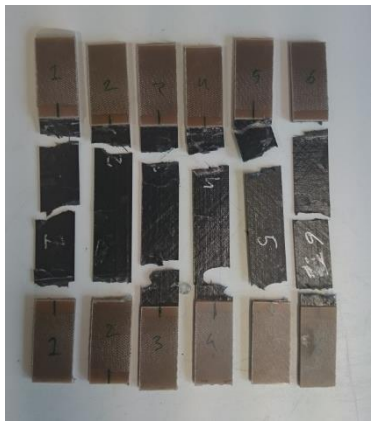
Case Study: Design a new clamp-band with ultra-thin ply technology

Detailed study of ultra-thin-ply effects on:
Laminate Stiffness
Tensile strength
Bearing strength

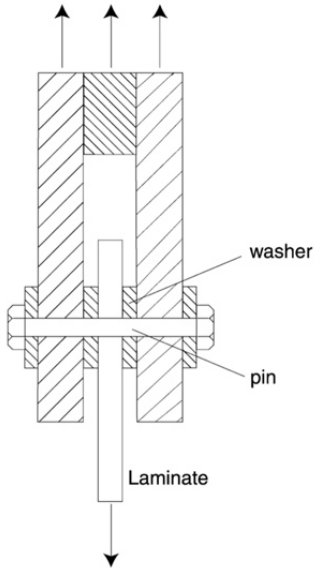
Numerical study by KTH Masters Student:
Can bearing failure for ultra-thin ply materials be predicted by simplified linear-elastic models?







Together ahead. RUAG

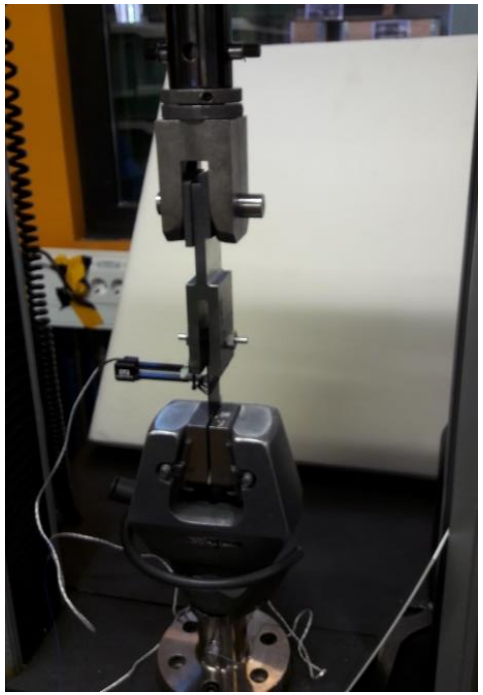


Q1- What effect does the amount and distribution of ultra-thin ply material have on the bearing strength of a given laminate with the same overall stiffness?

Detailed study on:
Laminate Stiffness
Tensile strength
Bearing strength

Laminates Proposed and Manufactured for Testing

Laminate ID	Lay-up*	T_{thin} [mm]	T_{thick} [mm]	T_{total} [mm]	% Thin-ply
1C	$[(45/0/90/-45)_2]s$	0	2.24	2.24	0
2B	$[45/90/0/90_2/-45/90/45/90_2/0/90/-45/90]s$	0.56	1.68	2.24	25
3B	[X/45/Y/0/Z/90/W/-45]s	1.12	1.12	2.24	50
5	$[(45/0/90/-45)/X_4]s$	1.12	1.12	2.24	50
4B	$[(45/0/90/-45)_8]s$	2.24	0	2.24	100

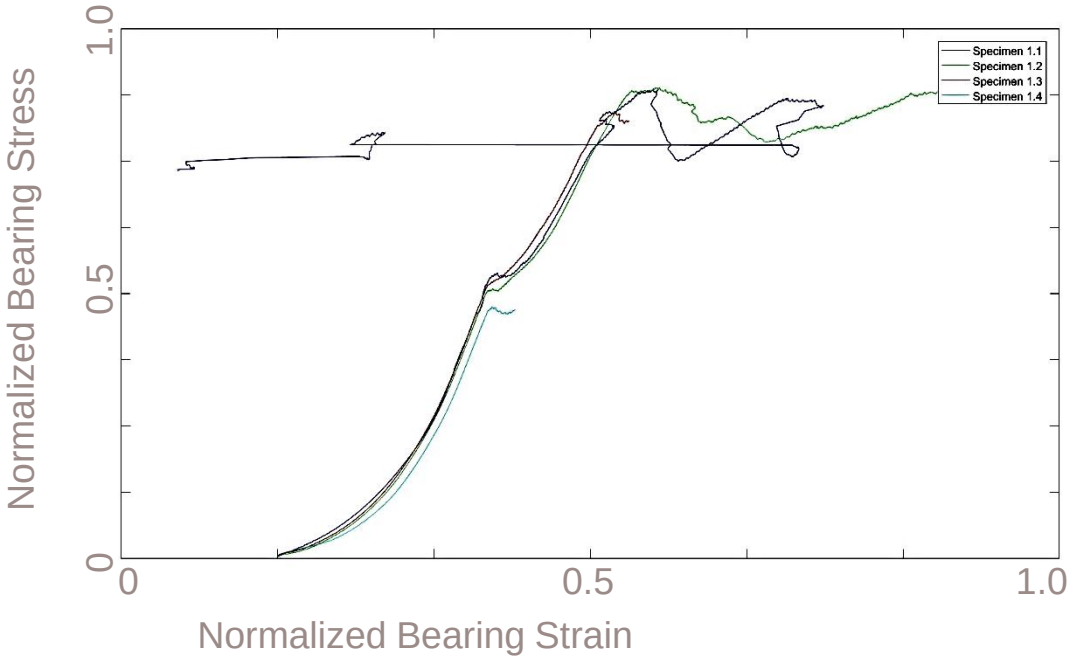


X =[45/0/90/-45]
Y= [0/90/-45/45]
Z= [90/-45/45/0]
W=[-45/45/0/90]

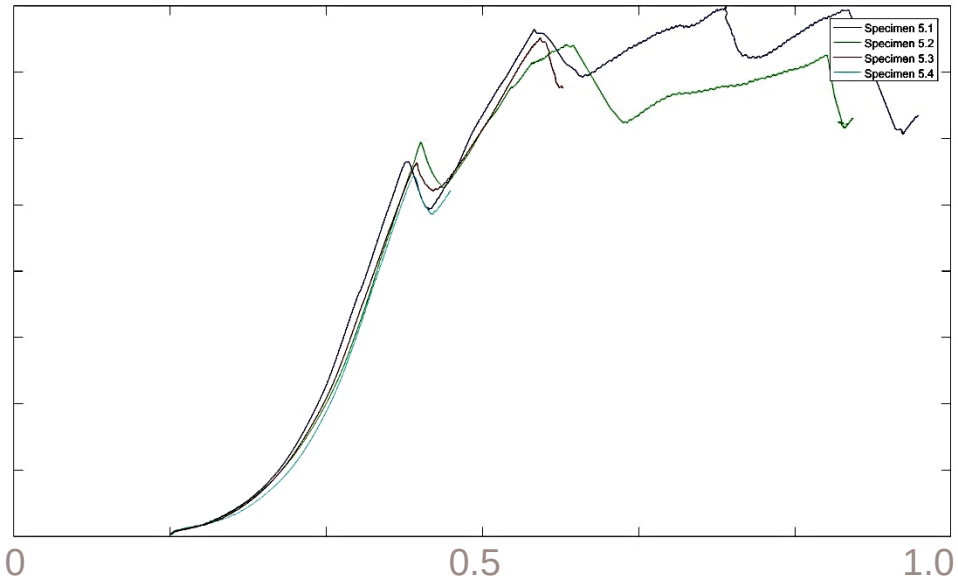
Red Text= Single UD thin-ply layer (0.03 mm)
Black Text = 4 UD Thin ply layers (equivalent to 1 ”conventional” ply)

Q1- What effect does the amount and distribution of ultra-thin ply material have on the bearing strength of a given laminate with the same overall stiffness?

Laminate 1 (Conventional)



Laminate 4 (100% Thin-ply)



Ca 50% increase of stress at onset of damage for 100% thin-ply solution

Q1- What effect does the amount and distribution of ultra-thin ply material have on the bearing strength of a given laminate with the same overall stiffness?

Normalized properties of thin ply bearing strength specimens

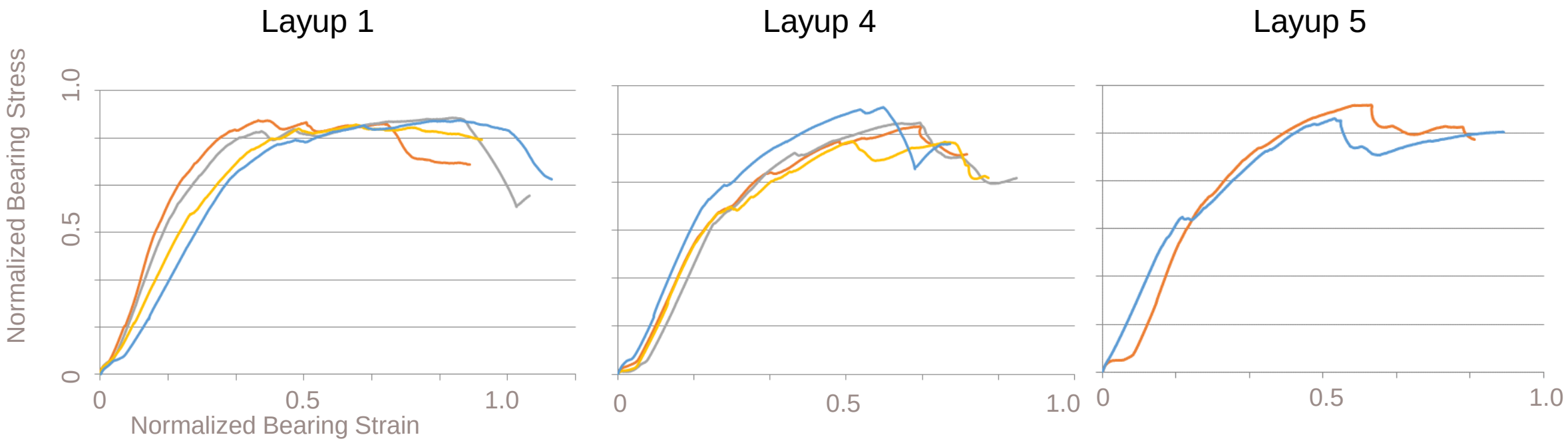
Laminate ID	Stiffness	Ultimate Bearing Strength	Stress at Onset of Damage	% Thin-ply
1C	1	1	1	0
2B	1.12	1.06	1.11	25
3B	1.01	1.10	1.21	50
5	1.11	1.10	1.39	50
4B	1.14	1.15	1.48	100

A1.1- Amount of ultra thin-ply material is important for onset of damage.

A1.2- Distribution of ultra thin-ply material is also important. Centralized stacks gave slightly better strength at onset of damage.

Q2- Can in-situ benefits of coupons scale to bonded structures?

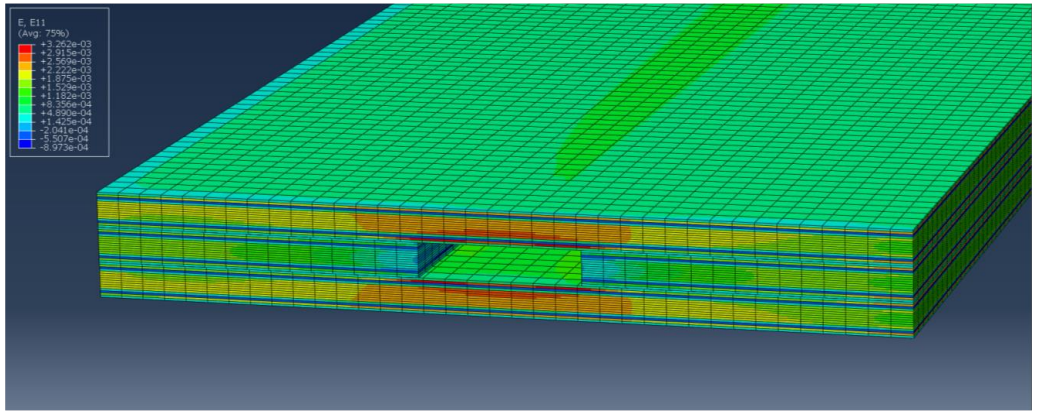
Bond 3 layers of Laminates 1,4,5 together. Repeat Bearing Strength Testing

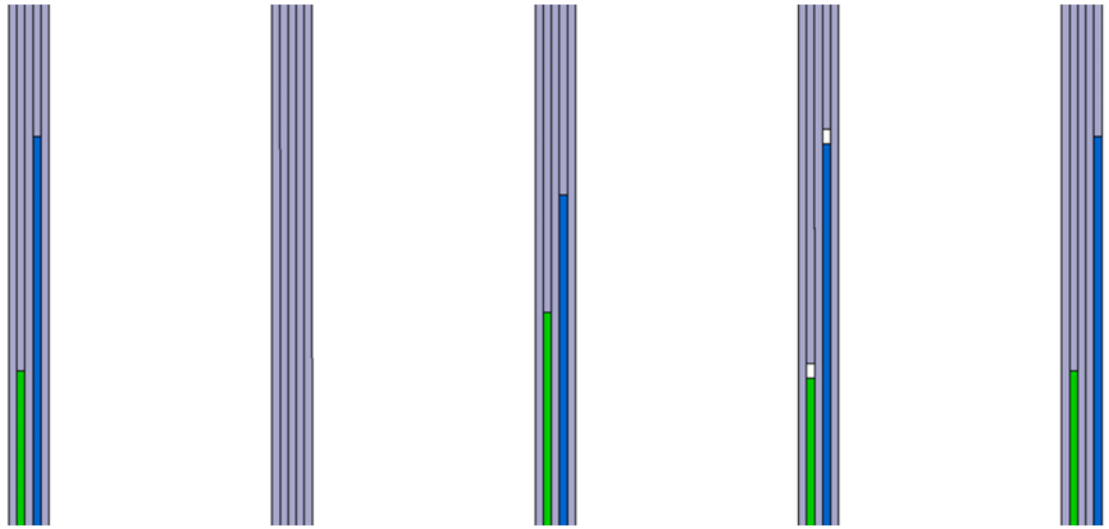


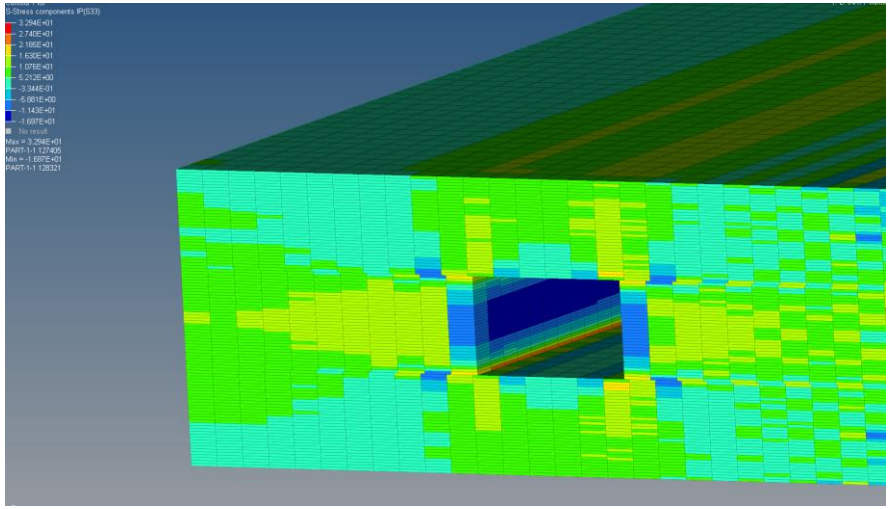
A2.1- Benefits seen previously do not seem to scale, however, later testing of bonded joints showed questionable bonding of layers- i.e. failure likely due to bond failure, not ply failure.

Q3- What effect do joints have on modular design?

Numerically evaluate different levels of overlap and gap-size to evaluate effect on clamp band stiffness and strength

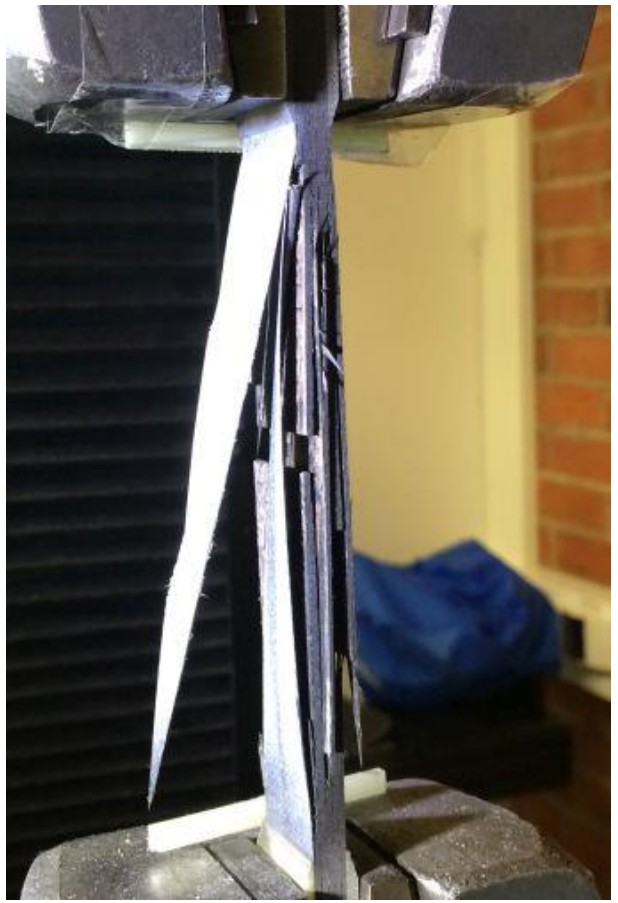






Q3- What effect to joints have on modular design?

Manufacture joint specimens and test.



A3.1-From measured specimens:
Presence of butt-joint most important factor. Reduces load capacity.
Relative distance between, size of gap, etc, less important.
Joints on surface most critical.

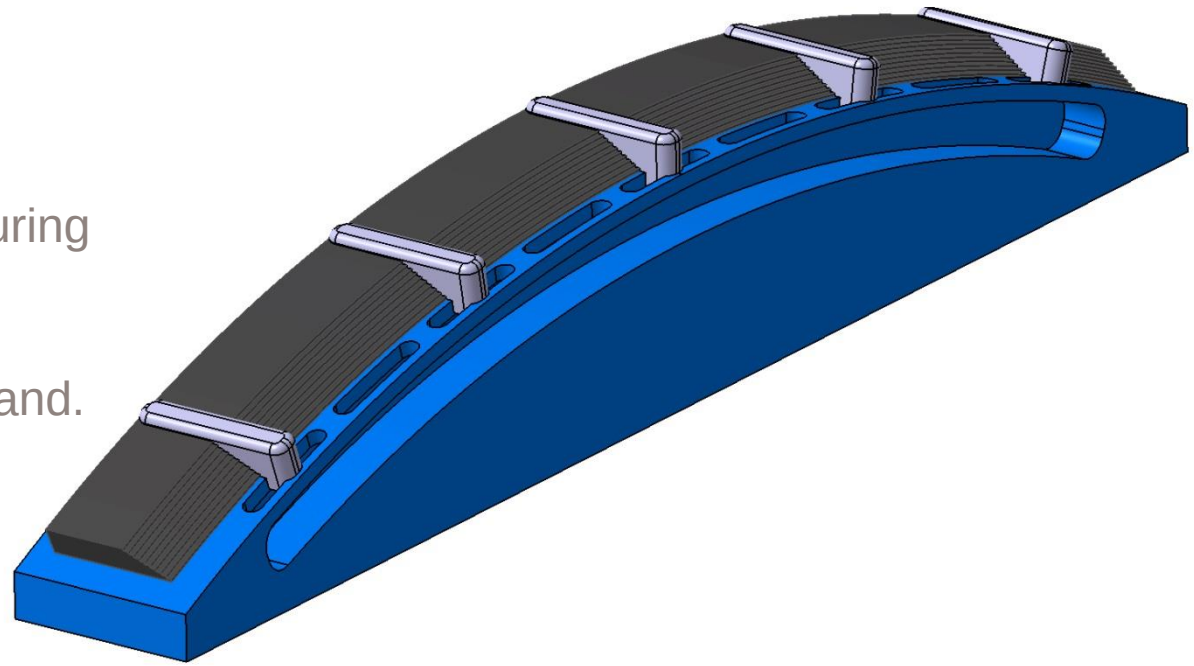
Questionable results due to poor bonding quality between laminates.
(Thin adhesive film used + relatively rough surface = poor bond)

Q4- How could a modular design be constructed with intentions to use automation?

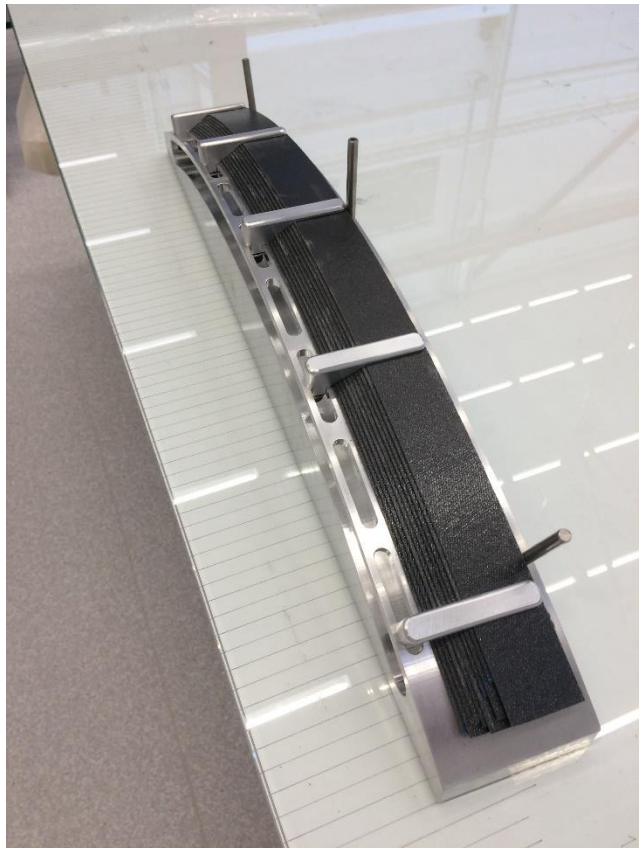
Establish a “universal” stack which can be pre-manufactured and cut into strips.

Evaluate a tooling concept to hold strips in place during assembly and while curing in oven.

Test manufacture a section, then an entire clamp band.



Q4- How could a modular design be constructed with intentions to use automation?

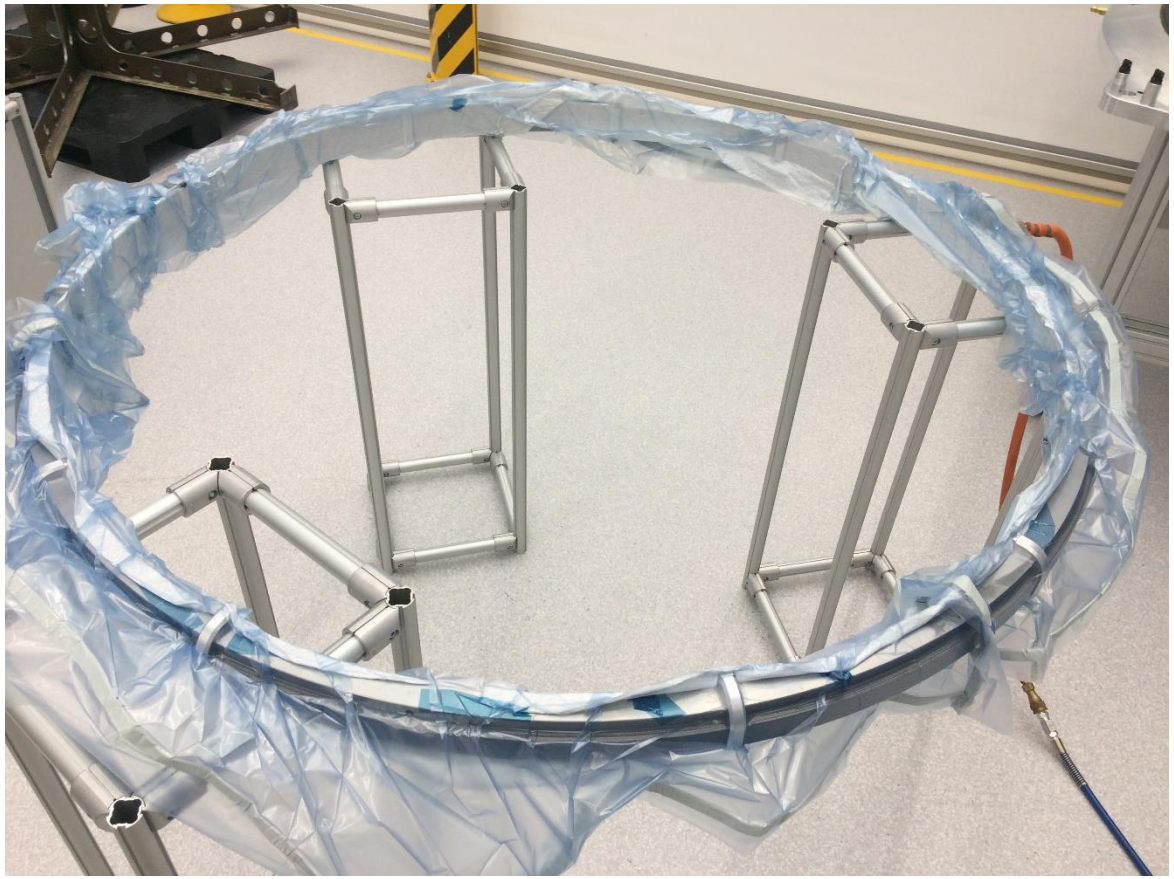


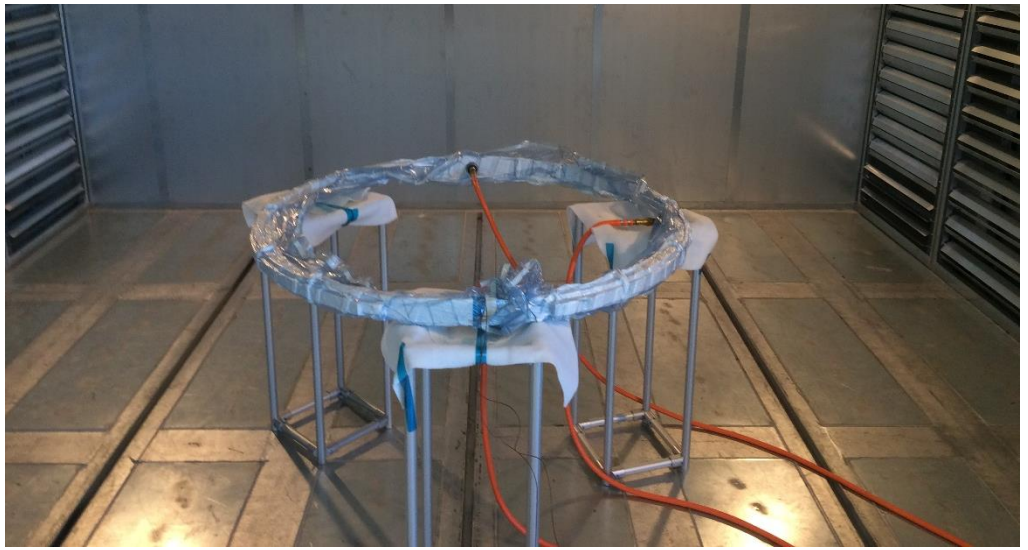
Test manufacture of a section.

Q4- How could a modular design be constructed with intentions to use automation?

Test manufacture of a full scale prototype.

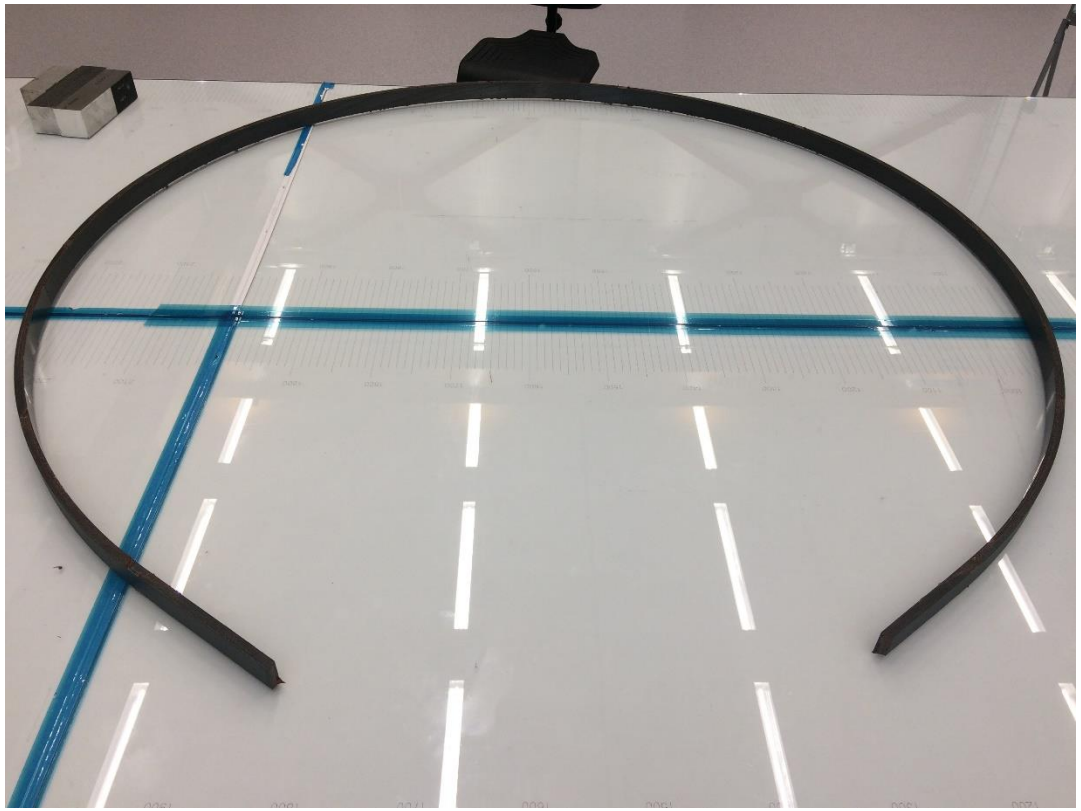
Q4- How could a modular design be constructed with intentions to use automation?





Test manufacture of a full scale prototype.

Q4- How could a modular design be constructed with intentions to use automation?



Prototype clamp band completed.

Final machining, fitting of hardware, and testing of band planned by Q1 2019.

Expected project outcomes- Conclusions and Lessons Learned:

- Increased margin of safety:
  Ultra-thin ply laminates increase bearing strength of carbon fibre laminates. The amount and distribution is a factor.

  Scale-ability to tested bonded stacks uncertain due to poor adhesion.

- Concepts for modular design:
  Modular designs manufacturable and promising.
  Butt-joints reduce strength, but due to poor adhesion conclusive results regarding feasibility cannot be presented at this time.

- Reduced manufacturing cost:
  The manufacturing process using pre-cured thin stacks, adhesive films, and vacuum bagged cure in oven proved very efficient and effective and suited towards future use of automation.

Future Work:

Adhesive bonding process for pre-laminated strips→ full potential not realized

Modelling aspects→ Bearing failure not captured yet, more work needed

Manufacturing process can be further developed

Together ahead. RUAG

THANK YOU FOR YOUR ATTENTION