University of BRISTOL

Bristol Composites Institute (ACCIS)

ADVANCED COMPOSITES COLLABORATION FOR INNOVATION & SCIENCE

Engineering and Physical Sciences Research Council

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EPSRC Centre for Doctoral Training in Advanced Composites for Innovation and Science

Advanced numerical methods for impact of composite materials

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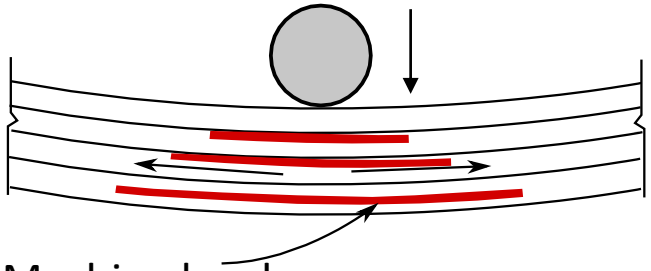
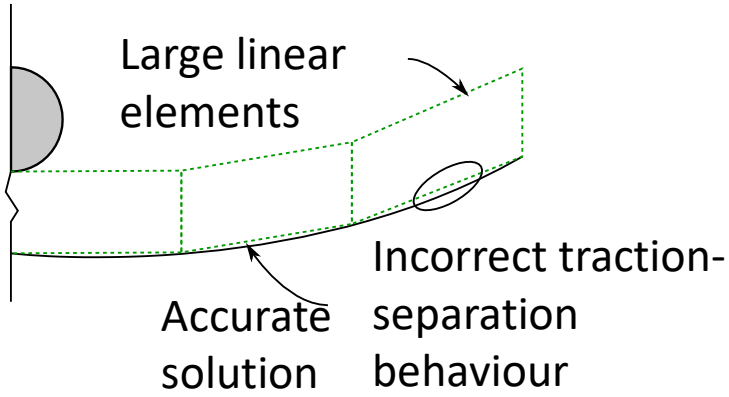
Damage modelling in composites



Continuum model + Cohesive zone modelling (CZM) and Continuum damage mechanics (CDM)

An integrated approach to solve problems in damage modelling



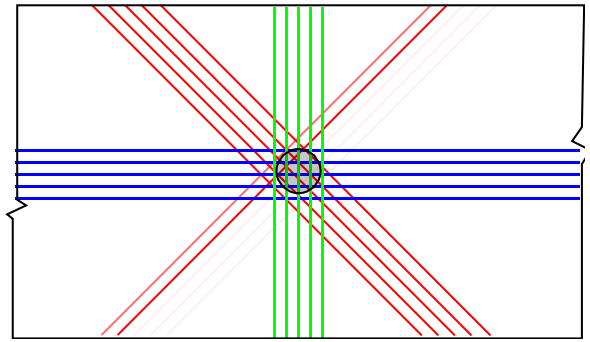
Meshing Burden - Need to pre-define cohesive elements in a mesh. → Adaptive modelling of cracks

Adaptive Mesh Segmentation (AMS)

- CZM linear elements require fine mesh
- High computational cost
- Large linear meshes introduce discretisation errors

→ Higher order cohesive segments

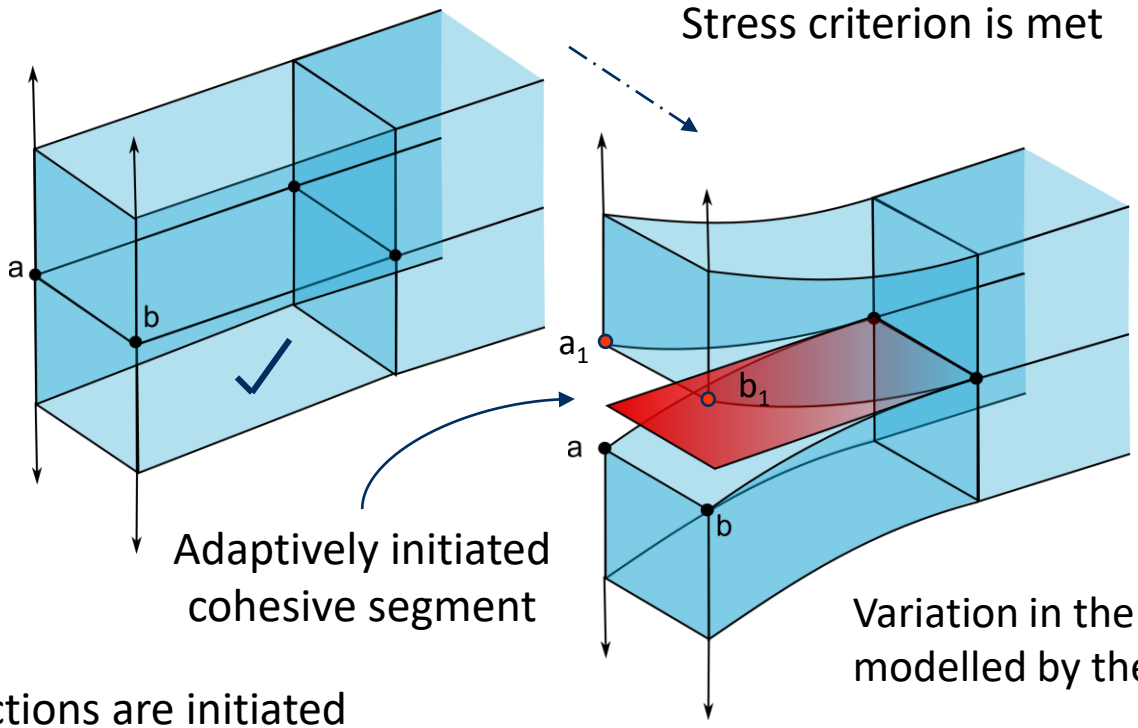
Higher order AMS



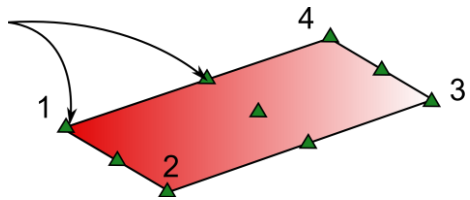
Matrix cracks

- Demonstrated with quasi-static and impact modelling cases

Higher order AMS



Tractions are initiated with the balance of nodal forces



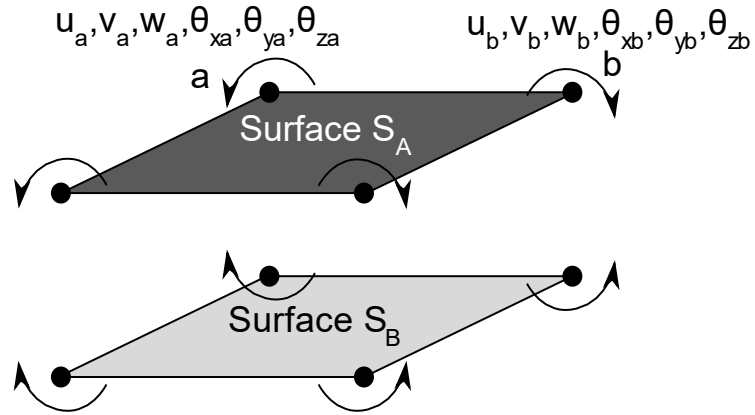
▲ Integration points

Variation in the traction field is modelled by the cohesive segment

- New nodes - a_1,b_1
- Existing nodes - a,b

Loss in rotational continuity is modelled using a Moment-Damage relationship.

Discretisation using coarser meshes



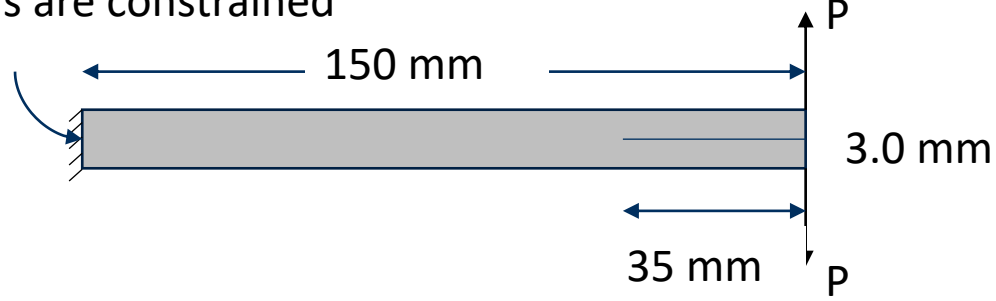
- Corner nodes of cohesive element with rotations

Rotation enriched cohesive elements

Higher order

For the same mesh size, Higher order AMS provides better accuracy

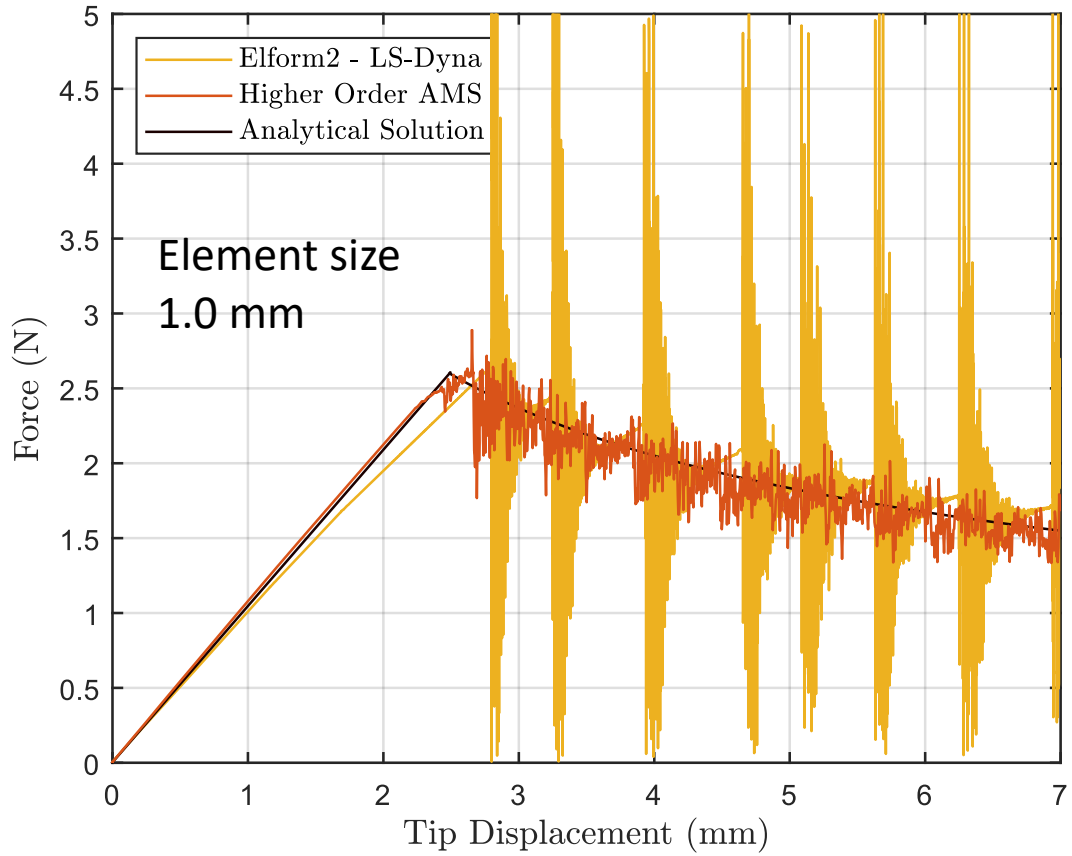
Ends are constrained



A test for coarser in-plane mesh

- Mode I is critical in determining cohesive element size due to lower fracture energy

Linear element gives best results at **0.25** mm mesh.



For similar accuracy – 50 % reduction in time using Higher order AMS in comparison with user defined linear elements

Jagan Selvaraj, Supratik Mukhopadhyay, Luiz F. Kawashita, Stephen R. Hallett, Modelling delaminations using adaptive cohesive segments with rotations in dynamic explicit analysis, Engineering Fracture Mechanics, Volume 245, 2021, 107571, ISSN 0013-7944

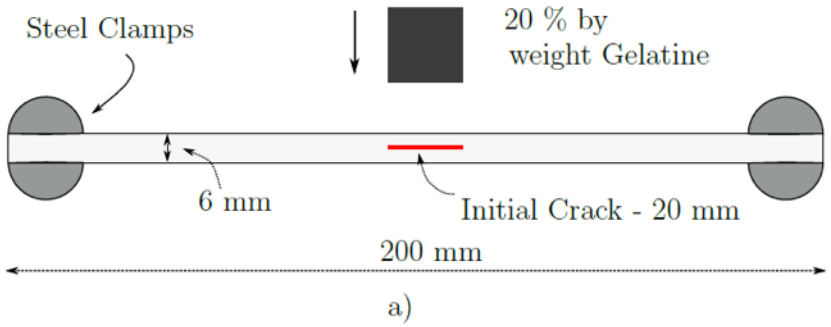
Soft Body Beam Bending (SBBB)

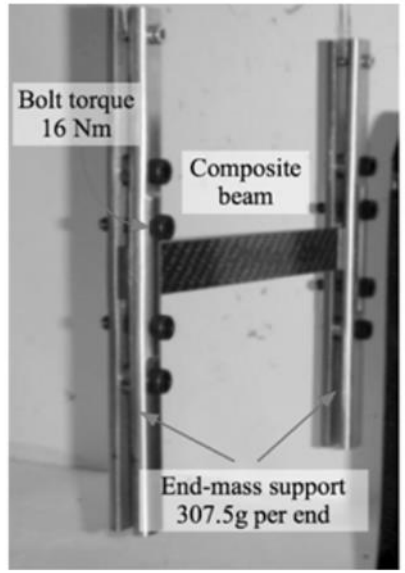
Delamination modelling in a dynamic case involving impact

Material

Material - IM7/8552 (6 mm) Unpinned

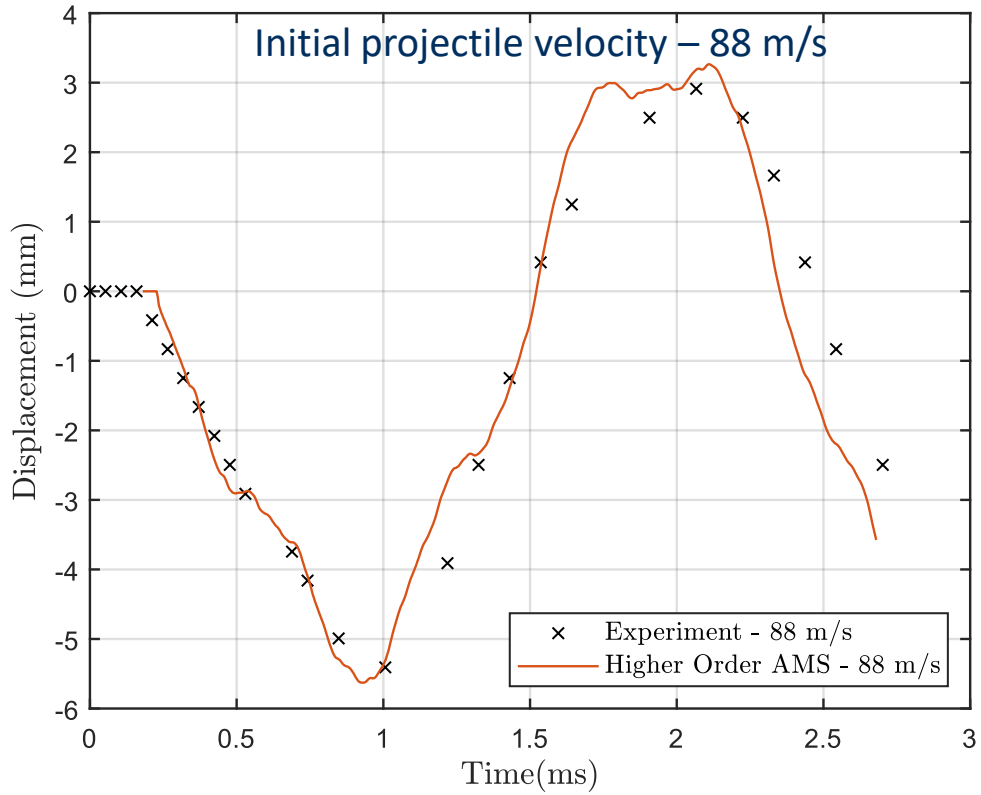
Layup - $([0/-45/0/45]_{3S})_S$



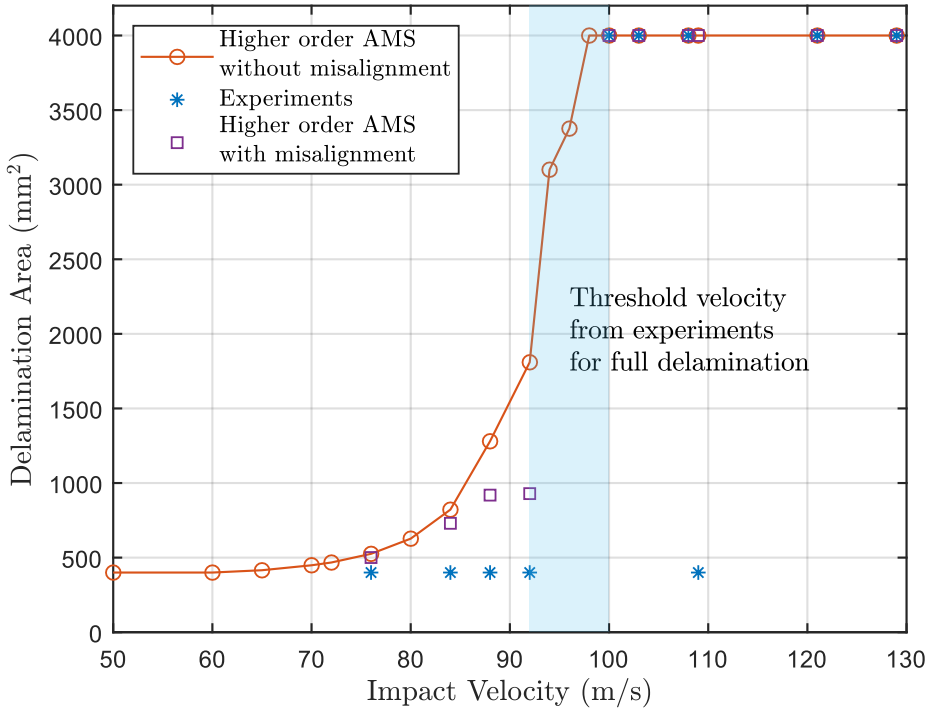


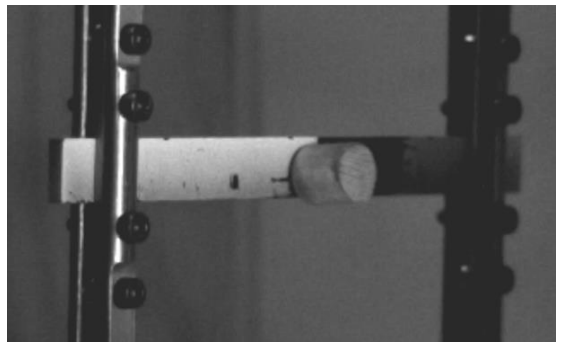
b)

Displacement time history against experiments

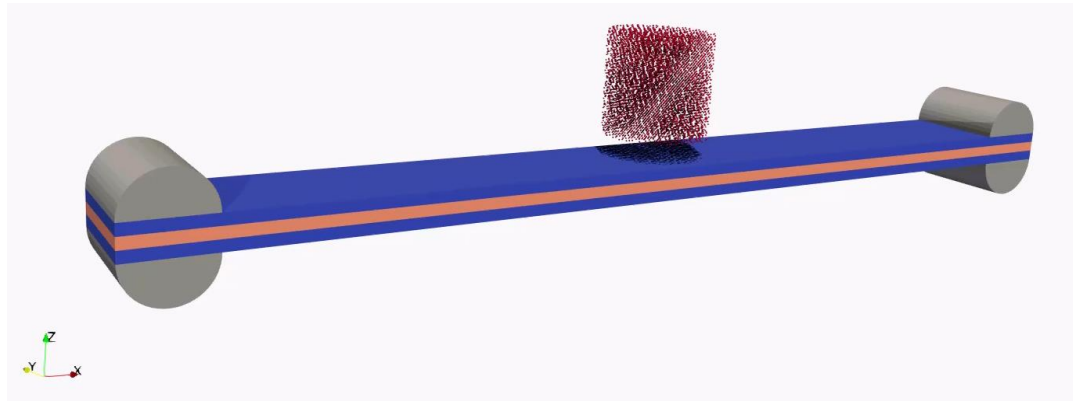


- Validation of numerical model against experiments
- Calculation of threshold velocity
- Influence of projectile misalignments
- Computational benefits in comparison with linear elements





Misalignment of the projectile



65 % less CPU time than linear elements

	Mesh size			Number of	Number of degrees
	x	y	z	elements	of freedom
Linear elements	0.5	0.5	1.0	96000	288000
Higher order AMS	1.5	1.5	1.0	10374	62444

4.5 times fewer degrees of freedom than linear elements

* Number of degrees of freedom required to achieve convergence in the delamination area.

Jagan Selvaraj, Luiz F. Kawashita, Mehdi Yasaee, Gordon Kalwak, Stephen R. Hallett, Soft Body Impact on Composites : Delamination experiments and Advanced Numerical Modelling, submitted to Composites Science and Technology

Summary

- A higher order element formulation - To overcome limitations associated with linear elements (CZM and continuum)
- An adaptive modelling method reduces meshing burden – ‘on-the-fly’
- The implementation provides improved delamination modelling whilst being computationally efficient – Fewer number of DOFs
- Higher order element reduces no. elements required through-thickness and allows for composite coupling effects, e.g. unsymmetric laminates

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