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Villum Center for Advanced Structural and Material Testing

Development of a Mode I/II/III test fixture for sandwich face/core fracture characterization

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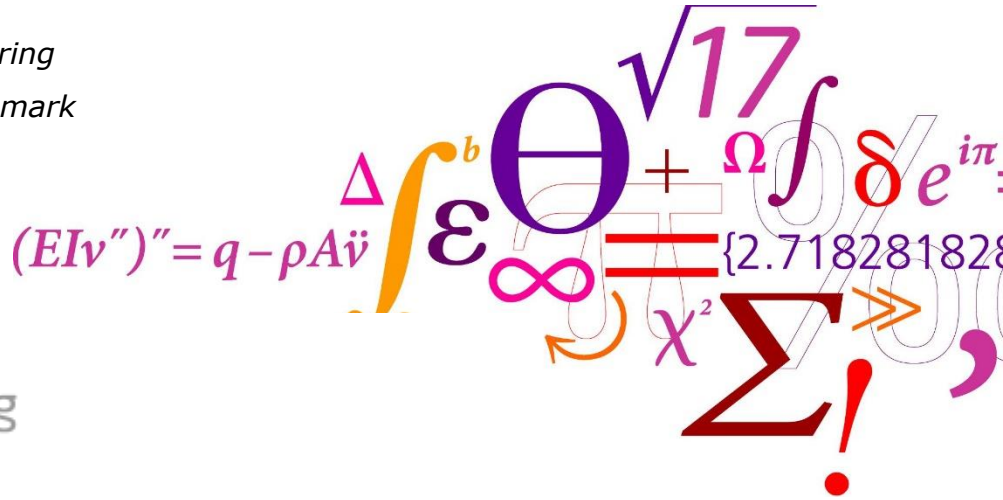

DTU Mechanical Engineering
Department of Mechanical Engineering

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Background and motivation

- Sandwich composites are used over a large range of engineering applications;
- Superior stiffness/weight and strength/weight ratios;
- Structure optimization brought to reach their performance limit

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Structural reliability reserve margins are reduced

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Damage assessment is essential to judge the reliability index of a structure

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Need of proper *fracture mechanical tools for* damage assessment

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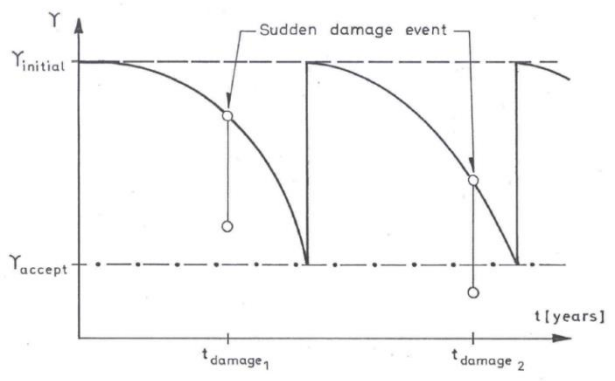
Measurement of interface fracture properties under the most general load set (mode I-II-III are present at the crack tip) is an increasingly important task



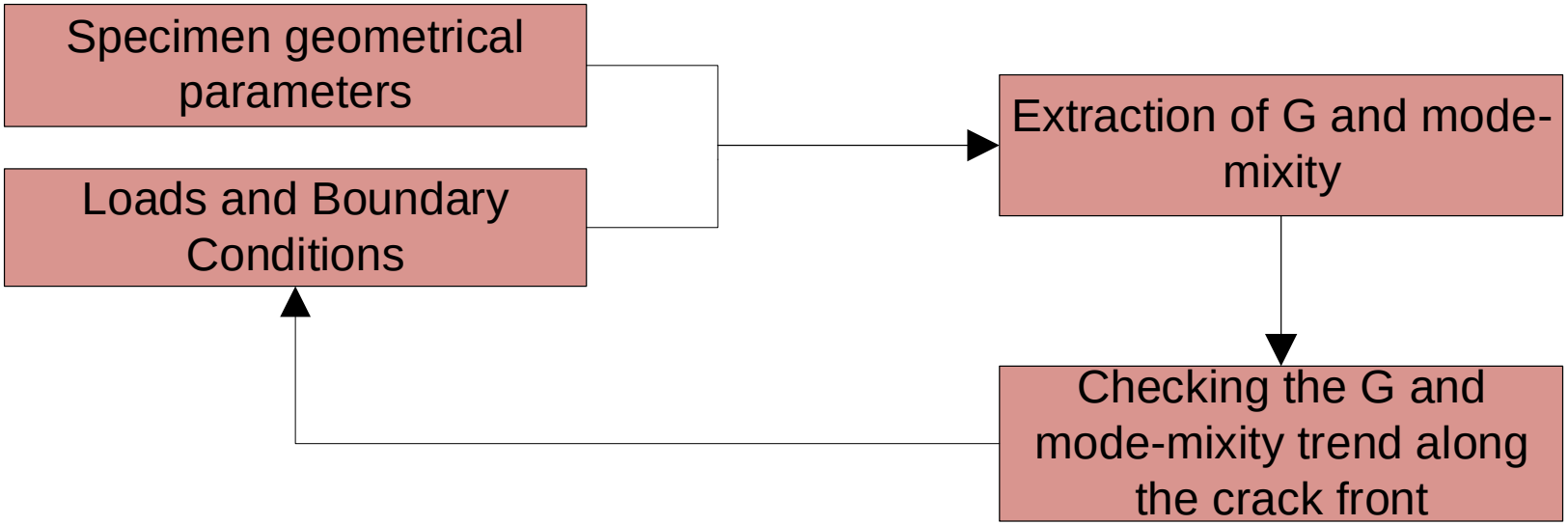
Problem Statement and Design Methodology

- **Main objective:**

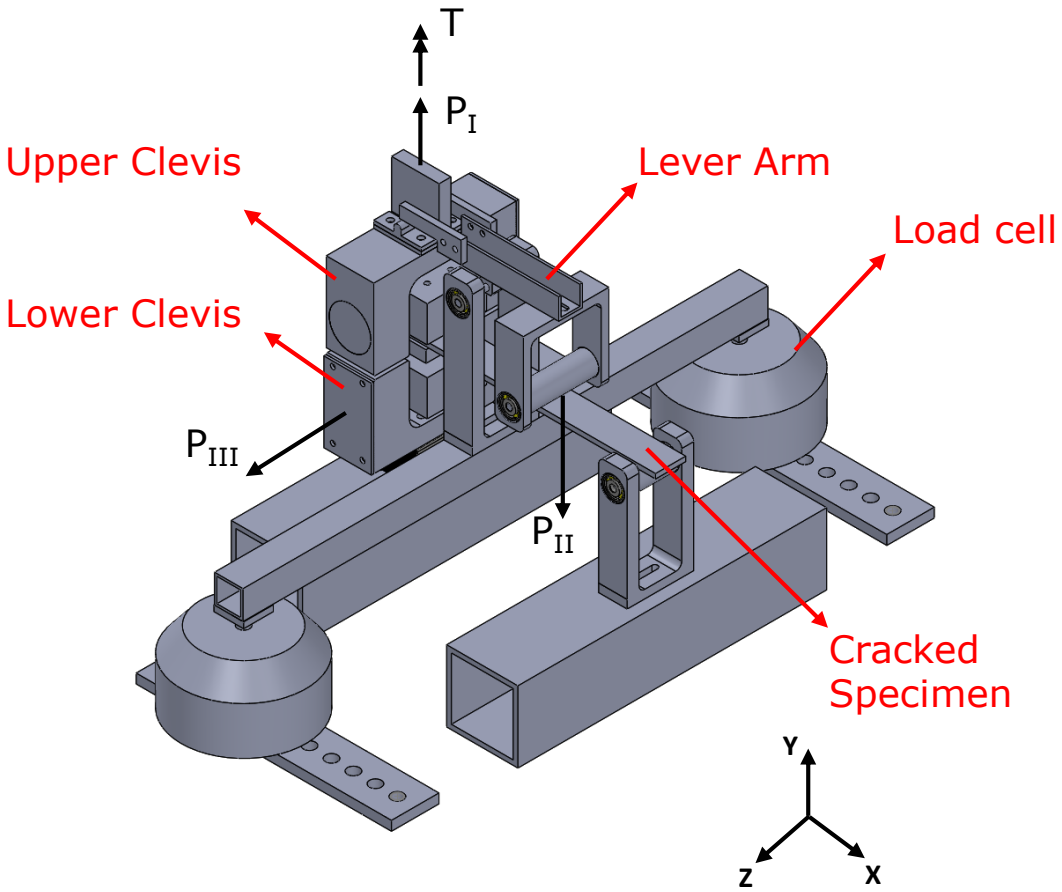
Measure the delamination (composite laminate) or the interface fracture toughness (sandwich composite), for fixed mode-mixity ratios between mode I, II and III.

- Design and construction of the new test rig;

- FE analysis to design properly the specimens.

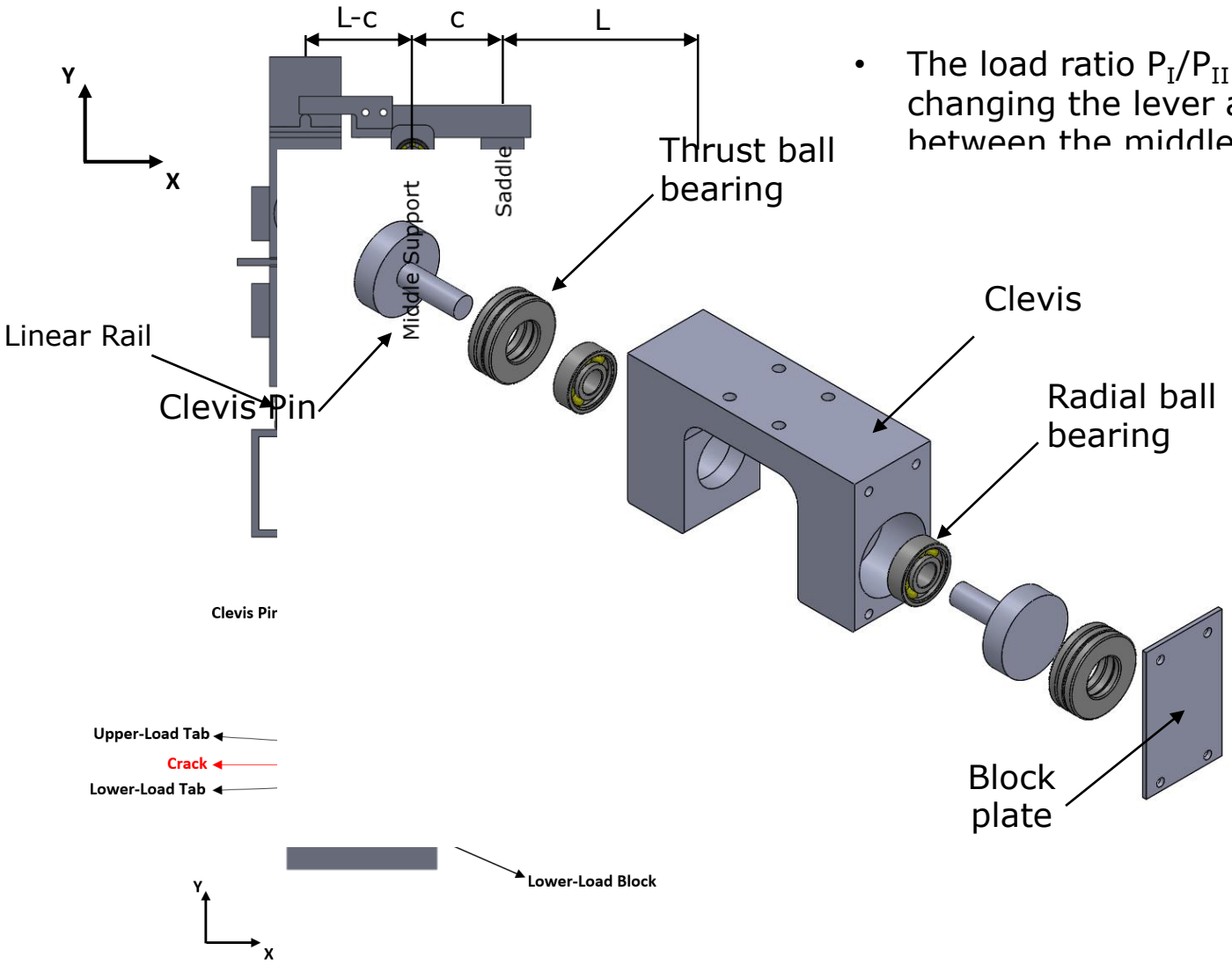


Test rig presentation



- The test rig will be implemented in a MTS 858 Axial-Torsional test machine;
- An additional external actuator introduces P_{III} along the z-direction;
- Mode I load (P_I) is applied onto the specimen by the MTS hydraulic actuator through the upper clevis;
- Mode II load (P_{II}) is transferred to the specimen by the lever arm action;
- Mode III load is applied by an additional actuator that is pushing on the lower clevis along the z-direction.

Test rig presentation



- The load ratio P_I/P_{II} can be varied changing the lever arm distance c between the middle support and the

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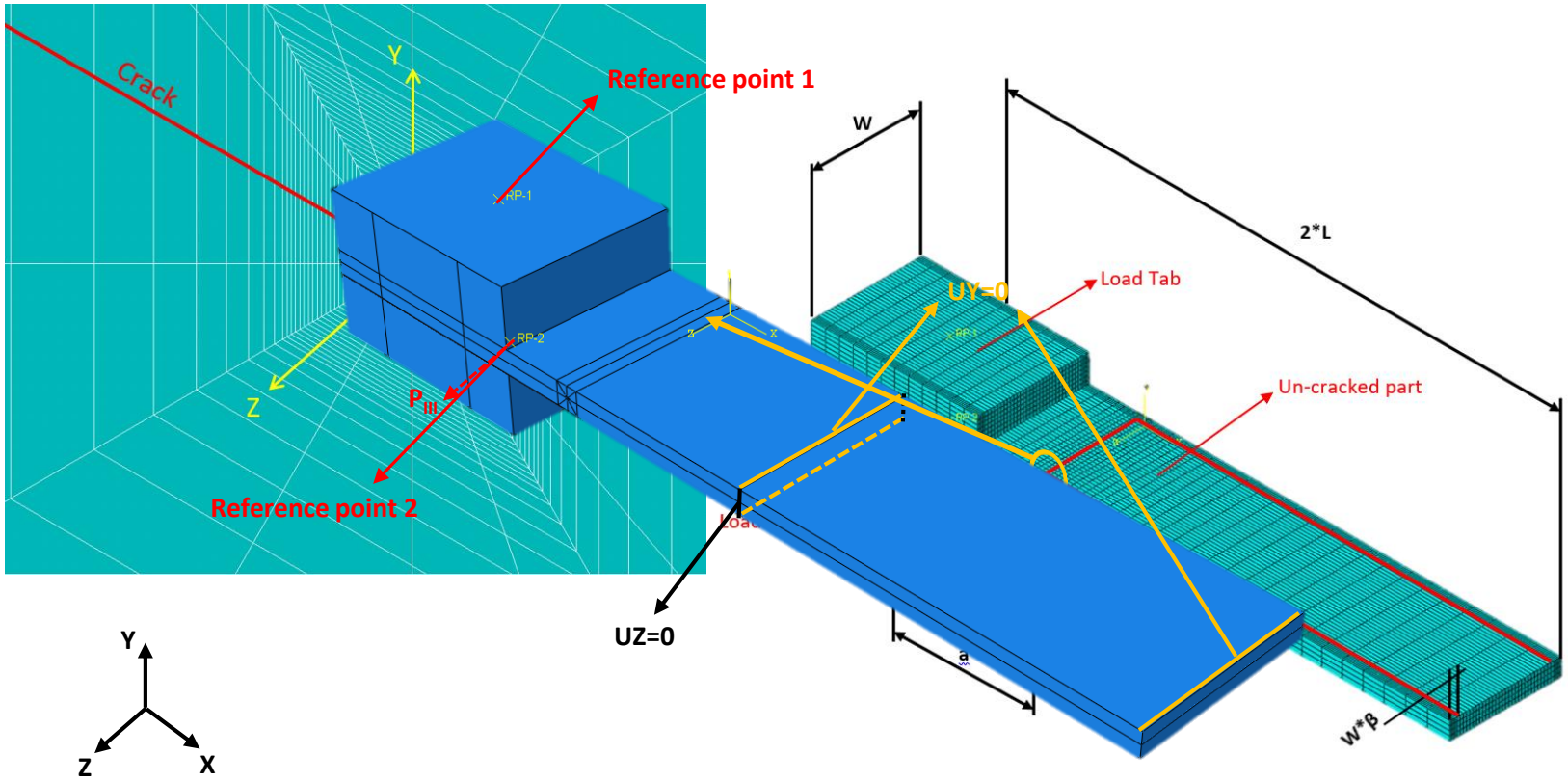
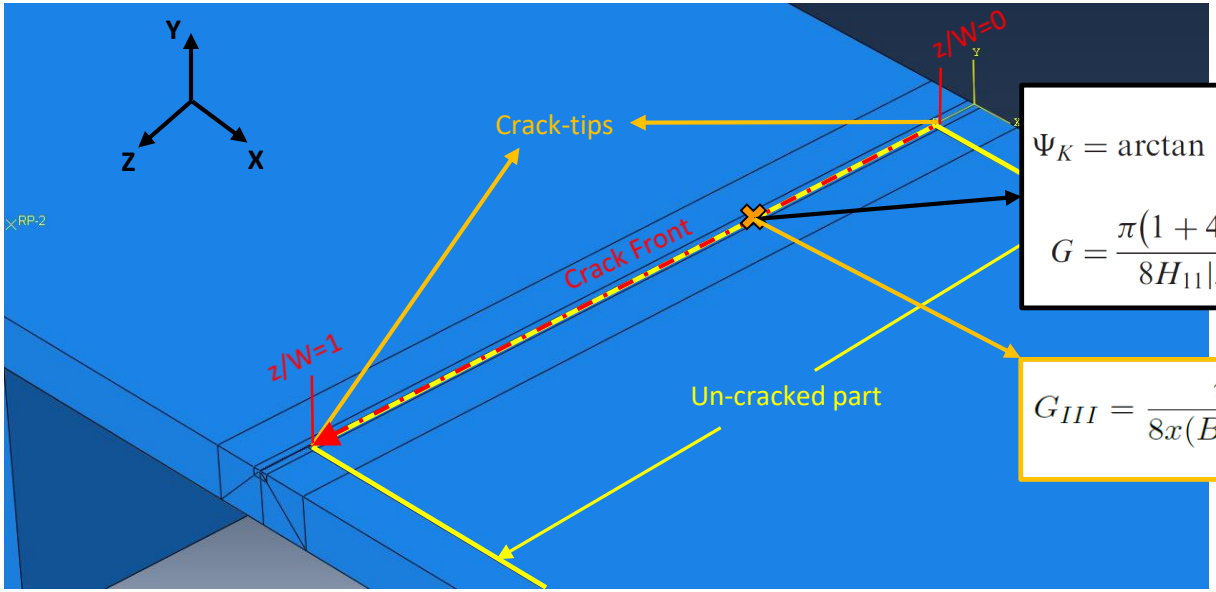
Numerical Model and materials simulated



Laminate	Elastic Moduli [GPa]						Poisson´s ratios		
	E_{11}	E_{22}	E_{33}	G_{12}	G_{13}	G_{23}	v_{12}	v_{13}	v_{23}
Unidirectional GFRP	48.00	8.00	8.00	4.00	4.00	3.00	0.285	0.285	0.333
Unidirectional CFRP	150.00	10.00	10.00	5.36	5.36	3.75	0.330	0.330	0.333

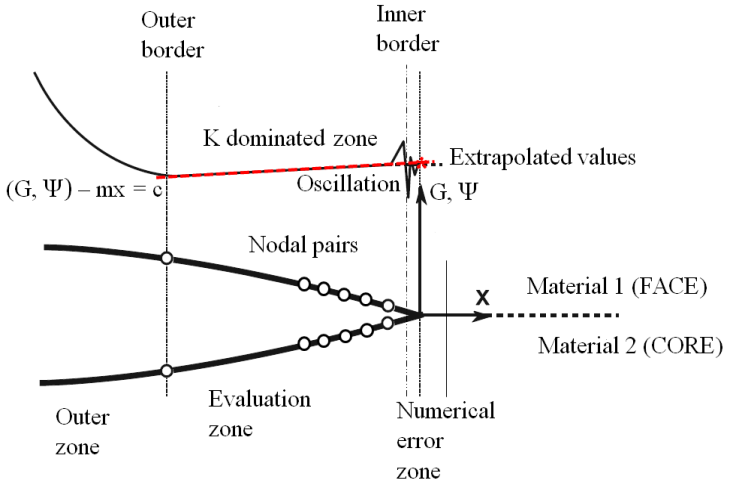
Numerical Model and materials simulated



$$\Psi_K = \arctan\left(\sqrt{\frac{H_{22}}{H_{11}}}\frac{\delta_x}{\delta_y}\right) - \varepsilon \ln\left(\frac{|x|}{h}\right) + \arctan(2\varepsilon)$$

$$G = \frac{\pi(1+4\varepsilon^2)}{8H_{11}|x|}\left(\frac{H_{11}}{H_{22}}\delta_y^2 + \delta_x^2\right).$$

$$G_{III} = \frac{\pi\delta_z^2}{8x(B_1+B_2)}$$

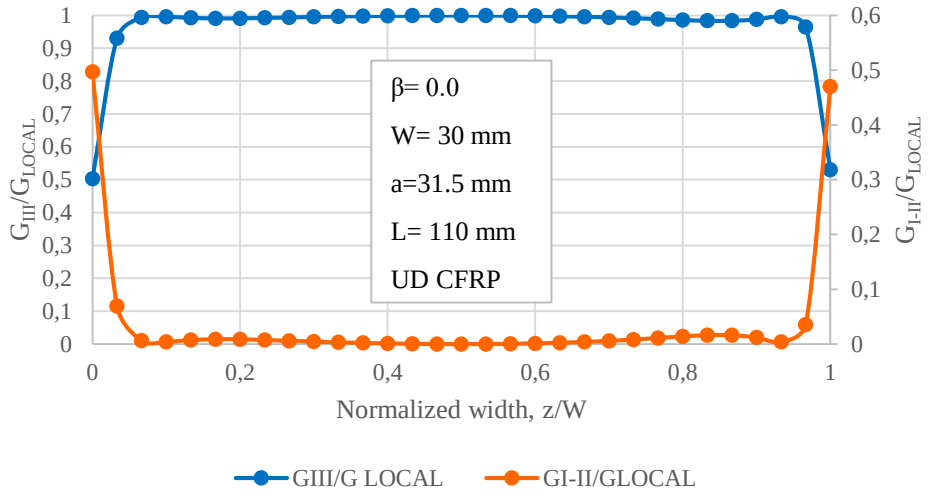


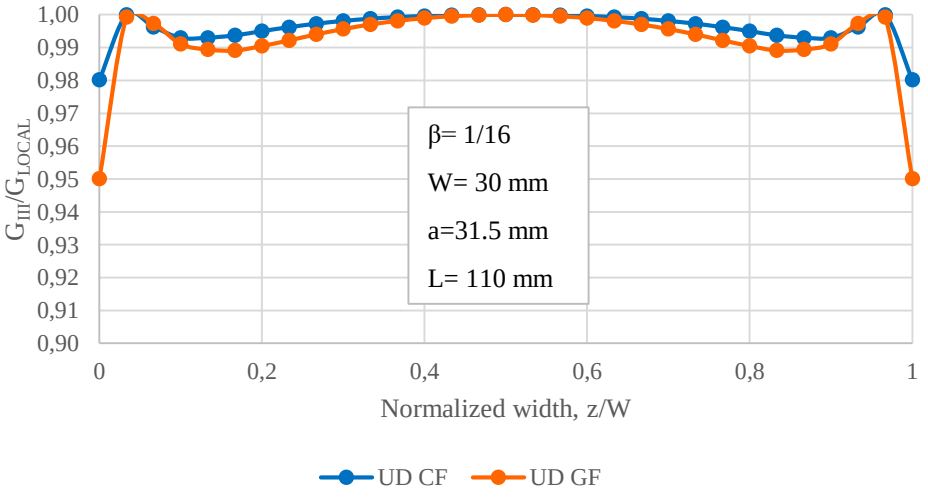
- The strain energy release rate (SERR) components were extracted along the crack front using the nodes relative displacements computed behind the crack front;
- The Crack Surface Displacement Extrapolation (CSDE, *Berggreen 2004*) method was applied in order to extrapolate the SERR components along the crack front.

Mode III analysis

- The presence of the longitudinal cuts is fundamental in order to achieve a **pure mode III state** also at the crack front free edges;

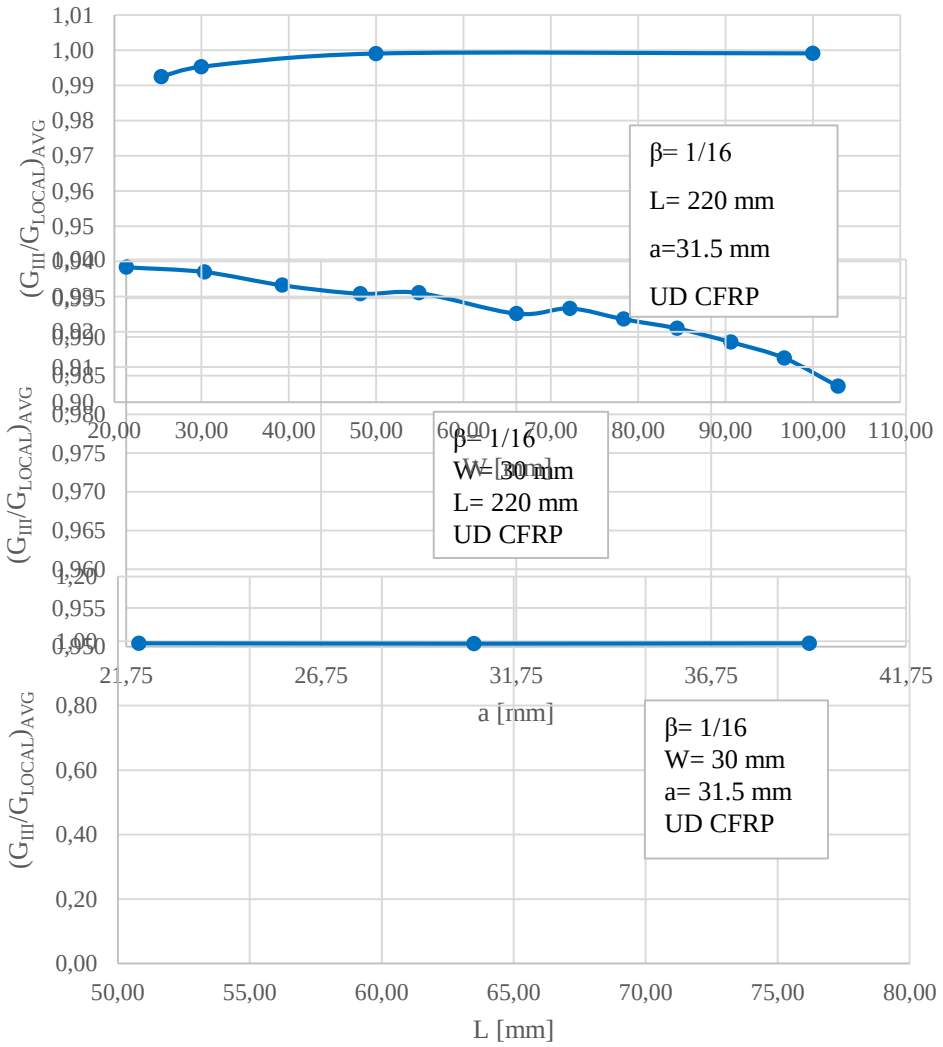
- In this way, it is possible to obtain an **homogeneous distribution of G_{III}** along the crack front **when only P_{III} is applied**.





Mode III analysis

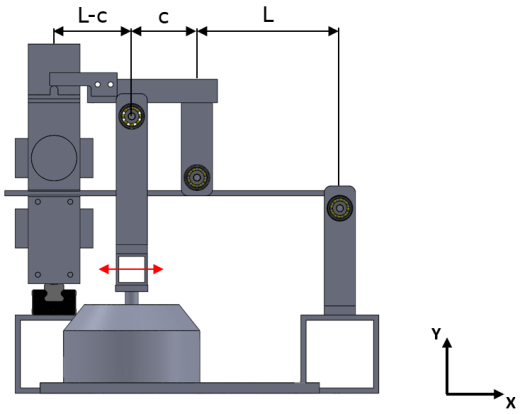
- The geometric parameters W and L do not influence significantly the average value of G_{III} along the crack front;
- It is recommended to choose the crack length a between 29 mm and 31 mm in order to maintain the average value of G_{III} as high as possible along the crack front.

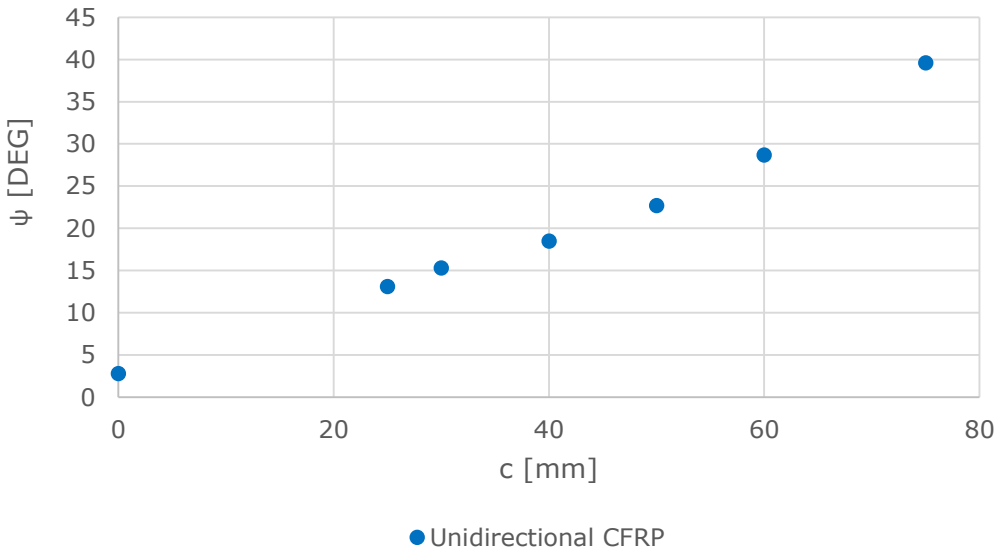


Mode I-II analysis

- It is possible to transfer different P_I/P_{II} load ratios onto the specimen changing the distance c;
- Different P_I/P_{II} load ratios induce different mode-mixity (between mode I and II) values at the crack tip;

c [mm]	Ψ [DEG]
0	2.6
75	40.1





Conclusions

In this preliminary work:

- A 3D FE model was built in order to understand which geometrical parameters, load and boundary condition sets can provide a pure mode III SERR distribution along the crack front for two kind of laminates;
- The achievable mode-mixity range (for mode I and II) was explored for different values of lever arm length c;
- A preliminary design of the new test rig was carried out. It will be implemented in a MTS 858 Axial-Torque test machine.

Future work:

- Additional numerical analyses on sandwich composites regarding the SERR distribution along the crack front;
- Test rig construction and preliminary experimental tests.

Acknowledgement

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Thanks for your attention