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DEVELOPMENT OF A MODE I/II/III TEST FIXTURE FOR COMPOSITE LAMINATES AND SANDWICH FACE/CORE FRACTURE CHARACTERIZATION

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1. INTRODUCTION

Sandwich structures are considered as key enablers for future and present lightweight structural applications in naval ships because of their superior stiffness/weight and strength/weight ratios compared with traditional metallic concepts as well as monolithic composite materials. Naval vessels are expected to encounter a large variety of load scenarios, which can cause different types of damages within the sandwich structure.

The most common and severe type of damage that a composite sandwich structure can experience is the lack of adhesion (a crack develops) between the face sheets and core known as a "debond". Therefore, the fracture characterization of the face/core surface is fundamental to predict the remaining life of a debond damaged sandwich structure.

The aim of this work consists in developing a test rig and a test procedure which is able to carry out the fracture characterization on a delaminated or debonded specimen (monolithic or sandwich composite specimen) in the most general loading scenario where all three types of loadings at the crack tip are present (Mode I-II-II).

2. THE TEST RIG

The test rig geometry (Fig. 1) is inspired from the STB test rig presented in [1] since in that work experimental results agreed well with the FEM analyses regarding pure Mode III and multiaxial (Mode I+III, II and II+III) fracture characterization of delaminated composite laminates.

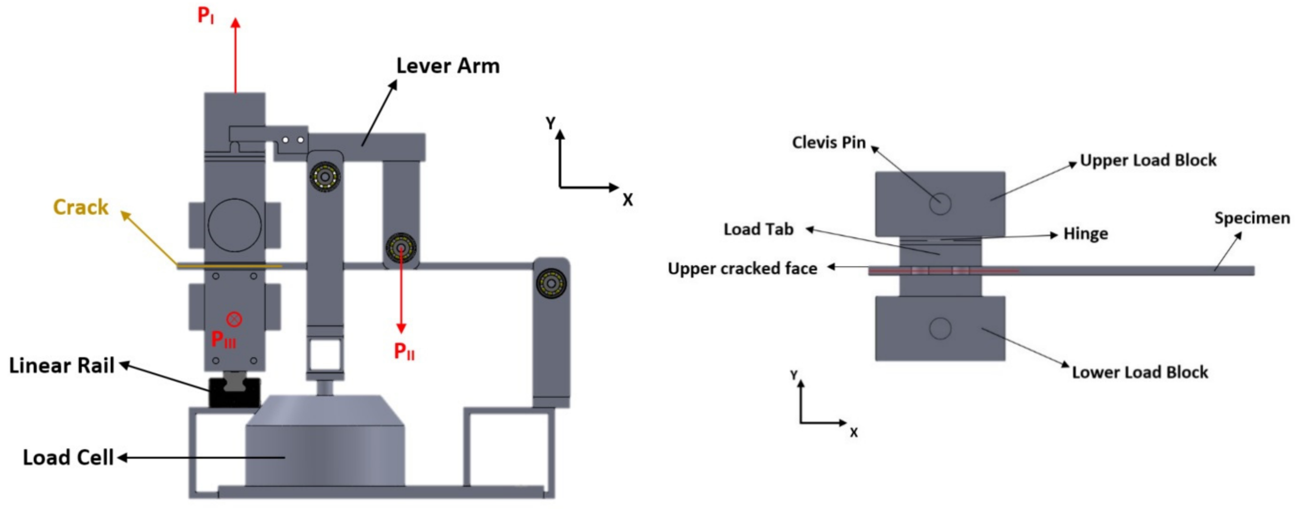

Fig. 1: Mode I-II-III test rig on the left and a detailed view of the cracked specimen with load tabs on the right.

The STB geometry was analyzed by building a 3D FEM model in order both to benchmark the strain energy release rate (SERR) distributions against those in the literature [1] and to understand how geometric parameters of the specimen influence SERR distributions along the debonded front.

The extraction of SERR values from the debond front in the FE model has been carried out by applying the CSDE method [2]. Experimental tests jointly with results from the FE model will be capable of gaining new and important insight regarding pure Mode III as well as multi-mode fracture characterization of face/core interfaces in composite sandwich structures.

3. NUMERICAL MODEL AND PRELIMINARY NUMERICAL RESULTS

This work will initially focus on the analytical/numerical analysis and experimental measurement of the Mode III fracture toughness regarding composite laminates (CFRP and GFRP, see table 1 for the material properties). Secondly, Mode III fracture toughness analysis will be extended also to foam cored composite sandwich specimens. Finally, the complete analysis will be addressed (analytical, numerical and experimental) regarding mixed-mode I/II/III fracture characterization utilizing the new test rig.

A 3D FE model (Fig. 2) of a CFRP and GFRP laminate specimen was built in order to extract the SERR trend along the crack front under pure mode III load conditions, using the CSDE method [2]. This procedure was adopted in order to check if a pure mode III state was present along the crack front with the external load imposed by the test rig. Material properties used in the FE model are reported in Table 1.

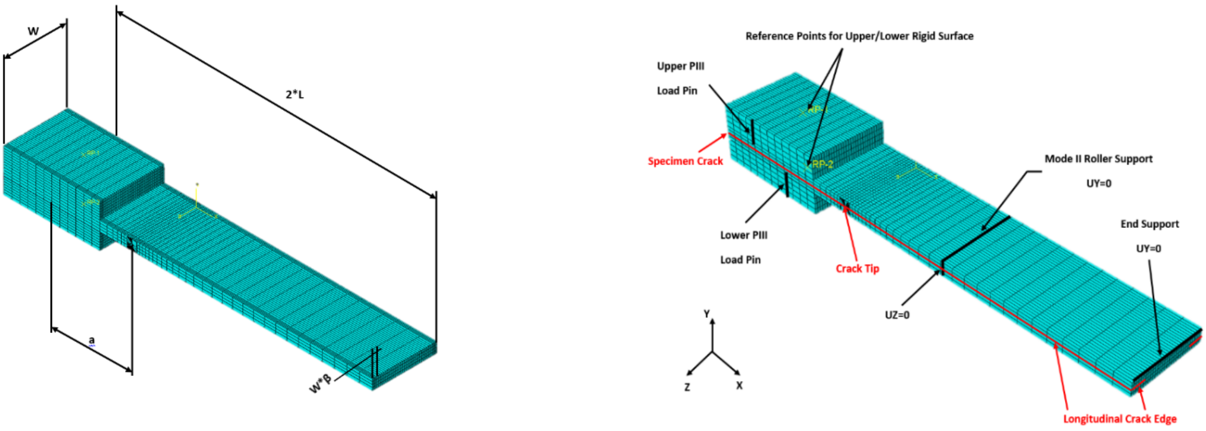

Fig. 2: 3D FEM model showing the principle geometrical parameters of the model and the boundary conditions applied.

The SERR values extracted along the crack front with the CSDE method [2] for CFRP and GFRP laminates are reported in Fig. 3. The ratio G_{III}/G_{TOT} (where G_{TOT} accounts for all three modes contributions, i.e. mode I-II and III) along the crack front is approximately equal to unity, thus indicating a pure mode III state is achievable with this preliminary design. Further numerical investigations will be carried out regarding the introduction of mode I and II.

Table 1: Material properties of the two laminates.

Laminate	Elastic Moduli [GPa]						Poisson´s ratios		
	E_{11}	E_{22}	E_{33}	G_{12}	G_{13}	G_{23}	ν_{12}	ν_{13}	ν_{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

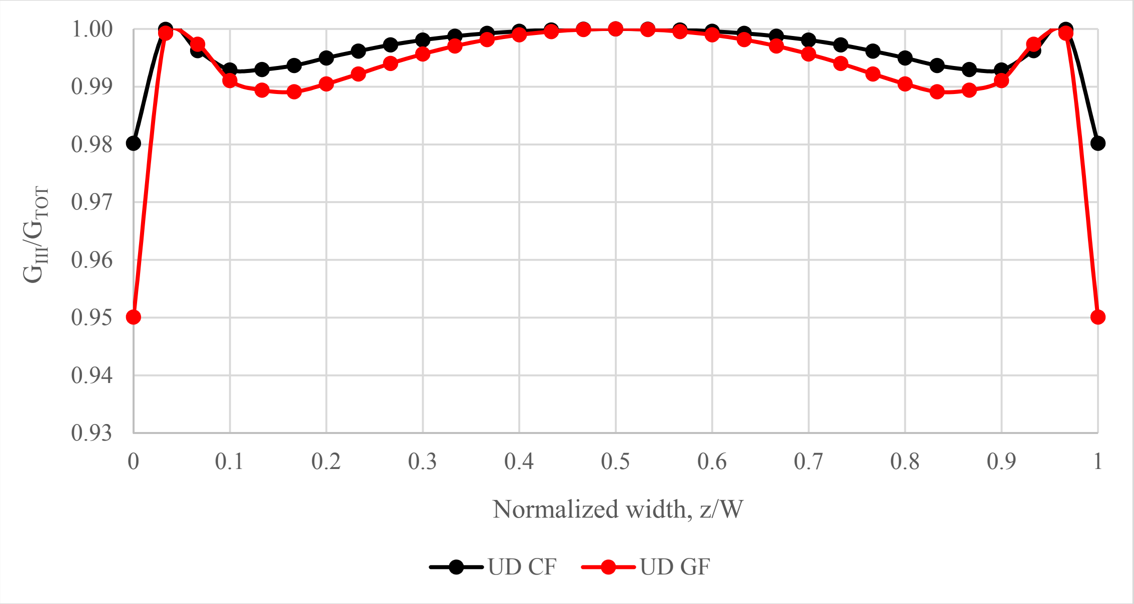

Fig. 3: G_{III}/G_{tot} trend along the crack front under pure mode III external load for two different composite laminates.

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