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PROGRAM BOOK

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1-9 - Modeling of Fracture in Hard and Sof materials — Afternoon Session

DAY: Thursday

ROOM: Ciano B

TIME 14:30-16:30

CHAIR: David Kammer, Mikhail Perelmuter

INVITED	333	**Multiscale Damage Models for Composite Laminates** Authors: Su Zhoucheng, Jerry Quek, Brian Cox, Sridhar Narayanaswamy Presenting Author: Sridhar Narayanaswamy
INVITED	1292	**The role of friction in the 3ENF and 4ENF delamination tests: an analytical solution** Authors: Francesco Parrinello, Guido Borino Presenting Author: Francesco Parrinello
INVITED	431	**Fracture modeling of adhesive connection by an imperfect soft interface model** Authors: Francesco Ascione, Marco Lamberti, Frédéric Lebon, Aurélien Maurel-Pantel, Maria Letizia Raffa Presenting Author: Francesco Ascione
	1140	**Influence of shear on interface fracture of sandwich beams** Authors: Roberta Massabò, Luca Barbieri Presenting Author: Roberta Massabò
	833	**Evaluation of facesheet-to-core interface strength in sandwich panels in the dynamic debonding propagation analysis** Authors: Vyacheslav Burlayenko, Tomasz Sadowski, Svetlana Dimitrova Presenting Author: Vyacheslav Burlayenko
	1250	**Crack front fingering in failure of heterogeneous brittle solids** Authors: Manish Vasoya, Véronique Lazarus, Laurent Ponson Presenting Author: Laurent Ponson

Coffee Break 16.30-17.00 - Ground floor and 1st floor

The role of friction in the 3ENF and 4ENF delamination tests: an analytical solution

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Keywords: Friction, Delamination, Toughness

In composite structures, the presence and growth of delamination mechanisms in static or fatigue loading conditions is of paramount interest and the American Society for Testing and Materials (ASTM) has adopted the three-points bend end-notched flexure test (3ENF) as the standard for measurement of mode II toughness. The drawback of the 3ENF test is the unstable crack growth and a modified version of the test, namely the four points bend end-notched flexure test (4ENF), has been proposed in [1]. The main advantage of the 4ENF over the 3ENF is that crack growth is stable under displacement control, but it can be strong influenced by the interlaminar frictional effects, as pointed out in [2].

The effect of frictional contact between the delamination surfaces has been initially analysed for the 3ENF test in [3], whereas the evaluation of frictional effects on the 4ENF test has been proposed in [4]. Recently, the analytical solution of the mode II delamination toughness in the 4ENF test, with interlaminar friction, has been proposed in [5].

In the present paper, the analytical solution of the mode II delamination toughness, in presence of friction on the delamination surface, is proposed also for the 3ENF delamination tests. This solution is rigorously developed in the framework of Classical Beam Theory (CBT), under Bernoulli bending condition, and in the framework of linear elastic fracture mechanics. The frictional phenomenon is modelled as rigid perfectly-plastic with Mohr-Coulomb activation condition and non-associative flow rule. The mode II fracture energy is defined by the Griffith approach, by evaluating the energy release rate and the frictional dissipation.

The results of the 3ENF and 4ENF mode II delamination toughness are compared for some values of the frictional coefficient. In order to verify the accuracy of the analytical solution, a comparison with a finite element numerical solution with cohesive-frictional interface element is presented.

References

[1] *Martin, R. and Davidson, B., "Mode II fracture toughness evaluation using four point bend, end notched flexure test.", Plas. Rubber Compos. Proc. Appl.,* **28(8)***, 401–406. (1999).*

[2] *Schuecker, C. and Davidson, B., "Effect of friction on the perceived mode II delamination toughness from three- and four-point bend end-notched flexure tests." ASTM Special Technical Publication,* **1383***, 334–344 (2000).*

[3] *Gillespie, J., Carlsson, L., and Pipes, R., "Finite element analysis of the end notched flexure specimen for measuring mode II fracture toughness", Composites Science and Technology,* **27(3)***, 177 – 197 (1986).*

[4] *Fan, C., Ben Jar, P.-Y., and Roger Cheng, J.-J., "A unified approach to quantify the role of friction in beam-type specimens for the measurement of mode II delamination resistance of fibre-reinforced polymers. Composites Science and Technology,* **67(6)***, 989–995. (2007).*

[5] *Parrinello, F., "Analytical solution of the 4ENF test with interlaminar frictional effects and evaluation of mode II delamination toughness." Journal of Engineering Mechanics, in press (2018).*