Book of abstracts of the 6th International Conference on Advanced Computational Methods in Engineering, ACOMEN 2014
23–28 June 2014.

Damage modeling of woven-fabric laminates with SAMCEF: validation at the coupon level

M. Bruyneel[1,2], J.P. Delsemme[1], A.C. Goupil[1,3], P. Jetteur[1], C. Lequesnes[1], T. Naito[4] and Y. Urushiyama[4]

[1] *LMS Samtech, A Siemens business, Liège Science Park, Belgium*

[2] *University of Liège, Belgium*

[3] *ISMANS, Le Mans, France*

[4] *Honda R&D, Tochigi, Japan*

e-mails: `Michael.Bruyneel@lmsintl.com`, `Jean-Pierre.Delsemme@lmsintl.com`, `Anne-Charlotte.Goupil@lmsintl.com`, `Philippe.Jetteur@lmsintl.com`, `Cedric.Lequesne@lmsintl.com`, `Tadashi_Naito@n.t.rd.honda.co.jp`, `Yuta_Urushiyama@n.t.rd.honda.co.jp`

Abstract

Inter and intra-laminar damages in laminated composites made up of woven fabric plies are considered. Simulation, carried out with the SAMCEF finite element code, is compared to experimental results and validations are done at the coupon level.

Key words: woven fabrics, damage models, laminar, SAMCEF

Inter and intra-laminar damage models for woven fabrics

The material model for the intra-laminar damage is based on continuum damage mechanics [1, 2]. In the laminate made of homogenous plies, damage variables impacting the stiffness of each ply are associated to the different failure modes and represent the fiber breaking, matrix cracking and de-cohesion between fibers and matrix. A specific identification procedure is used to determine the values of the damage model parameters.

This procedure is based on test results at the coupon level. It allows determining not only the elastic properties but also the value of the parameters describing the non-linear behavior of the material, including non-linearity in the fiber direction, as well as damage and plasticity in the matrix. The material parameters are then validated by comparing test and simulation results on a stacking sequence not used for the identification. In Figure 1, the identification is done on a balanced [45]n laminate, while the validation is carried out on a [67.5]n laminate.

The cohesive elements approach is used for modeling the inter-laminar damage, that is delamination. A damage model is assigned to some interface elements inserted between plies to represent their possible de-cohesion and a fracture criterion is used to decide on the inter-laminar crack propagation [3]. It is demonstrated here that, in general applications, modeling delamination alone is not enough, concluding that it is essential to model the damage inside

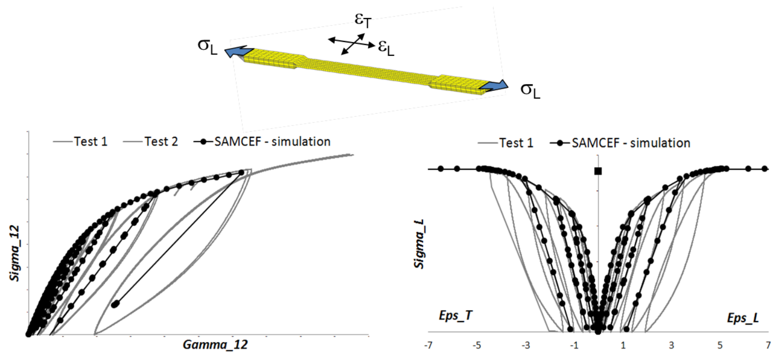

Figure 1: Left: identification on a [45]n; right: validation on a [67.5]n.

the plies besides the damage at their interface. This is illustrated for the ENF (End Notched Flexure) test case, as depicted in Figure 2, in which simulation is compared to the test results. In Figure 2, the dashed line represents the constant slope characterizing the beam stiffness when only delamination is taken into account. In reality, the ply is also damaged during the loading. When the simulation takes this effect into account, there is a good agreement with the experimental results.

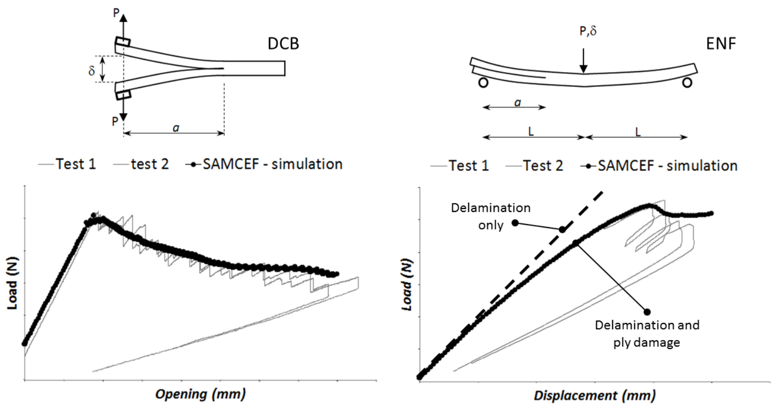

Figure 2: Left: DCB problem with 45° interfaces; right: ENF problem with 45° interfaces.

References

[1] LADEVEZE P., LE DANTEC S., *Damage modeling of the elementary ply for laminated composites*, Composites Science and Technology **43** (1992).

[2] HOCHARD C., AUBOURG P.A., CHARLES J.P. , *Modelling of the mechanical behavior of woven fabric CFRP laminates up to failure*, Composites Science and Technology **61** (2001) 221–230.

[3] ALLIX O., LADEVÈZE P., *Interlaminar interface modelling for the prediction of laminate delamination*, Composite Structures **22** (1992) 235–242.