EXPERIMENTAL AND NUMERICAL ANALYSIS OF PULL-THROUGH OF FASTENERS IN LAMINATES

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Summary. This paper presents an experimental and numerical study on failure mode occurring during pull-through tests of fasteners in laminates. It was observed that matrix cracking followed by delamination occurred in the thickness of the laminate. Splitting was also observed at the edge of the fastener head. A model previously developed for impact in laminate [1] is extended to this case. A good experimental/numerical comparison is achieved.

With the increasing use of composite materials in aerospace structures, carbon-fibre reinforced plastics (CFRP) assemblies with thin laminates are more and more present. In some cases as L-angle junctions, loadings on these assemblies can involve out-of-plane stresses. In this case, pull-through of the fastener head can occur [2]. This failure mode involves complex phenomena, including matrix cracking, splitting and delamination (see figure 1). A limited number of studies are dedicated to this subject. In fact, the damages that occur are basically the same as in impact. Thus, one of the key-points was a correct understanding and an efficient modelling of the damage scenario. Recently, the authors have developed an original approach based on cohesive elements and non linear springs able to model the damage scenario and especially the matrix cracking/delamination coupling [1]. This new approach will be extended to this case.

Thirty circular pull-through tests of a threaded fastener into a simply supported carbon-epoxy laminate, with various support diameters were conducted (see figure 2). Spatial displacements of the laminate surface and of the fastener head were measured by three-dimensional stereo-correlation system. The failure scenario, based on ultrasonic inspection and micrographic examinations at several loads was established. It is in accordance with existing studies [3]. The influence of the support diameter on failure scenario and on structural and ultimate loads is also studied.

The model is based on a special mesh which follows the orientation of the plies. Example is given figure 3 for a 0°/90° stacking sequence. Cohesive elements are used to model matrix...
cracking and delamination. Due to the mesh choice a natural coupling between these two modes can be performed. Simulation results were compared to experimental values and micrographic examinations. Promising correlations are found both for the failure scenario and for the failure loads.

Figure 1: Failure pattern

Figure 2: Test rig

Figure 3: Modelling principle

REFERENCES

