Visitor Research Report

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Area of Research: **Structural Mechanics**

Period of Visit: **July 28, 2008 through August 15, 2008**

Goals:
The main goal of the NIA visit has been to analyze the need to consider the hydrostatic pressure component in delamination damage model for polymer-based composite materials. The starting point is the damage model implemented by Turon of University of Girona, which is formulated by using continuum damage mechanics and implemented in a user element subroutine of ABAQUS finite element software.

Apart of it, the visit in NIA has been a gratefully experience looking toward to share knowledge about different studies carried out on composite materials during the past year by Dr. Carlos Davila, Dr. Pedro Camanho, and Emilio Gonzalez. In more detail, some items analyzed are:

- Approaches available to characterize quickly the nature of the impact behaviour on monolithic, flat and rectangular plates of polymer-based composite materials.
- Analytical models for the predictive description of the impact results.
- Constitutive model implemented in an explicit finite element code to describe the delamination damage mechanism.

Strategy:
Large experimental data demonstrate that hydrostatic pressure has effects on the elastic properties, the strengths, and fracture toughness (only in shear modes) of polymer-based composite materials.

On the other hand, there is another interesting result from experimental data of the tests to obtain the fracture toughness in pure mode II. These tests are *TCT* (transverse crack tension) and *ENF* (end-notched flexure). The results are that the fracture toughness obtained by means of *TCT* tests are higher than that of *ENF* tests, despite to use the same material. Probably, this result can be related with the hydrostatic components of the stress tensor.

There are several authors that have been implemented cohesive damage models by considering frictional effects in such away that take into account the compressive effect

of mode I in shear mode damage loading. These approaches are related directly with the hydrostatic effect commented.

Therefore, the strategy used is described sequentially by the following points:

1. State of the art of the tests carried out under different values of hydrostatic pressures.
2. State of the art of the *TCT* and *ENF* tests carried out. The goal is to describe the dependences of each test with their specimen geometric variables.
3. Finite element model to analyze the stress state at the crack tip for *TCT* and *ENF* tests. These *FEM* models have to be completely parameterized (by means of an input file of ABAQUS).
4. In function of the results extracted, the new cohesive damage formulation can be realized.
5. Cohesive damage implementation in a user material subroutine of ABAQUS/Explicit code.

Accomplishments:
Points 1 to 3 have been done. After read the different papers available in the literature, it is necessary to consider the mode I compression effect under shear delamination process. However, the consideration of the hydrostatic tensor is not clear yet.

About the *TCT* experimental data available is not enough to conclude that the fracture toughness obtained is higher than that of *ENF* tests. Therefore, it can be interesting to design a specimen matrix for *TCT* test to analyze in detail the geometric effects.

Future Work:
The future work derived is:

1. To design, manufacture, and test different cases of the *TCT* test.
2. Conclude what is the best option to consider the mode I compression effect under shear delamination process.
3. Formulate and implement the cohesive damage model.

Pending Publications:
A paper which contents all the things collected in the previous points.

Seminar Presented:
Specimen matrix definition for drop-weight impact test and compression after impact (*CAI*)