VISITOR RESEARCH REPORT

Visitor Name: **Daniele Versino**

Area of Research: **Refined Zigzag Theory Based Structural Analysis**

Period of Visit: **April 4, 2011 – June 24, 2011**

Goal:

The main scope of the research activity was to implement into ABAQUS and validate a shallow shell finite element based on the Refined Zigzag Theory for composite and sandwich beams, formulated by Dr. Alex Tessler and Marco Gherlone.

Strategy:

The element we have developed, as an ABAQUS user element, is a three-node triangular shallow shell that uses a drilling degree of freedom formulation. This element uses parabolic shape functions for the in-plane displacements and the deflection and linear shape functions for the average rotations and the zigzag functions amplitude. In order to reduce the total number of degrees of freedom the interdependent interpolation strategy(IIS) is used. This strategy, originally proposed by Tessler, allows to prevent some pathological shell element's problem, such as shear locking, and lead to an increased accuracy.

The element's validation was performed in 4 steps:

1. patch tests and simple load tests taken from the ABAQUS verification manual
2. Cook's problem, Scordelis-Lo roof problem and Pinched Hemispherical Cap problem
3. Pagano's problem
4. built-up structure

After the element passed the patch tests and the simple load test its accuracy was verified by taking as reference some widely-used problems whose analytical solution is known from literature(Cook's problem, Scordelis-Lo roof problem and the Pinched Hemispherical Test). For homogeneous laminates the element performs as good as the ABAQUS S3 element in bending end shear problems, better than the S3 element for pure membrane load cases.

The RZT's prediction capabilities were checked with the Pagano's problem: the results obtained with the RZT element were very accurate with respect to the analytical solution of the problem both for the displacements and for the section's stress resultants.

For this test the results obtained with the S3 element were very poor: it dramatically underestimates the displacements of at least 10 times.

The convergence of the solution for very complicated structures was verified by modeling a laminated built-up panel with a hole in the middle that undergoes to uniaxial compression. The results converge uniformly to the solution as the mesh becomes finer and finer.

Accomplishments:
A reliable shell finite element based on the Refined Zigzag Theory was implemented and validated. It increases the ABAQUS's prediction capabilities for problems were thick sandwiches or laminated structures are modeled.

Future Work:
Extend the element's capabilities by adding the mass matrix and the geometrical stiffness matrix in order to perform dynamic analysis and buckling analysis.