Delft University of Technology

Aerospace Structures & Computational Mechanics
**Ph.D. Seminar Series**

**Fardin Esrail**

# Efficient and accurate analytical models for the determination of the extent of damage and compression strength after impact in composite laminates

*M.Sc. Thesis*
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Ever since it was “discovered” as a serious issue limiting the performance of composite structures in the late 70s, impact has been a very hot research topic. People have developed dynamic and static models for the impact event and attempted to determine the resulting type, location, and amount of damage with various degrees of success. Furthermore, modeling the compression after impact has also received a lot of attention with numerous models developed ranging from simple curve fits to very detailed finite elements with updated stiffness properties or with the use of cohesive elements. However, even though the progress has been significant, either the accuracy of most methods is not satisfactory or the computational requirements are prohibitive for large scale implementation in industry design and analysis environments.

An approach will be presented that uses energy minimization to determine the stresses during impact in a quasi-isotropic laminate. The solution obtained captures the local contact stresses and global bending stresses at the same time. The classical plate solution is recovered outside the contact area. The resulting expressions are shown to agree well with known solutions of special cases (e.g. Love on isotropic semi-infinite plate). These stresses are combined in simple failure criteria to determine the extent of delaminations created, fiber damage, and matrix failure. The resulting damage contours are compared to test results from impacted specimens and are shown to be in excellent agreement with the exception of few cases that are under investigation.

Based on the predicted damage, new stiffness and strength properties are estimated for the damaged region in the form of concentric ellipses of different stiffness and strength. In addition, an analysis model for the determination of the stresses in a laminate with concentric elliptical inclusions of different properties was created. It was found to be in excellent agreement with finite element results.

The next stage of the work is to use the models presented to determine the compression after impact strength of composite laminates. As this is still work in progress, any ideas and comments about the entire body of the work but also in relation to the determination of the compression after impact strength would be greatly appreciated.

time: **Tuesday, June 11th, 2013, 16:00**
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