Helius:MCT for Progressive Failure Analysis of Composite Materials

A User's Review of Helius:MCT™ from Firehole Composites

By Thomas McQuigg[1,2]

An Introduction to Helius:MCT for Progressive Failure Analysis

Throughout 2010, I have had the pleasure of working with Firehole Composites and their composite laminate analysis software Helius:MCT in the course of my Ph.D. work at Virginia Tech. The focus of this work has been the development of a tool to predict compression after impact failure in honeycomb core sandwich panels through experimentation and finite element model development. As part of this work, a progressive failure analysis (PFA) of the facesheets was planned to predict material failure in that part of the model. When I began this work, Helius:MCT software was made available for my use through a mutual partner, NASA Langley Research Center.

I was interested in running my analysis on a Linux machine, so we obtained essentially a beta version of the Helius:MCT software made to operate on a Linux machine. The finite element analysis would be done through the commercially available Abaqus finite element code by Dessault Systems. Helius:MCT is essentially an add-on to Abaqus in the form of a plug-in which is accessible through the FEM pre-processor software, Abaqus/CAE, and a composite laminate material model which is installed and run as a part of the implicit Abaqus solver, Abaqus/Standard. At the time this work began, the Helius:MCT plug-in did not exist for the Linux version of Abaqus/CAE.

Although a PFA using Helius:MCT could still be done, I was still able to acquire a version of the Helius:MCT plug-in for pre-processing using a Windows machine. The reason for using the Helius:MCT plug-in to insert a PFA into the model is its ease of use. Once installed, the Helius:MCT plug-in is seamlessly integrate into the Abaqus/CAE preprocessor. This allows insertion of a material with the associated material properties and analysis options selected for a Helius:MCT PFA in a matter of

[1] Ph. D. Candidate in Aerospace Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA.
[2] Graduate Research Assistant, National Institute of Aerospace

seconds. As a simple graphical user interface, if you can point and click, you can run a Helius:MCT analysis.

Using Helius:MCT

To get started with running a Helius:MCT analysis, Firehole provides a wealth of information to help new users, including a user's manual, two example problems and two tutorials. In addition, to help obtain an understanding of how the progressive failure analysis works, a theory manual is provided. In the theory manual, the multi-continuum analysis used to convert the composite average stress state to constituent average state is explained, as well as the failure theory. The failure theory used is similar to other material strength based theories (such as Hashin or Tsai-Wu), but has the added benefit to be based on the constituent average stress state as opposed to the composite average state. Each of these theories is explained fully in the theory manual. However, at one point, I did request further information and additional documentation on the failure was quickly provided by a Firehole Composites engineer, Brady Adams.

In fact, Brady was available and exceedingly helpful throughout the process of installing, using and understanding the Helius:MCT software. Since my needs required a Helius:MCT installation slightly more complicated than the average user (due to the use of multiple computing platforms), at one point I was in daily contact with Brady through email and he responded each time with quick and thoughtful advice and technical support. In all forms, the help and support a Helius:MCT user receives from Firehole Composites exceeded my expectations.

In addition to the Helius:MCT Abaqus/CAE plug-in, two other pieces of software are included with the installation. The Material Manager is a separate graphical user interface that allows for the simple creation of materials for use with Helius:MCT. The user must provide standard material constitutive and strength properties for the laminate. If available, the user can also provide constituent material properties, but the Material Manager is able to establish *in situ* properties even if they are not available from the user. The other software is a command line program called X-Stiff, which has a very specialized purpose. This purpose is to calculate additional stiffness parameters automatically based on a given Abaqus input file. One example of the use of these stiffness parameters is to control zero energy deformation modes in elements which use reduced integration schemes. Normally, Abaqus calculates these behind the scenes, so some users may not be aware of their use or meaning. For a user-defined mechanical model, which Helius:MCT is treated as, these must be manually included. Since this process is time-consuming and tedious, X-Stiff is quite handy and a well-thought out addition to the Helius:MCT package.

While the software and support associated with Helius:MCT are very impressive, an actual analysis is where the benefits of using Helius:MCT for composite PFA really lay. Each analysis runs very quickly. This is due to the equilibrium convergence routine that is done within the Helius:MCT software in addition to the PFA. In addition, the analysis results for local material failure prediction are easy to understand through plots made in the Abaqus/Visualization module. Each of the results is explained clearly in the documentation and due to the basis in material strength and failure they are very intuitive.

I've also had the opportunity to compare Helius:MCT to the progressive failure analysis available built-in to Abaqus. In addition to the material stiffness and strength coefficients that are necessary to predict damage initiation, fracture energy values are necessary to define damage propagation in the material after initial damage onset. These values are not readily available in literature. Solution convergence is also more difficult with Abaqus' built-in PFA. To help with this, users can supply damage stabilization coefficients to slow down damage propagation. However, the result is a less realistic fracture so failure prediction is affected. Other more advanced techniques are available to help with convergence, but they result in significant solution efficiency reduction.

Demonstration

To demonstrate these observations the following simple analysis was done. An eight-ply balanced and symmetric laminate with 0, +/-45, and 90 degree orientation angles with an open hole at the center was given an applied longitudinal displacement to exceed its expected tensile strength. Laminate failure was analyzed using both Abaqus PFA and Helius:MCT and the following results were found. Figure 1 below shows tensile fiber fracture in red as characterized by both Abaqus PFA and Helius:MCT. The force required for global failure of the laminate is characterized as the maximum value in the force vs. displacement curve shown in Fig. 2. The results from both analyses method are strikingly similar. However, the computational time required for Abaqus to conduct this analysis using its built-in PFA was over 1300 seconds, compared to just under 150 seconds using Helius:MCT. This is almost 10 times the amount of computational time required per analysis!

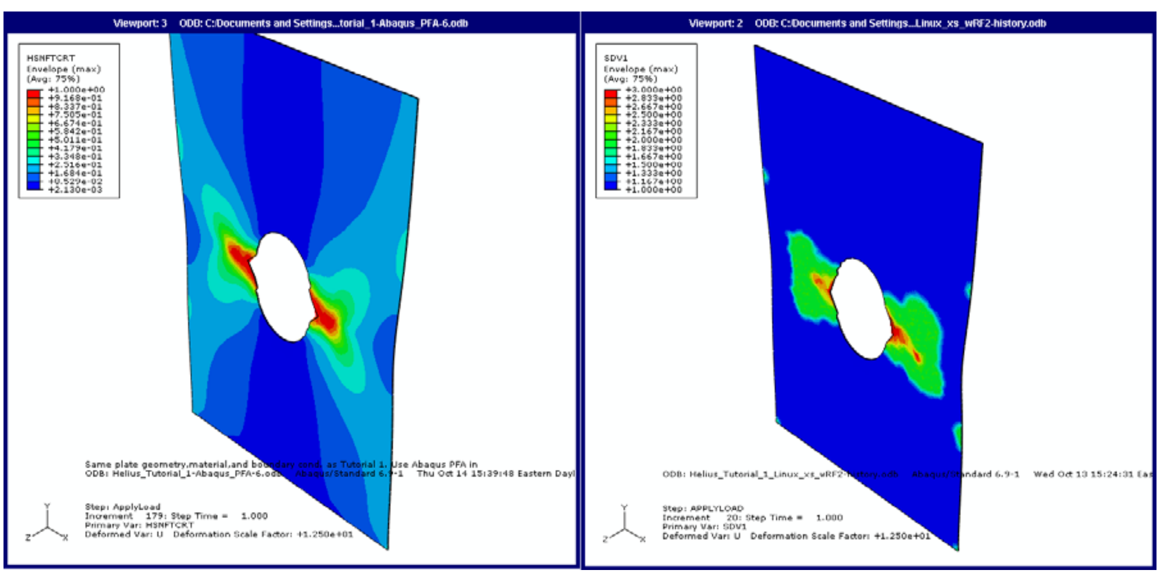

Figure 1. Fiber fracture (in red) shown in analyses conducted using Abaqus PFA (left) and Helius:MCT (right).

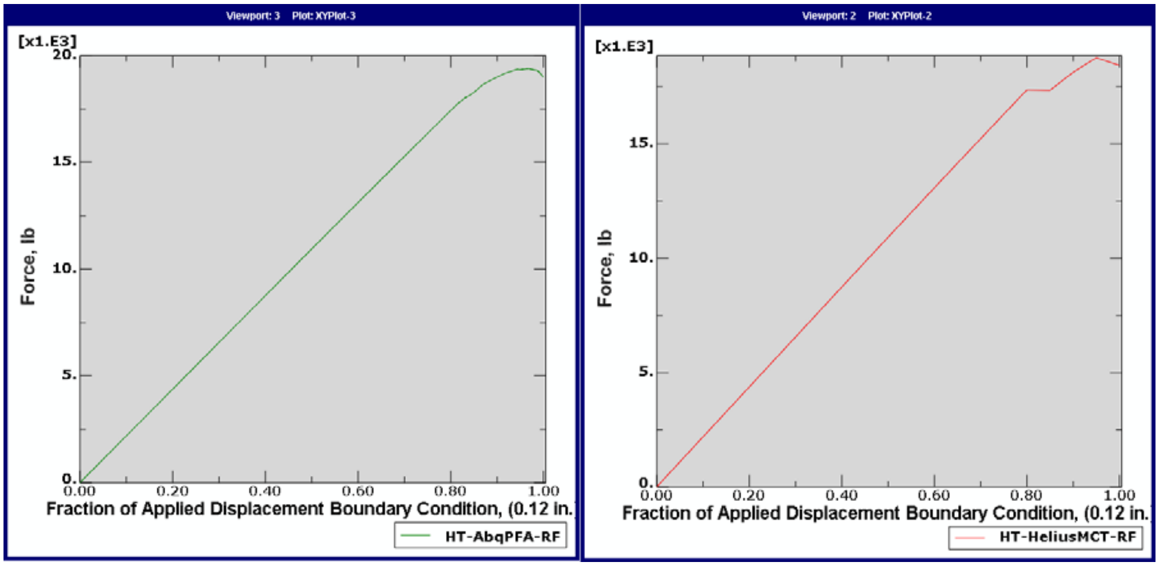

Figure 2. Reaction force vs. fraction of applied displacement for Abaqus PFA (left) and Helius:MCT (right).

Conclusion

Overall, I've been surprised at the robustness and ease-of-use of the Helius:MCT software from Firehole Composites. It's been a valuable tool in my work, as an efficient method of conducting a progressive failure analysis with good results. As a first-time user the documentation available was more than adequate. When that wasn't enough the support you receive from Firehole personnel is first class. I hope to continue to work with Firehole and Helius:MCT in the future.

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The Aerospace and Ocean Engineering Department, housed within the College of Engineering at Virginia Tech, grants degrees in both Aerospace and Ocean disciplines taking advantage of the commonality between the two disciplines. In addition the broad research capabilities of the department include such facilities as world class wind-tunnels, structural testing equipment, high-performance computer systems, and advanced spacecraft simulators.

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