FIREHOLE TECHNOLOGIES
ADVANCED COMPOSITES ANALYSIS

# Helius:MCT 3.0 Tech Brief

Helius:MCT 3.0 offers three significant enhancements beyond Helius:MCT 2.0: woven composite functionality, the ability to use temperature-dependent material properties for unidirectional mposites, and tool (Abaqus only) to automatically calculate the extraneous stiffness parameters needed when using a user material. This document highlights the utility of each of these enhancements and gives some examples of their use.

## Woven Composite Functionality

One of the primary features introduced by Helius:MCT 3.0 is woven composite functionality. This permits the finite element user to model woven composite structures using the same progressive failure methodology that has been successfully used for unidirectional composite structures [1-4]. This is accomplished using what is known as three-constituent multicontinuum theory (MCT) [5,6]. This approach allows volume average constituent (fiber and matrix) stresses to be extracted from homogenized composite stresses so that failure of each constituent can be evaluated. If any failure is detected, the elastic properties of the failed constituent are degraded and, correspondingly, the composite elastic properties are appropriately degraded. As with unidirectional composites, this approach is very computationally efficient, and the proprietary intelligent discrete softening (IDS) method is used to ensure robust convergence.

As an example of the capabilities of the woven composite functionality of Helius:MCT 3.0, we present results from a finite element progressive failure analysis of a pin-loaded coupon in tension. Using geometries and material properties reported by Ahn *et al*. [7], we modeled three different geometries of a pin-loaded coupon, labeled ED10, WD20, and WD25. The composite laminate was a combination of woven laminae and unidirectional laminae; all were carbon/epoxy. A tensile load was applied via a pin in the hole of the coupon.

Our analysis predicted three different failure modes: shear out (ED10), net tension (WD20), and bearing (WD25). Figure 1 shows the predicted failures in the coupons at two different times: the images on the left correspond to a time when only fiber failure is present, while the images on the right show fiber failure. The modes shown in the images on the right are exactly the failure modes reported by Ahn *et al*. for each coupon. The colors correspond to the nine failure states that are captured in our progressive failure analysis. Not only do our analyses predict the correct mode of failure, they also accurately capture the load-displacement behavior of the coupons. Figure 2 shows a quantitative comparison of the load-displacement curves from model results, with experimental results reported by Ahn *et al*. [7]. For the WD20 and WD25 coupons, the ultimate loads and displacements are in excellent agreement with experimental values. The ED10 fails earlier than the experimental results, both in displacement and load, but the results are still satisfying, given that only standard test data was used and the exact nature of the contact conditions was not known.

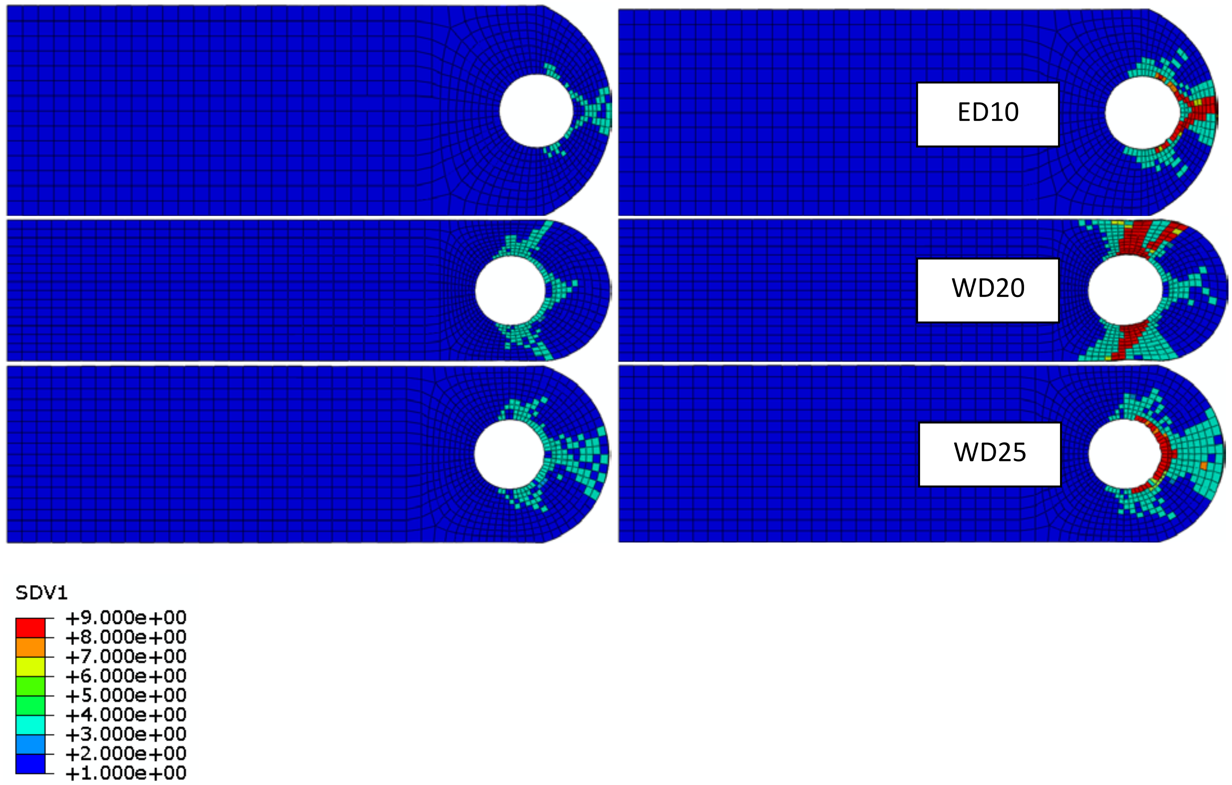


*Figure 1. Composite failure states predicted by finite element analysis using Abaqus and Helius:MCT 3.0. Images on the left correspond to a failure state with matrix failure only. Images on the right correspond to a failure state with fiber failure.*

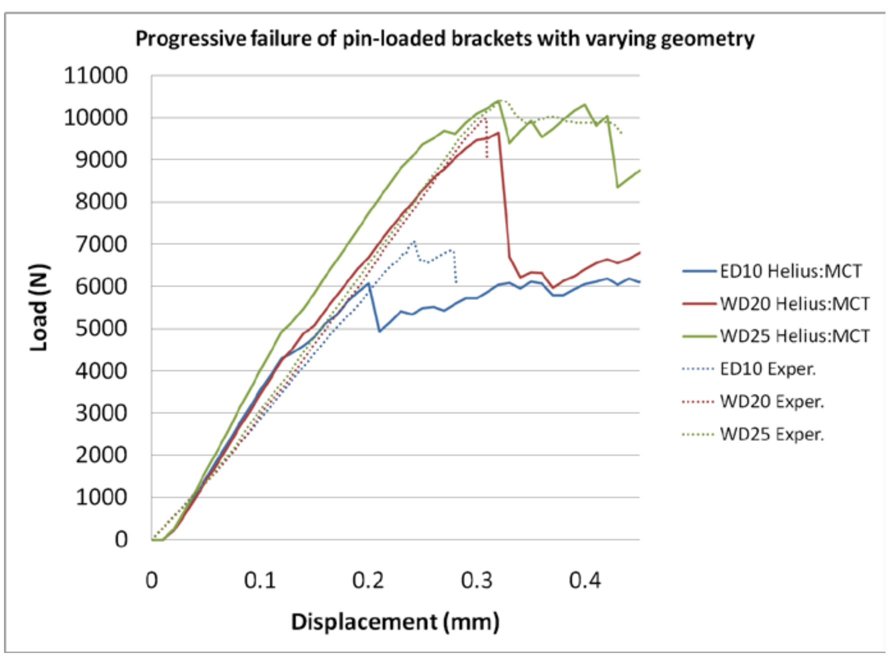


*Figure 2. Comparison of load-displacement curves predicted using finite element analysis with experiment* [7].

## Temperature-dependent material properties

Another major enhancement in Helius:MCT 3.0 is the ability to account for temperature-dependent material properties for unidirectional composites. This feature enables the user to input material properties and strengths at multiple temperatures, so that the thermomechanical behavior of the composite laminate can be properly modeled. In addition to material properties and strengths, the stress-free temperature must also be given. This enables Helius:MCT 3.0 to properly account for residual thermal stresses at different temperatures.

## Automatic calculation of extraneous stiffness parameters in Abaqus

When using user materials, one nuisance for analysts using Abaqus has been calculating the necessary extraneous stiffness parameters (hourglass and transverse shear) that Abaqus requires for reduced integration elements and inserting these values into the input file. This is particularly problematic when creating a large structural model that may contain many composite sections and/or materials. Helius:MCT 3.0 solves this problem by including a tool that automatically calculates these parameters and writes them to the appropriate location in the input file. This will increase the efficiency of the analyst and reduce the likelihood of copying errors that can easily arise from manual calculation and insertion of these parameters.

## References

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