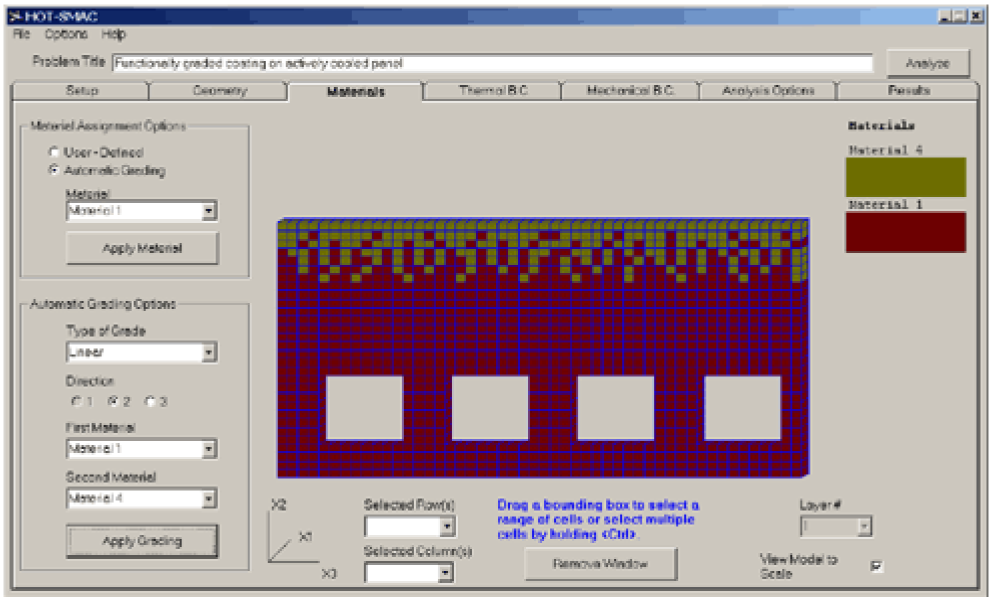
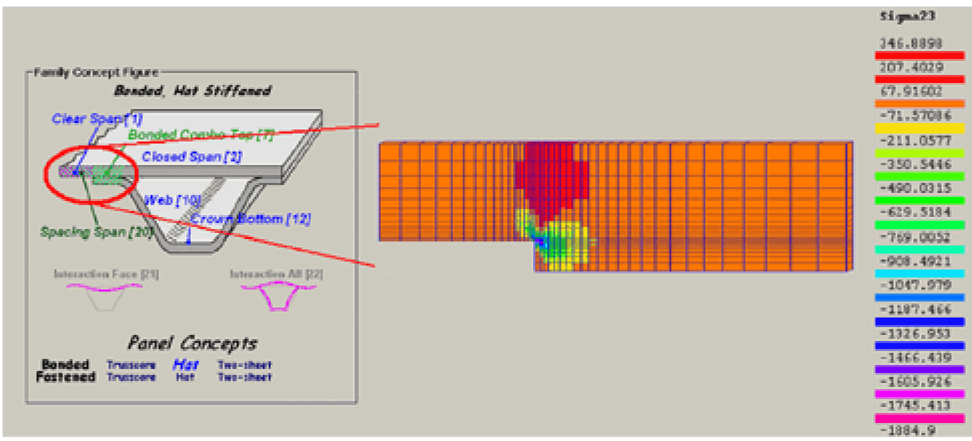
Higher-Order Theory--Structural/MicroAnalysis Code (HOT-SMAC) Developed



HOT-SMAC graphical user interface showing the material layout screen for a functionally graded material with a cooling channels problem.

The full utilization of advanced materials (be they composite or functionally graded materials) in lightweight aerospace components requires the availability of accurate analysis, design, and life-prediction tools that enable the assessment of component and material performance and reliability. Recently, a new commercially available software product called HOT-SMAC (Higher-Order Theory--Structural/MicroAnalysis Code) was jointly developed by Collier Research Corporation, Engineered Materials Concepts LLC, and the NASA Glenn Research Center under funding provided by Glenn's Commercial Technology Office. The analytical framework for HOT-SMAC is based on almost a decade of research into the coupled micromacrostructural analysis of heterogeneous materials (ref. 1). Consequently, HOT-SMAC offers a comprehensive approach for analyzing/designing the response of components with various microstructural details, including certain advantages not always available in standard displacement-based finite element analysis techniques. The capabilities of HOT-SMAC include combined thermal and mechanical analysis, time-independent and time-dependent material behavior, and internal boundary cells (e.g., those that can be used to represent internal cooling passages, see the preceding figure) to name a few. In HOT-SMAC problems, materials can be randomly distributed and/or functionally graded (as shown in the figure, wherein the inclusions are distributed linearly), or broken down by strata, such as in the case of thermal barrier coatings or composite laminates. The software's user-friendly graphical user interface (see the figure) enables engineers to specify problem geometry (such as cell definition), define material distribution with a variety of techniques for distributing materials, specify general thermal and mechanical boundary conditions, and view time-dependent temperature, stress, and strain results.

This capability was recently applied to a previously solved problem (ref.2) involving an actively cooled panel subjected to an intense flame boundary condition to validate the implementation of the recent software package. Furthermore, the following figure illustrates the kind of results available from HOT-SMAC for the free-edge region of the depicted hat-stiffened panel. Load levels determined from panel-scale structural analysis were employed as boundary conditions within HOT-SMAC. HOT-SMAC then determined the microscale in-plane shear stress field (as shown in the following figure). This type of coupled micromacroanalysis is an important strength of the HOT-SMAC software because local fields dictate local failures.



Example HOT-SMAC problem in which the in-plane shear stress field was determined for the hat-stiffened panel in the region of the flange-free edge.

The current version of HOT-SMAC is limited geometrically to two-dimensional problems (i.e., either plane stress or generalized plane strain). A team of researchers from Glenn, the University of Virginia, the Ohio Aerospace Institute, and Collier Research plan to extend the software to three dimensions and to tightly couple it with the commercial HyperSizer structural analysis and optimization software package (Collier Research Corporation, Hampton, VA). This will enable the optimization of microscale features (e.g., the reinforcement type and the distribution) to achieve a global- or structural-scale goal.

References

1. Aboudi, J.; Pindera, M.J.; and Arnold, S.M.: Higher-Order Theory for Functionally Graded Materials. CPSOA, Part B--Engineering, vol. 30, no. 8, 1999, pp.777-832.
2. Arnold, Steven M.; Bednarcyk, Brett A.; and Aboudi, Jacob: Thermo-Elastic Analysis of Internally Cooled Structures Using a Higher Order Theory. NASA/TM-2001-210702, 2001.

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