Software

Software for Simulating Progressive Fracture in Braided PMCs

Simulations provide guidance to increase efficiency of design and testing efforts.

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GENOA-PFA is a commercial version of the Composite Durability Structural Analysis (CODSTRAN) computer program, which simulates the progression of damage ultimately leading to fracture in polymer-matrix composite (PMC) material structures under various loading and environmental conditions. GENOA-PFA offers a number of capabilities beyond those of programs developed previously for the same purpose; these capabilities make GENOA-PFA preferable for use in analyzing the durability and damage tolerance of complex PMC structures in which the fiber reinforcements are in the forms of two- and even three-dimensional weaves and braids.

GENOA-PFA implements a progressive-fracture methodology, the basic concept of which is that a structure fails when flaws that may initially be small (even microscopic) grow and/or coalesce to a critical dimension such that the structure no longer has an adequate safety margin to avoid catastrophic global fracture. Damage is considered to progress through five stages: (1) initiation, (2) growth, (3) accumulation (coalescence of propagating flaws), (4) stable propagation (up to the critical dimension), and (5) unstable or very rapid propagation (beyond the critical dimension) to catastrophic failure. The computational simulation of progressive failure involves formal procedures for identifying the five different stages of damage, quantifying the amount of damage at each stage, and relating the amount of damage at each stage to the overall behavior of the deteriorating structure.

In GENOA-PFA, mathematical modeling of the physics of a PMC involves an integration of simulations at multiple, hierarchical scales ranging from macroscopic (lamina, laminate, and structure) to microscopic (fiber, matrix, and fiber/matrix interface) [see figure]. GENOA-PFA includes algorithms needed for simulating the progression of damage from various source defects; examples include (1) through-the-thickness cracks, and (2) voids with edge, pocket, internal, or mixed-mode delaminations.

The elements of a GENOA-PFA simulation include the following:

- nite-element analysis with through-the-thickness representation;
- Simulation of effects, on global static- and cyclic-fatigue strengths, of material defects and conditions, which can include voids, fiber waviness, and residual stresses;
- Inclusion of nonlinearities of materials through periodic updating of material-property parameters and inclusion of geometrical nonlinearities through Lagrangian updating;
- Simulation of the initiation and growth of cracks to failure under static, cyclic, creep, and impact loads;
- Progressive-fracture analysis to determine durability and damage tolerance;
- Identification of the fractional contributions of various possible composite failure modes involved in critical damage events; and
- Determining sensitivities of failure modes to such design parameters as fiber volume fractions, ply thicknesses, fiber orientations, and thicknesses of adhesive bonds.

GENOA-PFA can be used to investigate the deterioration of two- or three-dimensional PMC structures subjected to static, cyclic (fatigue), creep, and impact loading in hygrothermal environments. The use of GENOA-PFA can be expected to facilitate targeting of changes in design parameters for greatest effectiveness in reducing the probabilities of given failure modes.

This work was done by Frank Abdi of Alpha Star Corp. and Levon Minnetyan of Clarkson University for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

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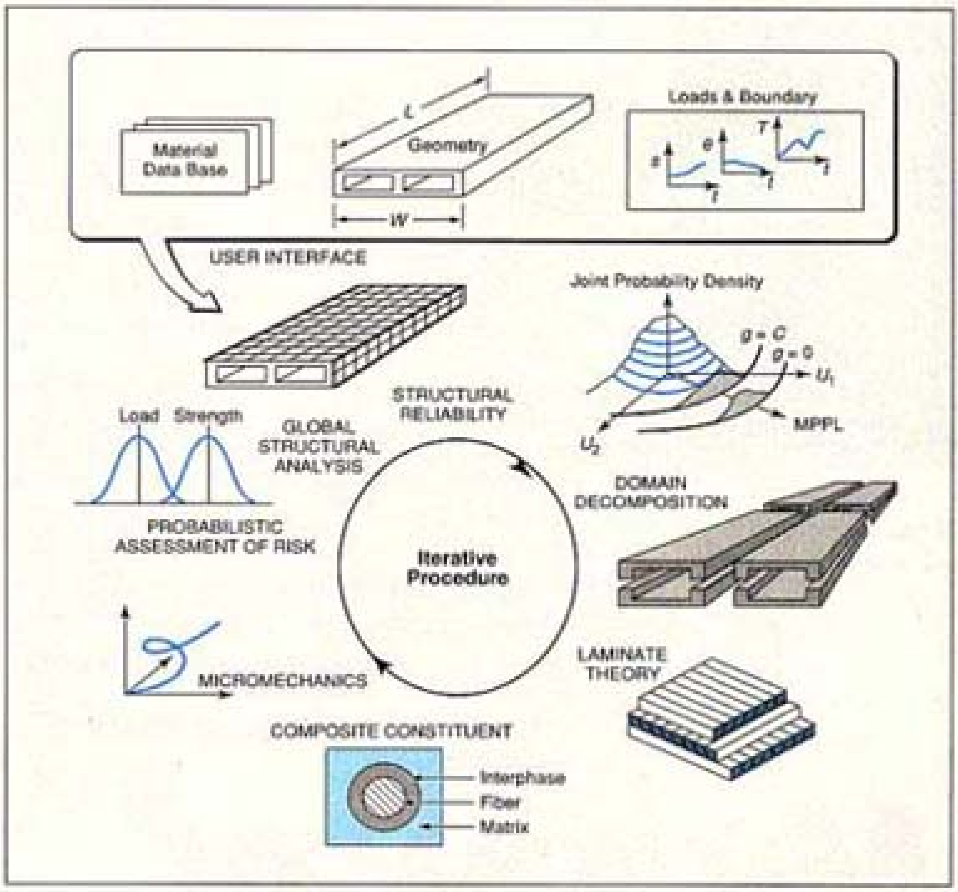

GENOA-PFA is a parallel-processing program for analysis of PMC structures. Simulations at macro-

The elements of a GENOA-PFA simulation include the following:

• Ply-layering methodology utilizing fi-

GENOA-PFA is a parallel-processing program for analysis of PMC structures. Simulations at macroscopic and microscopic scales are integrated to predict the overall degradation of a structure under prescribed loading and environmental conditions.