GENOA 5

Tested and Verified.™

GENOA Progressive Failure Dynamic Analysis (PFDA)

- **Augments Explicit Dynamics (ED) finite element analysis (FEA) with multi-scale composite mechanics.**
- **Damage tracking and fracture to determine all stages of damage evolution under impact, crush, or crash loading condition.**
- **Predicts and simulates all 5 stages of the impact process.**
- **Switch solvers/boundary condition/analysis type before or after impact event and keep residual damage and stresses.**
- **Calculates crack density, micro-cracks in the matrix, delamination within the plies, and fiber failure in tension and compression including micro-buckling.**
- **The damage tracking is done by identifying and accumulating damage at the "root cause" of the composite in matrix and fiber using dedicated physics based damage and failure criteria.**
- **Obtain Integrated Explicit Dynamics Solutions with LS DYNA, xDYNA, RADIOSS, ABAQUS, ANSYS**

GENOA Progressive Failure Dynamic Analysis (PFDA) provides engineers with well-established and verified multi-scale capability to characterize impact resistance of composite structures to determine: damage foot print, energy absorbed during impact, and post-impact residual strength and stiffness in tension, compression, and shear. GENOA PFDA will accurately predict the impact and post impact behavior of advanced composite laminates (2-D/3-D) considering effects of (1) defects, voids, fiber waviness, (2) micro-crack density (leakage, stiffness reduction), (3) residual stresses (winding, curing). Switch solvers/boundary condition/analysis type before or after impact event and keep residual damage and stresses.

GENOA PFDA Highlights

✓ **Supports full breadth of 2D/3D composite architectures**
- Laminated Tape Lay-Up, CVI, MI, EBC/TBC, SiC, Oxide
- Fiber Architecture (Woven, Triaxial, Harness Satin Weave, Braided,and Stitched)
- Fiber Coating (InterPhase)
- Fully integrated with MCQ Libraries and FE Solvers
- Effects of manufacturing defects

✓ **Determines impact behavior**
- Damage foot print
- Damage initiation and propagation to final failure
- Change ply layups to meet design requirements
- Residual impact behavior (TAI, CAI, FAI)
- Design failure envelope, fatigue analysis

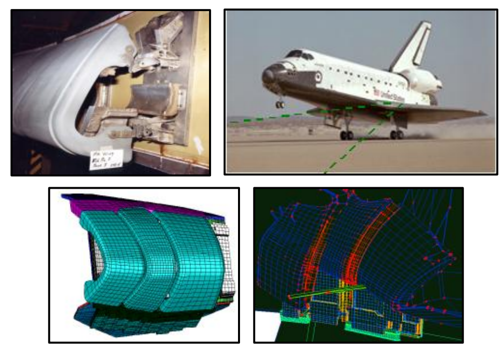
✓ **Supports Failure Criteria (In-built and User Defined)**
- Translaminar (Matrix, Fiber, Ply)a
- Interlaminar/Delamination (Tension, Shear, Relative Rotation)
- Interactive Strength (Tsai-Wu, Tsai-Hill, Puck, MDE, Hoffman, Hashin)
- Interactive Strain- Strain Invariant Failure Theory (SIFT)
- Maximum Stress, Maximum Strain, User Defined

✓ **Supports Detailed Micromechanical Degradation**
- **Micro Crack Density** – Formation of crack density in matrix loaded components reducing stiffness and strength
- **Matrix Defects** – Void shape, size distribution reducing stiffness and strength, matrix creep, fatigue
- **Fiber Strength Statistics** – Gradual failure "Rope effect" – Probabilistic Weibull distribution
- **Interphase Mechanics** – Fiber bridging

✓ **Supports Service Loading**
- Impact, Post Impact
- **Export Damage/Residual Stresses used in another simulation/solver**
- Change boundary conditions/solver/ analysis type
- Impact to static/fatigue/creep (any combination and sequence)

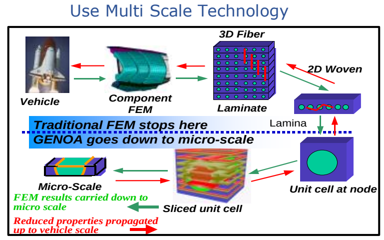
✓ **Includes Tutorials/Solutions**
- Progressive Failure Dynamic Analysis
- Progressive Failure Dynamic Analysis Sandwich Panel

Match test data using test validated approach for any model complexity (Columbia Accident PFDA Model Shown)

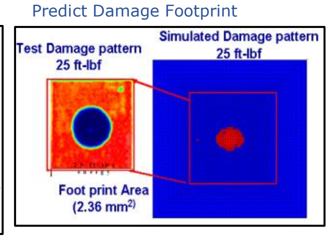


Ref: Collision provoked failure sequencing in space re-entry vehicles, J Comp & Structures June 2011

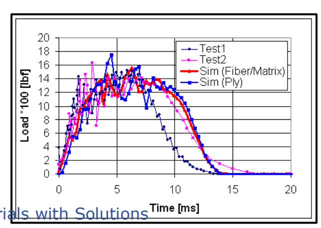
Use Multi Scale Technology



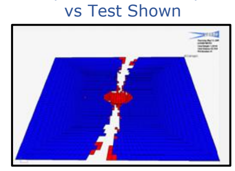
Predict Damage Footprint



Predict Damage Energy

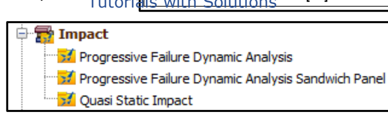


Compression After Impact vs Test Shown

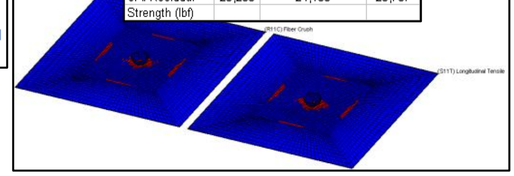


Type	Test	PFDA Fiber/Matrix Input	PFDA Ply Input
Impact Peak Load (lbf)	1460	1530	1530
CAI Residual Strength (lbf)	23,280	24,136	20,707

Tutorials with Solutions



Fiber Crushing and Tensile Failure (side by side)



- Quasi Static Impact

Key Benefits

- Rapid assessment/selection of composite impact and post impact damage tolerance to meet design requirements
- Reduce physical tests by over 65-70% thus saving significant costs
- Ease of use, results verified with test data for class of materials:
  Polymer: chopped, continuous, thermoset, thermoplastic, elastomer
  Ceramic
  Metals: Fracture Toughness, fatigue crack growth
  Nano
  Hybrid Composite (Glare)
- Compression, Tension, Fatigue, and Reliability After Impact
- Identification of damage initiation and propagation to final failure & modes of damage/failure
- Identify damage footprint and asses risk due to impact events

User Friendliness

- Graphic User Interface (GUI) is easy to learn with navigation tutorials and videos. Manages multiple projects, input and output for material characterization
- Quick import/export of material properties and laminate layups with commonly used third-party FE Solvers and UMATS: NASTRAN (.bdf), ABAQUS (.inp), ANSYS (.cdb), RADIOSS (.rad), LSDYNA (.k) and Optistruct (.fem)
- Easy creation and editing of composite laminates. Quickly study multiple designs.

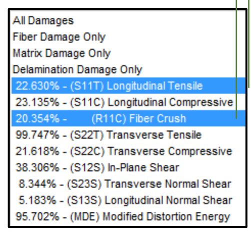
System Requirements

- Windows XP/Vista/7/8 or Linux (64-bit)
- Java 1.7 minimum Runtime Libraries
- Java3D 1.5

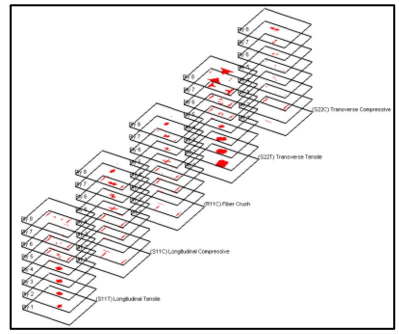
Minimum Configuration

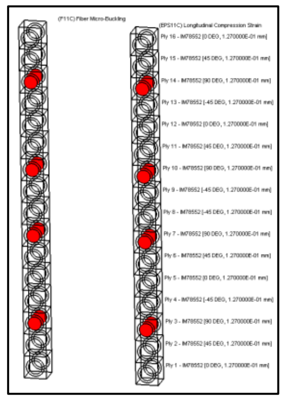
With the minimum configuration, performance and functionality may be less than expected.

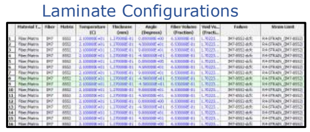
- 1 GHz or higher CPU, 4GB RAM, 10GB disk space

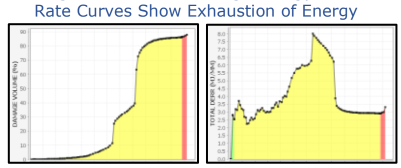


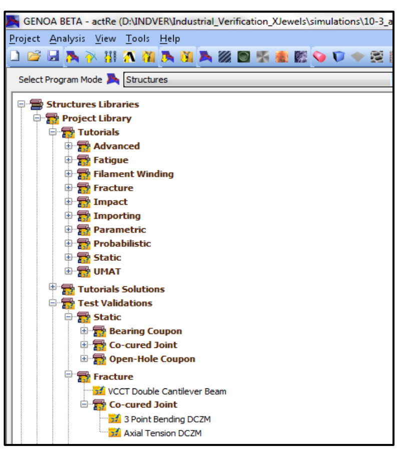
Easily Identify Damage Types and Location


Peel the Onion To Determine Ply Damages, Type, and Location


Identify Root Cause: Fiber/Matrix/Interphase Damage


Easy to Setup and Study Different Laminate Configurations

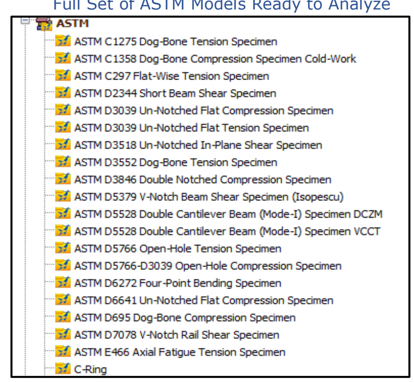

Damage Volume and Damage Energy Release Rate Curves Show Exhaustion of Energy



Model Tree GUI with Manuals, Tutorials, Validation Cases

Case Description:	Composite coupon subject to tensile cyclic loading
Example Location:	Tutorials > Fatigue > Quasi Static Fatigue
Model Description:	Nodes: 261; Elements: 224 Length: 1.0 (1.03091); Width: 0.1964 (0.196248); and Thickness: 0.10198
Material Description:	Fiber/Matrix (FVR = 55%), with nonlinear matrix stress-strain response Layup: [0/90/0/90/0/90/0] woven
Objective of Analysis:	Predict the fatigue life of the coupon
ASTM Number:	-
Control Type:	Load Control
Analysis Type:	Quasi-Static Fatigue
Solution:	*Fatigue 10

Every Case Has Step By Step and References



Full Set of ASTM Models Ready to Analyze

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MCQ: Composites, Ceramics, Metals, Nano, Chopped

GENOA: PFA, PFDA, UAB, URD, ABS, PCP, PA, Quasi Static Fatigue & Random Fatigue, Harmonic & PSD Fatigue, Fatigue with Fracture Mechanics, PFA_AGING, VCCT, DCZM, Filament Winding, Jobspooler, GENOA_CLOUD