

GENOA Progressive Failure Dynamic Analysis (PFDA)

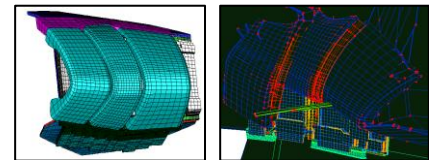
- Augments Explicit Dynamics (ED) finite element analysis (FEA) with multi-scale composite mechanics.
- Damage tracking and fracture to determine all stages of damage evolution under impact, crush, or crash loading condition.
- Predicts and simulates all 5 stages of the impact process.
- Switch solvers/boundary 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.

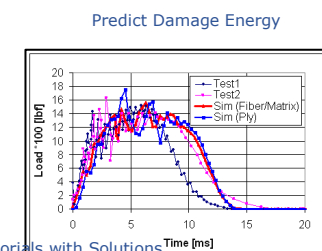
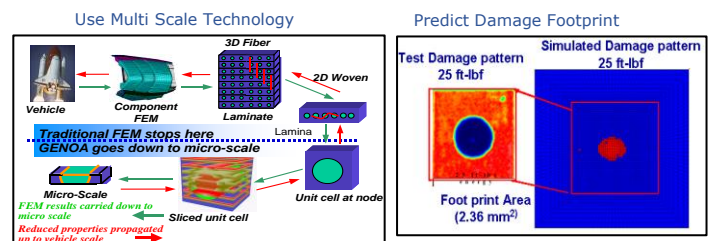
GENOA PFDA Highlights

- ✓ **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)
 - 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
 - Quasi Static Impact

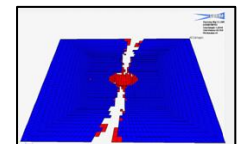
Match test data using test validated approach for any model complexity (Columbia Accident PFDA Model Shown)



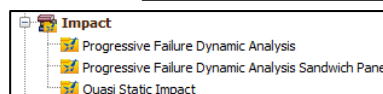
Ref: Collision provoked failure sequencing in space re-entry vehicles, J Comp & Structures June 2011



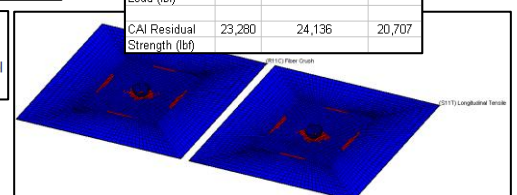
Compression After Impact vs Test Shown



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

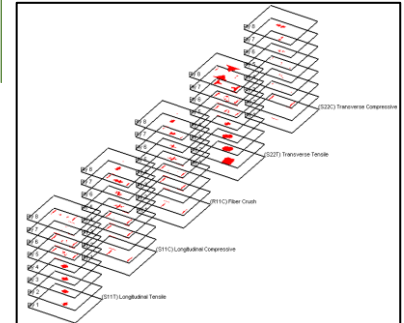
With the minimum configuration, performance and functionality may be less than expected.

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

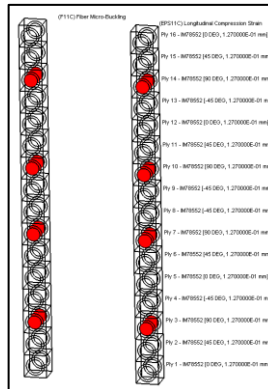
Easily Identify Damage Types and Location

All Damages
Fiber Damage Only
Matrix Damage Only
Delamination Damage Only
22.630% - (S11T) Longitudinal Tensile
23.135% - (S11C) Longitudinal Compressive
20.354% - (R11C) Fiber Crush
99.747% - (S22T) Transverse Tensile
21.618% - (S22C) Transverse Compressive
38.306% - (S12S) In-Plane Shear
8.344% - (S23S) Transverse Normal Shear
5.183% - (S13S) Longitudinal Normal Shear
95.702% - (MDE) Modified Distortion Energy

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



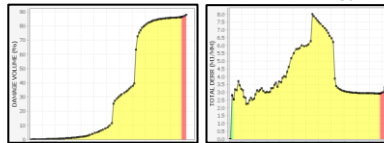
Identify Root Cause: Fiber/Matrix/Interphase Damage



Easy to Setup and Study Different Laminate Configurations

Order	Material	Thickness	Angle	Order	Material	Thickness	Angle
1	Matrix	0.125	0	1	Matrix	0.125	0
2	Fiber	0.125	90	2	Fiber	0.125	90
3	Matrix	0.125	0	3	Matrix	0.125	0
4	Fiber	0.125	90	4	Fiber	0.125	90
5	Matrix	0.125	0	5	Matrix	0.125	0
6	Fiber	0.125	90	6	Fiber	0.125	90
7	Matrix	0.125	0	7	Matrix	0.125	0
8	Fiber	0.125	90	8	Fiber	0.125	90
9	Matrix	0.125	0	9	Matrix	0.125	0
10	Fiber	0.125	90	10	Fiber	0.125	90
11	Matrix	0.125	0	11	Matrix	0.125	0
12	Fiber	0.125	90	12	Fiber	0.125	90
13	Matrix	0.125	0	13	Matrix	0.125	0
14	Fiber	0.125	90	14	Fiber	0.125	90
15	Matrix	0.125	0	15	Matrix	0.125	0
16	Fiber	0.125	90	16	Fiber	0.125	90
17	Matrix	0.125	0	17	Matrix	0.125	0
18	Fiber	0.125	90	18	Fiber	0.125	90
19	Matrix	0.125	0	19	Matrix	0.125	0
20	Fiber	0.125	90	20	Fiber	0.125	90
21	Matrix	0.125	0	21	Matrix	0.125	0
22	Fiber	0.125	90	22	Fiber	0.125	90
23	Matrix	0.125	0	23	Matrix	0.125	0
24	Fiber	0.125	90	24	Fiber	0.125	90
25	Matrix	0.125	0	25	Matrix	0.125	0
26	Fiber	0.125	90	26	Fiber	0.125	90
27	Matrix	0.125	0	27	Matrix	0.125	0
28	Fiber	0.125	90	28	Fiber	0.125	90
29	Matrix	0.125	0	29	Matrix	0.125	0
30	Fiber	0.125	90	30	Fiber	0.125	90
31	Matrix	0.125	0	31	Matrix	0.125	0
32	Fiber	0.125	90	32	Fiber	0.125	90
33	Matrix	0.125	0	33	Matrix	0.125	0
34	Fiber	0.125	90	34	Fiber	0.125	90
35	Matrix	0.125	0	35	Matrix	0.125	0
36	Fiber	0.125	90	36	Fiber	0.125	90
37	Matrix	0.125	0	37	Matrix	0.125	0
38	Fiber	0.125	90	38	Fiber	0.125	90
39	Matrix	0.125	0	39	Matrix	0.125	0
40	Fiber	0.125	90	40	Fiber	0.125	90
41	Matrix	0.125	0	41	Matrix	0.125	0
42	Fiber	0.125	90	42	Fiber	0.125	90
43	Matrix	0.125	0	43	Matrix	0.125	0
44	Fiber	0.125	90	44	Fiber	0.125	90
45	Matrix	0.125	0	45	Matrix	0.125	0
46	Fiber	0.125	90	46	Fiber	0.125	90
47	Matrix	0.125	0	47	Matrix	0.125	0
48	Fiber	0.125	90	48	Fiber	0.125	90
49	Matrix	0.125	0	49	Matrix	0.125	0
50	Fiber	0.125	90	50	Fiber	0.125	90
51	Matrix	0.125	0	51	Matrix	0.125	0
52	Fiber	0.125	90	52	Fiber	0.125	90
53	Matrix	0.125	0	53	Matrix	0.125	0
54	Fiber	0.125	90	54	Fiber	0.125	90
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62	Fiber	0.125	90	62	Fiber	0.125	90
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64	Fiber	0.125	90	64	Fiber	0.125	90
65	Matrix	0.125	0	65	Matrix	0.125	0
66	Fiber	0.125	90	66	Fiber	0.125	90
67	Matrix	0.125	0	67	Matrix	0.125	0
68	Fiber	0.125	90	68	Fiber	0.125	90
69	Matrix	0.125	0	69	Matrix	0.125	0
70	Fiber	0.125	90	70	Fiber	0.125	90
71	Matrix	0.125	0	71	Matrix	0.125	0
72	Fiber	0.125	90	72	Fiber	0.125	90
73	Matrix	0.125	0	73	Matrix	0.125	0
74	Fiber	0.125	90	74	Fiber	0.125	90
75	Matrix	0.125	0	75	Matrix	0.125	0
76	Fiber	0.125	90	76	Fiber	0.125	90
77	Matrix	0.125	0	77	Matrix	0.125	0
78	Fiber	0.125	90	78	Fiber	0.125	90
79	Matrix	0.125	0	79	Matrix	0.125	0
80	Fiber	0.125	90	80	Fiber	0.125	90
81	Matrix	0.125	0	81	Matrix	0.125	0
82	Fiber	0.125	90	82	Fiber	0.125	90
83	Matrix	0.125	0	83	Matrix	0.125	0
84	Fiber	0.125	90	84	Fiber	0.125	90
85	Matrix	0.125	0	85	Matrix	0.125	0
86	Fiber	0.125	90	86	Fiber	0.125	90
87	Matrix	0.125	0	87	Matrix	0.125	0
88	Fiber	0.125	90	88	Fiber	0.125	90
89	Matrix	0.125	0	89	Matrix	0.125	0
90	Fiber	0.125	90	90	Fiber	0.125	90

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



Every Case Has Step By Step and References

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 (F/R = 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: -

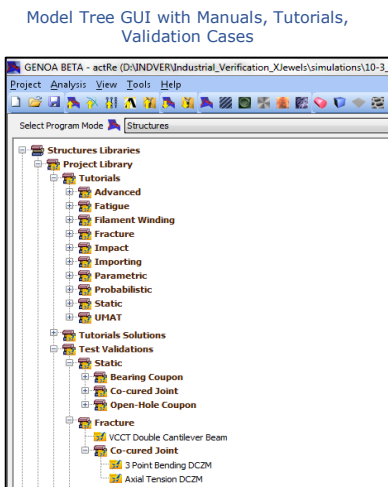
Control Type: Load Control

Analysis Type: Quasi-Static Fatigue

Solution: *Fatigue 10

Full Set of ASTM Models Ready to Analyze

- ASTM C 1275 Dog-Bone Tension Specimen
- ASTM C 1358 Dog-Bone Compression Specimen Cold-Work
- ASTM C297 Flat-Wise Tension Specimen
- ASTM D2344 Short Beam Shear Specimen
- ASTM D3039 Un-Notched Flat Compression Specimen
- ASTM D3039 Un-Notched Flat Tension Specimen
- ASTM D3518 Un-Notched In-Plane Shear Specimen
- ASTM D3552 Dog-Bone Tension Specimen
- ASTM D3846 Double Notched Compression Specimen
- ASTM D5379 V-Notch Beam Shear Specimen (Isopescu)
- ASTM D5528 Double Cantilever Beam (Mode-I) Specimen DCZM
- ASTM D5528 Double Cantilever Beam (Mode-II) Specimen VCCT
- ASTM D5766 Open-Hole Tension Specimen
- ASTM D5766-D3039 Open-Hole Compression Specimen
- ASTM D6272 Four-Point Bending Specimen
- ASTM D6641 Un-Notched Flat Compression Specimen
- ASTM D695 Dog-Bone Compression Specimen
- ASTM D7078 V-Notch Rail Shear Specimen
- ASTM E466 Axial Fatigue Tension Specimen
- C-Ring



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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