



**MCQ**  
**Chopped**  
Tested and Verified.™

## Material Characterization & Qualification – Chopped

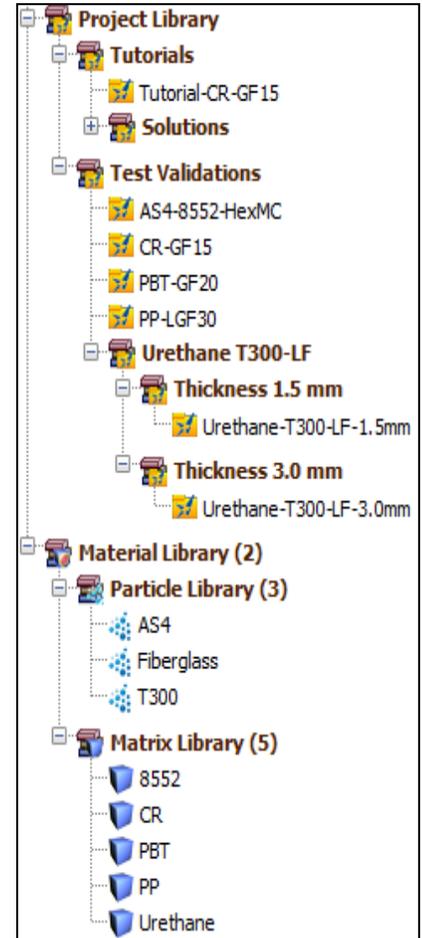
- **MCQ-Chopped** is a Multi-Scale material modeling, characterization & qualification software that analytically predicts chopped properties and performance
- Comes with material data, tutorial solution and test validation

MCQ-Chopped is designed to help predict chopped properties based on effective particles (e.g., chopped fibers) and matrix material properties, it also includes: **1)** assuming **uniform orientation** through the width and length of the representative volume element (flat coupon), **2)** the particles can be **aligned, in-plane random**, and **completely random** in orientation in three-dimensional space, **3)** particles can also be **user specified** based on test observation or output from analysis using other Software packages (e.g., **Moldflow**, **Moldex 3D**, etc.). MCQ-Chopped allows characterizing chopped fiber reinforced composite material properties as a function of several manufacturing, geometric, and material variables. Chopped fiber reinforced composite coupon test data in literature show lots of scatter mainly due to limited test and scatter in the manufacturing, geometric and material property variables. Material Uncertainty analysis allows estimating mean chopped fiber reinforced composite material properties for particles aligned, 2D random and 3D random situation in the matrix and for user specified orientations. MCQ-Chopped is capable of predicting chopped properties considering particle-matrix Interphase, uniform or non-uniform dispersion or particles and multiple types of particles.

## MCQ-Chopped Highlights

- ✓ **Chopped Mechanics:**
  - Predict aligned, in-plane random and 3D random material properties
  - Reverse engineer effective constituent material properties
- ✓ **Orientation Distribution Determination:** Predict effective % orientation distribution of the fillers through-thickness
- ✓ **Chopped Characterization:** Graphically verify the variation in aligned layer properties with variation in constituent material properties and manufacturing variables
- ✓ **Material Nonlinearity:** predict aligned layer, 2D random, 3D random and user defined layup stress-strain curve using matrix stress-strain curve as input.
- ✓ **Aligned Layer Nonlinearity:** Reverse engineer aligned layer stress-strain curve from flow or cross-flow direction test stress strain curve
- ✓ **Progressive Failure:** Predict damage evolution, damage growth and final failure for chosen orientation (e.g., user defined, flow or cross-flow direction un-notched coupons)
- ✓ **Design Failure Envelope:** Predict damage initiation and final failure of coupons subjected to biaxial loading
- ✓ **Parametric Carpet Plot:** Effective material property prediction for several different orientation % distribution of plies through-the-thickness
- ✓ **Material Uncertainty:** Predict average material properties (flow, cross-flow, user defined) directions considering material uncertainty, orientation, and thickness effect
- ✓ **Fatigue:** Predict effective S-N curve for the aligned layer, 2D random, 3D random and user defined orientation using matrix S-N curve as input

## Material Database, Tutorial, Test Validation



**Input: Fiber/Matrix Properties, Particle Properties, Fabrication Variables and Orientation Distribution**

**Fiber Properties**

**Particle**

- Description: Fiberglass
- Type: [Isotropic]
- Density:  $\rho = 2.500000E-09$  tonne/(mm<sup>3</sup>)
- Mechanical
  - Modulus:  $E = 7.239500E+04$  N/(mm<sup>2</sup>)
  - Poisson Ratio:  $\nu = 2.200000E-01$
  - Strength
    - ST = 1.000000E+03 N/(mm<sup>2</sup>)
    - SC = 3.447379E+03 N/(mm<sup>2</sup>)
- Interface
  - SHEAR = 3.000000E+01 N/(mm<sup>2</sup>)
  - ADHESION\_FACT = 5.000000E-01

**Matrix Properties**

**Matrix**

- Description: PBT (Polybutylene Terephthalate)
- Density:  $\rho = 1.235000E-09$  tonne/(mm<sup>3</sup>)
- Mechanical
  - Modulus:  $E = 2.400000E+03$  N/(mm<sup>2</sup>)
  - Poisson Ratio:  $\nu = 3.000000E-01$
  - Strength
    - ST = 5.000000E+01 N/(mm<sup>2</sup>)
    - SC = 5.000000E+01 N/(mm<sup>2</sup>)
    - SS = 5.000000E+01 N/(mm<sup>2</sup>)

**Particle Properties and Fabrication Variables**

Chopped Composite Editor

Property	Value
Shape	FIBER
Type	STRAIGHT
Void Volume (Fraction)	1.000000E-02
Volume (Fraction)	1.100000E-01
Length (mm)	1.500000E+00
Width (mm)	1.300000E-02
Height (mm)	1.300000E-02
Enable Interphase	false
Dispersion	UNIFORM

**Weight Fraction = 0.200**

**Orientation Distribution**

Enable Orientation:

Total Thickness (mm): 1.000000 [Apply]

Number of Aligned Layers: 1 [Apply]

Orientation Angle Mode: User Defined

Material Type: Rotated Aligned

Enable Strain Limits:

User Defined Orientation Angles

Angle Offset: 0.000000

Description	Value
Steps	100
Fiber Diameter (mm)	0.000000E+00
Out of Plane Fiber Orientation (Degrees)	1.000000E+01
Void Parameters	
RHO Void (tonne/mm <sup>3</sup> )	1.205000E-12
Alpha Void (L/C)	3.400000E-03
KE Void (SI/BEHS/mm)	5.500000E-18
KT Void (mN/m)	2.500000E-02
Percolation Exponents	
Electrical Lower Exponent (a)	8.700000E-01
Electrical Upper Exponent (b)	2.000000E+00
Thermal Lower Exponent (c)	8.700000E-01
Thermal Upper Exponent (d)	2.000000E+00

**Perform Chopped Mechanics** →

**Modulus**

Chopped Mechanics Properties Output

Modulus for Rotated Aligned Mechanical Properties

Property	Value
E11	8.389090E+03 (N/(mm <sup>2</sup> ))
E22	2.961080E+03 (N/(mm <sup>2</sup> ))
E33	2.921420E+03 (N/(mm <sup>2</sup> ))
G12	1.113140E+03 (N/(mm <sup>2</sup> ))
G13	1.176110E+03 (N/(mm <sup>2</sup> ))
G23	1.071150E+03 (N/(mm <sup>2</sup> ))

**Poisson's Ratio**

Chopped Mechanics Properties Output

Poisson's Ratio for Rotated Aligned Mechanical Properties

Property	Value
NU12	2.673530E-01
NU23	3.748690E-01
NU13	3.403630E-01

**Strength**

Chopped Mechanics Properties Output

Strength for Rotated Aligned Mechanical Properties

Property	Value
S11T	1.104980E+02 (N/(mm <sup>2</sup> ))
S11C	2.156100E+02 (N/(mm <sup>2</sup> ))
S22T	3.460520E+01 (N/(mm <sup>2</sup> ))
S22C	3.460530E+01 (N/(mm <sup>2</sup> ))
S33T	3.506520E+01 (N/(mm <sup>2</sup> ))
S33C	3.523470E+01 (N/(mm <sup>2</sup> ))
S12S	3.467640E+01 (N/(mm <sup>2</sup> ))
S13S	3.358620E+01 (N/(mm <sup>2</sup> ))
S23S	3.759760E+01 (N/(mm <sup>2</sup> ))

**Input: Orientation Distribution Determination (ODD) Setup**

Name	Value
Match	
Flow Modulus E11 (N/(mm <sup>2</sup> ))	5.960000E+03
Cross Flow Modulus E22 (N/(mm <sup>2</sup> ))	3.020000E+03
Lower Angle Bound	2.100000E+01
Upper Angle Bound	4.200000E+01

• Flow and Cross Flow Modulus can be obtained from either test or from Moldex 3D Orientation tensor  
 • This equivalent laminate layup is generated assuming that E11 and E22 obtained from this laminate layup will be within 5% of the initial values assumed

**Perform ODD Analysis** →

**Output: Reverse engineered effective orientation through-thickness**

Enable Orientation:

Total Thickness (mm): 1.000000 [Apply]

Number of Aligned Layers: 20 [Apply]

Orientation Angle Mode: User Defined

Material Type: Rotated Aligned

Enable Strain Limits:

User Defined Orientation Angles

Layer Orientation	Thickness (mm)
1	-42.0
2	-42.0
3	-21.0
4	21.0
5	21.0
6	-21.0
7	26.25
8	26.25
9	42.0
10	42.0
11	42.0
12	42.0
13	26.25
14	26.25
15	-21.0
16	-21.0
17	-21.0
18	-21.0
19	42.0
20	42.0
21	42.0

Angle Offset: 0.000000

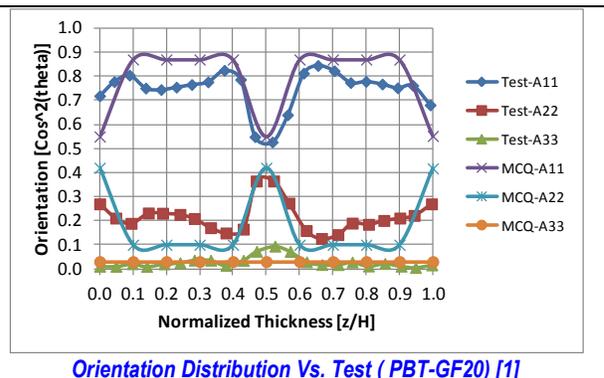
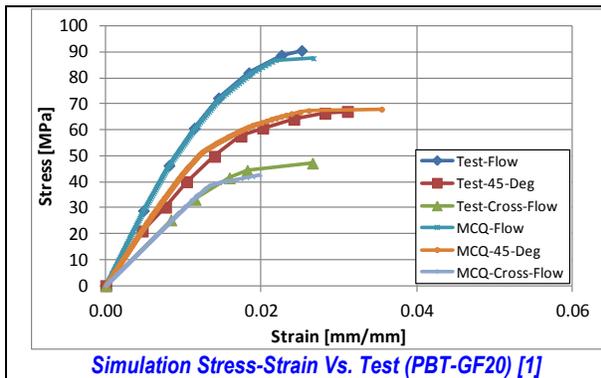
**Input: Test Stress-Strain Curve**

Strain (mm/mm)	Stress (N/(mm <sup>2</sup> ))
0.000000E+00	0.000000E+00
1.820000E-03	9.700000E+00
3.640000E-03	1.940000E+01
5.460000E-03	2.910000E+01
7.280000E-03	3.880000E+01
9.100000E-03	4.850000E+01
1.092000E-02	5.820000E+01
1.274000E-02	6.790000E+01
1.456000E-02	7.760000E+01
1.638000E-02	8.730000E+01
1.820000E-02	9.700000E+01

**Perform Aligned Layer Non-Linear Analysis** ↓

**Calibrated SS Curve**

**Note:** A user defined material input for both implicit and explicit finite element analysis can be created using the above information (Aligned layer ply properties and calibrated stress-strain data)



**References:**

1. Abumeri, G. H., Lee, and M., (2006). A Computational Simulation System for Predicting Performance of Chopped Fibers Reinforced Polymer Composites. ERMR-2006-Elastomer-Reno.