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Altair Technology Conference 2017

복합재를 위한 선형/비선형 해석과 최적화 기법

알테어 사업개발팀 강민구

ATC 2017

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결론

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복합 재료 개론

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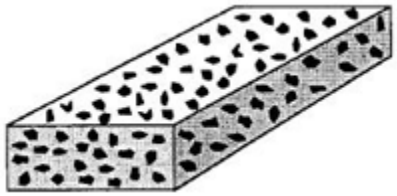
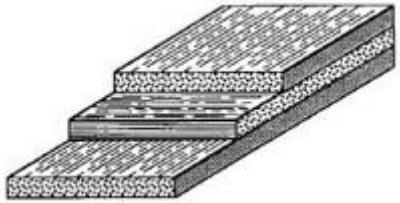
복합 재료 소개

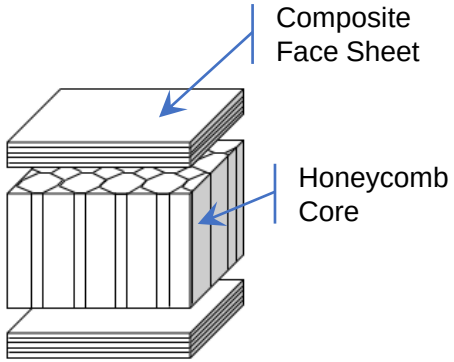
- 복합 재료의 종류



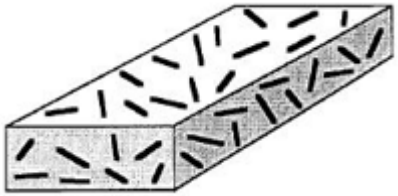
Particulate



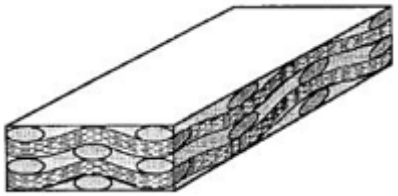
Long Fiber in Laminate



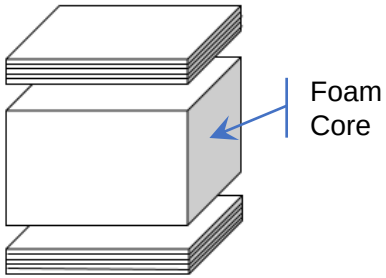
Core stiffened Laminate



Short Fiber



Woven Fiber



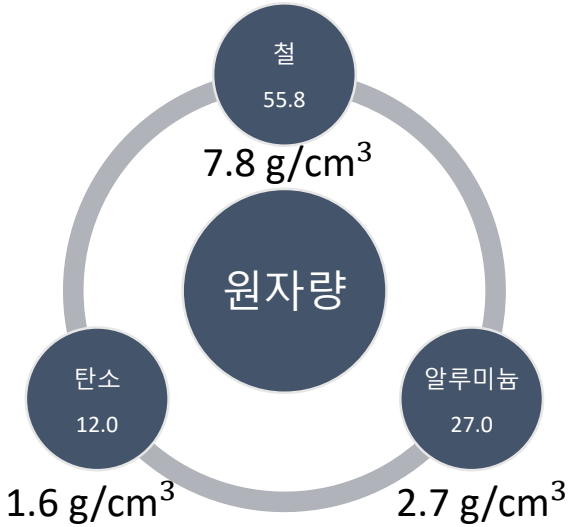
Core stiffened Laminate

CFRP와 기계적 재료 특성

- 경량 고강도의 고성능재료
  - 철보다 강하고 알루미늄보다 가볍다.

고장력강판

- 인장강도 5배
- 비중 ¼배
- 중량당 강도 20배



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복합 재료 FEA 모델링

- **복합 재료의 모델링**
  - Zone based composite modeling
  - Ply based composite modeling
  - Composite laminate modeling techniques
  - Shell to solid conversion for composites

Traditional Zone-Based Composite Modeling

Requires one property for each laminate zone

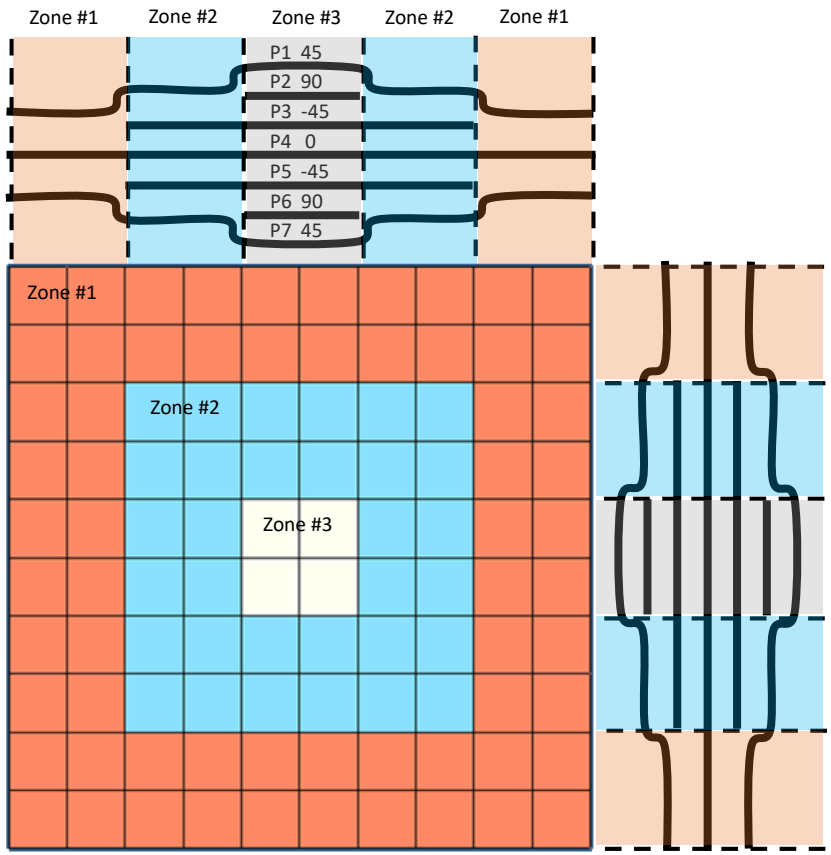
Zone-based modeling limitations include:

1. Data duplication
2. Difficult to interpret ply shape
3. No relationship to the manufacturing process
4. Model updates require multiple steps

Zone #1 Property Table			
Ply	Mat	Thk	Theta
P7	M1	0.01	45
P1	M1	0.01	45

Zone #2 Property Table			
Ply	Mat	Thk	Theta
P7	M1	0.01	45
P5	M1	0.01	-45
P3	M1	0.01	-45
P1	M1	0.01	45

Zone #3 Property Table			
Ply	Mat	Thk	Theta
P7	M1	0.01	45
P6	M1	0.01	90
P5	M1	0.01	-45
P3	M1	0.01	-45
P2	M1	0.01	90
P1	M1	0.01	45

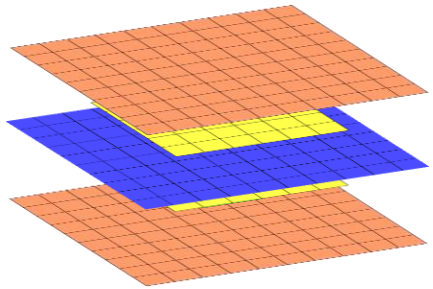


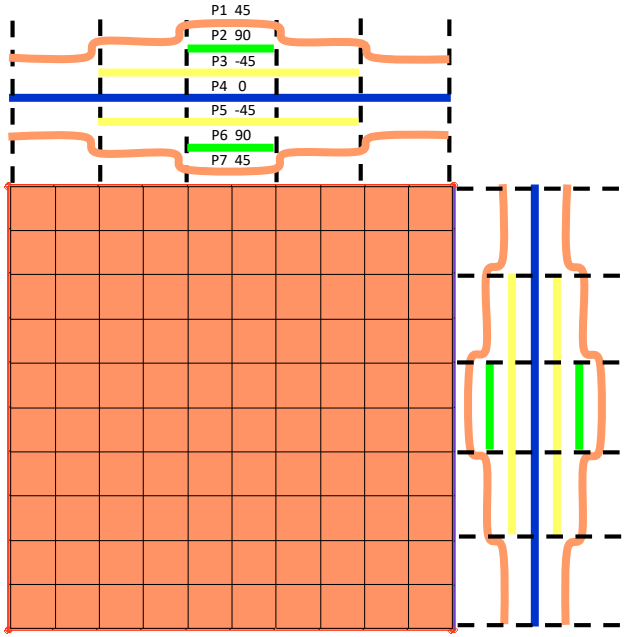
Modern Ply-Based Composite Modeling

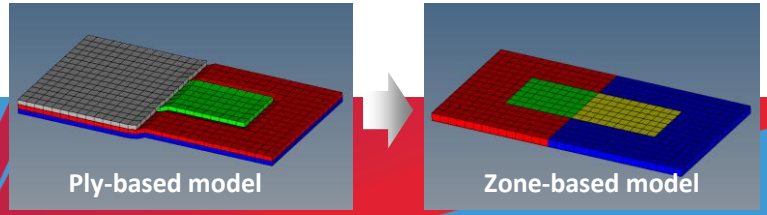
An individual composite part is one laminate made up of plies which are stacked in a given sequence!

- No data duplication
- Plies defined as “physical objects” w/ shape
- Direct relationship to the manufacturing process
- Model updates require single step

Stack Table			
Ply	Mat	Thk	Theta
P7	M1	0.01	45
P6	M1	0.01	90
P5	M1	0.01	-45
P3	M1	0.01	-45
P2	M1	0.01	90
P1	M1	0.01	45

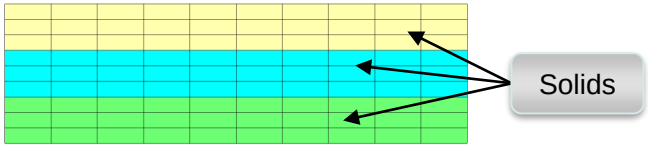




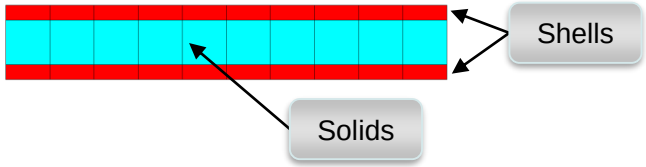


Composite Laminate Modeling Techniques

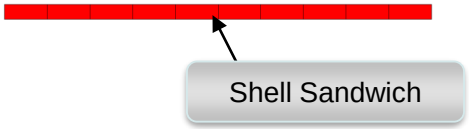
- Each ply with at least one solid
  - Large model, long CPU time
  - Advance Mass Scaling to increase simulation speed
  - High accuracy



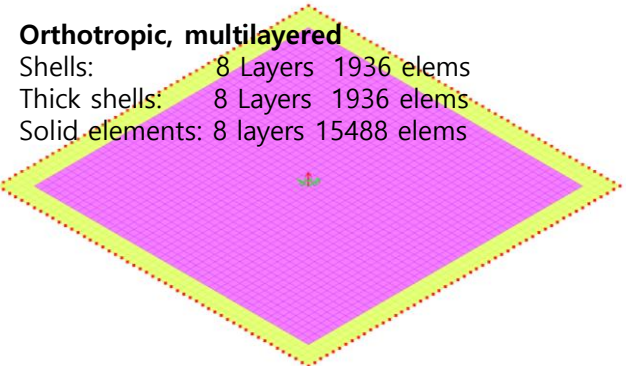
- Mixed approach (middle layer thick)
  - Shells for top and bottom ply
  - Solid, thick shell or cohesive for middle layer
  - Medium size model, significant CPU time

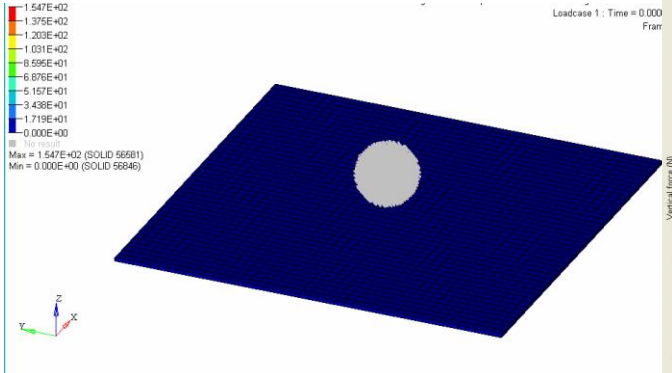


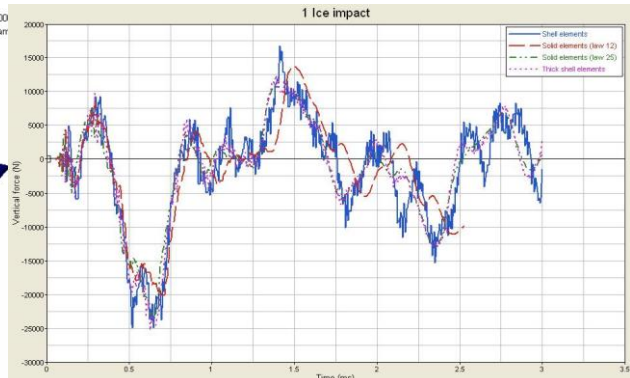
- Shell & Thick Shell
  - One shell element through the thickness
  - Multiple plies, with different materials
  - “Standard size “ model



Orthotropic, multilayered
Shells: 8 Layers 1936 elems
Thick shells: 8 Layers 1936 elems
Solid elements: 8 layers 15488 elems

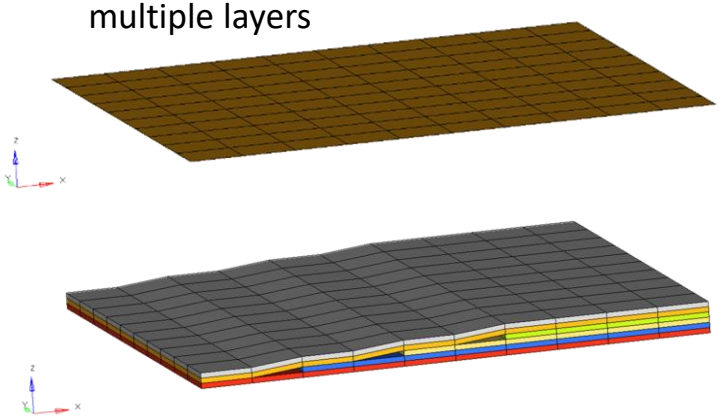




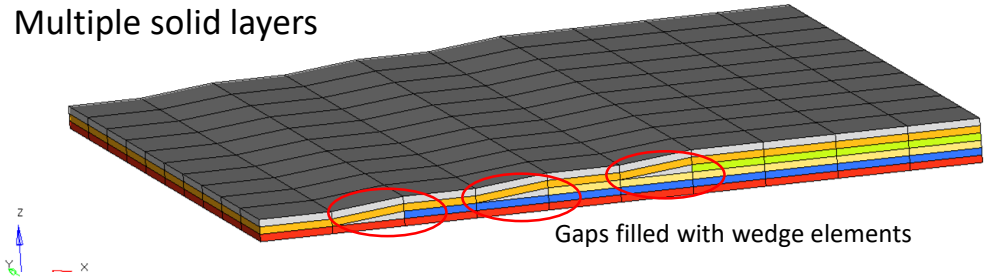


Shell to Solid Conversion

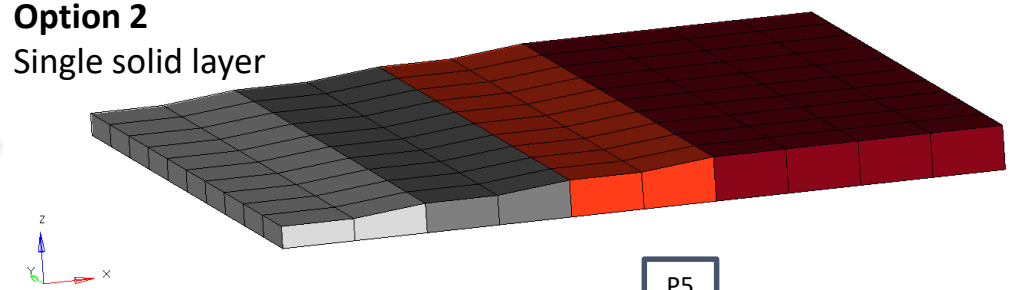
Shell composite
multiple layers



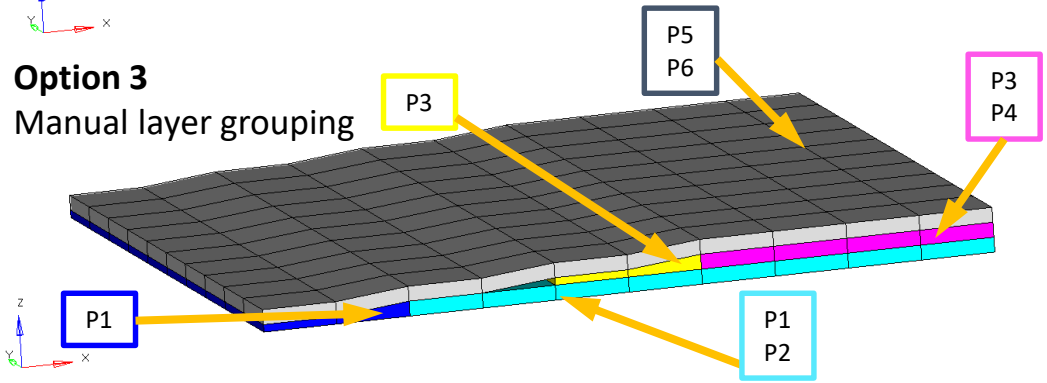
Option 1
Multiple solid layers



Option 2
Single solid layer

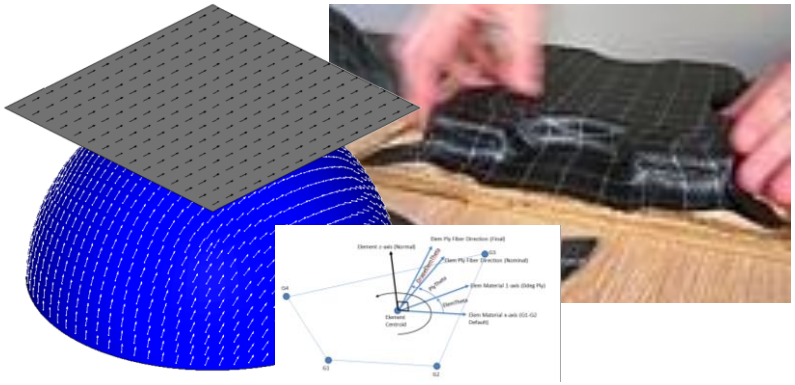


Option 3
Manual layer grouping



복합 재료 해석과 설계 검증

- **복합 재료와 시뮬레이션**
  - OptiStruct composite analysis
  - RADIOSS composite analysis



HyperMesh를 사용하시나요? 그렇다면 Ply Drape Estimator를 확인해 보세요.

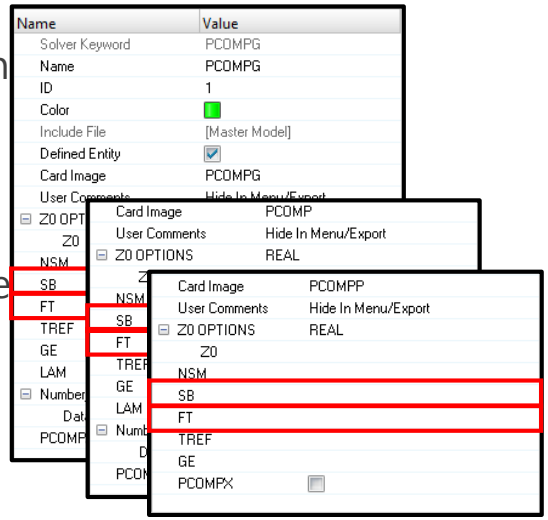
OptiStruct Composite Analysis

Standard failure theories are available in OptiStruct

Properties

- Failure theories available(FT):
  - Hill, Hoffman, Tsai-Wu, Maximum Stress / Maximum Strain
- Additional results for laminate composite failure
  - Bonding failure

  (SB: Allowable inter-laminar shear stress in the bonding mate
  - Failure index



Materials

- Orthotropic materials (MAT8)
- Isotropic materials (MAT1)
- Anisotropic materials (MAT2)

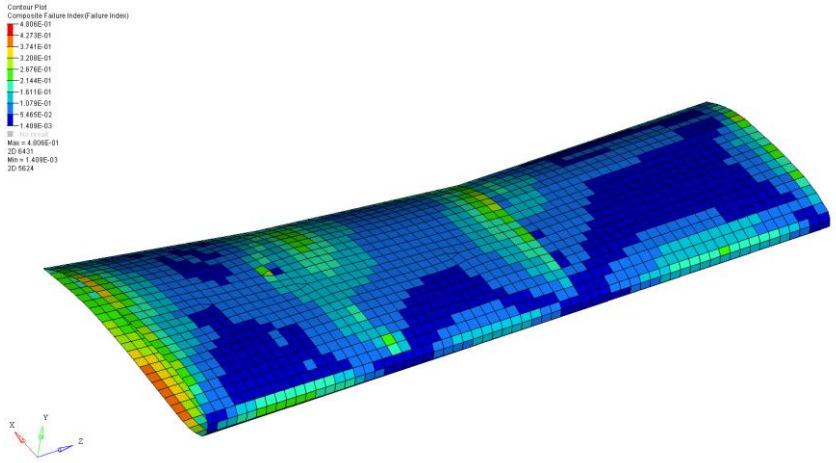
OptiStruct Composite Analysis

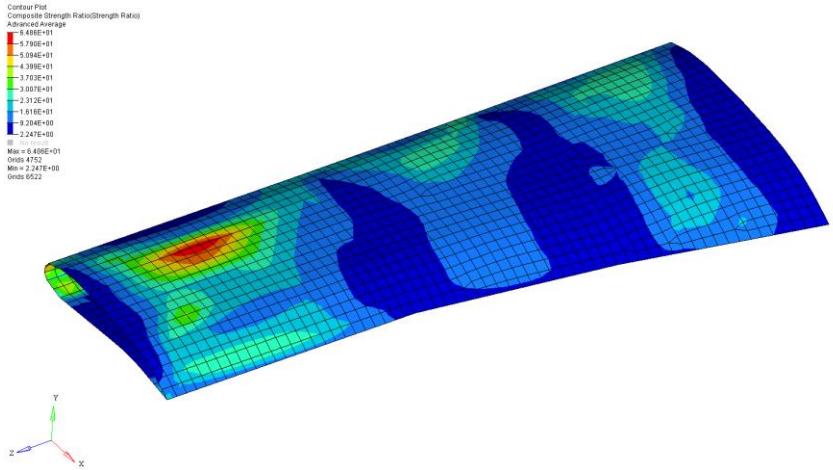
The failure index

- The failure index for the composite shell element is taken from the worst failure values across all the individual plies and bonding layers
  - Failure of a single layer qualifies as failure of the composite

Strength Ratio

- Strength Ratio (SR) is a direct failure indicator whereas failure index only indicates if failure has occurred
  - SR = 1.2 indicates that the applied loads can be increased by 20% before failure occurs
  - FI = 0.8 indicates that failure has not occurred but does not indicate 20% safety margin

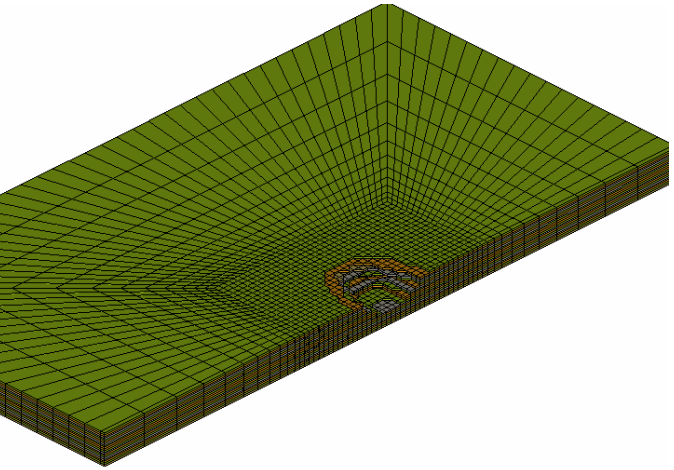


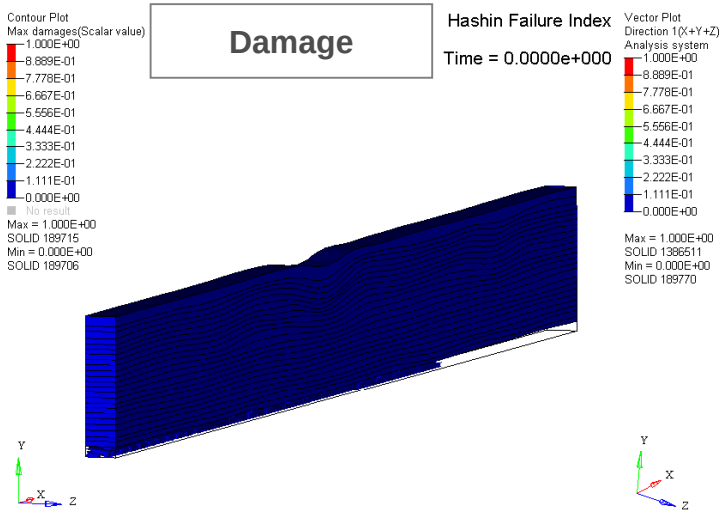


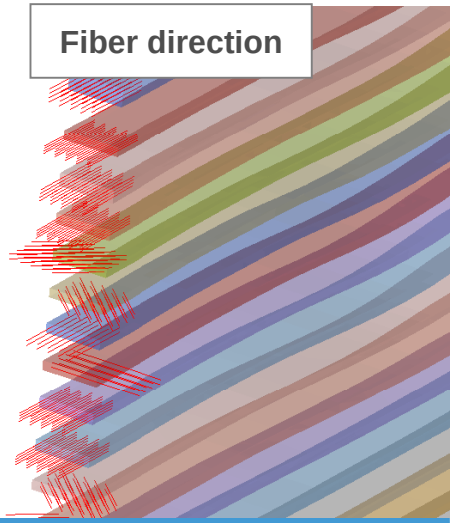
RADIOSS Composite Analysis

Failure models for composites

- HASHIN : Hashin Composite Failure Model used for fiber
- PUCK : Puck Composite Failure Model used for the matrix
- LAD_DAMA : Ladeveze Composite Failure Model used for the delamination







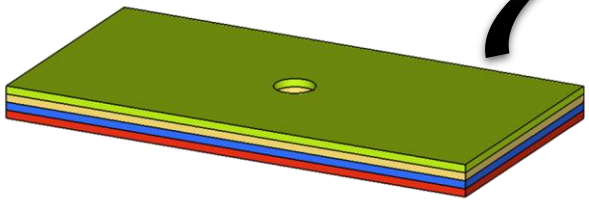
복합 재료의 최적설계

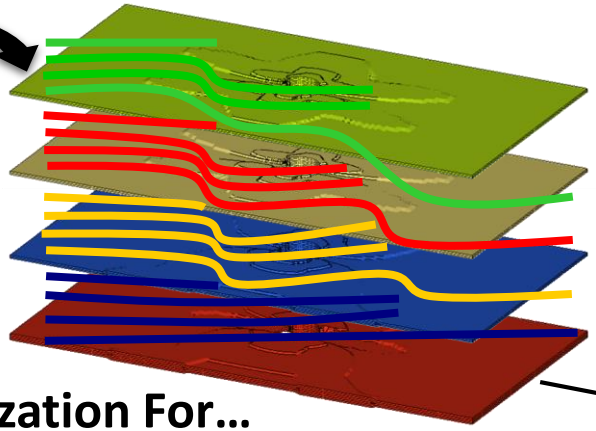
- **고강성, 고강도, 경량화 성능의 조율**
  - OptiStruct Optimization

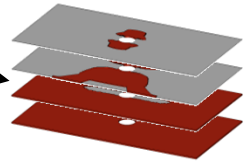
Composite ***Free-Size*** Optimization

What are the Optimal Shapes of my Plies?

Initial Design







Do Optimization For…

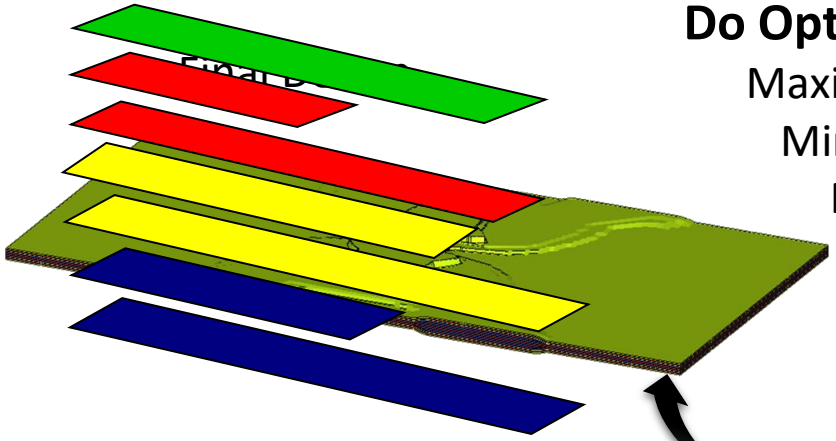
Maximize stiffness

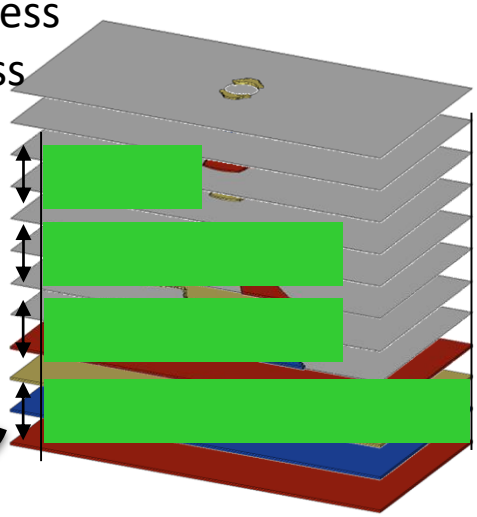
Minimize mass

No failure

Buckling

…





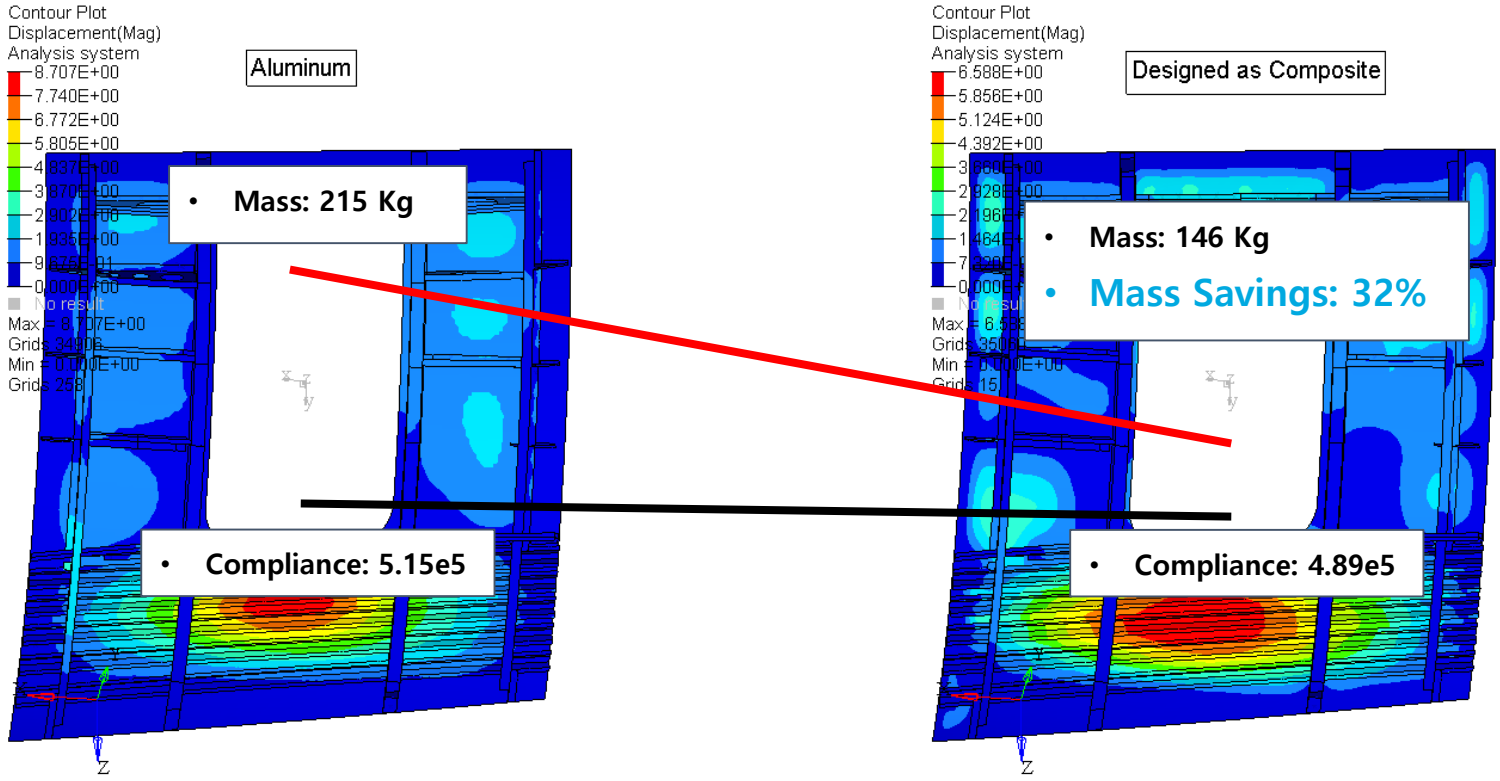
Composite ***Shuffling*** Optimization

How Do I Best Stack My Plies?

Composite ***Size(Gauge)*** Optimization

How Many Plies of Each Shape Do I Need?

Metal vs. Composite



복합 재료와 재료 물성

- **소재 단위로부터의 기계적 물성 특성 연구**
  - Multiscale 설계, 시뮬레이션?
  - Multiscale Designer란?
  - Multiscale Examples
    - Example 1 ~ 3
  - Multiscale Designer 작업 순서
    - Step 1 ~ 4
  - Virtual testing
  - License & Installation

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Multiscale Designer란?

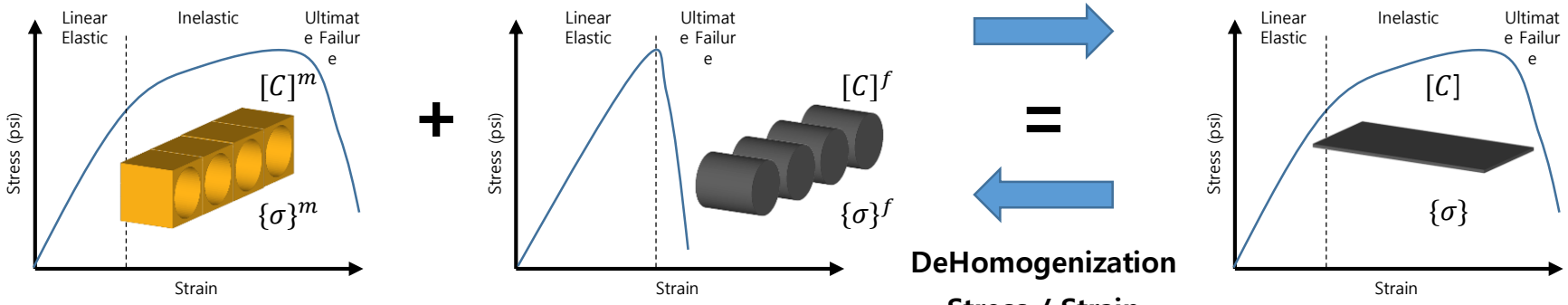
Multiscale 물성모델 개발

- 복합 재료 선형/비선형/파단 특성을 소재 레벨(Fiber/Matrix) 거동으로부터 취득

$$E = E^m V^m + E^f V^f$$

Homogenization

Stiffness



DeHomogenization

Stress / Strain

$$\{\bar{\varepsilon}\}^m = [A]^m\{\varepsilon\}$$
$$\{\bar{\varepsilon}\}^f = [A]^f\{\varepsilon\}$$

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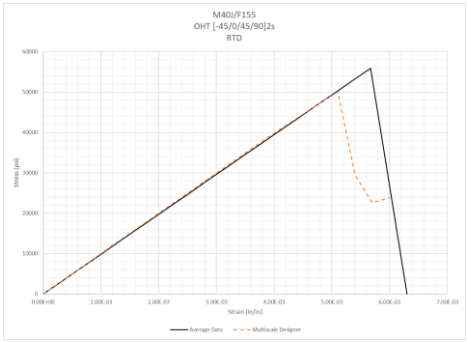
Multiscale Designer란?

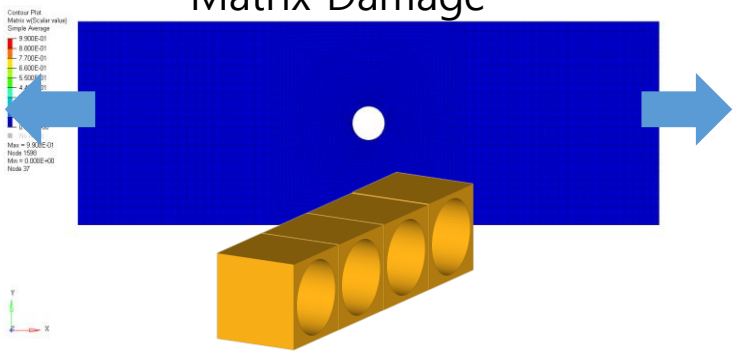
Multiscale 물성모델 개발

- FEA 시뮬레이션을 위한 Multiscale 물성모델 적용

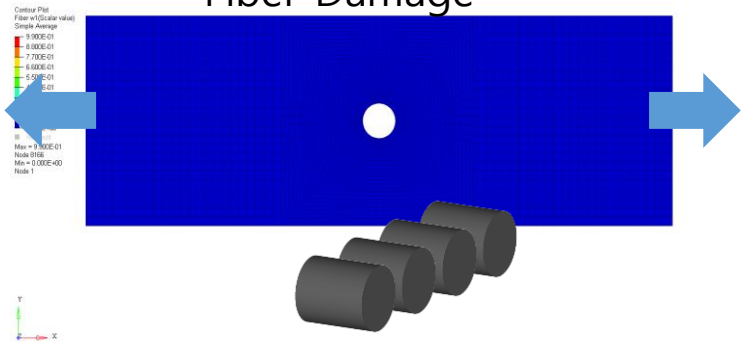
Open Hole Tension (OHT)



Matrix Damage



Fiber Damage



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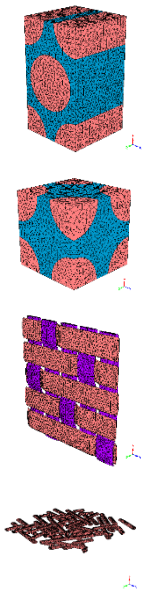
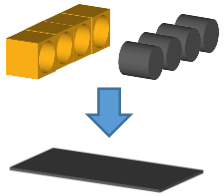
Multiscale Designer 작업 순서

Step 1 Unit cell model definition

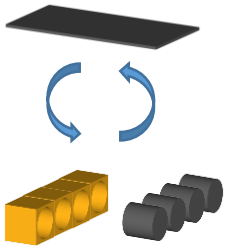


Step 2 Linear material characterization

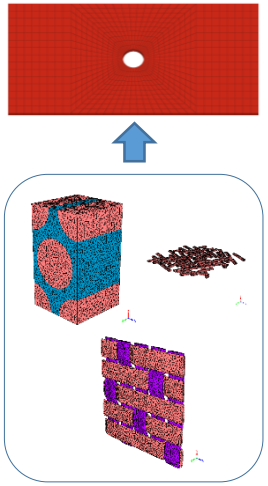
Forward



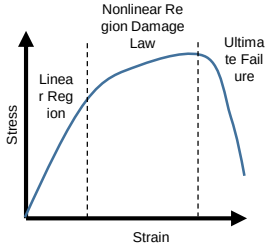
Inverse



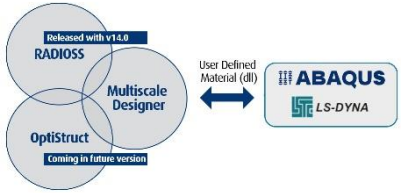
Step 3 Reduced order model computation



Step 4 Nonlinear material characterization



Step 5 Virtual testing



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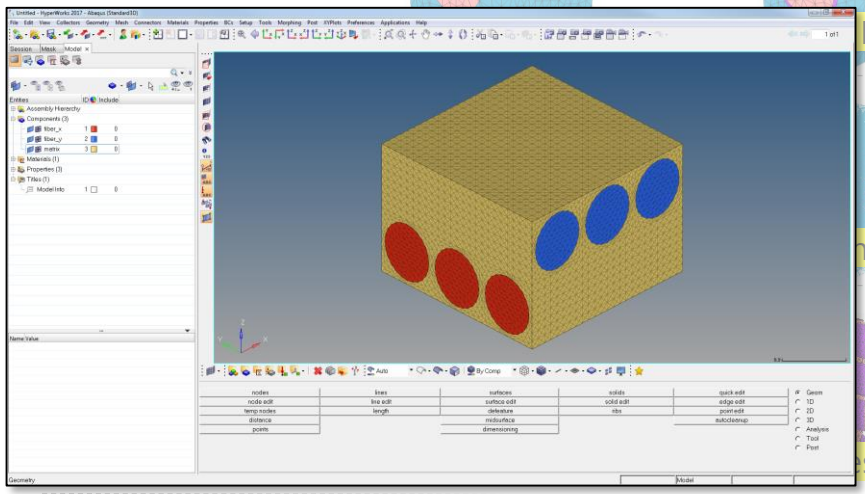
Step 1 Unit cell 자동 모델링

Fibrous



Interphase

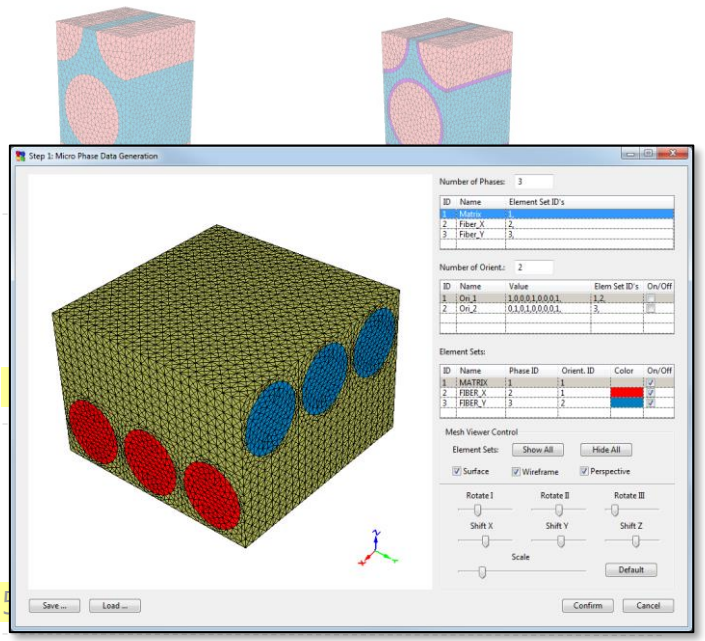
Satin

Random inclusion

HyperMesh

2D Chopped Fiber

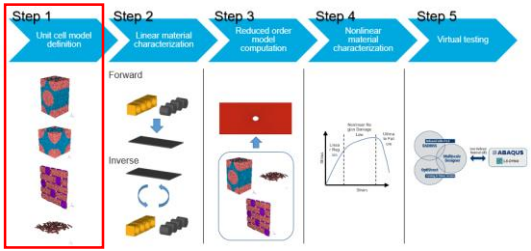
3D Chopped Fiber



MultiScale Designer

Ellipsoids

Spherical



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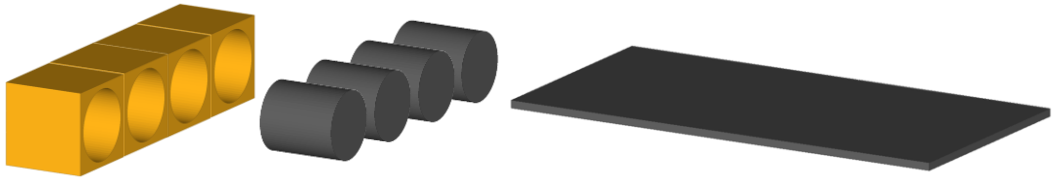
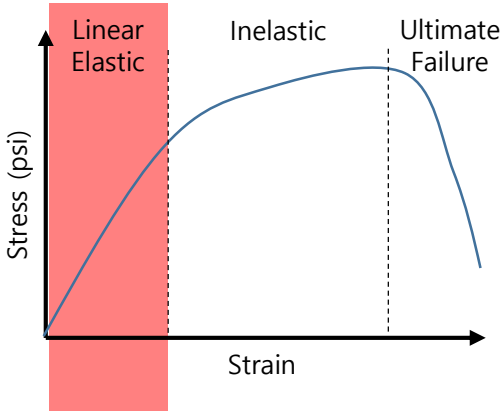
Step 2 선형 물성 획득

1. Forward Characterization

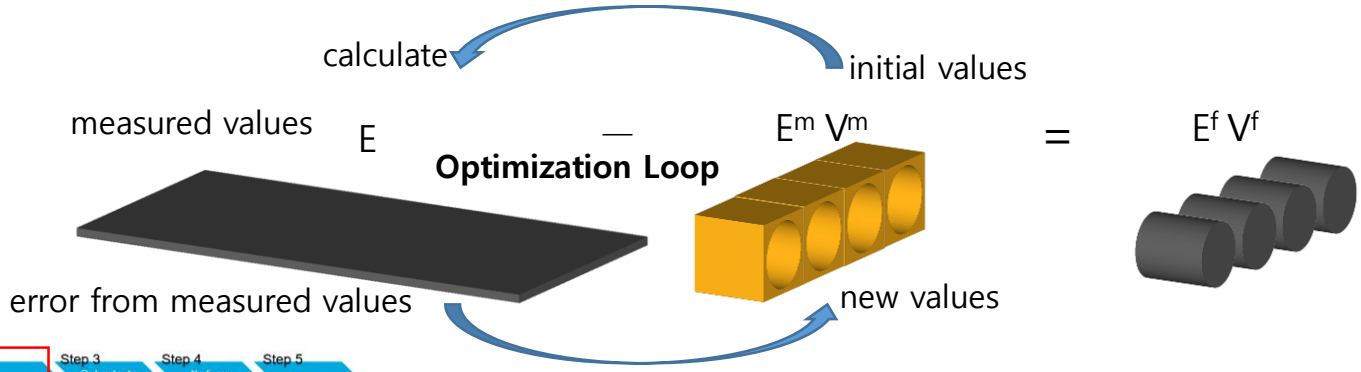
$E^m V^m + E^f V^f = E$

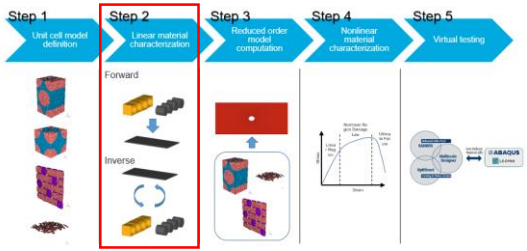




2. Inverse Characterization

Many times Ef is not known but E and Em are known from test





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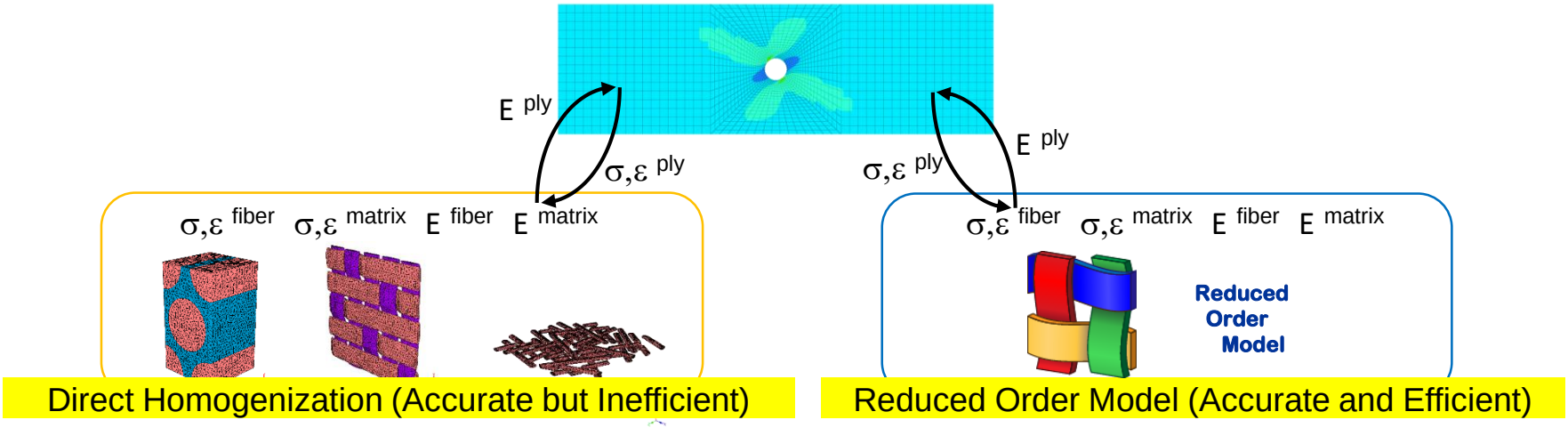
Step 3 감차 모델 시뮬레이션

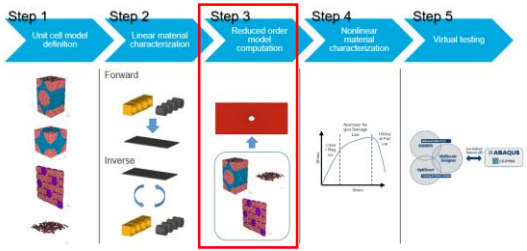
PROBLEM

Solving FEA unit cell models at every element gauss point for every nonlinear iteration is computationally expensive and unrealistic with todays computer power

Solution

ROM obtains FEA unit cell results accuracy with analytical efficiency





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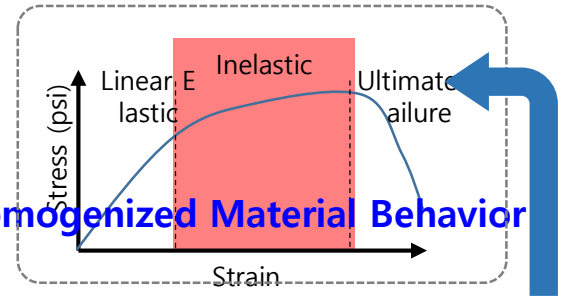
Step 4 비선형 물성 획득

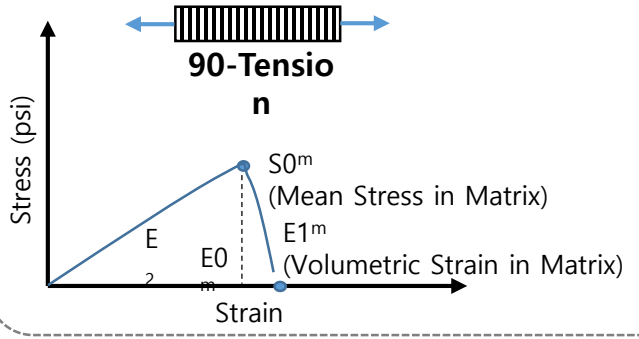
Each phase characterized with one continuum damage law

- Isotropic Continuum Damage
- Orthotropic Continuum Damage
- Hybrid Isotropic Damage & Plasticity
- …

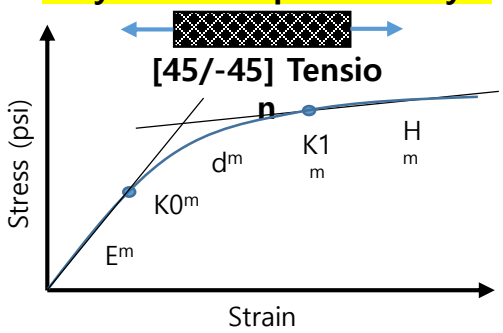


Matrix Nonlinear Properties

Hybrid Isotropic Damage

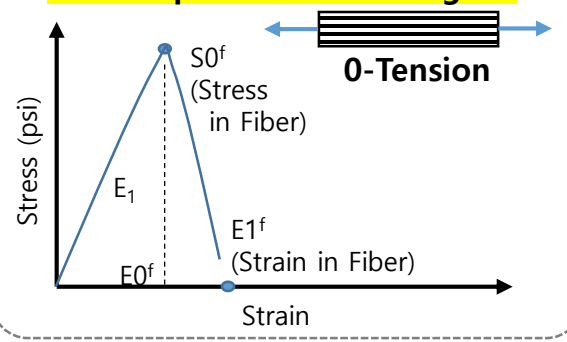


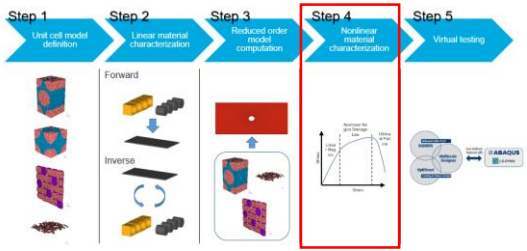
Hybrid Isotropic Plasticity



Fiber Nonlinear Properties

Isotropic Bilinear Damage





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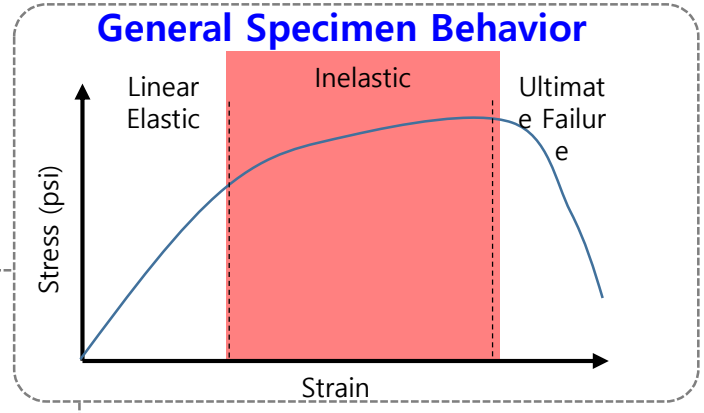
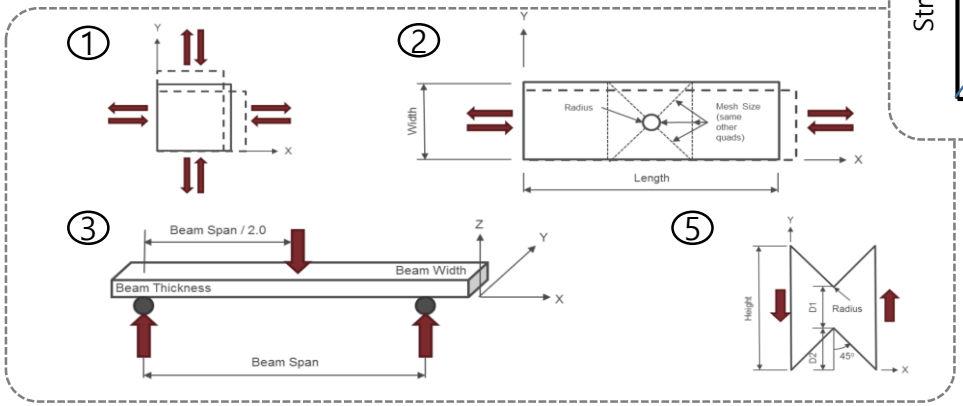
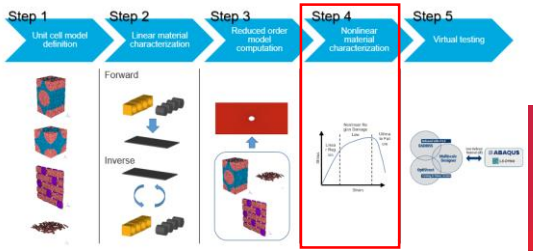
Step 4 비선형 물성 획득

Built-in Parameteric Virtual Testing for the following specimens

1. Unnotched Tension/Compression
2. Open hole Tension/Compression
3. 3-Point Bend (short beam shear)
4. 4-Point Bend
5. V-Notch rail Shear







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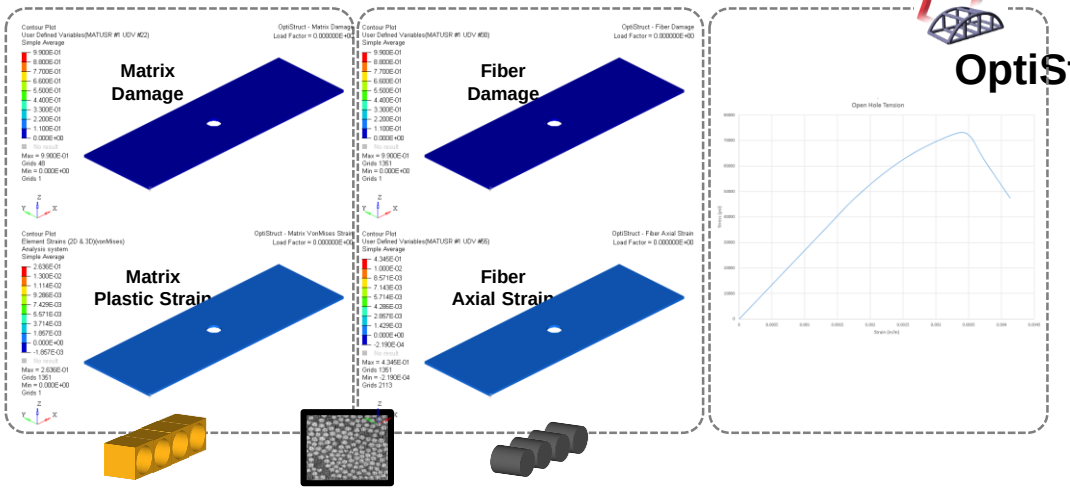
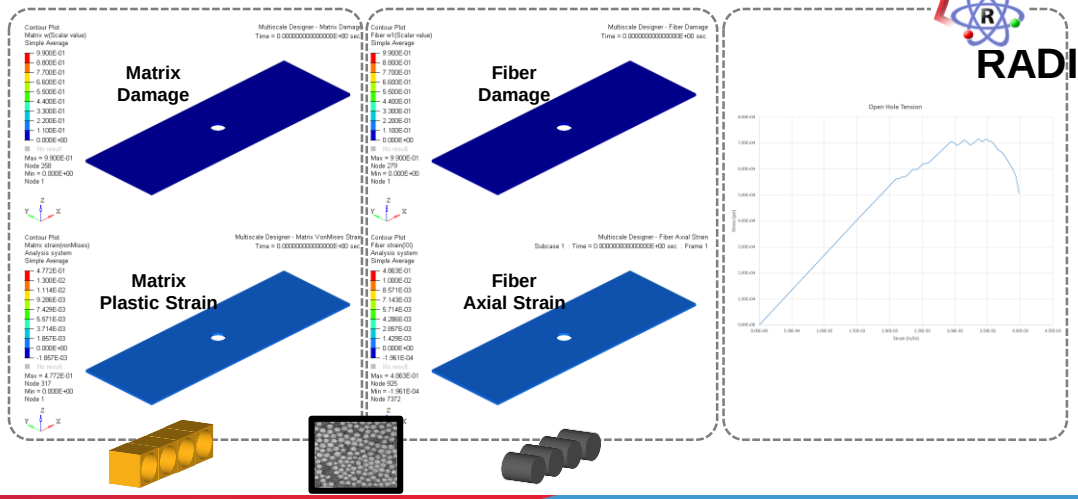
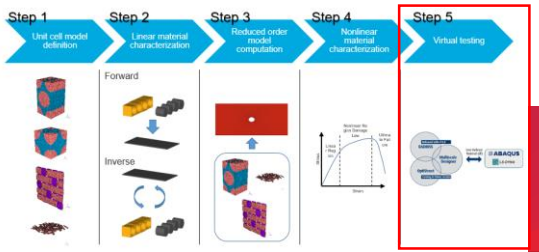
Step 5 Virtual testing



OptiStruct 2017



RADIOSS 14.0



Design the Difference with **Digital twin**

ATC 2017

Design
the Difference
with
Digital twin

Altair Technology Conference 2017

결론

ATC 2017

결론

소재 특성 고려한 복합 재료 물성 개발

Multiscale Designer
Evaluate the
micromechanical response

최적화 설계 알고리즘으로 시행착오 최소화
최저중량 최고성능 설계

OptiStruct Optimization
Optimize composite lay-ups
Minimize weight and maximize strength

시험 전 충분한 구조/충돌 시뮬레이션NG요인 제거

OptiStruct
Structural performance analysis

RADIOSS
Dynamic or impact performance analysis

복합 재료 시뮬레이션 모델링의 기본

HyperMesh
Modern Ply Based
Composites Pre-Processing

시뮬레이션 결과 그래프/영상 분석 도구

HyperView
Post-Processing & Failure Analysis for
Composites

감사합니다

support@altair.co.kr