Altair HyperWorks 2024 新版本发布会

AI 赋能技术创新，开启仿真新篇章

2024年8月28日 | 北京

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复合材料仿真及优化方案

Altair 梁 闯

复合材料仿真及优化方案

1 复合材料数据库及虚拟试验

2 复合材料建模可视化

3 复合材料工艺/结构仿真

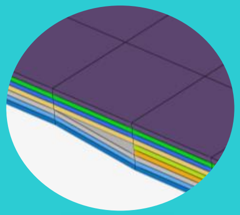
4 复合材料结构优化设计

5 复合材料结构强度校核流程

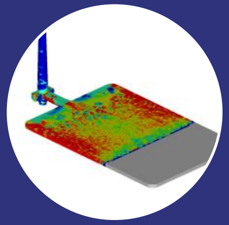
Altair 复合材料一站式解决方案

Altair复合材料工作流程

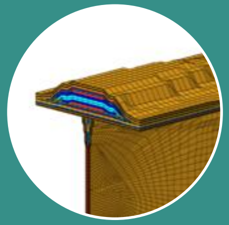
复合材料
数据库及虚拟试验



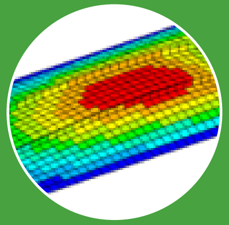
复合材料
建模可视化



复合材料
工艺/结构仿真



复合材料
优化设计



复合材料
设计认证

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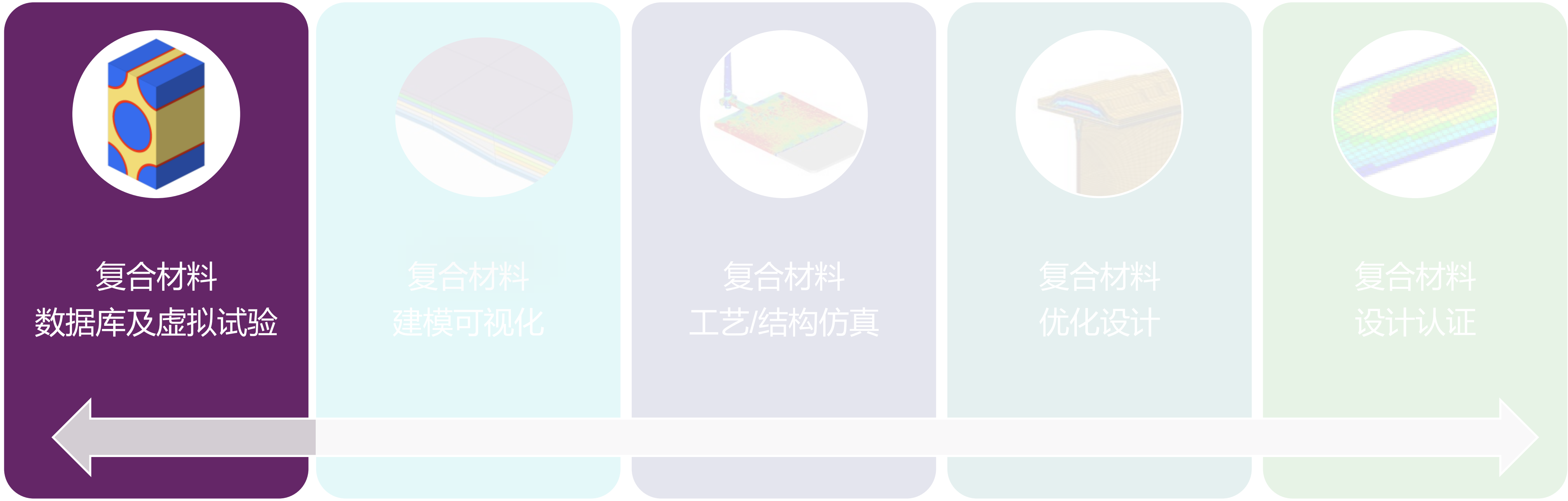
Altair 复合材料一站式解决方案

Altair复合材料工作流程



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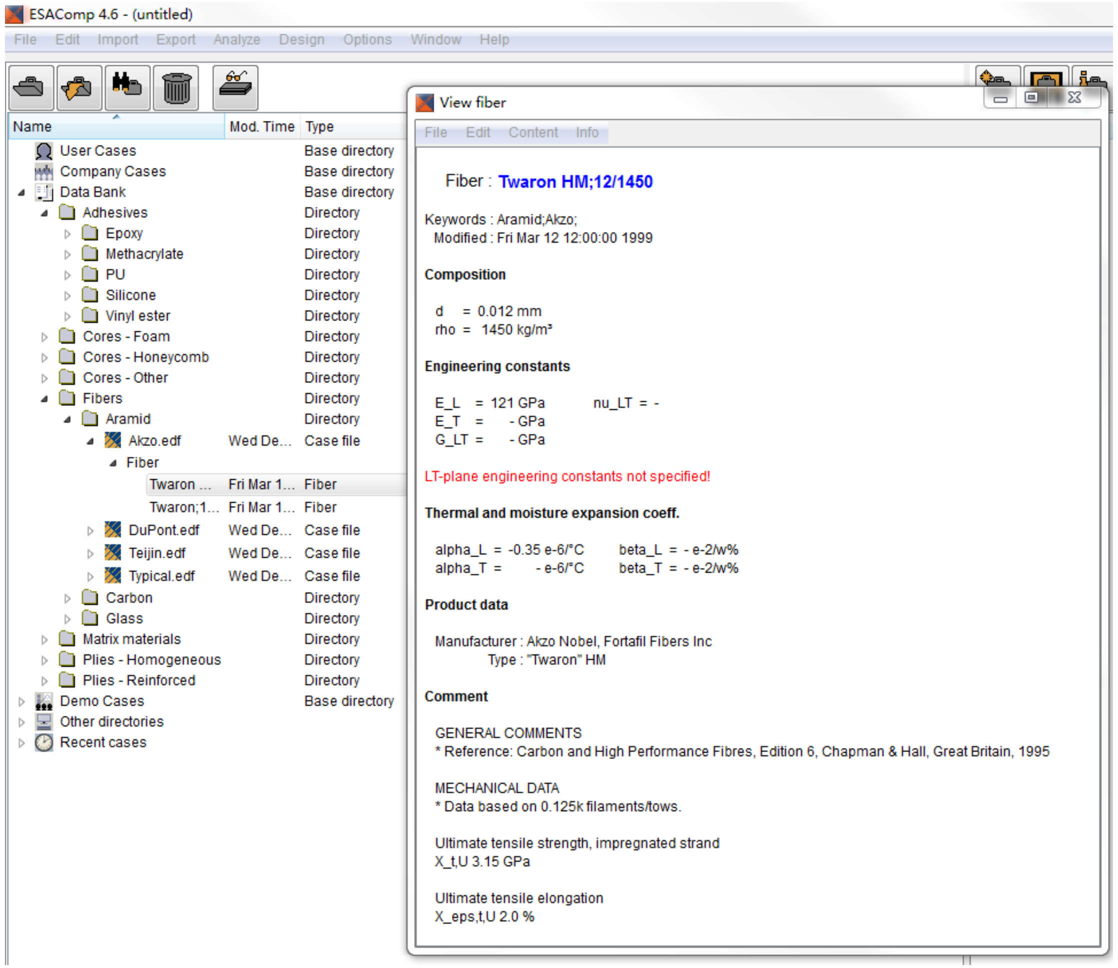
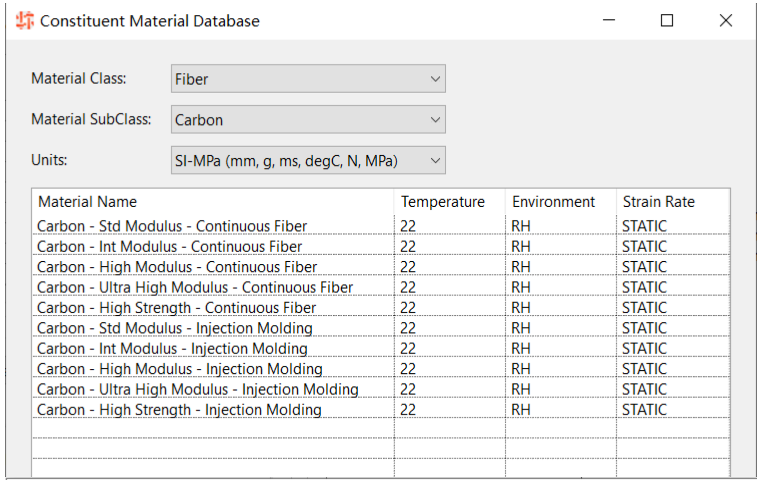
ESAComp复合材料数据库

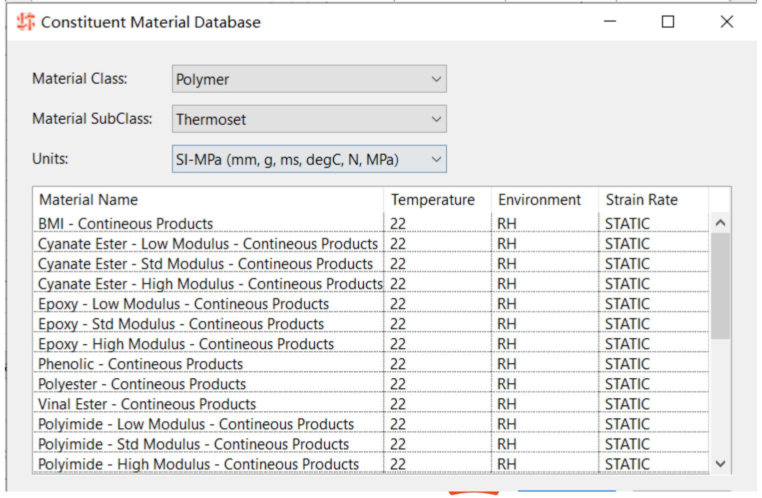
Altair材料数据库包含上千种材料，不仅提供航空航天领域的材料，还包括其他工业级的常用材料。大部分数据来自材料供应商，但也有一些典型的材料数据出自多个来源。

提供

- 纤维
- 基体材料
- 均匀板
- 纤维增强板
- 粘胶
- 核心层泡沫
- 蜂窝铝等材料库







ALTAIR MATERIAL DATA CENTER ~ 48,000

TYPE	METALS	PLASTICS
PRODUCER (100+)	Bilstein (coming soon) FH Aachen (coming soon) SALZGITTER AG Mensch, Stahl und Technologie	BASF (BASF We create chemistry) DOW (Dow) Dupont (DUPONT) NCAMP (NCAMP National Center for Advanced Materials Performance) Total Wevo (wevo) Wanhau CAMPU (CAMPUS)
PROVIDER (10+)	BAOSTEEL MATDAT	M-Base Engineering + Software sabic
FE-SOLVER	ALTAIR · SIMULIA ABAQUS · Ansys · esi · PAMCRASH · LS-DYNA	

ALTAIR

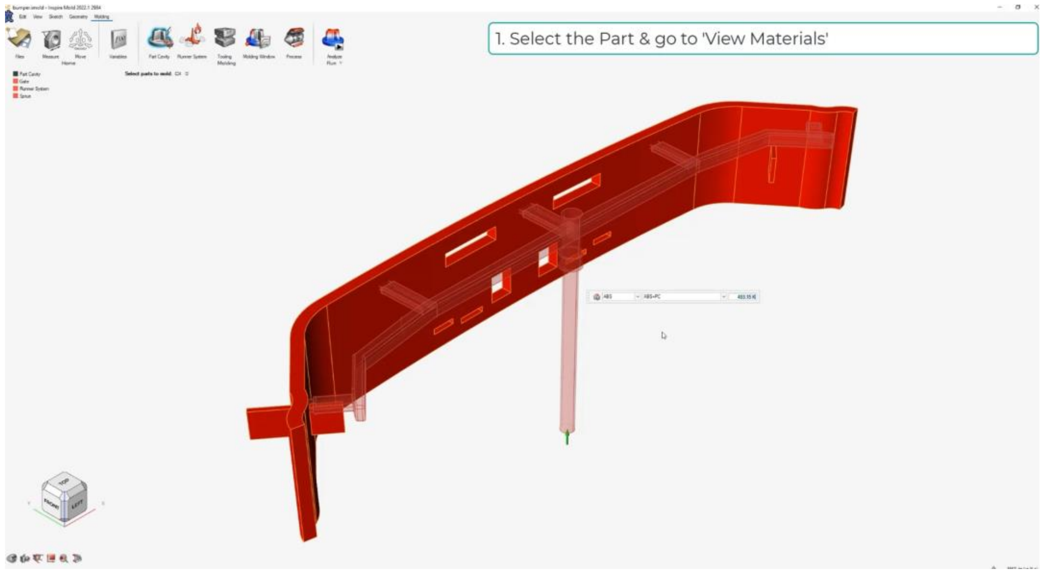
客户端访问

实现真正的多学科 CAE 工作流程

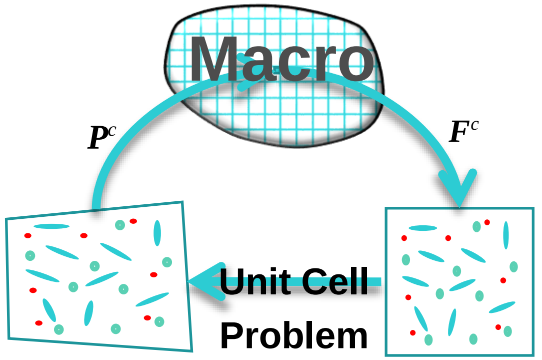
统一的用户界面，用于在所有桌面产品中搜索、浏览和使用材料

Inspire PolyFoam Inspire Extrude Inspire Mold Inspire Form Inspire Studio Inspire Simsolid HyperWorks **Simlab** Flux Flux Motor **Feko** ....

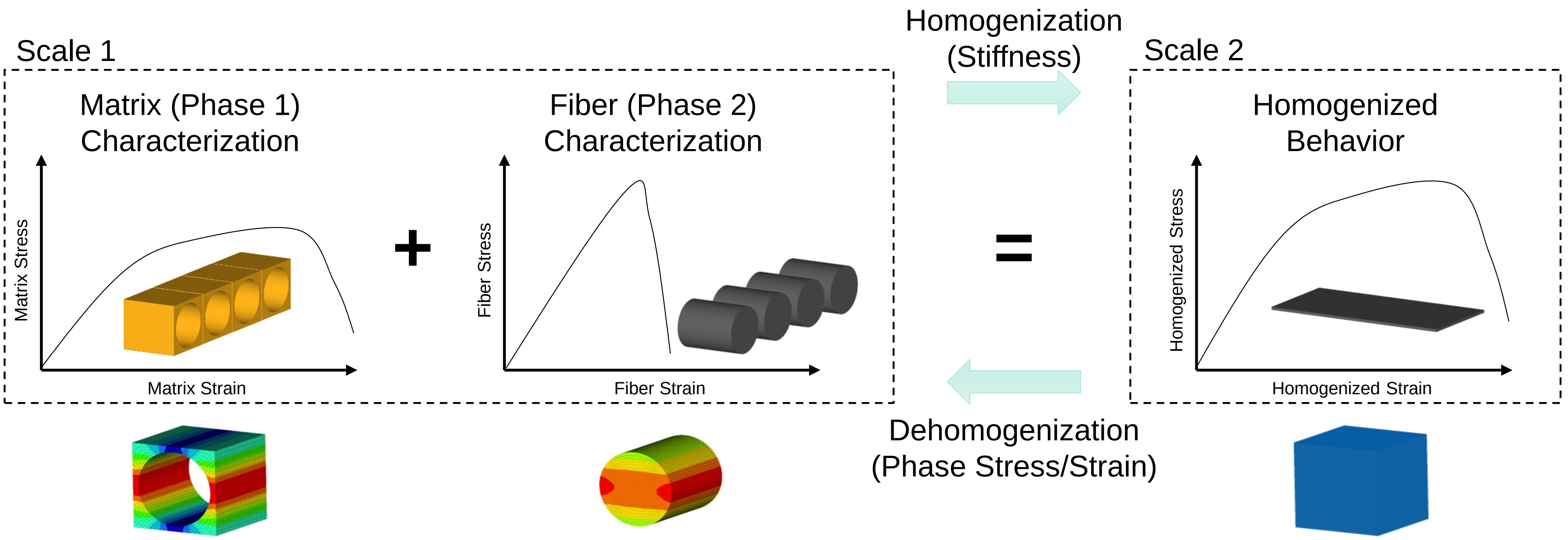
工艺仿真 结构仿真 电磁仿真



复合材料多尺度模型开发



- 从微观材料属性生成宏观材料属性
- 从宏观材料属性反推微观材料属性



非线性模型及虚拟试验库

各向同性损伤

- 双线性、三段损伤模型

各向异性损伤

- 双线性、三段损伤模型

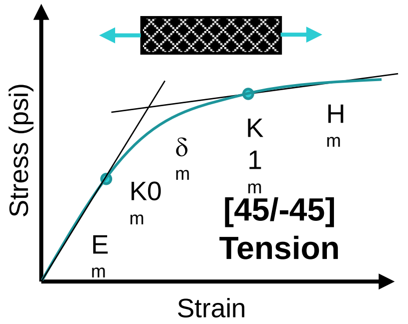
率相关塑性

粘塑性

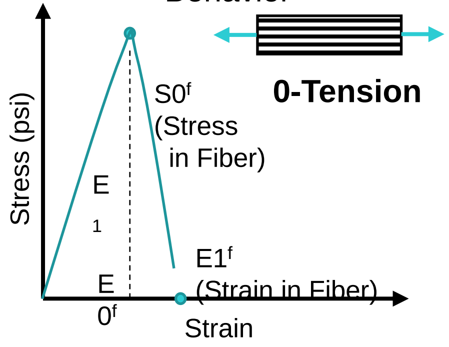
各向同性塑性及损伤混合模型

……

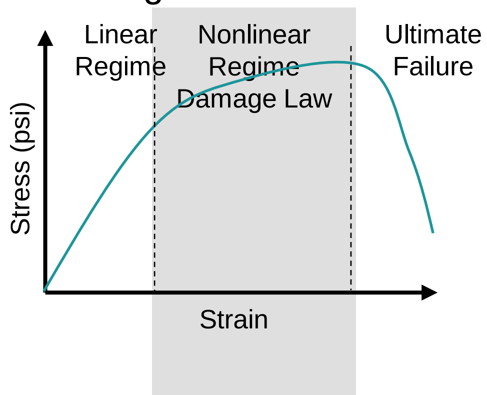
Matrix Distortion Behavior



Fiber Axial Strain to Failure Behavior

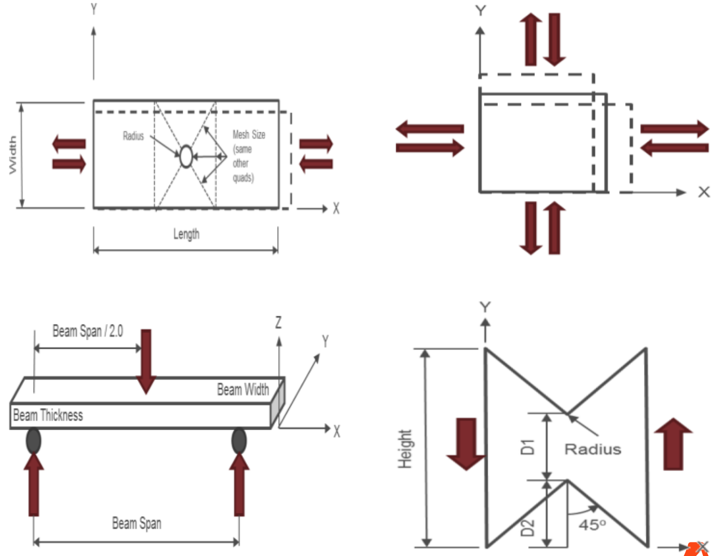


Homogenized Behavior



集成ASTM 和 ISO 标准，参数化建立试验模型

1. 无损板拉压试验 (UNT/C)
2. 开孔板拉压试验 (OHT/C)
3. 3-点 & 4-点 弯曲
4. V形切口钢轨剪切试验
5. 狗骨试验



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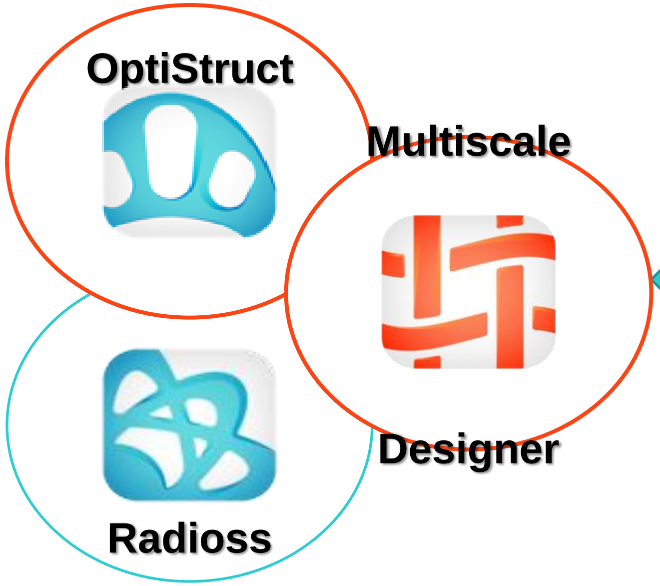
材料模型联合仿真

基于物理场的材料模型可提高预测准确性并保持计算效率

同一材料模型

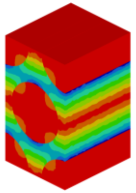
- 适用于所有求解器（隐式和显式）
- 适用于所有求解序列（线性和非线性）
- 适用于所有单元类型（实体和壳）

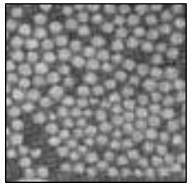


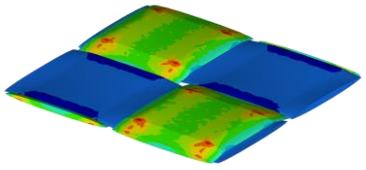
Multiscale Designer Plugins

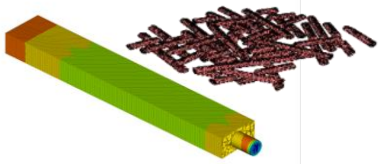
User Materials (*.dll)

ABAQUS
LS-DYNA
ANSYS









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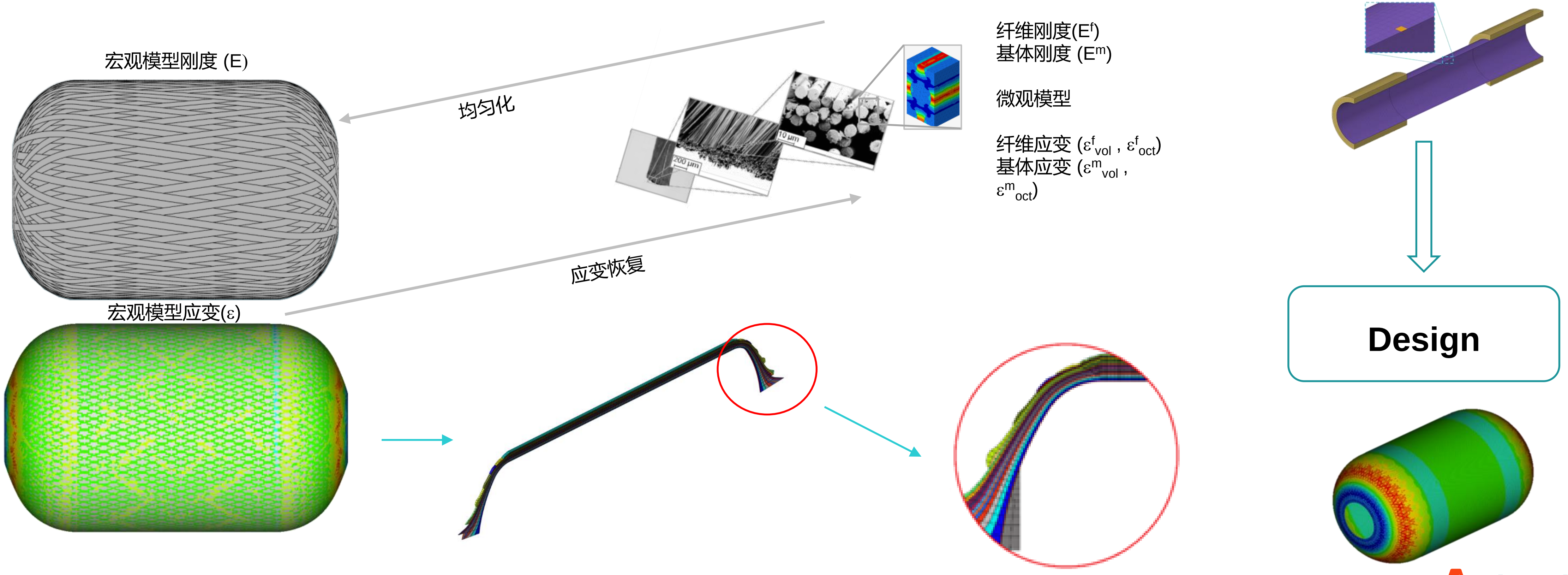
实体模型替换案例——压力容器

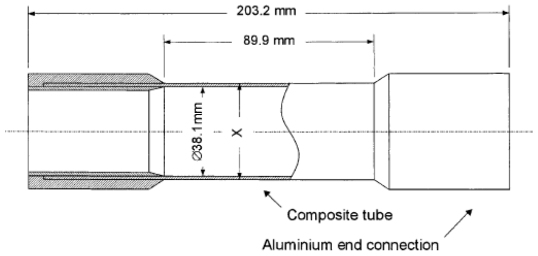
纤维和基体刚度的均匀化以获得精确的Tow刚度特性

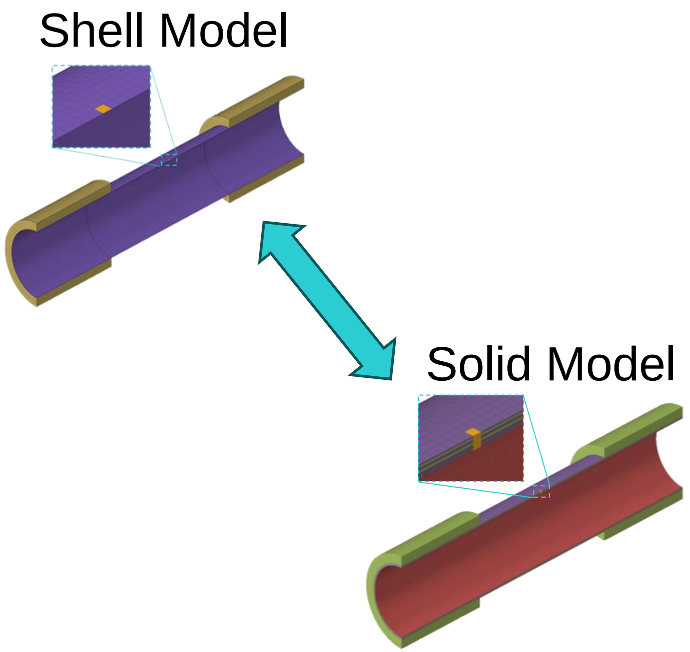
对丝束应力/应变进行去均匀化，以获得准确的纤维和基体应力/应力



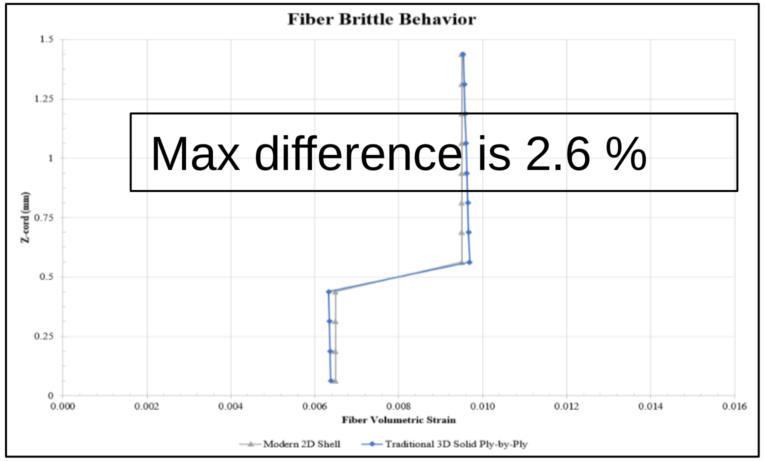
分析验证——模型及结果

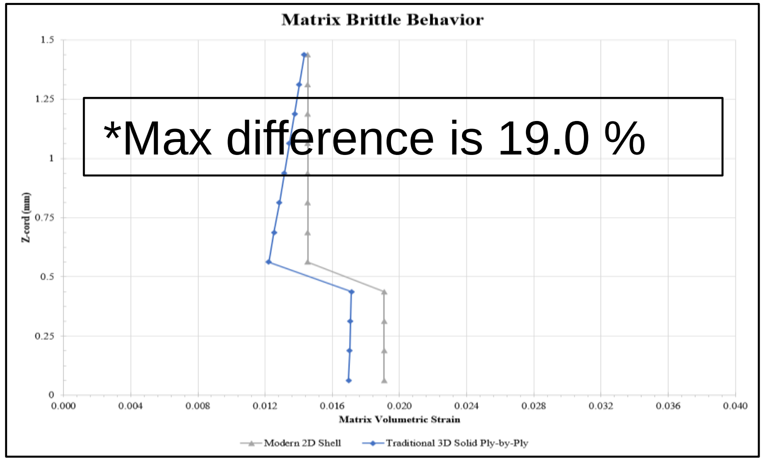
Mertiny P., Ellyin F., and Hothan A. “**An experimental investigation on the effect of multi-angle filament.**”

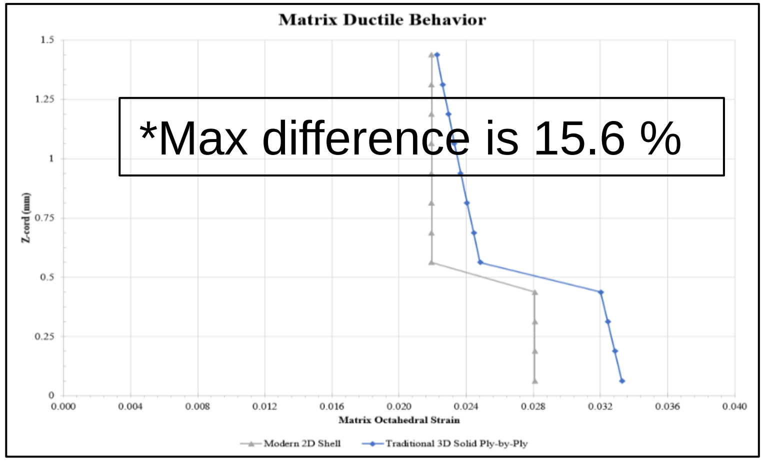




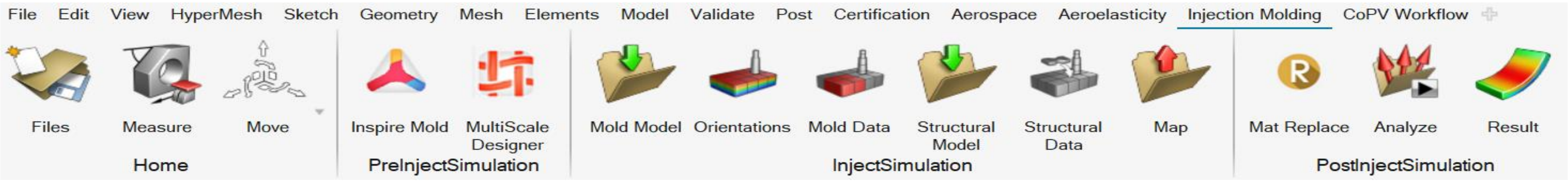
Stacking Sequence	[30/-30/-30/30]	[60/-60/-60/60]	[60/-60/-60/60]
Winding Angle	±30° (Layer 1)	±60° (Layer 2)	±60° (Layer 3)
Total Thickness (mm)	1.5		
Loading	Closed end - 2 hoop : 1 axial		

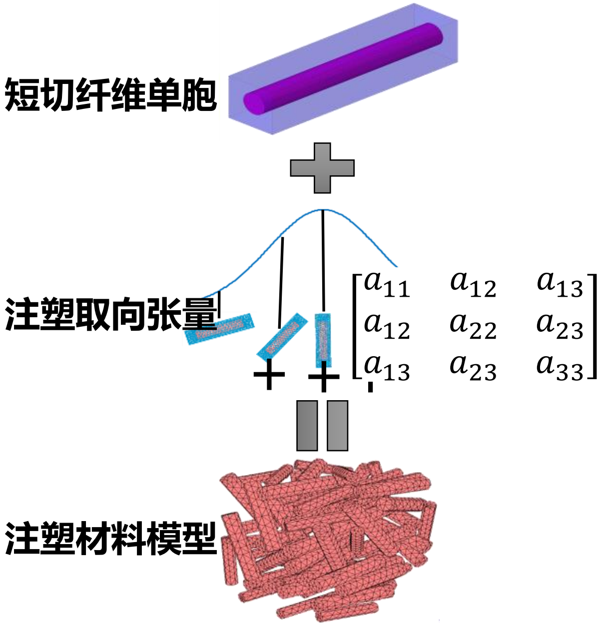


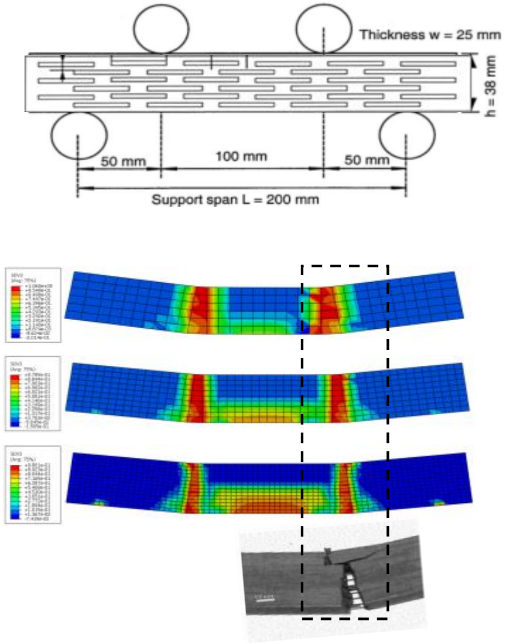


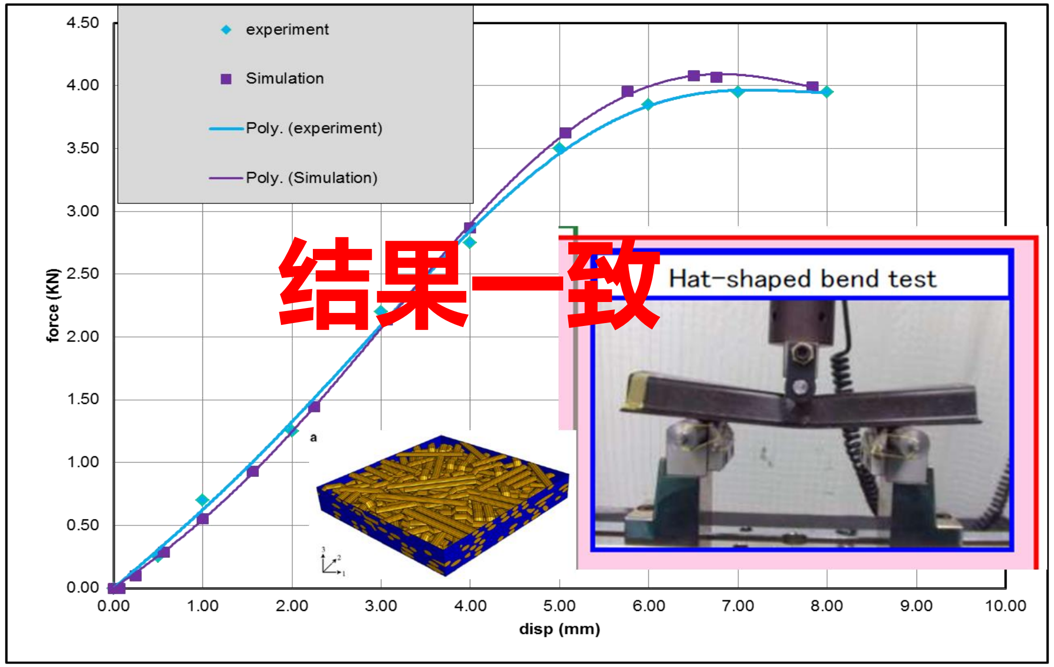


短切纤维注塑案例——试验与模拟结果对比









Altair 复合材料一站式解决方案

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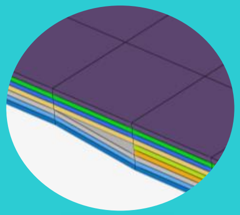
复合材料
虚拟试验



复合材料
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复合材料
设计认证

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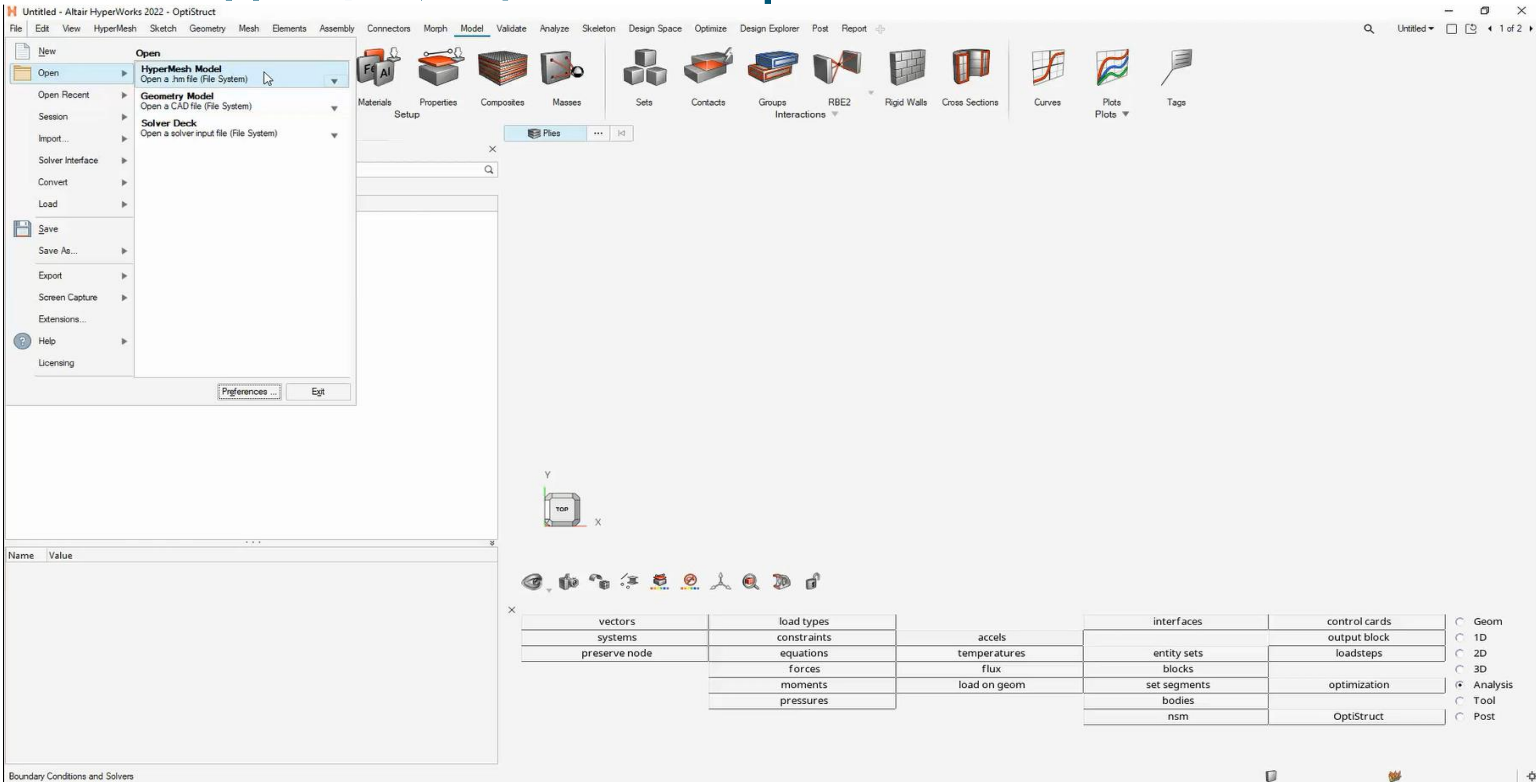
全新的复合材料建模流程 —— Composite Browser



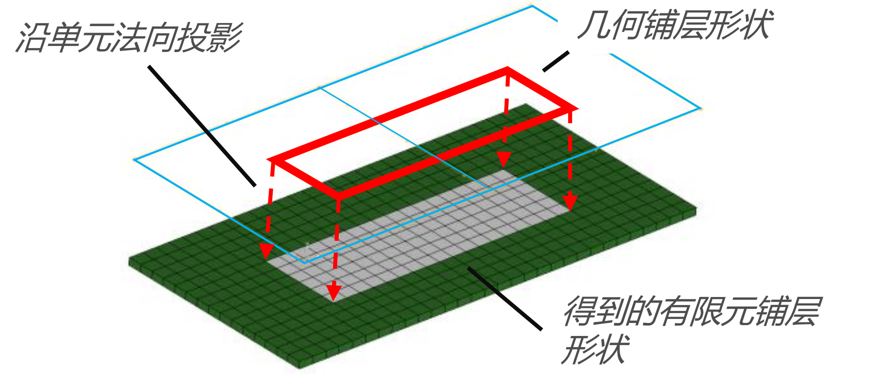
复合材料数据快速导入

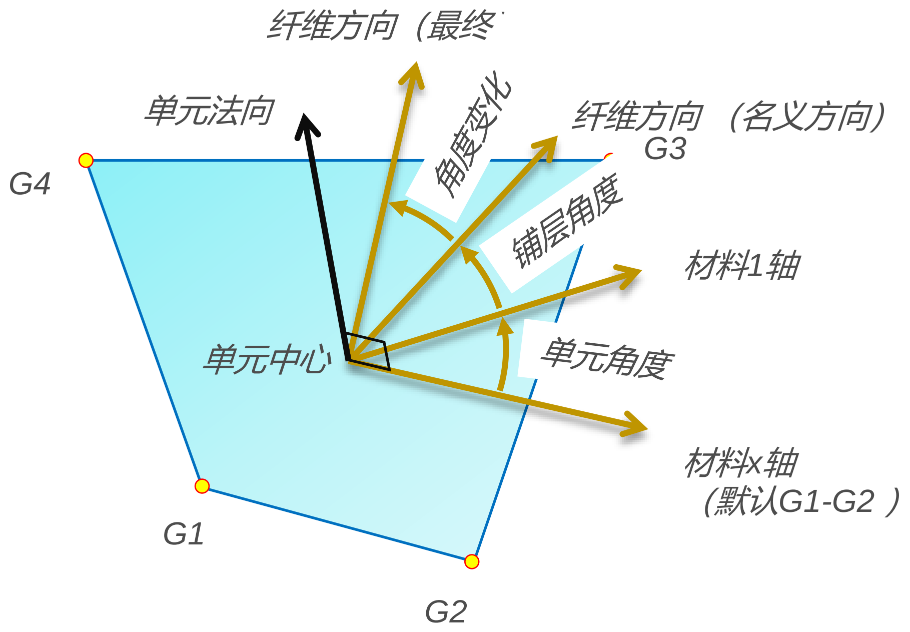
CAD数据导入

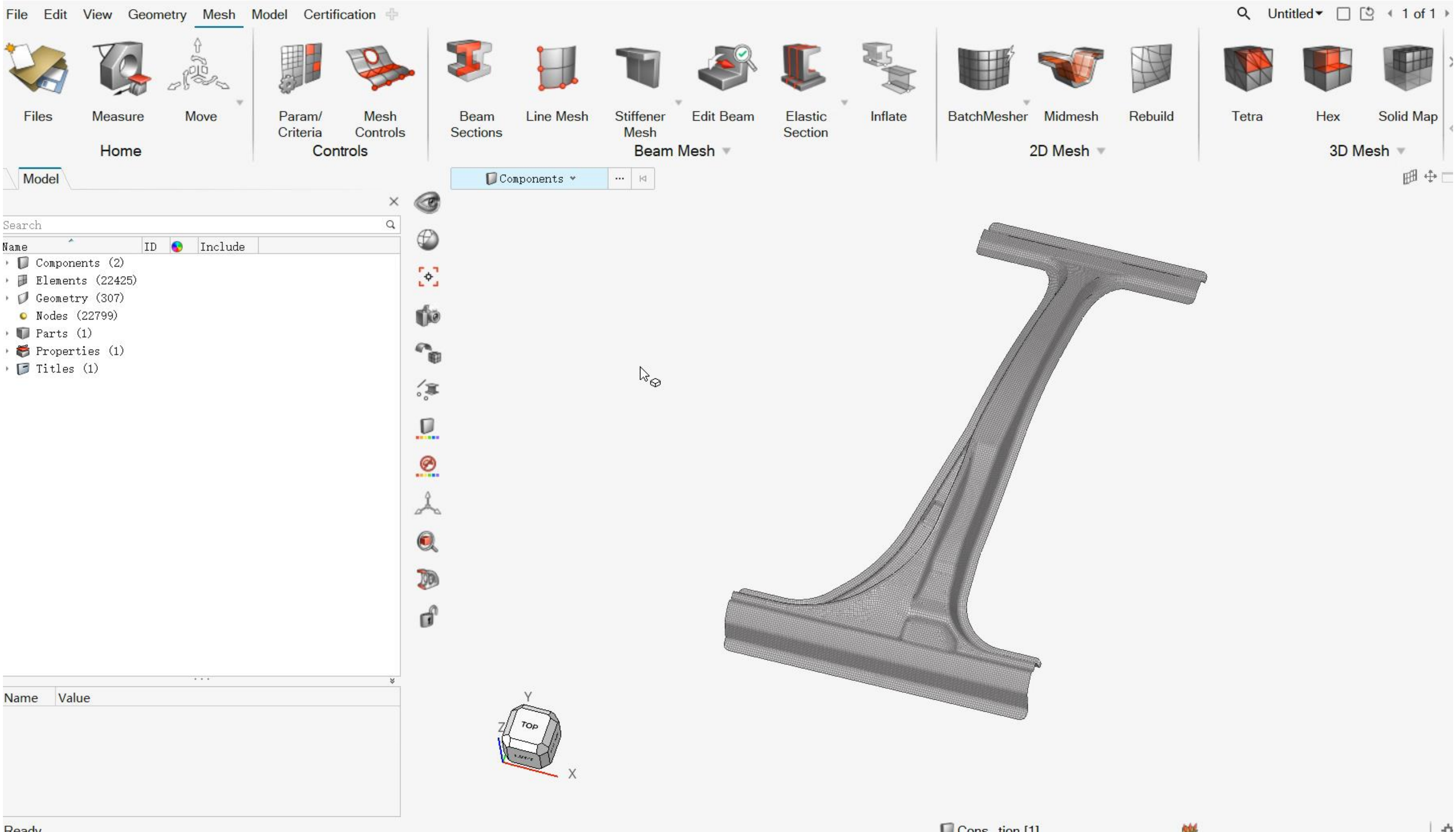
- ○ 铺层几何
- ○ 铺层层叠次序➔层合板
- ○ 主坐标系
- ○ 铺层厚度
- ○ 铺层方向
- ○ 工艺仿真数据

- Drape 数据➔表(Fibersim)
- 模流方向张量

- ○ 材料属性



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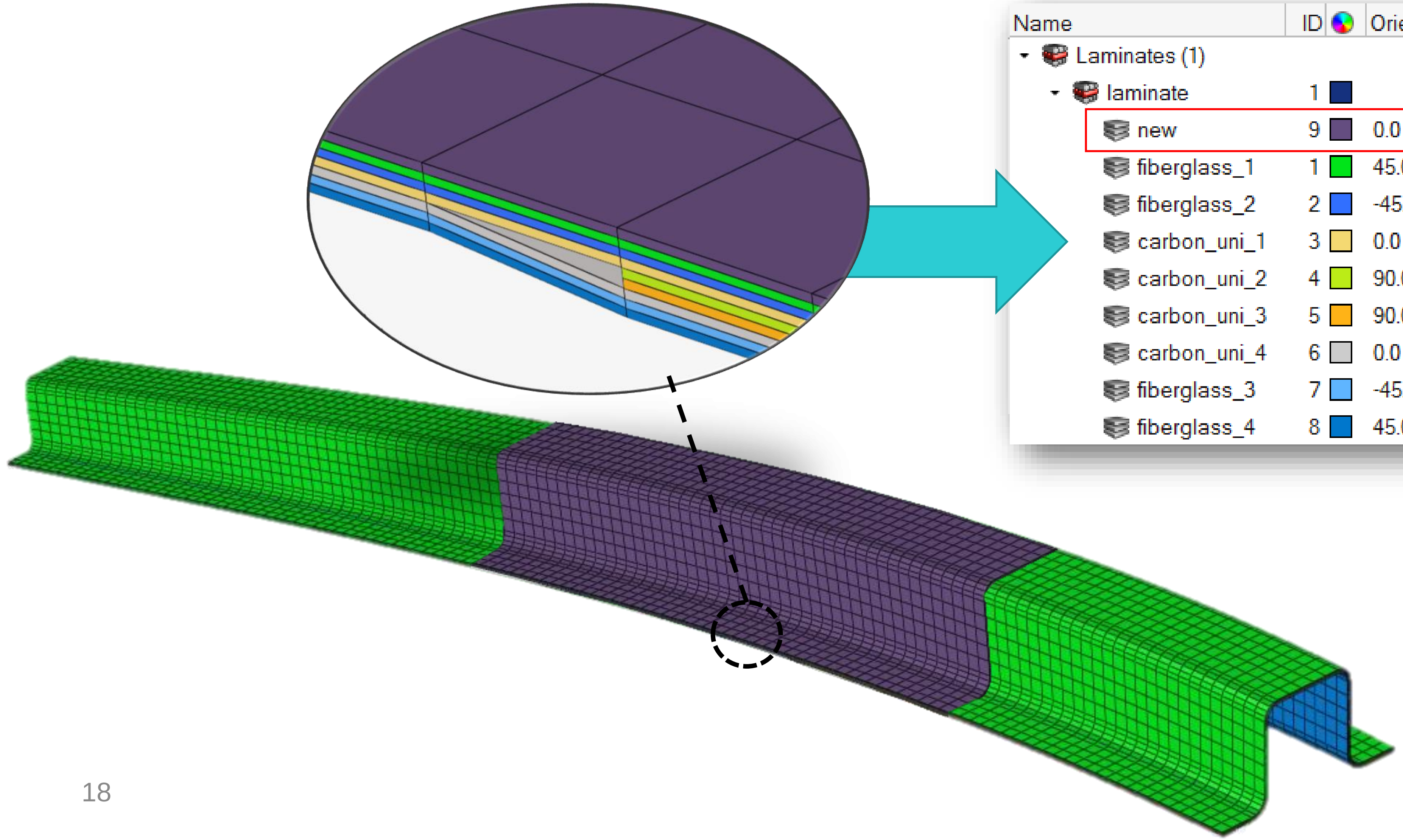
Untitled
1 of 1
Files
Measure
Move
Home
Param/ Criteria
Mesh Controls
Controls
Beam Sections
Line Mesh
Stiffener Mesh
Edit Beam
Elastic Section
Inflate
Beam Mesh
BatchMesher
Midmesh
Rebuild
2D Mesh
Tetra
Hex
Solid Map
3D Mesh
Model
Components
Search
Name
ID
Include
Components (2)
Elements (22425)
Geometry (307)
Nodes (22799)
Parts (1)
Properties (1)
Titles (1)
Name
Value
Y
TOP
Z
X
Ready

基于铺层建模

可转为基于区域建模



Name	ID	Orientation	Thickness	Material	Shape
Laminates (1)					
laminate	1				
new	9	0.0	0.2	carbon_epoxy	new
fiberglass_1	1	45.0	0.18	glass_epoxy	full
fiberglass_2	2	-45.0	0.18	glass_epoxy	full
carbon_uni_1	3	0.0	0.2	carbon_epoxy	full
carbon_uni_2	4	90.0	0.2	carbon_epoxy	partial
carbon_uni_3	5	90.0	0.2	carbon_epoxy	partial
carbon_uni_4	6	0.0	0.2	carbon_epoxy	full
fiberglass_3	7	-45.0	0.18	glass_epoxy	full
fiberglass_4	8	45.0	0.18	glass_epoxy	full

Name	Value
Solver Keyword:	PCOMPP
Name:	property1
ID:	1
Color:	
Include:	[Master Model]
Defined:	
Card Image:	PCOMPP
Laminate:	<Unspecified>
User Comments:	Hide In Menu/Export
Z0 OPTIONS:	REAL
Z0:	0.0
NSM:	
SB:	
FT:	
TREF:	
GE_USEMAT:	
GE:	

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复合材料建模可视化

可视化检查与数值模型关联的工程数据

铺层数据实时3D显示

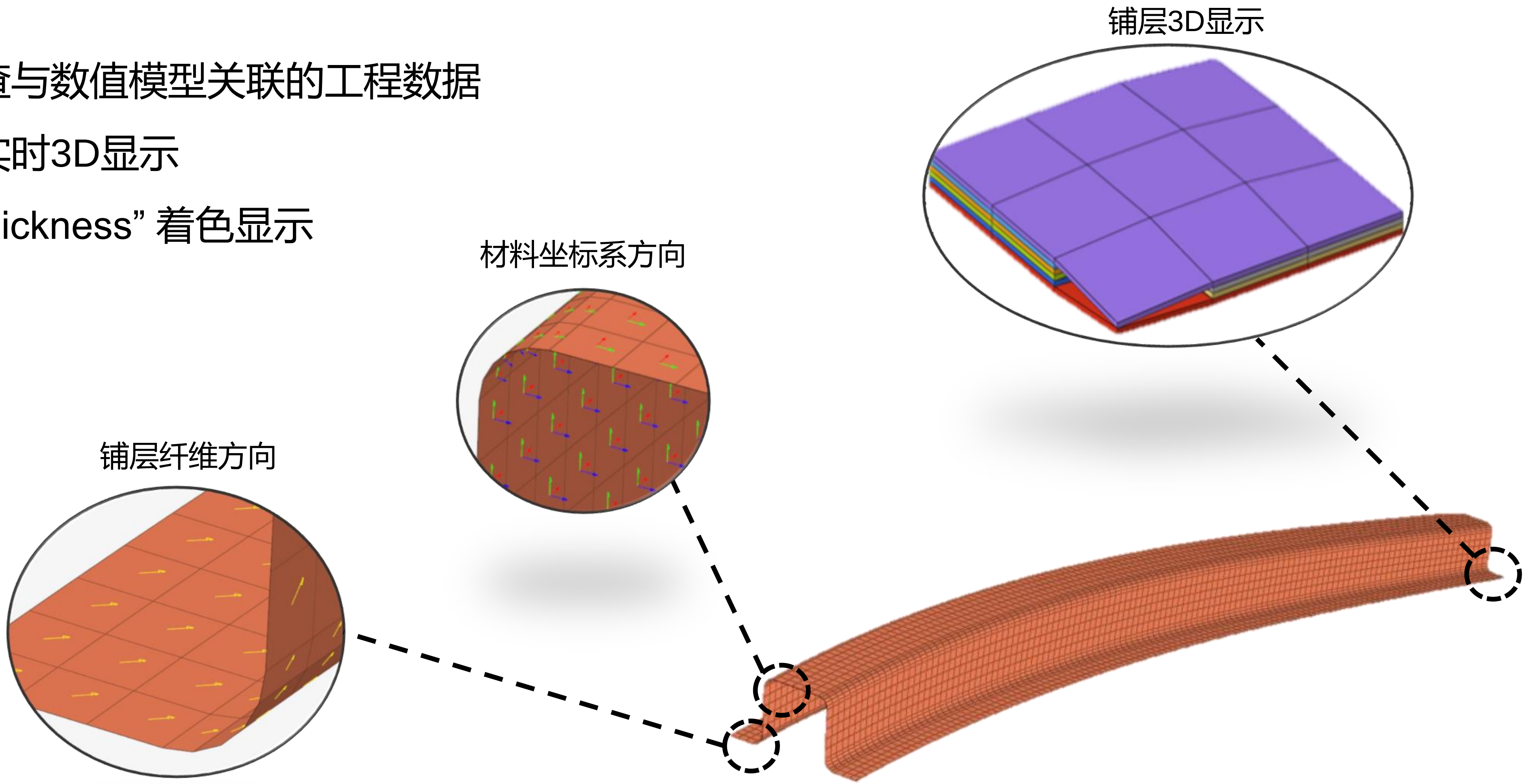
按 “by Thickness” 着色显示

单元法向

材料方向

Ply 方向

Ply 扩展



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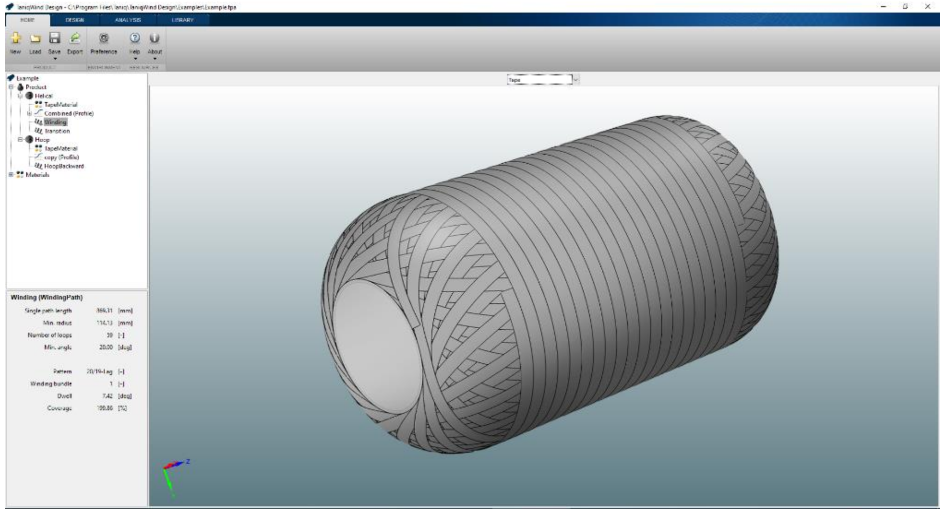
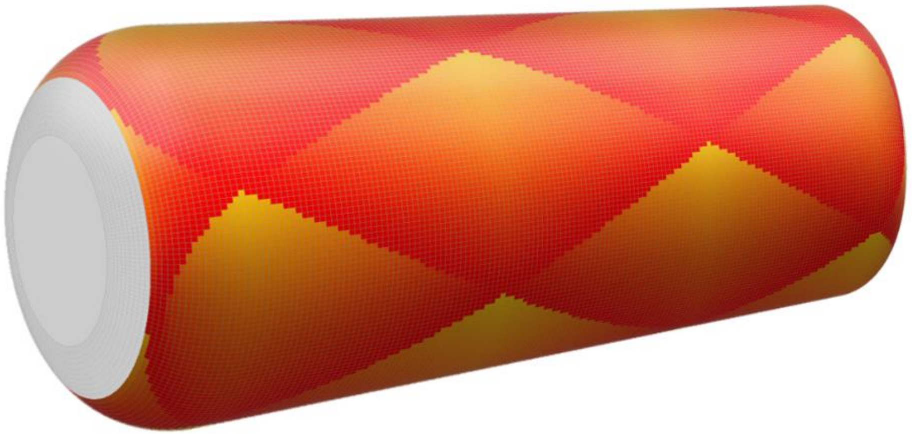
纤维缠绕设计模块——TANIQWIND Design

- 主要特点：
- 芯模生成（连续剖面）
- 芯模数据导入功能（包括.DXF）
- 管道和轴对称心轴几何形状
- 绕线路径和模式生成器
- 测地线和非测地线绕组路径
- 恒定平面内曲率路径
- 圆周（箍）绕组
- 螺旋绕组
- 过渡层绕组
- 覆盖路径
- 分段路径选项，用于设计高级绕组路径
- 绕组路径和图案模拟
- 导出基于铺层的缠绕模型：包含的网格/铺层/材料等信息





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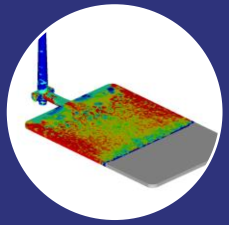

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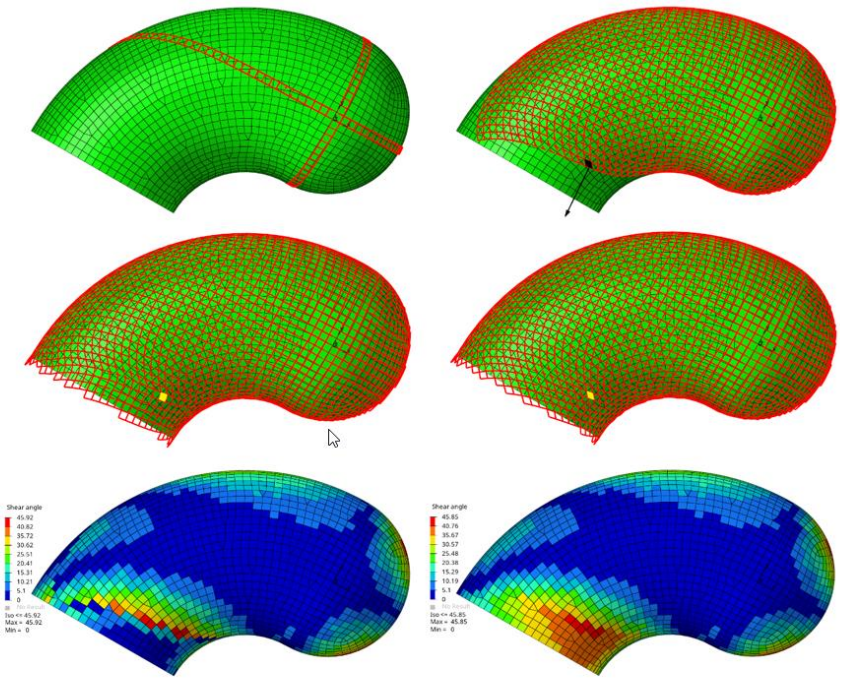
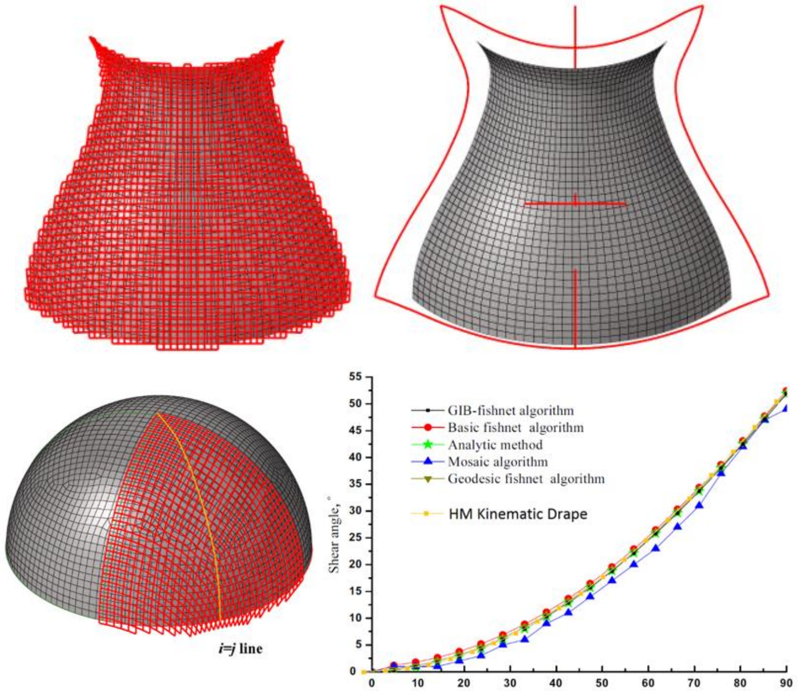
复合材料铺覆仿真

- 手动/自动铺层工艺仿真，铺覆仿真可获得：
  - 单路径/双路径铺覆，
  - 结果直接与网格关联，实时显示真实纤维方向
  - 纤维方向偏角，剪切角及厚度，铺层展开形状





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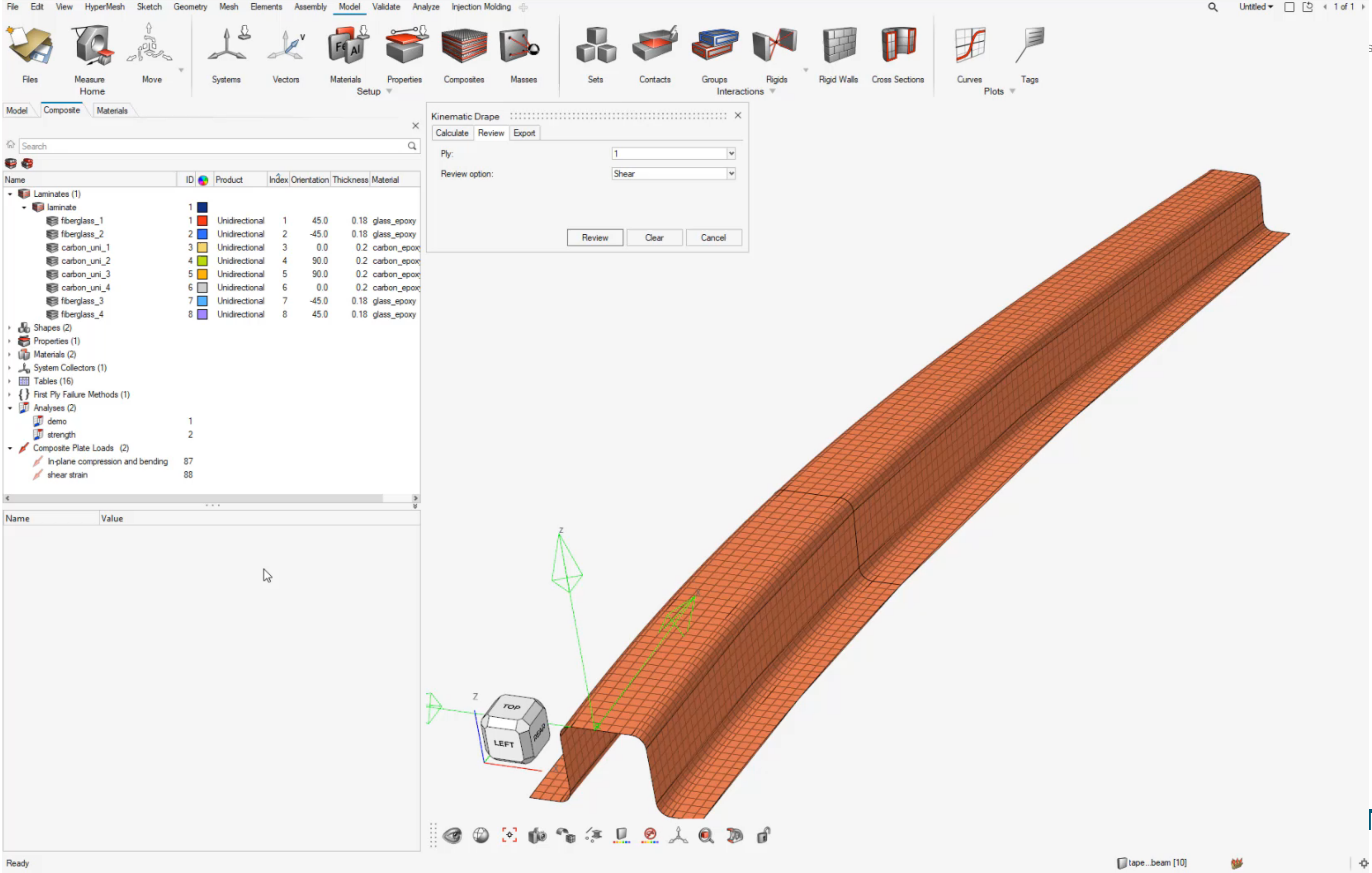

File Edit View HyperMesh Sketch Geometry Mesh Elements Assembly Model Validate Analyze Injection Molding
Untitled 1 of 1
Files Measure Move
Home
Systems Vectors Materials Properties Composites Masses
Setup
Sets Contacts Groups Rigids Rigid Walls Cross Sections
Interactions
Curves Tags
Plots
Model Composite Materials
Search
Name ID Product Index Orientation Thickness Material
Laminates (1)
laminate 1
fiberglass_1 1 Unidirectional 1 45.0 0.18 glass_epoxy
fiberglass_2 2 Unidirectional 2 -45.0 0.18 glass_epoxy
carbon_uni_1 3 Unidirectional 3 0.0 0.2 carbon_epoxy
carbon_uni_2 4 Unidirectional 4 90.0 0.2 carbon_epoxy
carbon_uni_3 5 Unidirectional 5 90.0 0.2 carbon_epoxy
carbon_uni_4 6 Unidirectional 6 0.0 0.2 carbon_epoxy
fiberglass_3 7 Unidirectional 7 -45.0 0.18 glass_epoxy
fiberglass_4 8 Unidirectional 8 45.0 0.18 glass_epoxy
Shapes (2)
Properties (1)
Materials (2)
System Collectors (1)
Tables (16)
First Ply Failure Methods (1)
Analyses (2)
demo 1
strength 2
Composite Plate Loads (2)
In-plane compression and bending 87
shear strain 88
Name Value
Kinematic Drape
Calculate Review Export
Ply: 1
Review option: Shear
Review Clear Cancel
TOP LEFT REAR
Ready
tape...beam [10]

TAIR

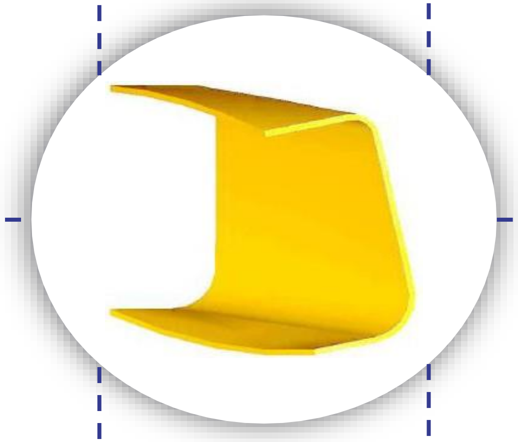
固化工艺仿真LMAT

- 适用于热固性及热塑性复合材料
- 与OptiStruct耦合进行固化-结构热仿真

平面内及厚度方向CTE不一致

不对称铺层

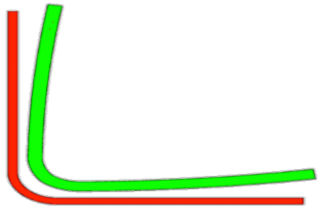
固化收缩及固化裂纹



固化放热

固化梯度及玻璃化时间等

模具形变补偿



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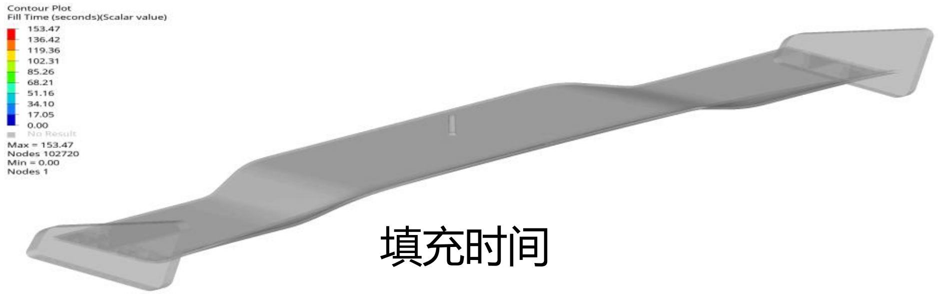
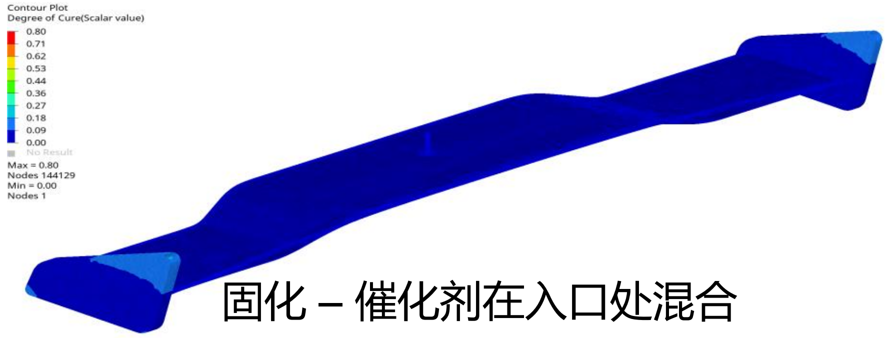
树脂传递模塑RTM工艺仿真

- 填充时间
- 固化程度
- 温度
- 压力

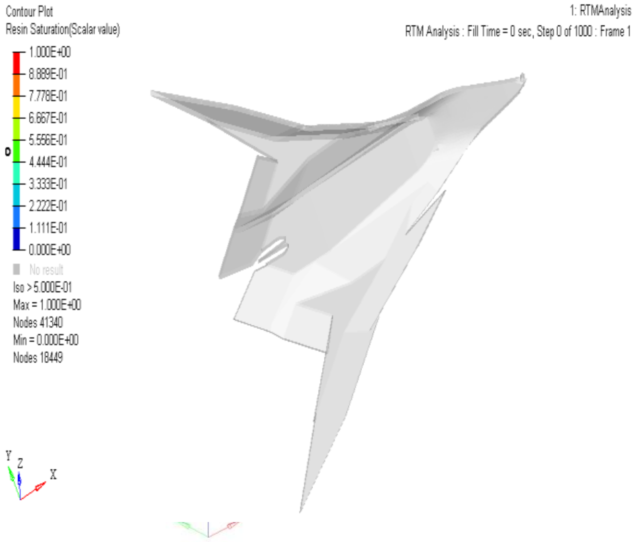
- 竞流效应
- 短料
- 提前固化
- 困气



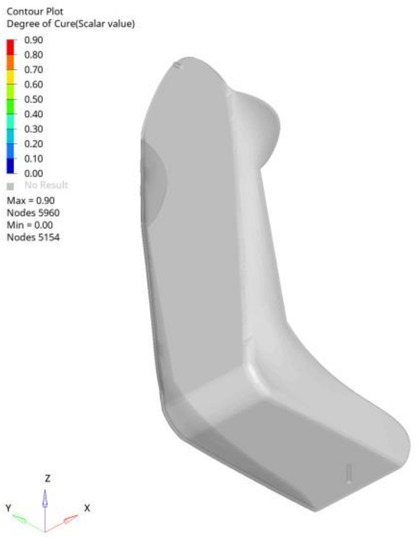
填充时间



固化 – 催化剂在入口处混合



树脂饱和度



固化度

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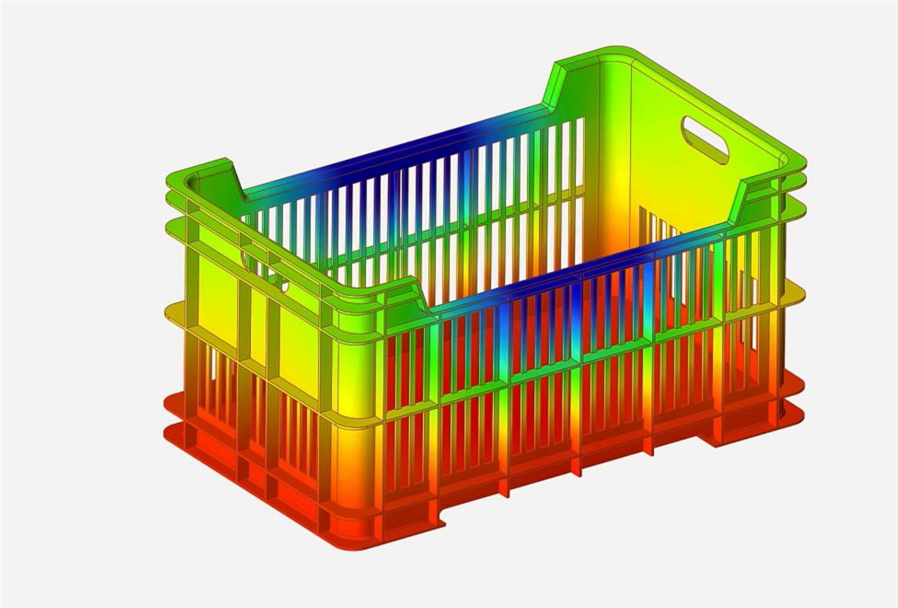
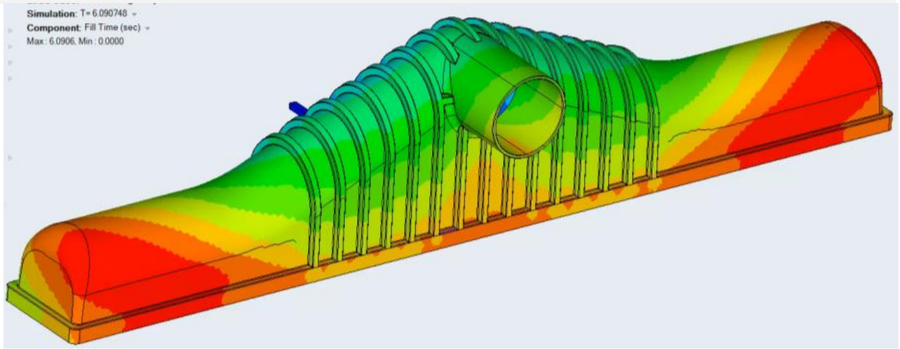
短纤注塑工艺仿真 Next-Generation 3D

支持的物理过程

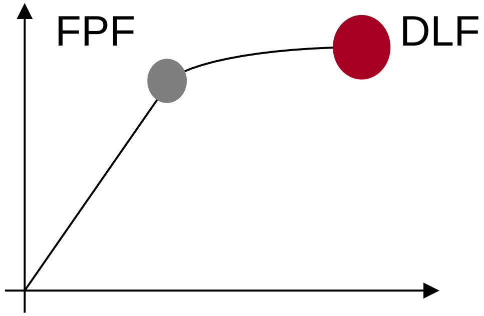
- 充型 (F)
- 保压 (P)
- 冷却 (C)
- 翘曲 (W)
- 全过程 (F + P + C + W)
- 冷却 + 翘曲
- 充型 + 保压 + 翘曲
- 瞬态模具冷却
- 纤维定向
- 热流道分析

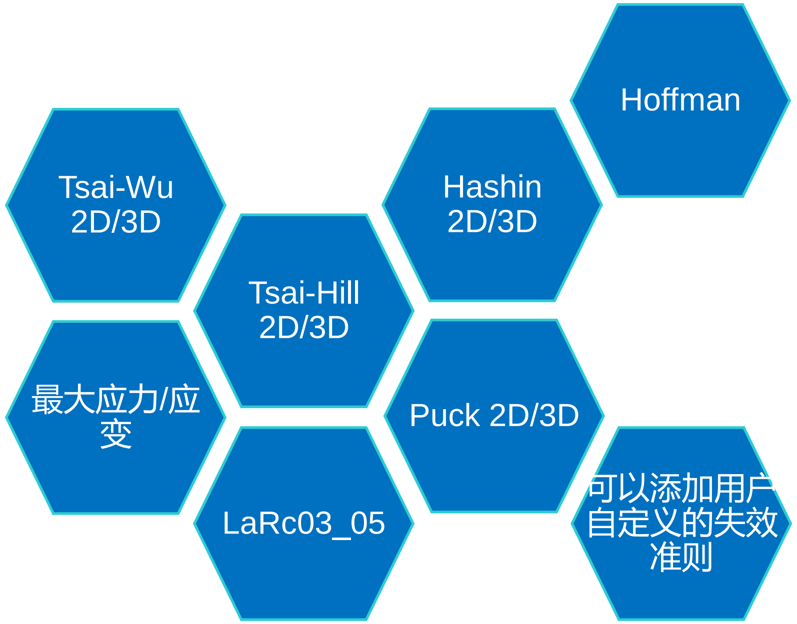




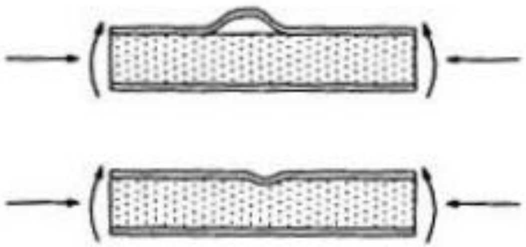
充型结果	保压结果
温度	温度
速度	速度
压力	压力
充型时间	凹痕
困气位置	模具温度
熔接线位置	
纤维定向	
模具温度	
冷却结果	**翘曲结果**
产品温度	变形量
模具温度	

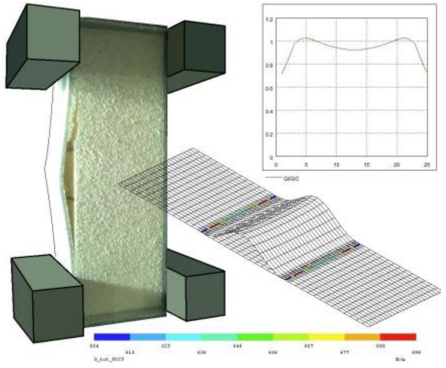
复合材料失效

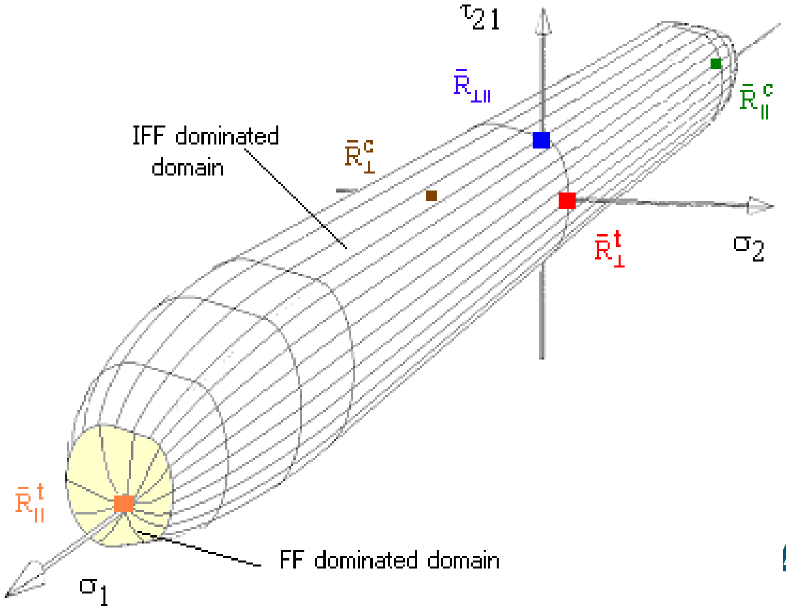




- 基于铺层的失效准则
- ILS层间剪切失效分析
- 失效模式与临界层预测
- 基于解析法FPF首层失效分析和 DLF逐层失效分析
- 基于有限元渐进失效分析（隐式/显式）
- 夹层板芯层剪切失效与皮层屈曲分析

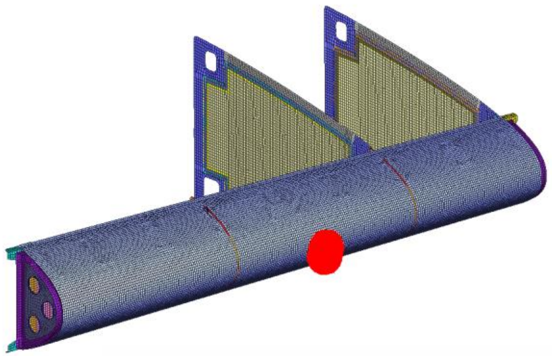




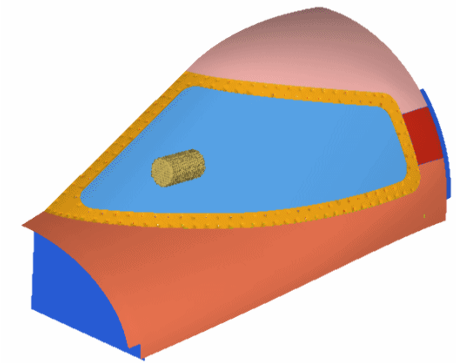


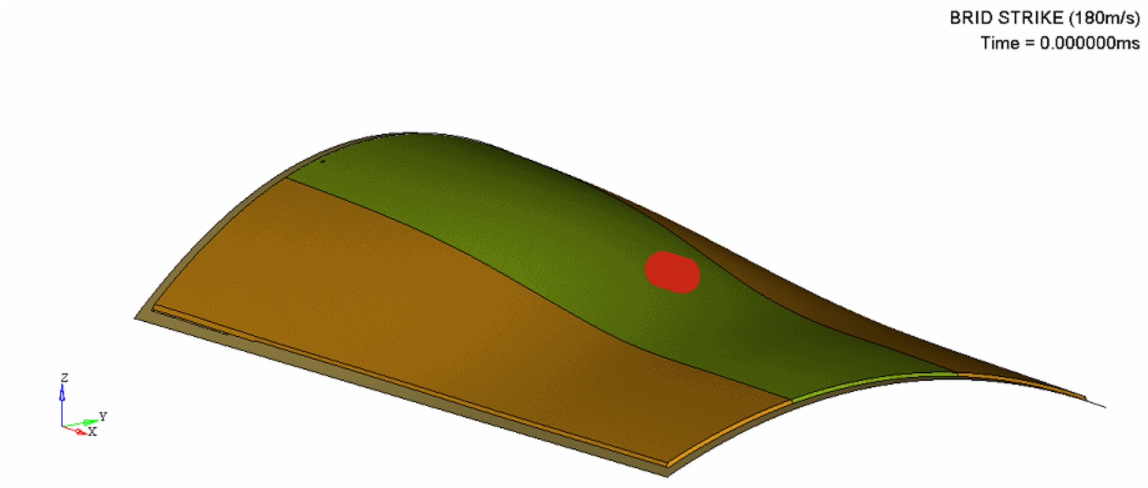
复合材料显式分析

机翼前缘鸟撞模拟

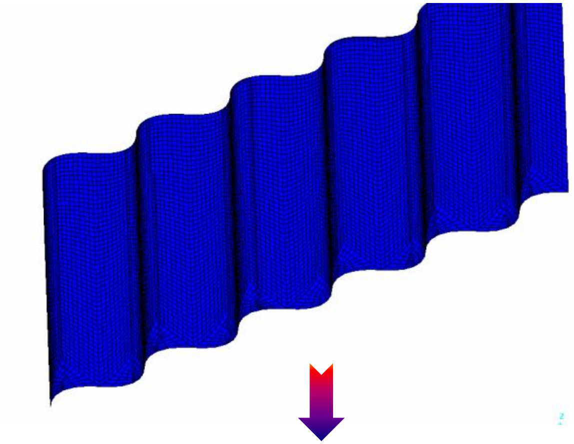


驾驶舱前风挡玻璃鸟撞模拟





复材冲击



ALTAIR

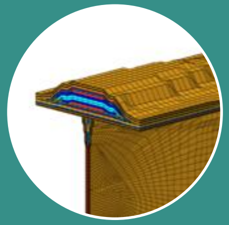
Altair 复合材料一站式解决方案

Altair复合材料工作流程

复合材料
虚拟试验

复合材料
建模可视化

复合材料
工艺/结构仿真

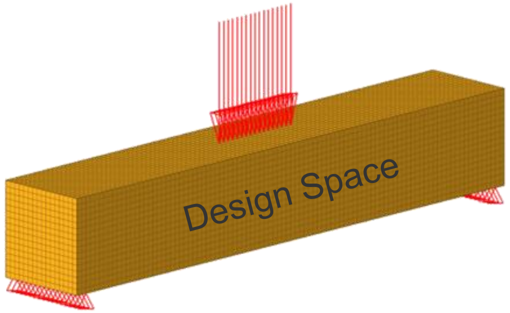


复合材料
优化设计

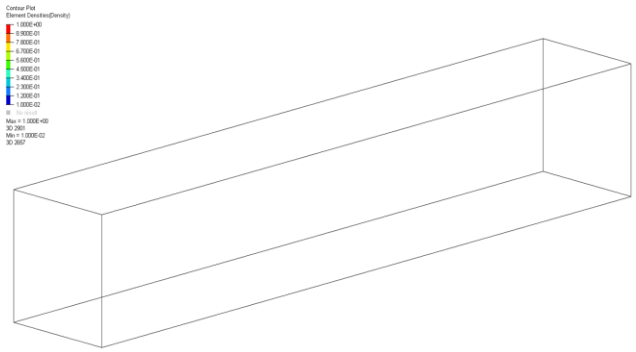
复合材料
设计认证

复合材料优化设计流程

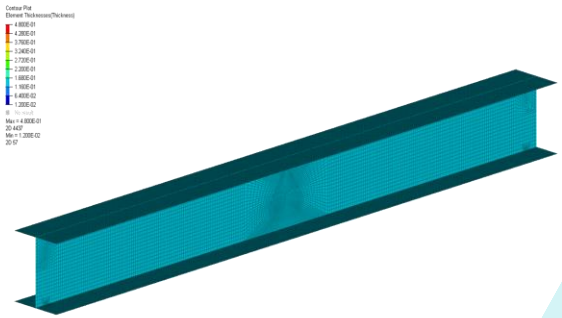
① **初始设计空间**

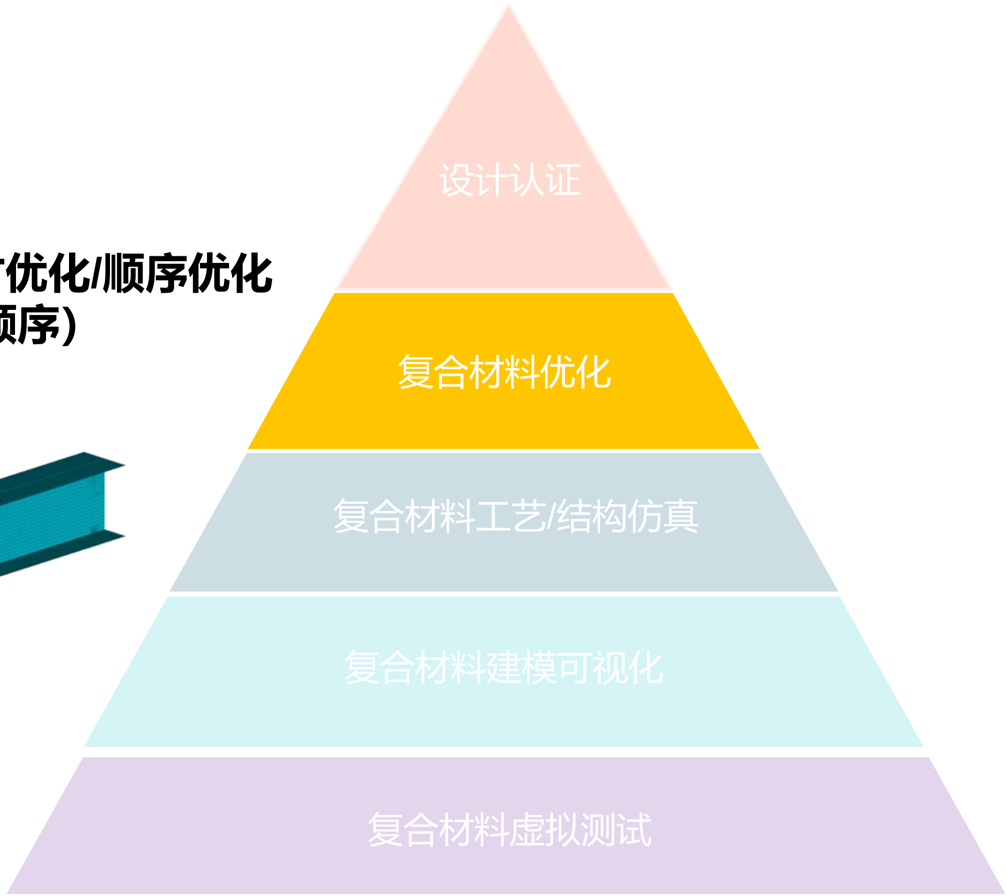


② **拓扑优化（优化结构构型）**



③ **复合材料自由尺寸/尺寸优化/顺序优化（优化铺层形状/厚度/顺序）**





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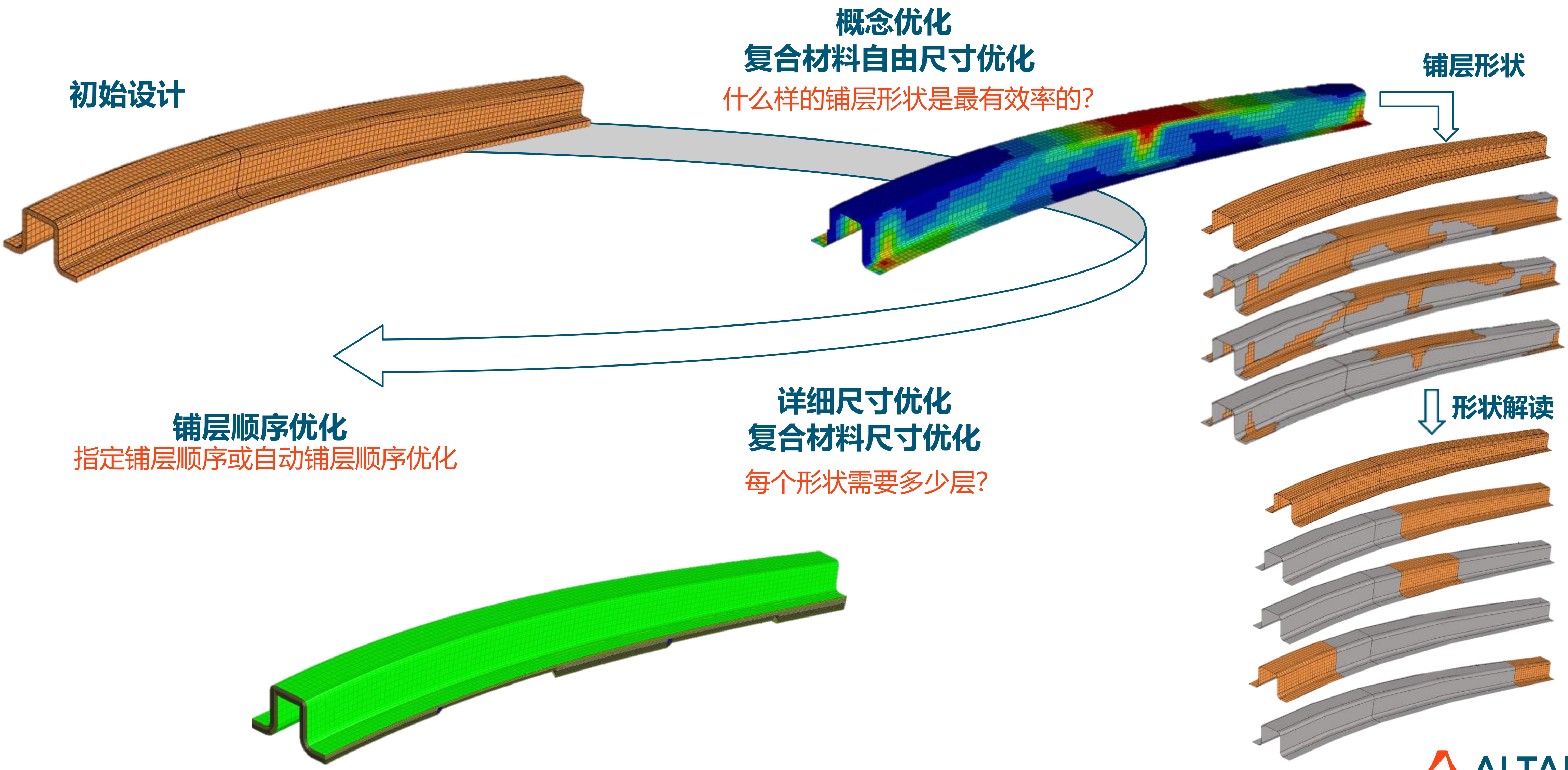
复合材料铺层设计流程



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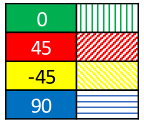
复合材料设计制造约束

- 最小和最大层合板总厚度
- 单个角度铺层最小和最大厚度
- 单个角度铺层最小和最大厚度百分比
- 各个角度铺层间厚度相关性
  - 连续相同角度铺层数不能超过3或4层
  - 45度和-45度铺层数相等
  - 表面铺层序列
  - 中间铺层序列

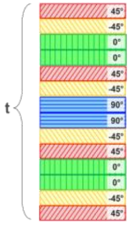


铺层角度

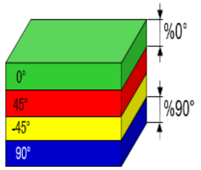
铺层厚度

Orient.	T
45	1.10
-45	1.10
0	2.00
0	2.20
90	1.50
45	1.30
-45	1.30
0	2.70
90	1.60
45	1.15
-45	1.15
0	1.60

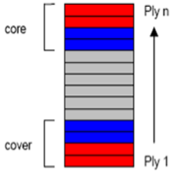
45/-45 °平衡



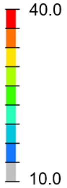
对称



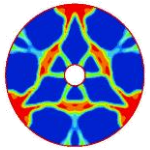
角度百分比



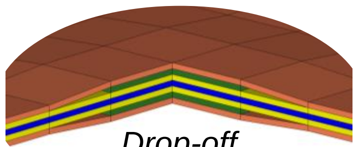
铺层顺序



层合板厚度

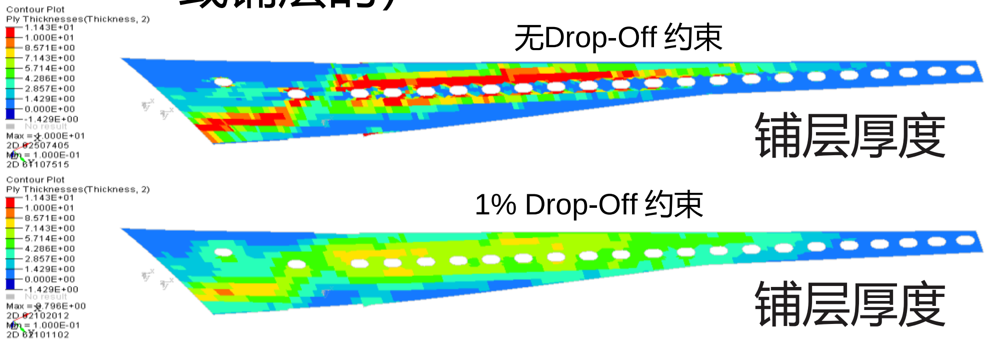


铺层形状对称



Drop-off

- 复材铺层的 drop-off 约束
  - 减少由于应力集中造成的层间分离破坏
  - 可定义厚度或某方向上的drop off
  - 可依据drop off 的角度或厚度来定义约束
  - 在复合材料自由尺寸优化中有效（基于单元的）
  - 在复合材料尺寸优化中有效（基于属性或铺层的）



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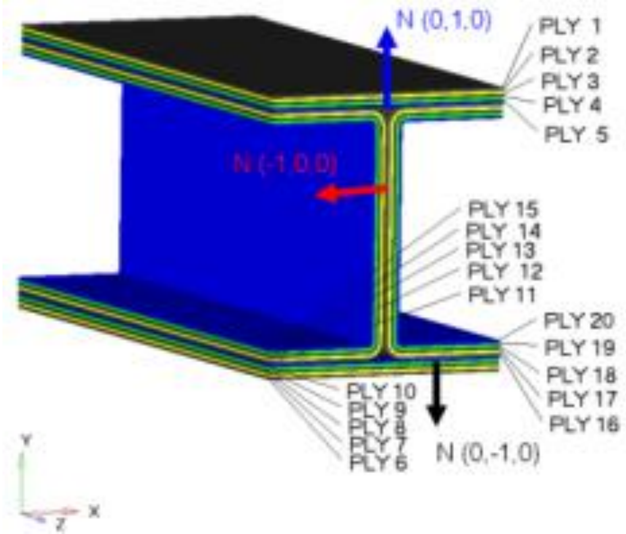
复合材料优化响应

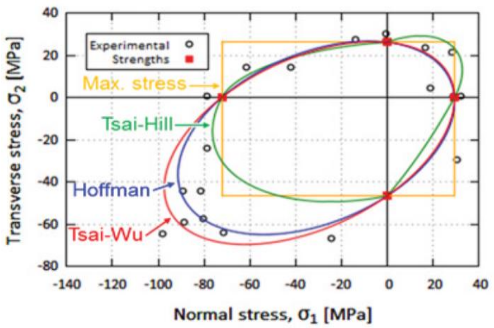
复合材料单个铺层(PLY)响应

- 应力响应
- 应变响应

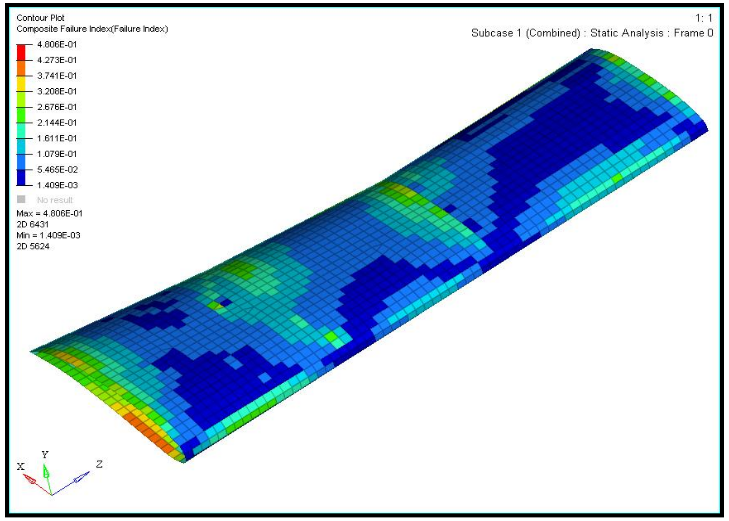


○ 失效响应

- Hill
- Hoffman
- Tsai-Wu
- Hashin
- Puck
- Max strain
- Max Stress
- Failure Index



Failure criteria



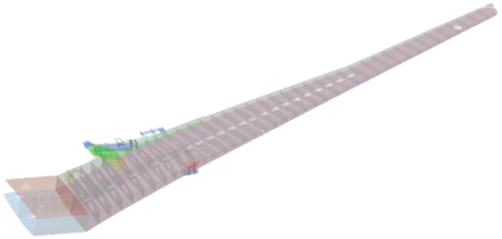
复合材料机翼设计流程

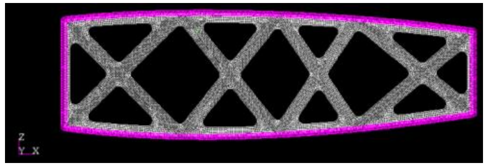
C1

机翼布局优化

粗网格模型

优化:
- 肋板和长桁间距
- 长梁间距
- 局部拓扑优化



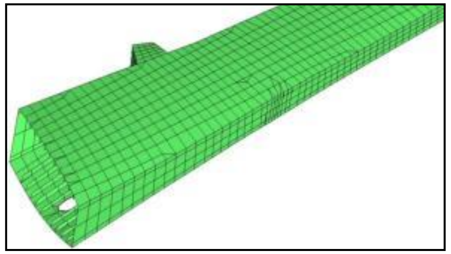


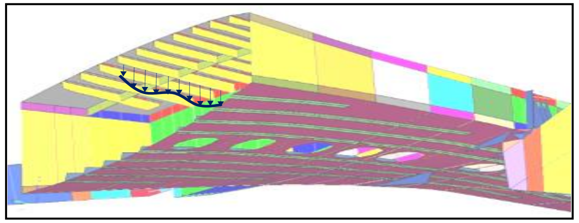
C2

机翼快速成型

较细网格板壳模型
（理想链接，1D长桁）

优化:
- 蒙皮，大梁，长桁的厚度
- 静力和疲劳工况
- 板壳的稳定性



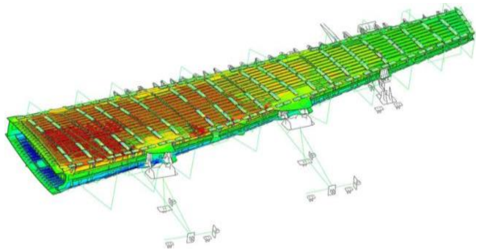


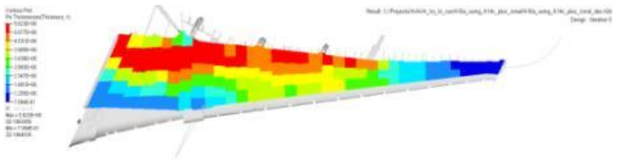
C3

机翼详细设计

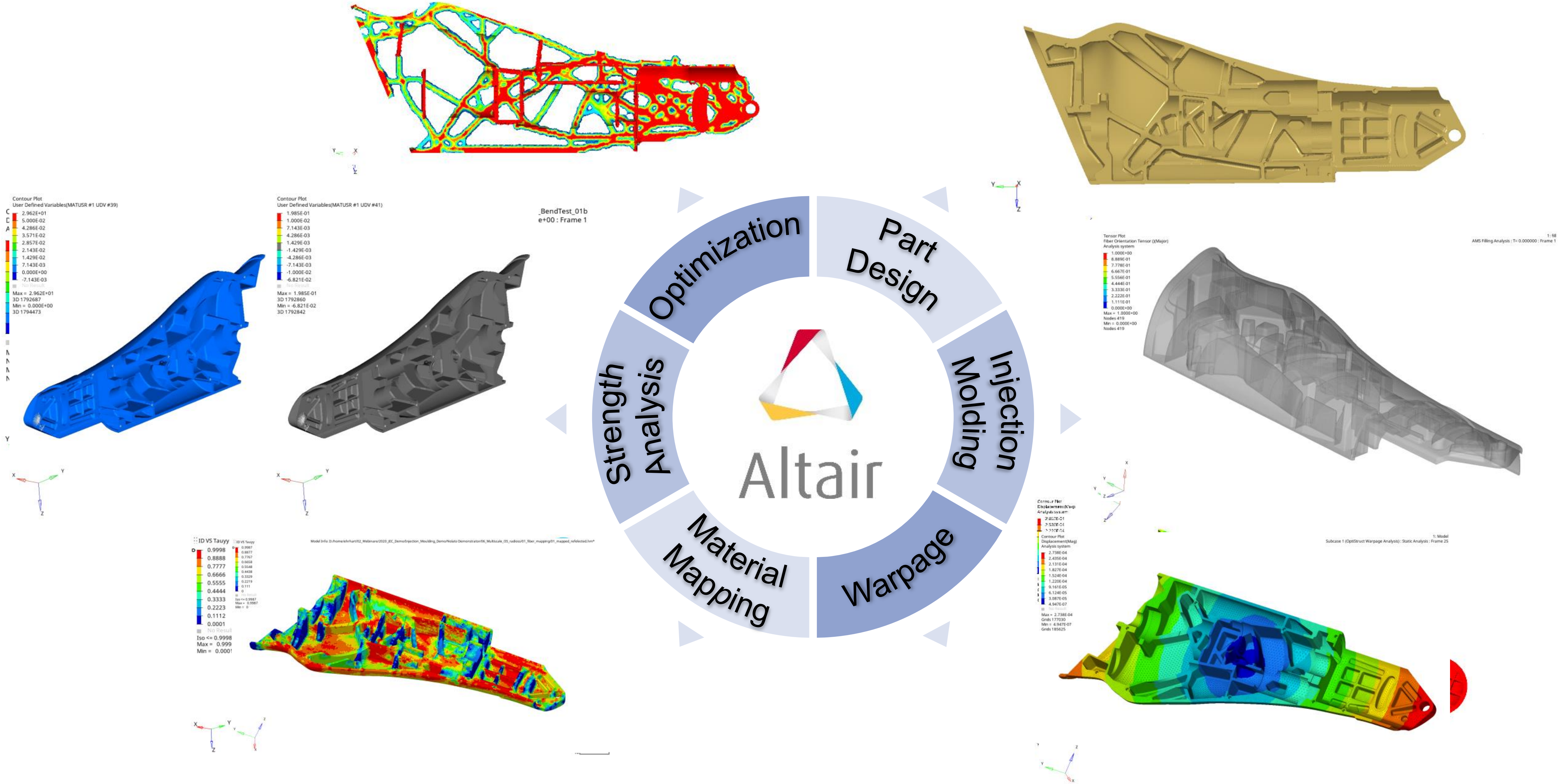
高保真的细网格模型
（实体/壳/连续壳/钉/接触等细节）

优化:
- 详细的尺寸和形状优化
- 几何非线性
- 材料非线性





短纤注塑结构优化



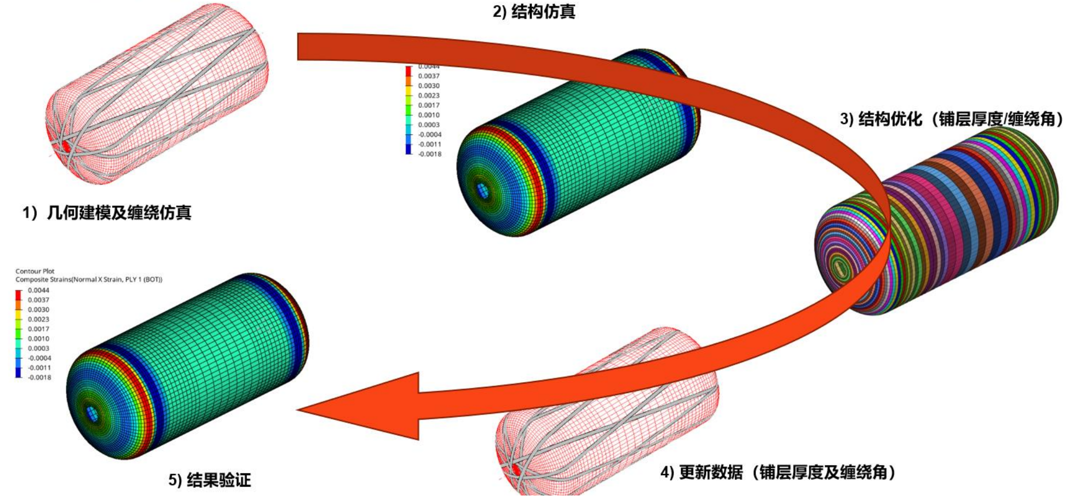
Optimization
Part Design
Injection Molding
Warpage
Material Mapping
Strength Analysis
Altair

缠绕复合材料设计仿真及优化

优势

- 气瓶设计到仿真数据完整性
- 基于铺层建模，有限元模型自动生成
- 气瓶铺层优化设计
- 气瓶建模及铺层可视化

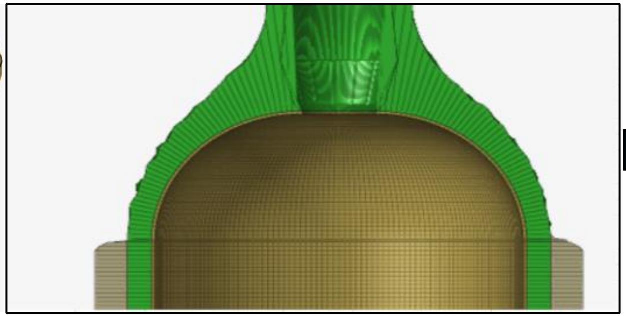
CPV设计流程



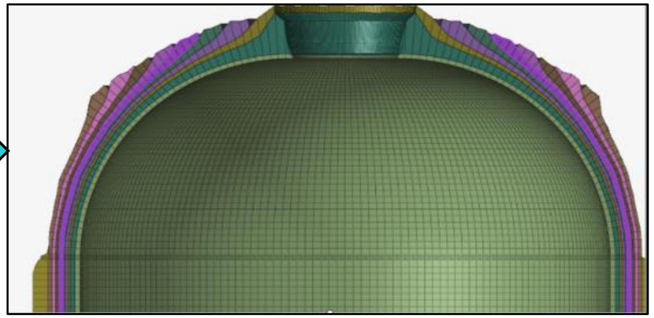
案例展示

IV气瓶
134L-70MPa
内胆外径358mm
T800碳纤维

初始设计



OS优化设计

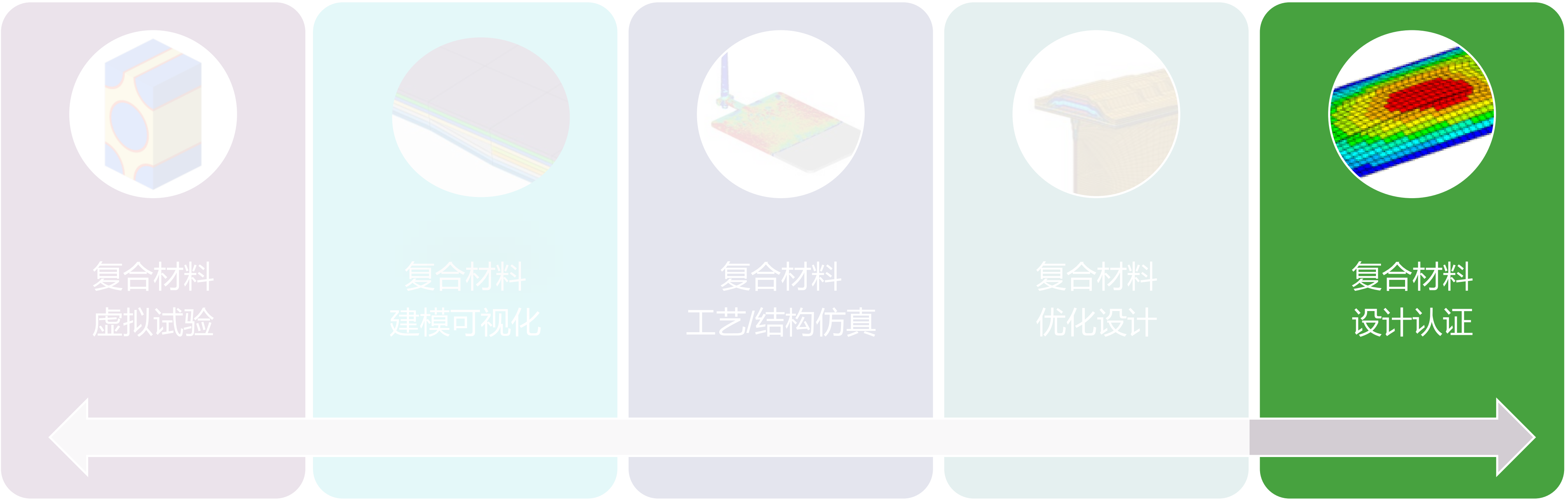


IV型瓶，重135kg

IV型瓶，重91kg，减重44kg，32%

Altair 复合材料一站式解决方案

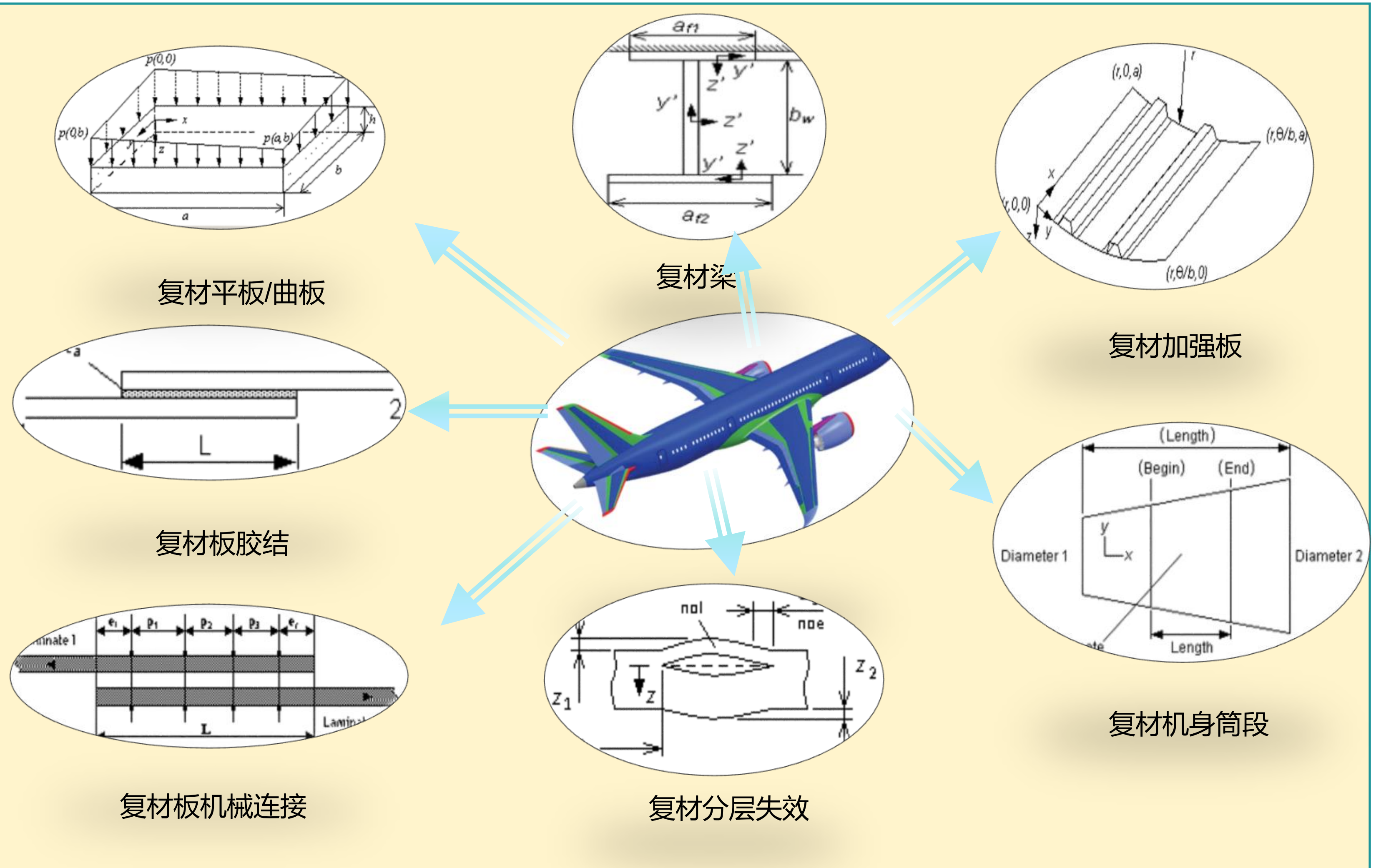
Altair复合材料工作流程



典型结构单元校核-ESAComp

ESAComp

- 复合材料梁，板，粘胶/机械连接的设计与校核
- 线性分析，非线性分析，屈曲分析，首层失效/末层失效分析
- 内嵌基于概率分析的层合板设计



HyperMesh融合ESAComp

Integrated Composite Stress Toolbox

材料级

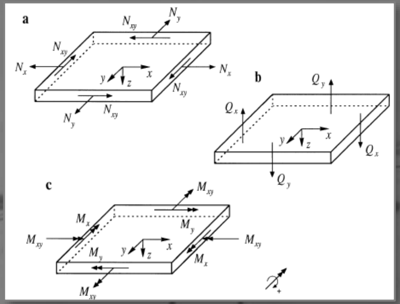
铺层级

层合板级

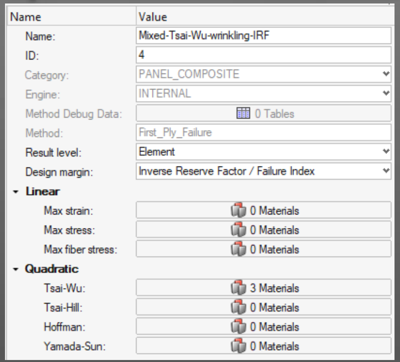
铺层区域

分析

板载荷



首层失效准则



Name	Value
Name:	Mixed-Tsai-Wu-wrinkling-IRF
ID:	4
Category:	PANEL_COMPOSITE
Engine:	INTERNAL
Method Debug Data:	0 Tables
Method:	First_Ply_Failure
Result level:	Element
Design margin:	Inverse Reserve Factor / Failure Index
Linear	
Max strain:	0 Materials
Max stress:	0 Materials
Max fiber stress:	0 Materials
Quadratic	
Tsai-Wu:	3 Materials
Tsai-Hill:	0 Materials
Hoffman:	0 Materials
Yamada-Sun:	0 Materials

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HyperMesh融合ESAComp

Integrated Composite Stress Toolbox

分析

Classical Laminate Theory (CLT)
First-Order Shear Deformation Theory(FSDT)
First Ply Failure (FPF) criteria

工程常数

载荷响应/ 失效

强度校核

HyperMesh融合ESAComp

Integrated Composite Stress Toolbox

分析

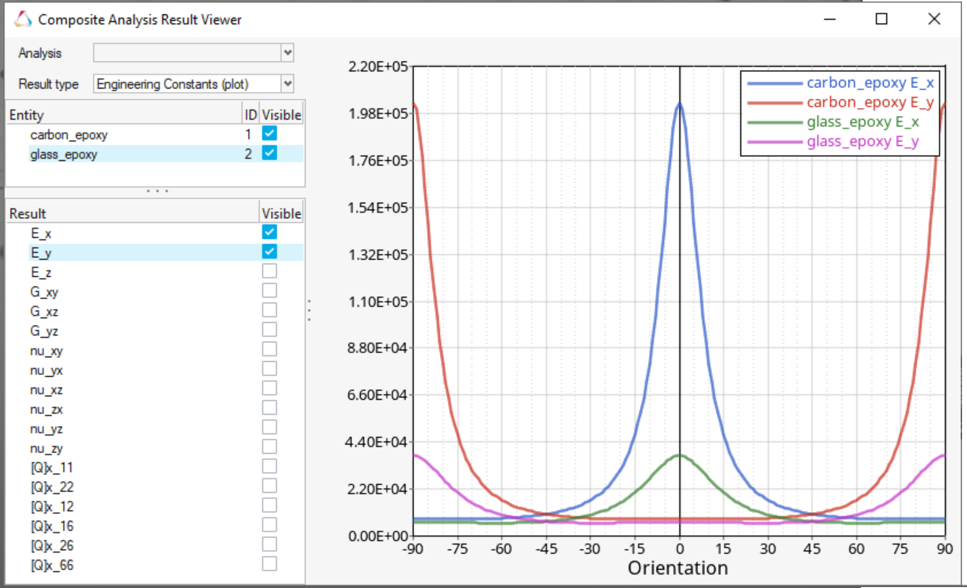
工程常数

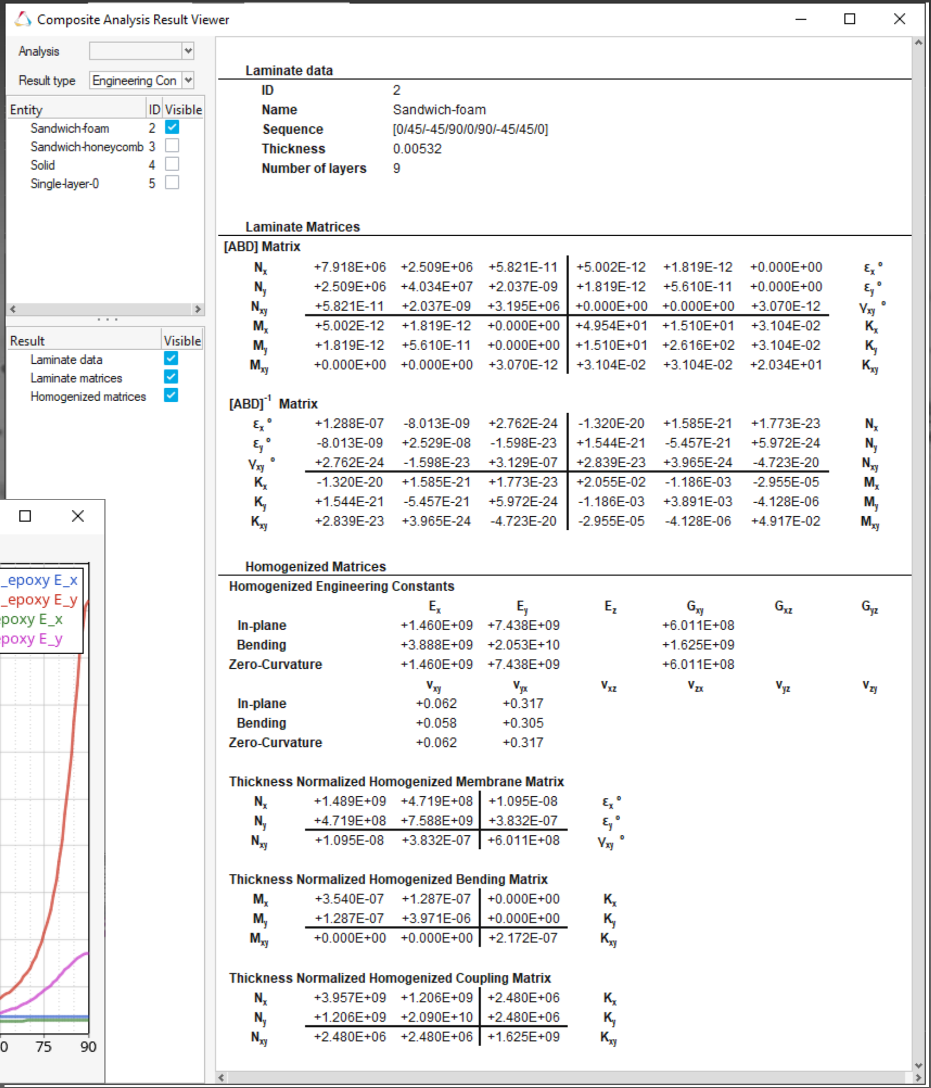
材料级

铺层级

层合板级

铺层区域





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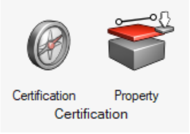
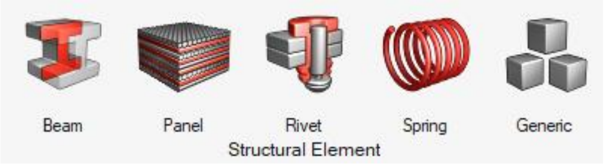
端到端的工作流程

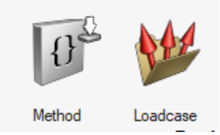
探测工具



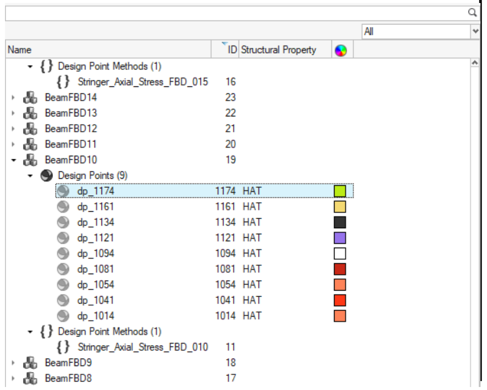


- 选择评估区域
- 探测结构单元
- 以set方式组织结构单元
- 赋予结构单元属性

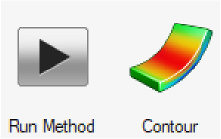
方法及工况管理



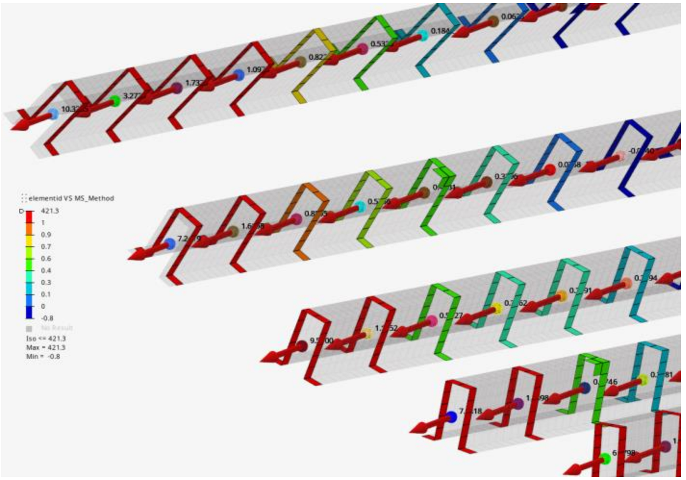
- 创建评估方法
  - 材料许用值
  - 几何模型参数
- 集成半解析评估公式
  - 集成EsaComp first_ply_failures准则
  - Python
  - OML
  - TCL
- 选择评估工况
- 提取载荷



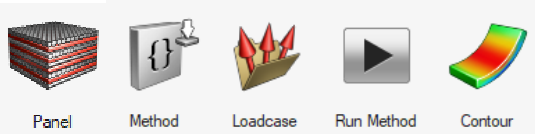
评估及结果可视化

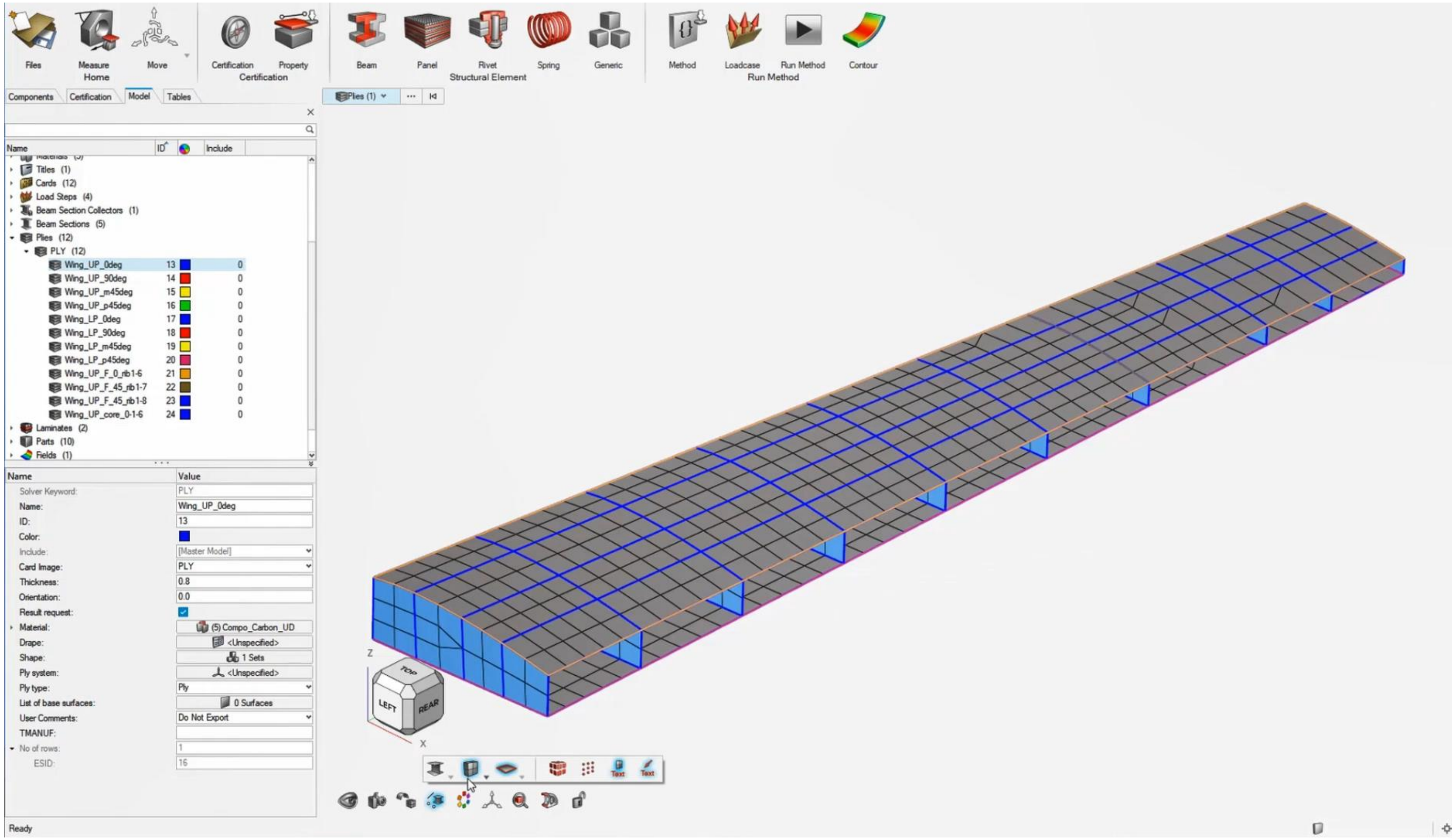


- 评估计算
- 找到临界安全裕度
- 结果显示及解读



复合材料蒙皮校核





- 检测复材板
- 创建First Ply Failures方法
- 激活多种失效准则
- 检查材料许用值
  - 从Metadata中读取
  - 面外许用值
- 显示安全系数
- 标记最危险工况

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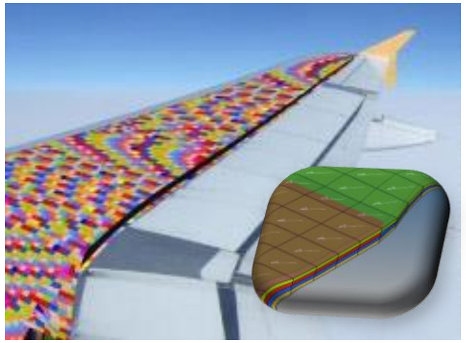
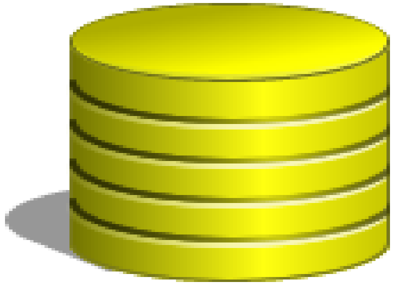
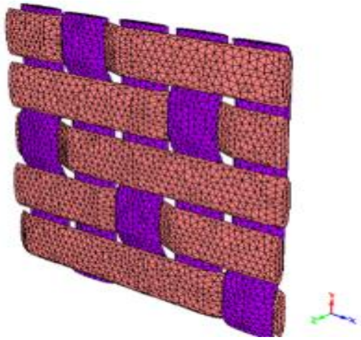
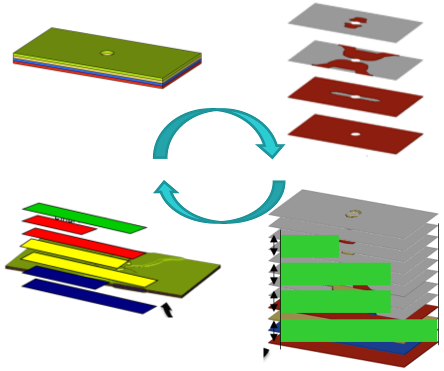
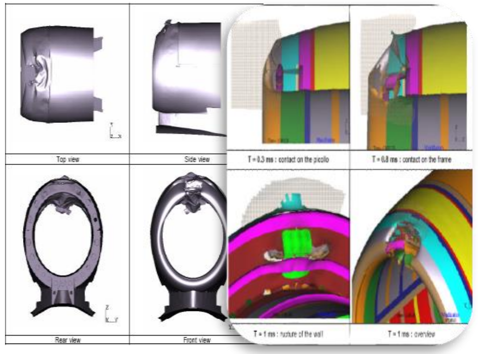
小结

Altair 提供完整的复合材料一站式解决方案

- 从微观材料到宏观材料
- 从工艺仿真到结构仿真
- 从优化设计到强度校核
- 全流程仿真平台

前后处理	*材料库*	*微观尺度建模*	*复合材料优化及设计*	*强度校核*
HyperMesh HyperView	*MD* *ESACOMP* *AMDC*	MD	*OptiStruct* *ESACOMP*	*OptiStruct* *ESAComp* *StressToolBox*

THANK YOU

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#ONLYFORWARD

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