图片由 Adept Airmotive 提供

基于Autodesk Moldflow的复合材料联合仿真解决方案

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Moldflow 复合材料分析最新技术

Autodesk

结晶对流动的影响

- 计算由流动和温度引起的晶核生成和相对结晶率 (α):

粘度

$$\eta(\dot{\gamma},\alpha)=\eta_a\left(1+\frac{(\alpha/A)^{\beta_1}}{(1-\alpha/A)^{\beta}}\right),\ \alpha<\mathrm{A}$$

比热

$$c_p(\alpha,T)=\alpha\,c_{p_s}(T)+(1-\alpha)c_{p_a}(T)$$

导热性

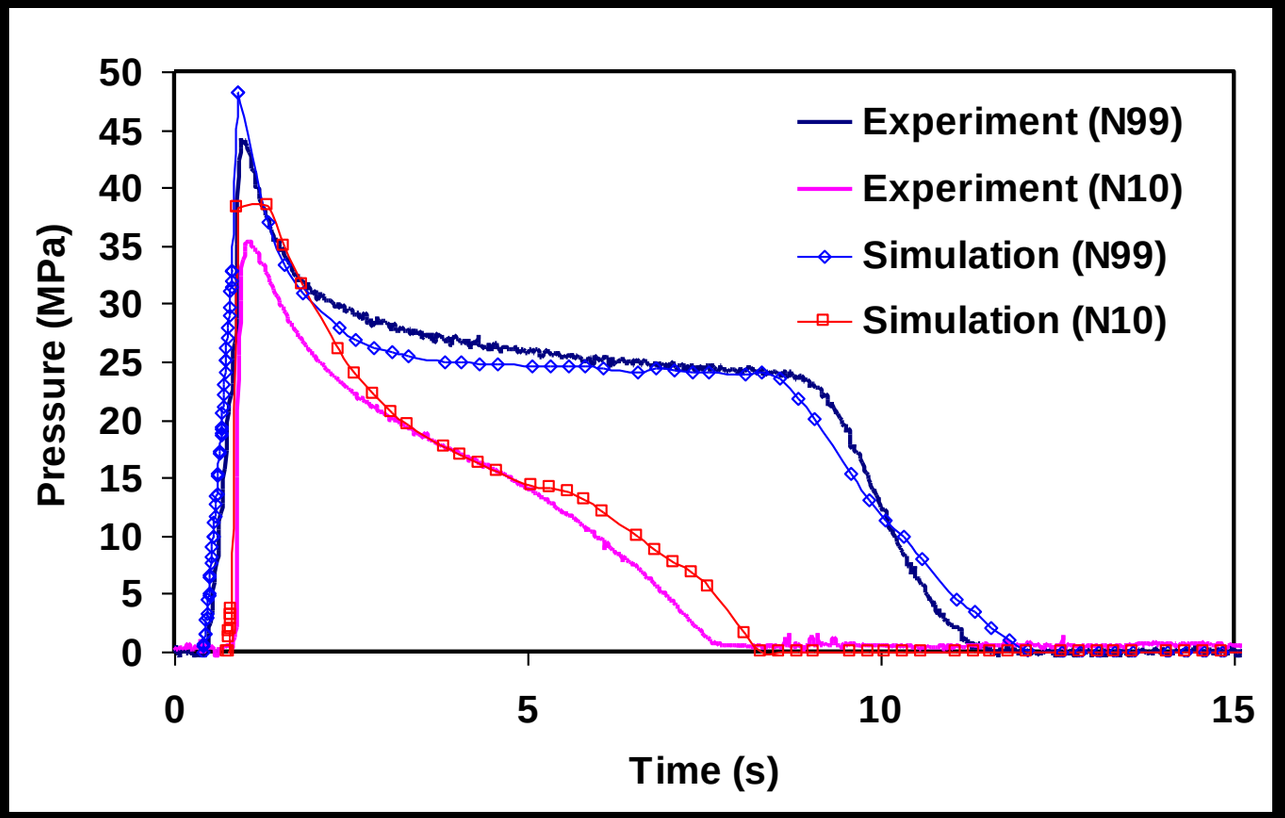
$$k(T)=\alpha\,k_s(T)+(1-\alpha)k_a(T)$$

密度

$$\nu=\alpha\nu_s(p,T)+(1-\alpha)\nu_a(p,T)$$

温度方程

$$\rho(\alpha)\,c_p(\alpha)\frac{DT}{Dt}=k(\alpha)\nabla^2T+\boldsymbol{\sigma}:\mathbf{D}+\rho_c H_c\chi_\infty\frac{\partial\alpha}{\partial t}-\frac{T}{\rho(\alpha)}\frac{\partial\rho(\alpha)}{\partial T}\frac{Dp}{Dt}$$

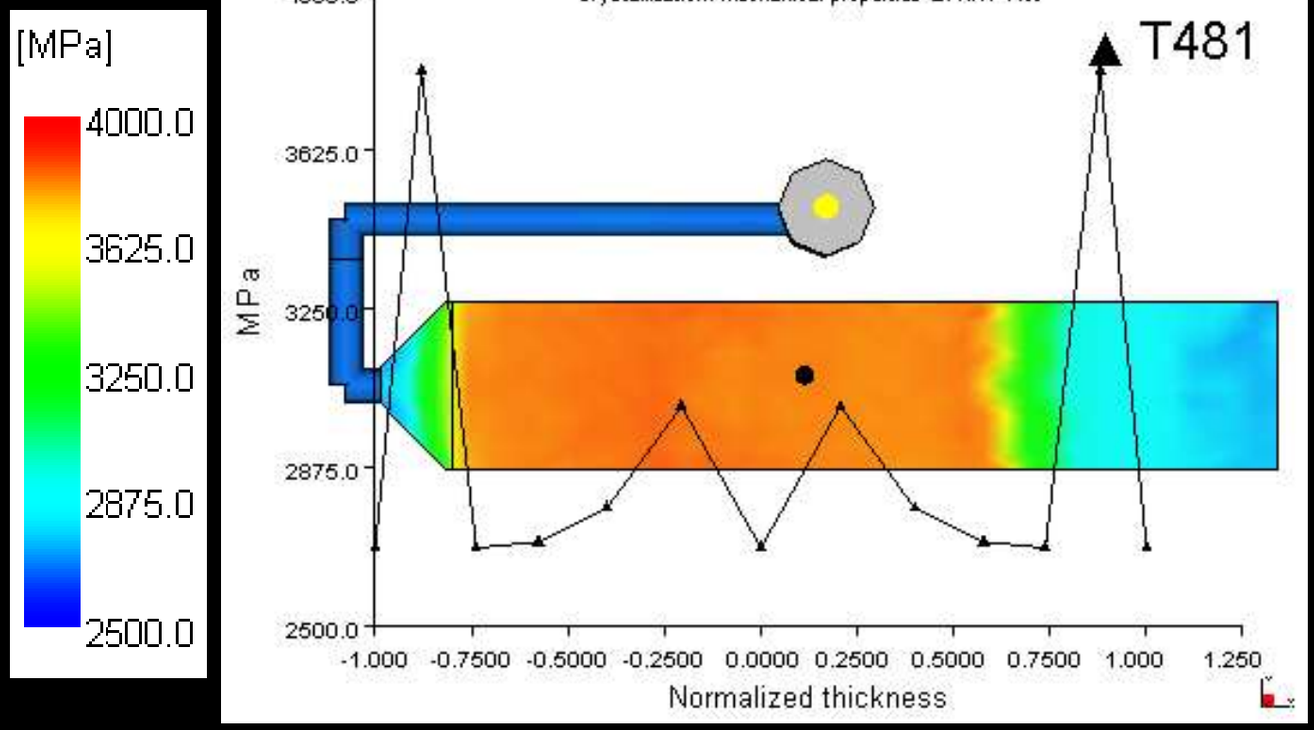


Autodesk

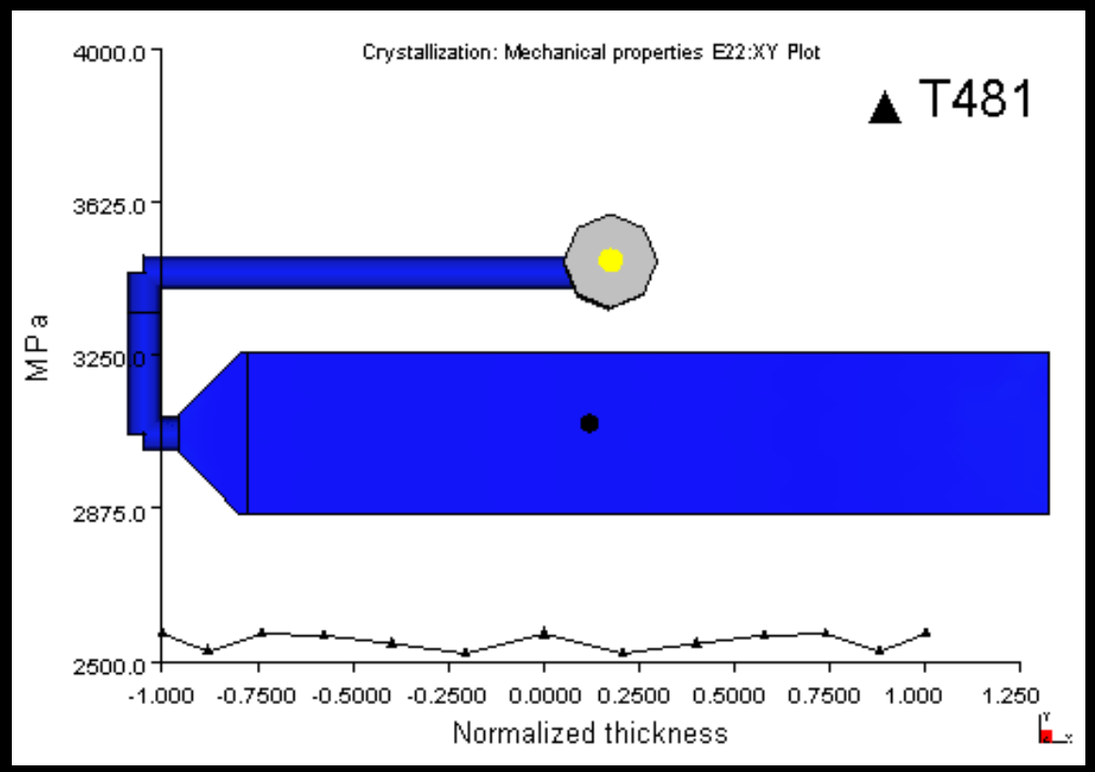
结晶导致的线性刚度模量

- 由于形态不同导致刚度的各向异性
- 未充填的PBT
  - 公称厚度= 0.88

流动方向



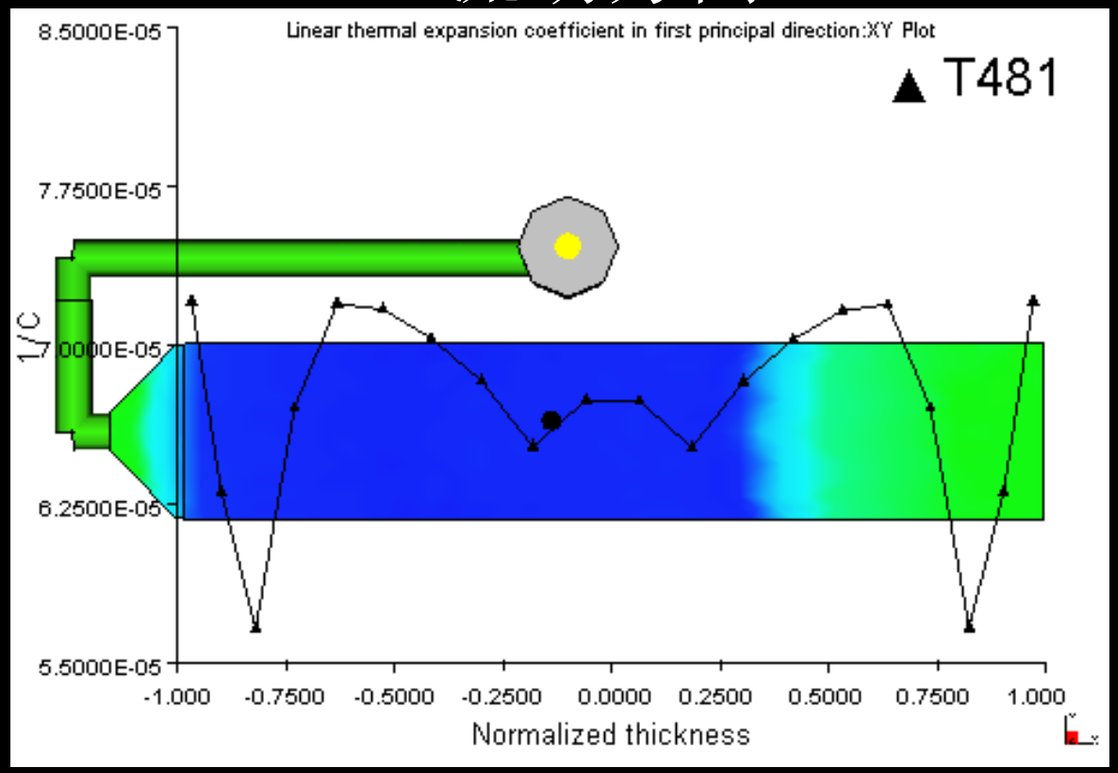
垂直流动方向



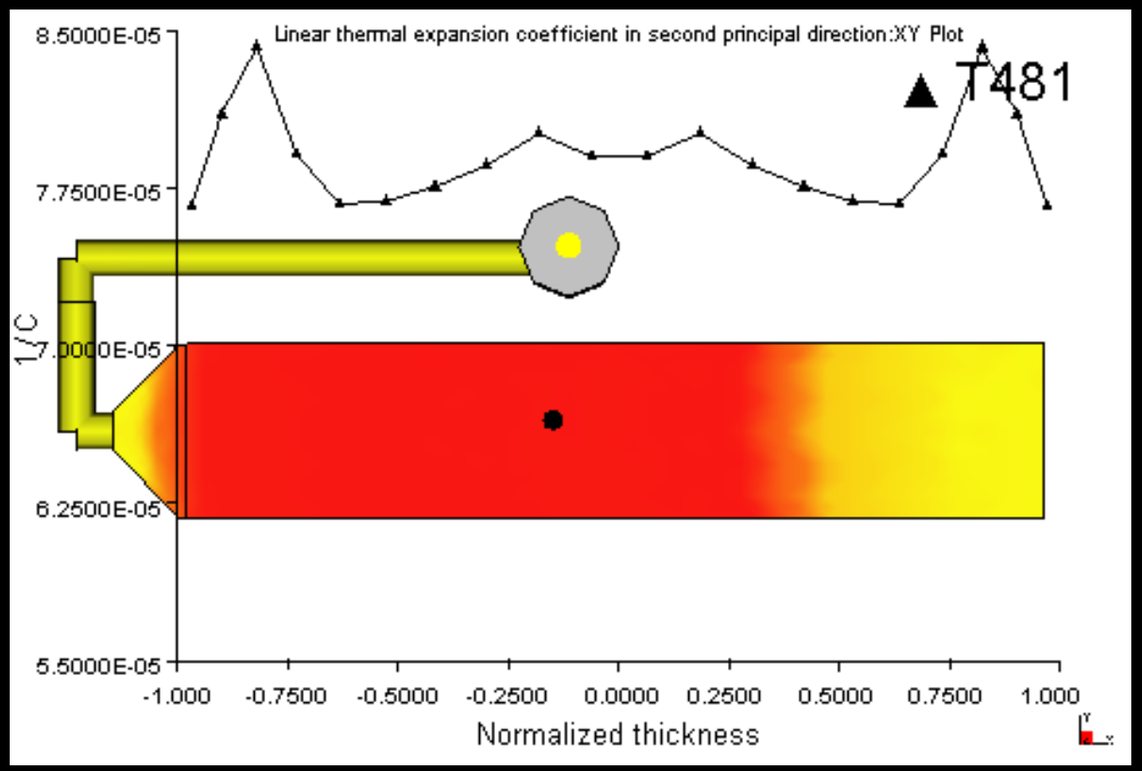
结晶导致的线性热膨胀系数

- 由于形态不同导致线性热膨胀系数的各向异性
- 未充填的PBT
  - 公称厚度= 0.82

流动方向

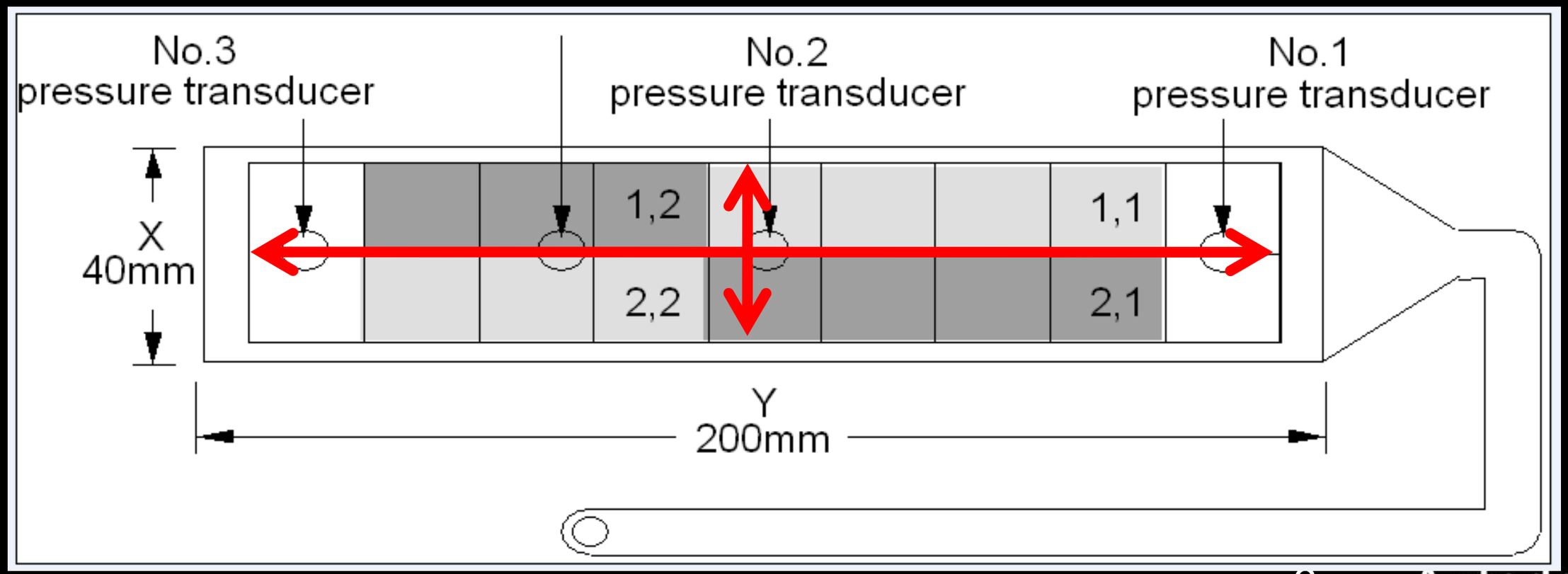


垂直流动方向



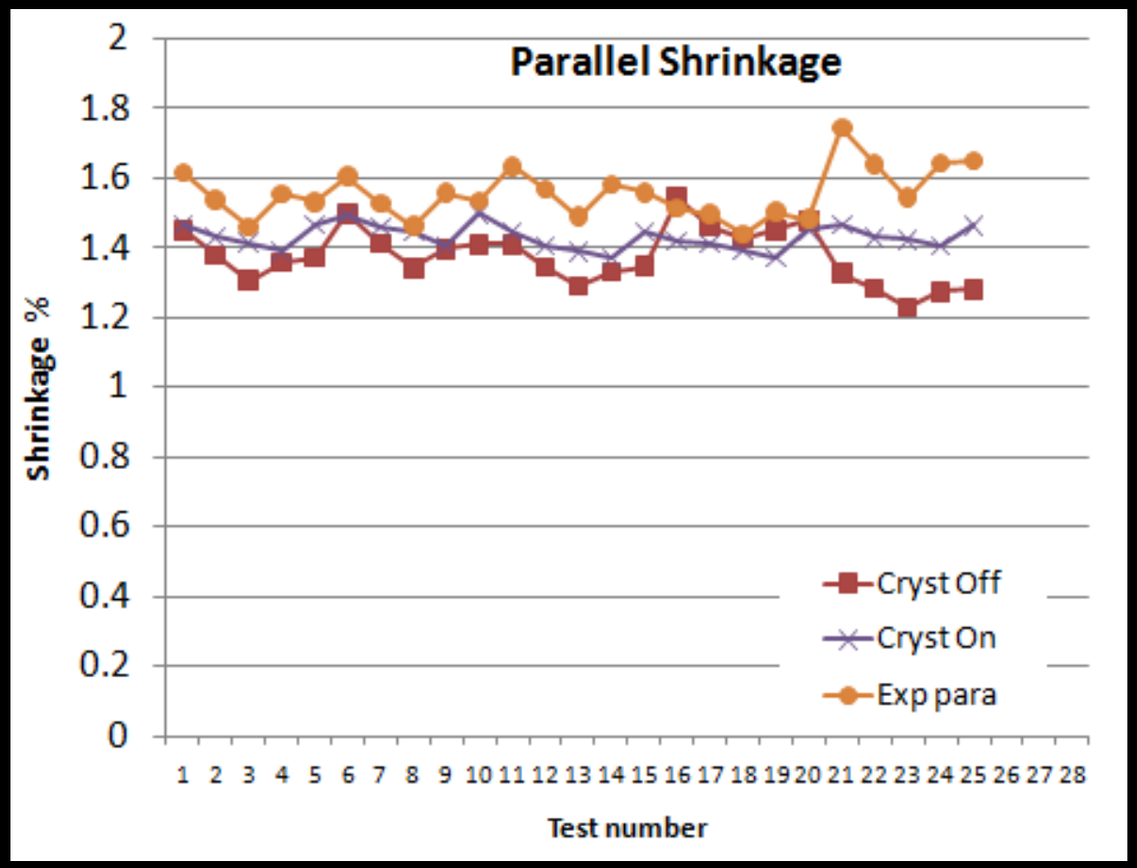
线性收缩预测的验证

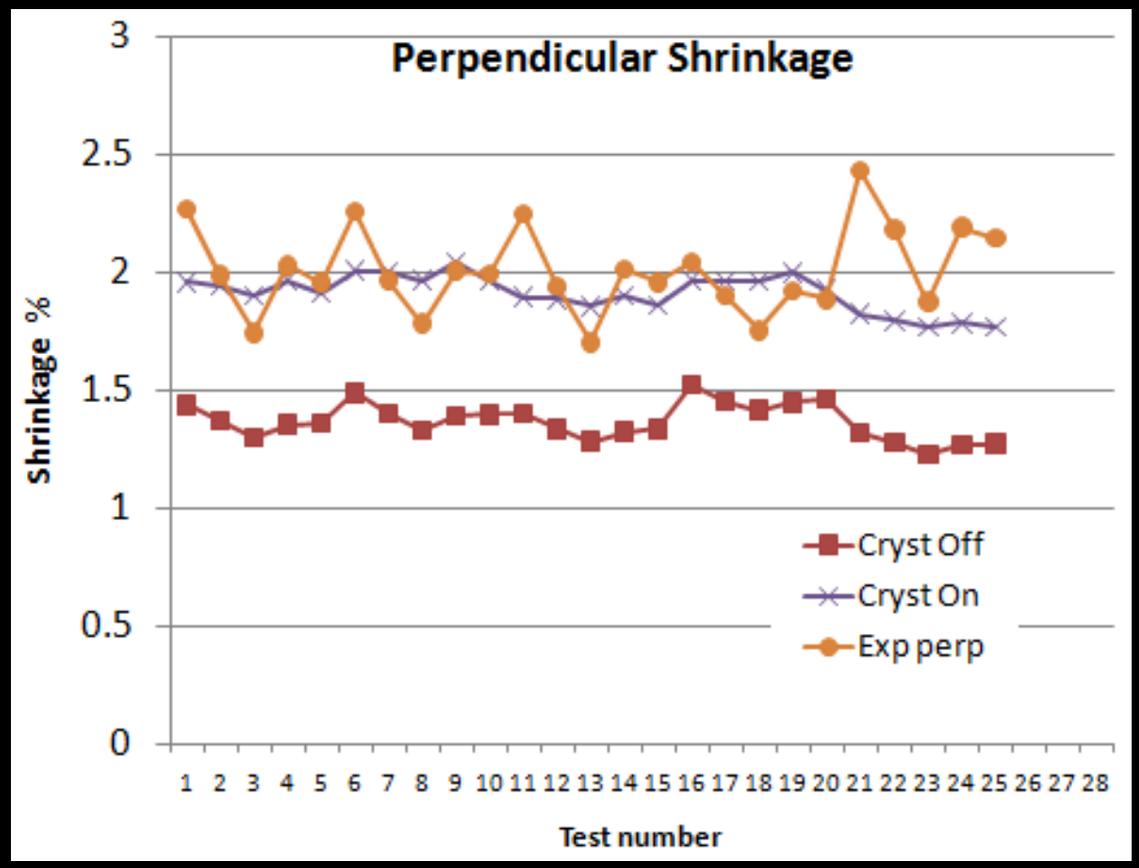
- 对长方形样件测量流动方向上的收缩量和垂直流动方向上的收缩量
  - 可以假定单向流动
  - 各种样件厚度进行测试



线性收缩预测 使用VS不使用结晶分析

- 线性收缩水平和收缩各向异性有明显改进



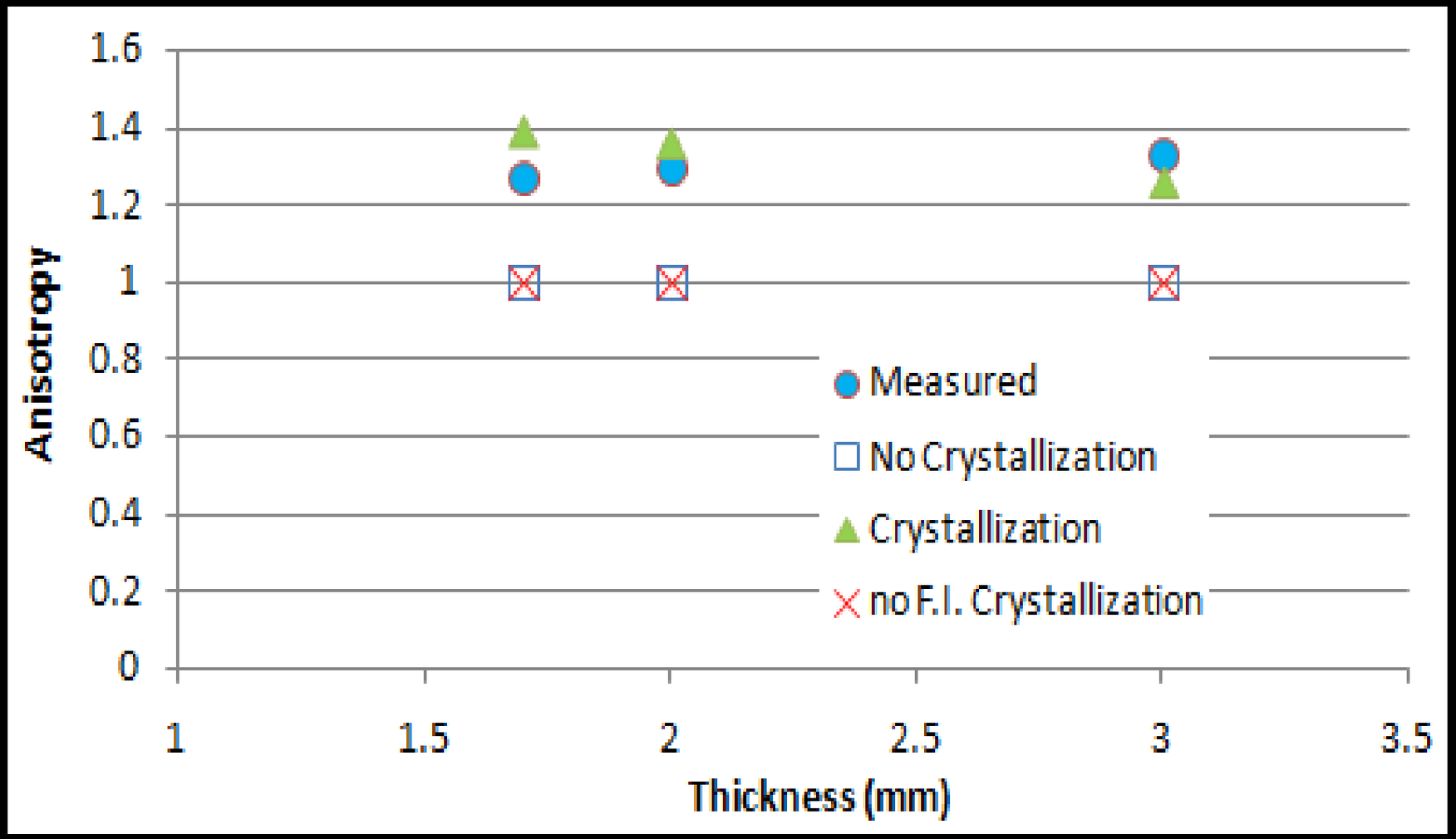


没有使用CRIMS模型

Autodesk

收缩预测-使用vs不使用 流动诱导结晶

- 各项异性率 = 垂直收缩量/ 平行收缩量



没有使用CRIMS模型

Autodesk

结晶性: 材料数据有效性

- 20 款材料数据经过测试定义
  - 10 款没有充填物
  - 10 款含玻纤
- 其它材料使用常规参数，由这20款材料数据转换得到
  - 可能不准确
- 结晶材料特性可以从欧特克Moldflow材料实验室获得

长玻纤断裂分析

- 长玻纤的优质特性
- 自由的CAR工程
- 长玻纤-热塑性塑料(LFT)由ACC提出
- 一些长纤维材料的主要供应商
- Ticona , SABIC, RTP, DOW, DuPont

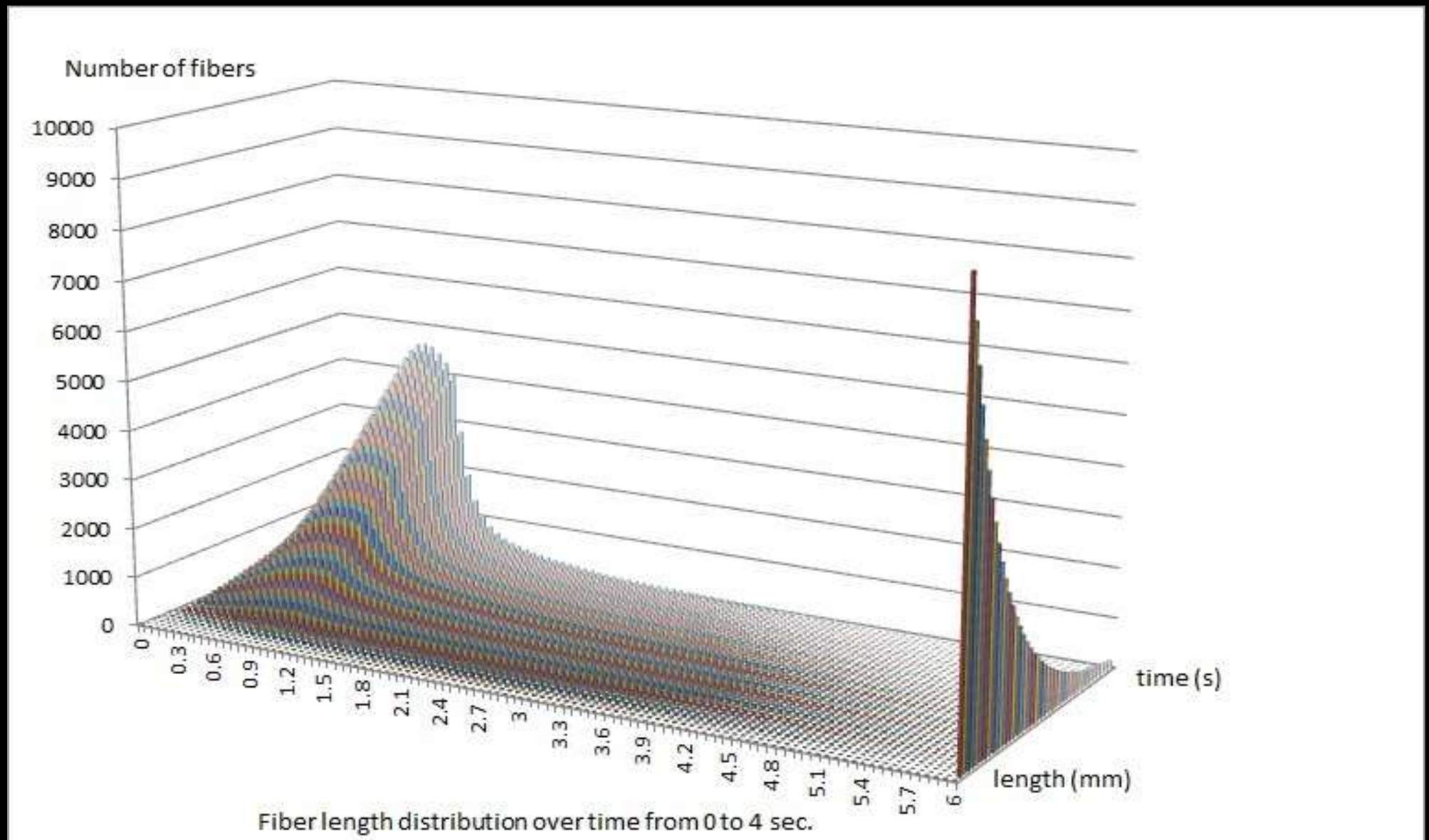




热塑性塑料长玻纤断裂分析应用在 Moldflow 2013

- 考虑到长玻纤在流道和型腔中的断裂
- 预测长玻纤的分布

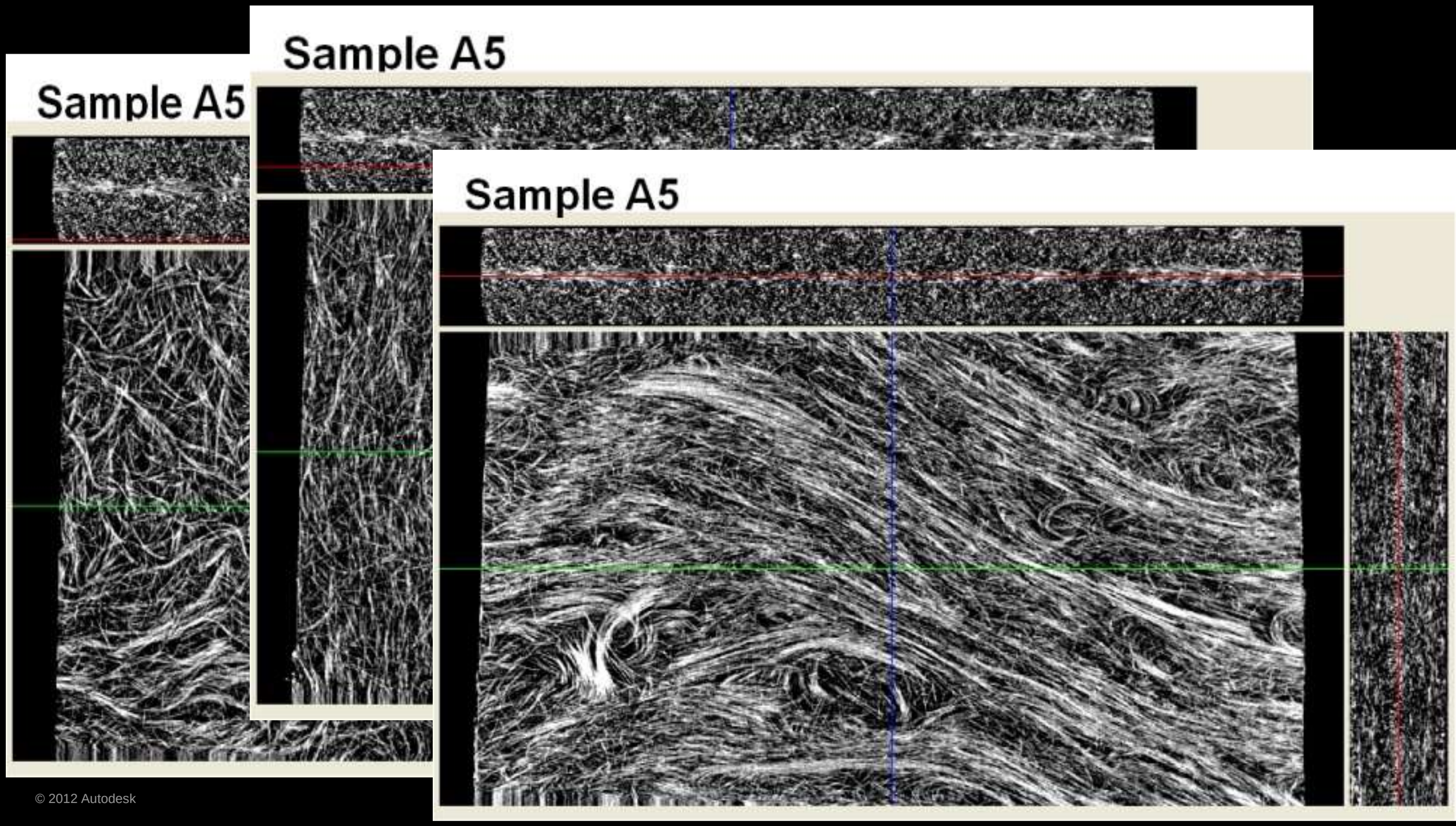
长玻纤随时间的分布



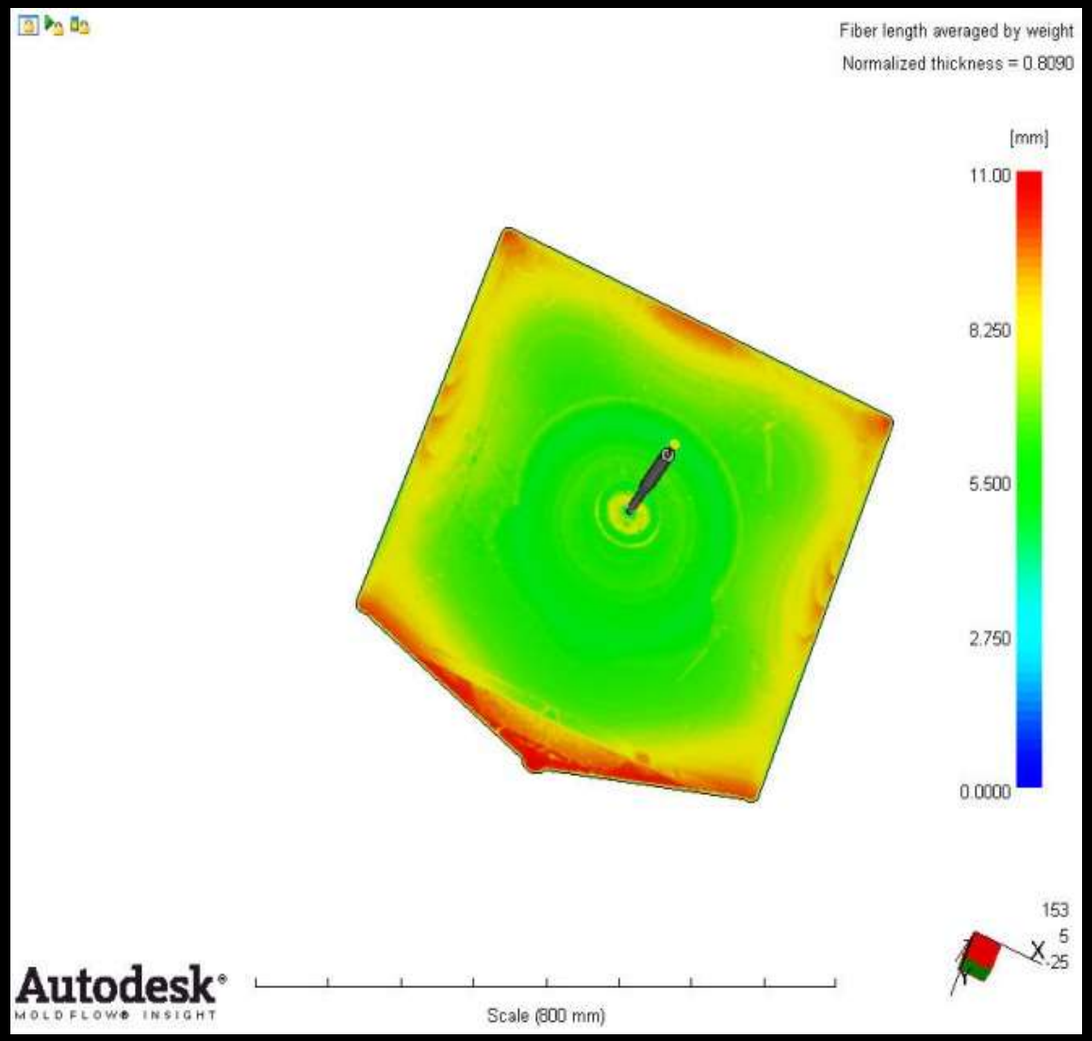
Fiber length distribution over time from 0 to 4 sec.

Courtesy to Ticona

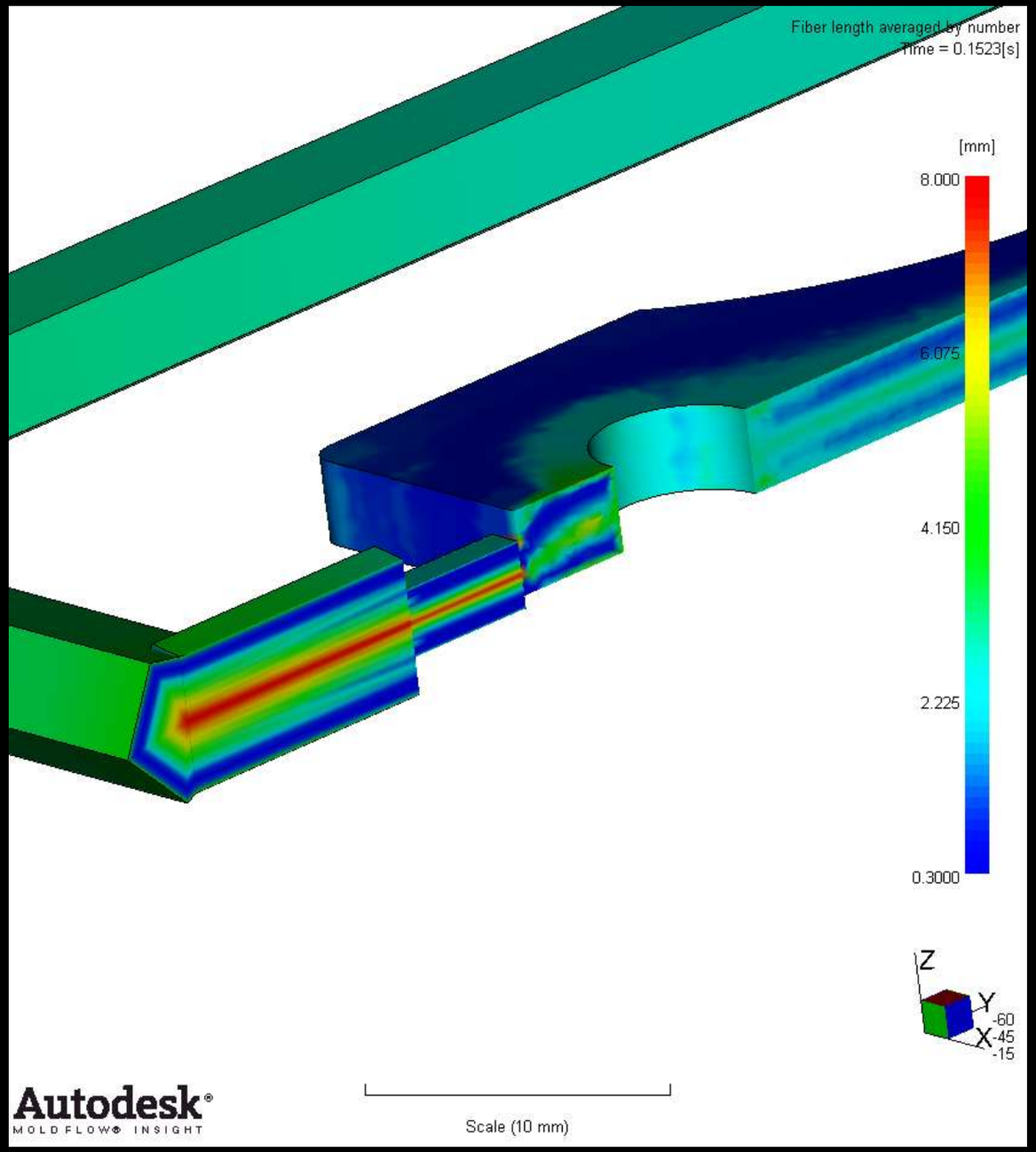
长玻纤的空间分布



长玻纤分布预测



Ticona薄片采用中性面网格

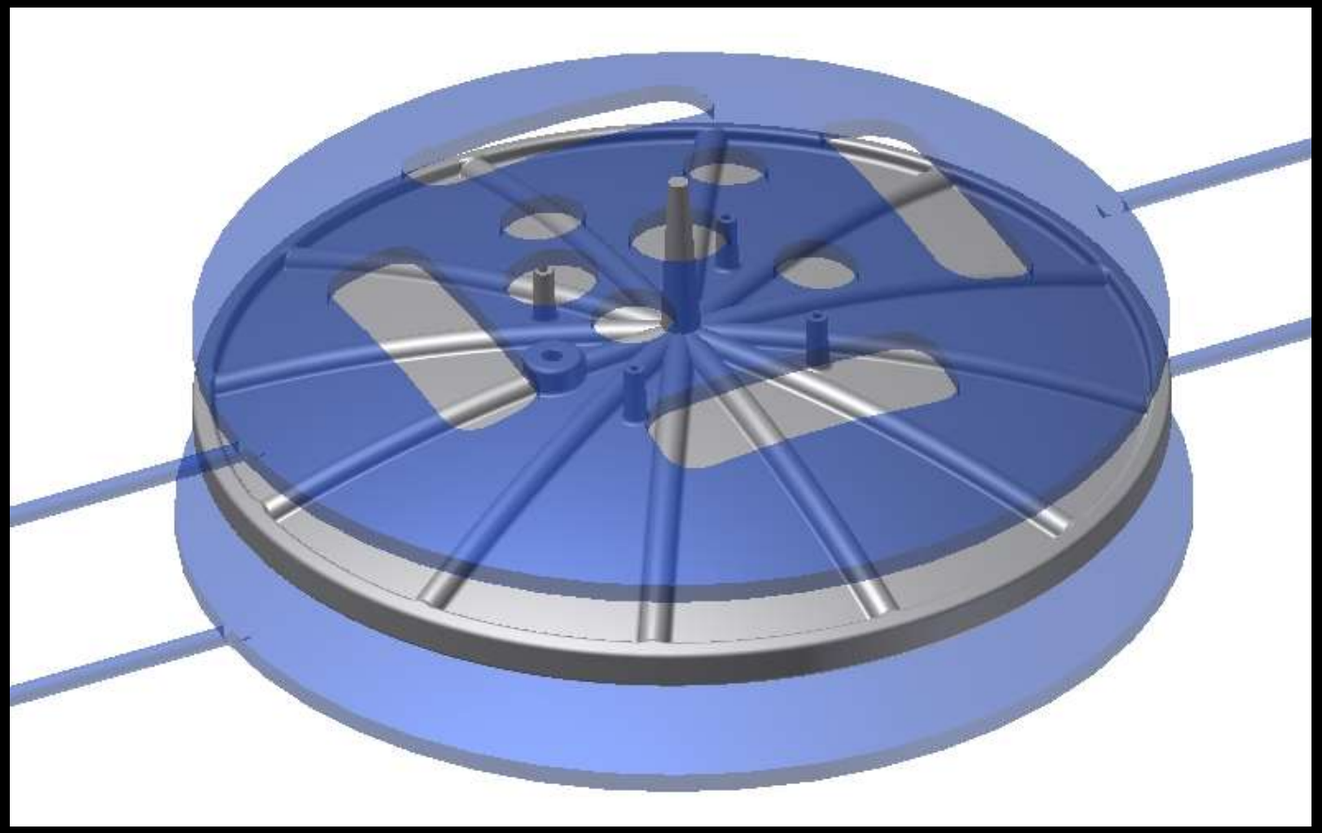


柱体单元到四面体单元的连接

Autodesk

模拟异型冷却水路

- 复杂的三维冷却水路
- 温度控制遵循产品形状
- 柱体单元不适用于分析



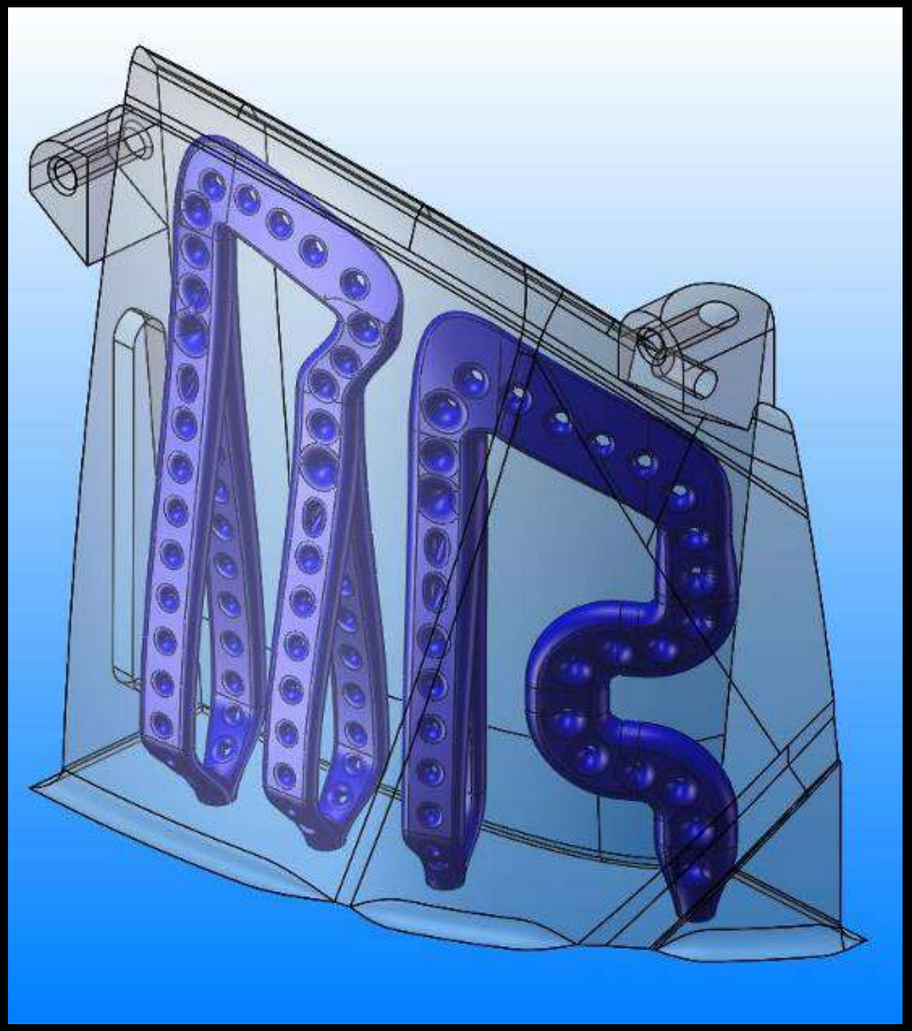
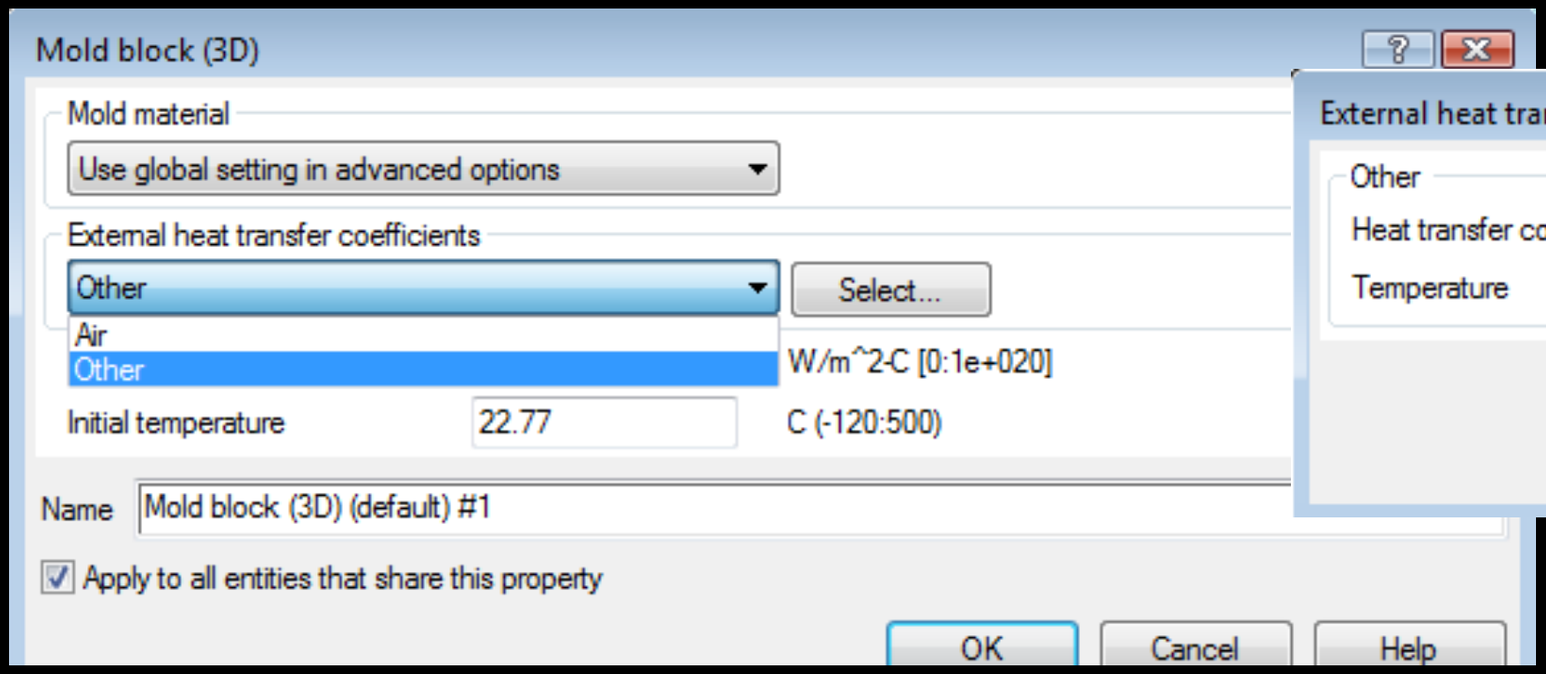
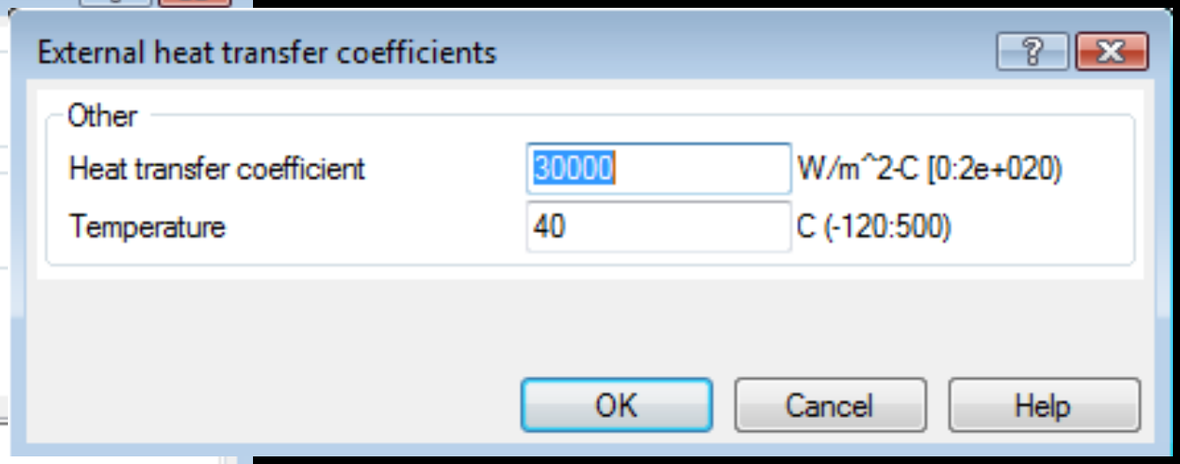


Image from Pôle Européen de Plasturgie

通用的边界条件

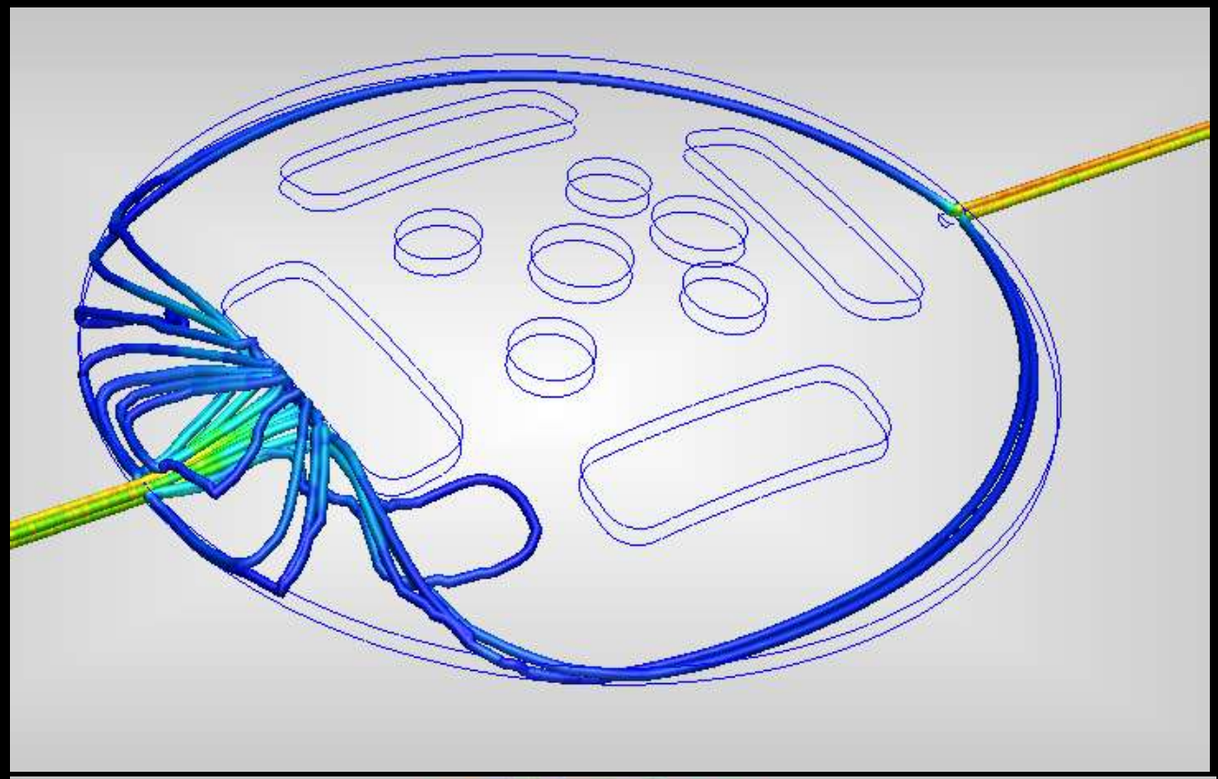
- 模具四面体单元的外部将面向：
- 默认的边界条件是导热至空气
  - 通过选择“其他”选项，任何其他接触条件都可被设定
  - 可用于模拟复杂的三维冷却水路

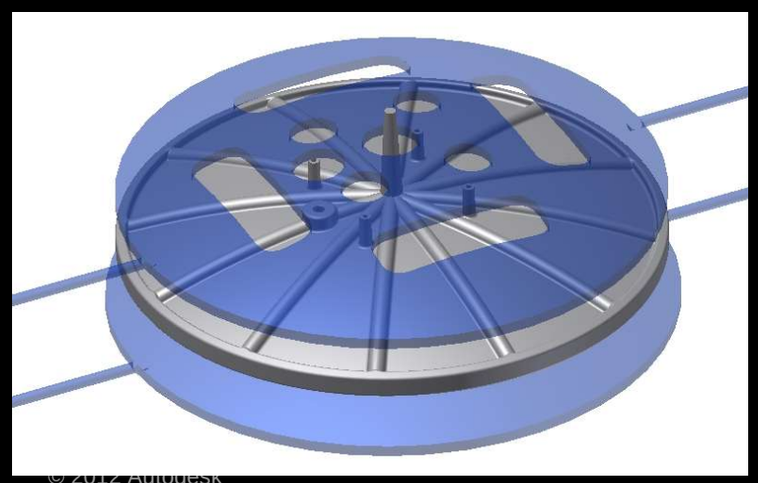


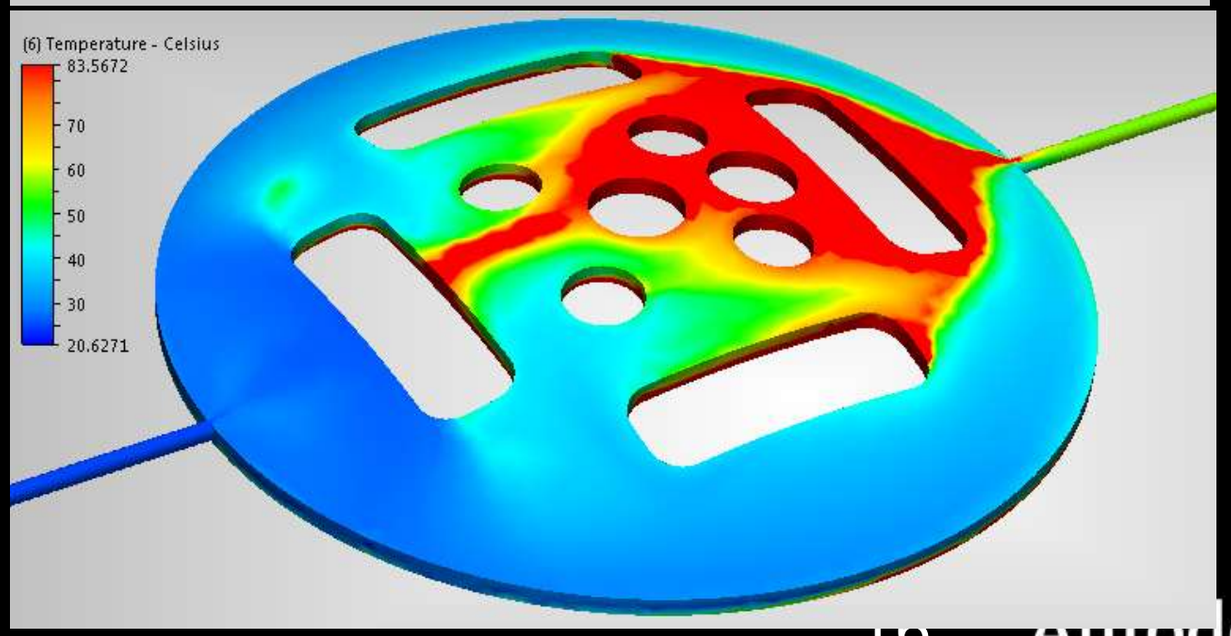


使用 Autodesk Simulation CFD

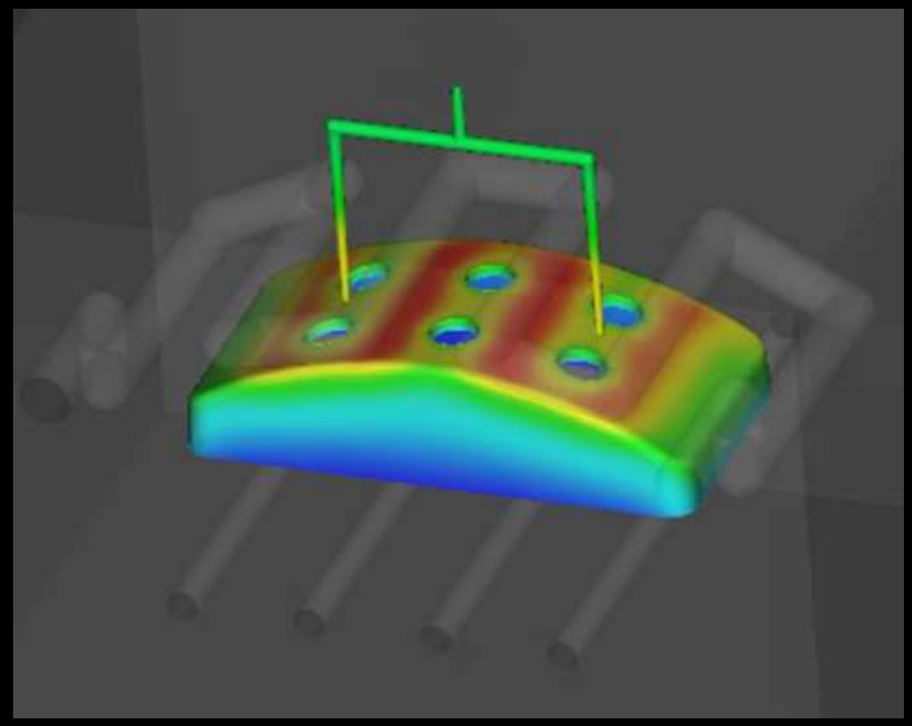
- 强大的在3D冷却水路中冷却剂流动的流体力学模拟计算
  - 确定死角
  - 排除热点
- 与Moldflow Insight瞬态冷却集成





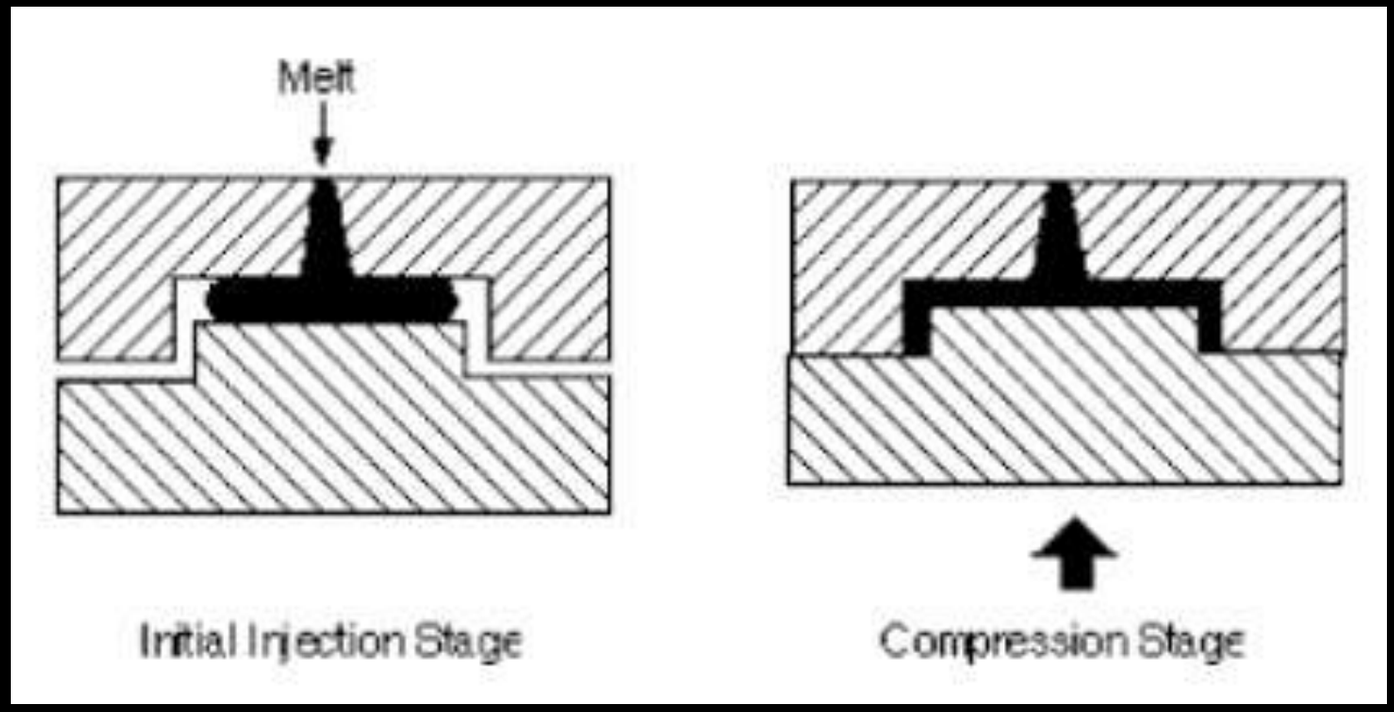


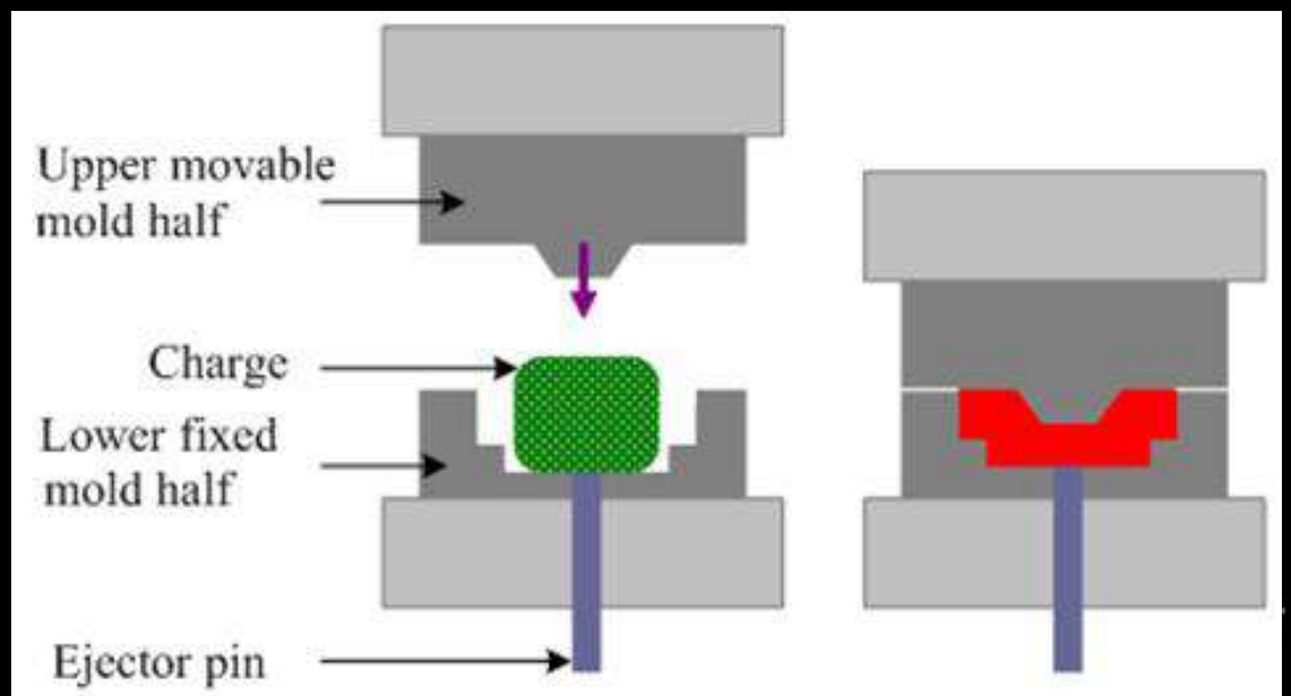
- **Autodesk Simulation Moldflow Insight 2013**
  - 模具热分析 – 冷却 (FEM)
  - 计算速度
  - 结晶
  - 长玻纤断裂分析
  - 其他改进
- 技术预览
  - 粘弹性
  - 皮层滑移
  - 随形冷却
  - 注压成型& 3D压缩成型
  - 3D 网格边界层
  - 3D 屈曲分析
  - 双组分注射
  - Autodesk Simulation的集成仿真



3D 注压成型分析

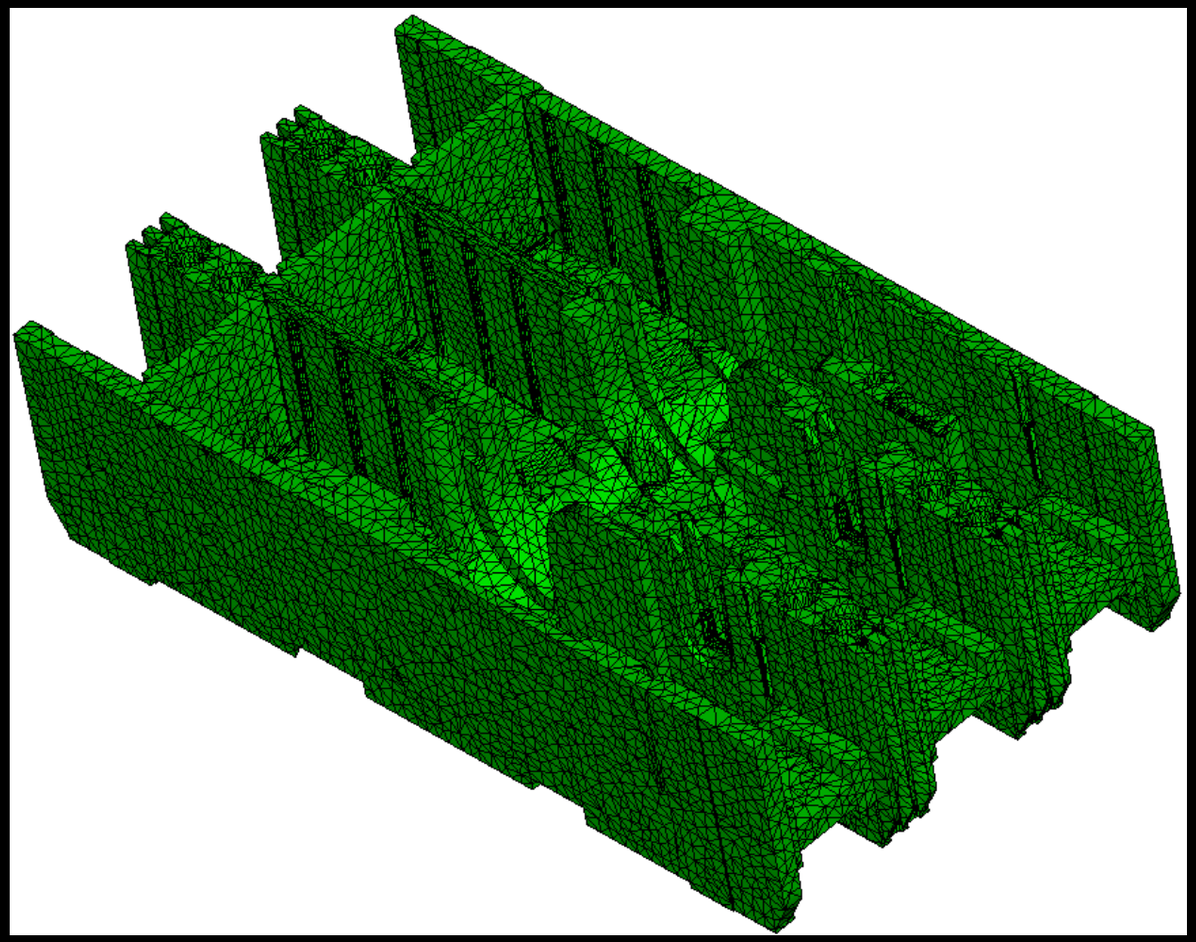
- 基于3D网格的分析:
  - 注射-压缩成型
    - 型腔通过注射的方式部分充填
  - 压缩成型
    - 料胚放置到打开的型腔中
- 适用于热固行或热塑性





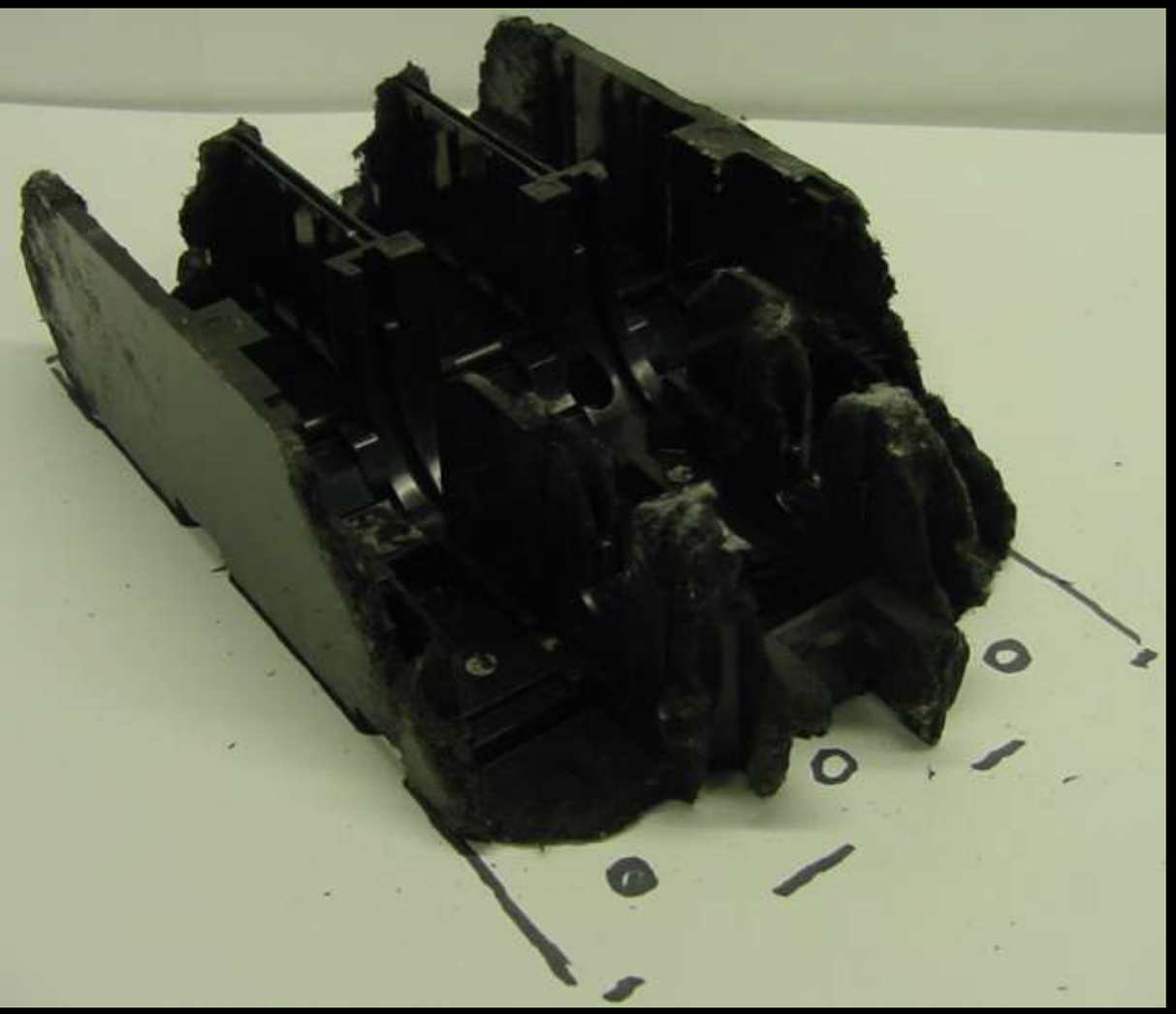
3D 注压成型

- 材料: 热固性
- 工艺条件：
  - 压缩前的开模距离: 15 mm
- 产品大致尺寸：200 x 145 x 50 mm
- 产品公称壁厚：~ 6 mm
- 压缩完成后，包括窗口区域的壁厚将变成0.25 mm

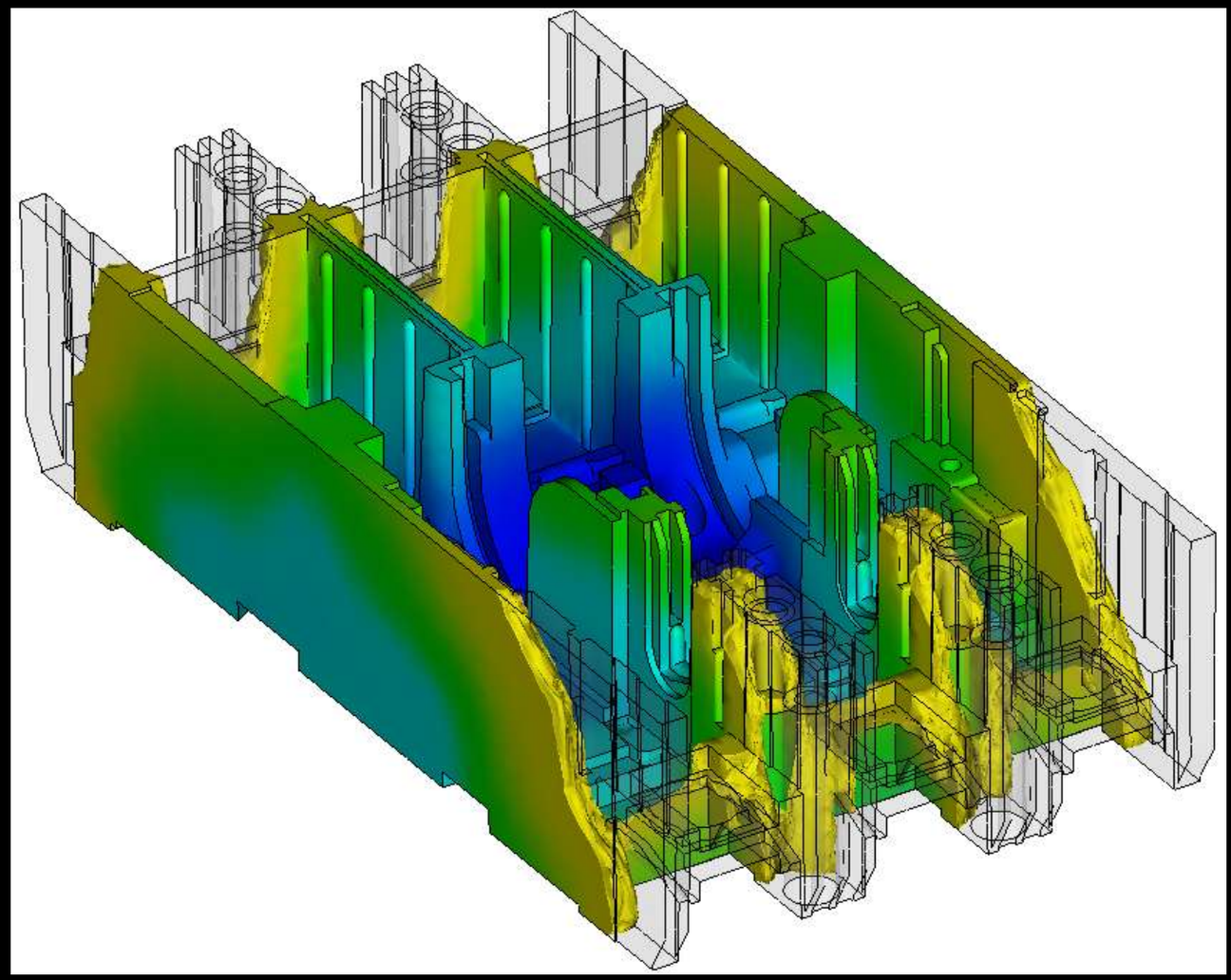


案例由施耐德电气提供

3D 注压成型充填样式对比



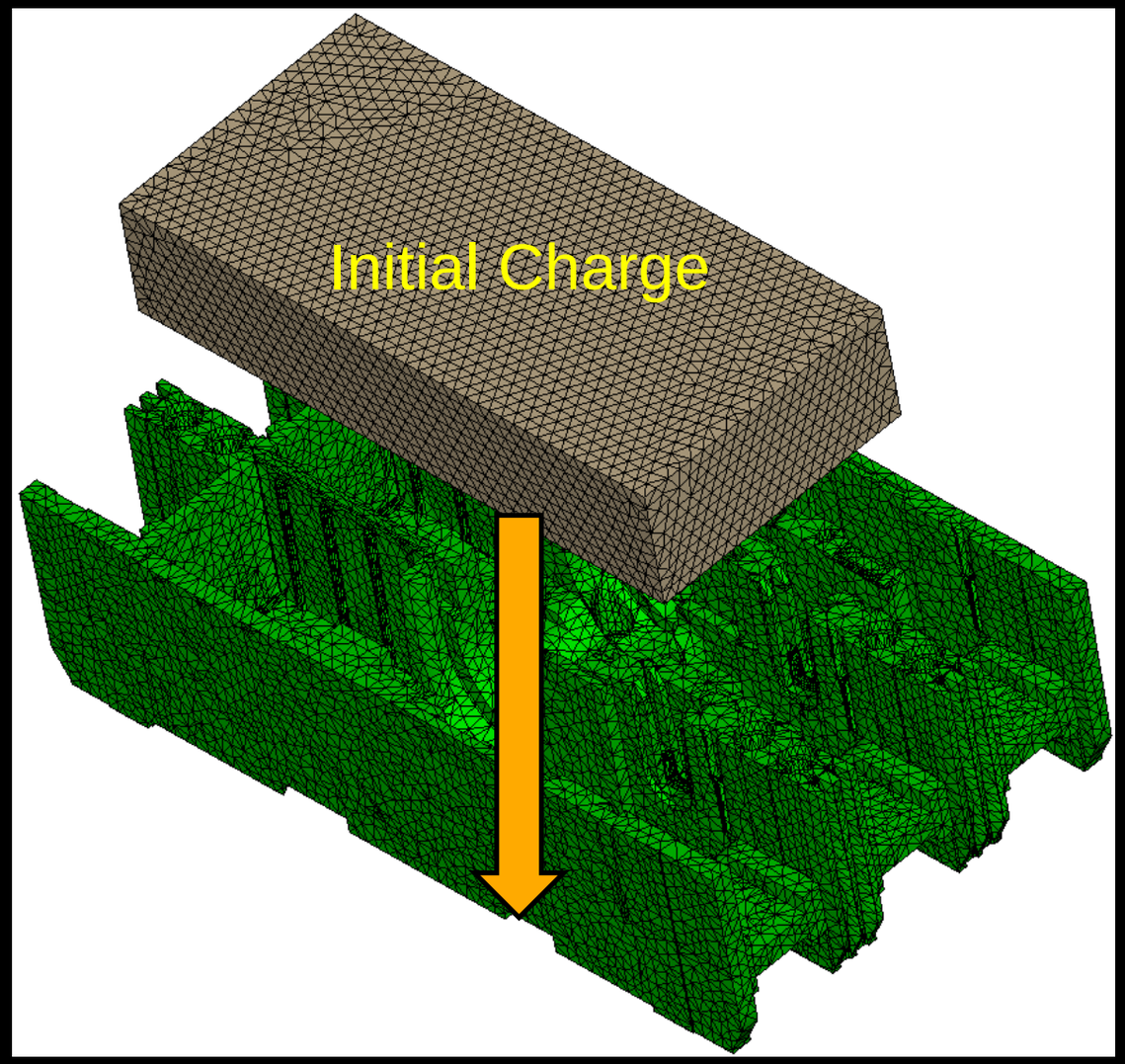
Experiment



Simulation

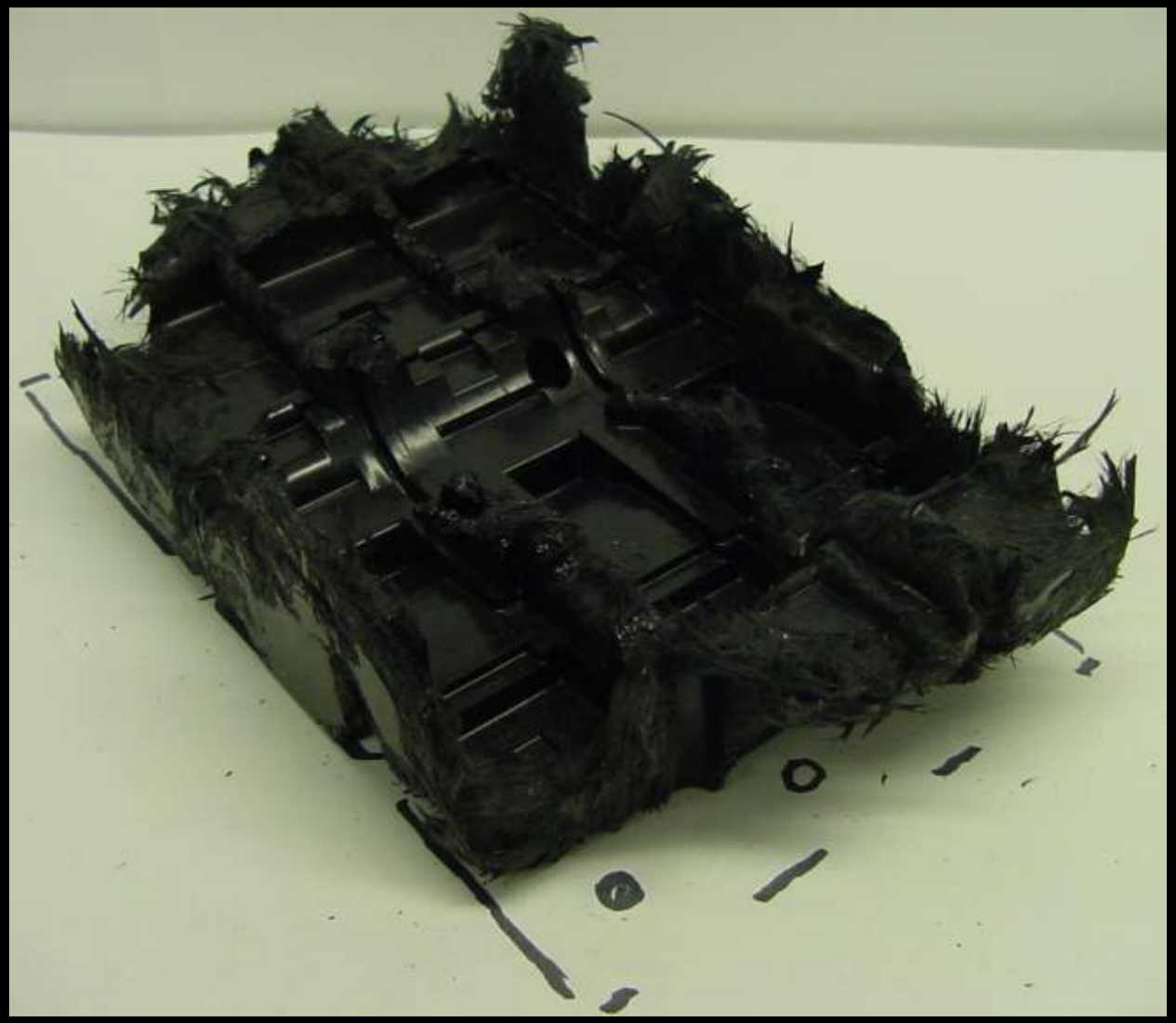
3D 压缩成型

- 纯粹的压缩成型
- 材料: 热固性
- 工艺条件:
  - 压缩前的开模距离: ~ 50 mm
- 胚料: 矩形料胚，尺寸约: 155 x 71 x 31 mm)

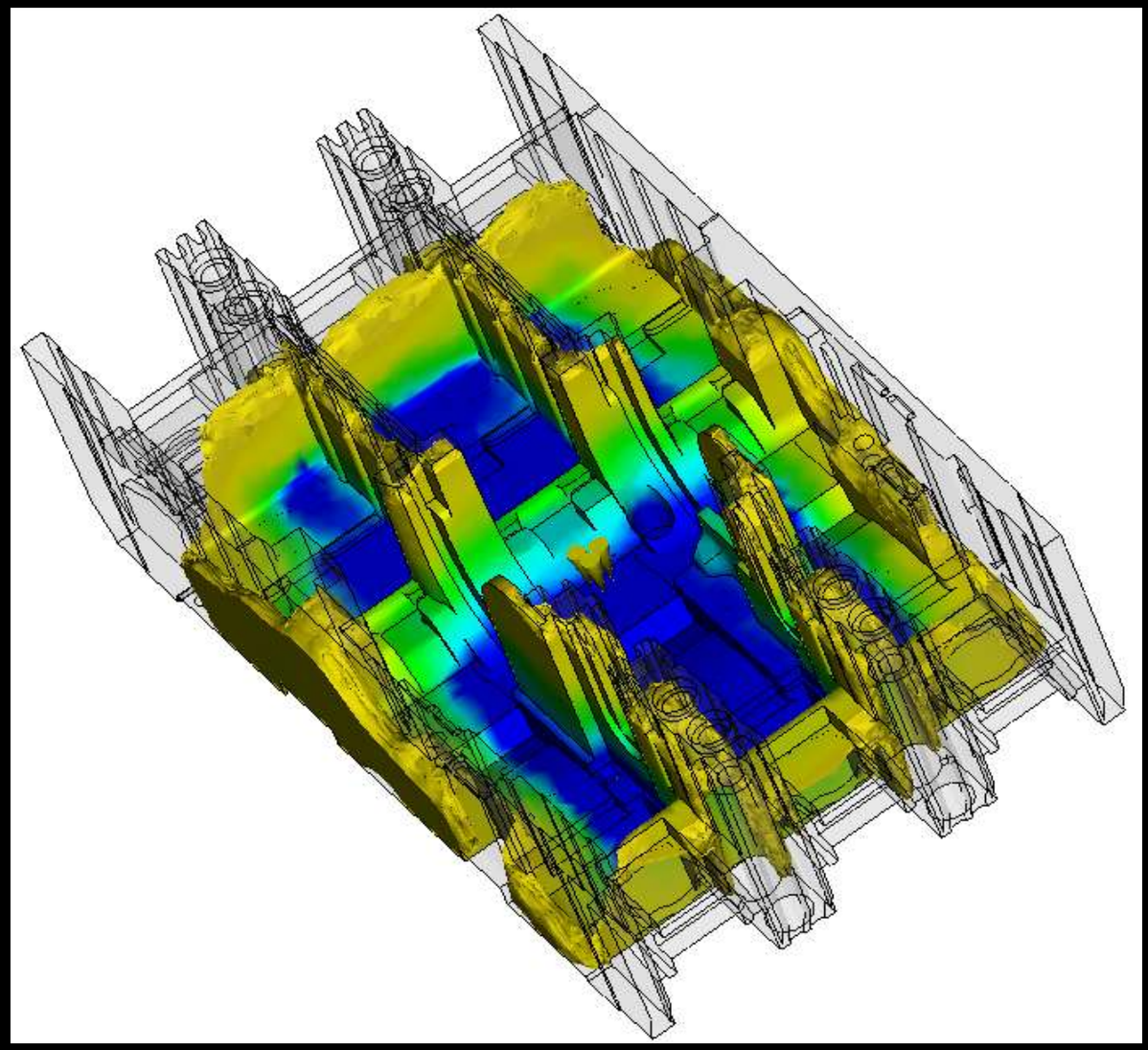


案例由施耐德电气提供

3D 压缩成型充填模式对比



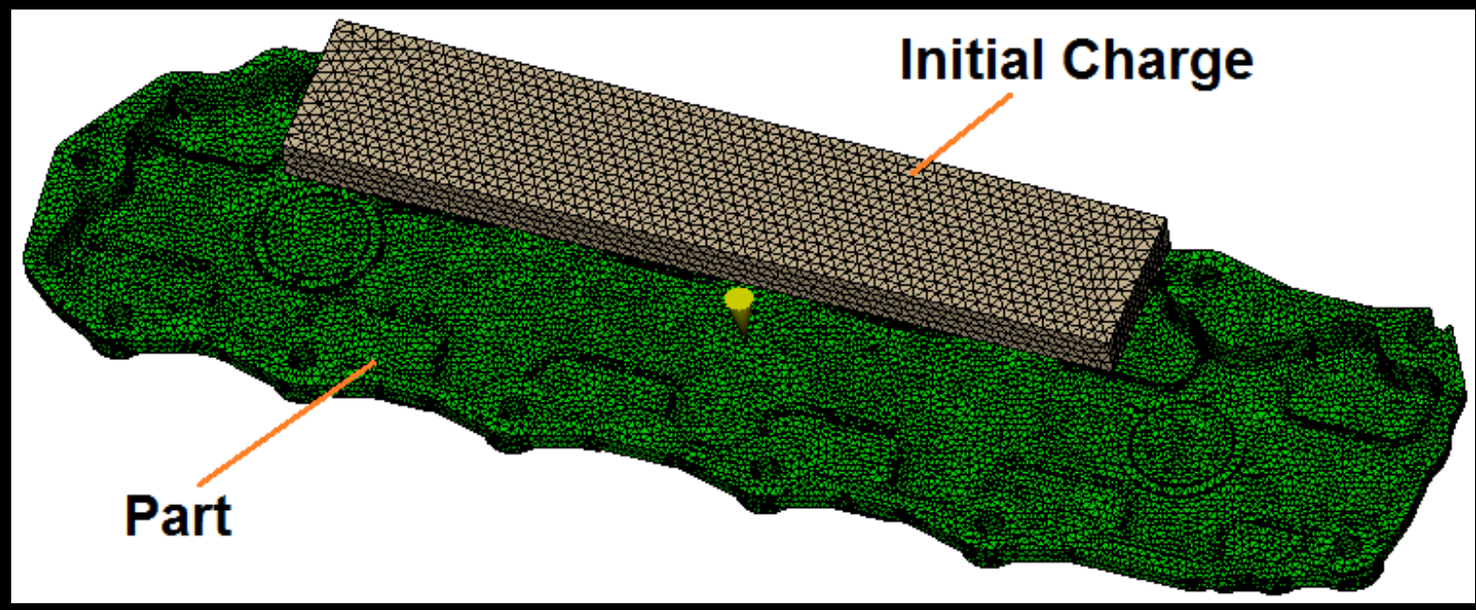
Experiment



Simulation

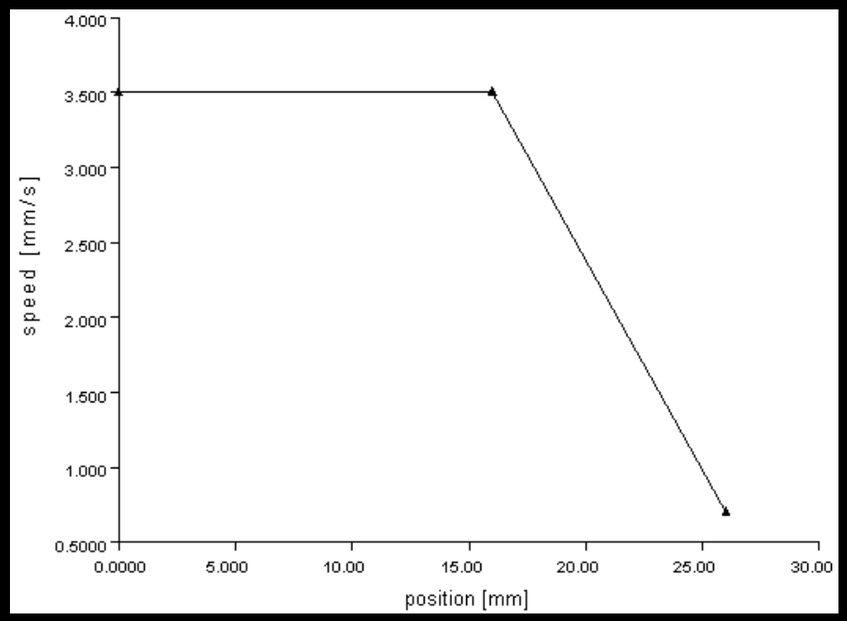
压缩案例2

- 压缩成型 (由美国Premix公司提供)
- 长度: 800 mm
- 宽度: 200 mm
- 公称壁厚: 4 mm

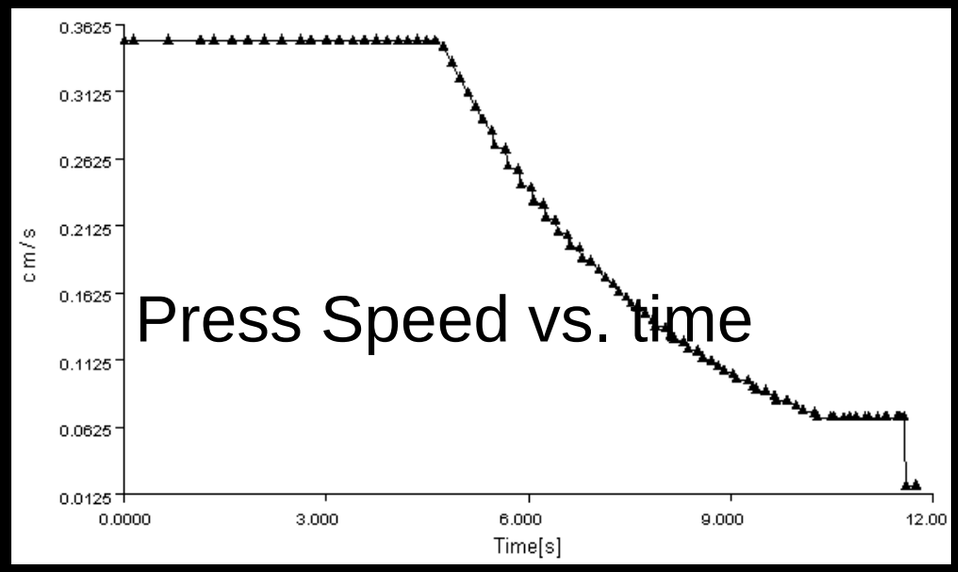


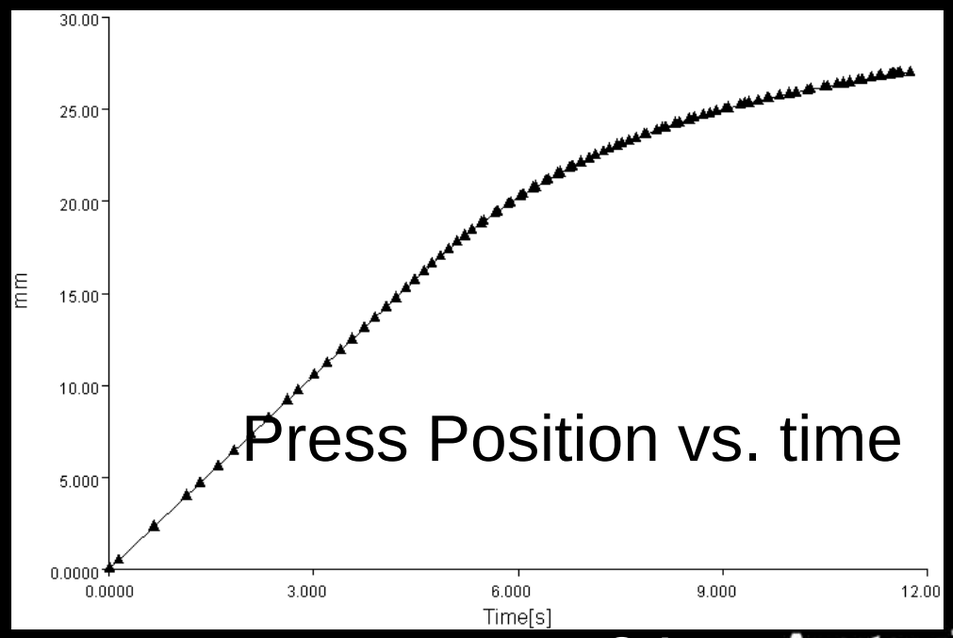
压缩案例2

- 热固性 Sheet Molding Compound (Premi-Glas 1286: Premix)
- 34% 玻纤
- 初始玻纤长度: 12 mm

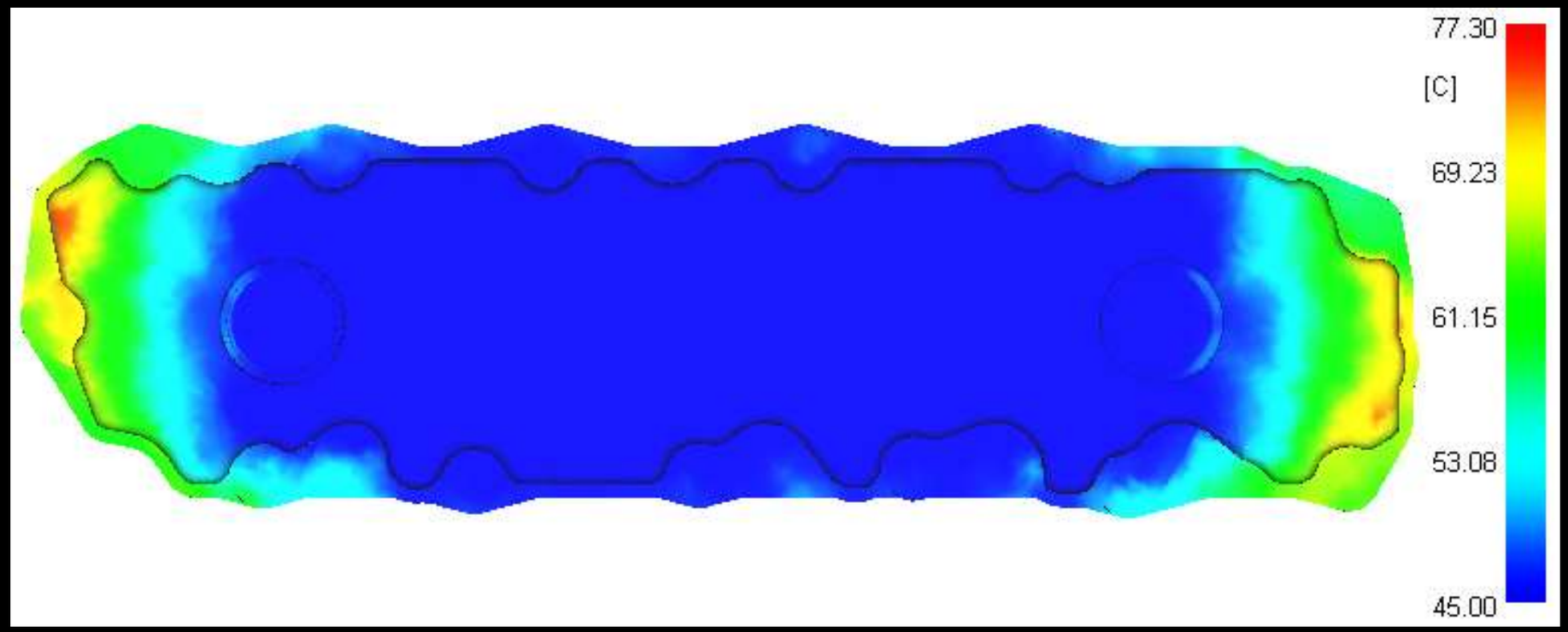


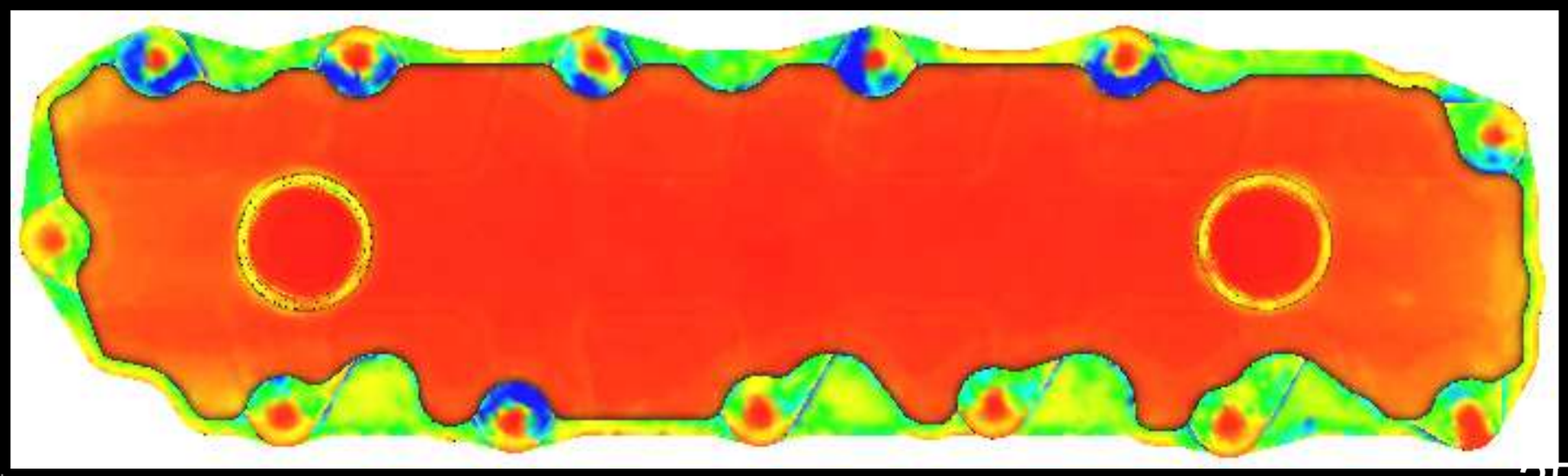
输入: 压缩速度 vs. 位置



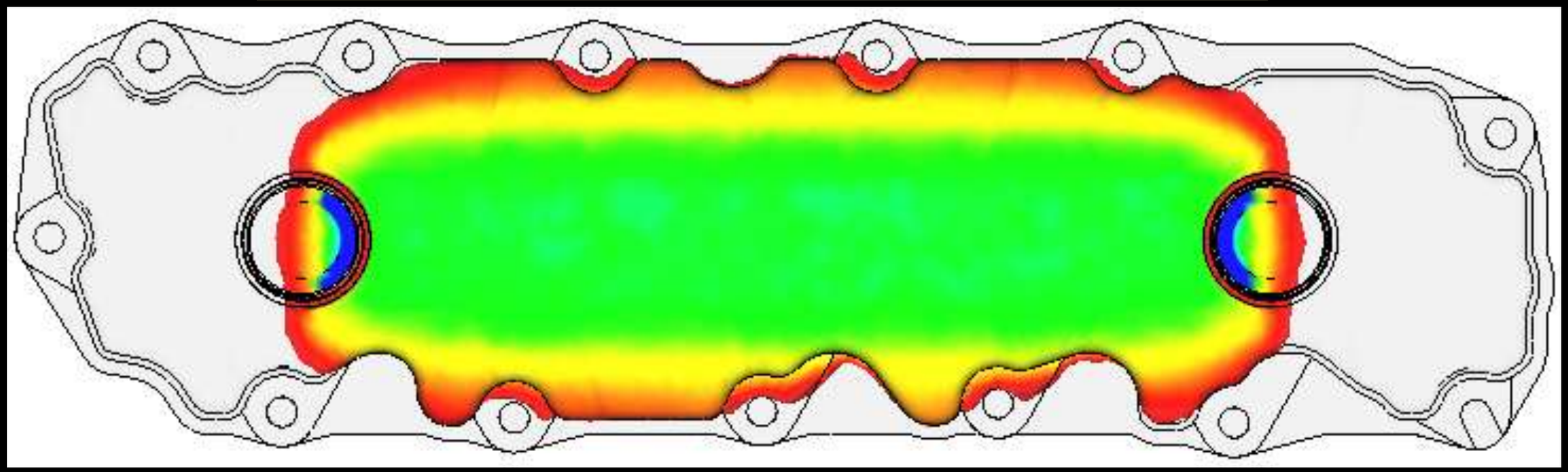


料峰温度, Degree of Cure

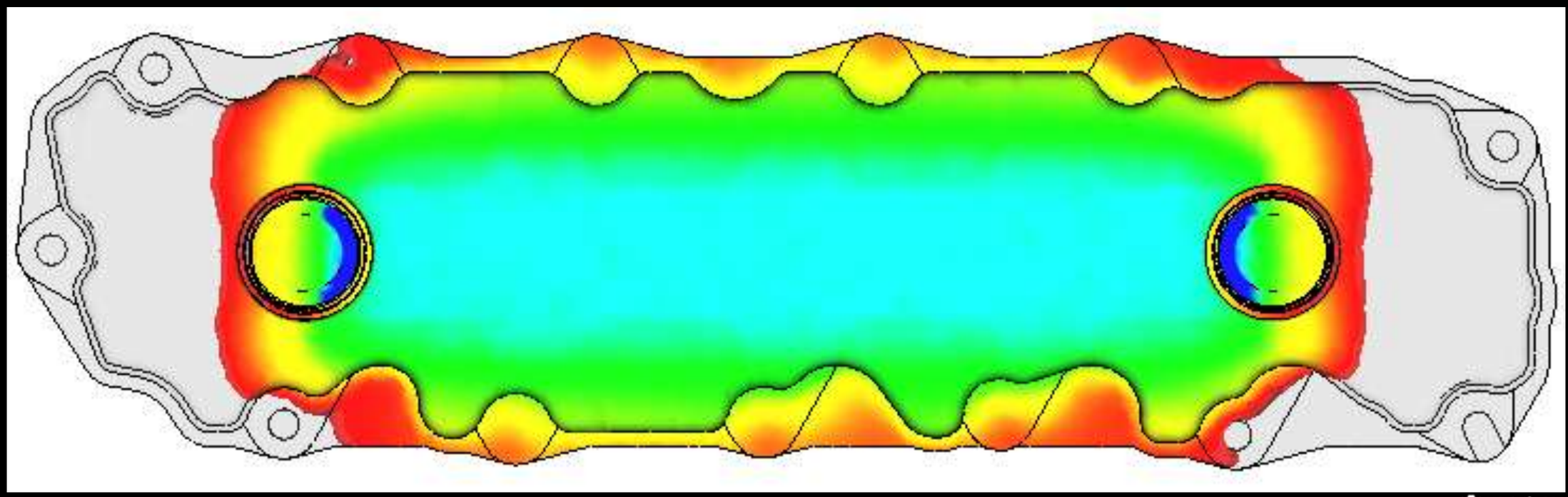




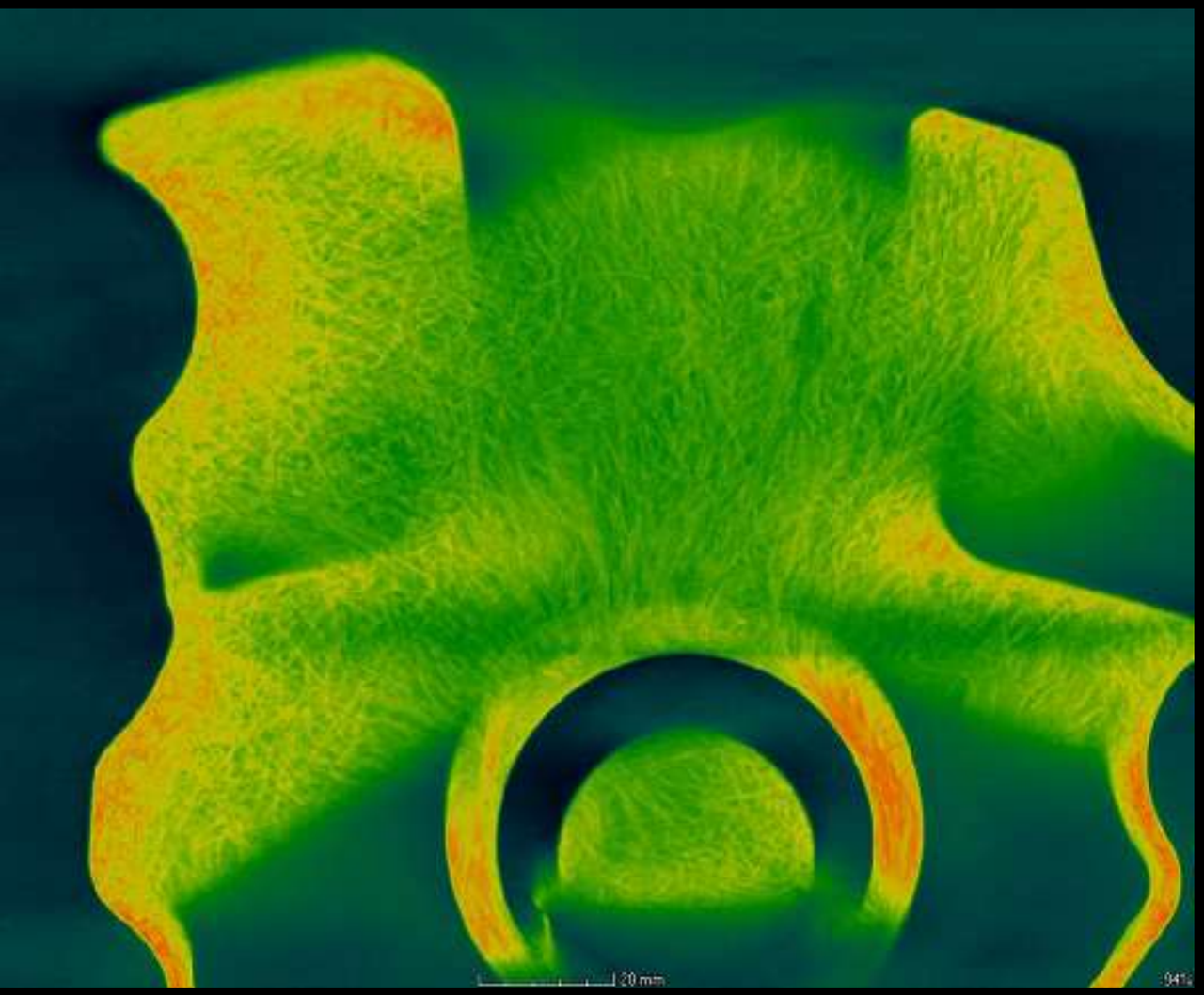
充填模式对比 (1)



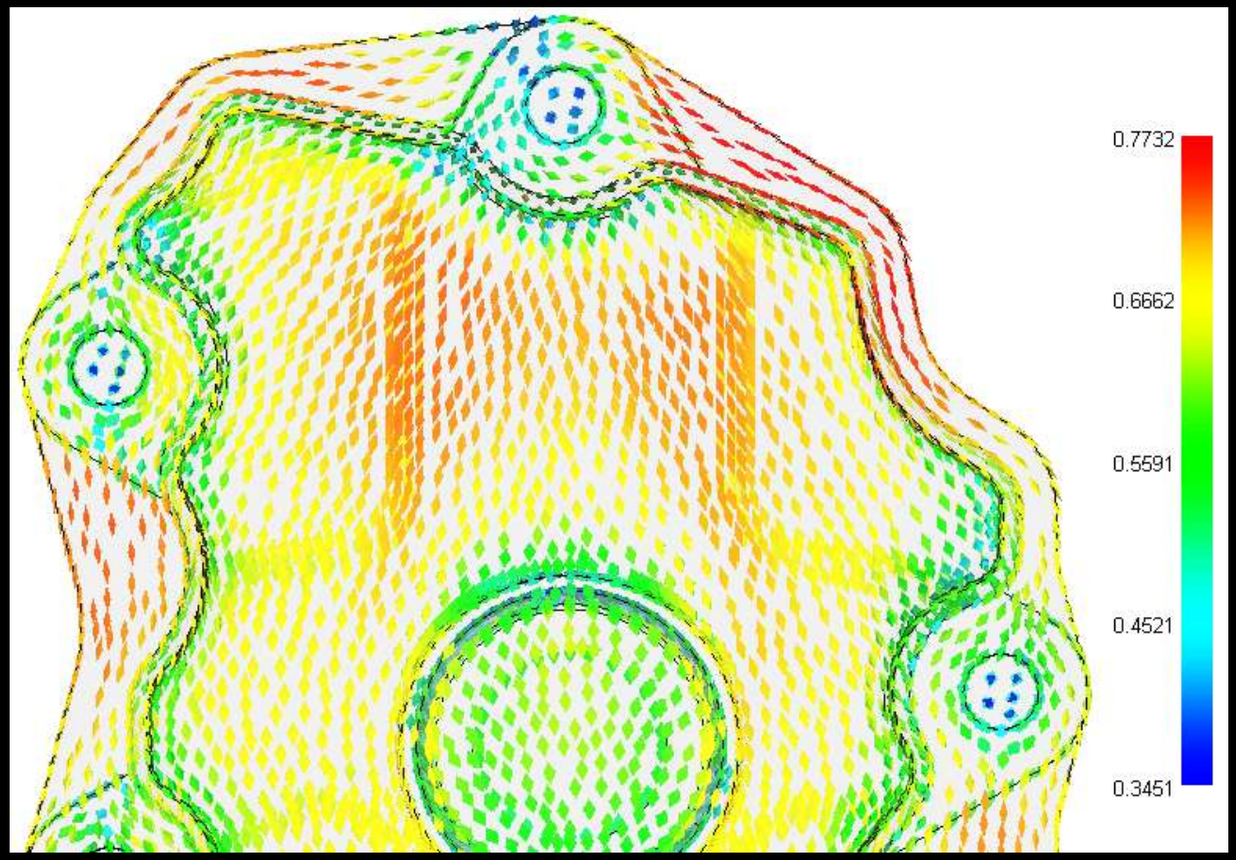
充填模式对比 (2)



压缩成型的玻纤取向



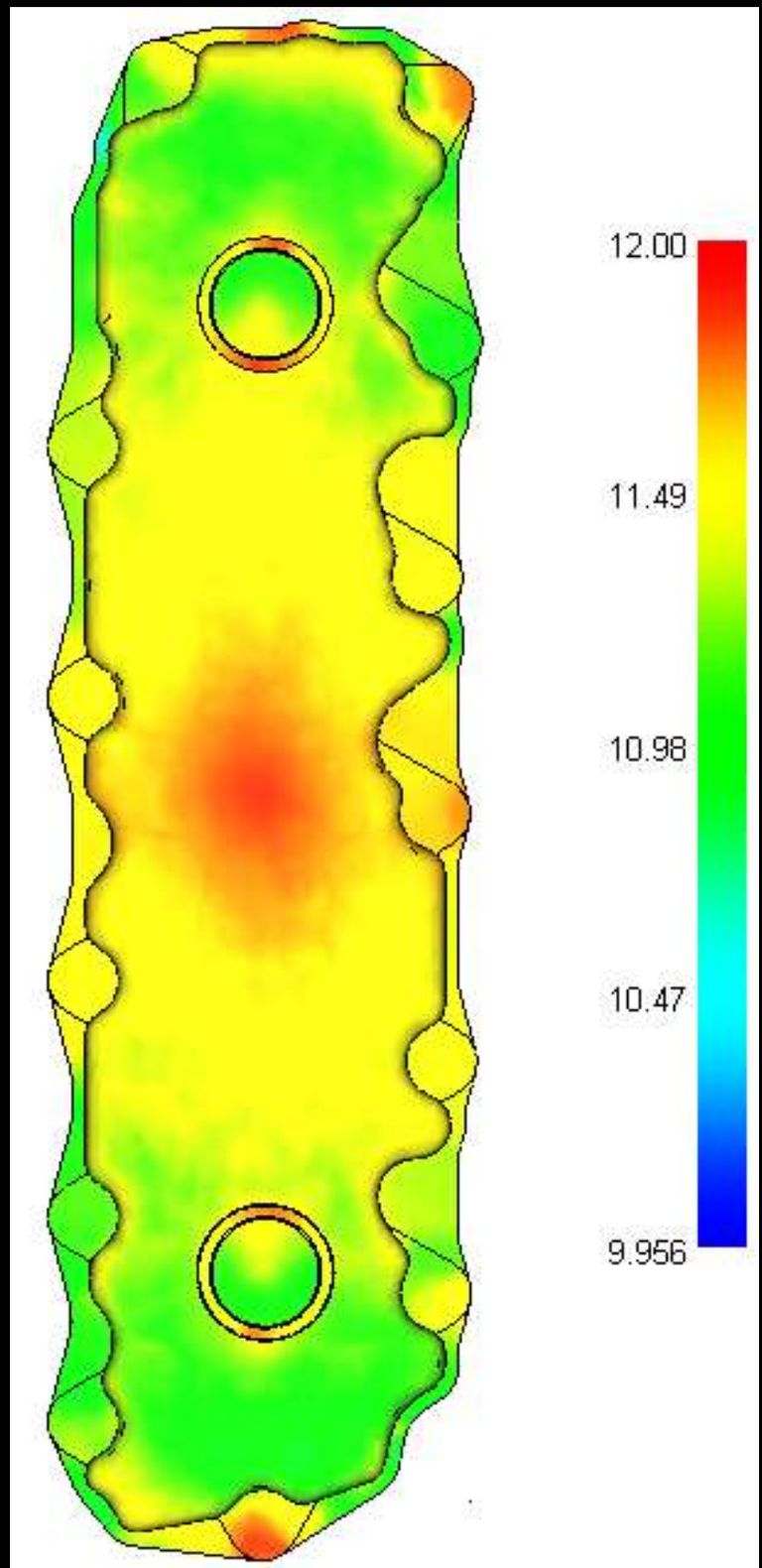
- CT Scan



Numerical Simulation

Autodesk

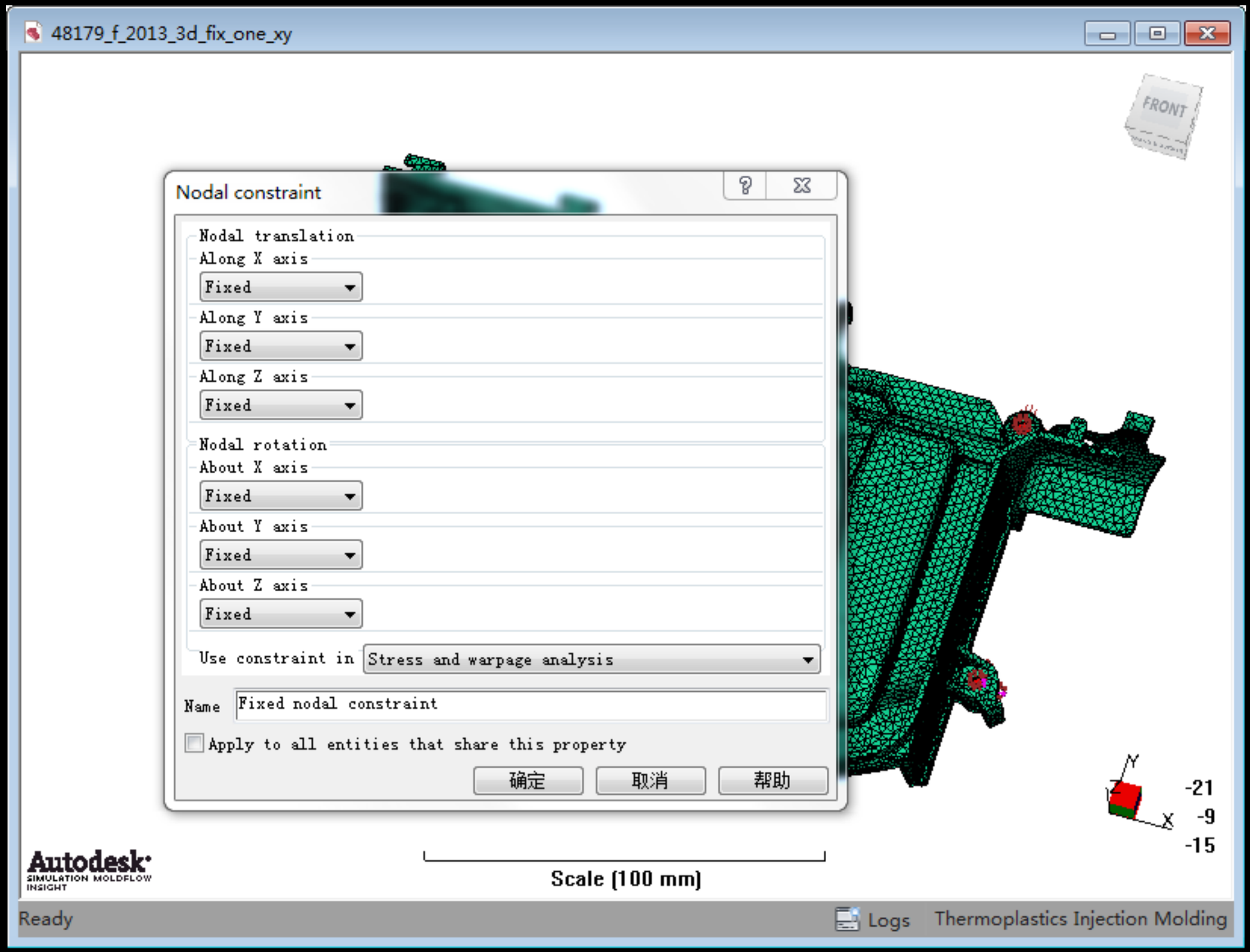
玻纤长度分布



Moldflow / Structural Software Interface

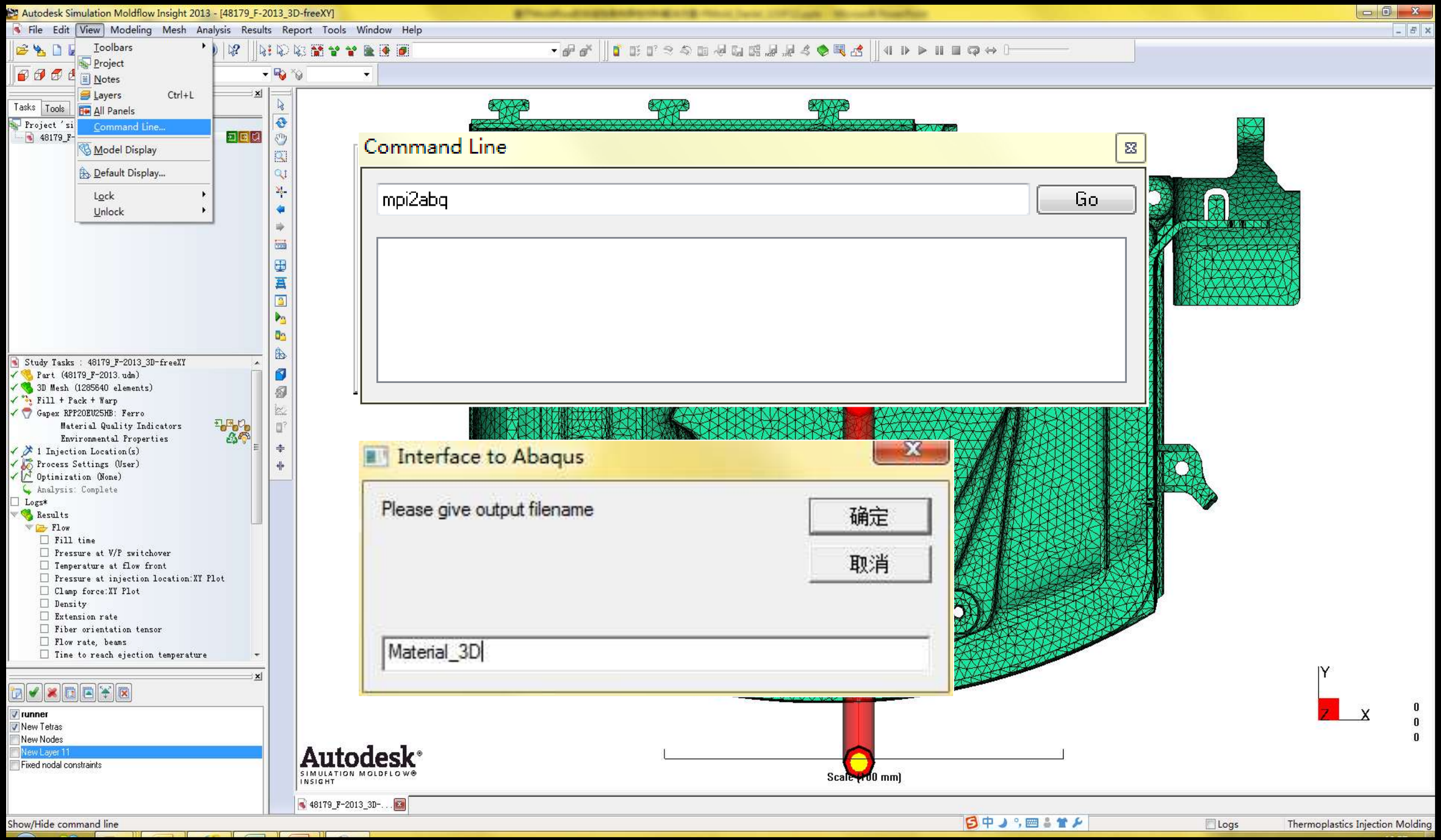
Autodesk

Proposal1: Set Constrain in Moldflow directly



Autodesk

Proposal2: “mpi2abq” or “mpi2ans” as command

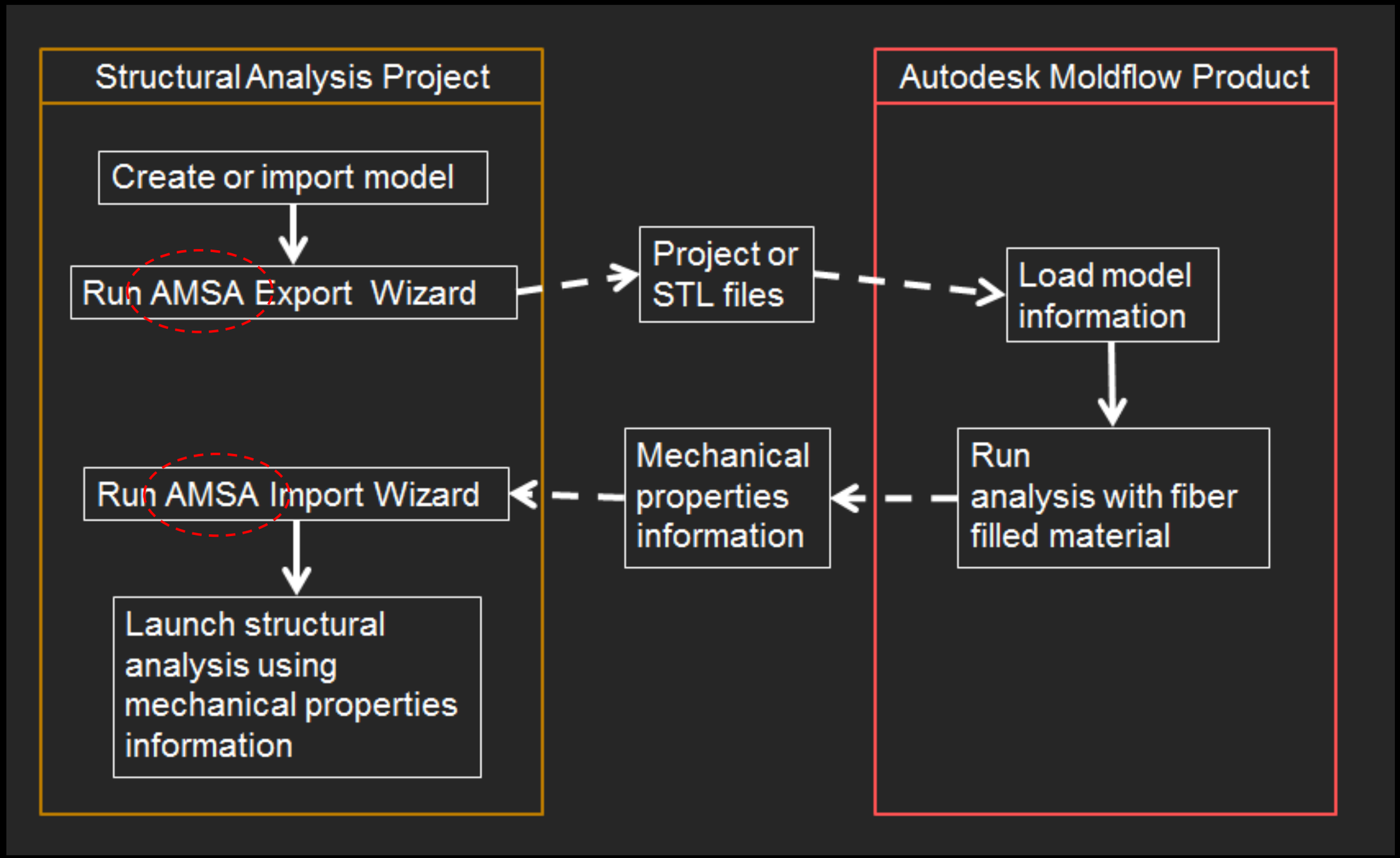


Autodesk

Moldflow should produce the files as following

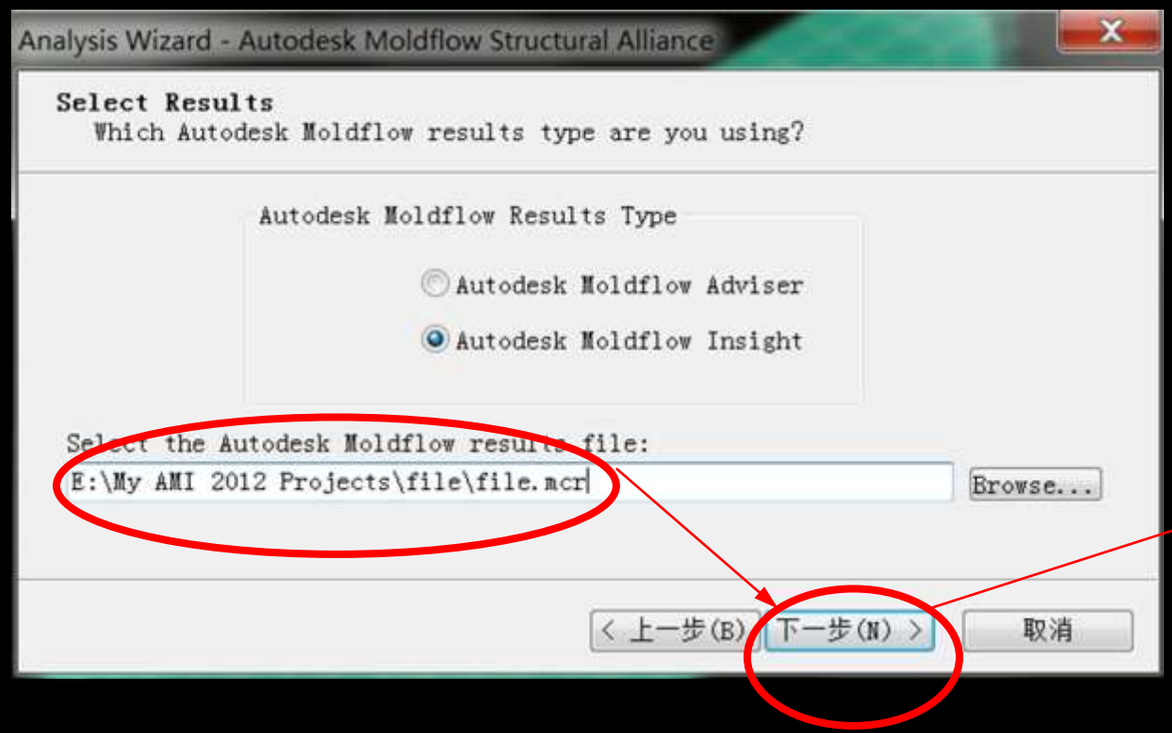
Data type	Filled model
Finite element mesh data	input_name_mesh.inp
Results data	input_name_v12.xml input_name_v13.xml input_name_v23.xml input_name_g12.xml input_name_g13.xml input_name_g23.xml input_name_ltec_1.xml input_name_ltec_2.xml input_name_ltec_3.xml input_name_e11.xml input_name_e22.xml input_name_e33.xml input_name_initStresses.xml input_name_principalDirections.xml

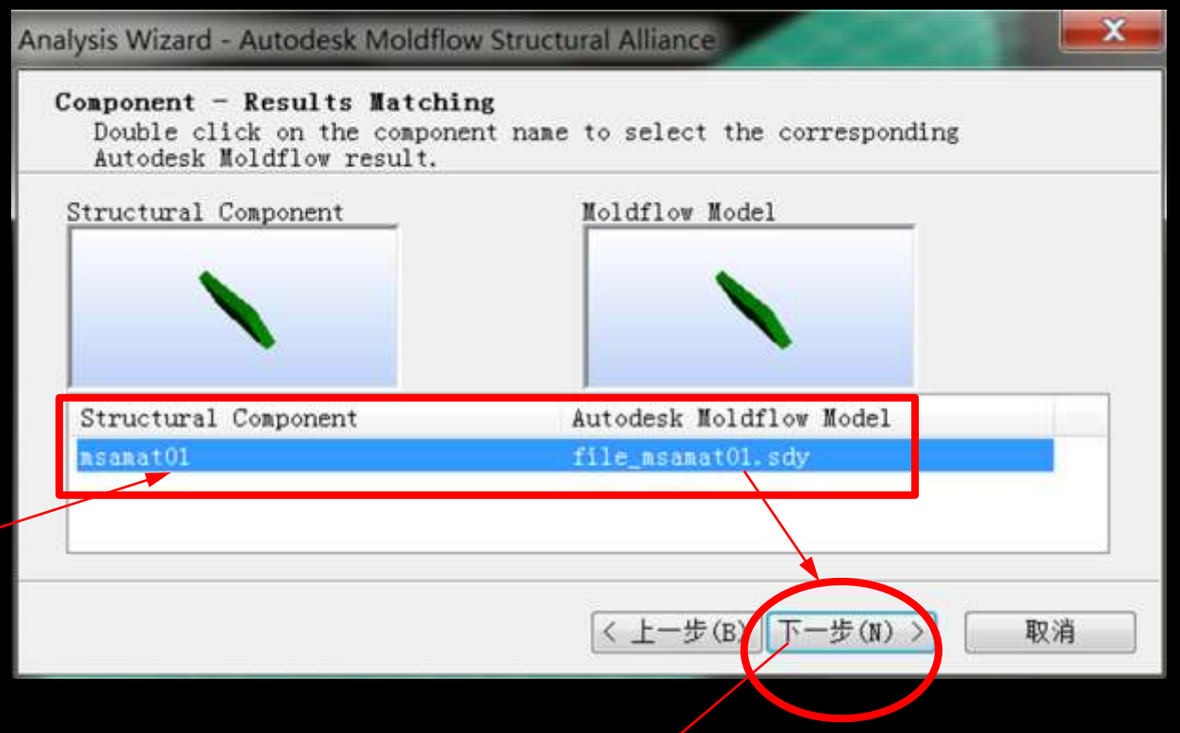
Proposal3: Run AMSA Analysis Wizard

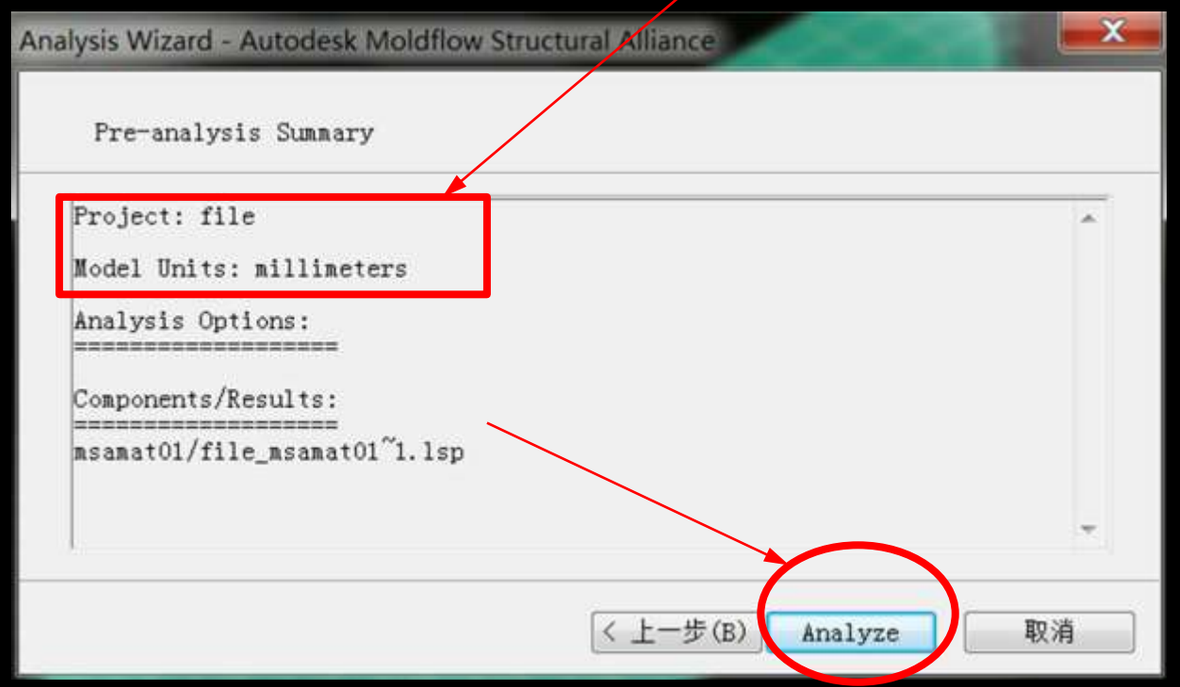


Autodesk

Run AMSA Analysis Wizard







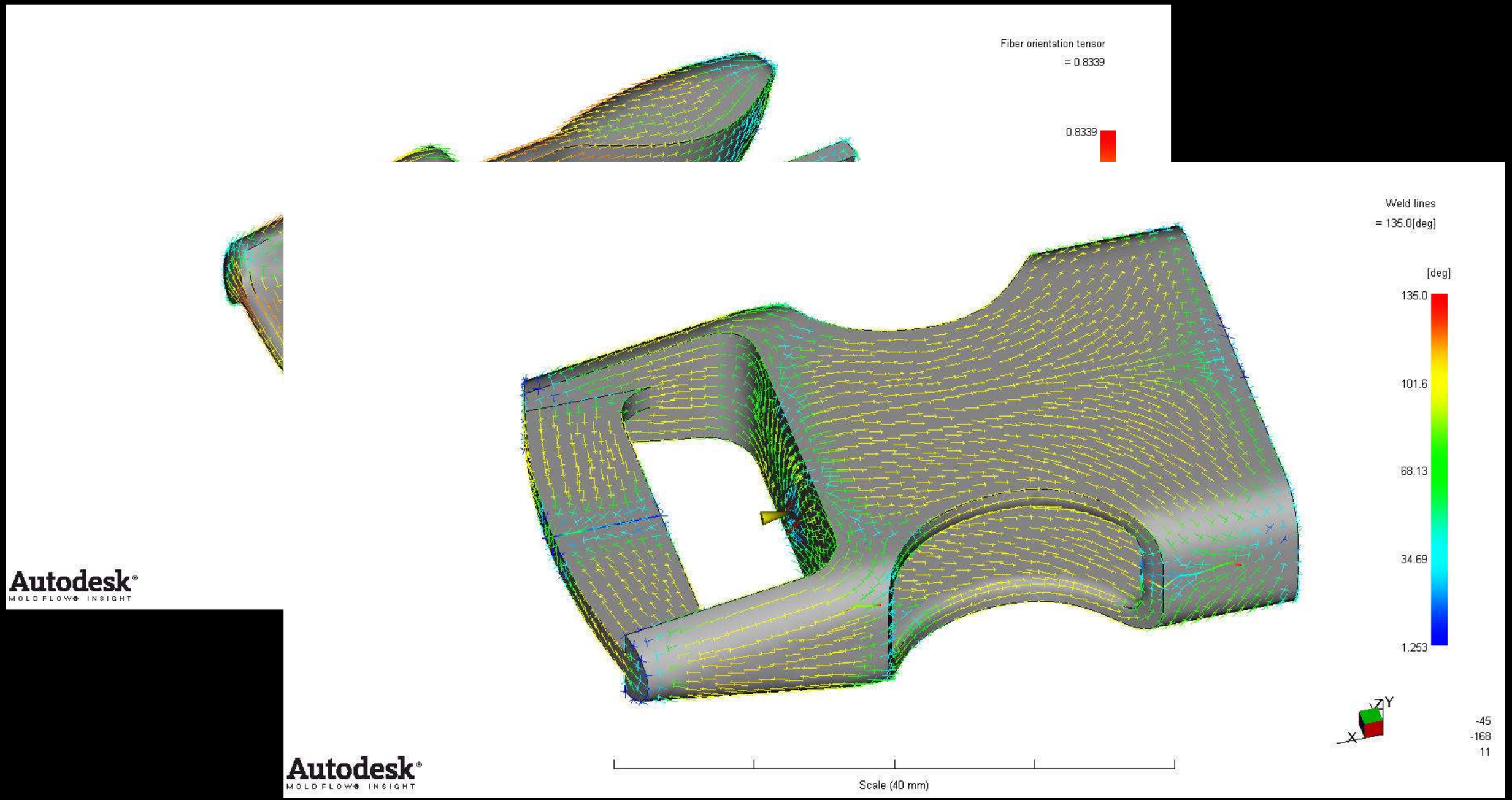
Associate moldflow models with structural components.

Autodesk

Autodesk Simulation w/ AMSA

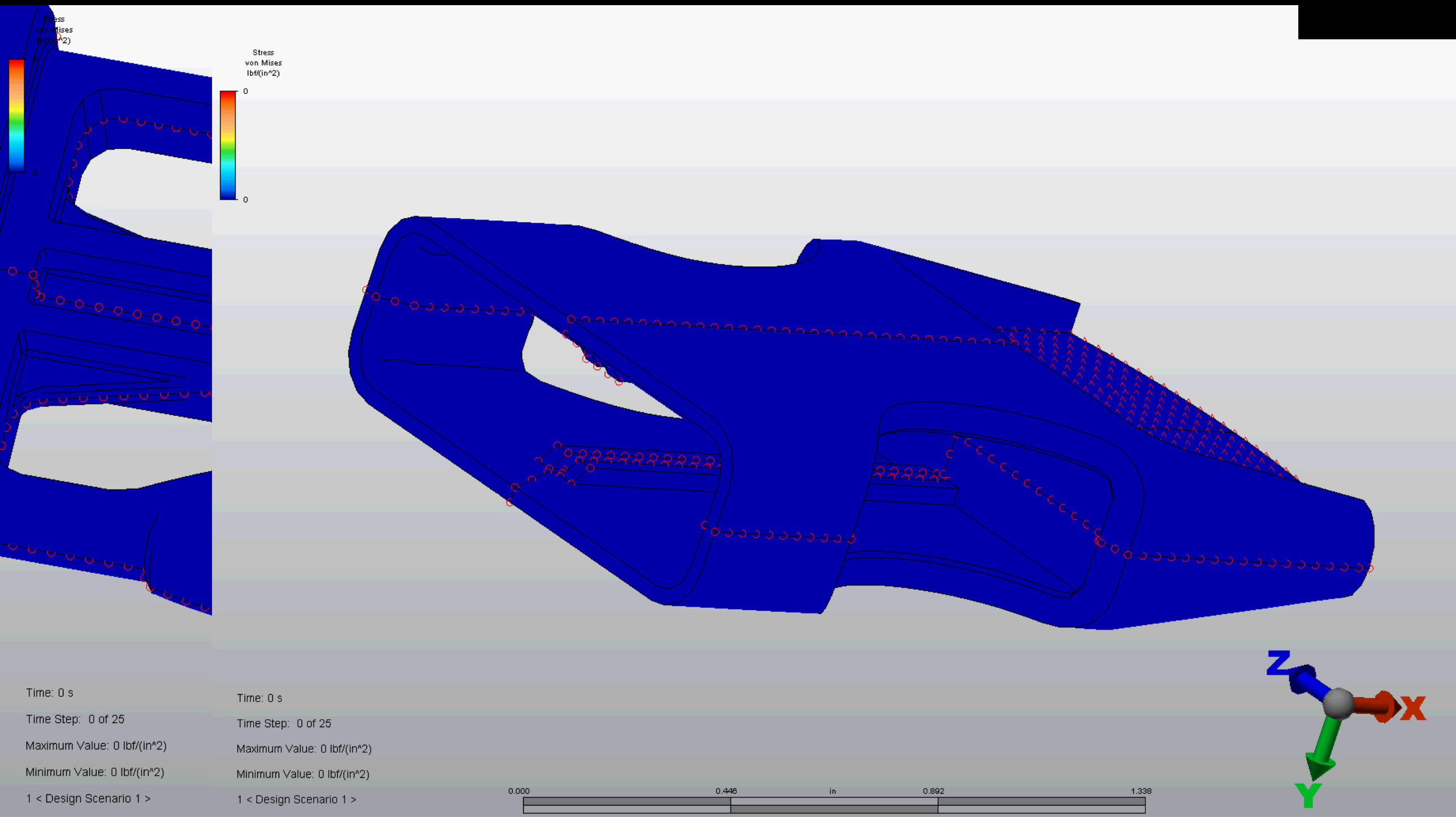
- Autodesk Simulation对于注塑成型分析和应力分析的连接可通过基于节点的映射计算顺畅的实现
- 对于用含玻纤材料成型的部分，材料的各向异性和非均质特性可以被捕获并映射到应力分析
- 残余应力和热-继续属性也都将被映射。实列表明，该映射方法是有效的，在不同的分析软件中都具有良好的一致性

玻纤增强产品的屈曲

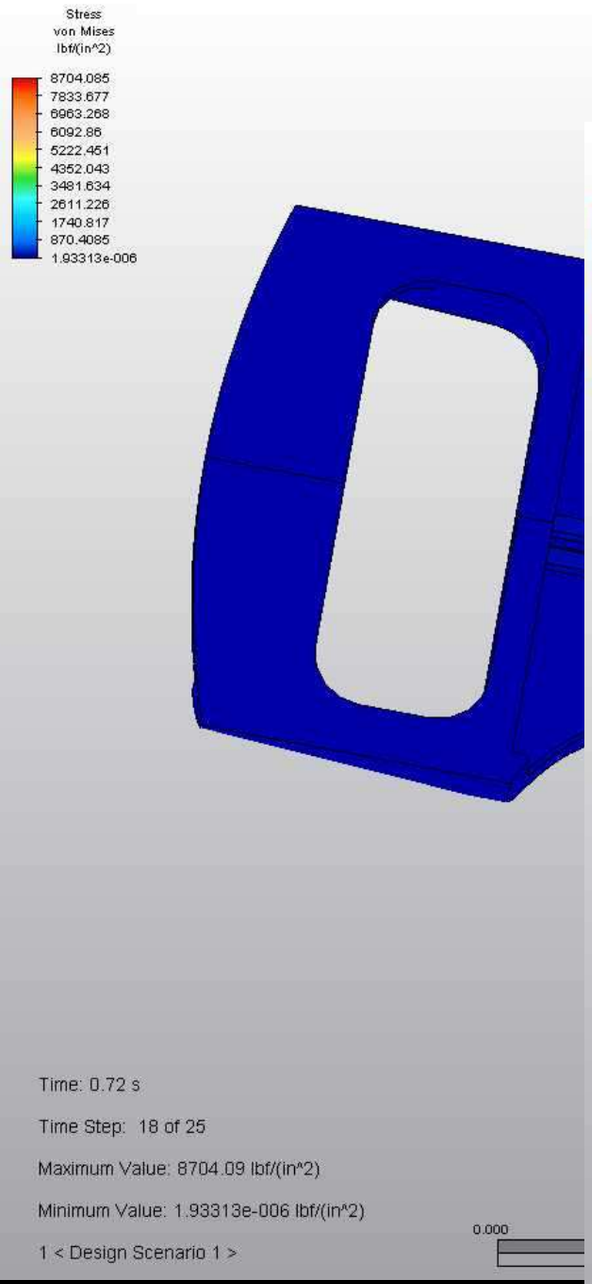


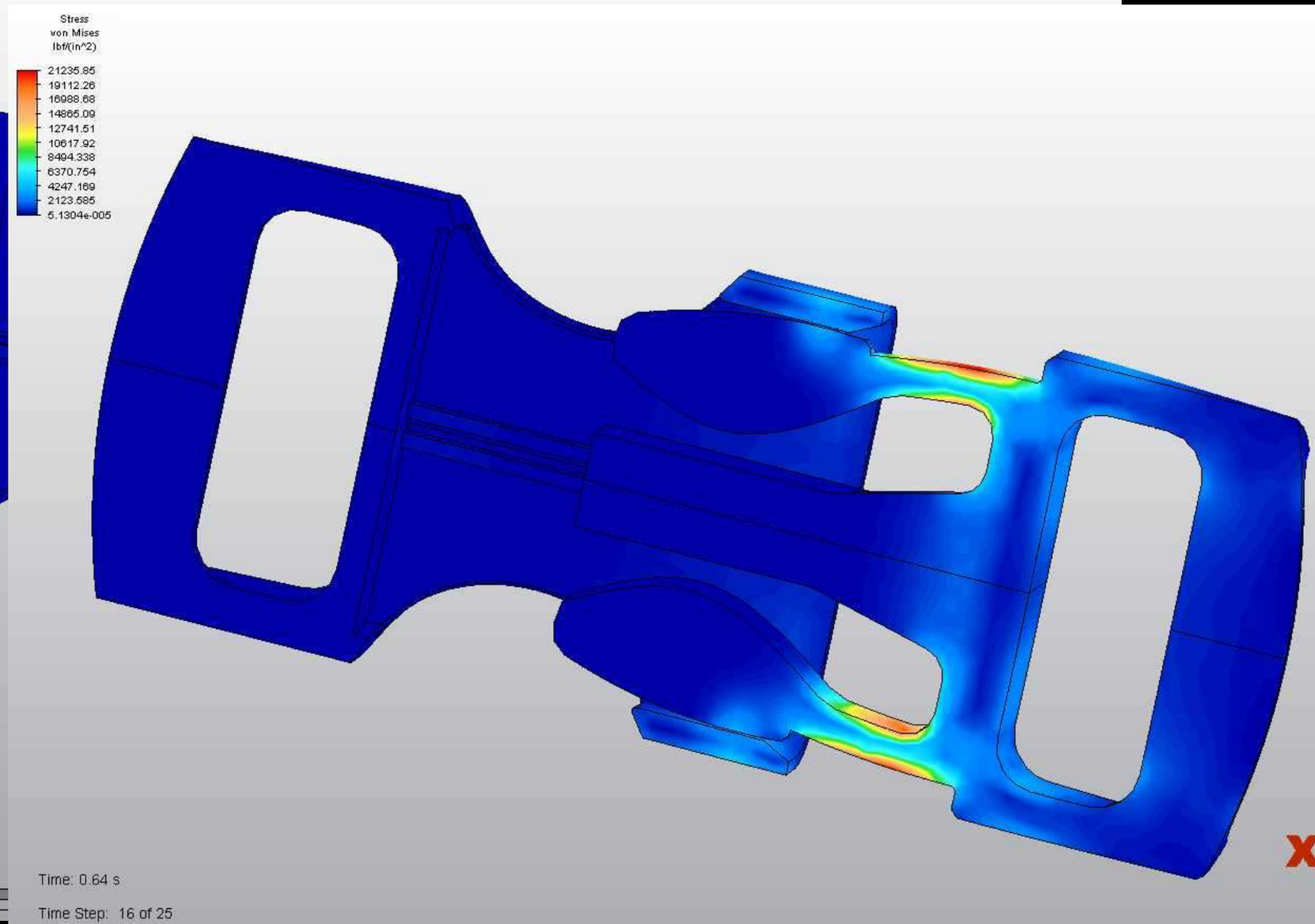
Autodesk

屈曲产品的线性接触分析

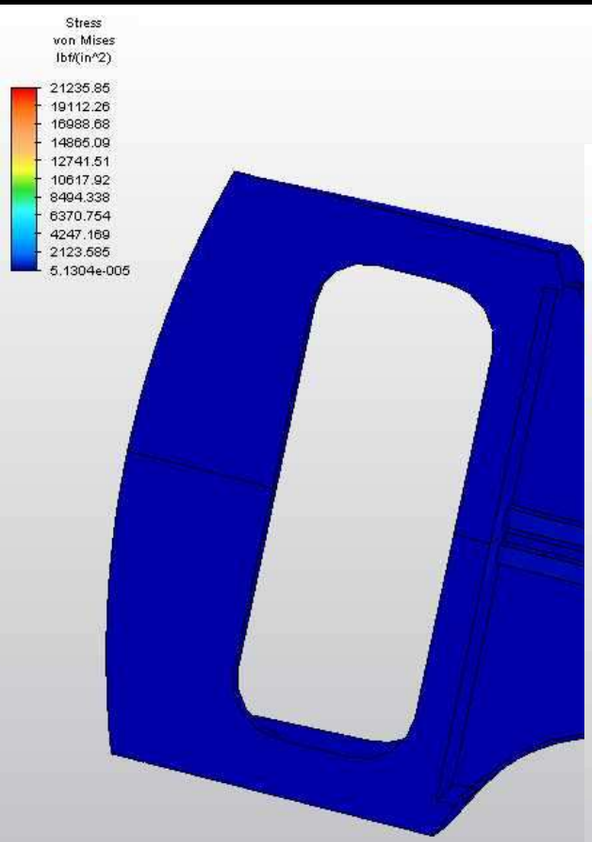


是否含玻纤的比较





是否包含残余应力的比较



Time: 0.64 s

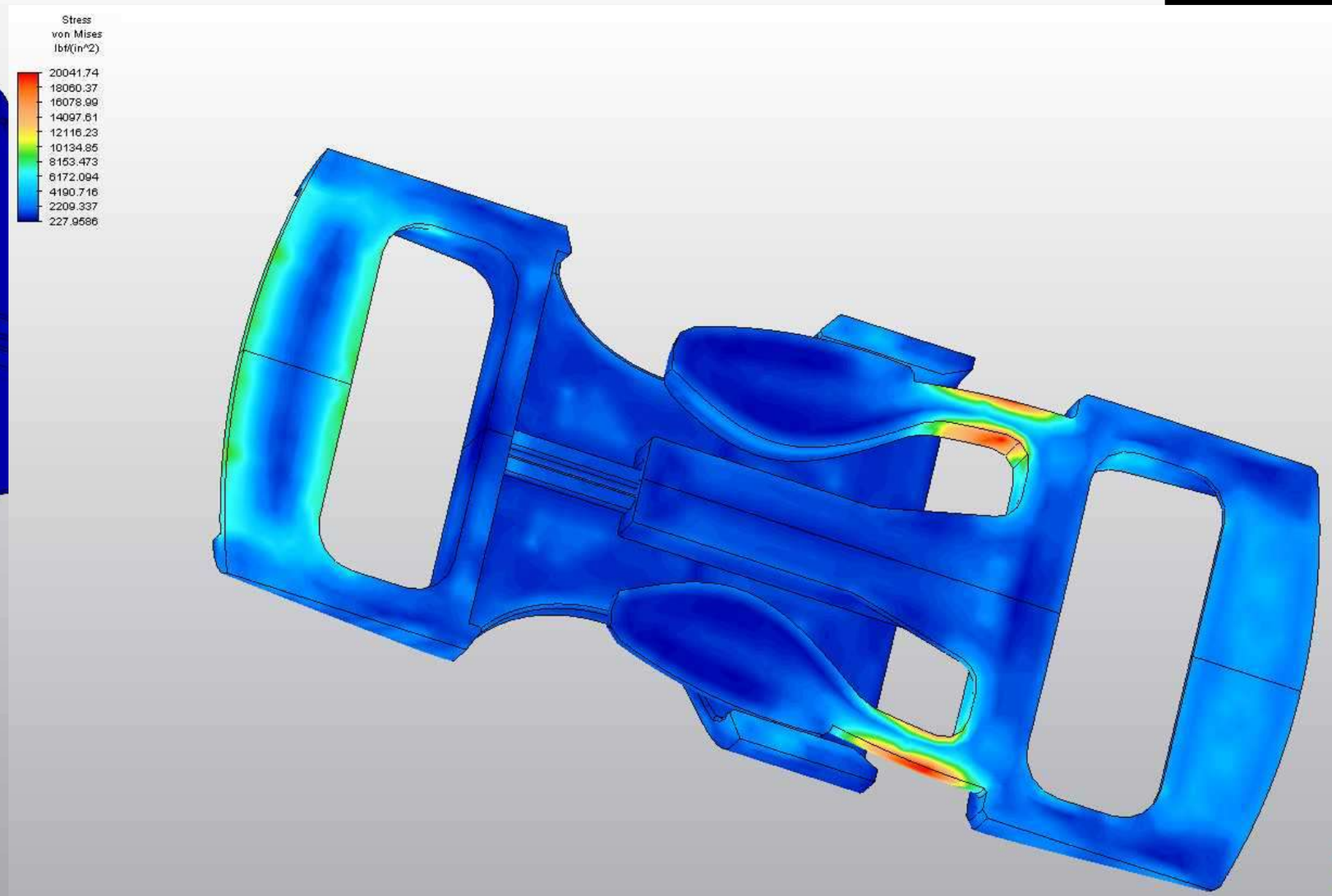
Time Step: 16 of 25

Maximum Value: 21235.8 lbf/(in^2)

Minimum Value: 5.1304e-005 lbf/(in^2)

0.000

1 < Design Scenario 1 >



Time: 0.76 s

Time Step: 19 of 25

Maximum Value: 20041.7 lbf/(in^2)

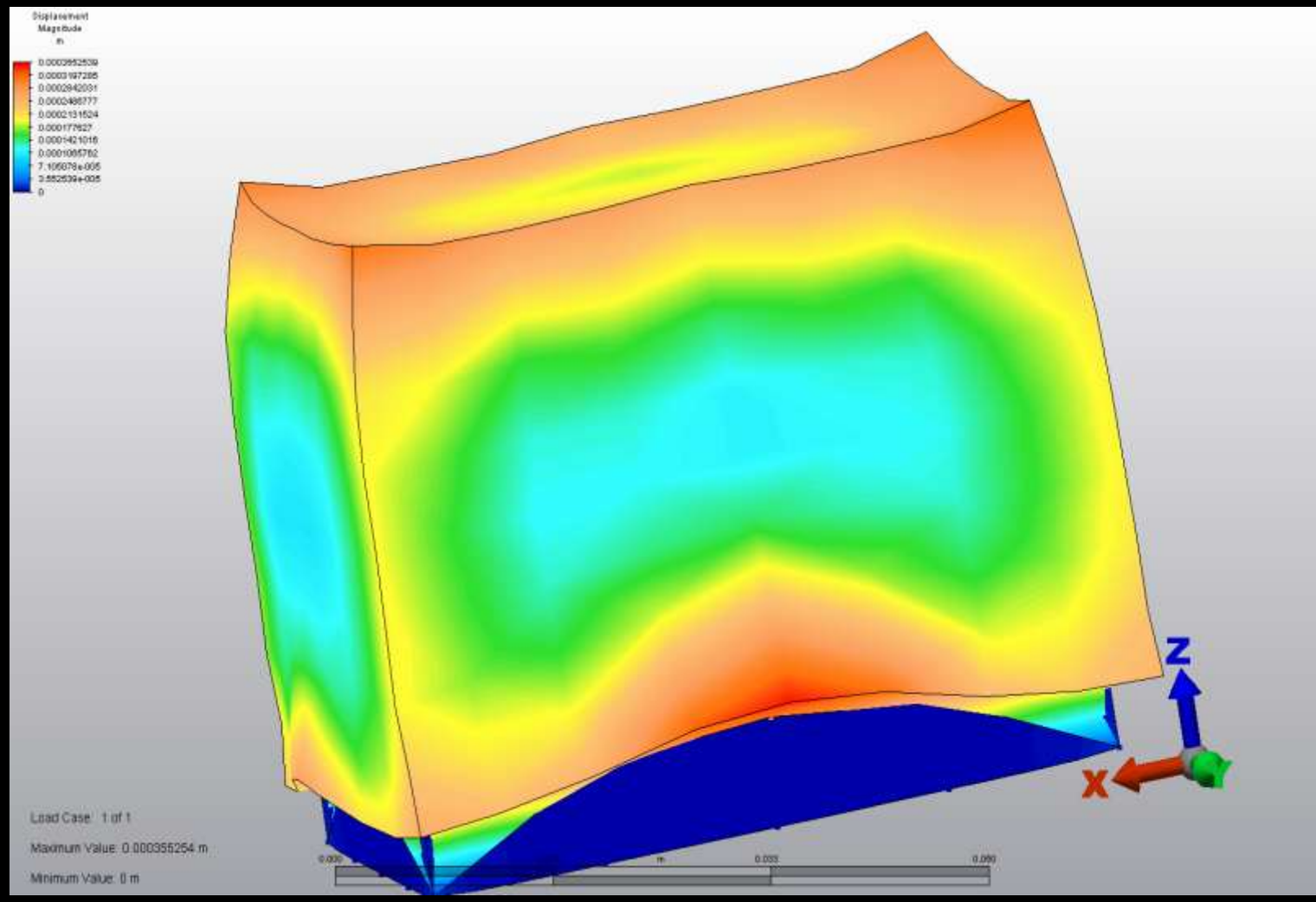
Minimum Value: 227.959 lbf/(in^2)

1 < Design Scenario 1 >

0.000 0.739 in 1.478 2.217

Autodesk Simulation的最新整合

- 顶出力的计算
  - 考虑与型芯的摩擦
  - 残余应力/压力
  - 塑料产品的变形



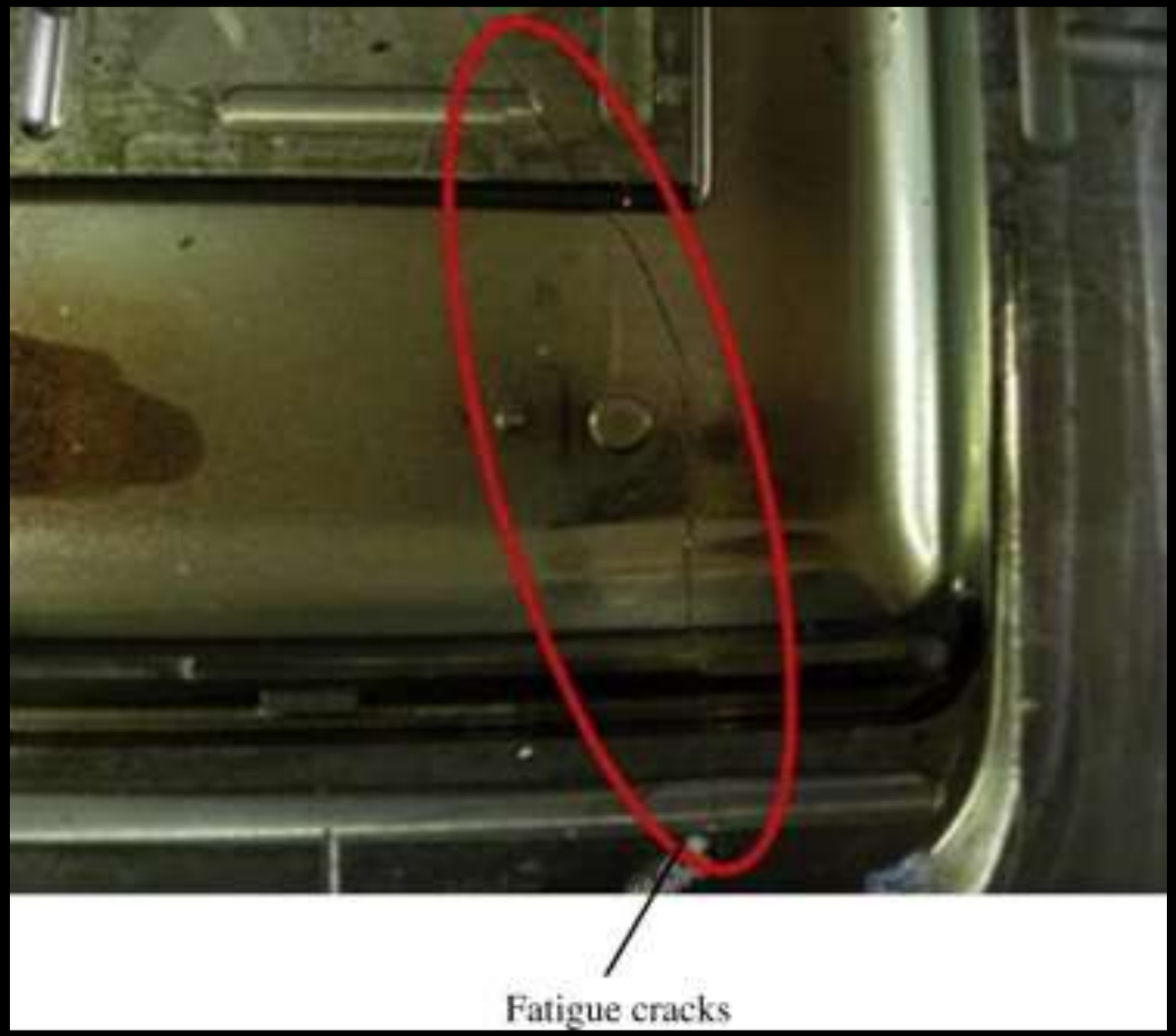
模具疲劳分析及寿命预测

费用节省估计

节省一套模具 ($550,000)
节省模具维修 ($65,000 +)
CAE的费用 ($10,000-)
净节省 ($605,000)
还未包含停机导致的费用

Autodesk 仿真工具

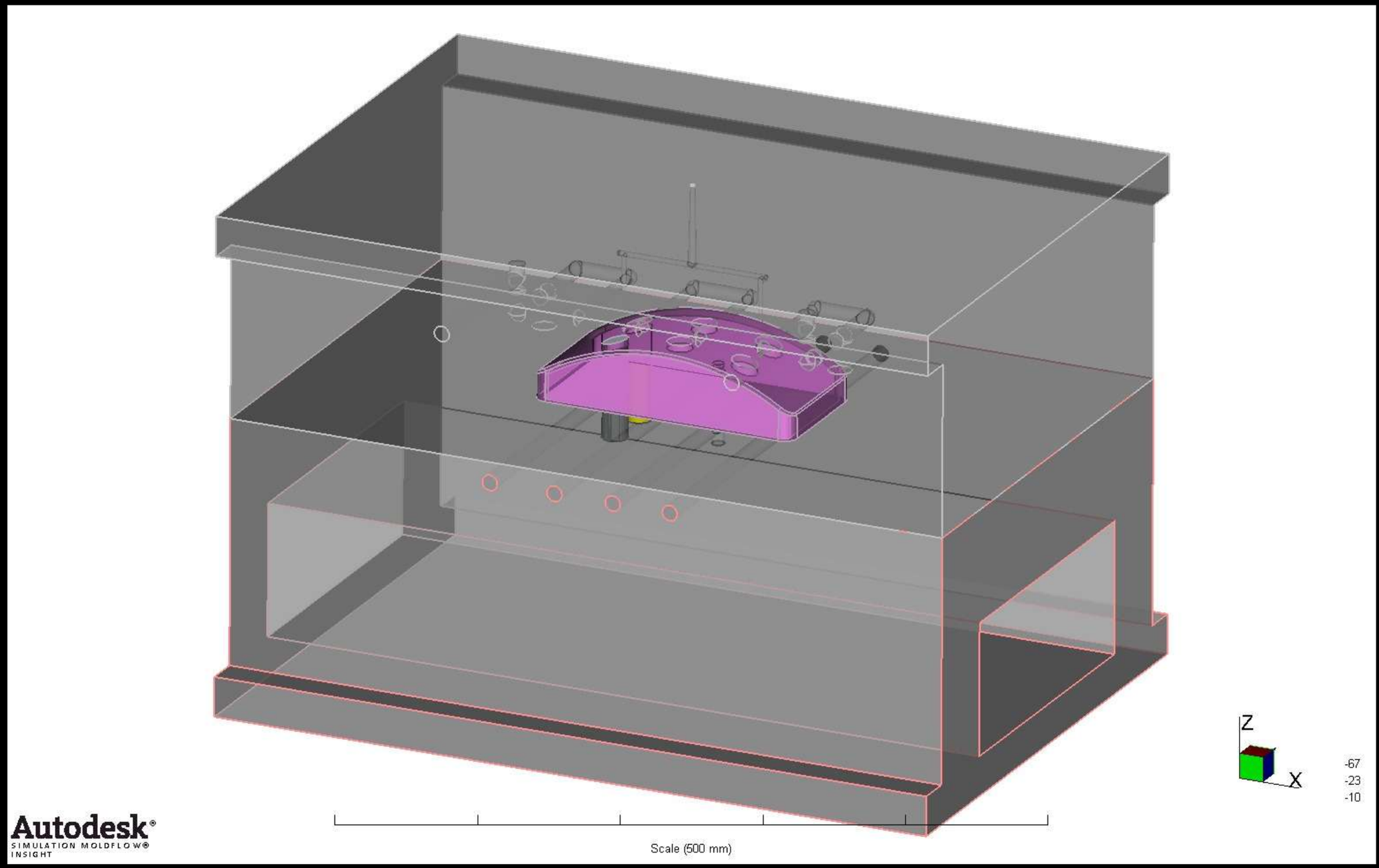
- **Moldflow**
  - 瞬态冷却分析
  - 流动分析及型芯偏移分析
- **Mechanical**
  - 热应力分析
  - 线性静态应力分析
  - 疲劳向导



自动的仿真工具可分析模具失效的3个主要原因

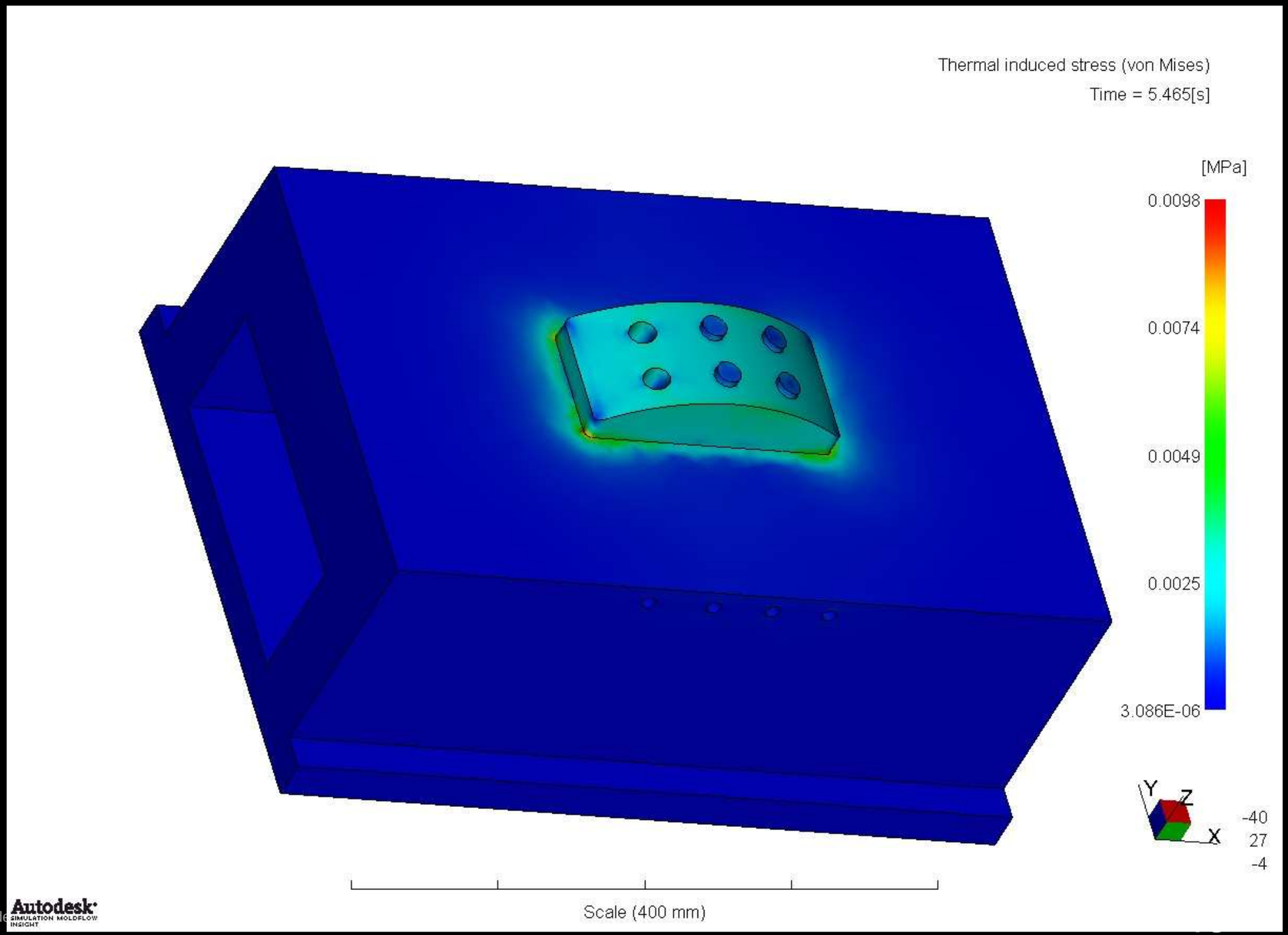
- 快速加热和冷却产生的热应力
  - 瞬态冷却(FEM)分析与Simulation Multiphysics的整合
- 注塑压力不平衡导致的模具变形
  - 包含型芯偏移在内的流动分析与线性静态应力分析的整合
- 锁模力在模板内所产生的应力
  - 基于流动分析所计算的锁模力自动进行的线性静态应力分析
- 通过疲劳向导编译求解模具疲劳

模具疲劳实例



Autodesk

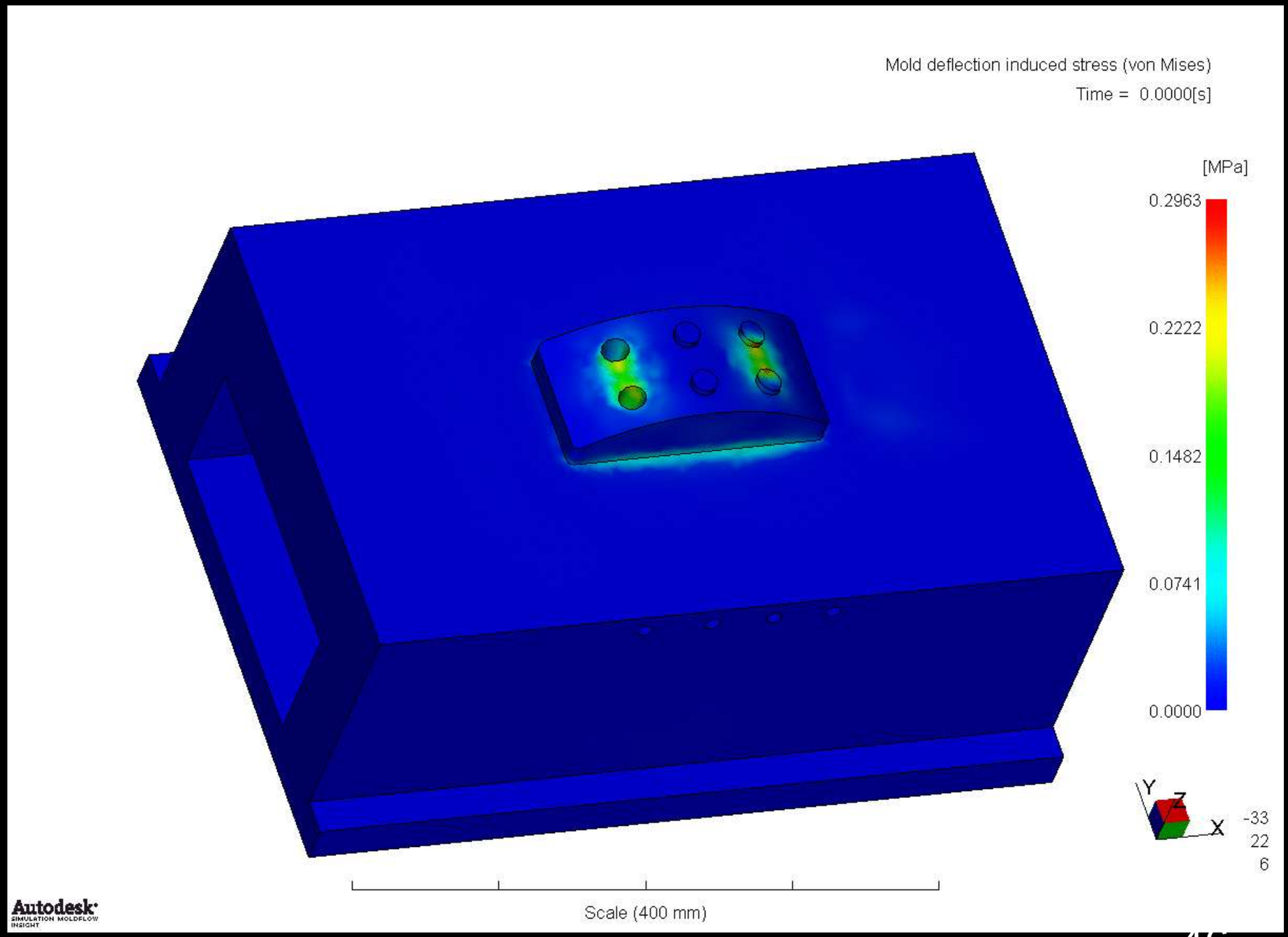
热导致的模具应力



Autodesk Simulation Moldflow Insight

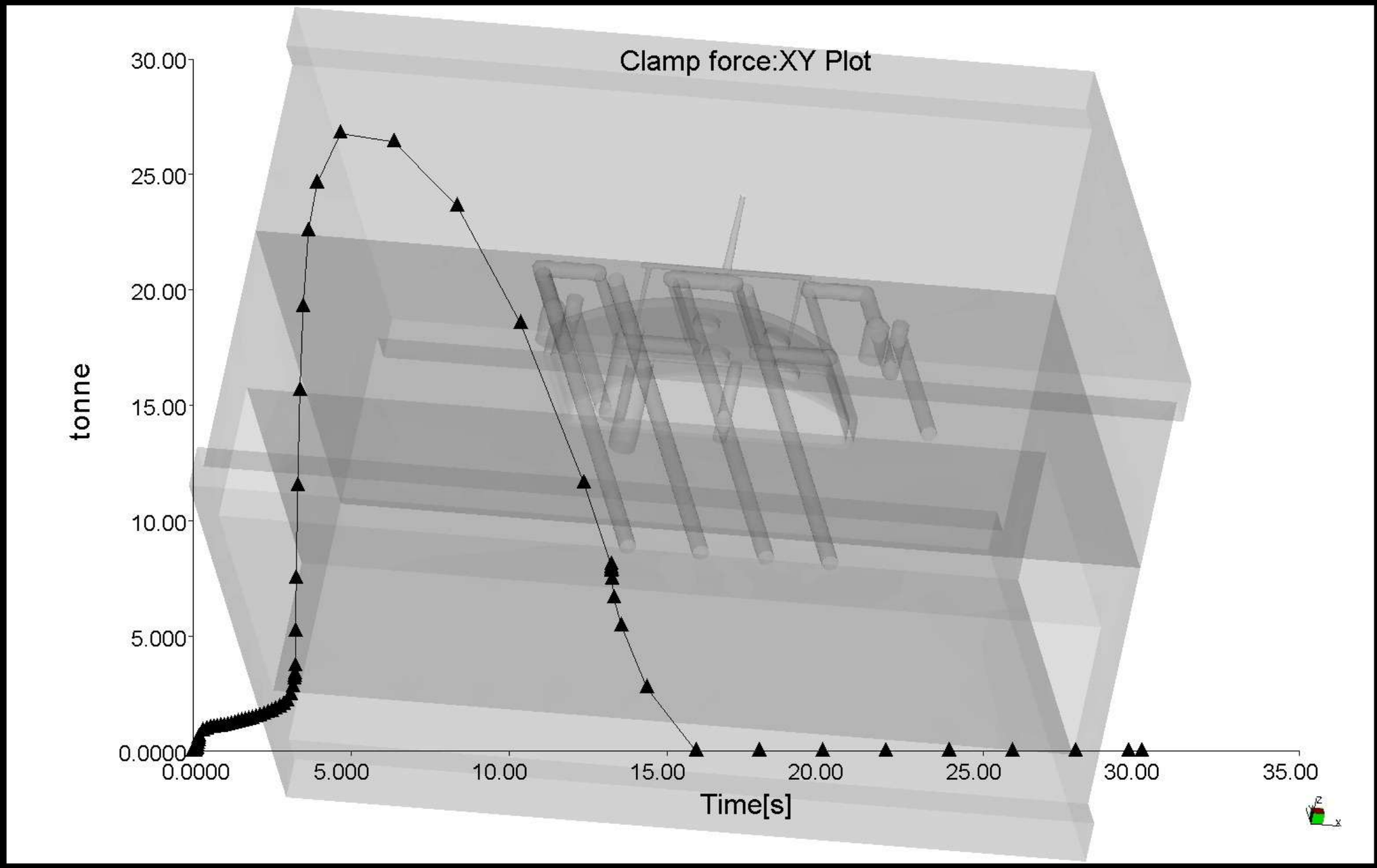
Autodesk

模具变形导致的模具应力



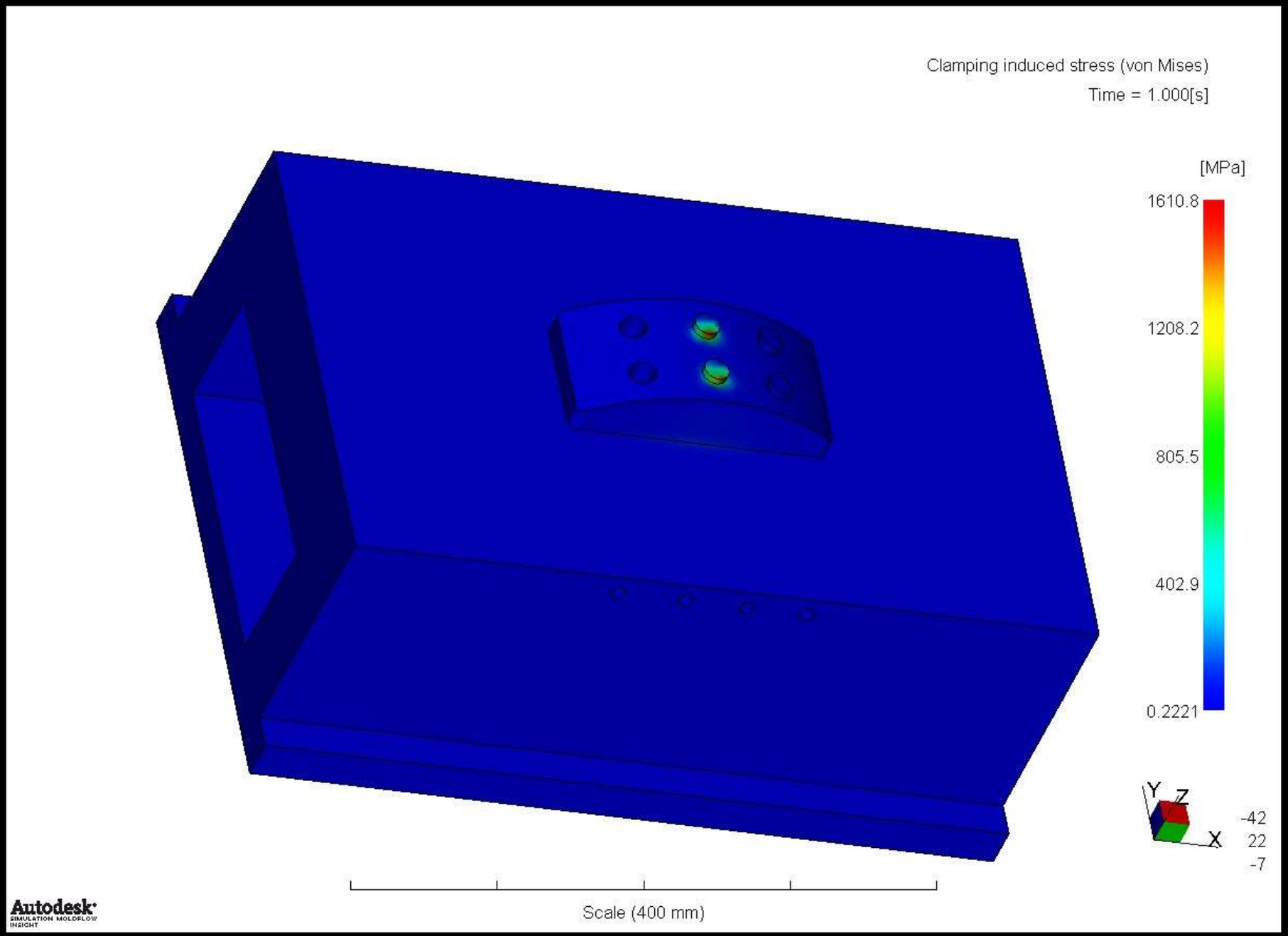
Autodesk

锁模力曲线



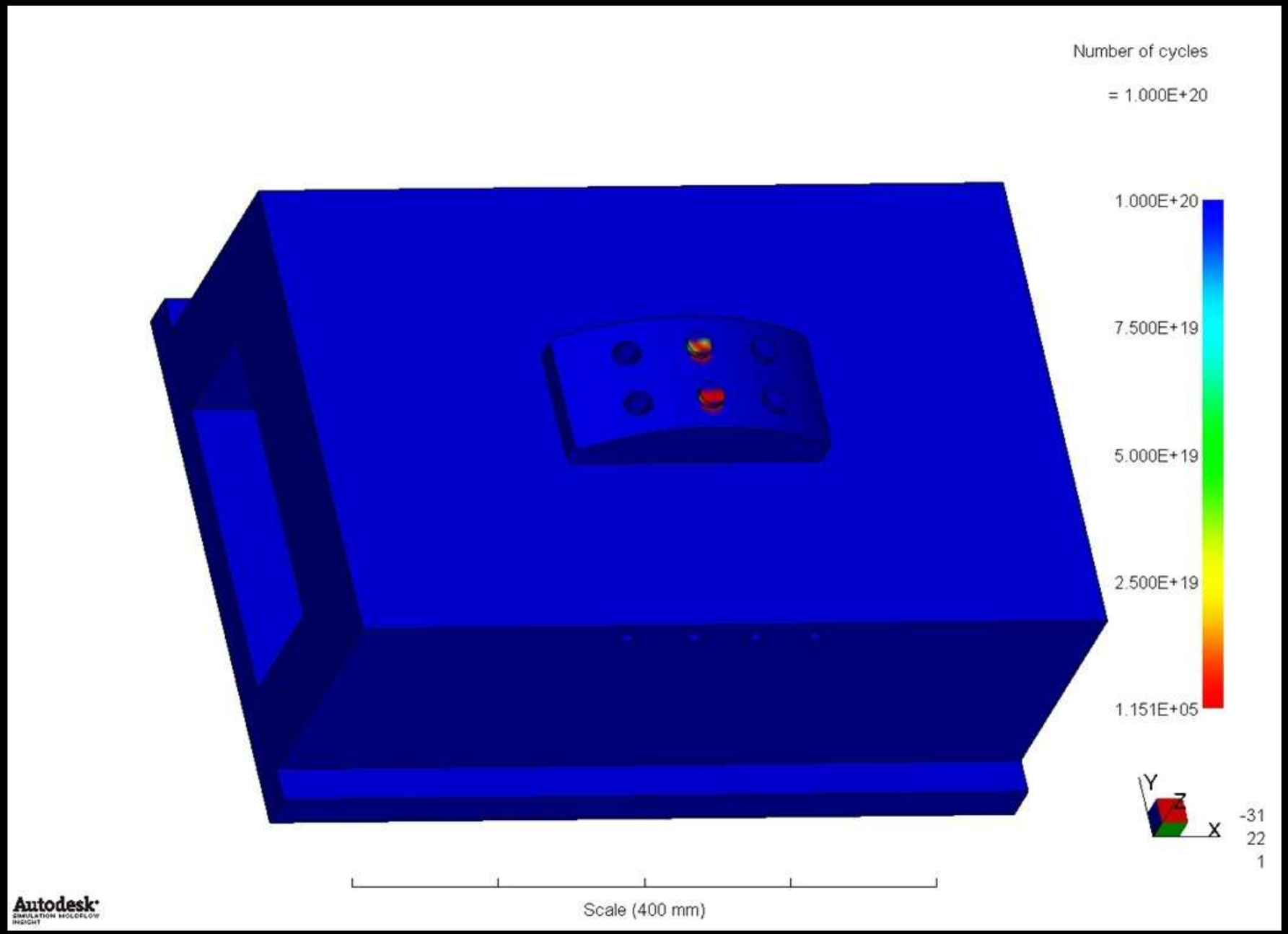
Autodesk

锁模力导致的模具应力



Autodesk

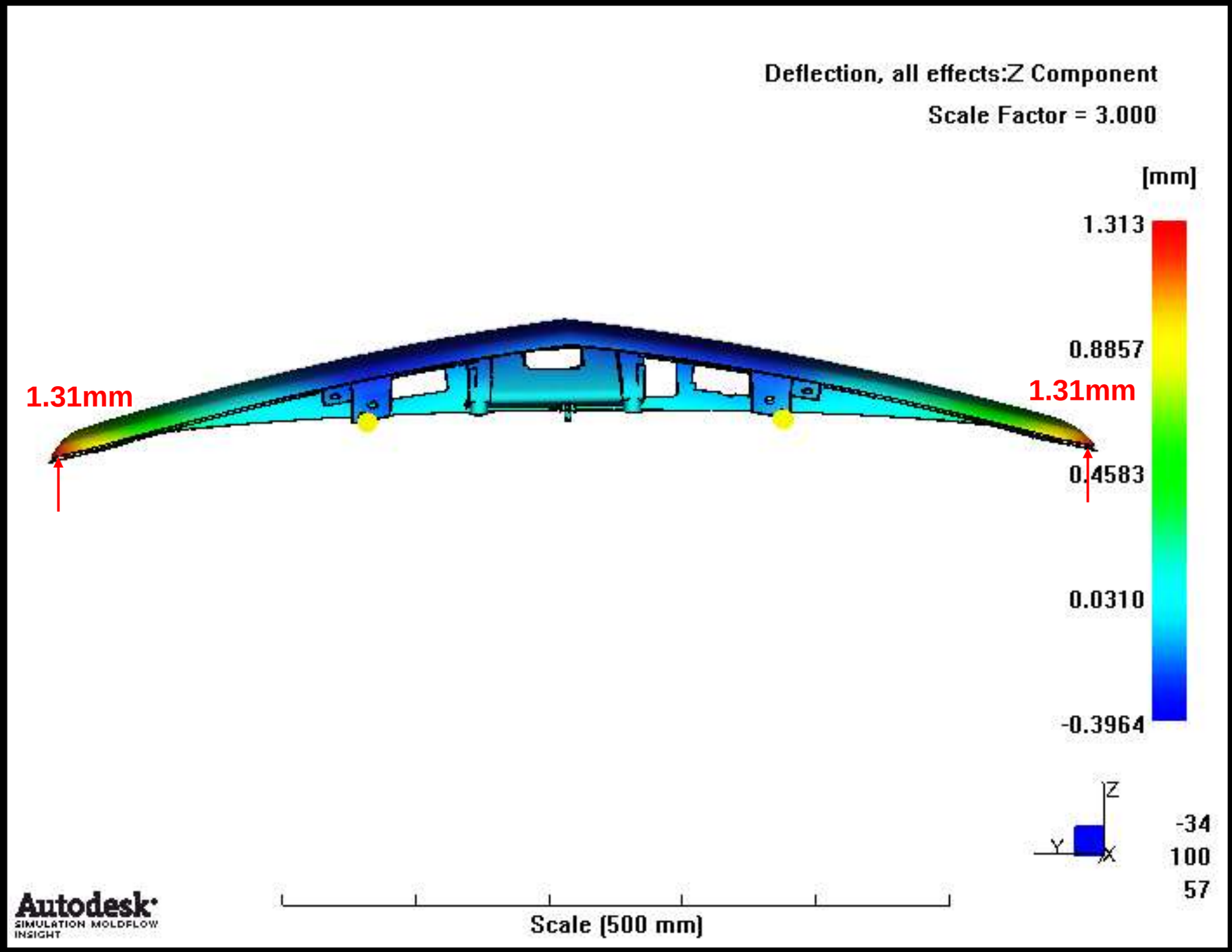
周期数 --- 模具破坏从哪里开始?



Autodesk

Case Study (Moldflow warpage result)

Door handle moldflow free state warpage result.



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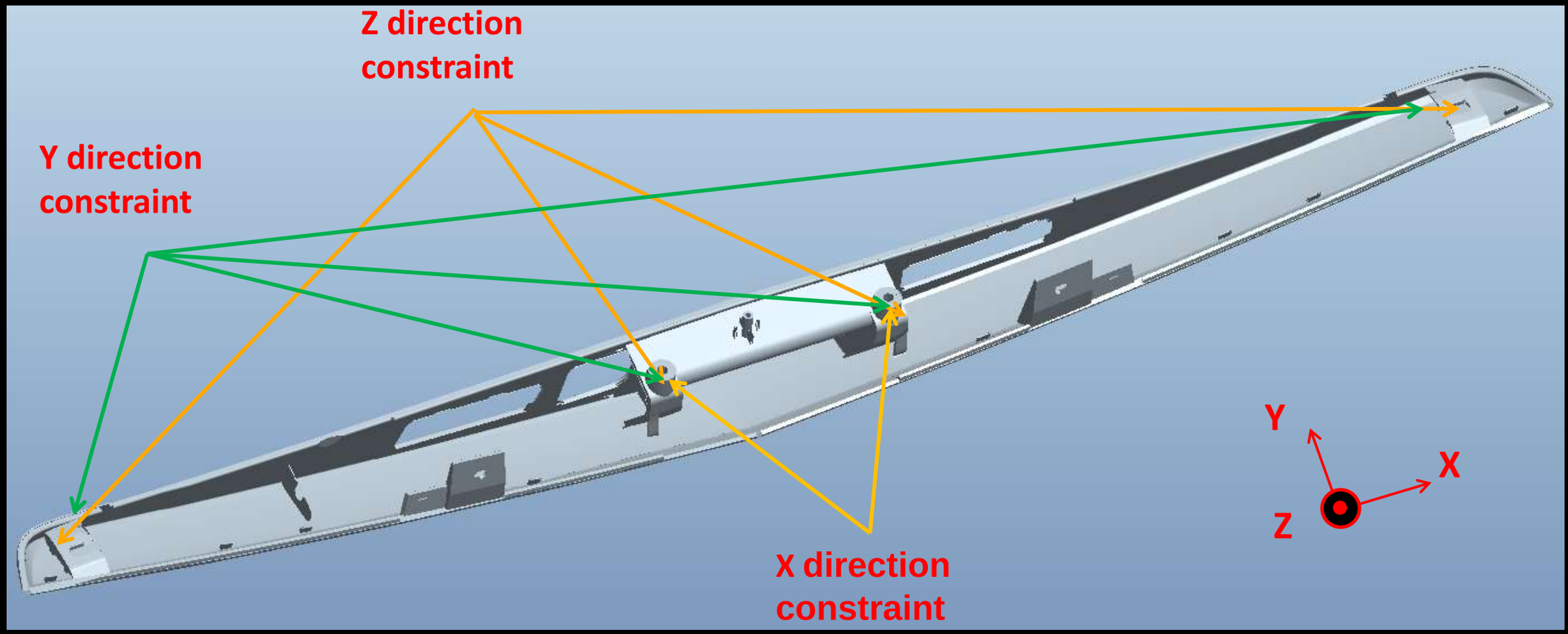
Constraints situation



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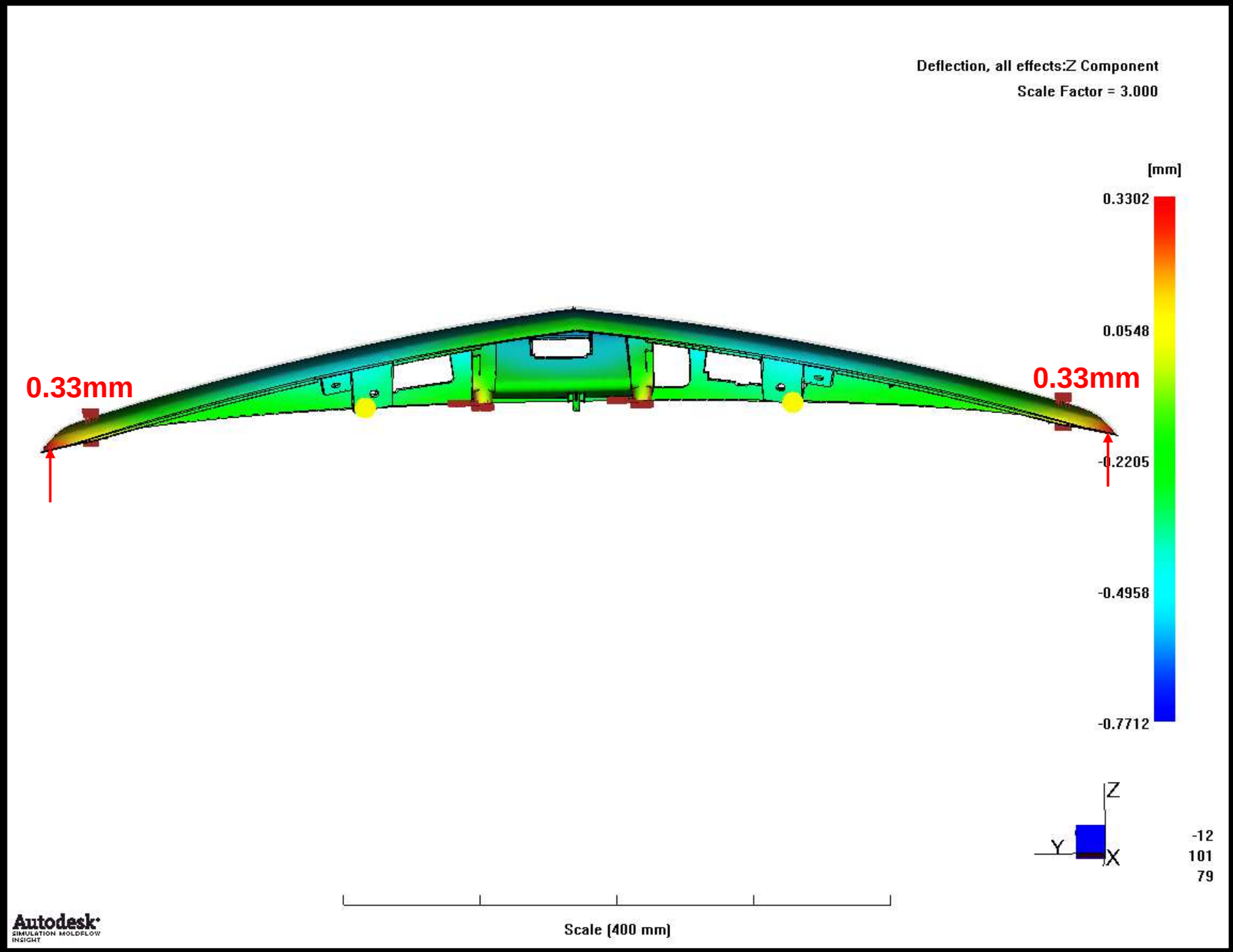
Case Study (Assembly-based warpage by Proposal1)

Put constraint directly on Moldflow to make warpage analysis.



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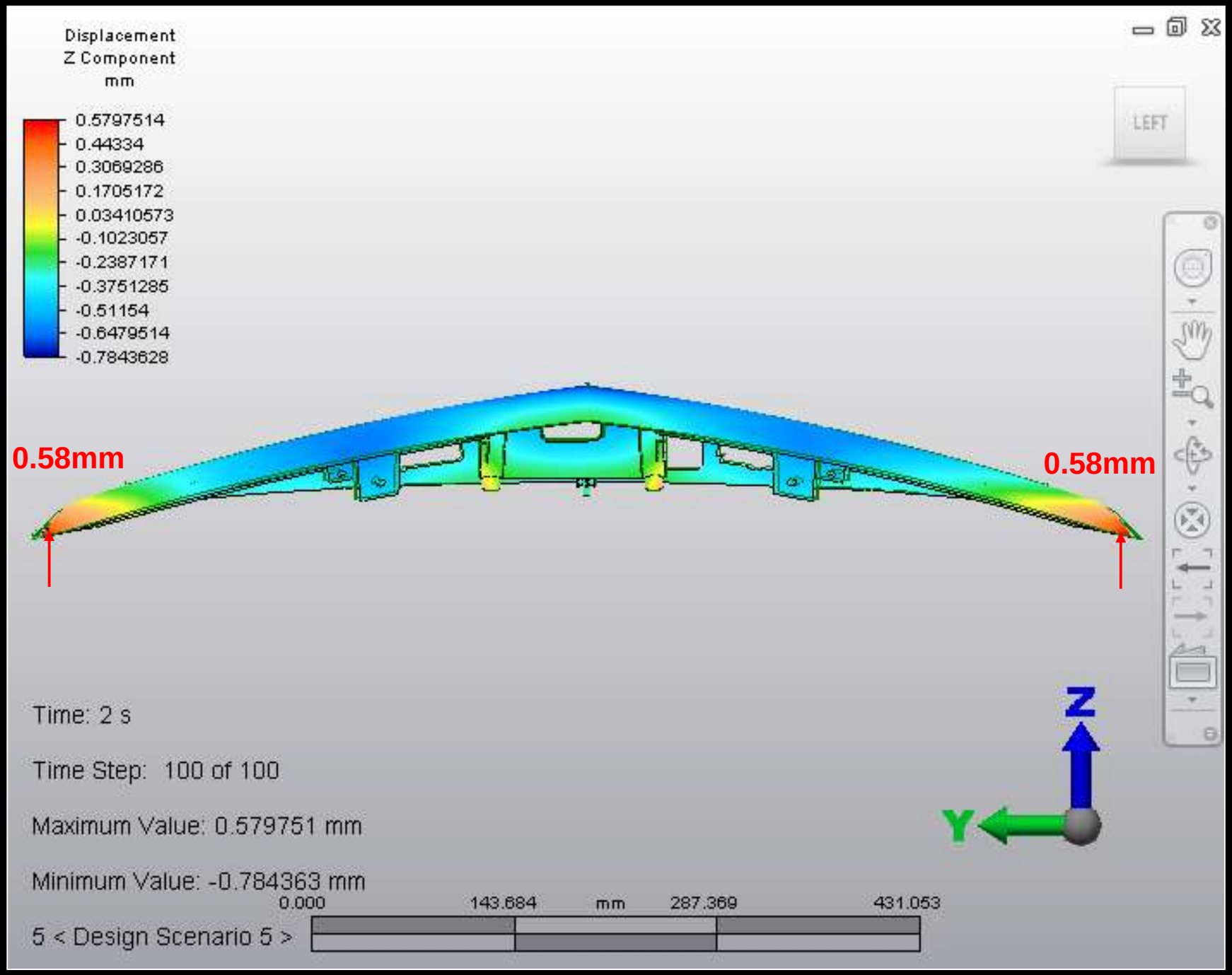
Case Study (Assembly-based warpage by Proposal3)

Release residual stress in Mechanical first, then make displacement installation.



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Actual installation results comparison

Actual warpage tested by inspection tool :

Z direction deflection

= 1.25mm - 0.7mm(theoretical gap)

= 0.55mm

➔Proposal **3 result 0.58mm is closest to actual result.**

Proposal4: From CAE to Multi-Scale Modeling

Process FEA	Material Testing & Modeling	Structural FEA

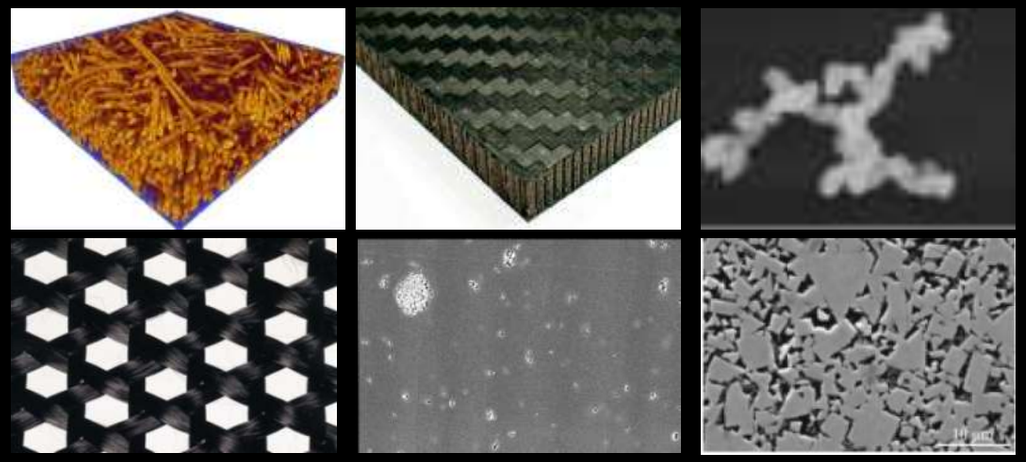
Injection Molding

Autodesk® MOLDFLOW® INSIGHT

Moldflow

digimat®

Abaqus Solution Partner — SIMULIA



Drapage

VISTAGY engineer success™

Simulayt

ANSYS®

LSTC Livermore Software Technology Corp.

Altair

esi get it right™

CAMPUS®

matereality

GRANTA MATERIAL INTELLIGENCE

SAMTECH

Autodesk

Note: This list is not exhaustive. The Logos are Trademarks or Registered Trademarks of their respective owners

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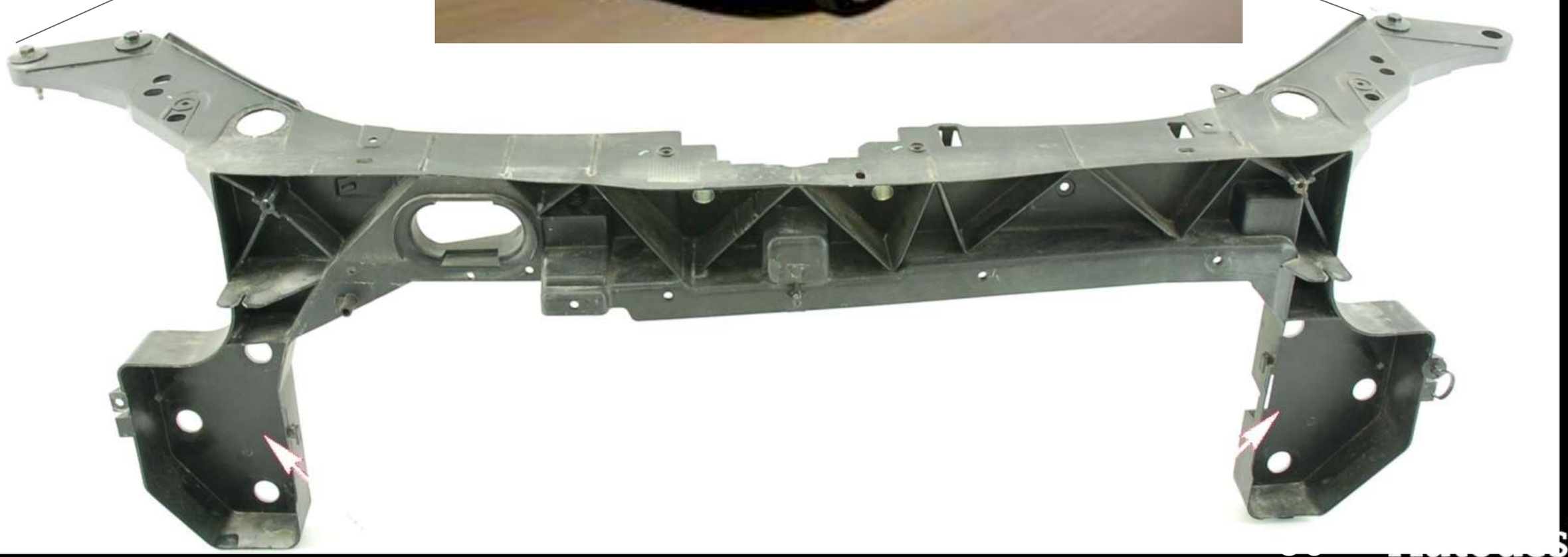
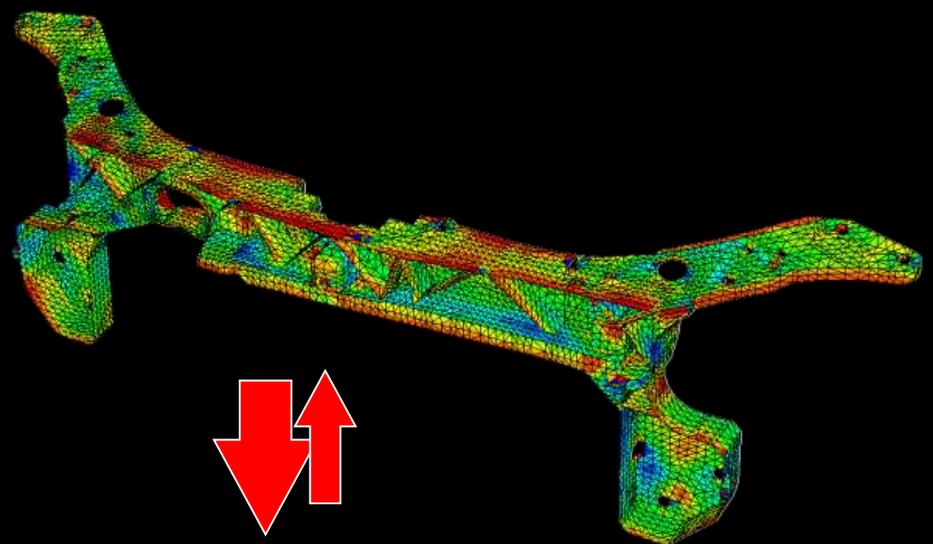
Need for composites Modeling ?

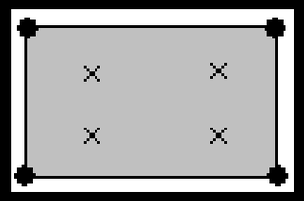


Not taking Microstructure into account…

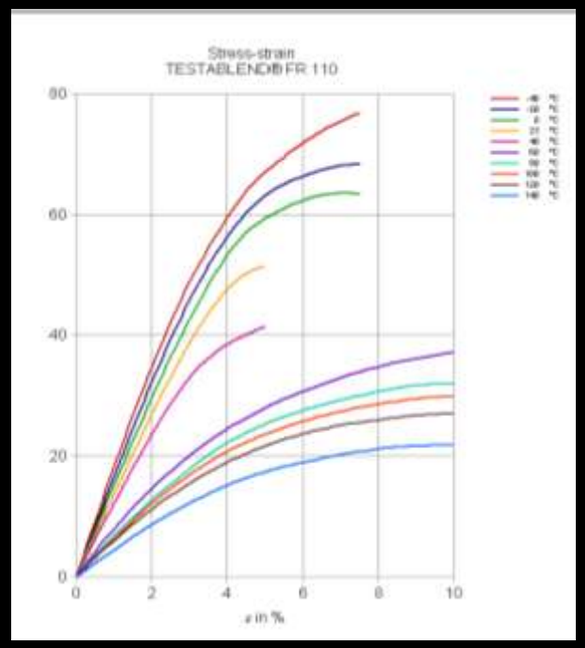
FE-Code



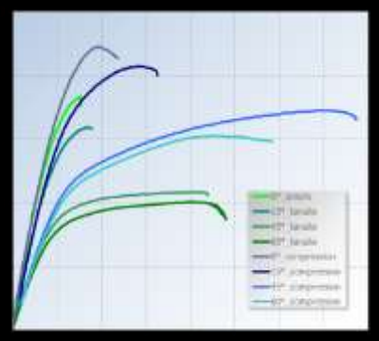
Element



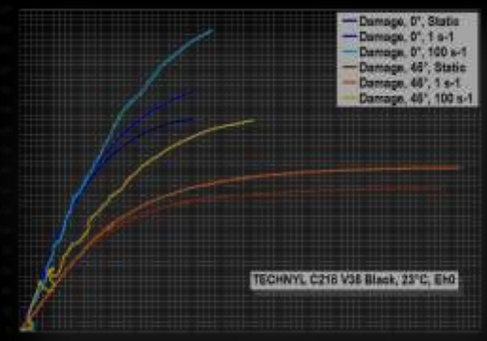
Material



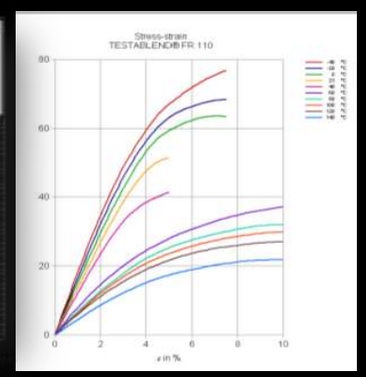
Angle
& Loading



Strain-Rate



Temperature



Test Data:

Tension, Compression, Shear, …

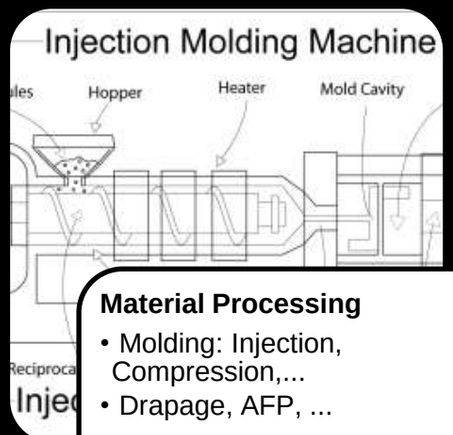
Postulated Material Models:

Elastic, Elasto-Plastic, …

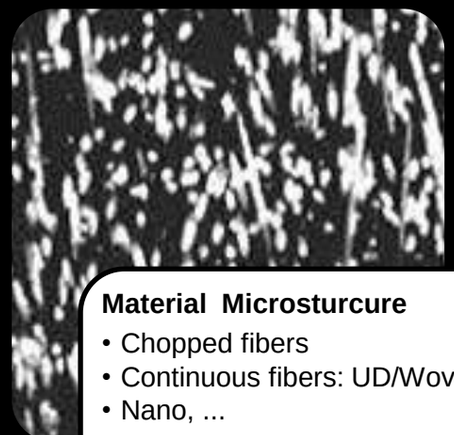
Simplified behavior:

Isotropic, Homogeneous, …

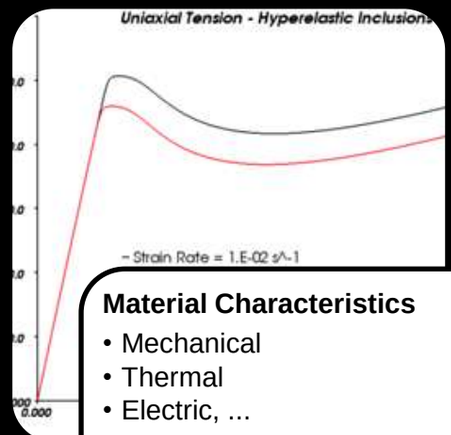
Accounting for Process↔Material↔Structure



Material Processing
- Molding: Injection, Compression,...
- Drapage, AFP, ...



Material Microsturcure
- Chopped fibers
- Continuous fibers: UD/Woven
- Nano, ...



Material Characteristics
- Mechanical
- Thermal
- Electric, ...

Part/Vehicle Performance

→ Clear relation between the processing and the structural performances of composite parts.

But how to account for this relation?

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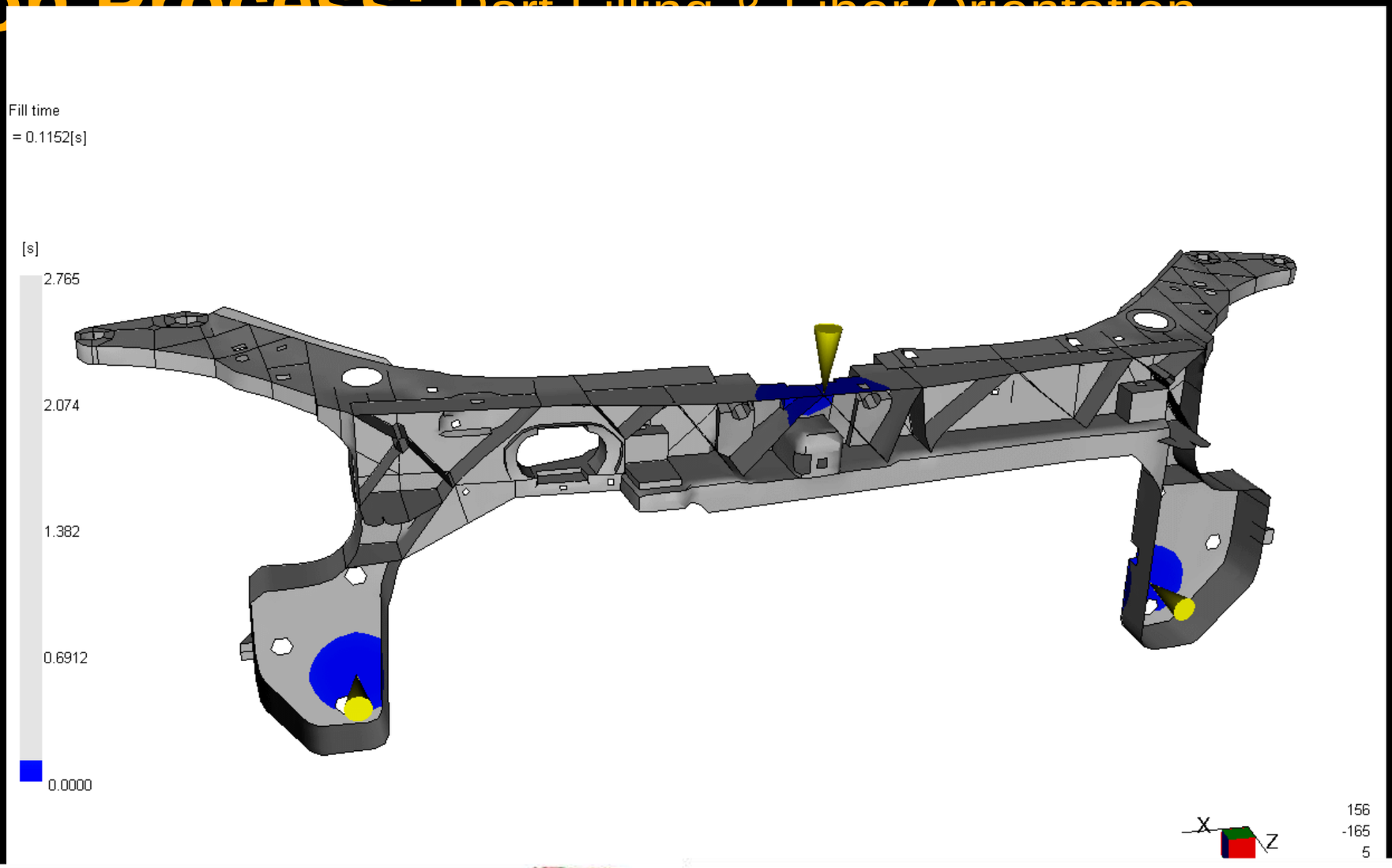
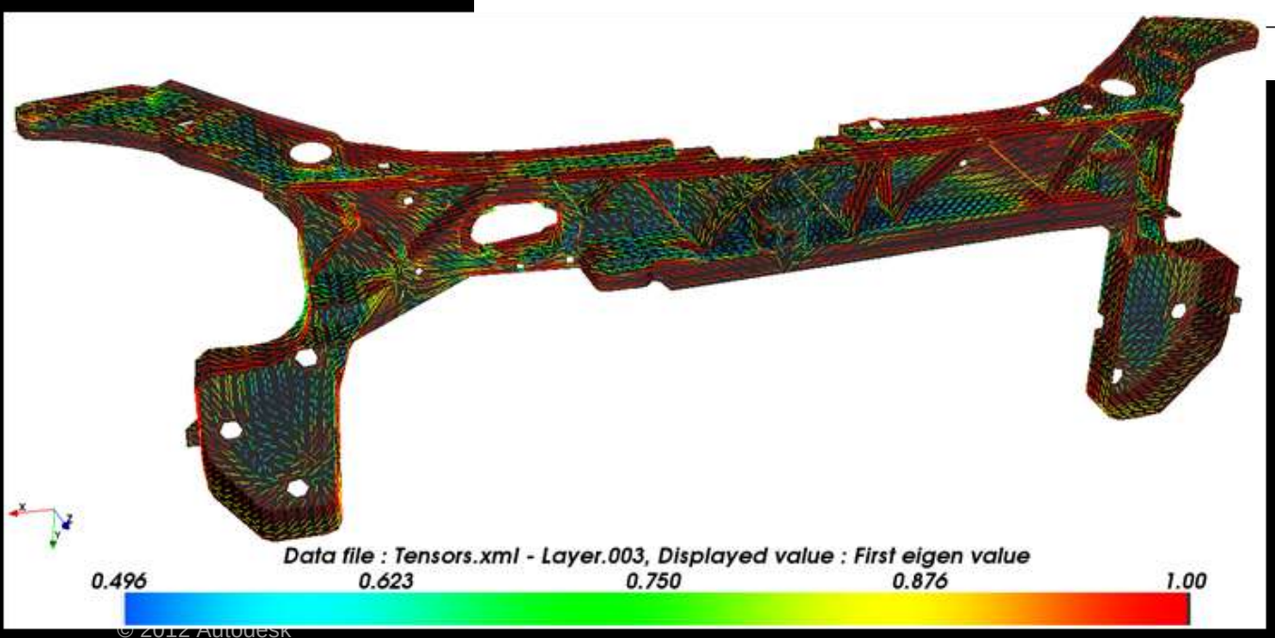
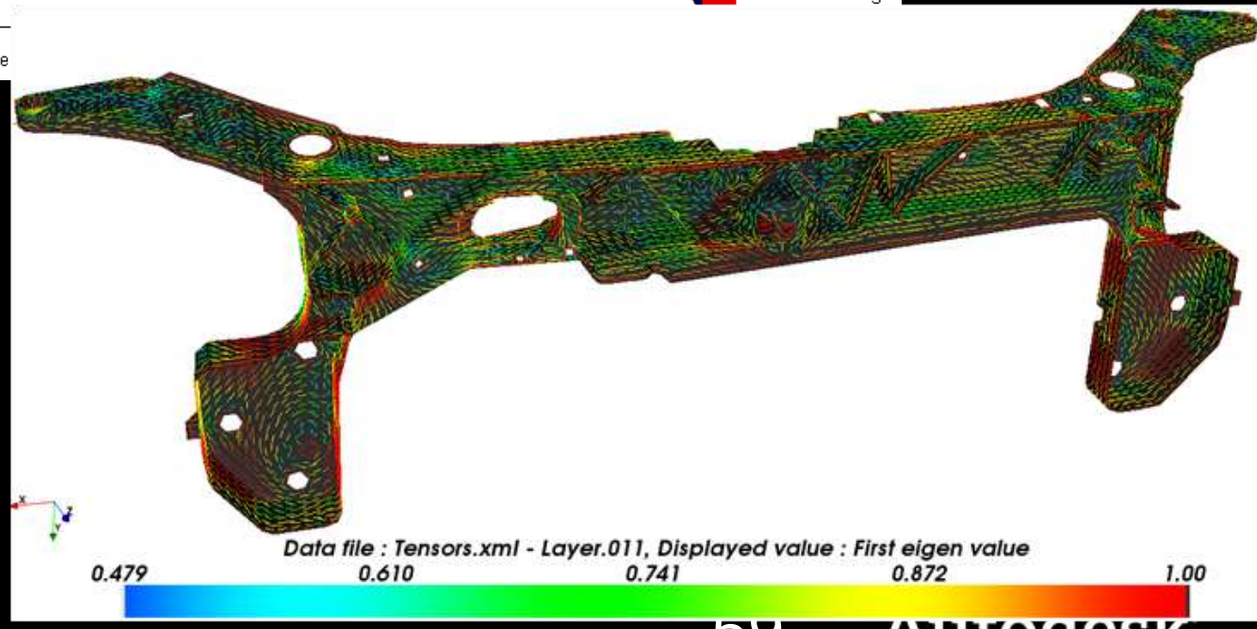
Injection Process: Part Filling & Fiber Orientation





Scale



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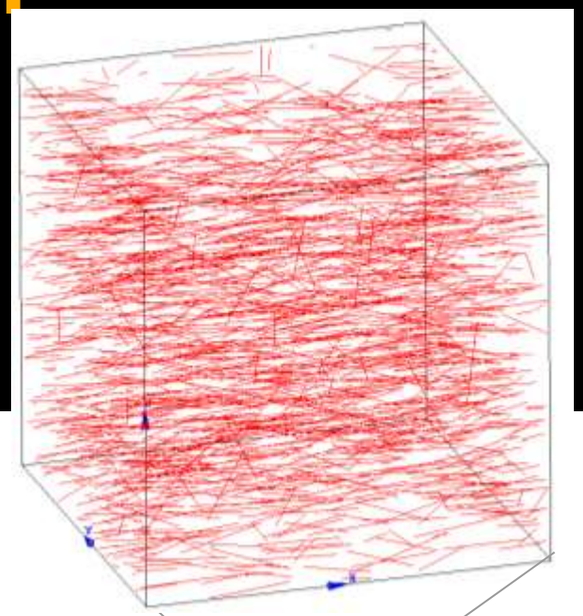
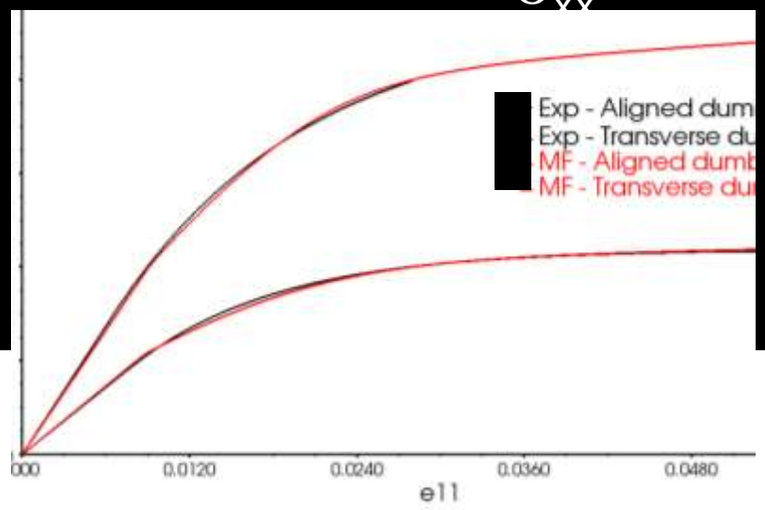
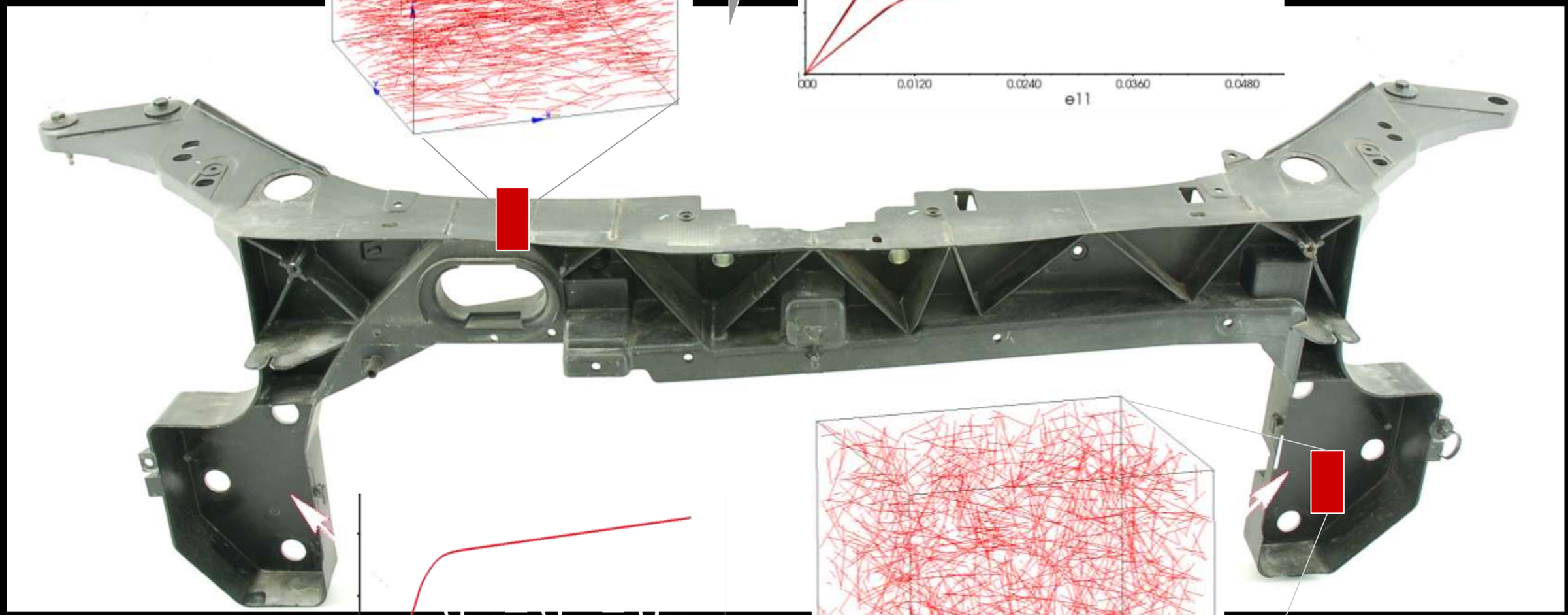
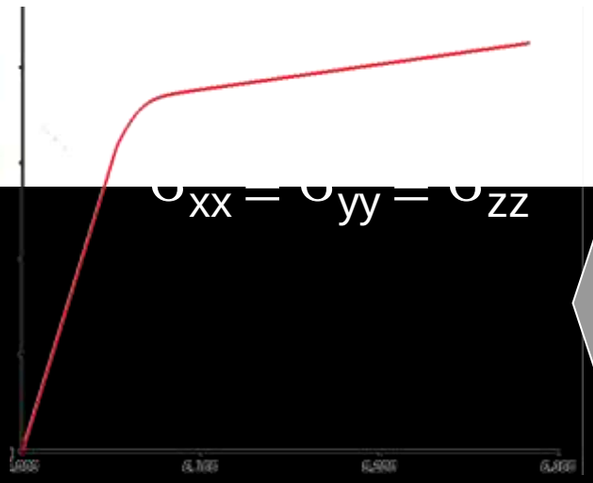
Thermoplastics anisotropic properties









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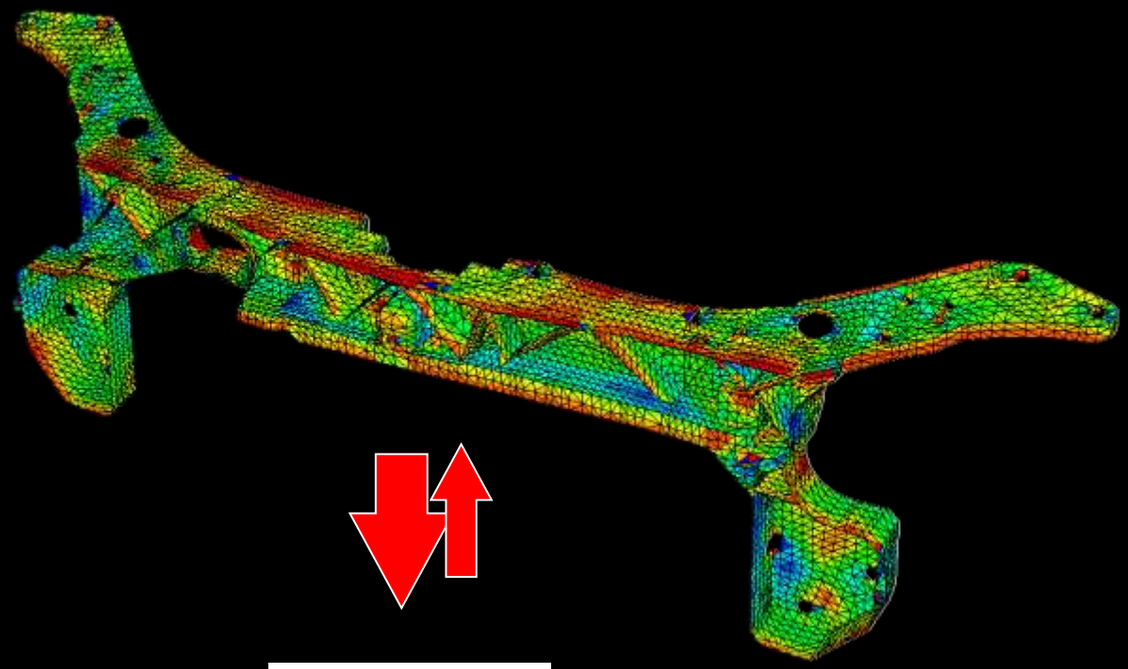
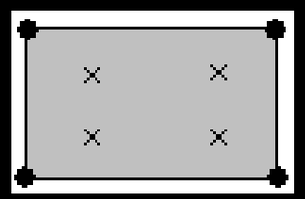
Nonlinear Mutli-Scale Modeling

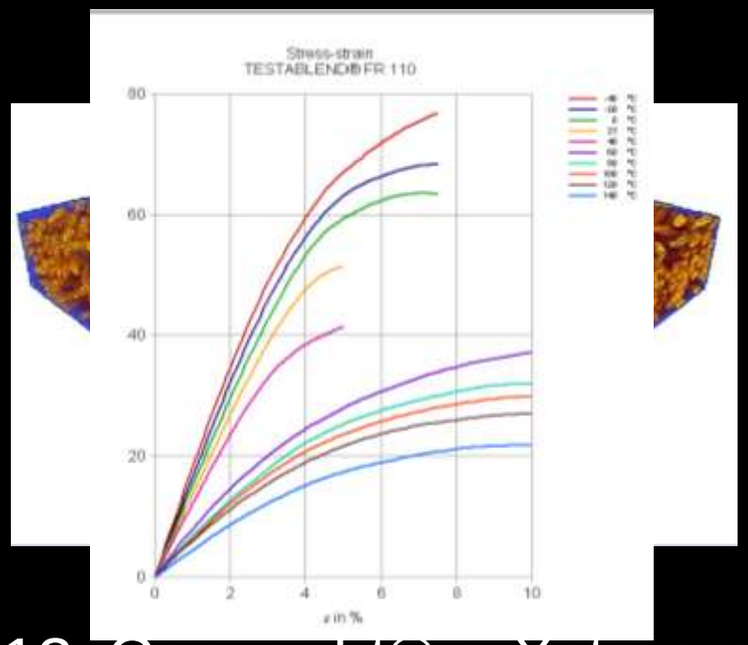
FE model



Element



Material



Replace the usual basic material models by DIGIMAT material models !

Accounting for

- Local microstructure (AR, θ, w.f.)
- Nonlinearity
- Strain-rate dependency
- Thermo-dependency

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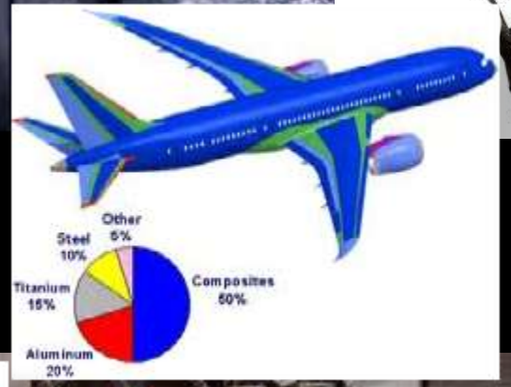
Composites is important in our daily



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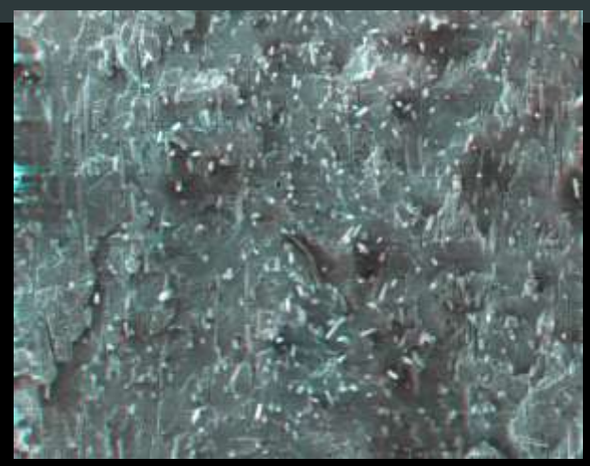
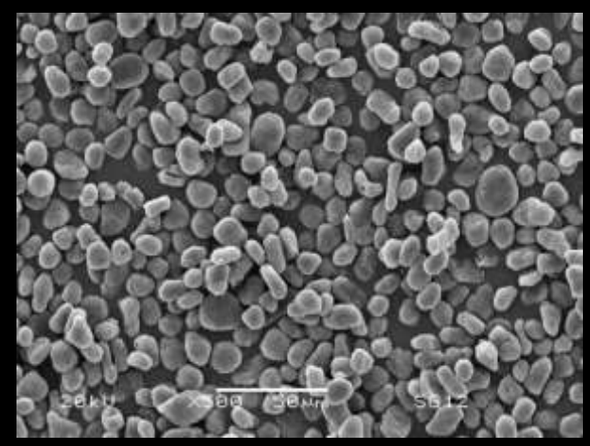
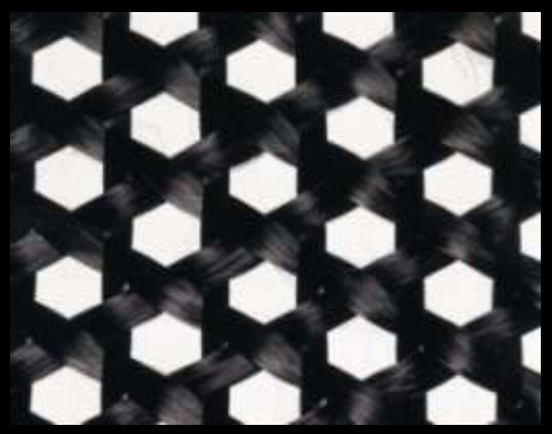
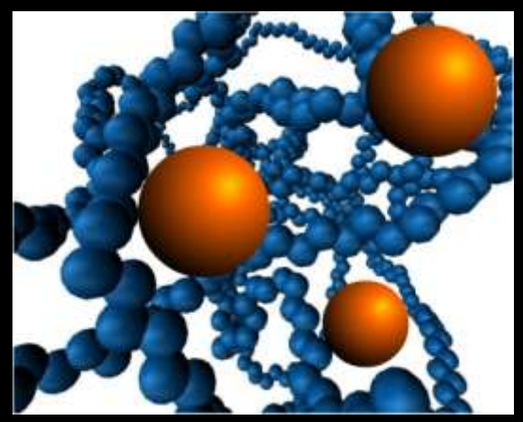
Material Suppliers

- Material Suppliers
  - Plastics
  - Composites
  - Rubber
  - Nano Materials
  - Hard Metals, Graphite, Ceramics etc…









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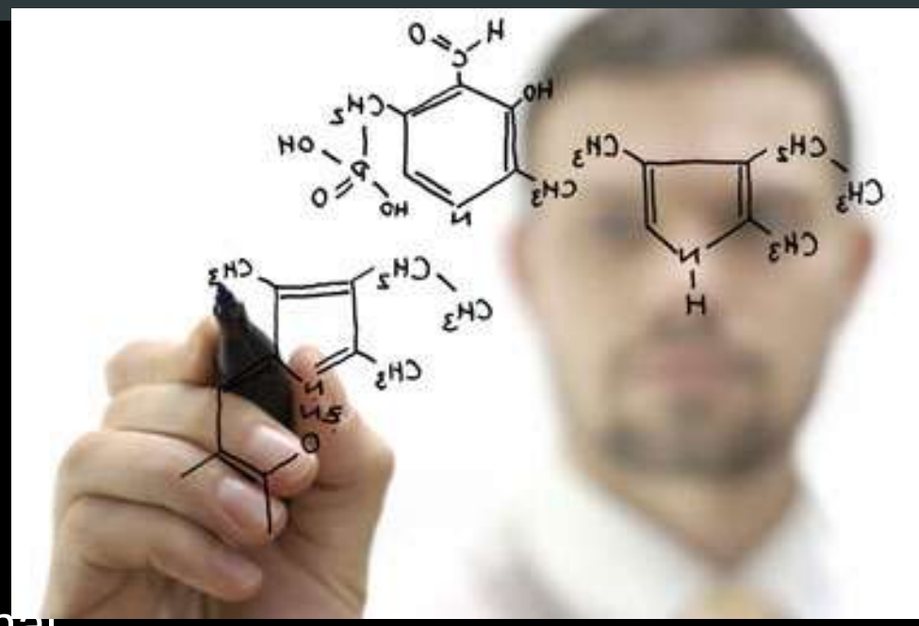
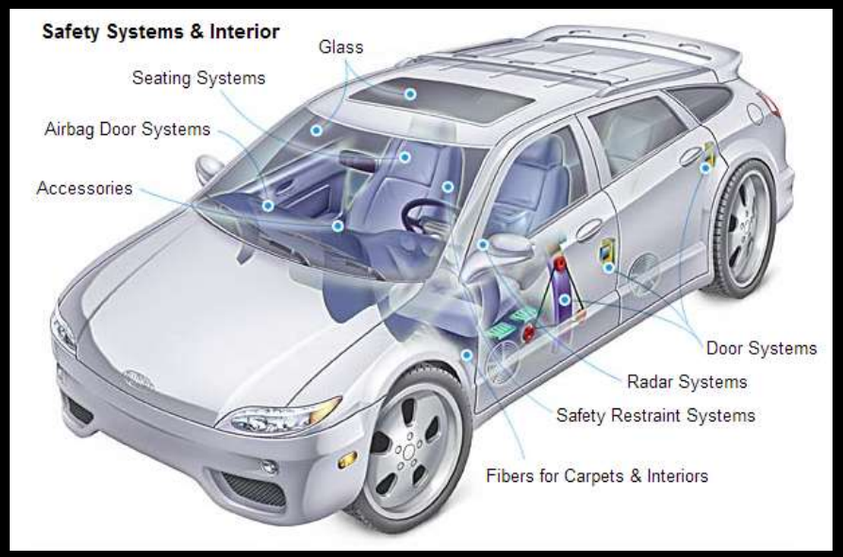
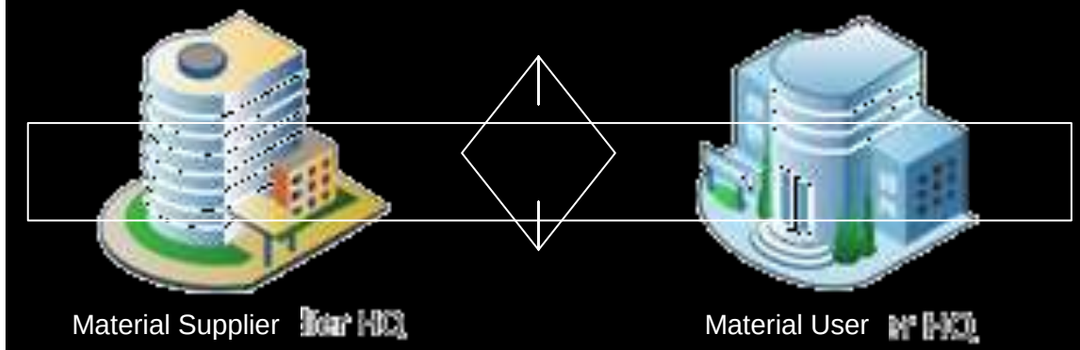
- Material Engineers:
  - To Understand & Optimize Material Behavior
    - How to design/select the optimal material?
  - To Reduce Material Testing (Time & Cost)
    - How to optimally process the material?
  - To Promote Material Usage and Support the Internal and External



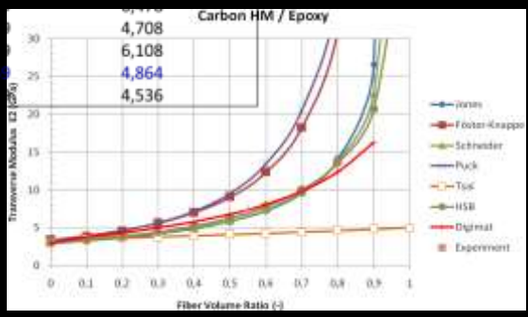
Users of the Materials

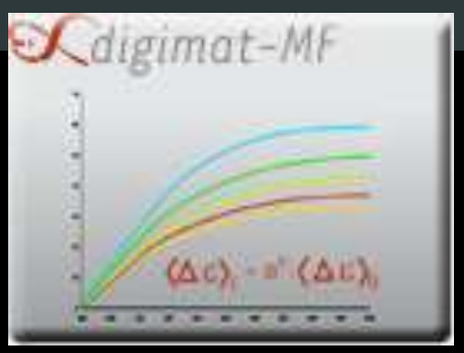




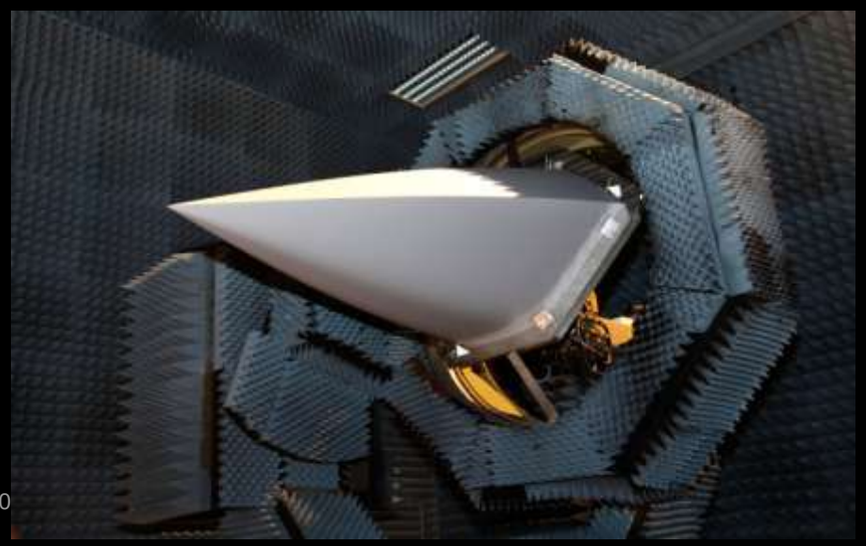
DIGIMAT 349,590 12,590 0,252 0,515 4,505 4,150

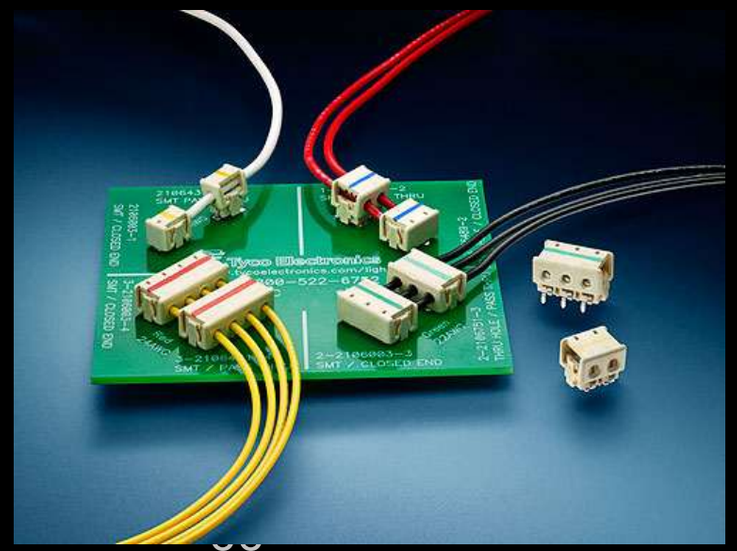
Halpin-Tsai 349,555 12,878 0,259





- **Material "Users" (OEMs & Suppliers**
  - Automotive
  - Aerospace
  - Consumer (Electronics) Products
  - Defense
  - Industrial Products
  - Medical Devices
  - Others ...





- **Material “Users” (OEMs & Suppliers)**
  - To Understand & Optimize Structural Behavior
    - How to design the optimal component?
  - To Reduce Component and System Testing (Time & Cost)
    - How to optimally process the part to meet the requirements?
  - To meet regulations and increasing constraints
  - To maintain leadership and reduce time-to-market

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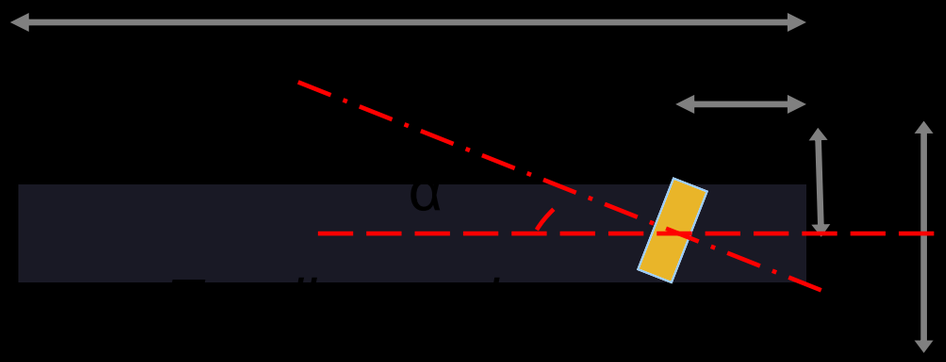
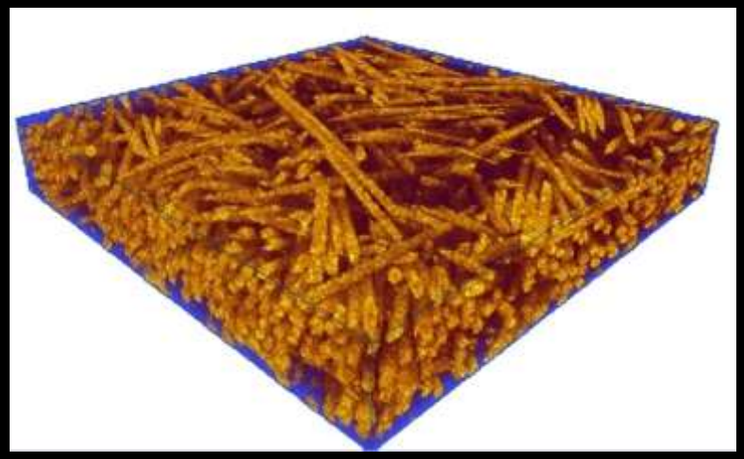
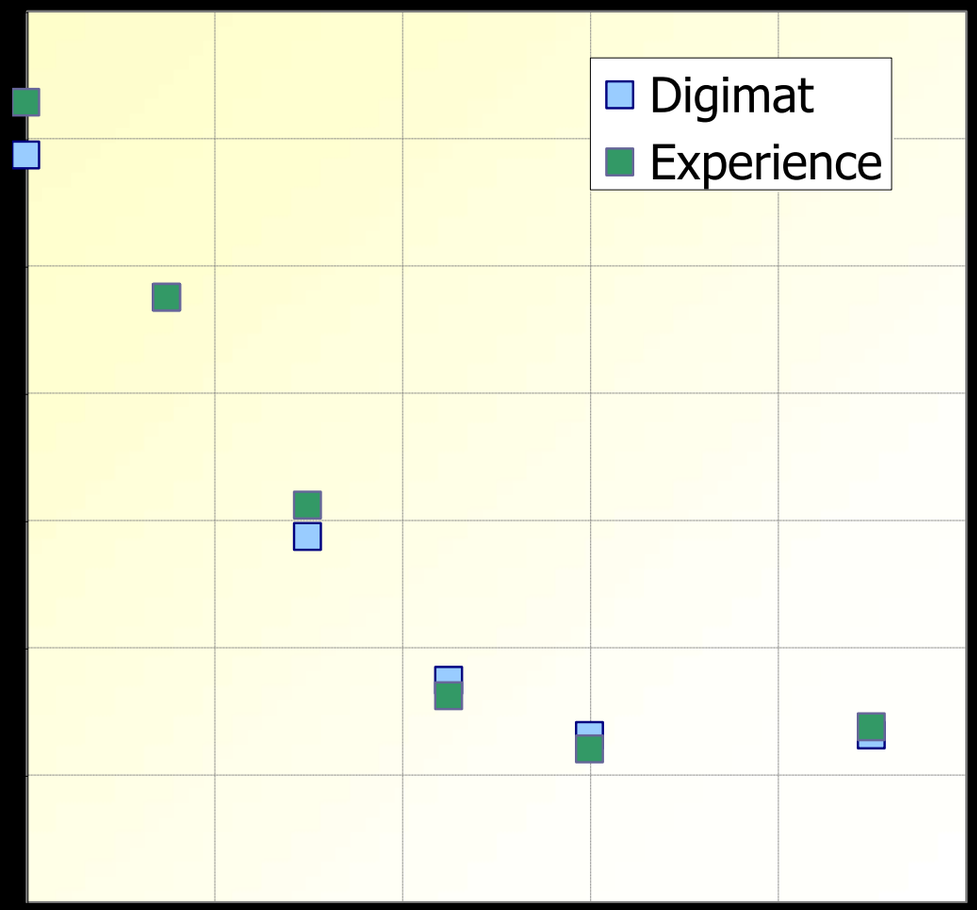
eStream
ENGINEERING

FEW EXAMPLES ...

Mechanical: Young's Modulus







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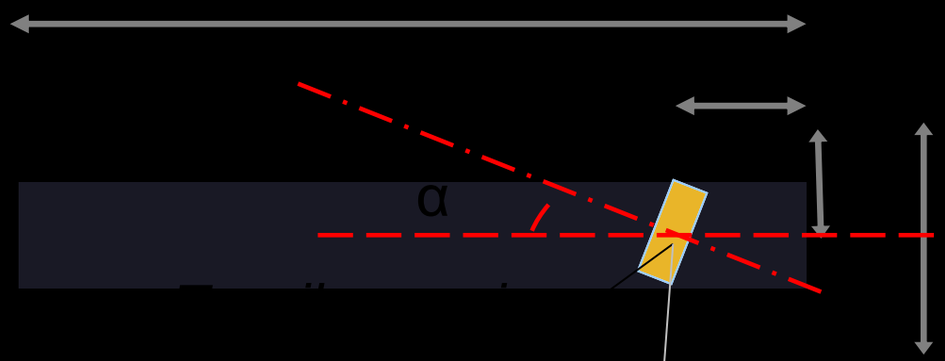
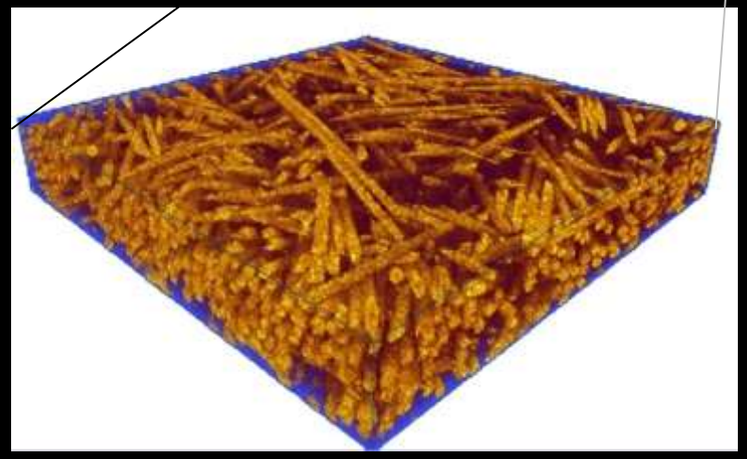
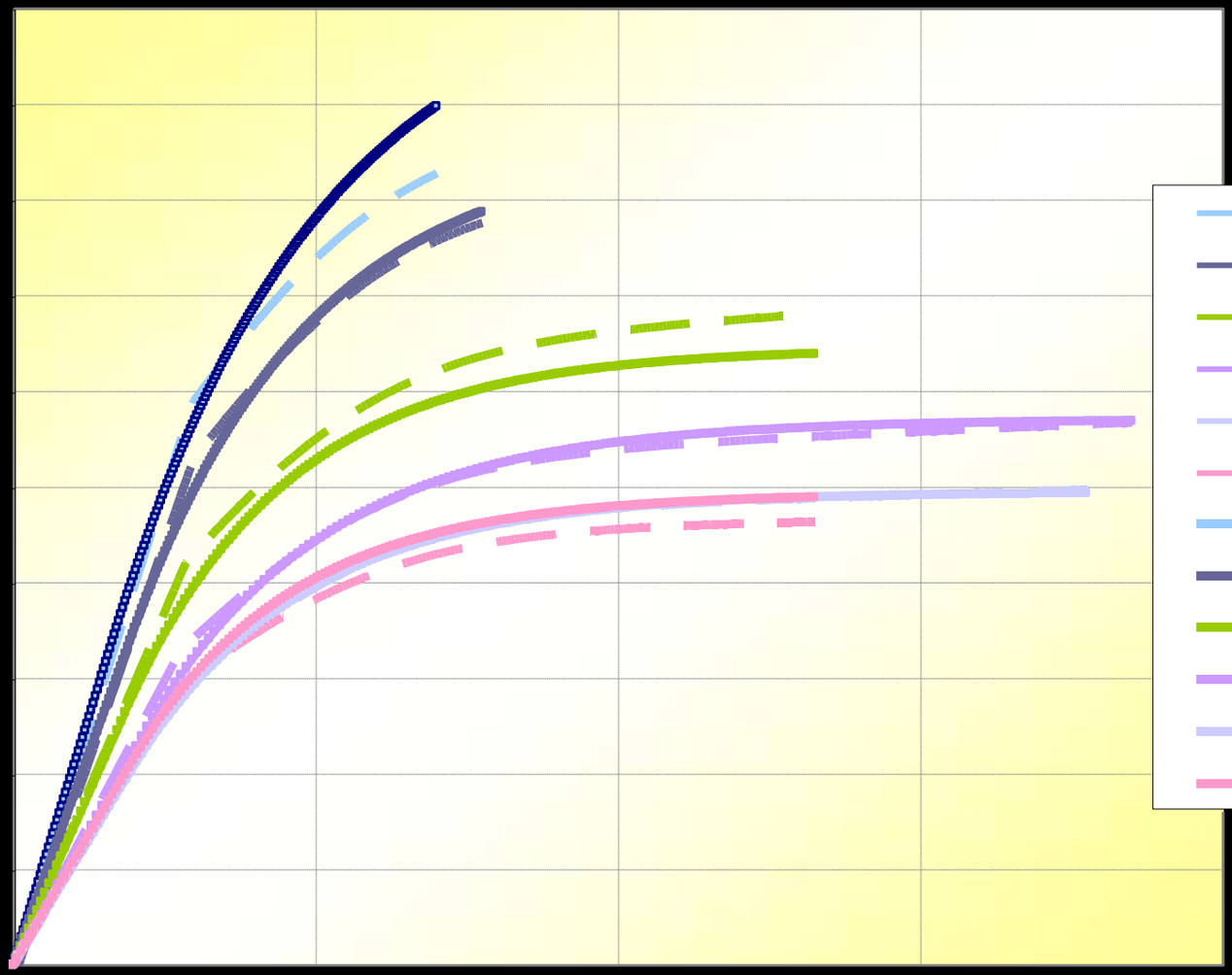
Mechanical: Non-linear Stress-Strain







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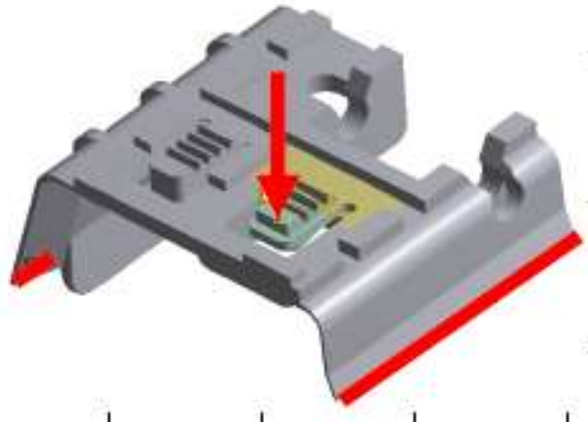
0,08

Rhodia

Roof System Bearing: Local Stiffness

Bearing. Simulation Results of Local Load Case

Ticona



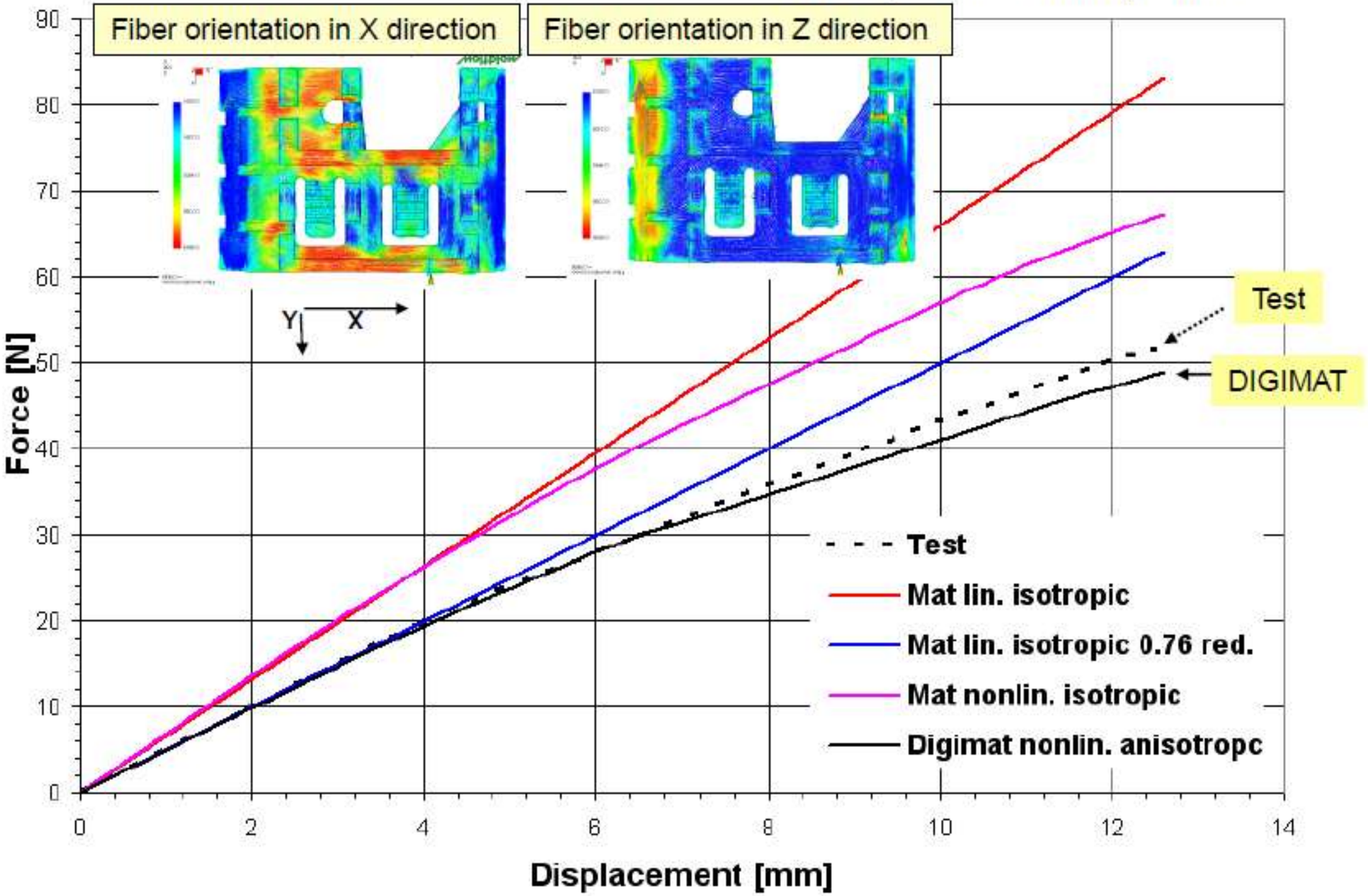
Celanese

Roof System Bearing: Global Stiffness

Bearing. Simulation Results of Global Load Case

Ticona

Results very sensitive to boundary conditions

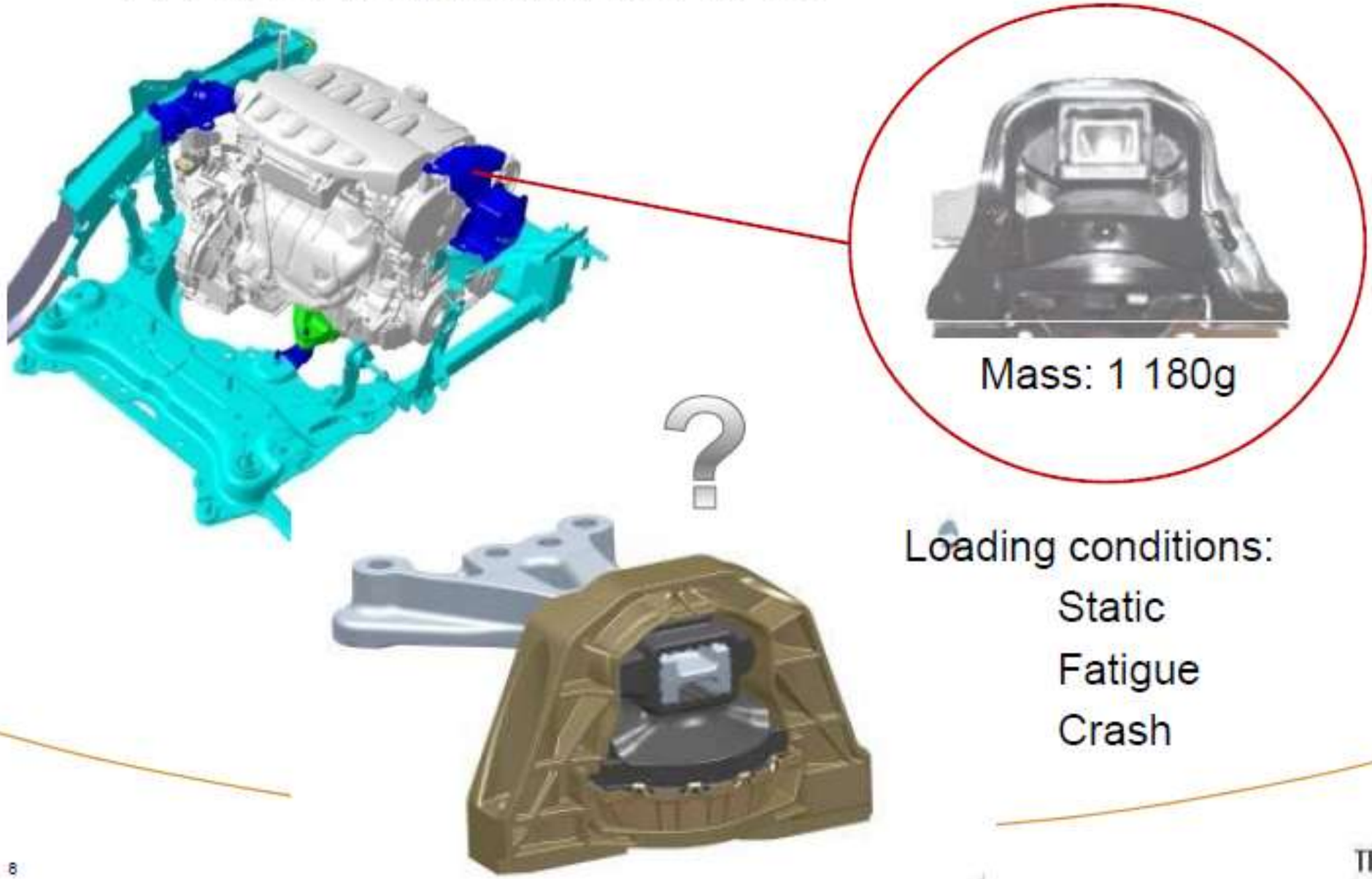


Celanese

Trelleborg/Engine Mount

Application to engine mounting system

- Cascading mass saving to engine mounting system:
  FIAPLAST program launched in 2007



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Trelleborg/EngineMount: Sim Method

FIAPLAST: accounting anisotropy in FEA

MOLDFLOW

HYPERMESH

MATERIAL DATA BASE

Rhodia

Chemistry is our world, Responsibility is our way

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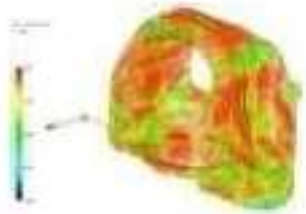
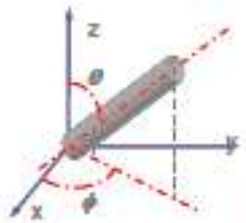
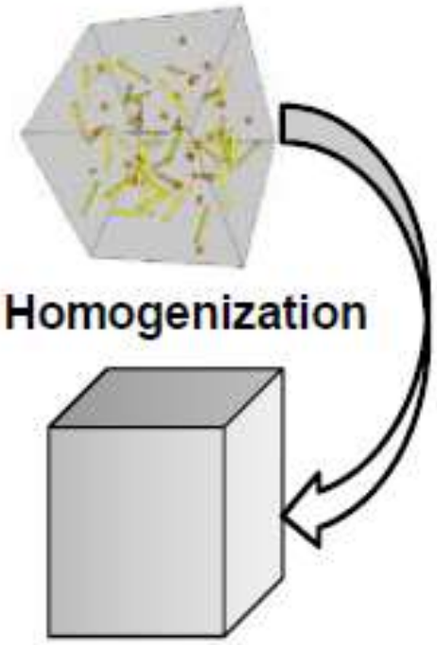
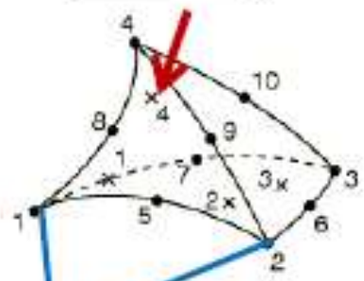
BOUNDARY CONDITIONS → ABAQUS

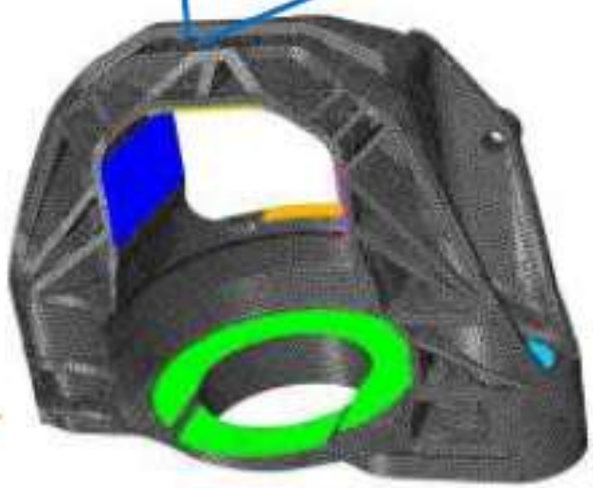






Homogenization





TRELLEBORG

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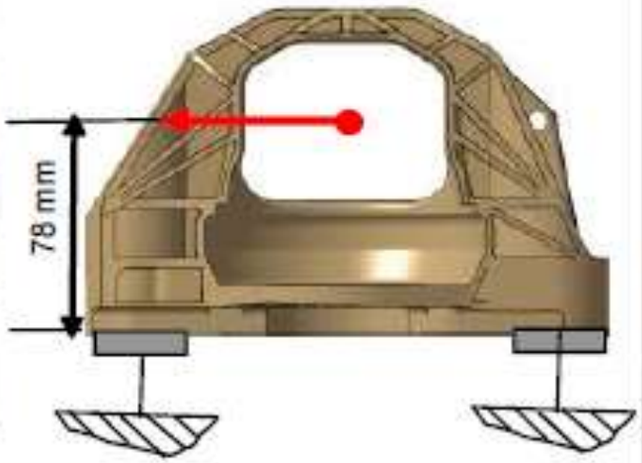
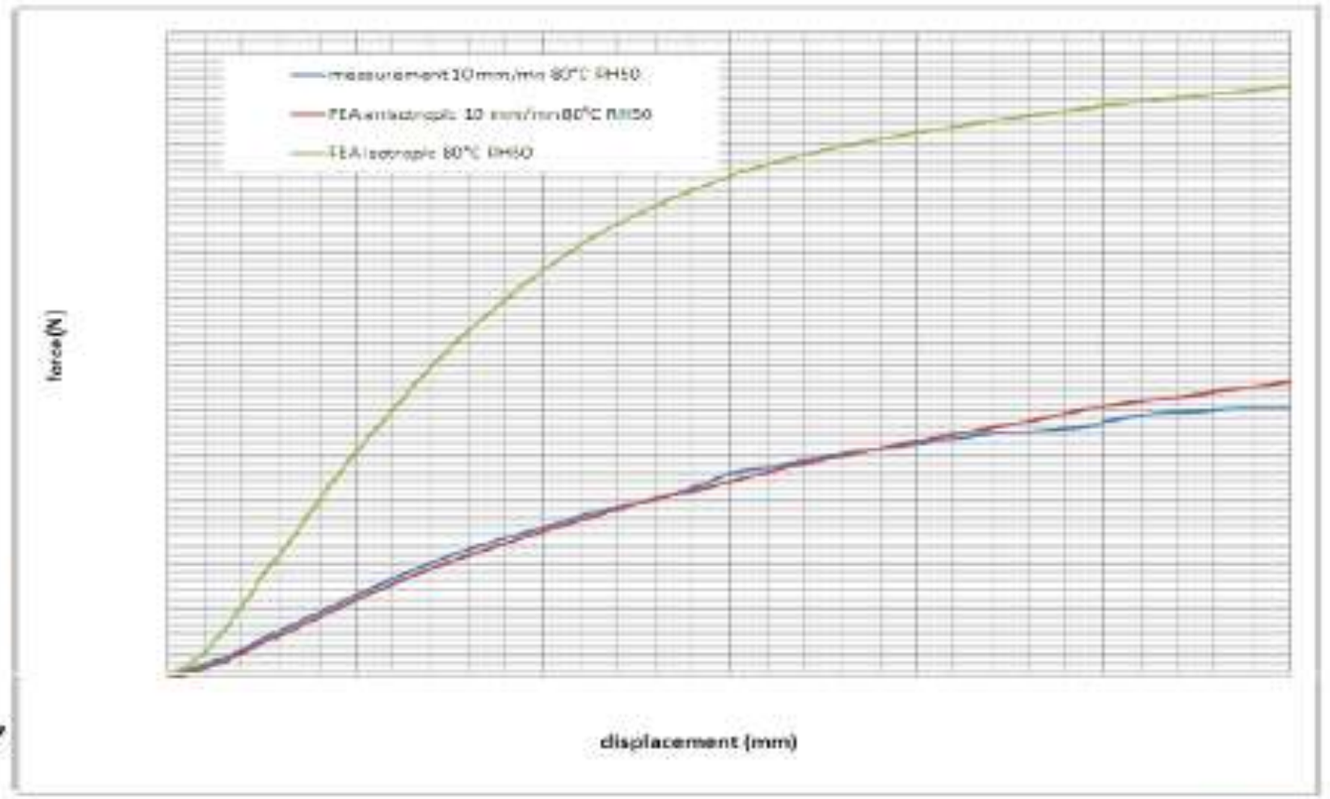
Trelleborg/Engine Mount: Results Validation

Anisotropic FEA → quasi static correlation

- **Testing conditions**
  - Water content: RH50
  - Temperature: 80°C
  - Testing speed: 10 mm/mn





Trelleborg Failure criterion

TRELLEBORG

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Trelleborg/Engine Mount: Conclusions

Conclusion - Outlook

- An industrial FEA procedure accounting non linearity and anisotropy of PA6.6 GF reinforced is available.
- Good correlation FEA/test achieved for static and fatigue
- Part availble for mass production

Mass: 710 g

Cost: -15%

Start of production 2012

- Crash simulation validation (on going)
- Life duration prediction development: DURAFIP

TRELLEBORG

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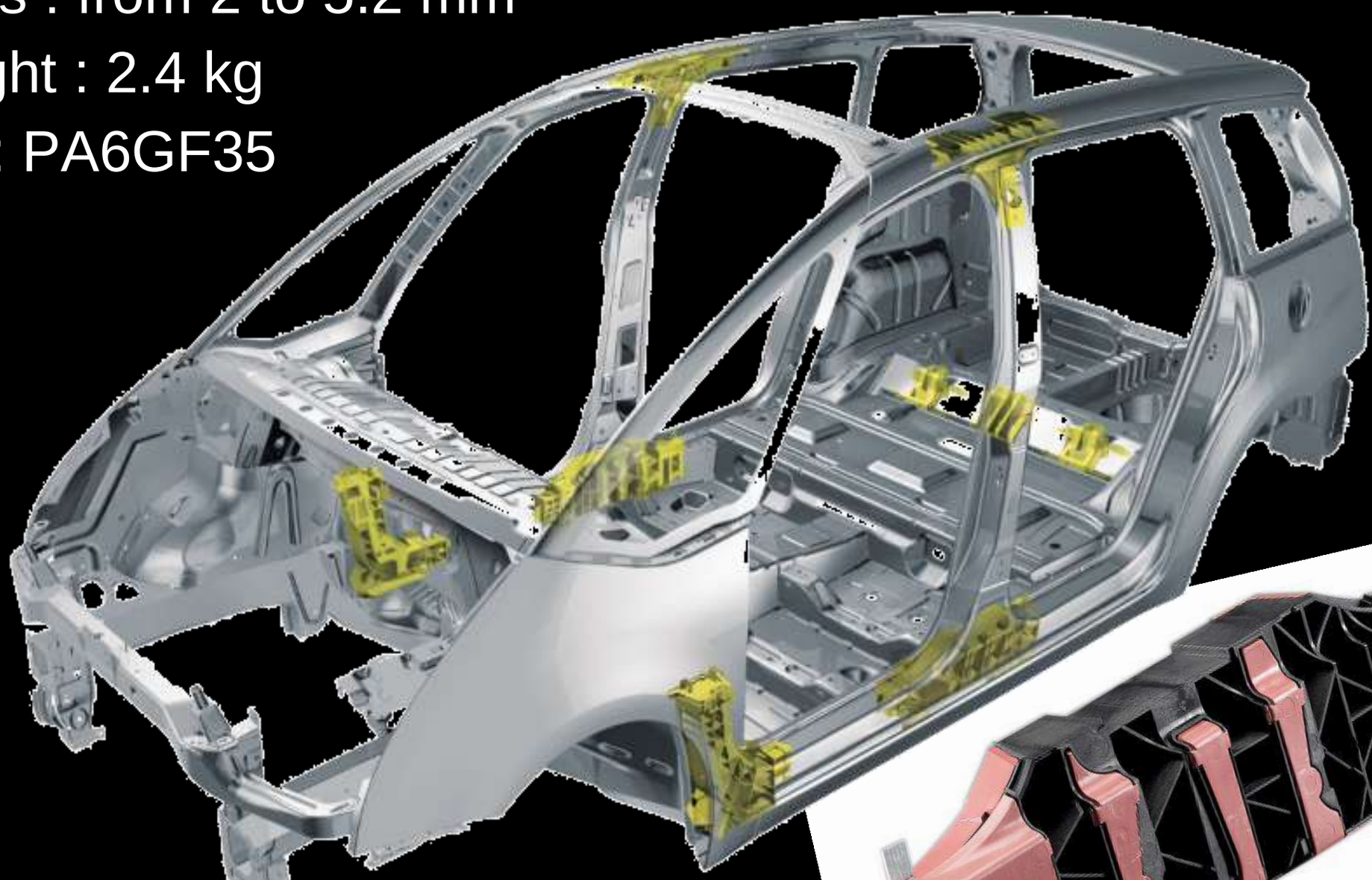
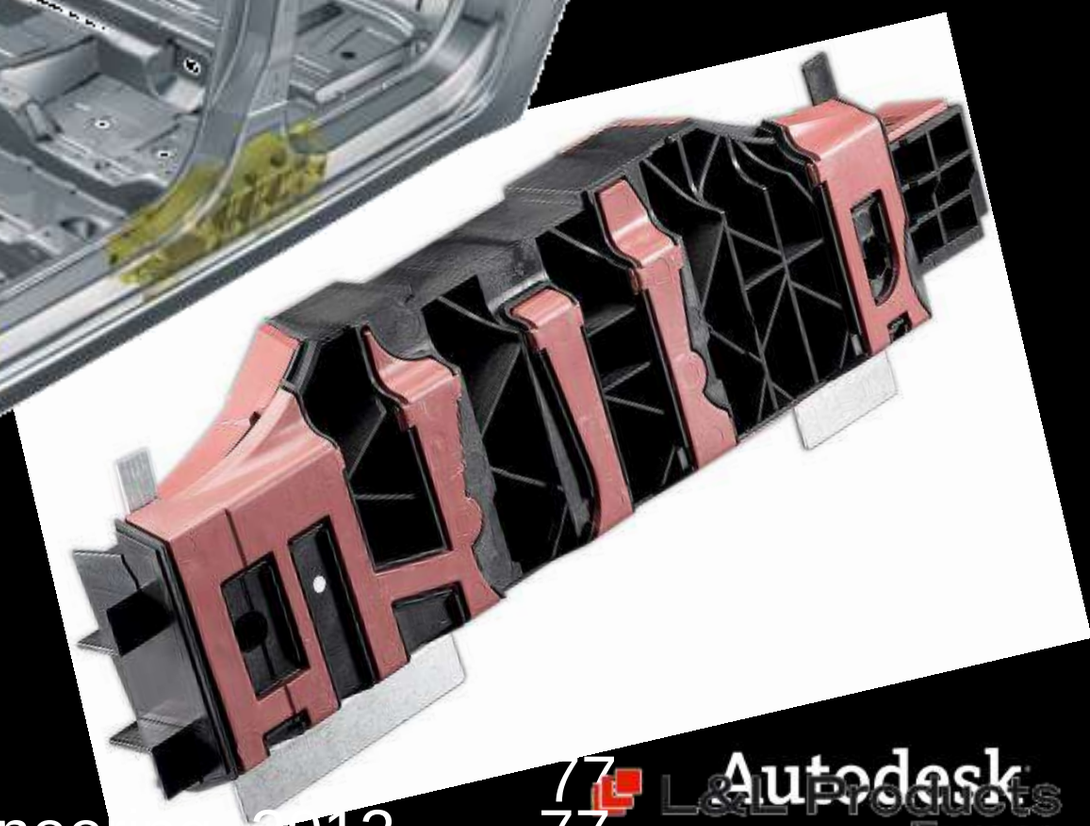
Lower B Pillar Insert

- Part size : # 600 * 170 * 85 mm
- Thickness : from 2 to 5.2 mm
- Part weight : 2.4 kg
- Material : PA6GF35





Dr. F. Braymand, L&L Products
"Improved Physical Property Prediction of Short FRP"
(Session 5)

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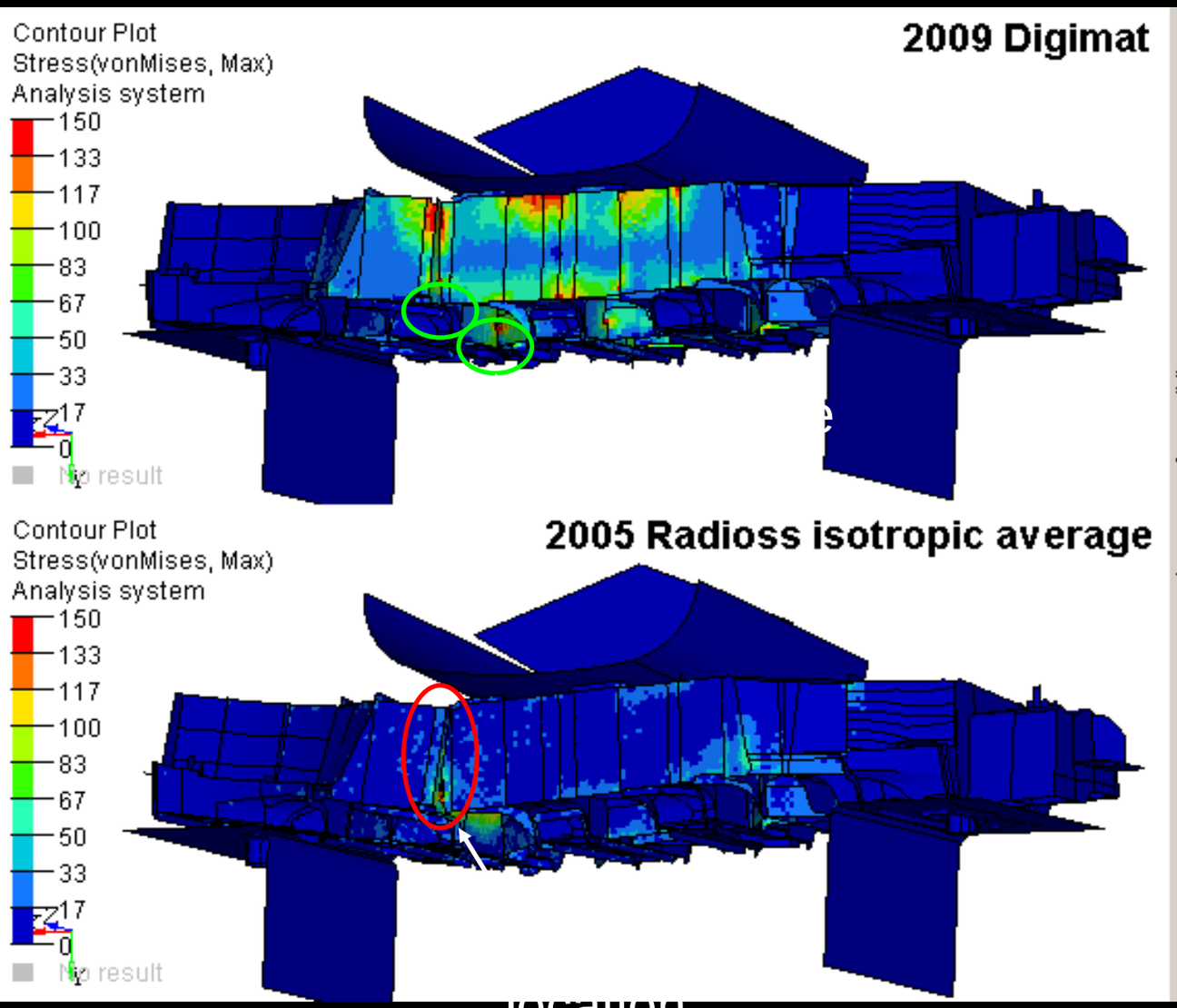
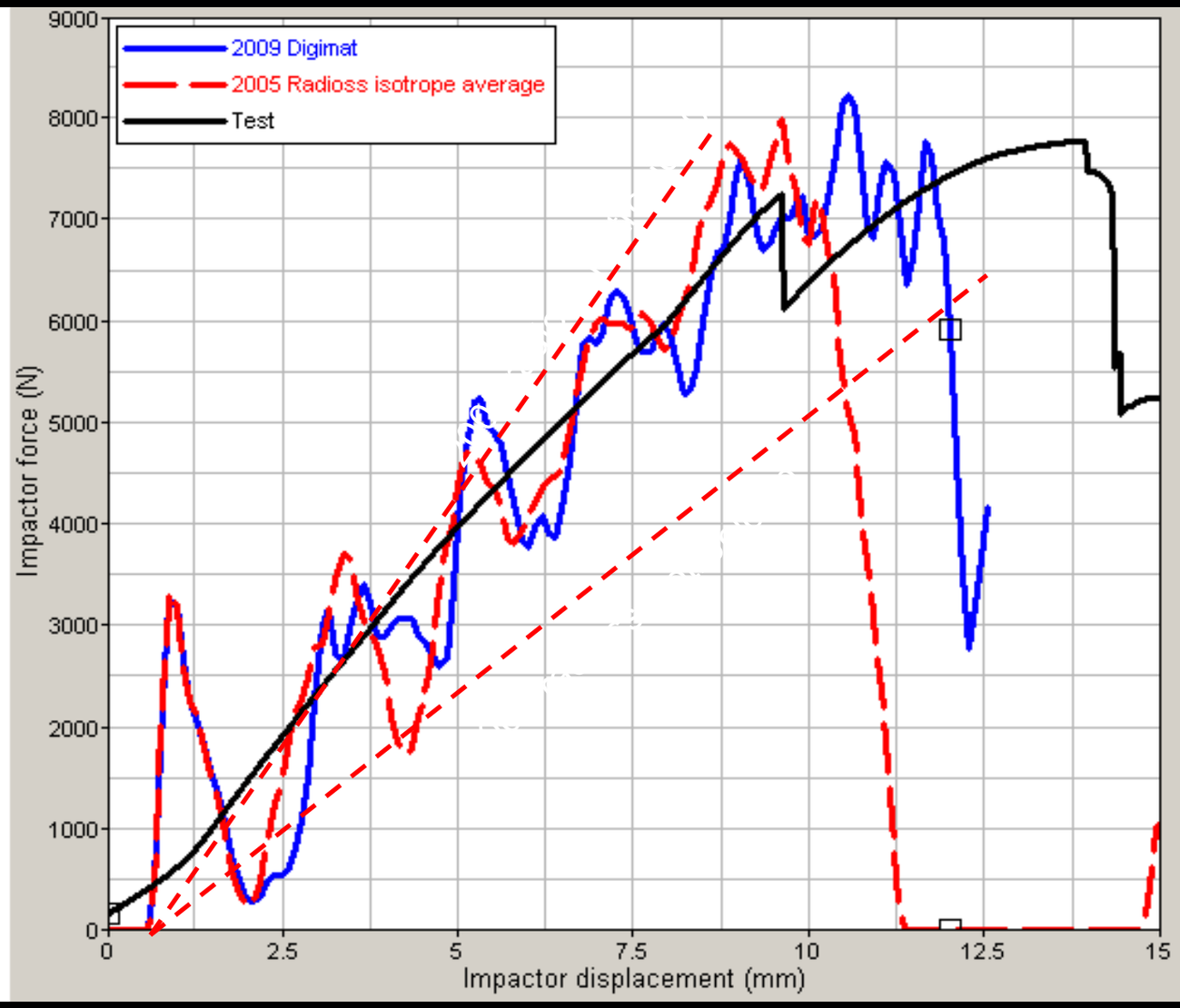
Lower B Pillar Insert: Crash & Failure



location



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HUNTSMAN
Rhodia
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Ford
HONDA
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RENAULT
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DELPHI
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