Injection Molding Fiber Orientation, Property Predictions, and Failure Analysis

Presented by

Robert Sherman

Senior CAE Analyst, RTP Company

What We'll ***TRY*** to Cover

- Source of Fiber Orientation
  - What Causes it
- New AMI 2012 Analysis Features
  - RSC Factor & Its Effects
- Modulus (& Stress) Predictions
  - Without RSC
  - Various RSC Factors
- Improved Stress Predictions

Structural Composites from the Injection Molding Process

- Injection molding products are being utilized in increasingly structural applications
- To date, analysis has consisted of quasi-isotropic analysis
- Quasi-isotropic analysis ***CANNOT*** optimize orthotropic materials properly
- Orthotropic analysis requires failure analysis and strength allowables
- What can be utilized???

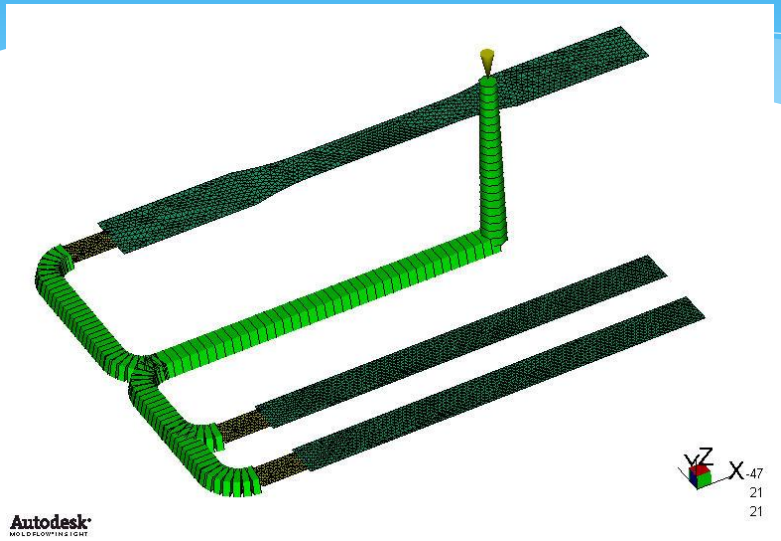
Structural Composites from the Injection Molding Process

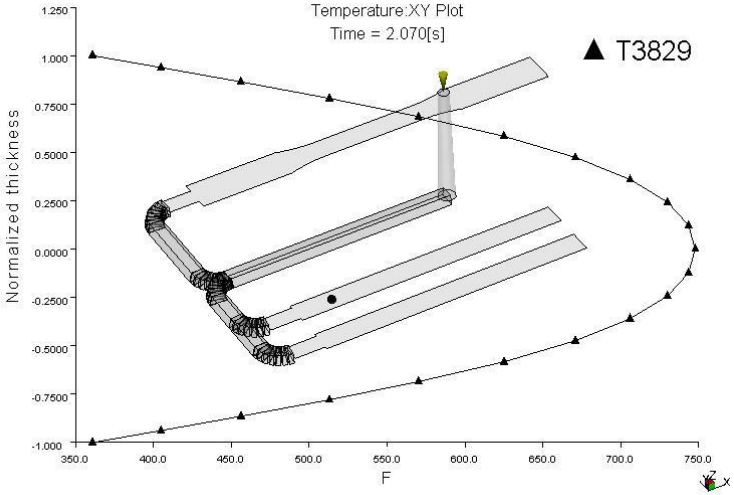
- Sensible approach to the problem: Composite laminate analysis
  - Injection molded materials can be treated like continuous fiber composites
  - Problem : Infinite number of orientations!
  - Systematic approach for evaluation is needed in order to prevent unexpected failures
  - Linear material approach initially

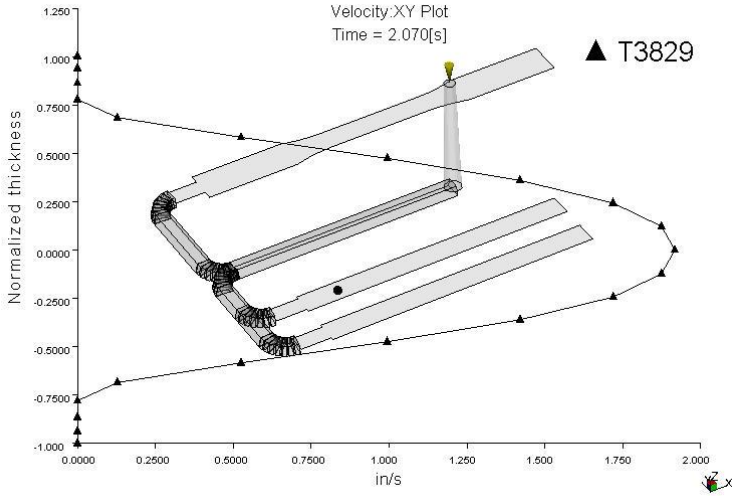
What Causes Fiber Orientation ?

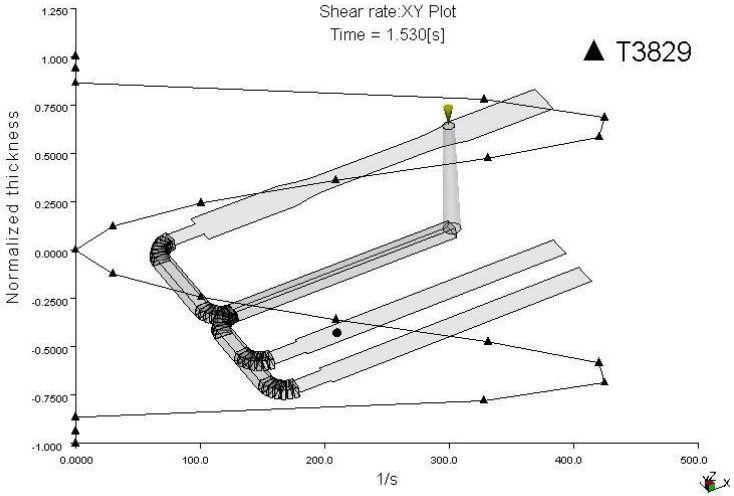
- Two primary forces
  - High shear rate & velocity gradient through part thickness
  - Extensional forces in flow front expansion and contraction
- Fiber orientation is “history” dependent – effects are cumulative as polymer flows from gate to end-of-flow

What Causes Fiber Orientation ?

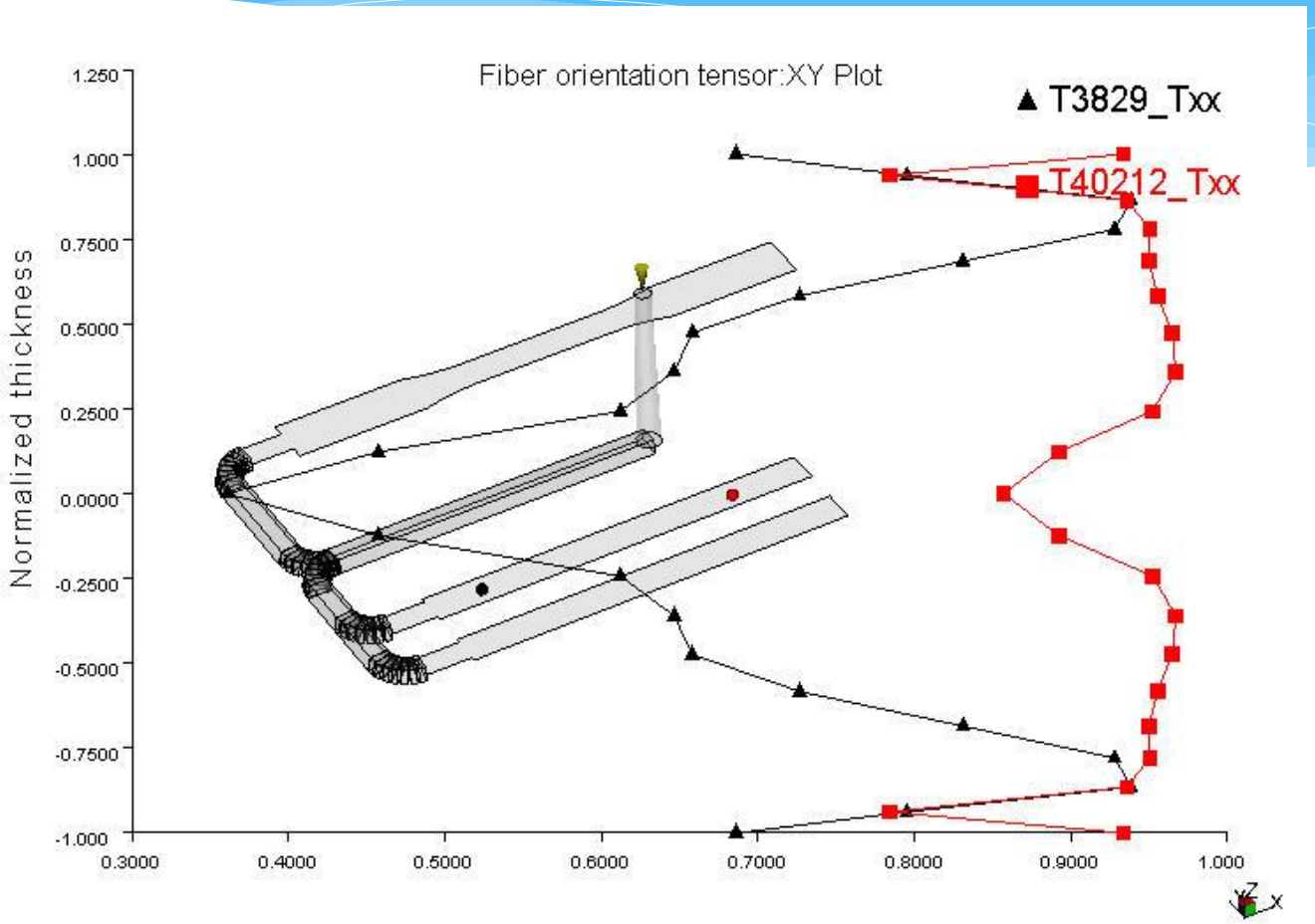




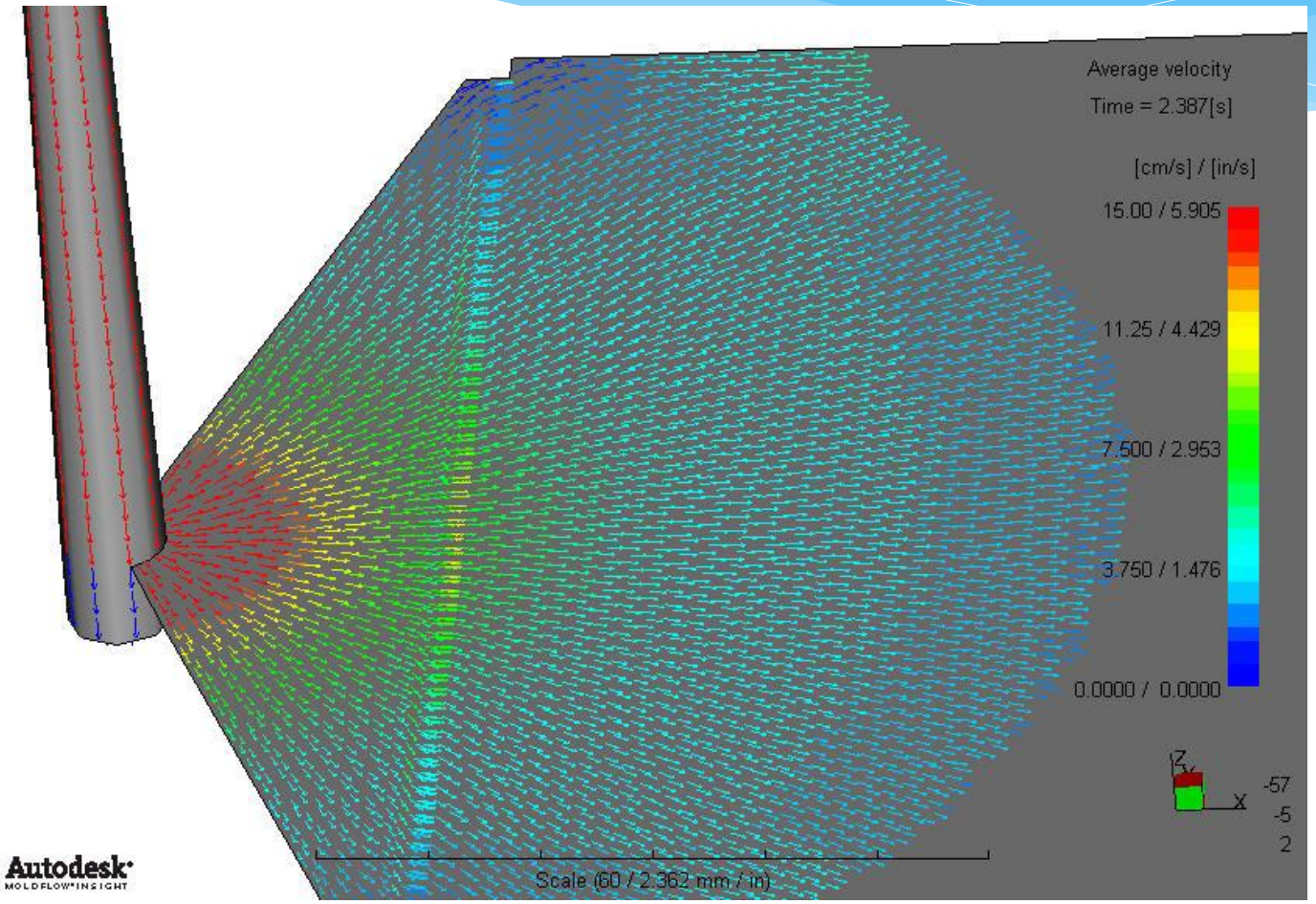




What Causes Fiber Orientation ?



What Causes Fiber Orientation ?



Fiber Orientation

- Shearing forces in outer laminates
- Expansional/contractional forces in middle laminates
- Changing flow directions during fill/pack
- Orientation behavior is sum of the cumulative effects

Autodesk® Moldflow® Insight New Analysis Features

- Fill Preview (real-time fill prediction solver)
- Inventor Fusion Interface for model simplification
- Transient cooling analysis
- Venting analysis
- Long fiber orientation capability (ARD model)
- Short fiber orientation improvements (RSC model)

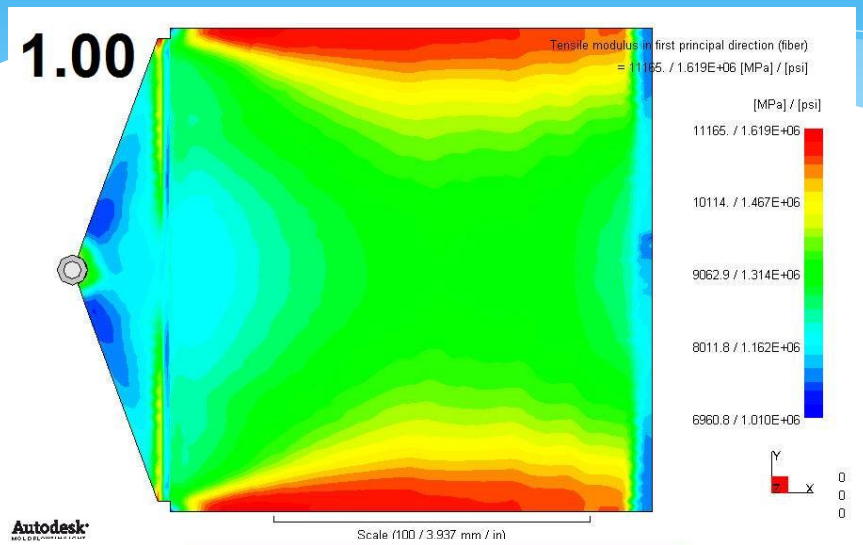
Reduced Strain Closure (RSC) Factor

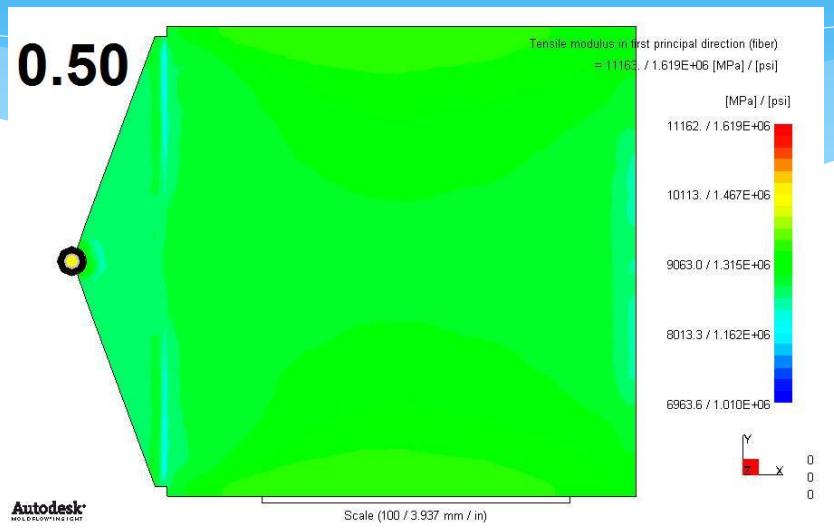
- All fiber orientation predictions previously were fully developed "steady state" orientation
- Reality – orientation takes time to fully develop
- RSC factor introduced to control the rate of development of orientation
- Problem: limited validation to date (Delphi; 2 PBT materials)
- Take "cup half-full" approach

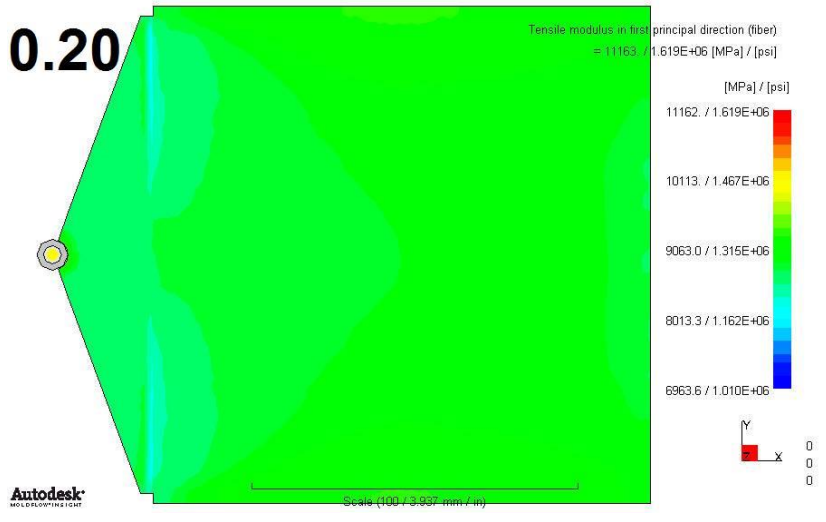
How Can We Validate Fiber Orientation ?

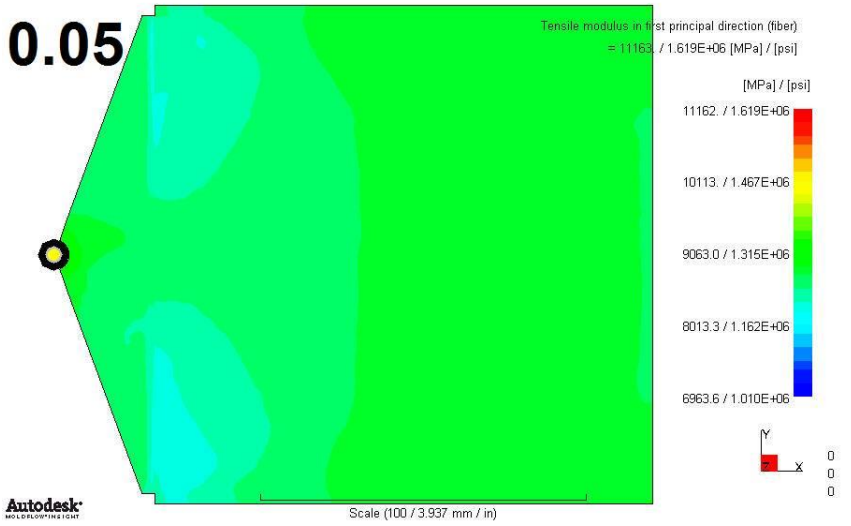
- Qualitative validation can utilize microscopy
  - Made quantitative with shape recognition software
- Micro tomography analysis (Skyscan)
- Simpler (cheaper) method of validation needed for number of materials needing validation
- Utilize tensile modulus predictions and measurements as “first cut” validation
- Later confirm with flexural stiffness verification

What does RSC Factor Do?

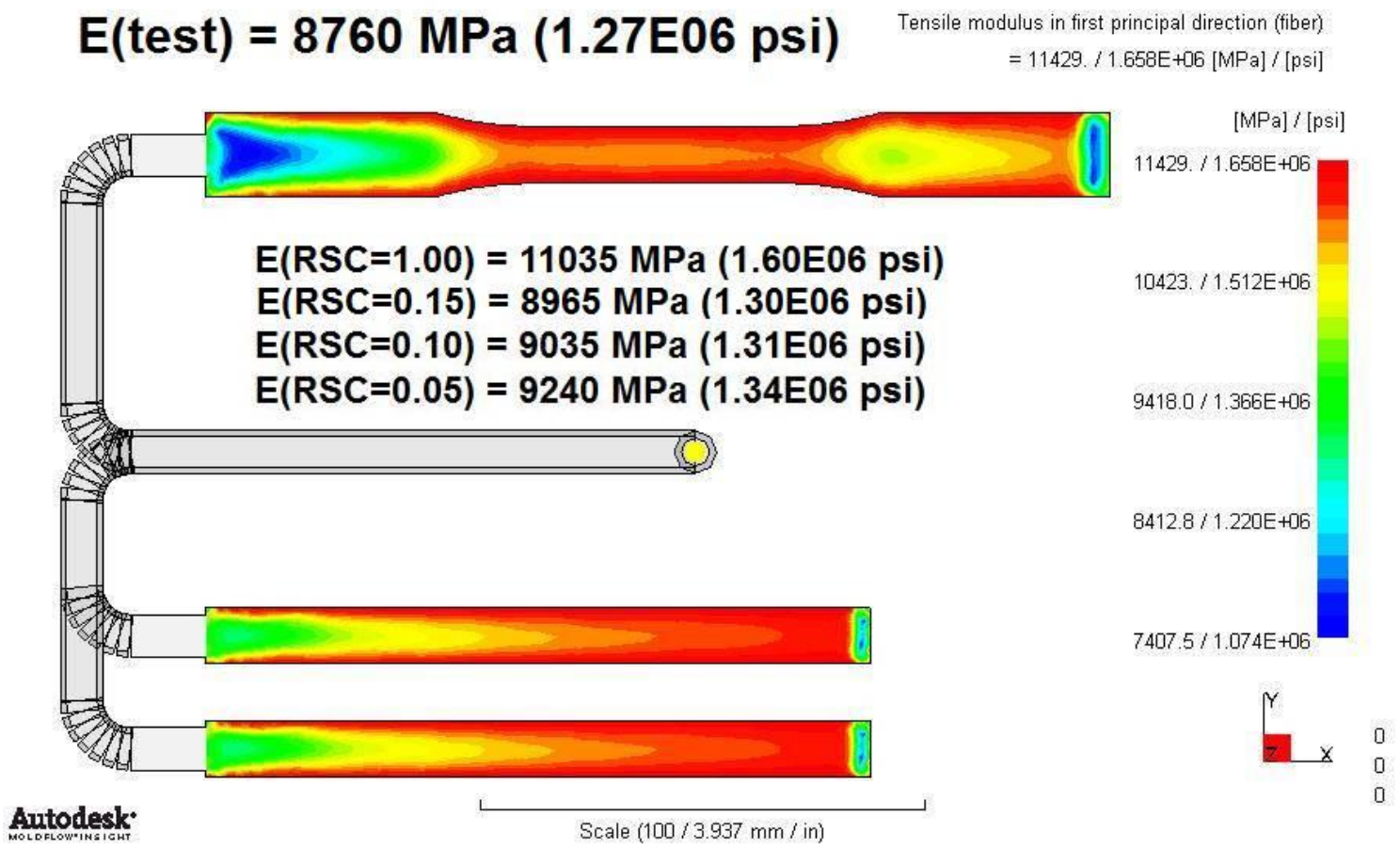




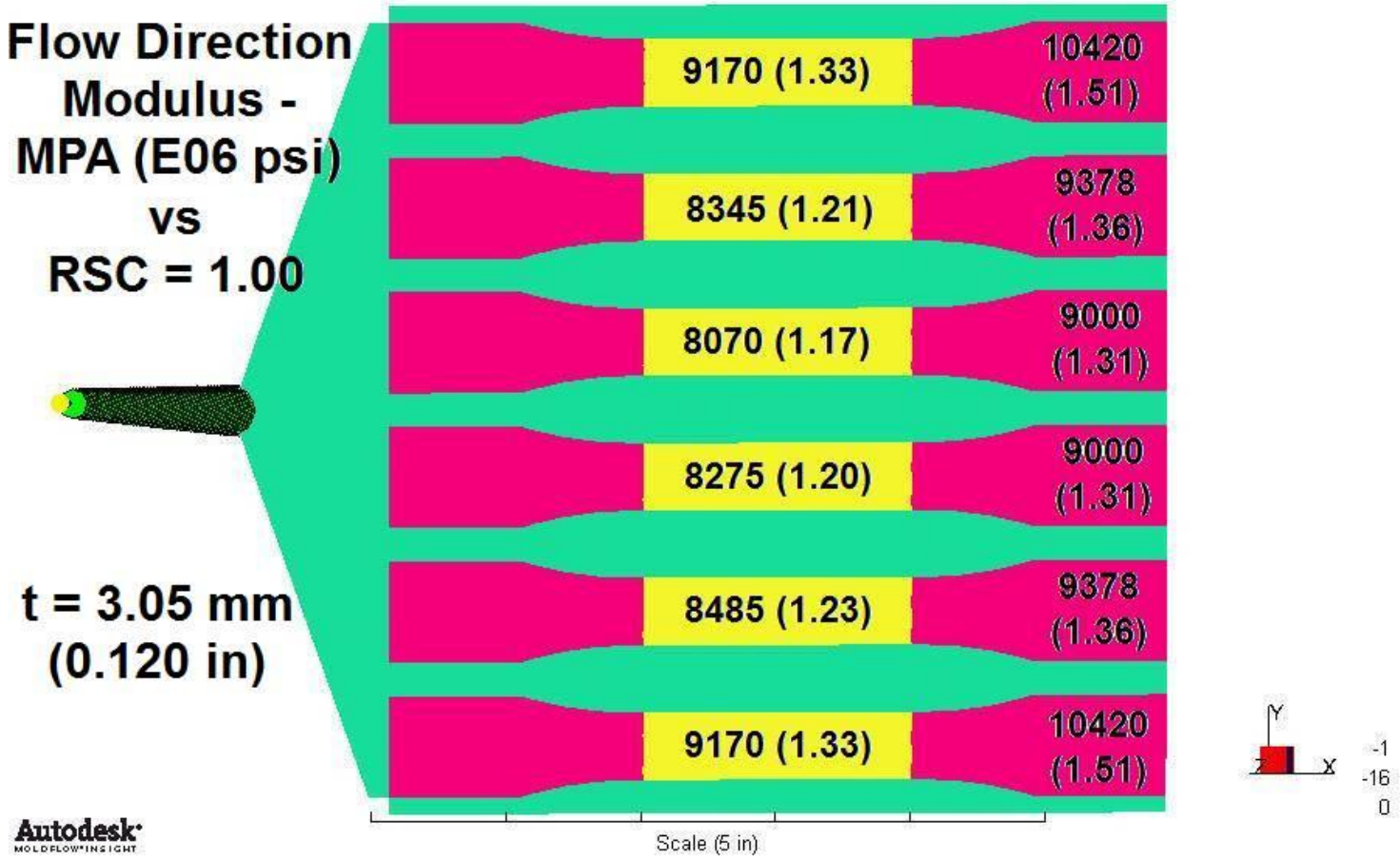




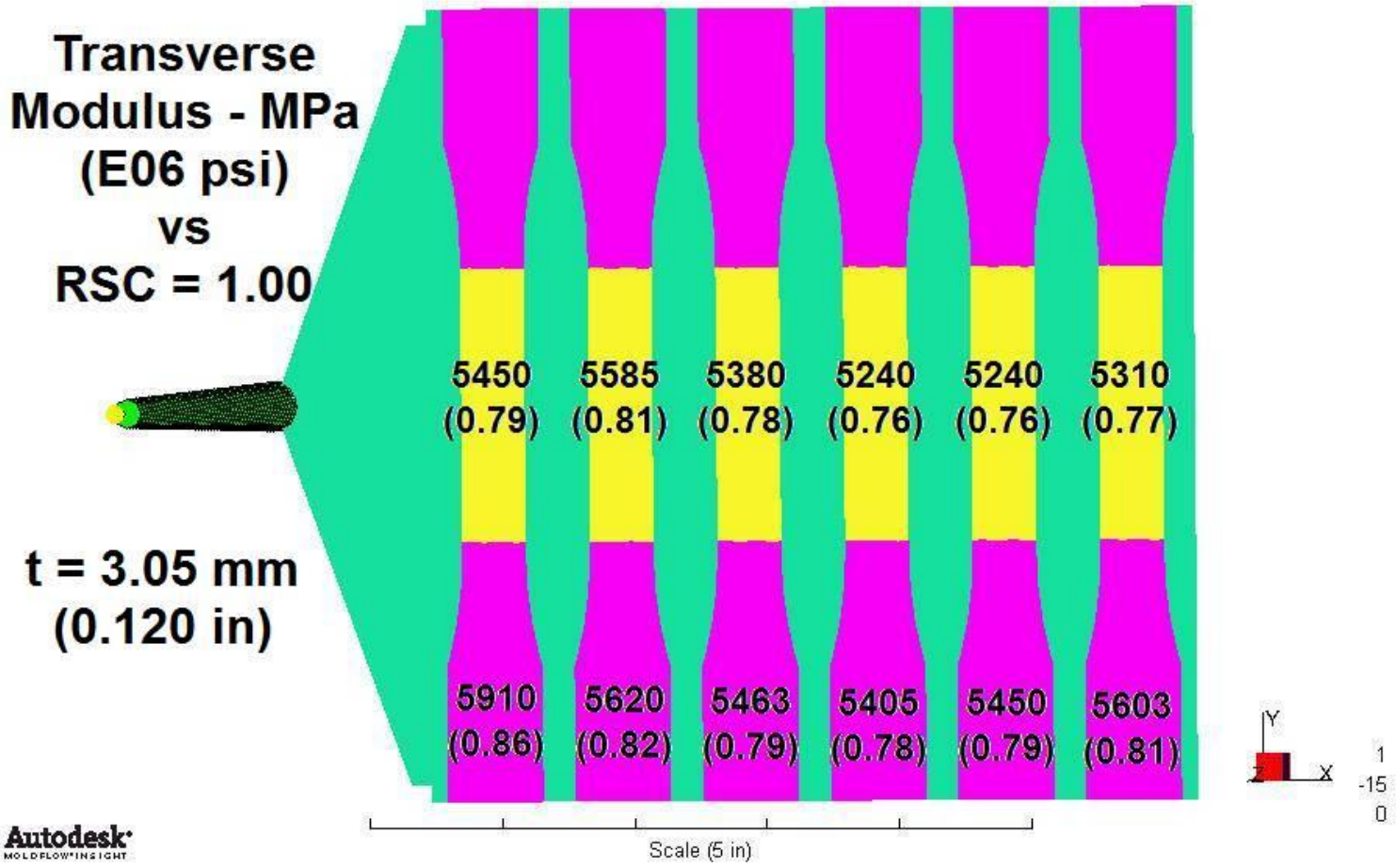
Look at Molded Tensile Bars First



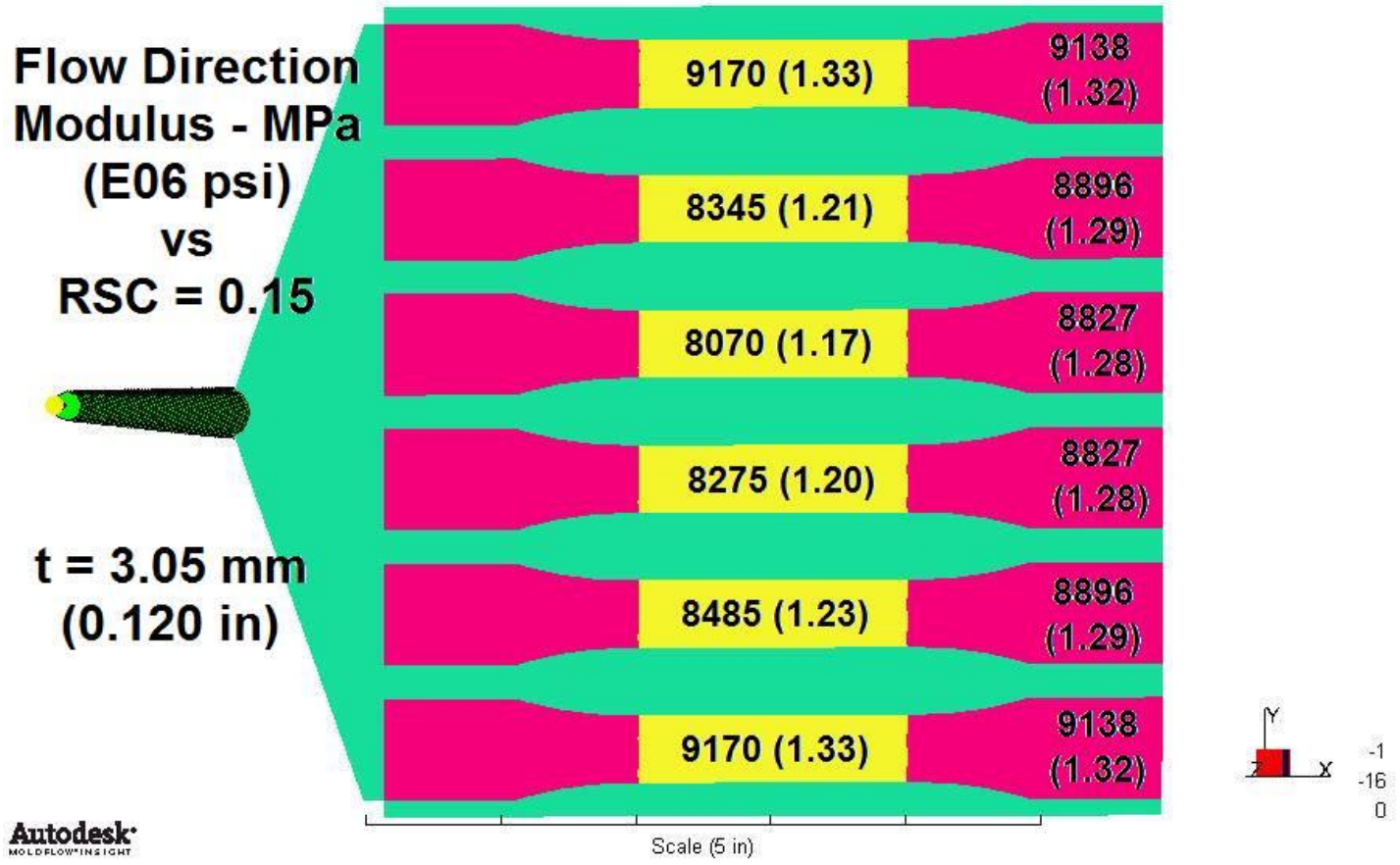
Flow Direction Modulus (RSC=1.00) t = 3.05 mm (0.120 in)



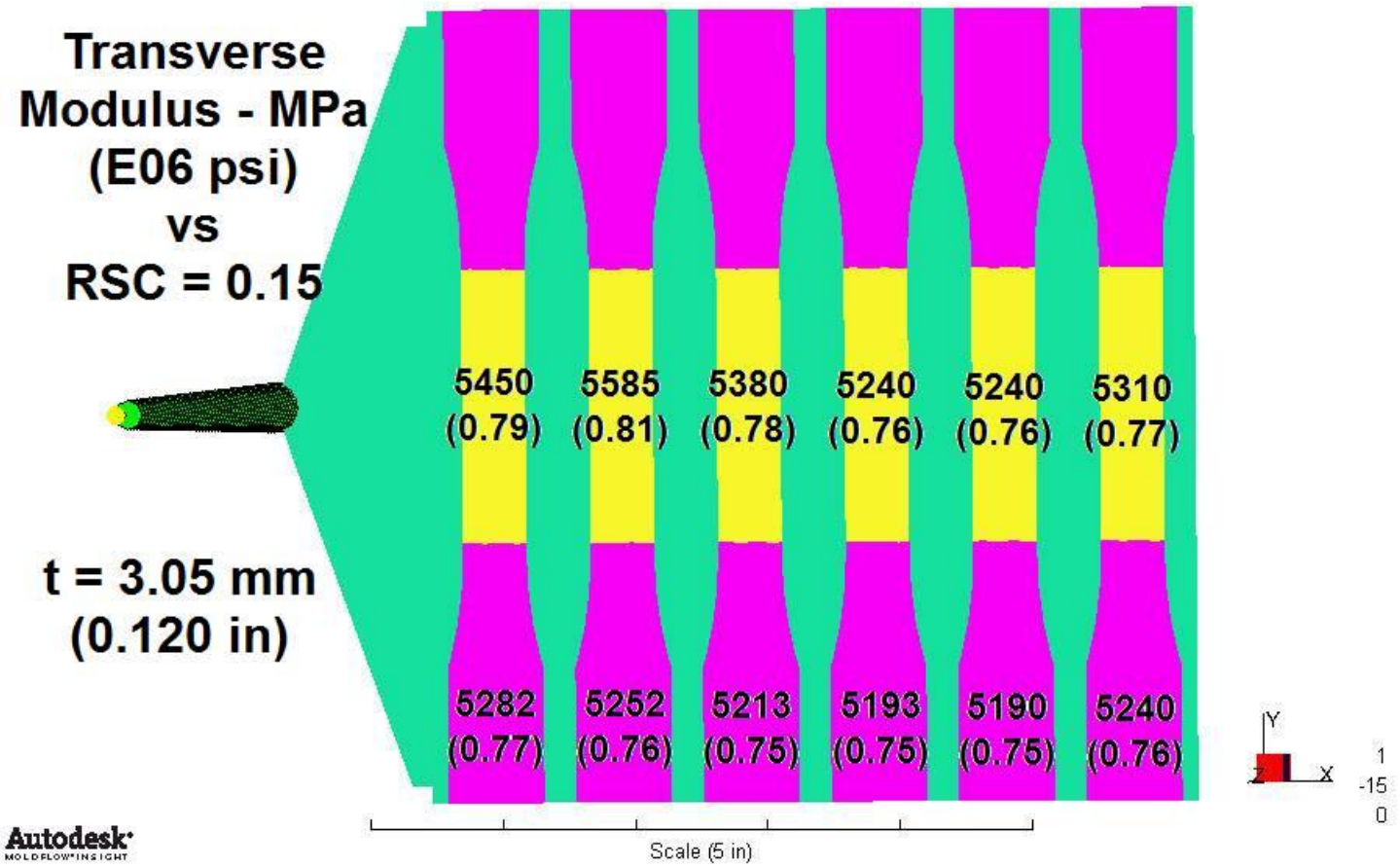
Modulus Transverse to Flow (RSC=1.00) t = 3.05 mm (0.120 in)



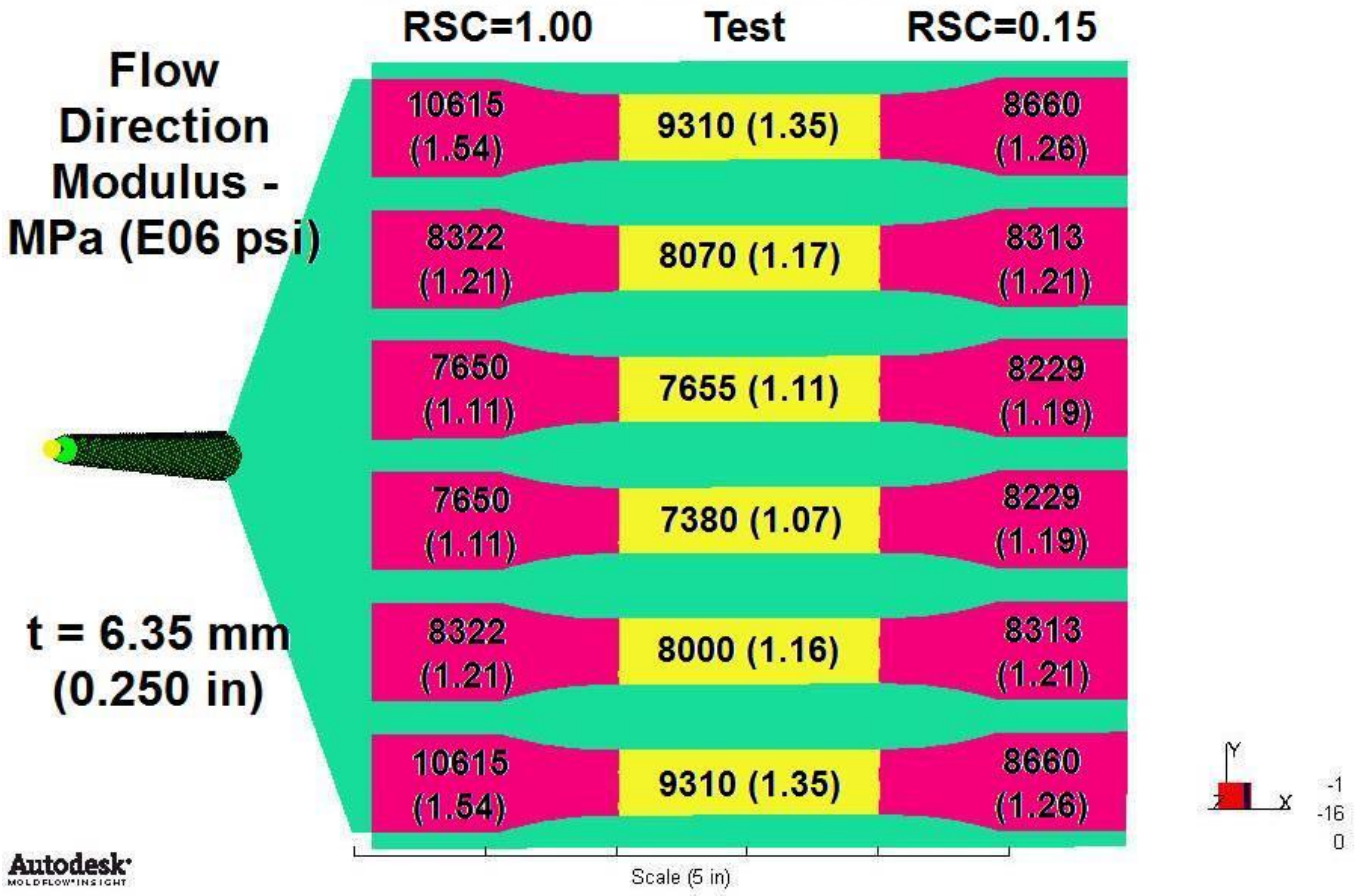
Flow Direction Modulus (RSC=0.15) t = 3.05 mm (0.120 in)



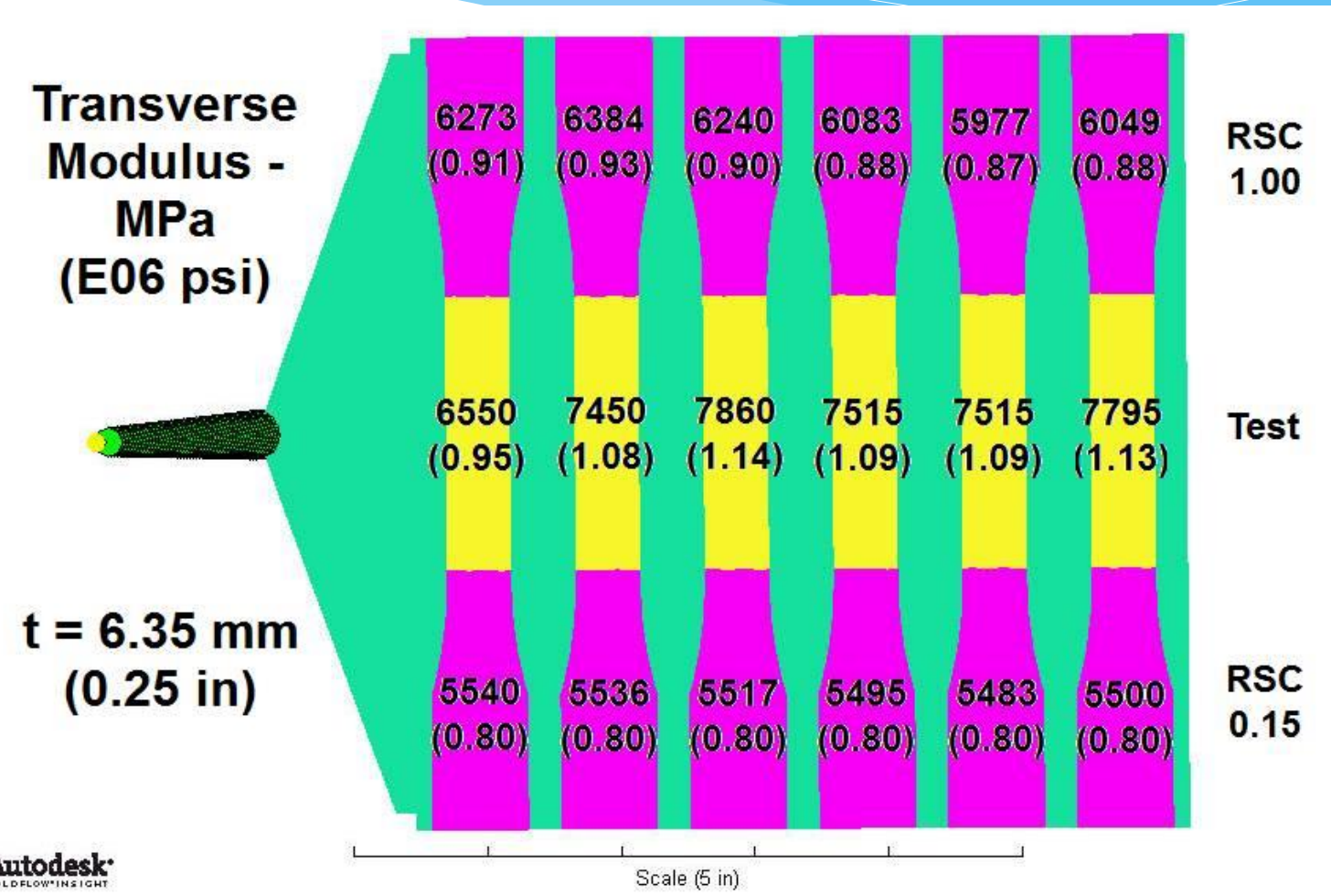
Modulus Transverse to Flow (RSC=0.15) t = 3.05 mm (0.120 in)



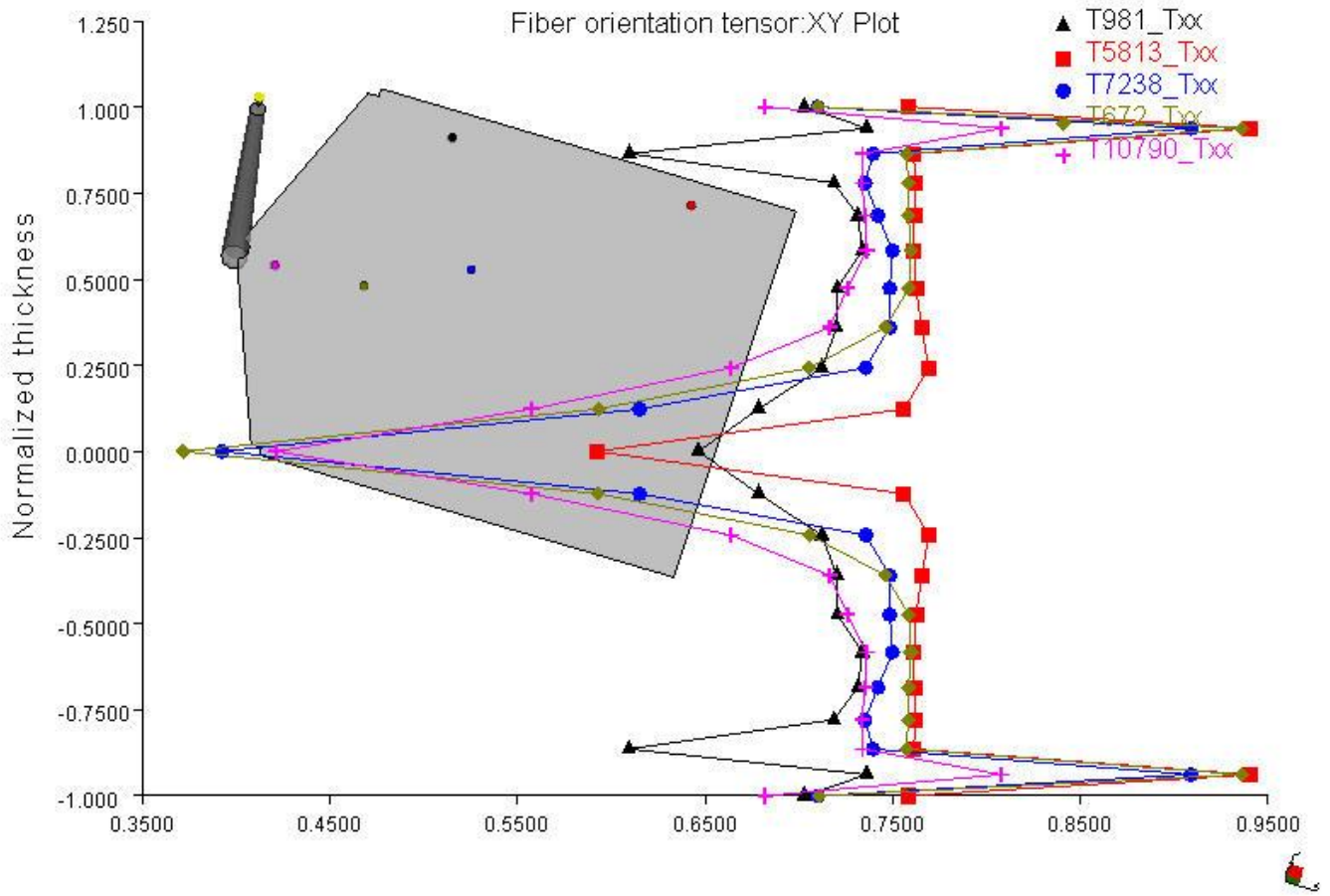
Flow Direction Modulus
t = 6.35 mm (0.250 in)



Modulus Transverse to Flow
t = 6.35 mm (0.250 in)



Laminate Stress Analysis



Summary

- RSC factor clearly ***seems*** to improve the fiber orientation predictions
- More correlation is needed (flexural modulus)
- Other possible influencing factors may need improvement
  - Relook at fiber A/R utilized (usually too low)
  - Other boundary conditions
- More materials to determine factors influencing RSC

Thank You!

Presented by
Robert Sherman
Senior CAE Analyst, RTP Company
rsherman@rtpcompany.com