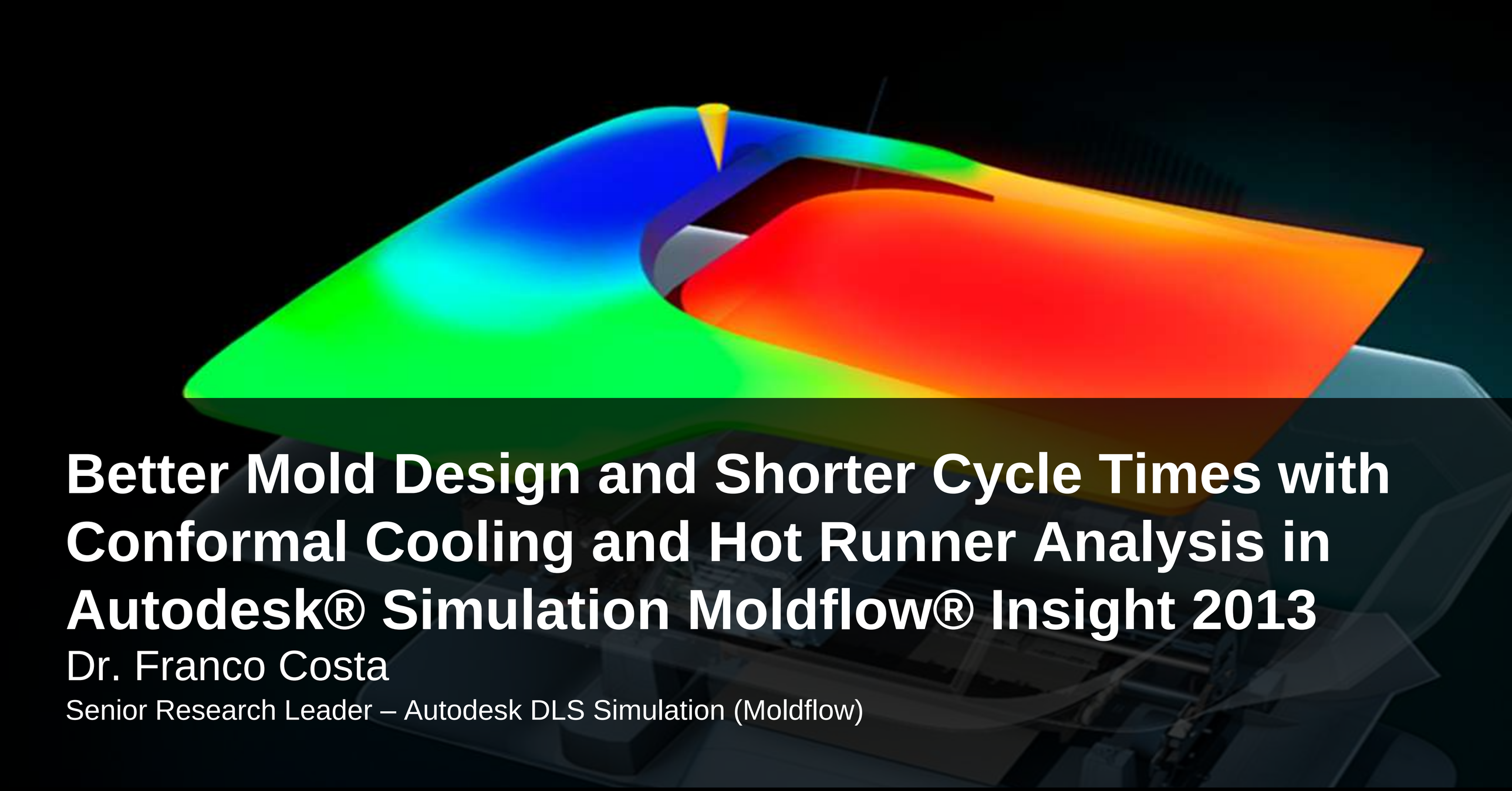

# Better Mold Design and Shorter Cycle Times with Conformal Cooling and Hot Runner Analysis in Autodesk® Simulation Moldflow® Insight 2013

Dr. Franco Costa

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# Class Summary

Detailed analysis of mold designs is becoming increasingly necessary as advanced mold technologies are adopted. Conformal mold cooling is a cooling technique that aims to offer optimal cooling conditions exactly where you need them. The technology has been around for many years, but has become a real option now with the better and cheaper ways to manufacture conformal cooling cores. Hot runner systems are very commonly used in plastic injection molding. Although these are simple systems on the surface, what actually happens inside the hot runners and how they lose heat into the mold can be quite complex. With the Cool (FEM) functionality inside Autodesk Simulation Moldflow software coupled with Autodesk® Simulation CFD software, you now have the capability to model even the most complicated conformal geometries and hot runners in full three-dimensional detail of all components. This process enables you to evaluate and optimize the hot runner and conformal cooling design to achieve an optimal mold design and injection molding process.

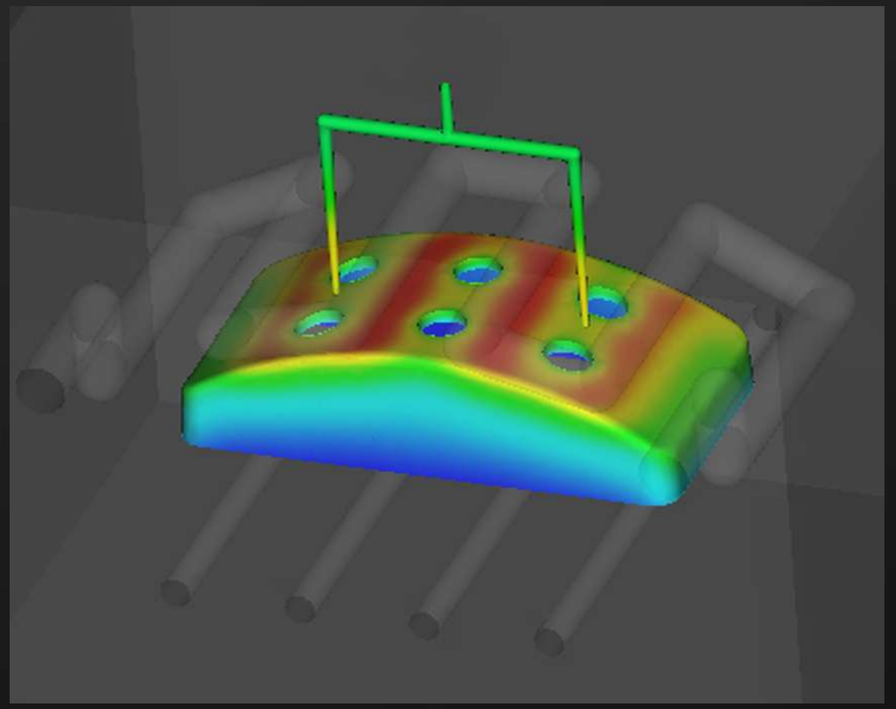
# Learning Objectives

At the end of this class, you will be able to:

- Explain what hot runners and conformal cooling are and why they are used
- Describe advances in simulation of hot runners and conformal cooling in Simulation
- Use Simulation Moldflow Insight to troubleshoot and optimize hot runners Moldflow Insight 2013
- Use Simulation Moldflow Insight to evaluate whether an investment in conformal cooling will pay off

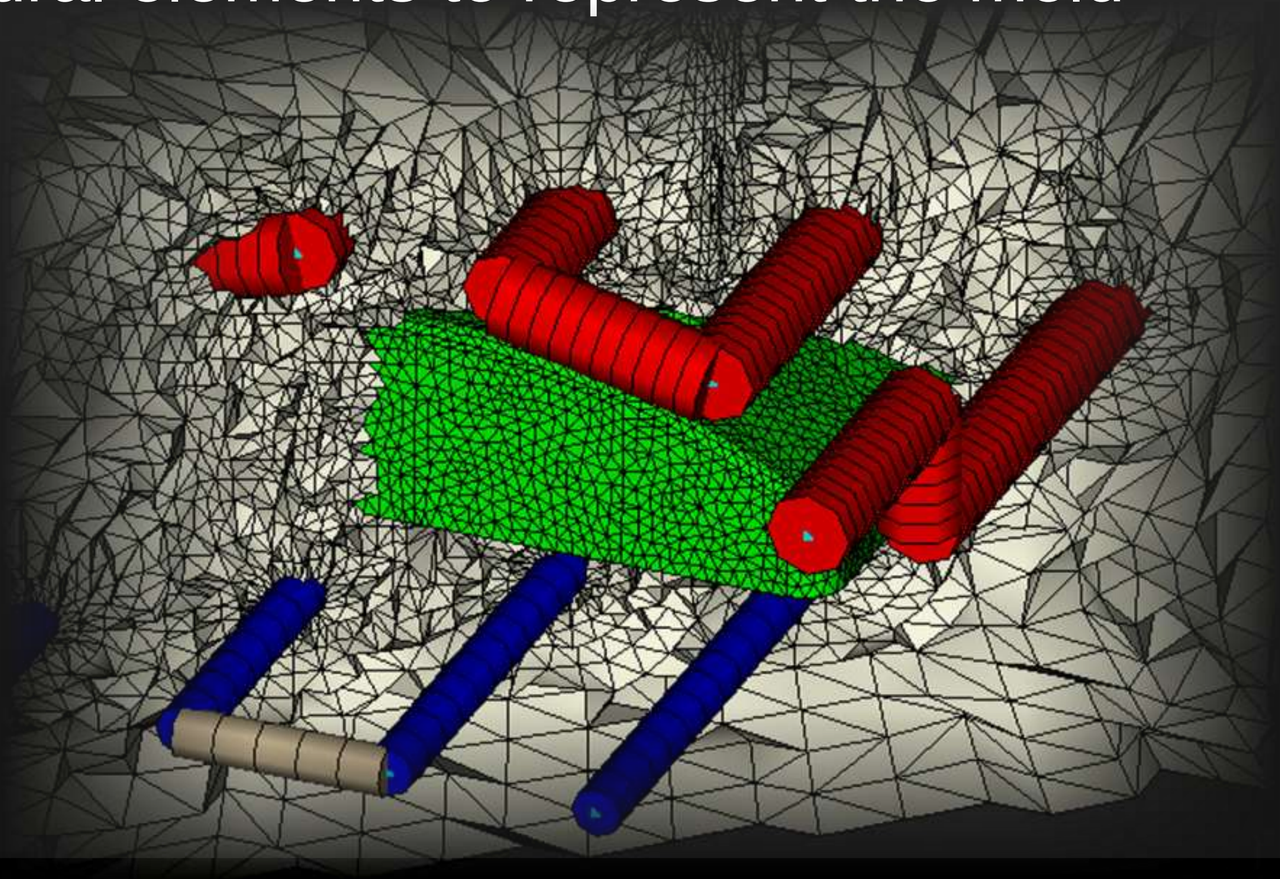
# Contents: Transient Mold Temperature Solution

- Features in Moldflow Insight 2013
  - Rapid Temperature Cycling
  - Geometry tools
- Preview
  - Conformal Cooling / 3D Channels
  - Geometry tools
- Hot Runner Component Analysis

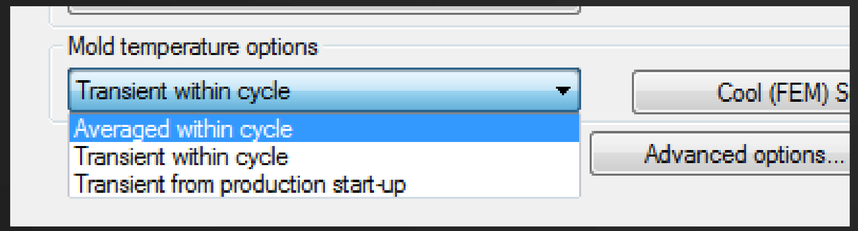


# Mold Thermal Analysis - Cool (FEM)

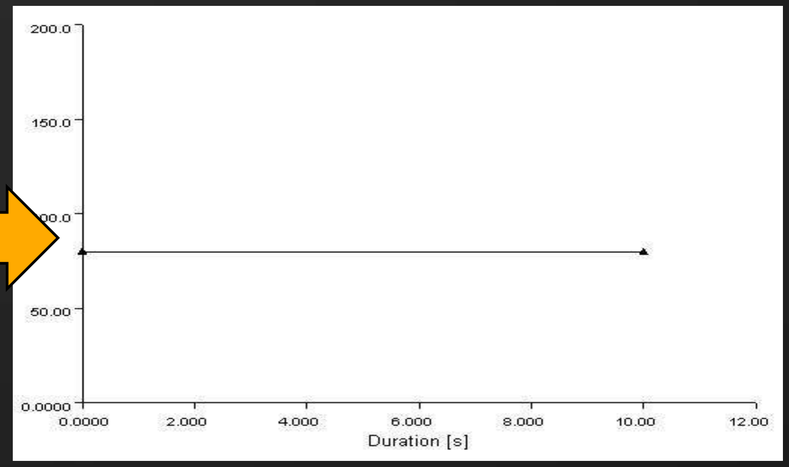
- With Transient Cool Option
- Uses tetrahedral elements to represent the mold

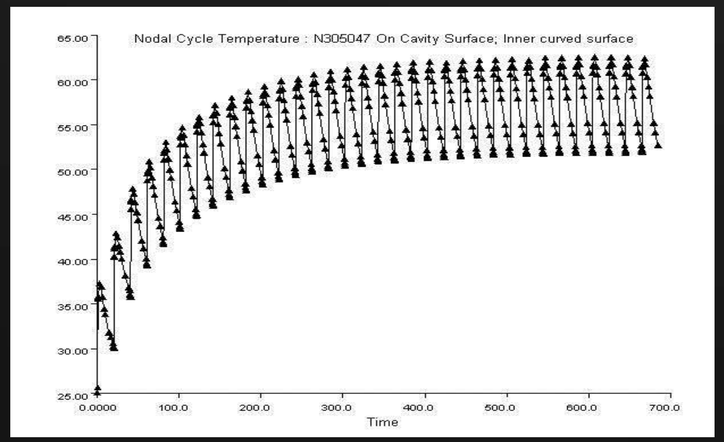


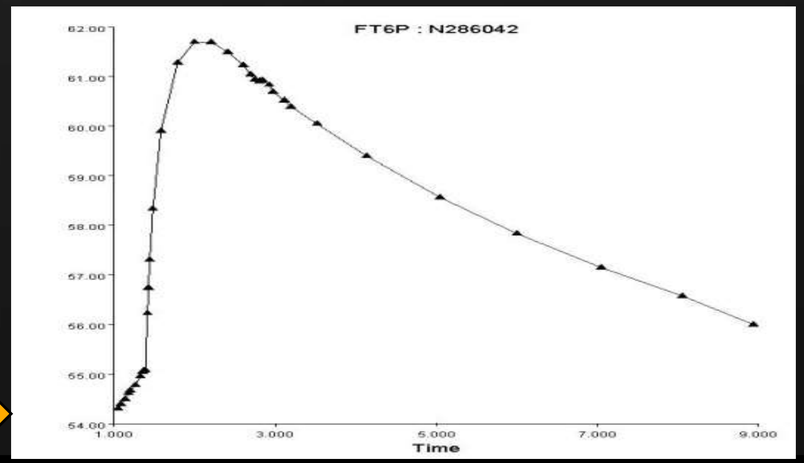
# Mold Temperature Analysis Options




- Average within Cycle (Steady-State)
  - Equivalent to standard cool analysis in Insight 2011
- Full transient history from product start-up

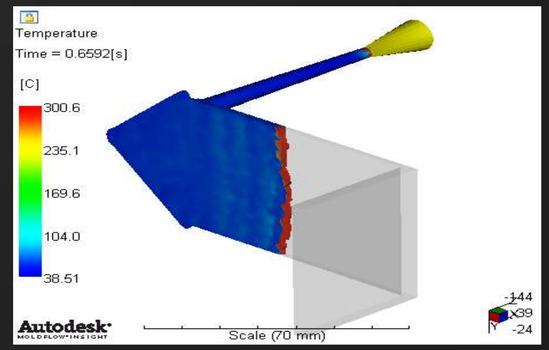


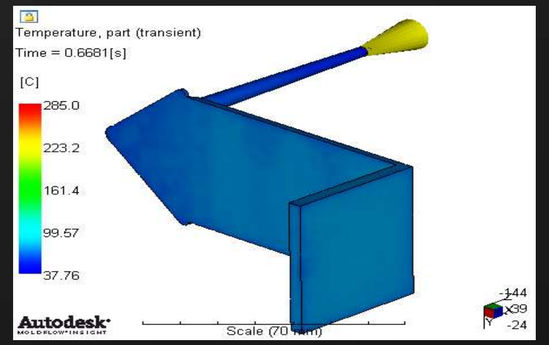



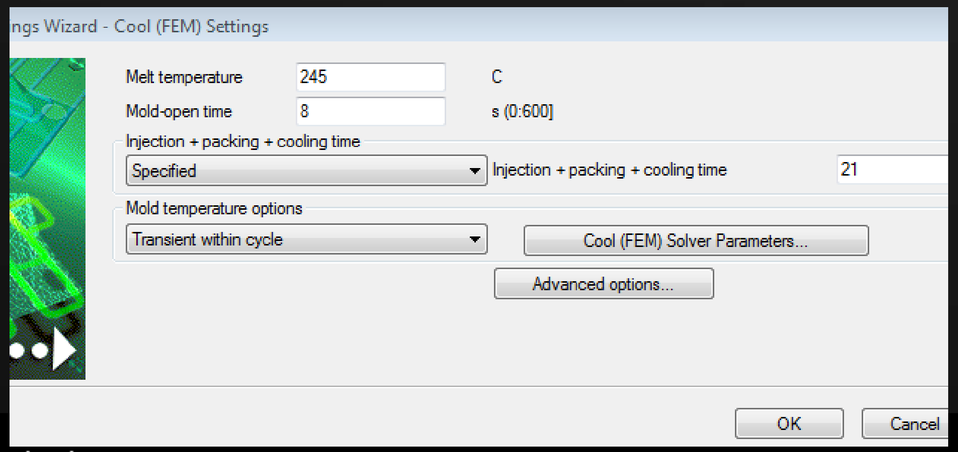



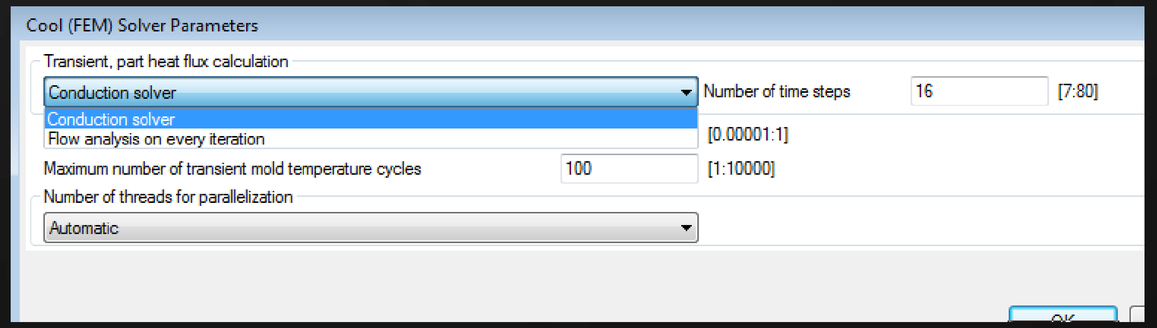
# Two options for Part heat calculation

- Full flow analysis at every iteration
  - Includes full effect of shear heating and material convection
- Conduction solver
  - Assumes the cavity is instantly filled at melt temperature
  - Same as used for the conventional (BEM) Cool analysis
  - Much faster analysis



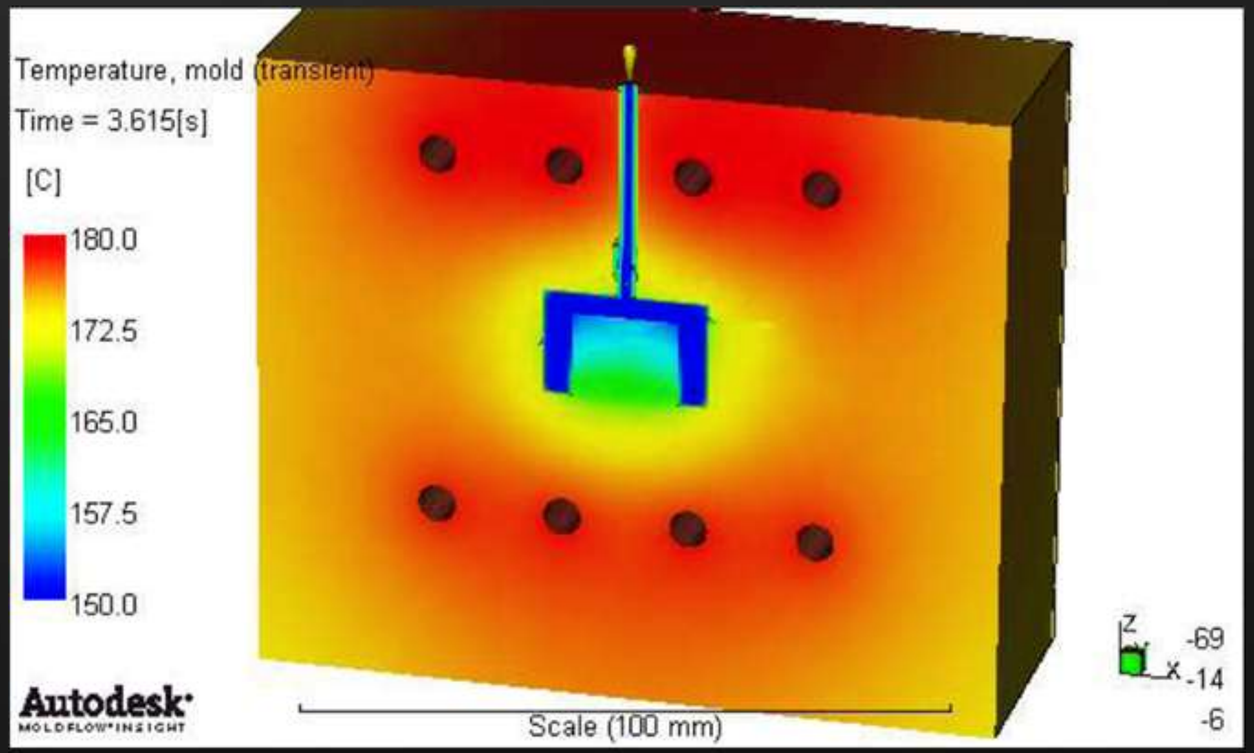



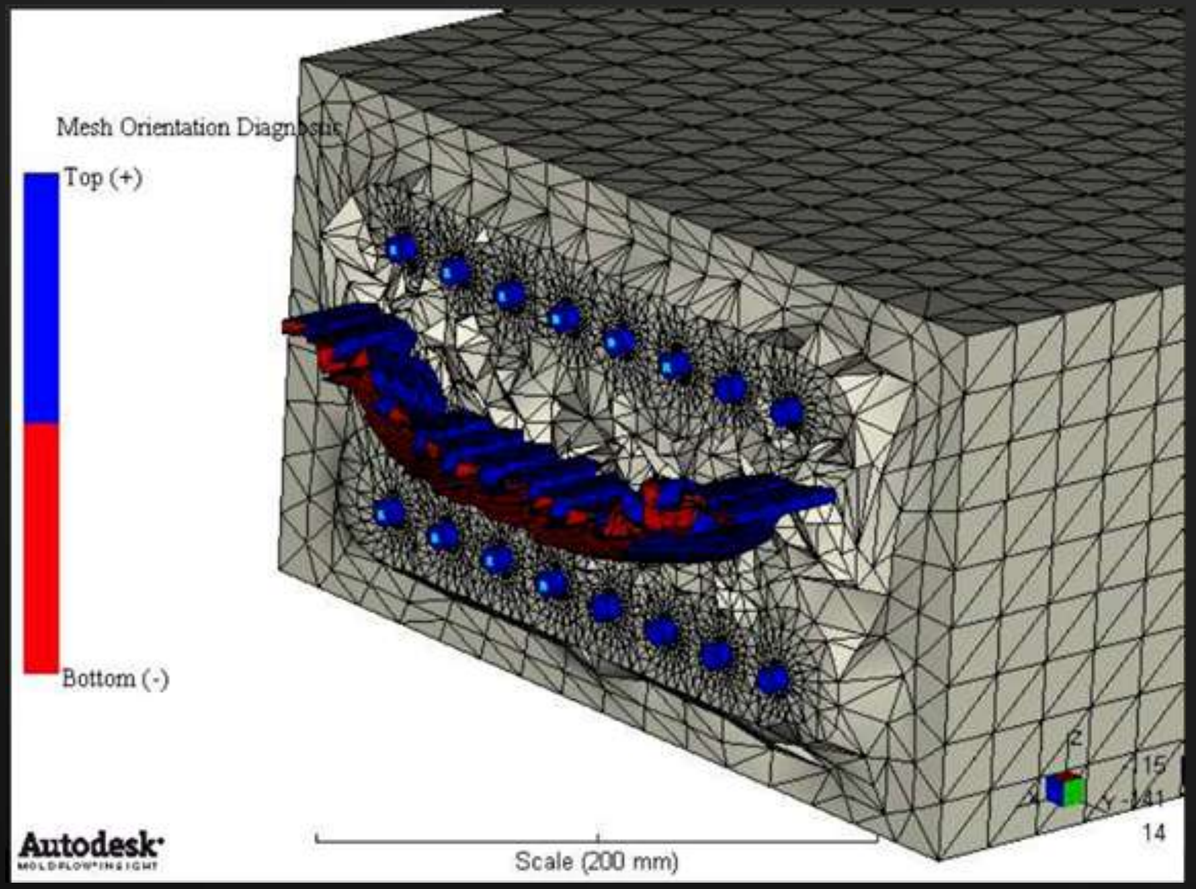



# New in 2013: Mold Heating for Reactive Molding

- Can be found as “Cool (FEM)” in the analysis sequence
  - Reactive molding requires heat to start chemical reaction
  - Mold is heated using heater cartridges or hot fluid.
  - Can be Transient or “Average within cycle” (Steady State)



# Cool (FEM) for Dual Domain




- Transient Cool analysis for Dual-Domain part meshes
  - 3D Tetrahedral Mold mesh
  - 1D beam cooling channels
  - Cannot choose full flow on every iteration

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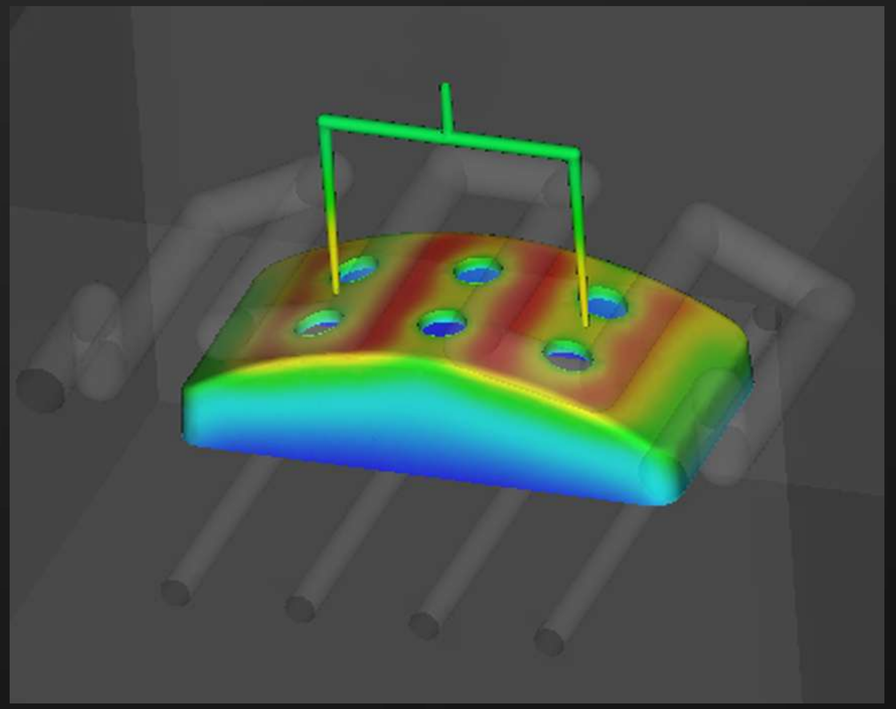


# Rapid Temperature Cycling

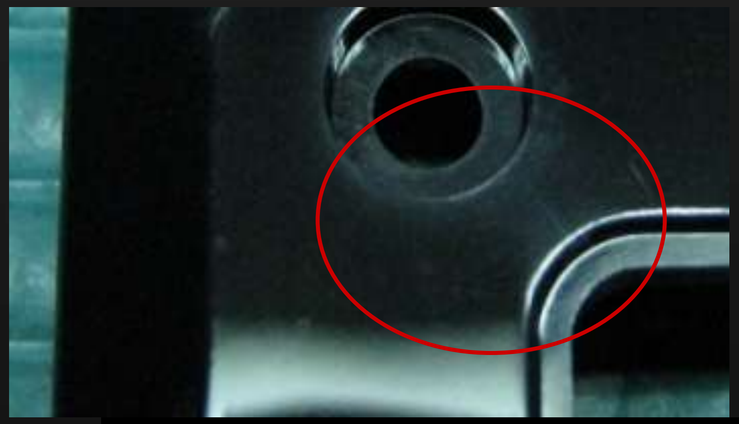
(RTC ®) / RHCM® / Variotherm ®

- Heat Mold for Filling
  - Eliminate visible weld-lines
  - Increase flow length
  - High (uniform) gloss finish
  - Eliminate Gate Marks (Cold slugs)
  - Typically only the cavity side is heated
- Heat by: Steam,Water, Electrical or Induction
- Cool Mold during Packing
  - Reduce cycle time

Conventional Molding

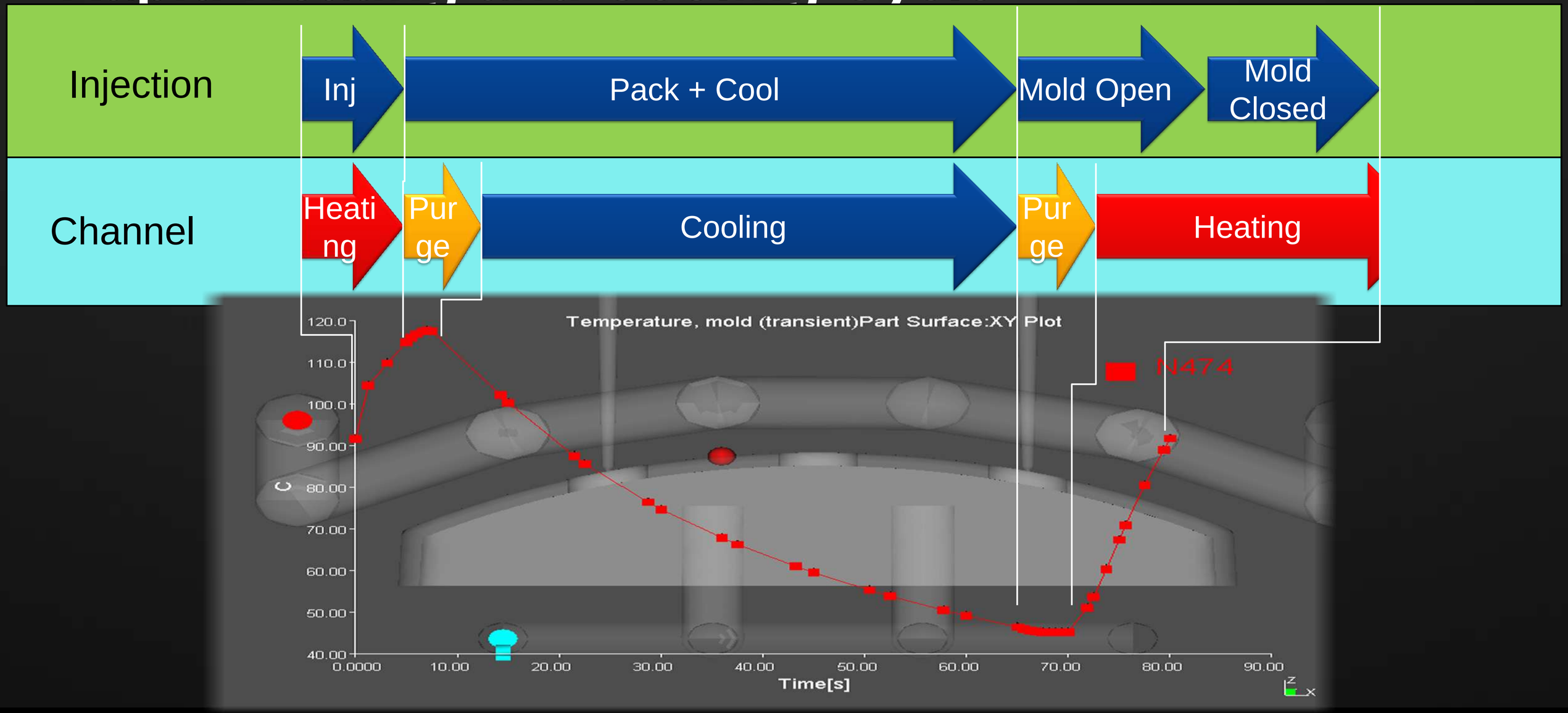
With RTC

ABS



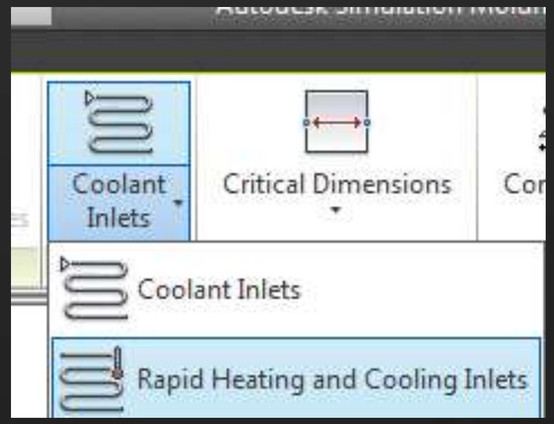
Images courtesy of GasInjection World Wide

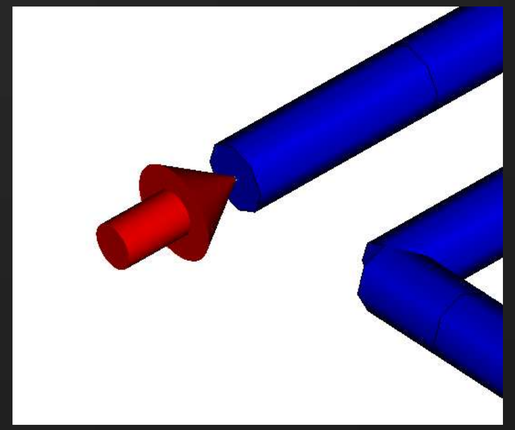
# Rapid Heating and Cooling Cycle

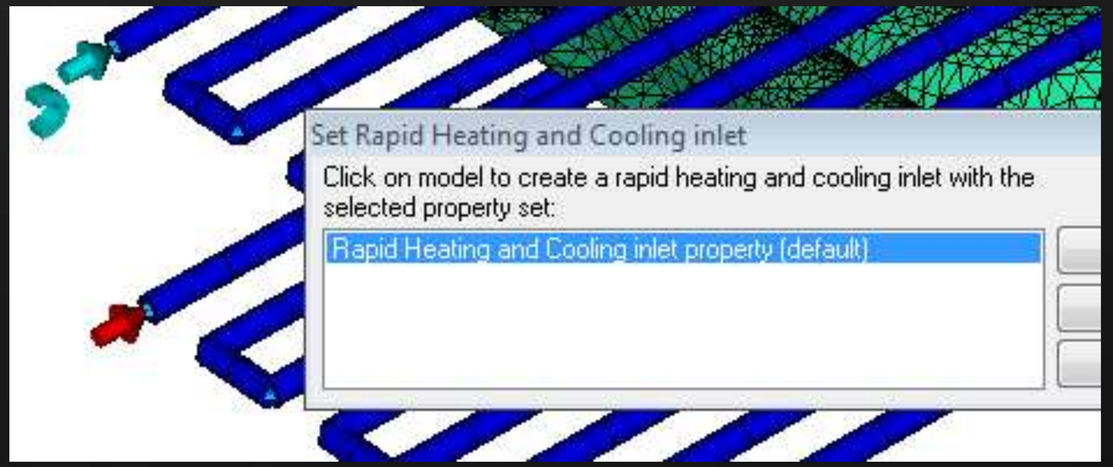


# Rapid Temperature Cycling

- New Rapid Heating and Cooling property type for cooling channel inlet
- Can only be selected once an analysis sequence containing Cool (FEM) has been selected
  - Not supported by Boundary Element Cool
- Allows specification of:
  - Heating
  - Cooling
  - Timing

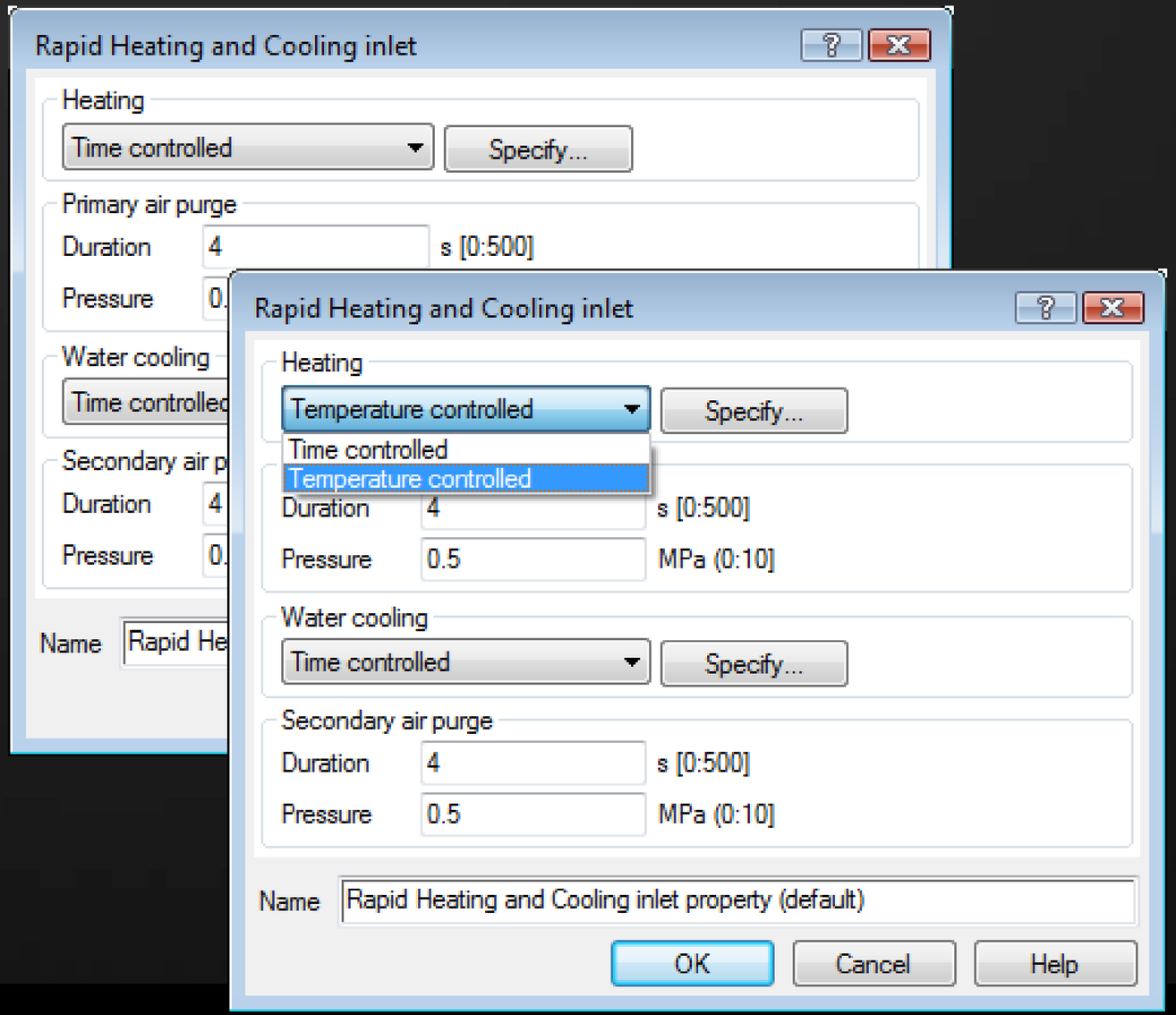




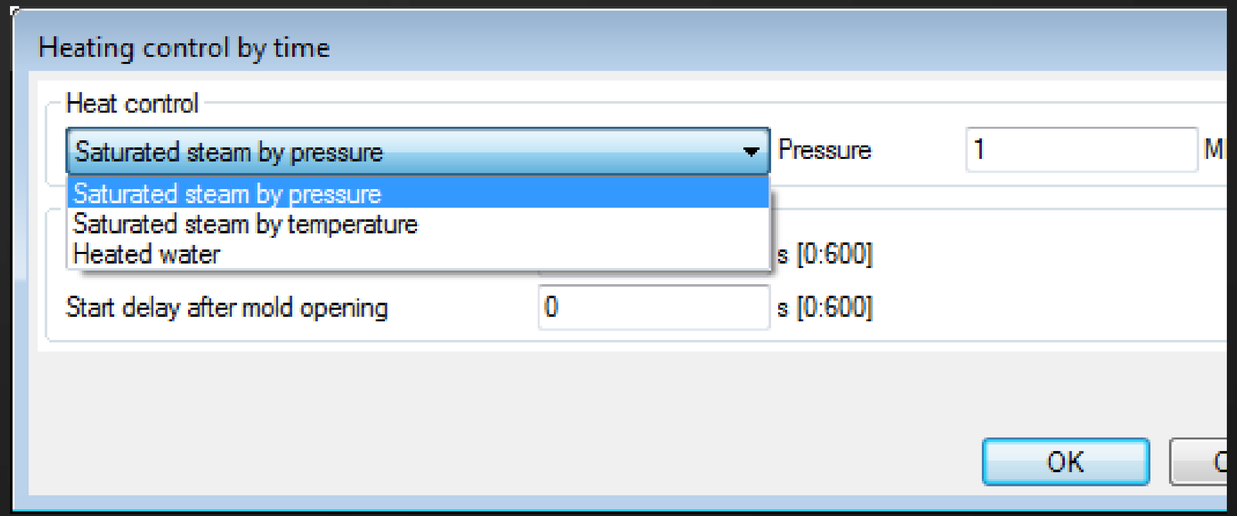
# Rapid Temperature Cycle

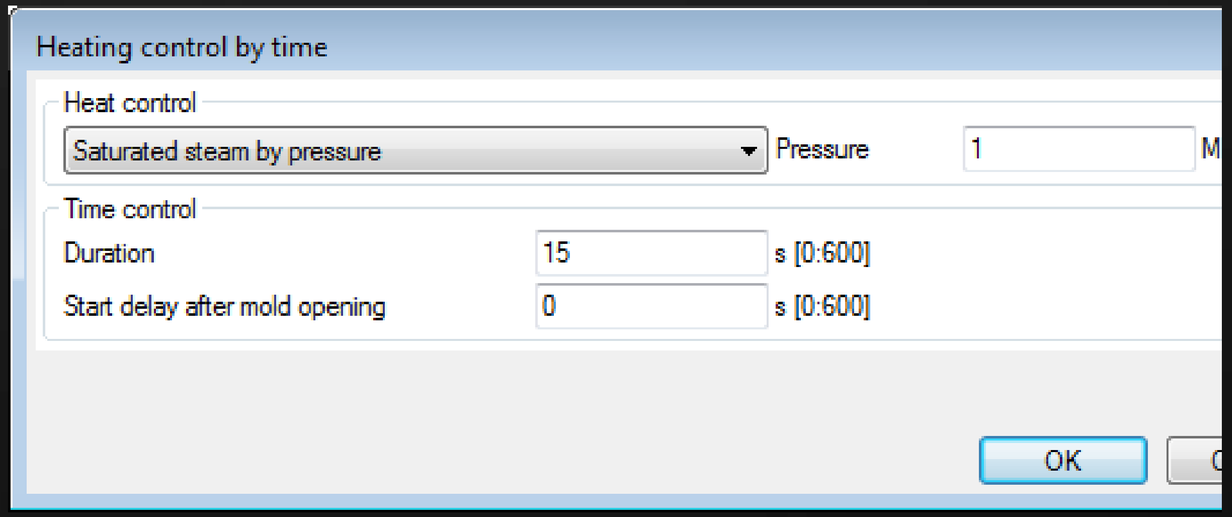
- Process Cycle
  - Heating Phase
  - Air Purge
  - Cooling Phase
  - Air Purge
- Heating and Cooling phases:
  - Time Controlled, or
  - Temperature (Thermocouple) Controlled



# Rapid Temperature Cycle: Heating Phase

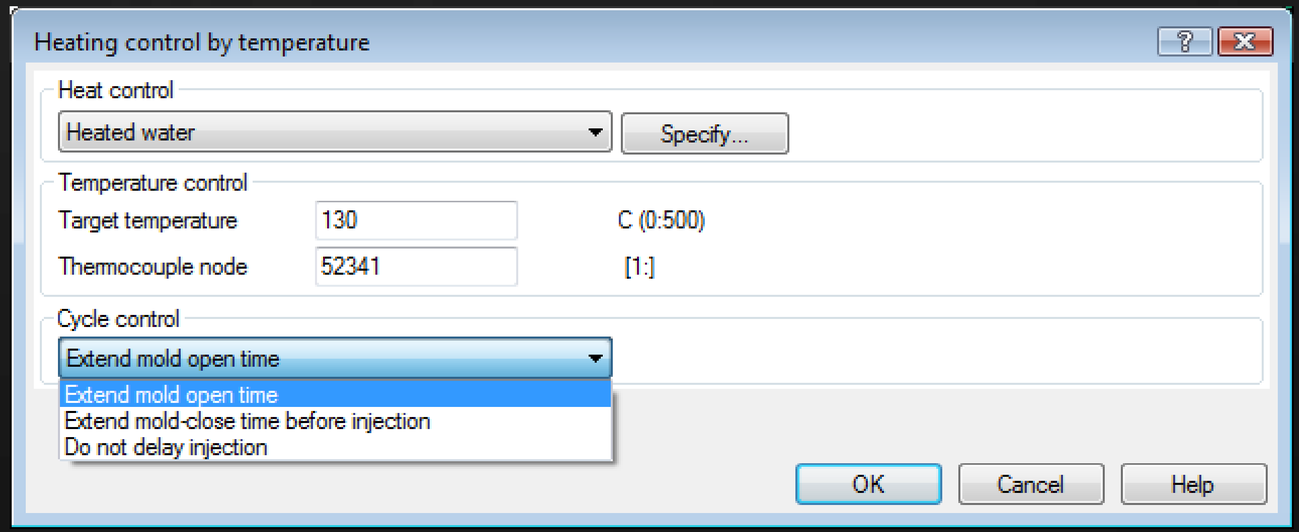
- Heating Fluid
  - Saturated Steam by set Pressure
  - Saturated Steam by set Temperature
  - Heated (pressurized) water
- Timing
  - Duration of Heating fluid flow
  - Start time referenced from mold opening



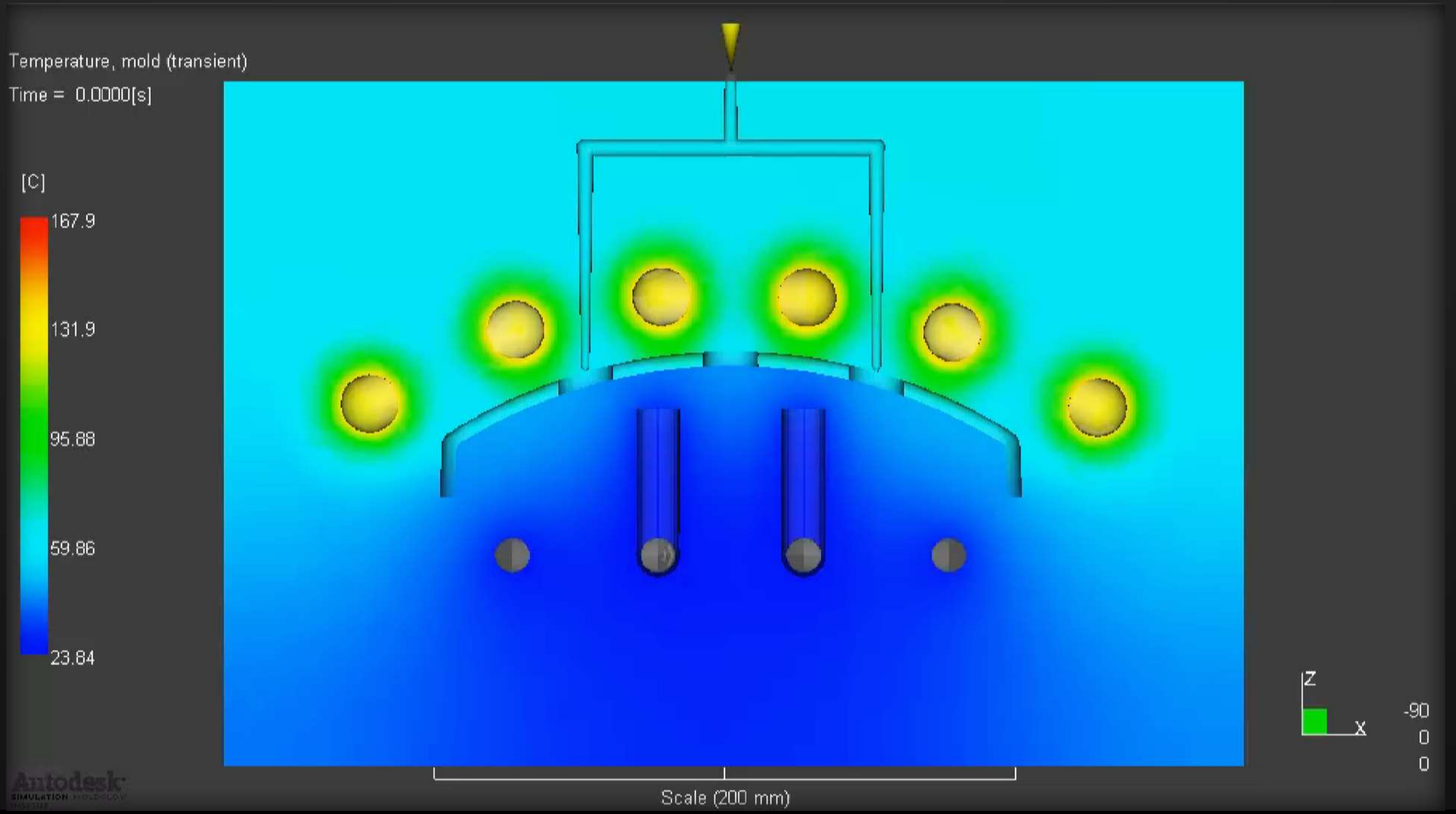



# Rapid Temperature Cycle: Temperature Control

- Heating Phase / Cooling Phase continues until a target temperature is achieved at Thermocouple
  - Specify Thermocouple location by node number
  - Thermocouple would typically be placed near the cavity
- Specify how the cycle control waits until heating is complete
  - Delay mold closing
  - Delay start of Injection
  - Do not delay injection
- Mold opening / ejection will always wait for the cooling phase to be completed



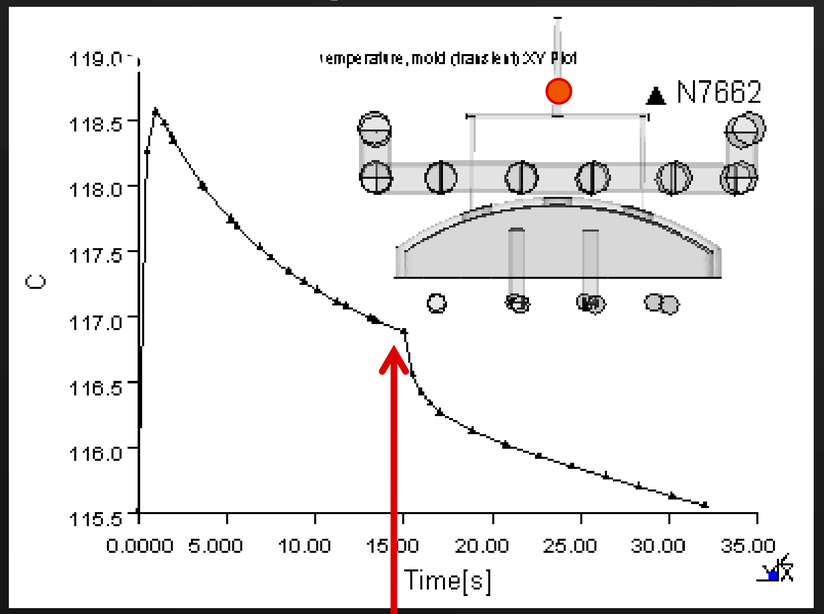
# Example: Heating and Cooling Cycle



# Example: Cyclic Mold Heating and Cooling Result

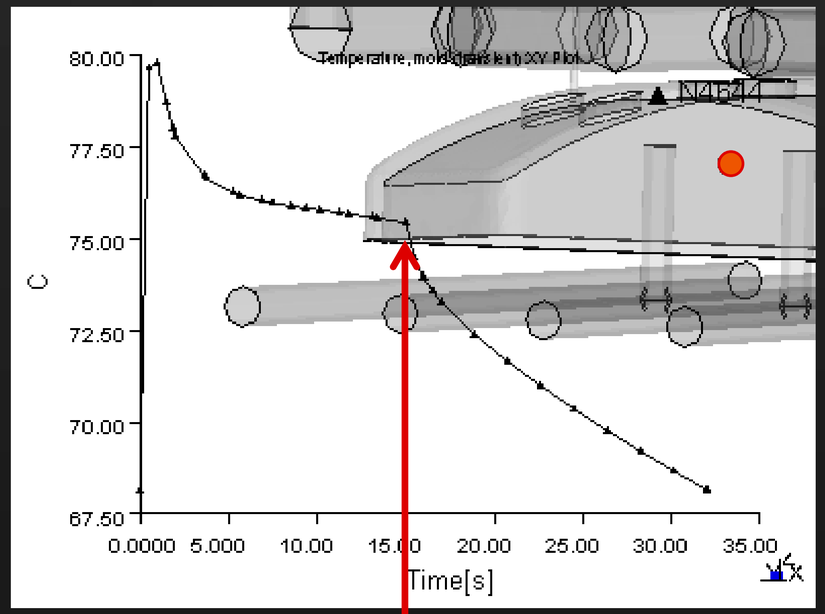
Mold Temperatures:

At Sprue surface



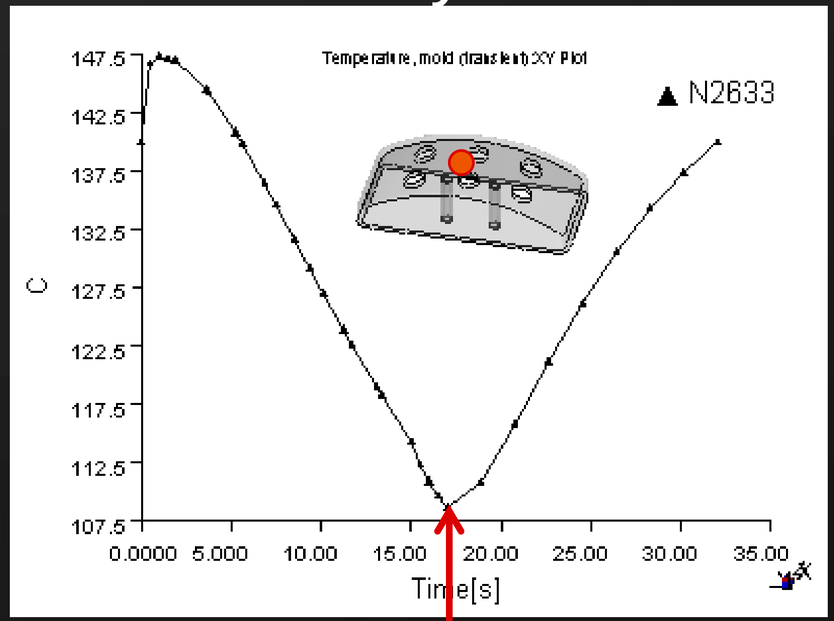

Time of Ejection

On Core-side surface




Time of Ejection

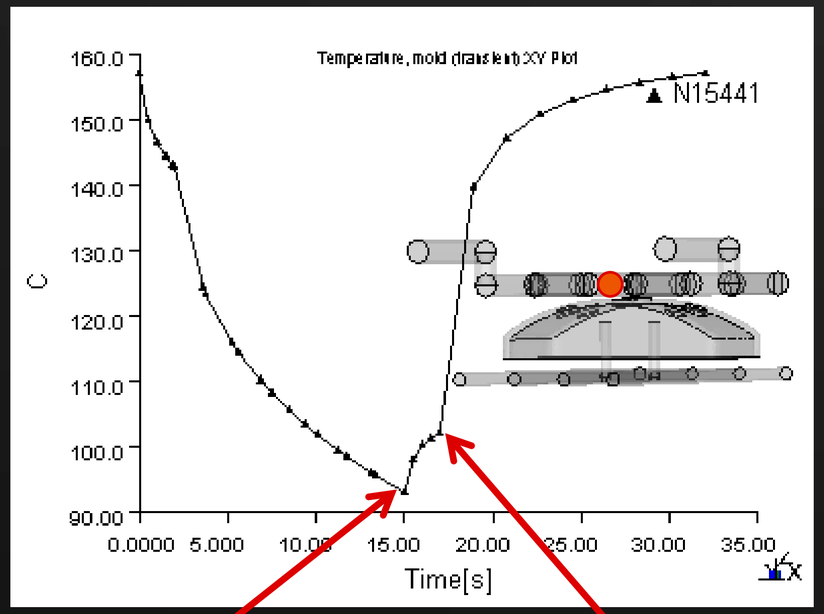
On Cavity-side




Time of Ejection

# Example: Cyclic Mold Heating and Cooling Result

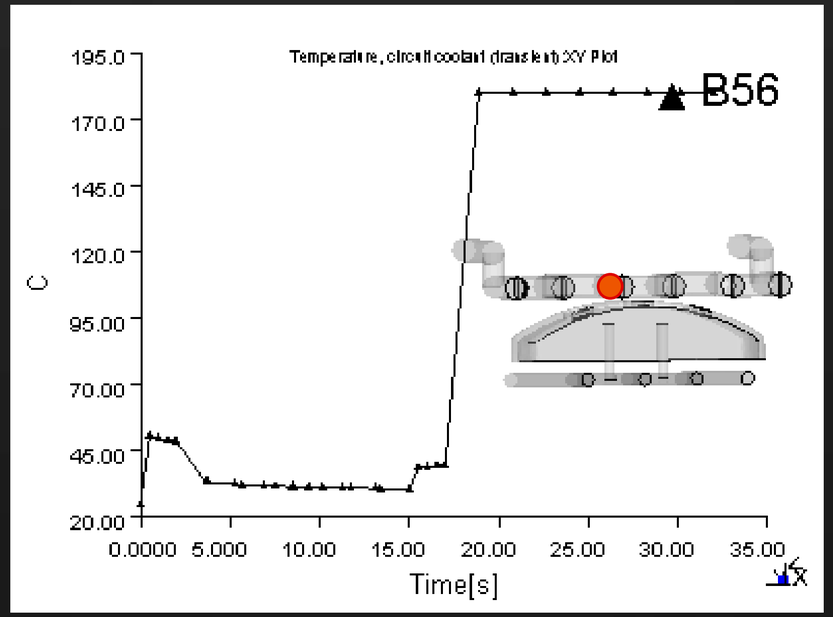
Mold Temperature at Steam/Water channel



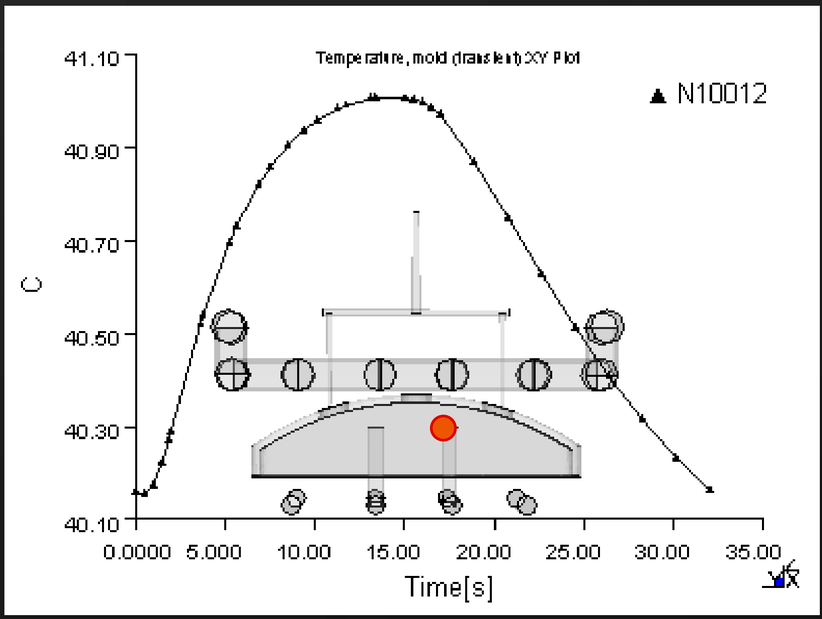

Cooling flow stopped

Steam Heating Start

Fluid Temperature in Steam/Water channel

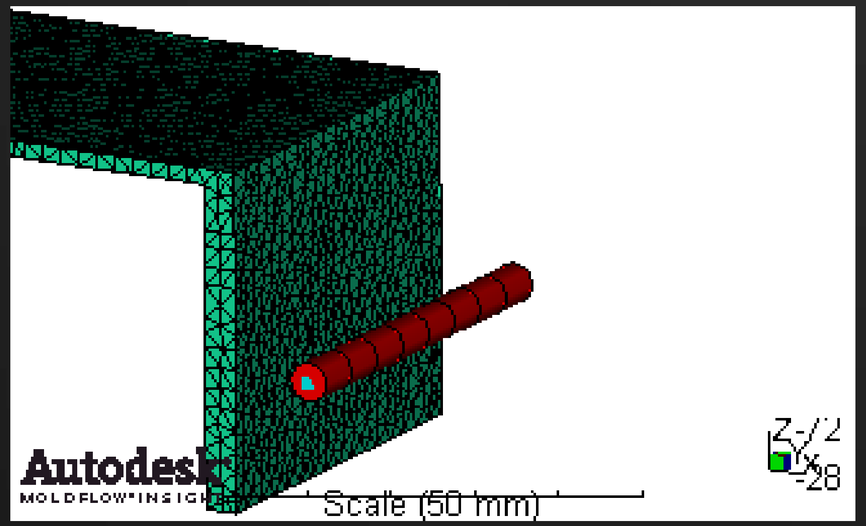


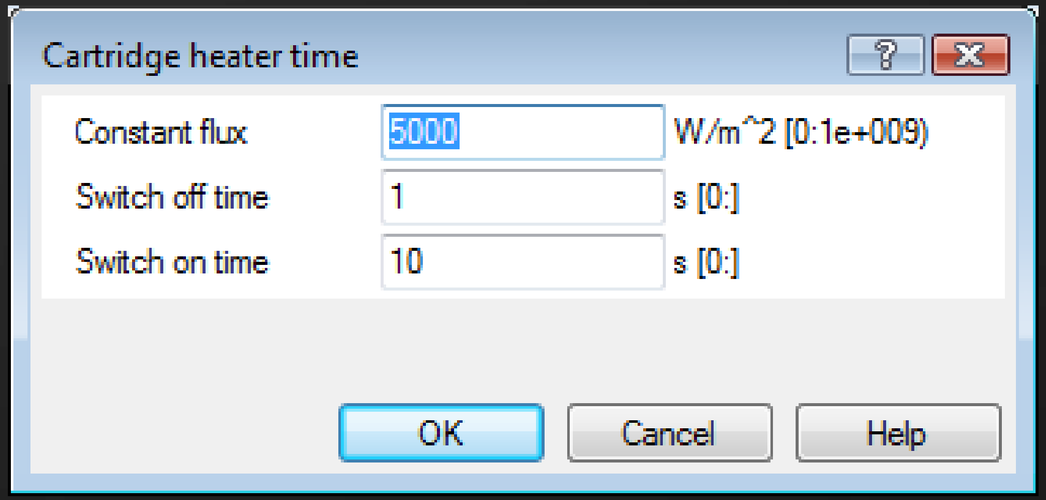

Mold Temperature on Bubbler surface

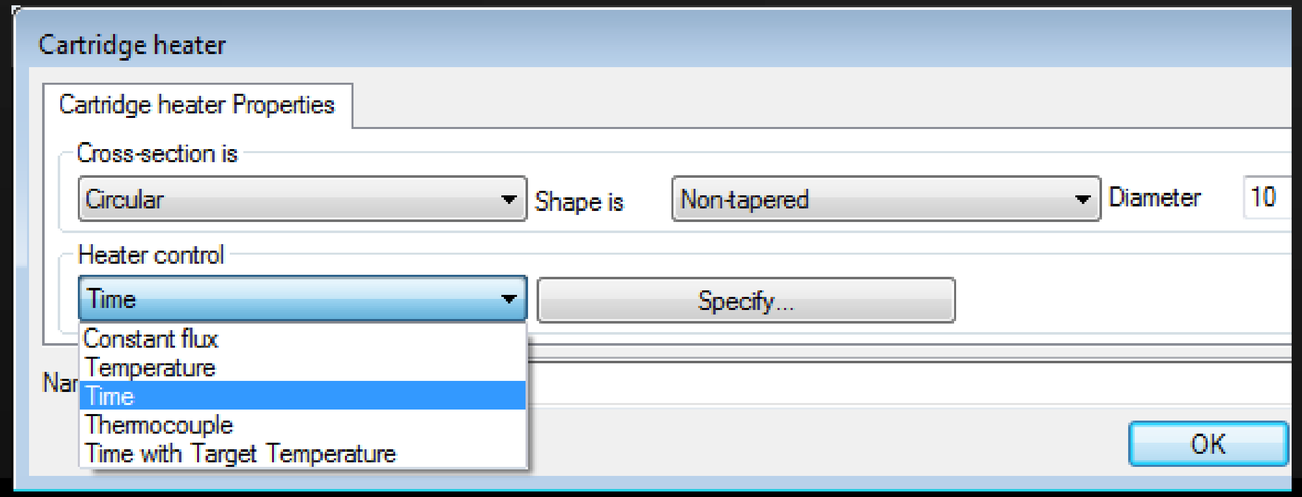


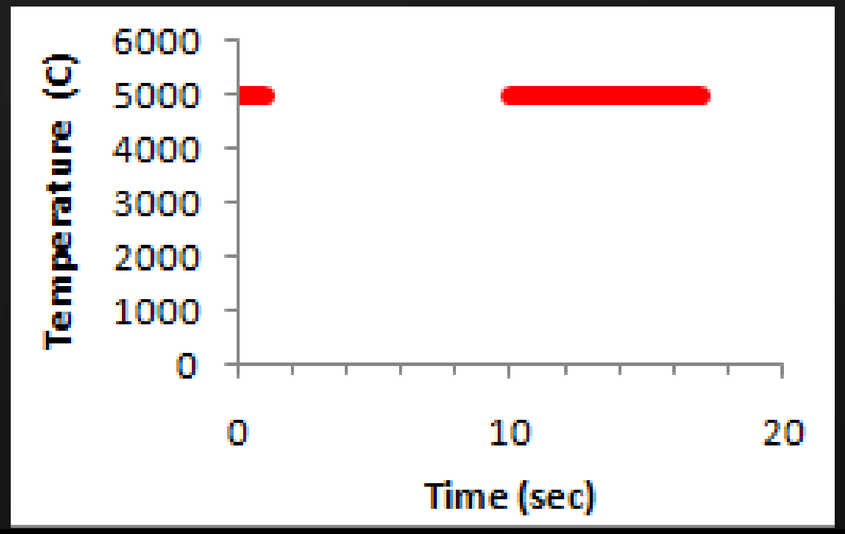
# Additional Cartridge Heater Controls

- Time Control



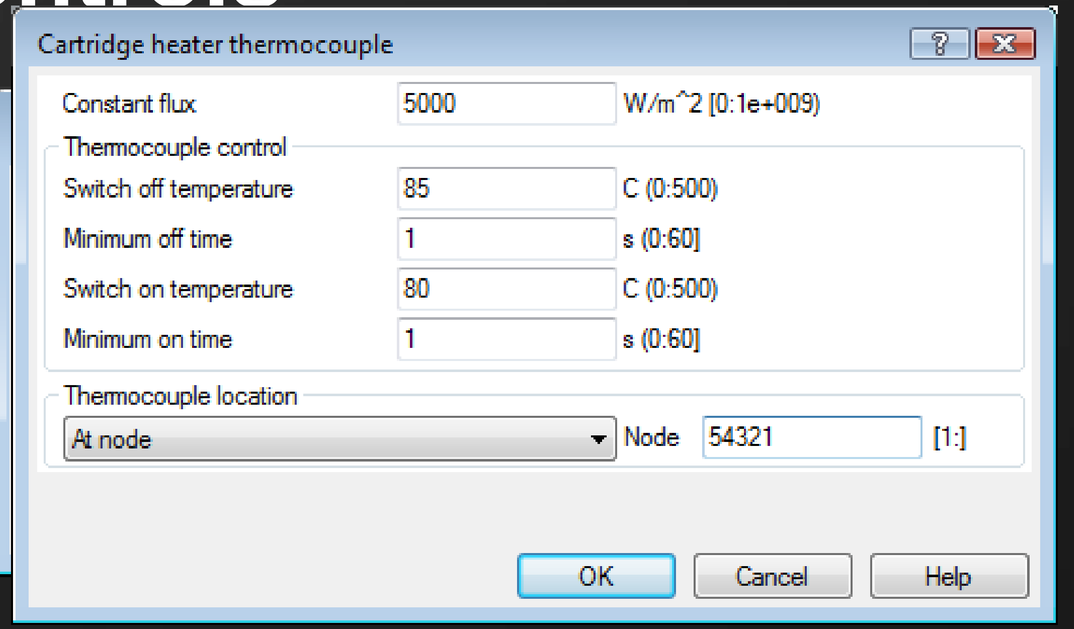



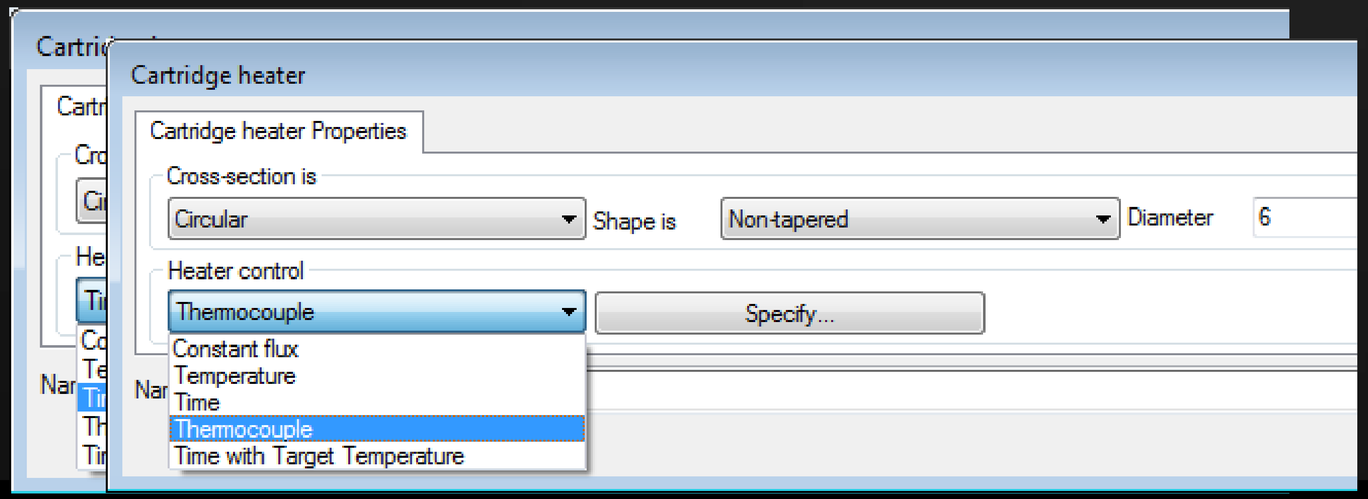



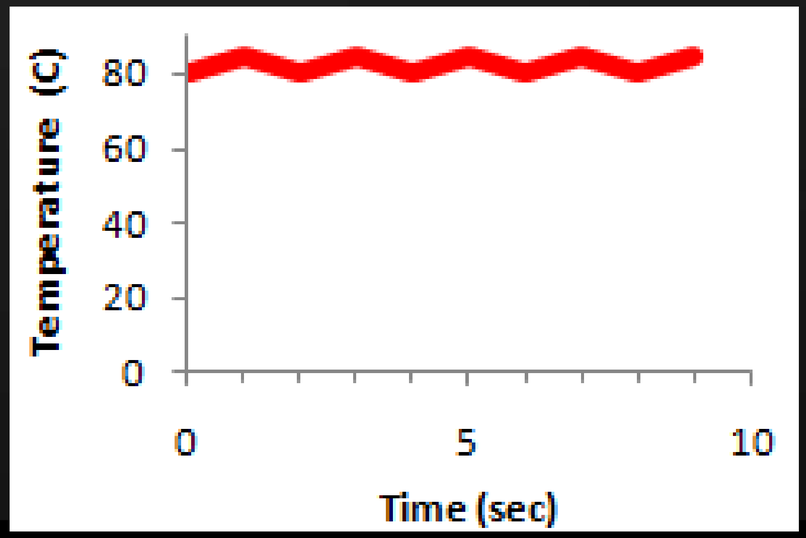



# Additional Cartridge Heater Controls

- Time Control
- Thermocouple
  - Switches Heat Flux On/Off to try maintain temperature within set range at a thermocouple

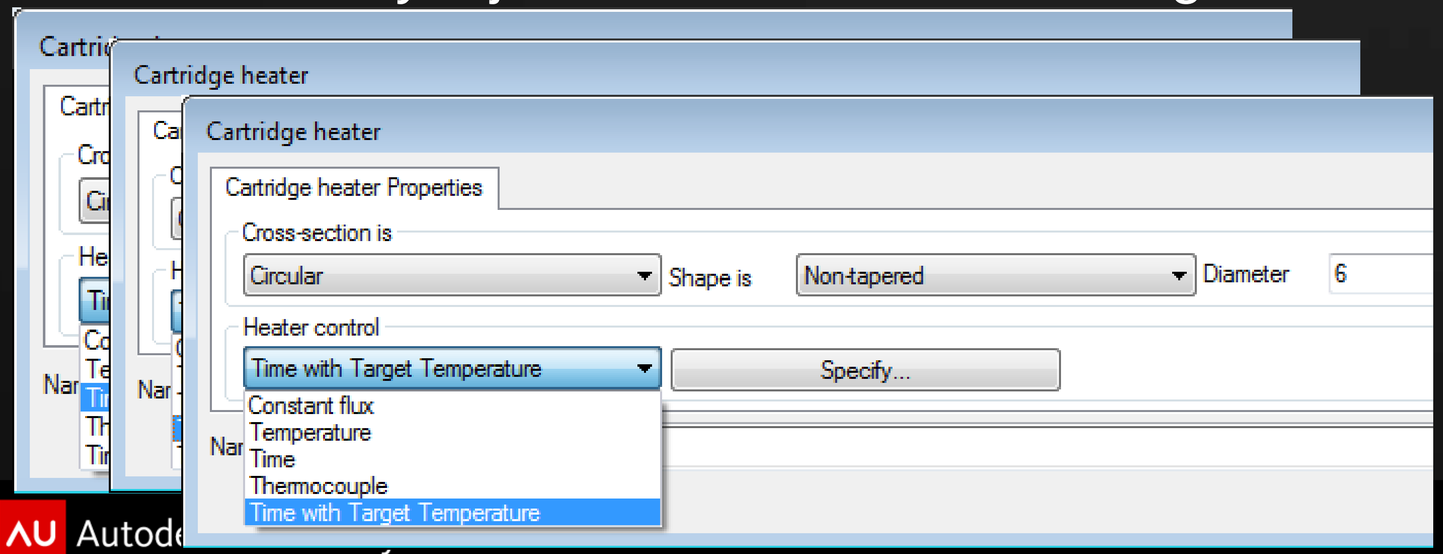


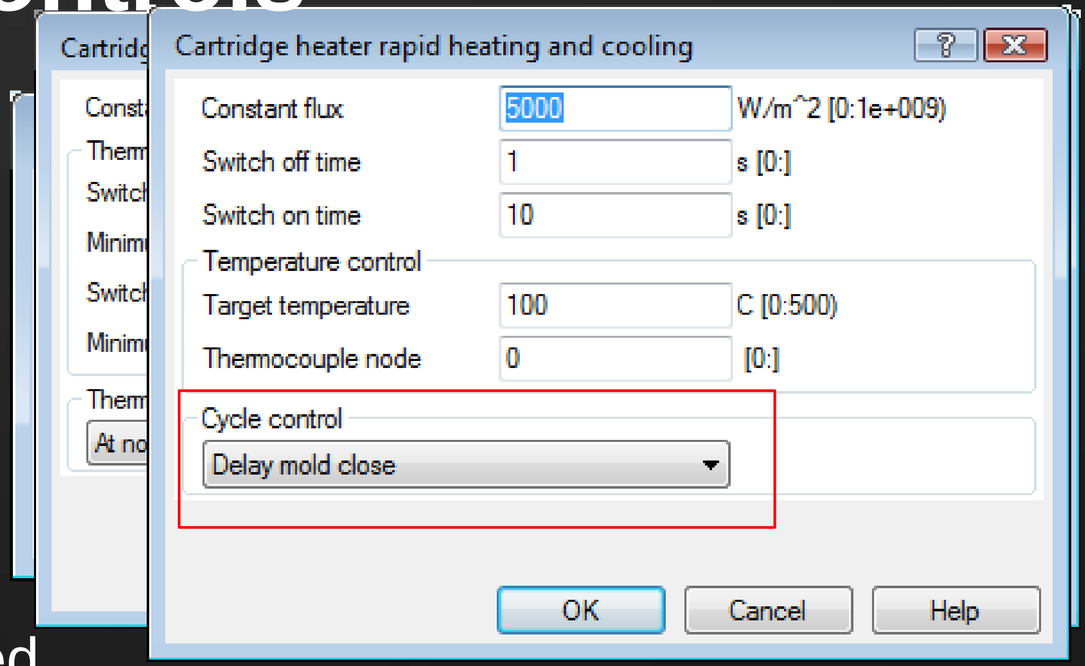



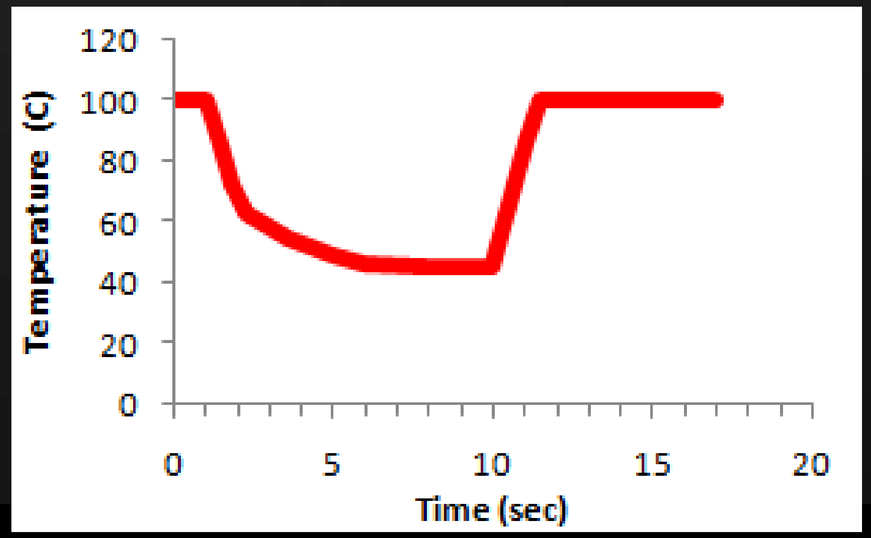



# Additional Cartridge Heater Controls

- Time Control
- Thermocouple
  - Switches Heat Flux On/Off to try maintain temperature within set range at a thermocouple
- Time & Target Temperature for RTC
  - Specify On/Off periods in the cycle
  - Specify a target temperature at control node
  - Can delay Injection/mold close until target reached

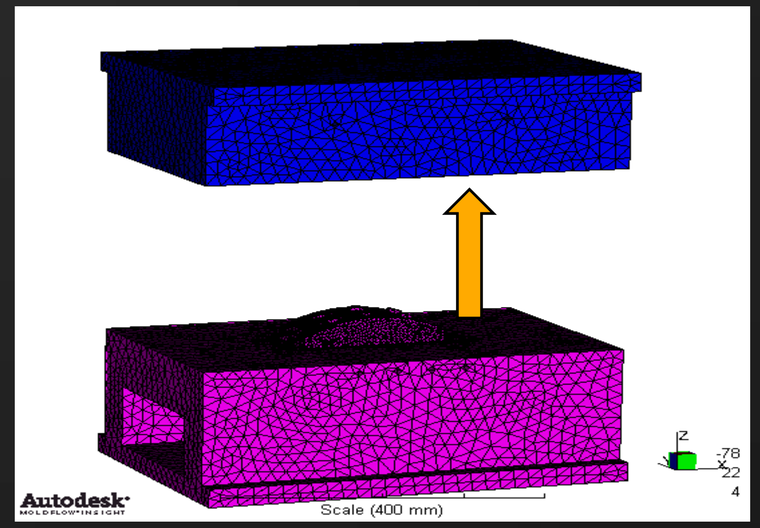


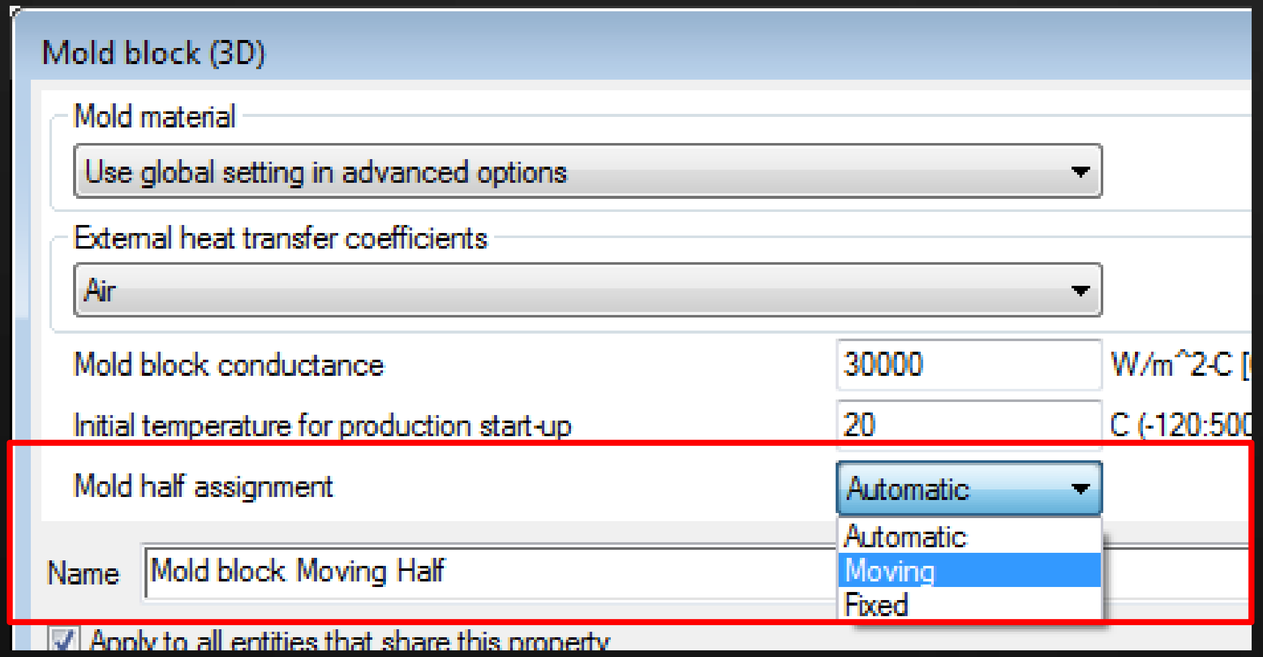



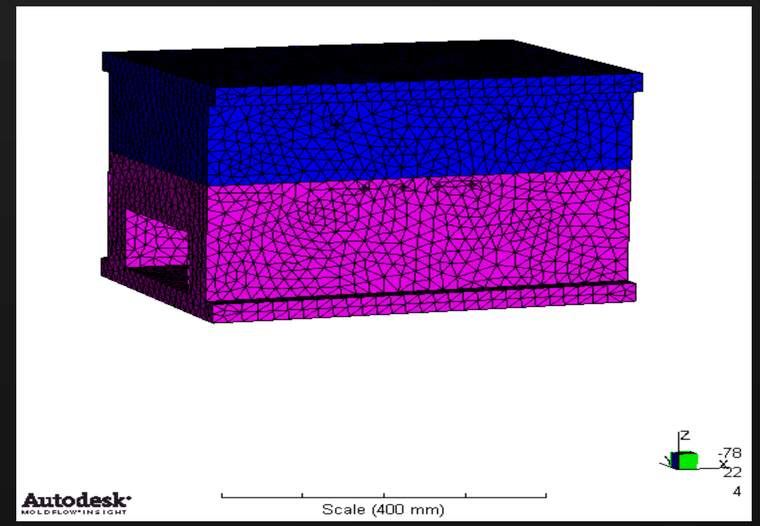



# Thermal Isolation During Mold Open

- Rapid heating usually only on cavity (fixed-side)
- Heating Phase may start while mold is open
  - No thermal contact between mold halves
  - Assign automatically (Can override)

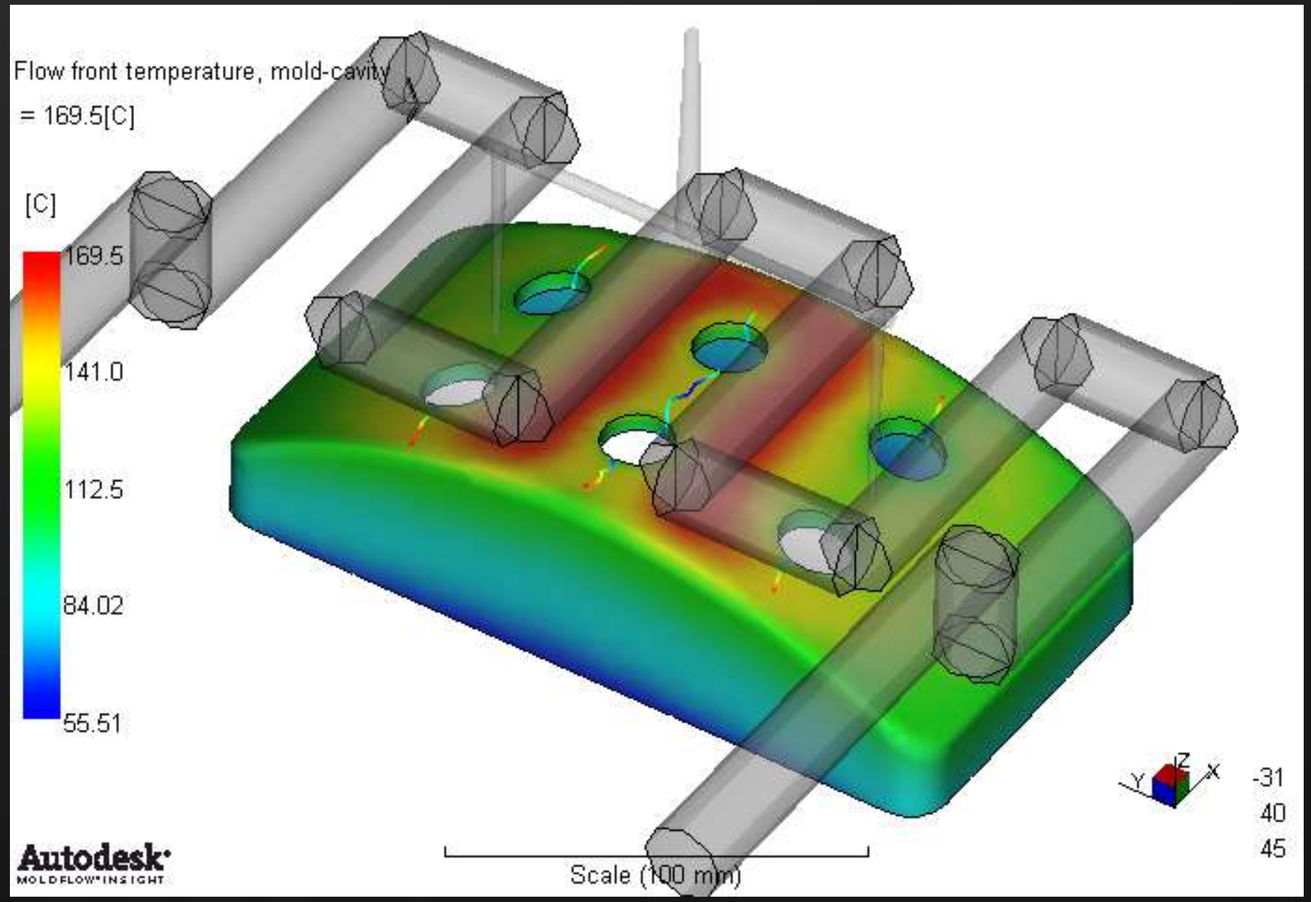


# New Result: Flow Front Cavity Surface Temperature

- Cavity surface temperature at the time of filling
  - Useful to understand gloss and weld-line appearance



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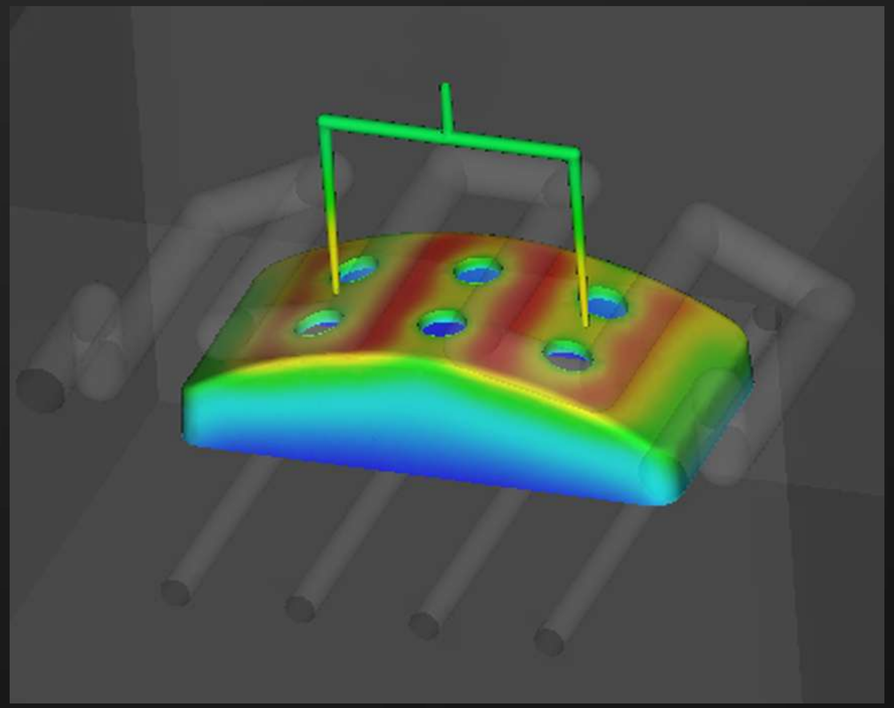
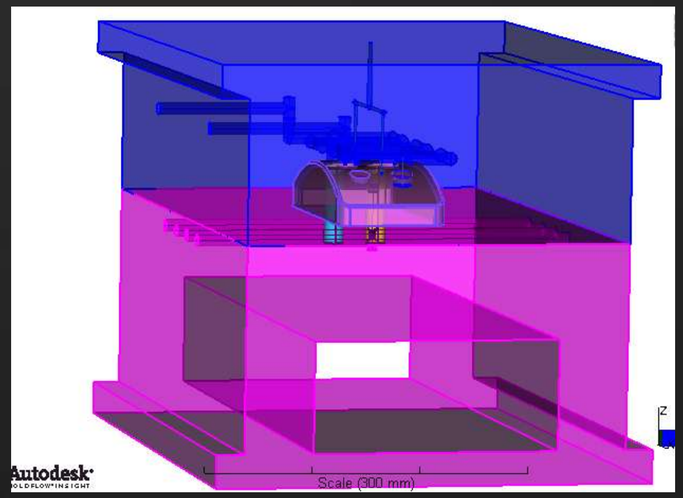
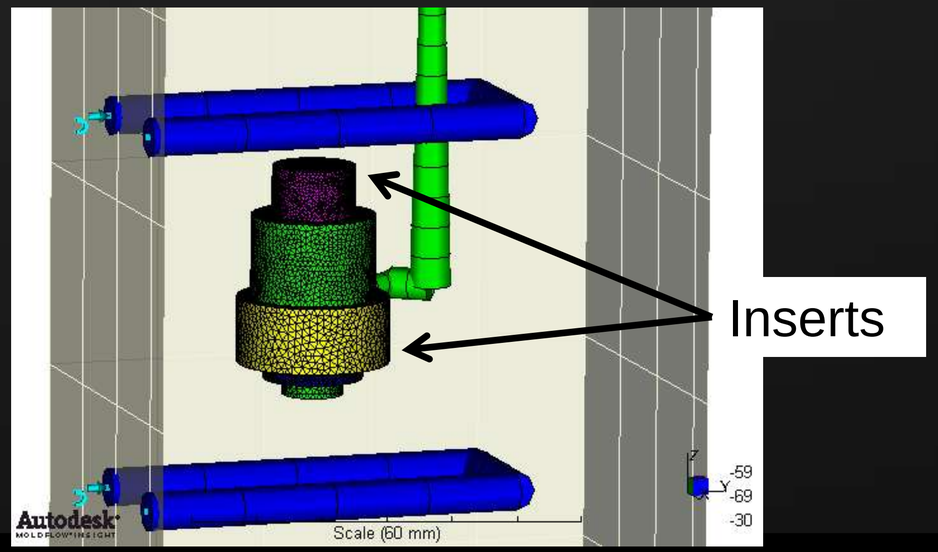


# Mold Mesh Preparation: 2 Possibilities

- 1: CAD geometry of mold
  - Can specify local mesh densities
  - Optional: Simplify geometry in Inventor Fusion or CAD Doctor

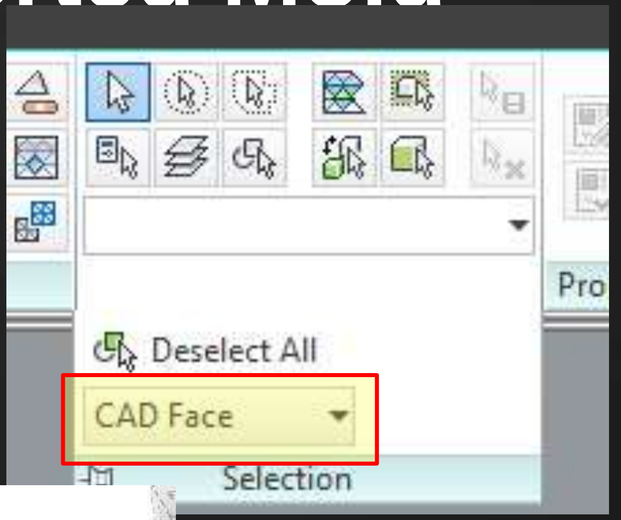


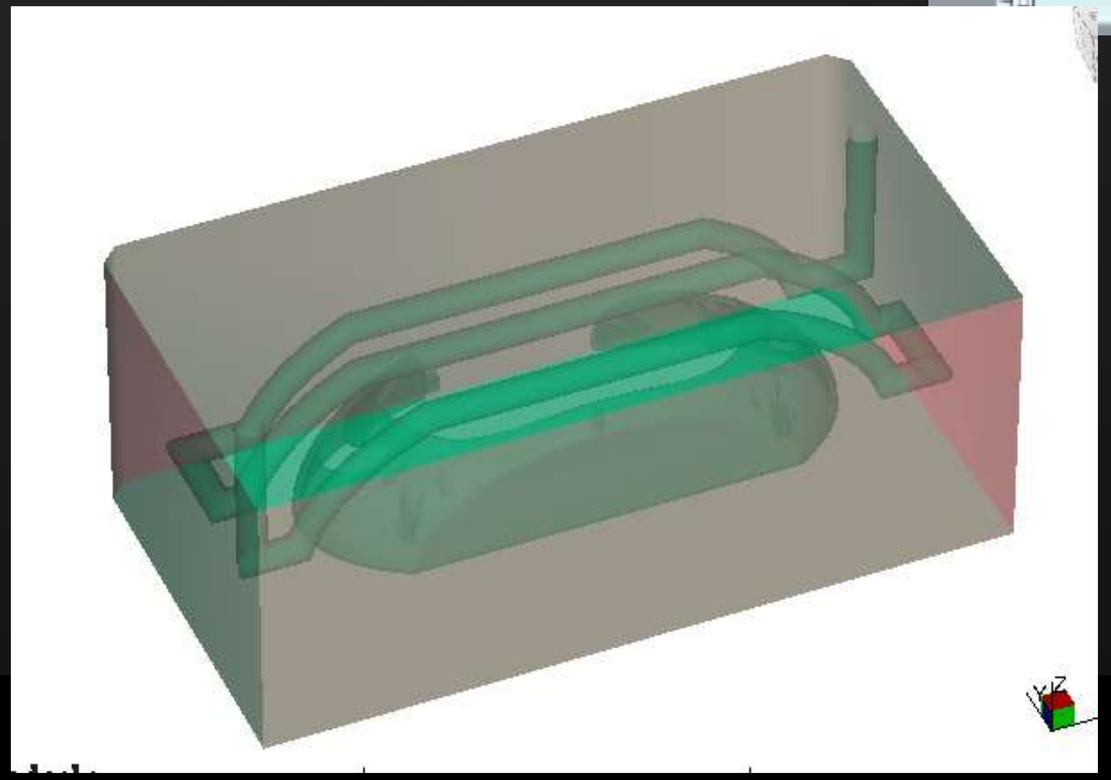

- 2: Mold Mesh Wizard
  - If you don't have the mold CAD
  - Start from existing study file
  - Part, feed system and cooling lines
  - Automatically created a mold mesh around these components
  - New: Inserts now also supported



# Specifying Mesh Density on CAD Imported Mold

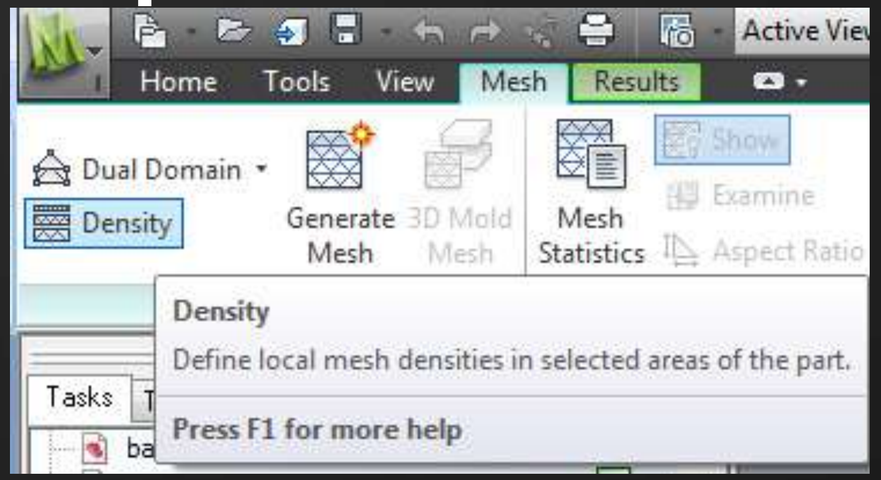
- Change Selection mode to allow CAD Faces to be picked
  - On the “Mesh” Menu
- Select only the outer mold surfaces
  - Hold down “Ctrl” key for multiple selections

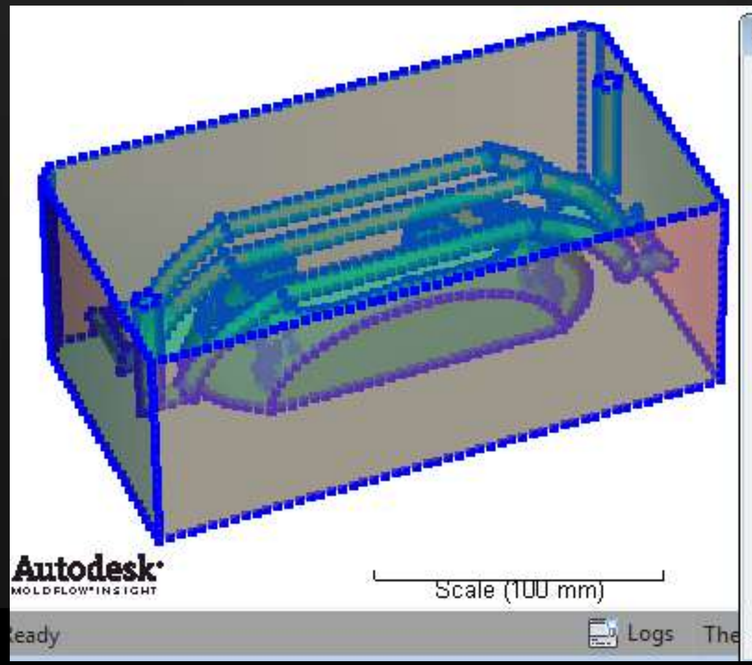


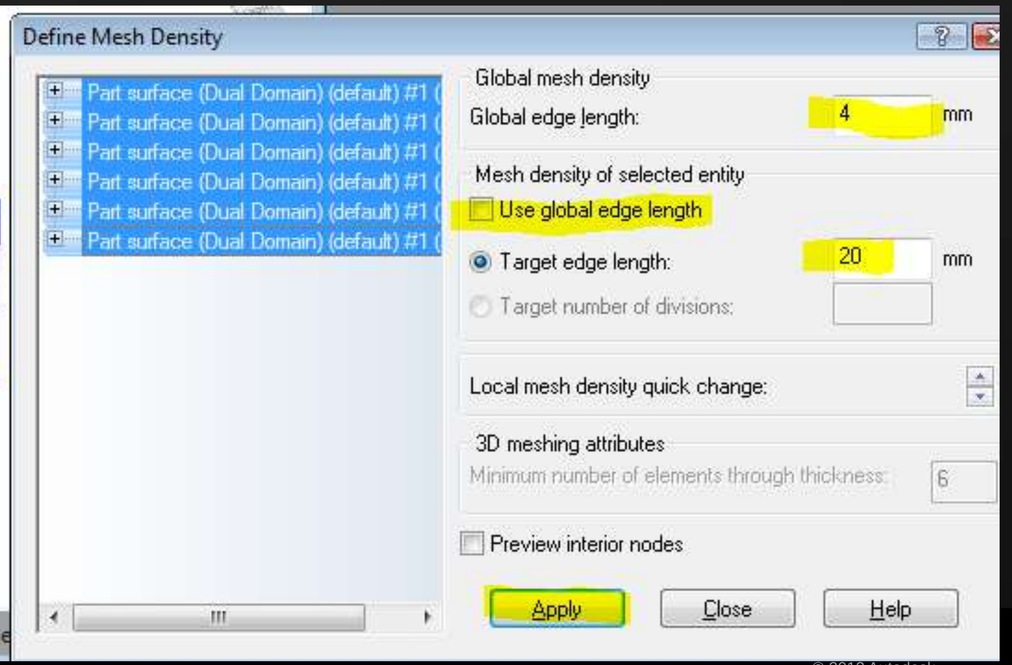



# Specifying Mesh Density on CAD Imported Mold

- Specify a larger element size on the outer surfaces than the internal (Global) size
- Select all surfaces in the list
- Deselect “Use global edge length”
- Set Target edge length
- Click Apply
  - Do not just “close”

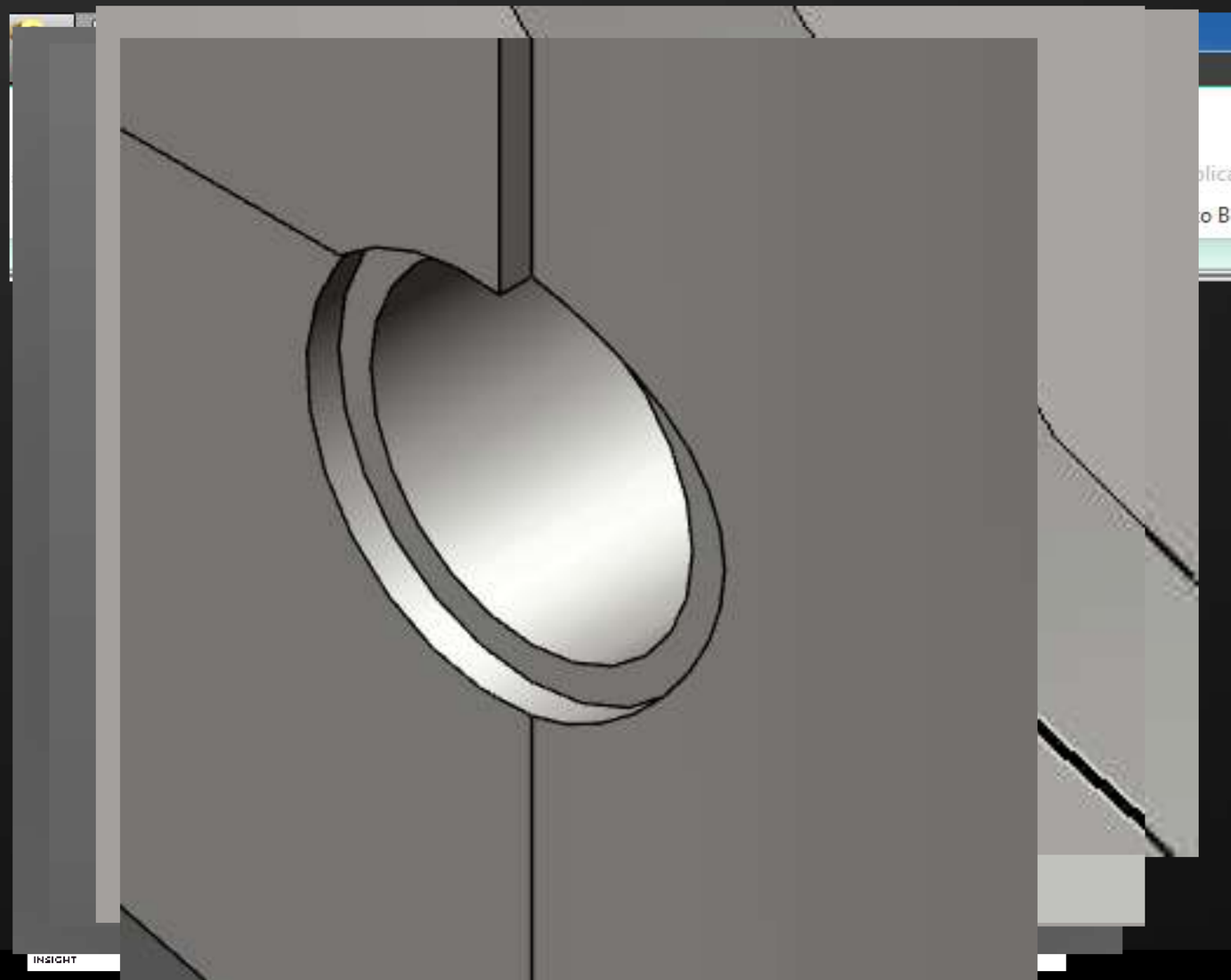


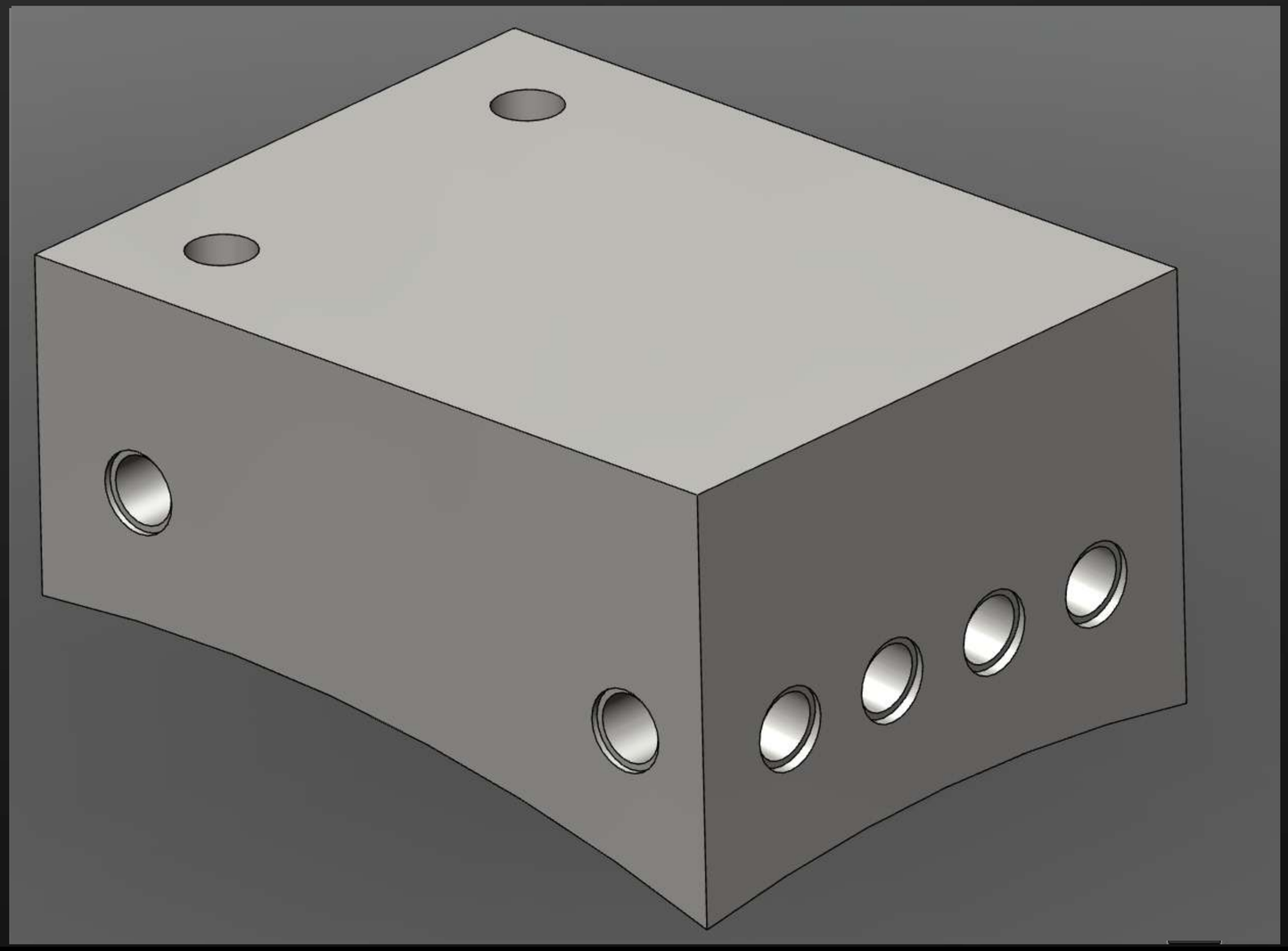
# Simplify CAD model in Autodesk Inventor Fusion

- Mold geometry has some unnecessary small features
  - Will require a fine mesh on outer surfaces
- Push to Inventor Fusion from inside Moldflow Insight
- Select face
- Hover over adjacent face & click
- Remove features by pushing to adjacent face
- Repeat for other features



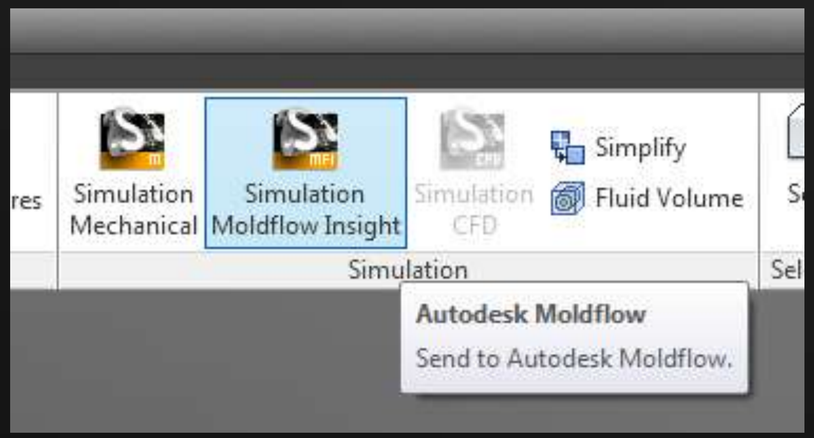
# Simplify CAD model in Autodesk Inventor Fusion

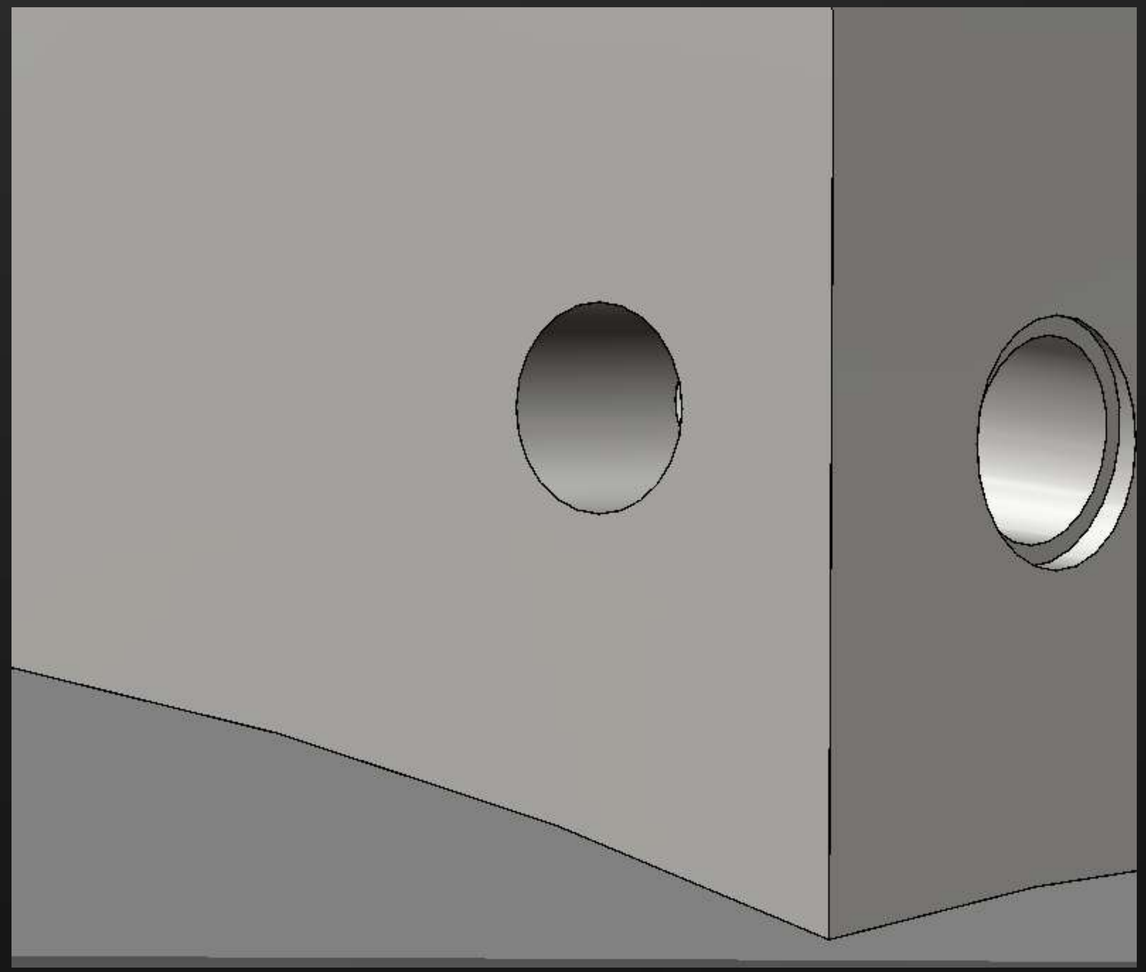
- Remove fillets, chamfers and rounds
  - Select and Delete



# Simplify CAD model in Autodesk Inventor Fusion

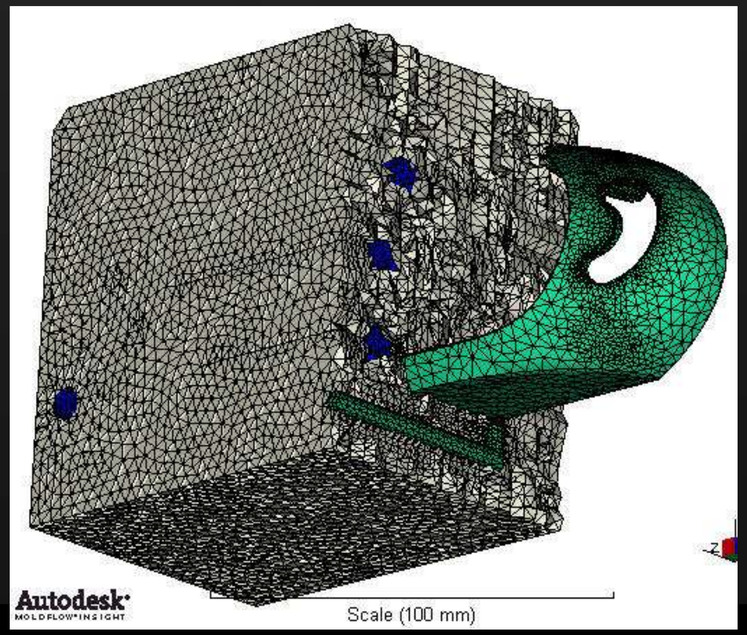
- Simplify holes
  - By select and pull to face
- Export to Moldflow Insight

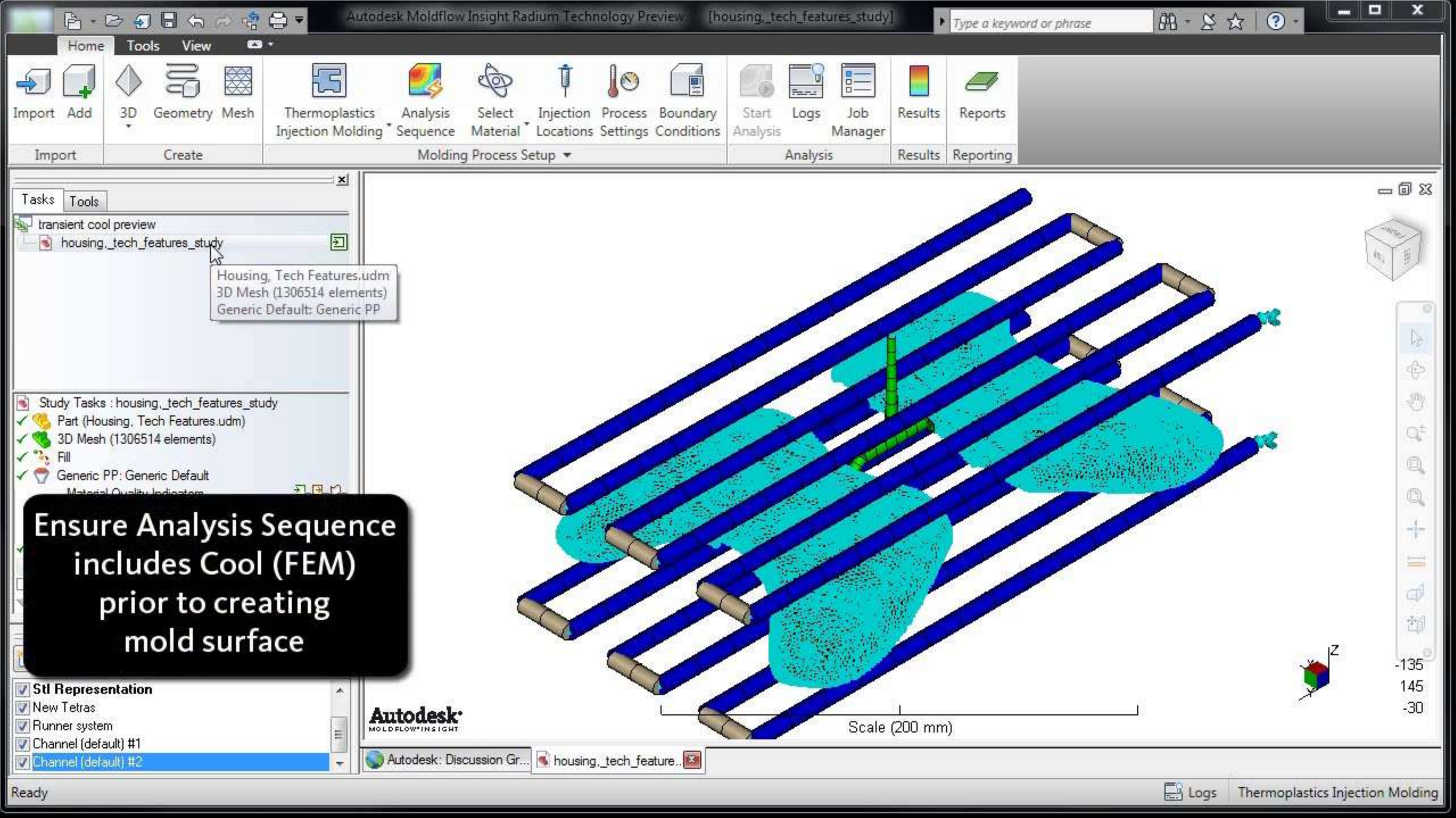


# Build 3D mold in Moldflow Insight

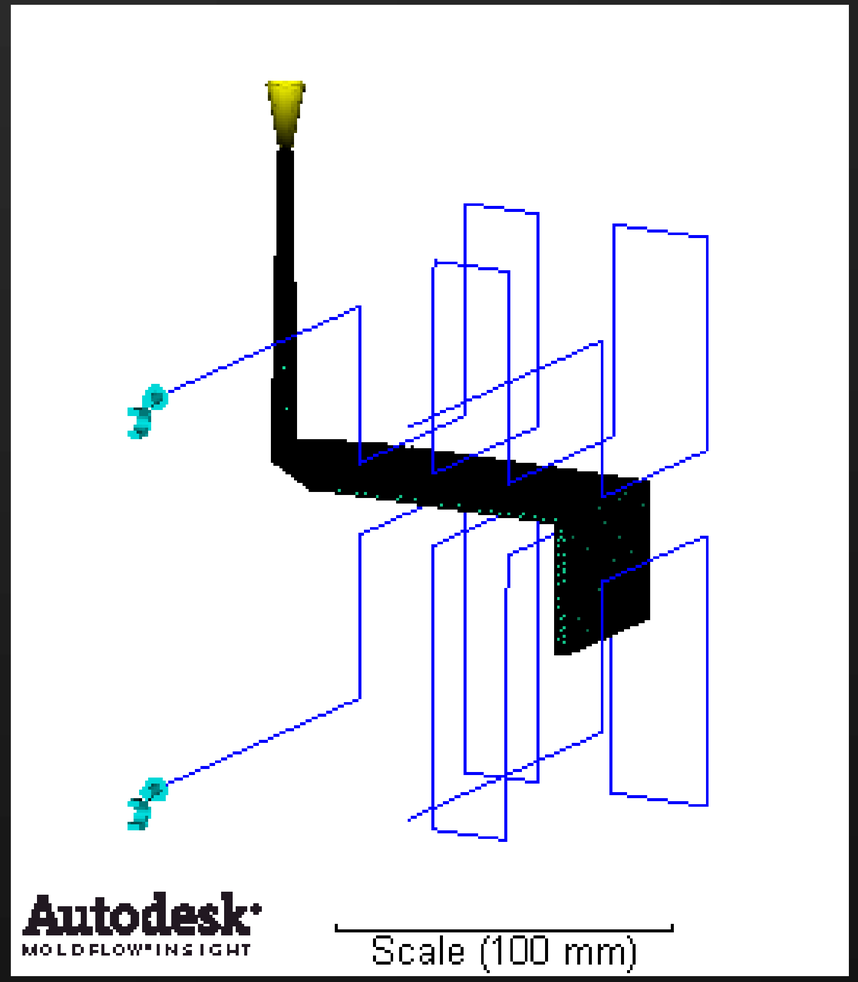
1. Start from an existing Moldflow Insight study file
   - With cavity mesh and cooling circuit lines and feed system lines
2. Use Mold Surface Wizard to define mold size
3. 3D Mold mesh wizard in two stages to build the mold mesh from these features and boundary.




Autodesk Moldflow Insight Radium Technology Preview [housing,_tech_features_study]
Type a keyword or phrase
Home
Tools
View
Import
Add
3D
Geometry
Mesh
Thermoplastics Injection Molding
Analysis Sequence
Select Material
Injection Locations
Process Settings
Boundary Conditions
Start Analysis
Logs
Job Manager
Results
Reports
Import
Create
Molding Process Setup
Analysis
Results
Reporting
Tasks
Tools
transient cool preview
housing,_tech_features_study
Housing, Tech Features.udm
3D Mesh (1306514 elements)
Generic Default: Generic PP
Study Tasks : housing,_tech_features_study
Part (Housing, Tech Features.udm)
3D Mesh (1306514 elements)
Fill
Generic PP: Generic Default
Ensure Analysis Sequence includes Cool (FEM) prior to creating mold surface
Stl Representation
New Tetras
Runner system
Channel (default) #1
Channel (default) #2
Autodesk
MOLDFLOW INSIGHT
Scale (200 mm)
Z
-135
145
-30
Autodesk: Discussion Gr...
housing,_tech_feature...
Ready
Logs
Thermoplastics Injection Molding

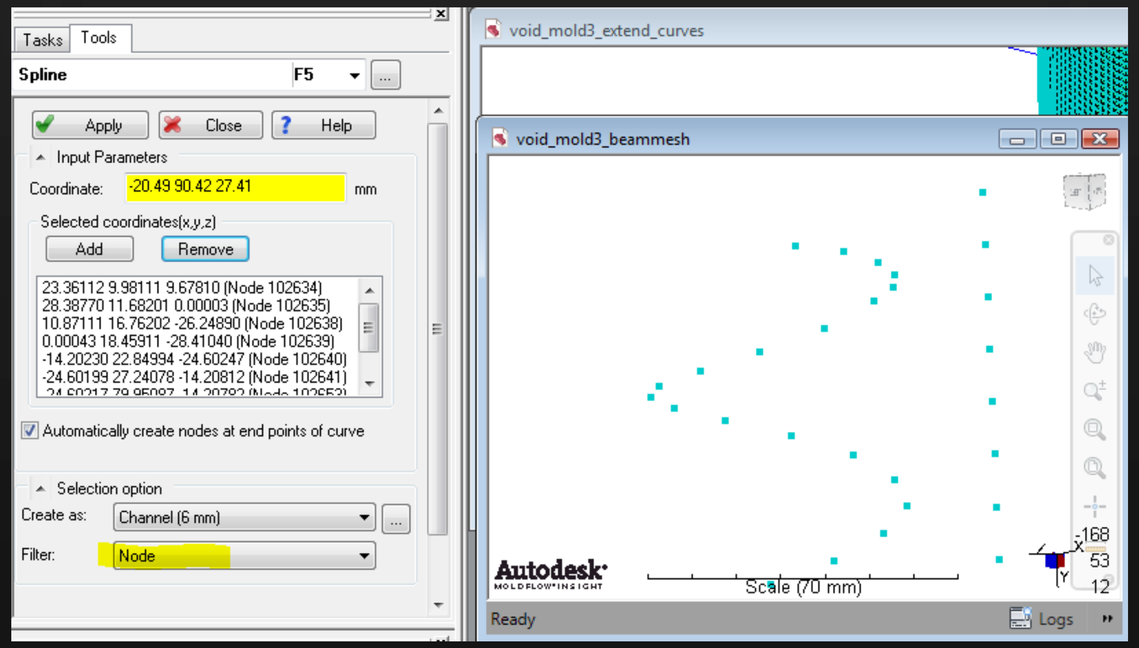
# 3D Mold Meshing – Detailed Walkthrough (1)

- Start with an existing study file
  - Need a 3D Part mesh
  - Runner system can be tetrahedra or 1D curves
  - Cooling lines must have 1D curves (not just beam elements)
  - If you don’t have the 1D curves you can create them using the beam nodes as end points



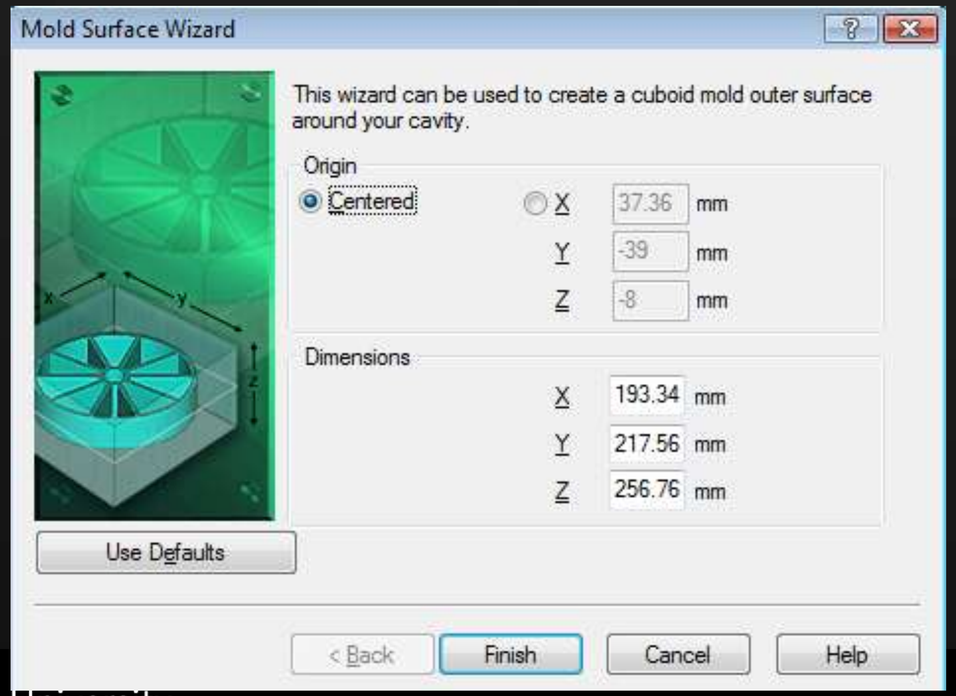
# 3D Mold Meshing – Detailed Walkthrough (2)

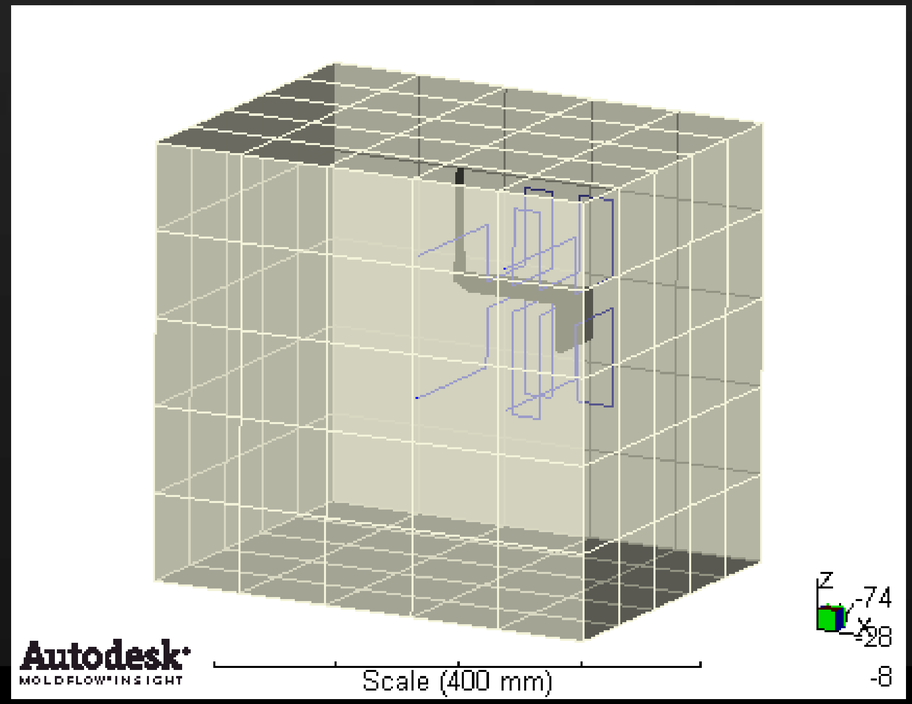
- To create straight channel lines, use “Create Line”
  - Pick the existing mesh nodes get the end coordinates
  - Extend cooling channels all the way to the intended mold boundary
- If you have a curved cooling channel without the 1D curve: Create curve by Spline



# 3D Mold Meshing – Detailed Walkthrough (3)

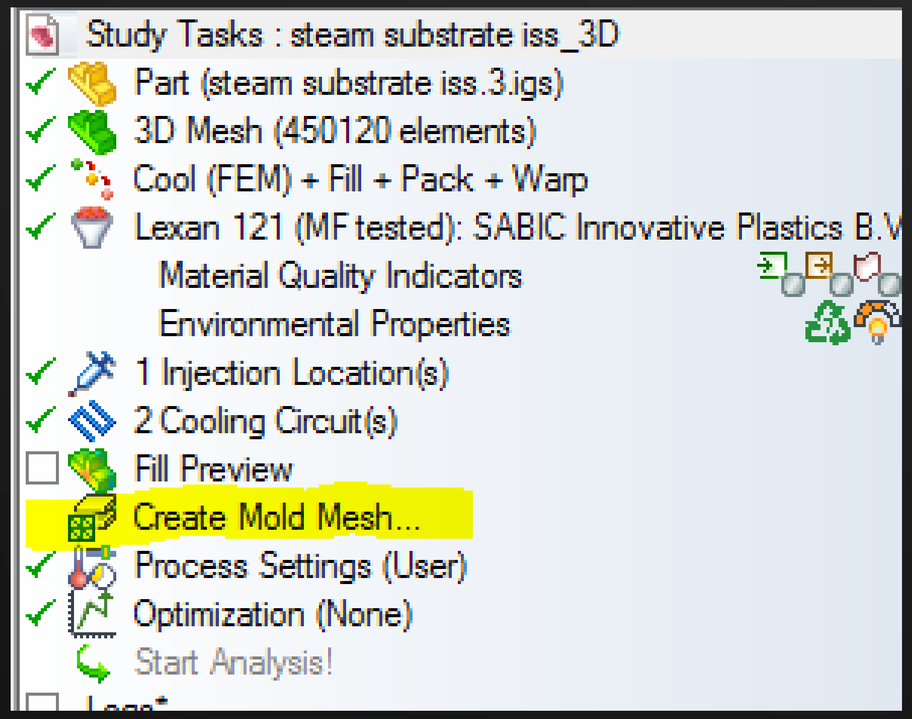
- Set analysis type to Cool (FEM)
- Create outer mold boundary with the “Mold Surface” Wizard
  - Similar to the existing mold surface wizard for convential cool (BEM)
  - Will create only the mold region – not the triangle surface elements

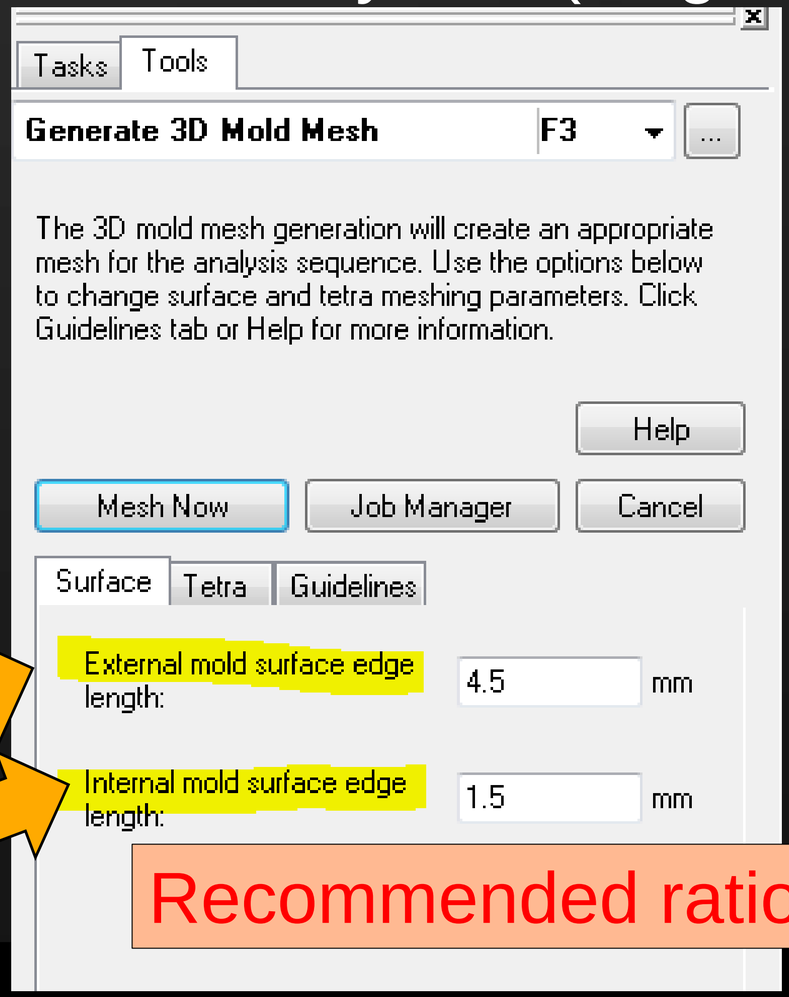


# 3D Mold Meshing – Detailed Walkthrough (4)

- Launch the 3D Mold Meshing Tool from the study tree (stage 1)



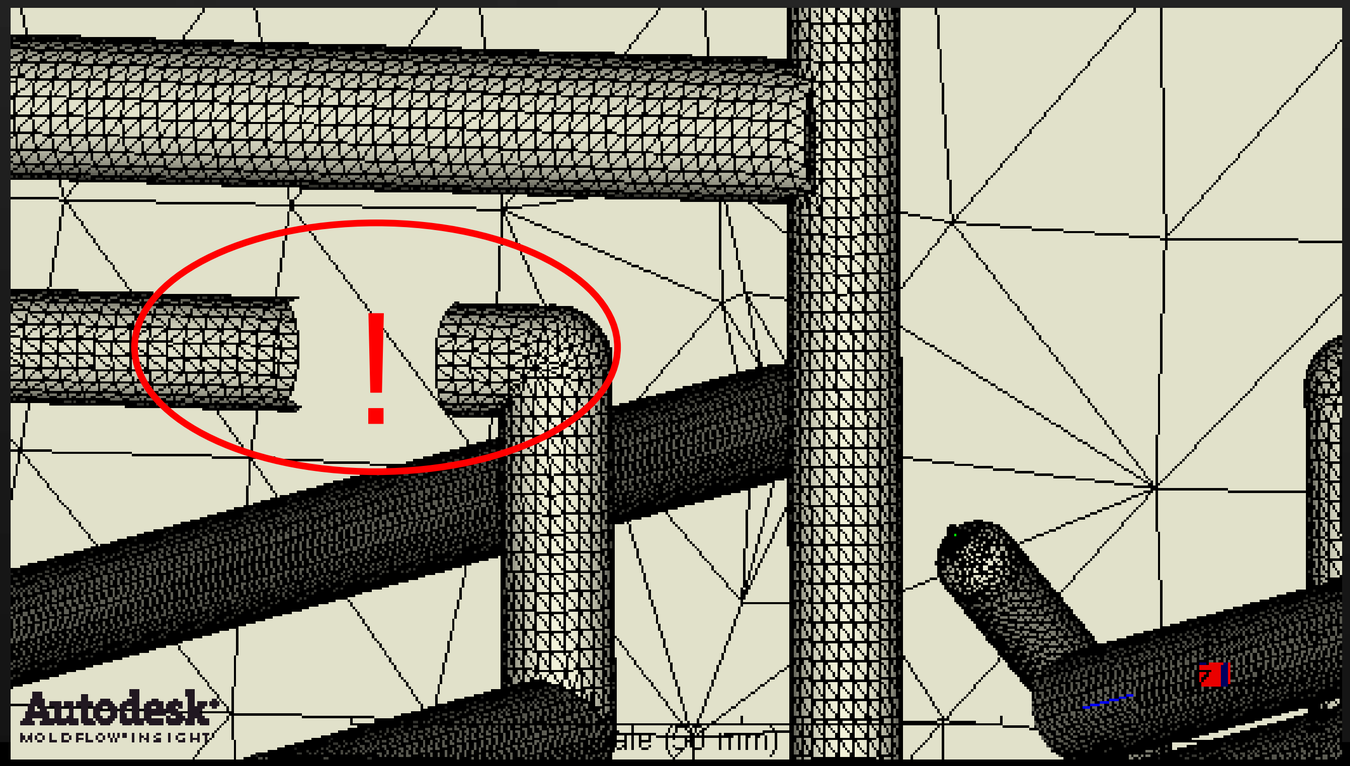




- External: Outer boundary
- Internal: Cavity and Circuits

Recommended ratio: 3 to 4

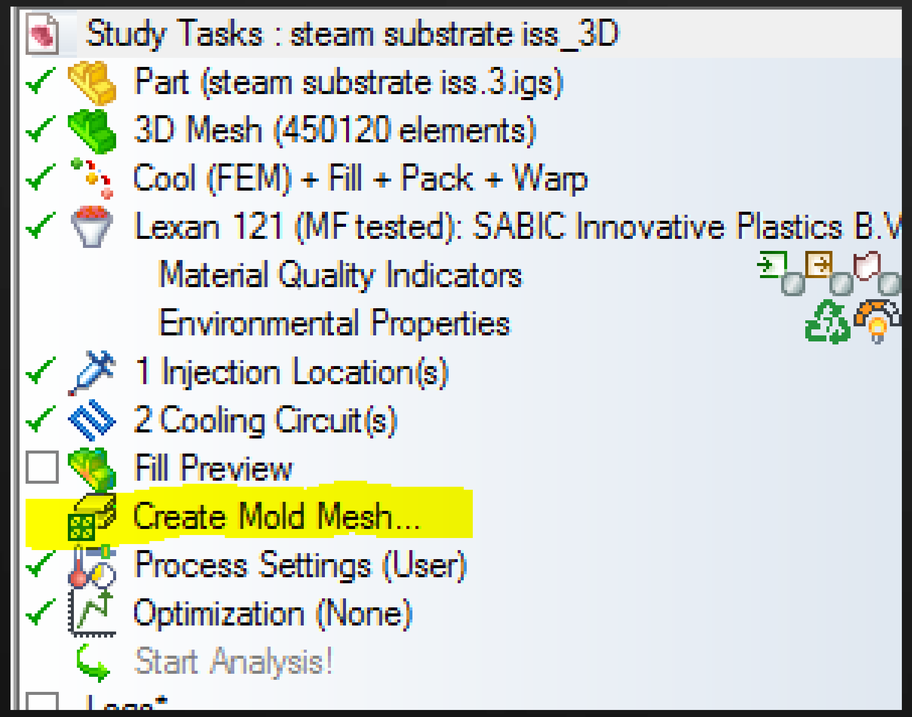
# 3D Mold Meshing – Detailed Walkthrough (5)

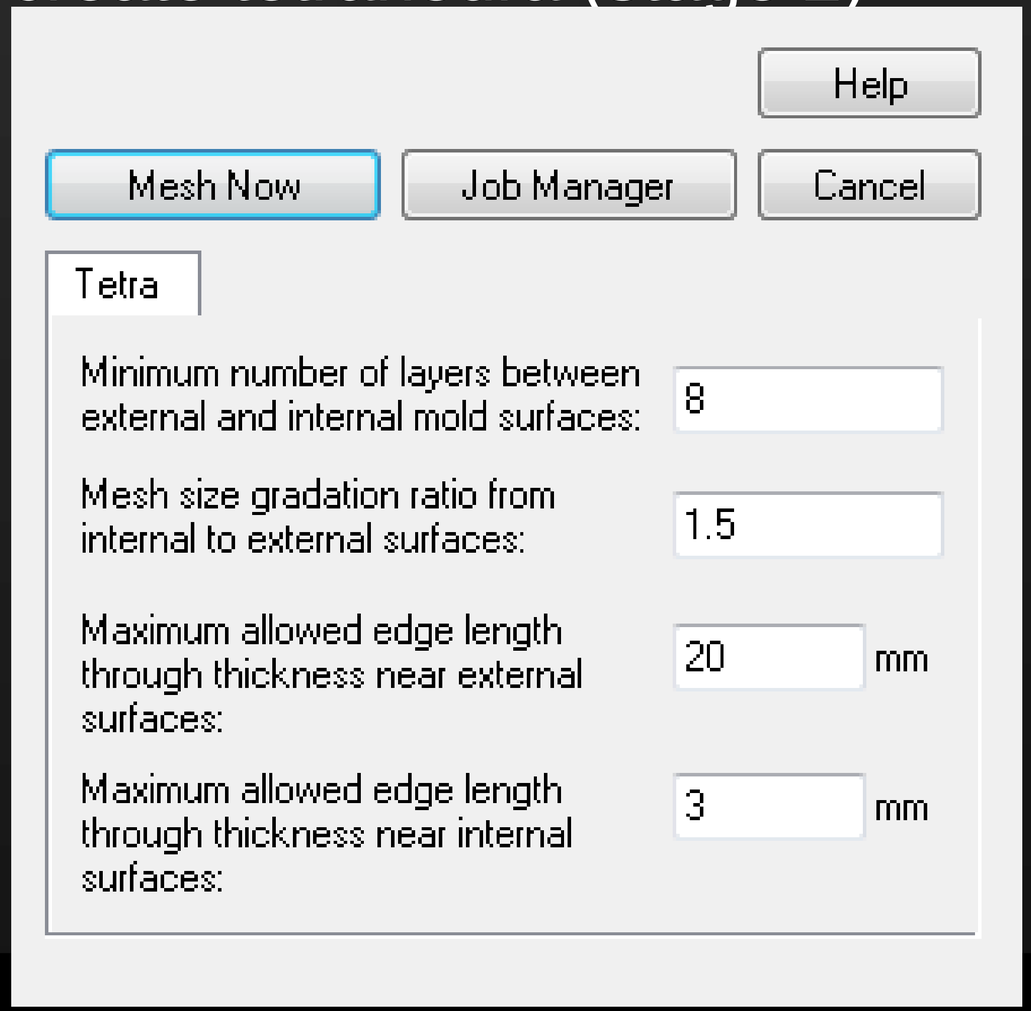
- Result is a surface mesh on the cavity & feed system, channels and outer boundary
- Use Cutting Plane to check all 1D curves were present



# 3D Mold Meshing – Detailed Walkthrough (6)

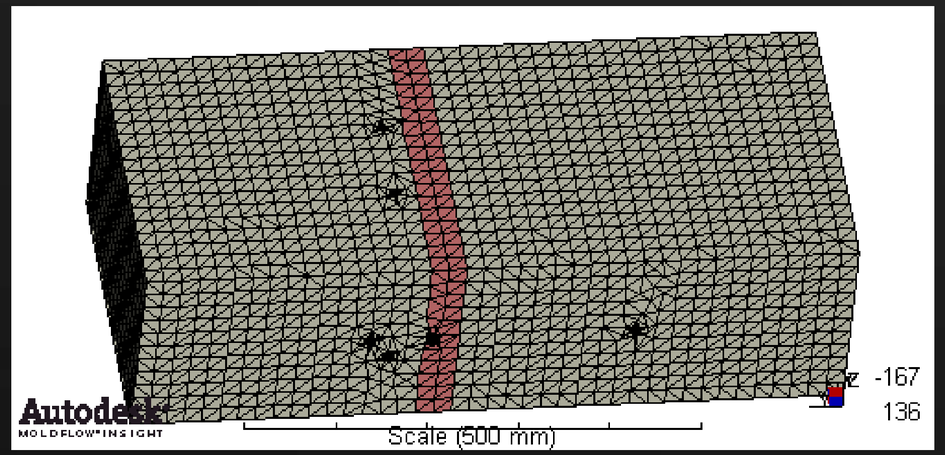
- Launch 3D Mold Meshing again to create tetrahedra (stage 2)

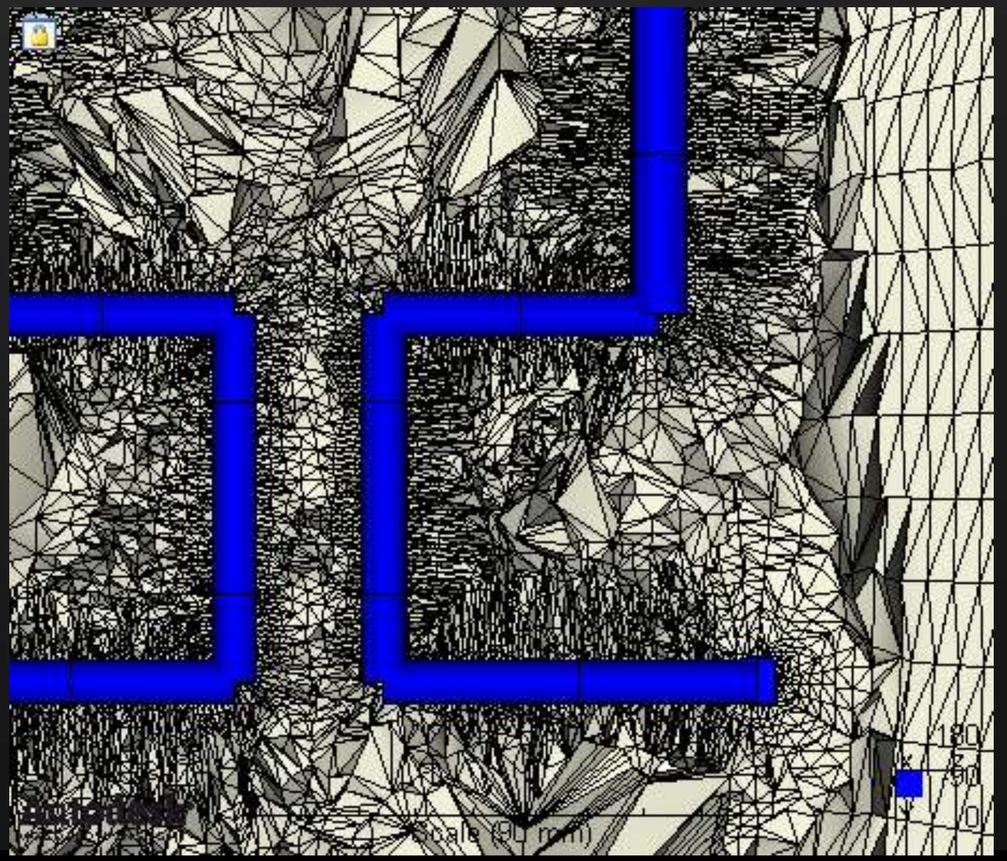


# 3D Mold Meshing – Detailed Walkthrough (7)

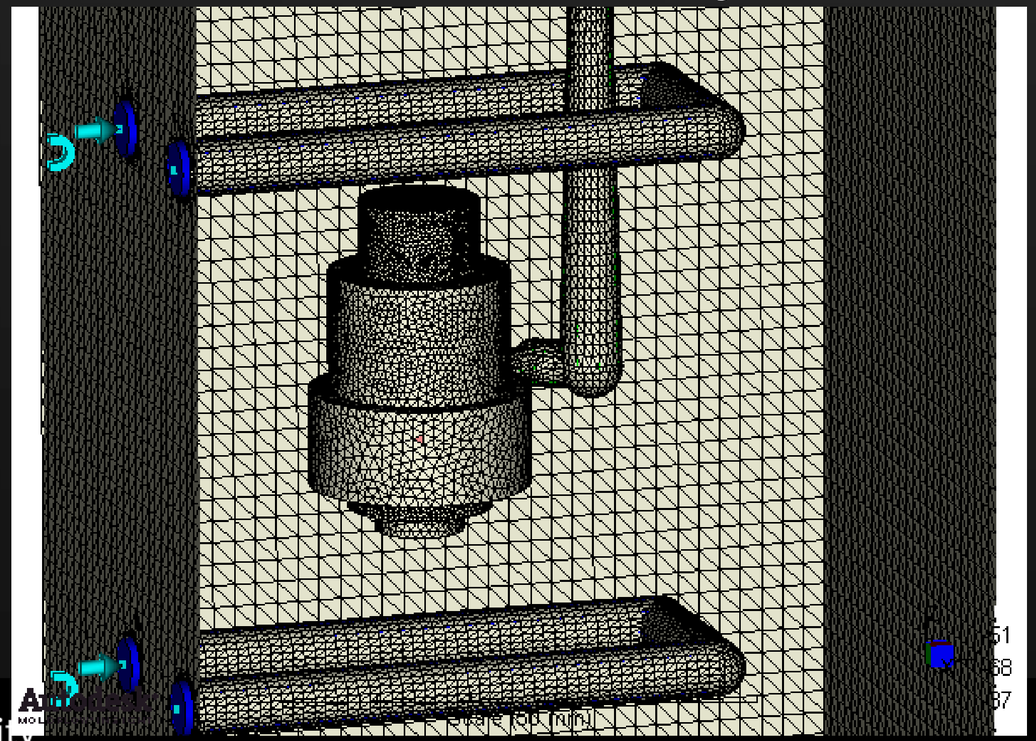
- If you want to see what the internal mold mesh looks like:
  - Put some elements onto a different la
  - Hide all other layers

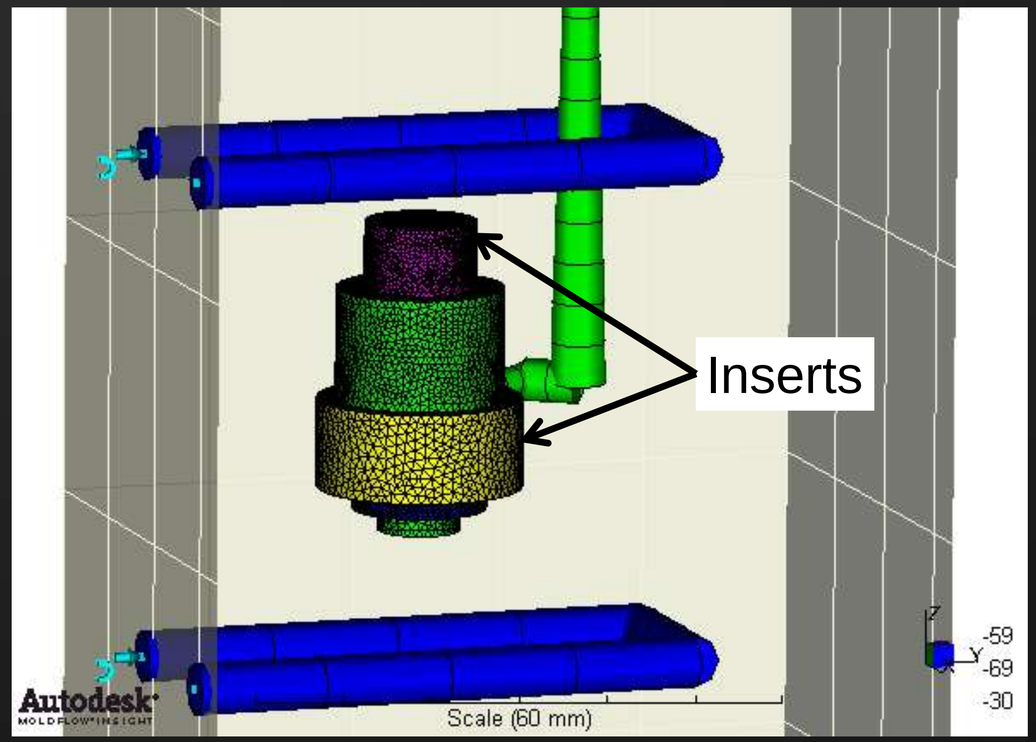


# Mold Meshing for Assemblies

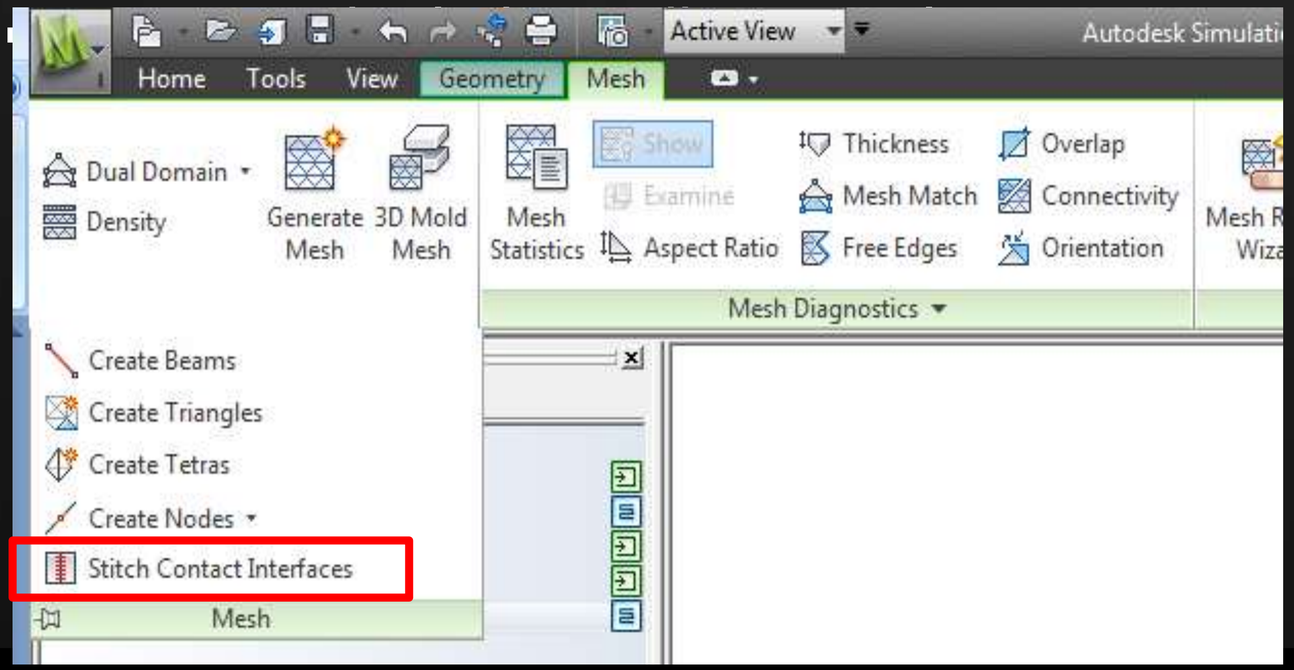
- 3D Mold Meshing Wizard creates mold geometry around part, channels and feed system
  - First creates a surface boundary

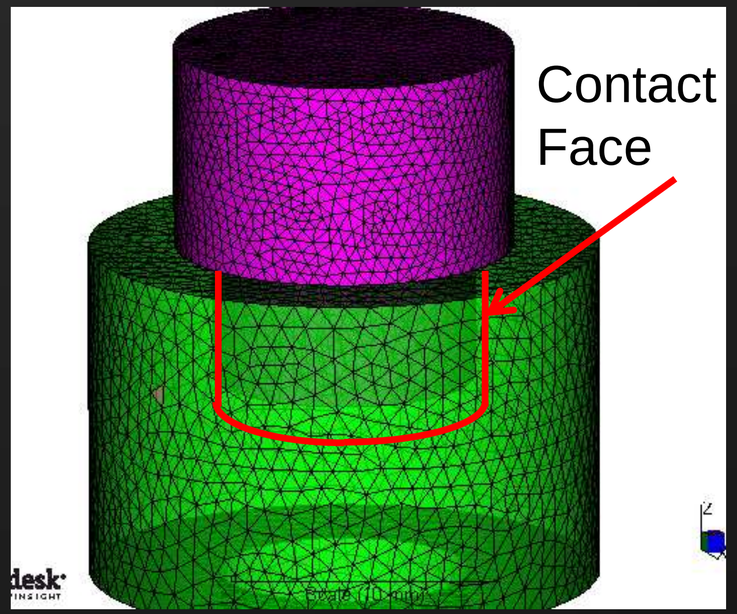




# Mold Meshing Wizard for Assemblies

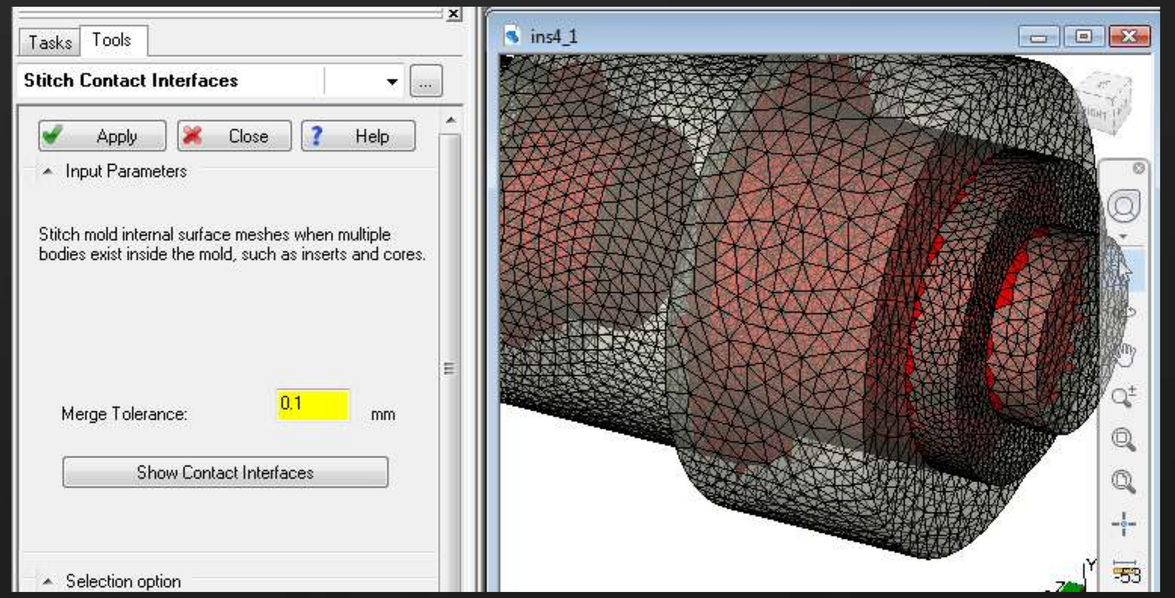
- Insert contact faces would cause a double boundary
- Stitch together the surface meshes of the cavity and inserts



# New Surface Stitching Tool

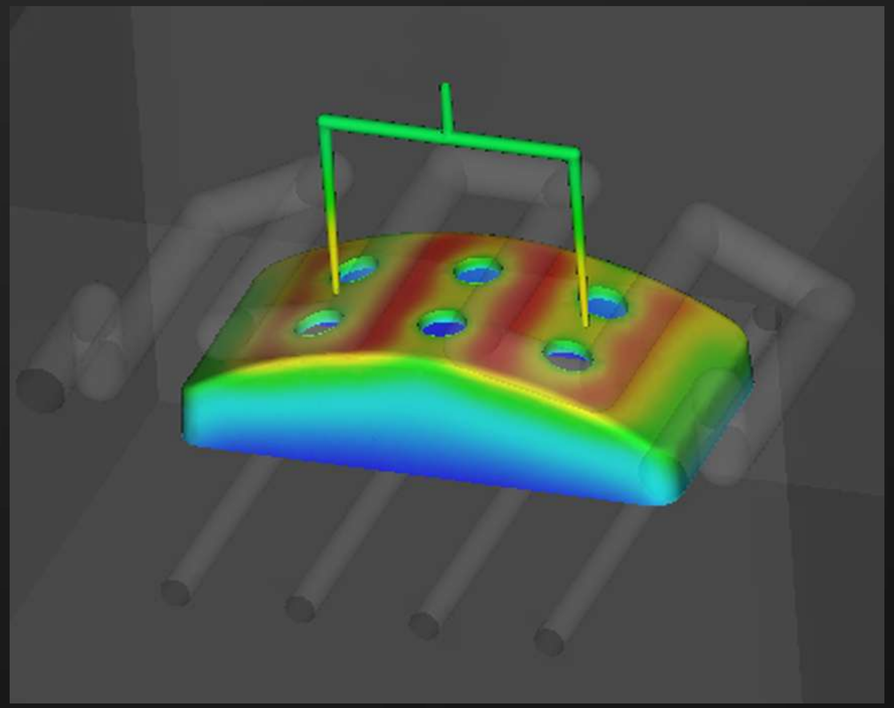
- Eliminates contact surfaces
  - Stitches together at boundaries
  - Preview shows contact areas
  - Specify tolerance




- Use Before launching 3D Mold Meshing
- Works on whatever is visible

# Contents: Transient Mold Temperature Solution

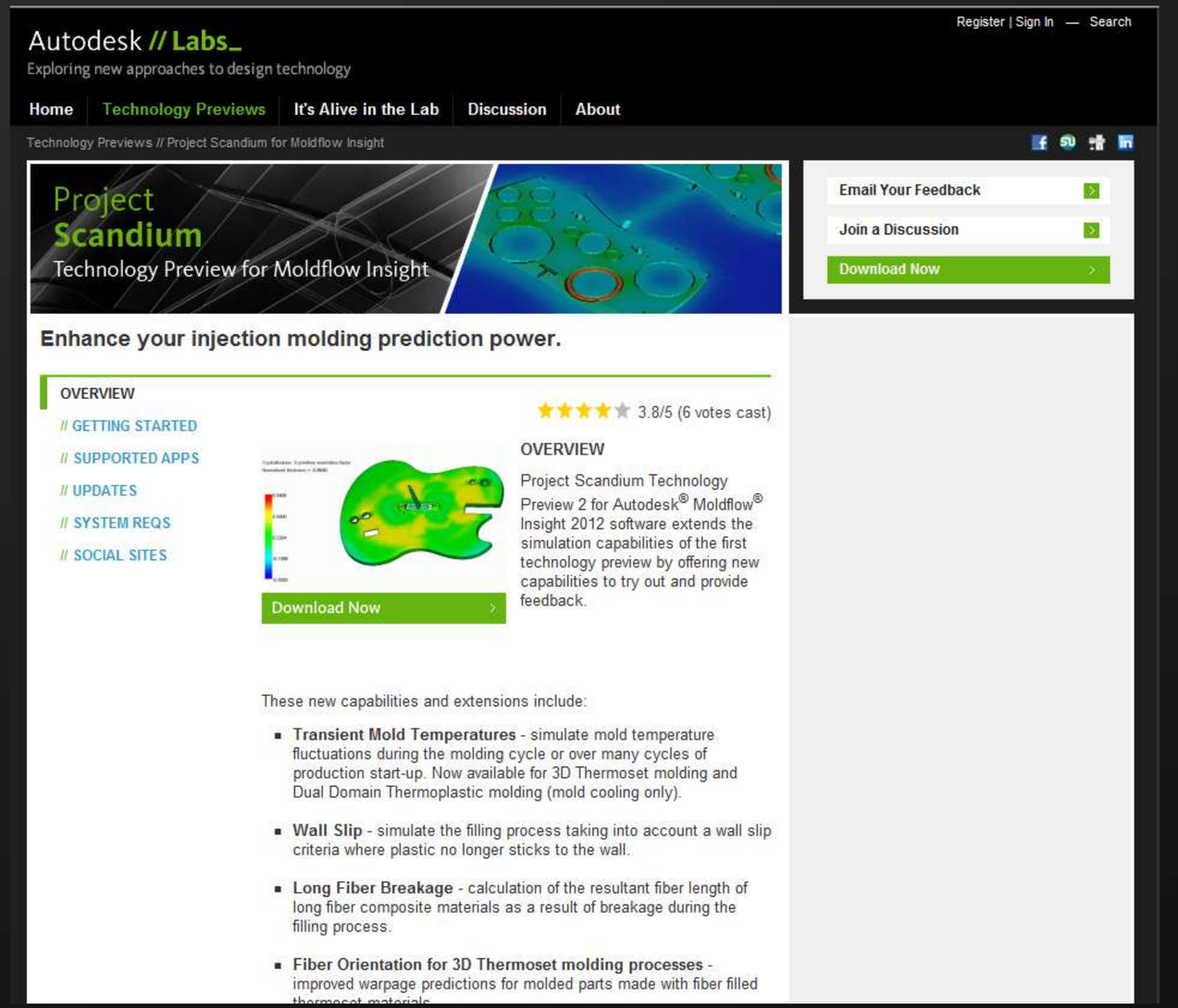
- Features in Moldflow Insight 2013
  - Rapid Temperature Cycling
  - Geometry tools
- Preview
  - Conformal Cooling / 3D Channels
  - Geometry tools
- Hot Runner Component Analysis



# Scandium Technology Preview

- Free download
  - //labs.autodesk.com/utilities/scandium
- English, Windows only
- Requires current Autodesk Moldflow Insight license
- Provides extended functionality and new prototype features for testing and user feedback

No guarantee that these features will survive or graduate to the official release



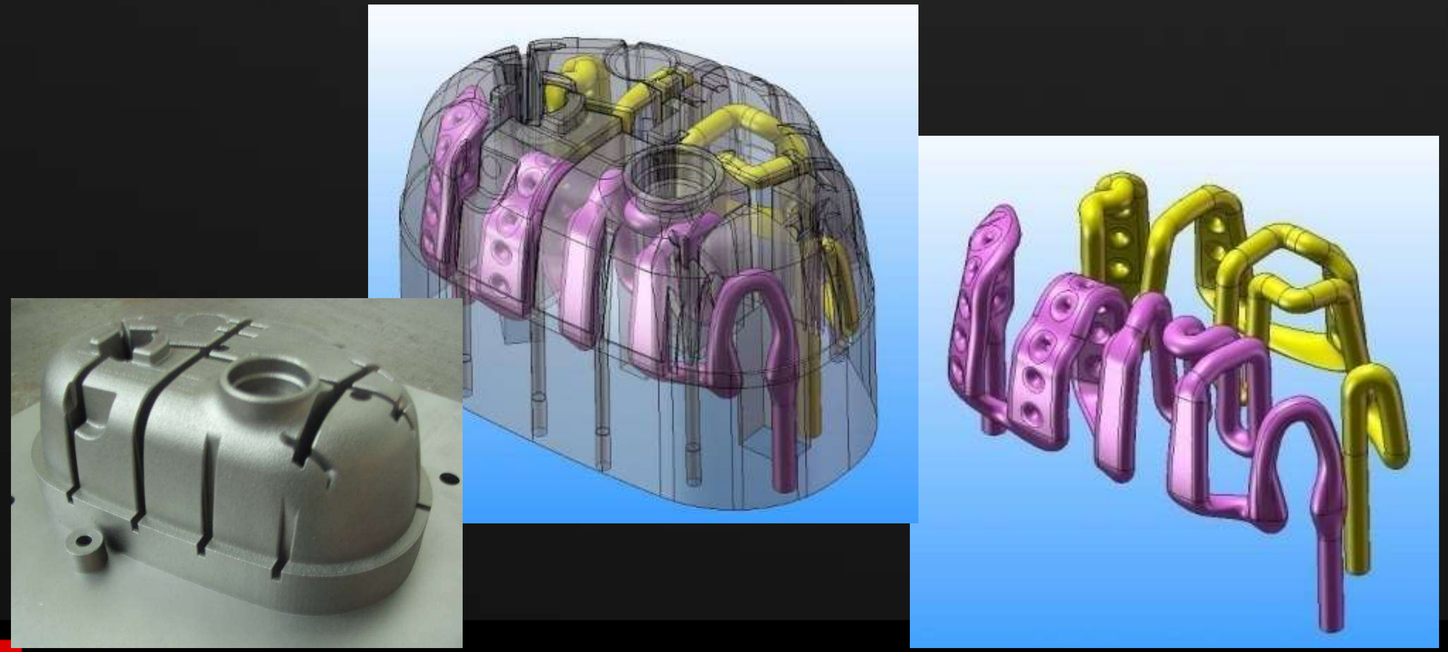
# Disclaimer

*We may make statements regarding planned or future development efforts for our existing or new products and services. These statements are not intended to be a promise or guarantee of future delivery of products, services or features but merely reflect our current plans, which may change. Purchasing decisions should not be made based upon reliance on these statements.*

*The Company assumes no obligation to update these forward-looking statements to reflect events that occur or circumstances that exist or change after the date on which they were made.*

# Simulating Conformal Cooling Channels

- Complex 3D cooling channels
- Temperature control follows part shape
- May not be suited to simulation with beam elements



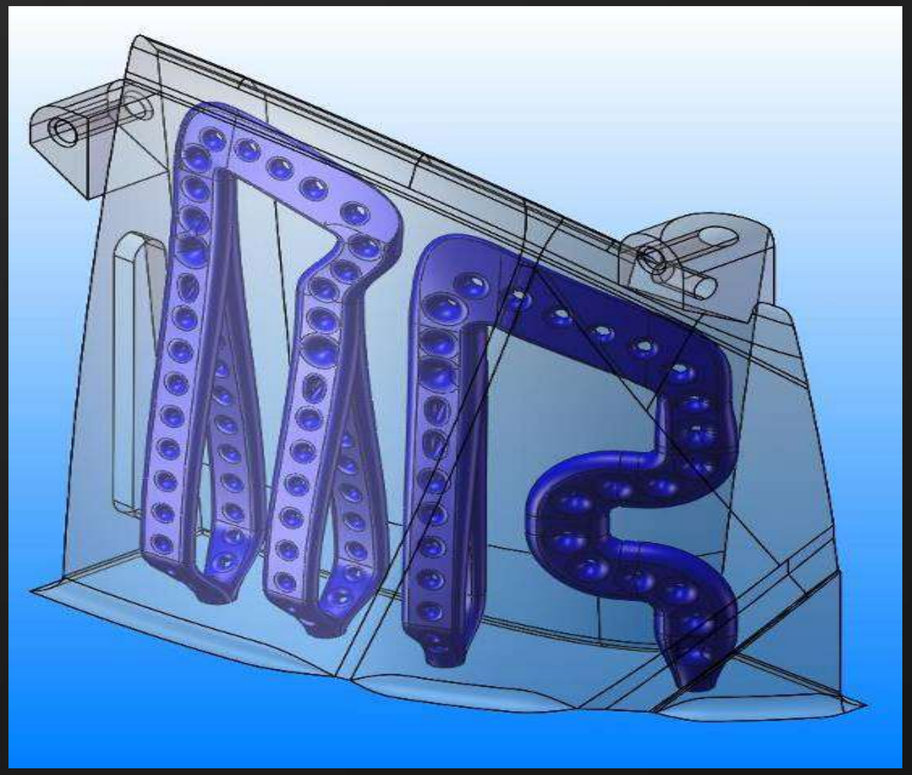
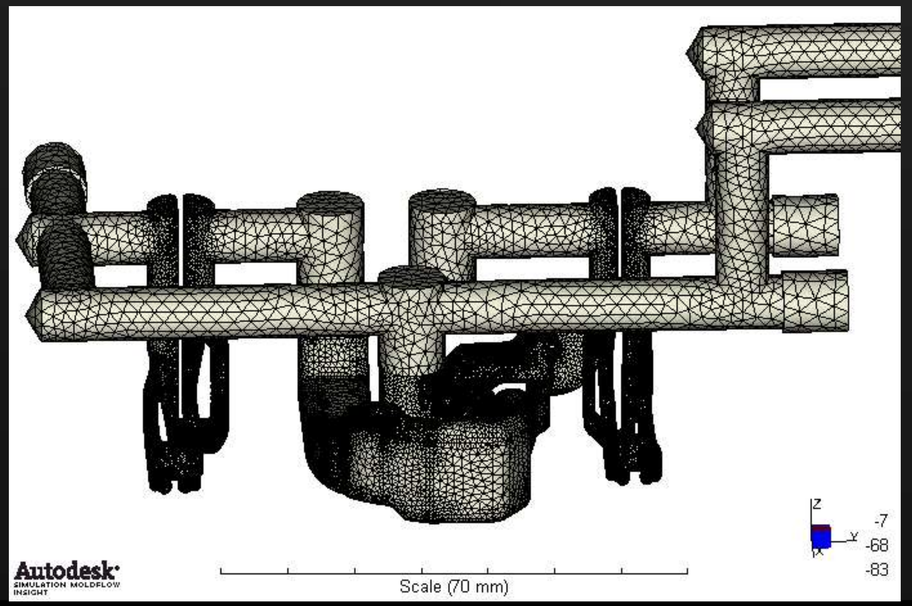
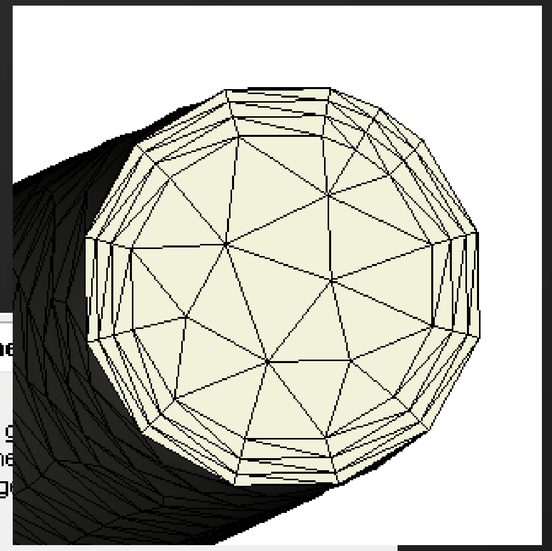


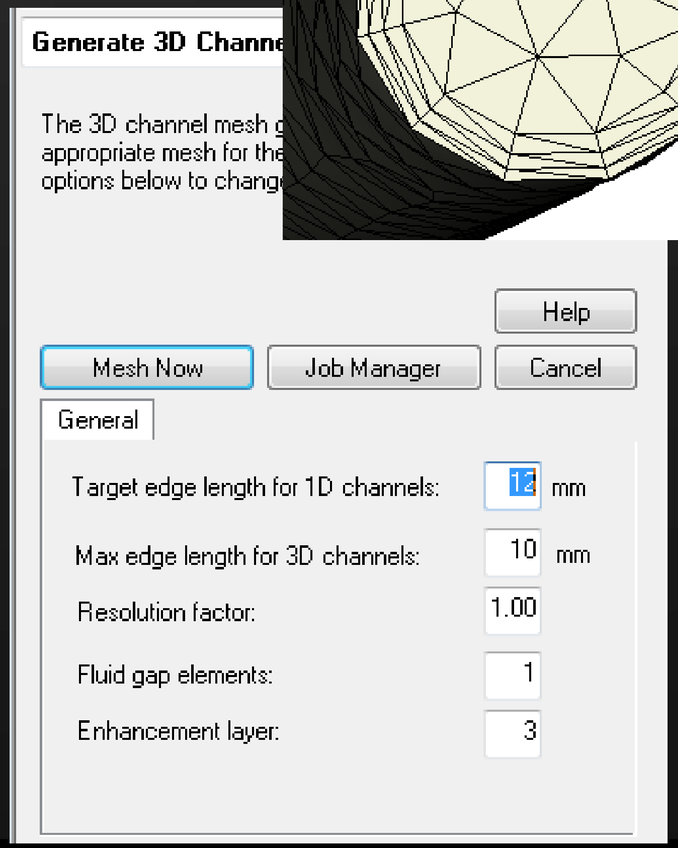
Image from Pôle Européen de Plasturgie

# Use Autodesk Simulation CFD for Coolant 3D meshing and Flow Solver

- Meshing is optimized for low viscosity water flow
  - Boundary layer meshing (Enhancement layer)
  - Mesh refinement in areas of high curvature

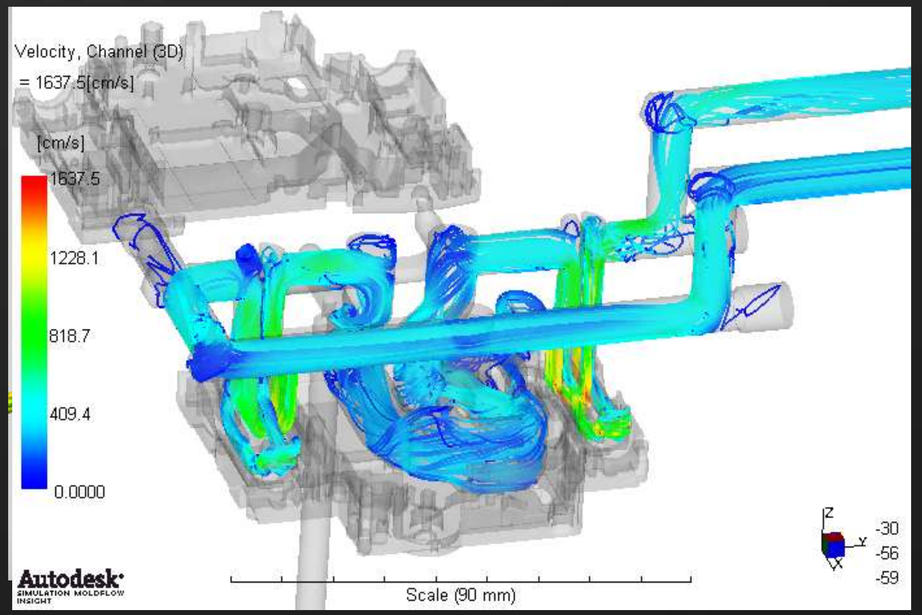


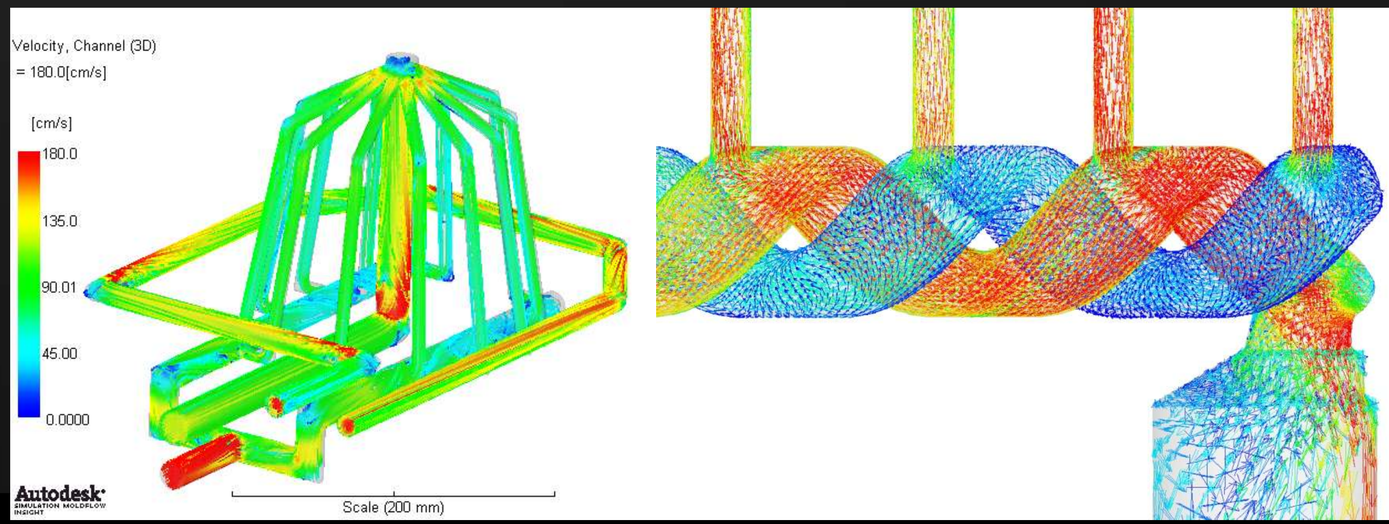





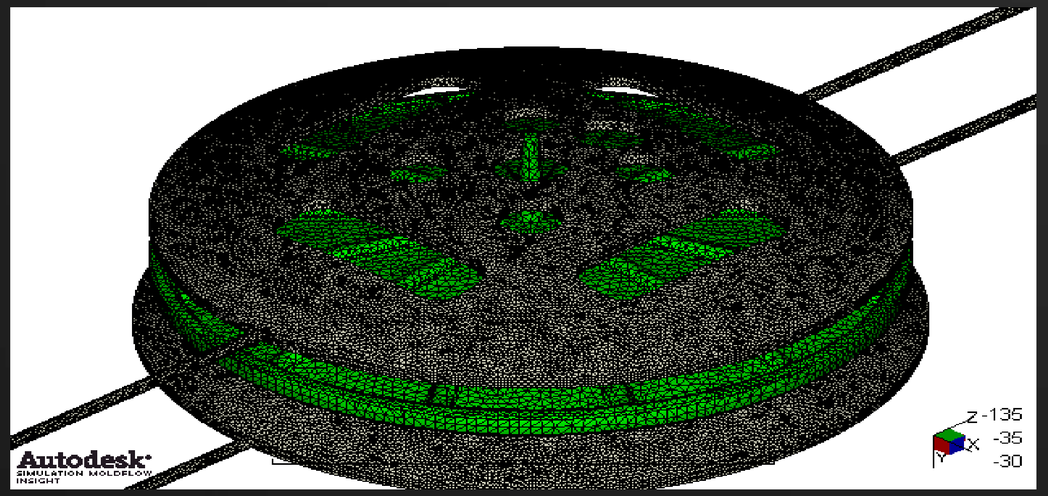
# Use Autodesk Simulation CFD

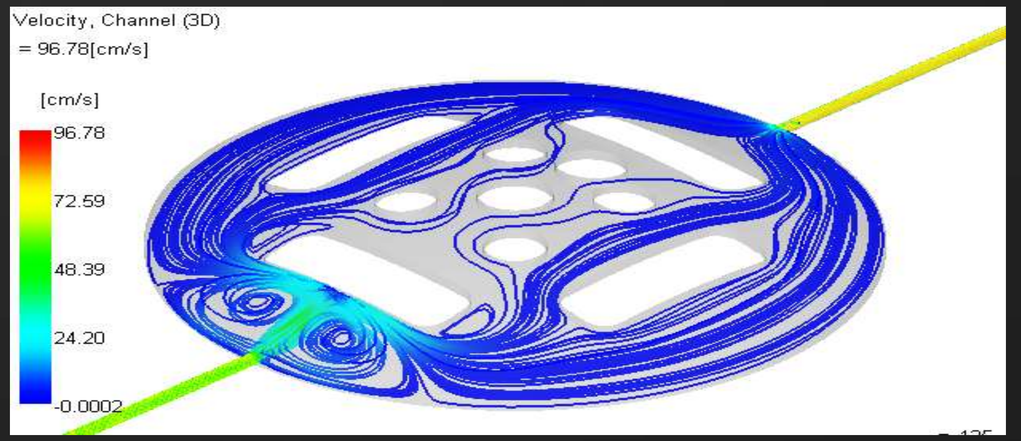
- Powerful Computational Fluid Dynamics simulation of coolant flow in 3D cooling channel
  - Identify dead-zone
  - Eliminate hot-spots
- Integrate this CFD solution into Moldflow Insight Cool (FEM)



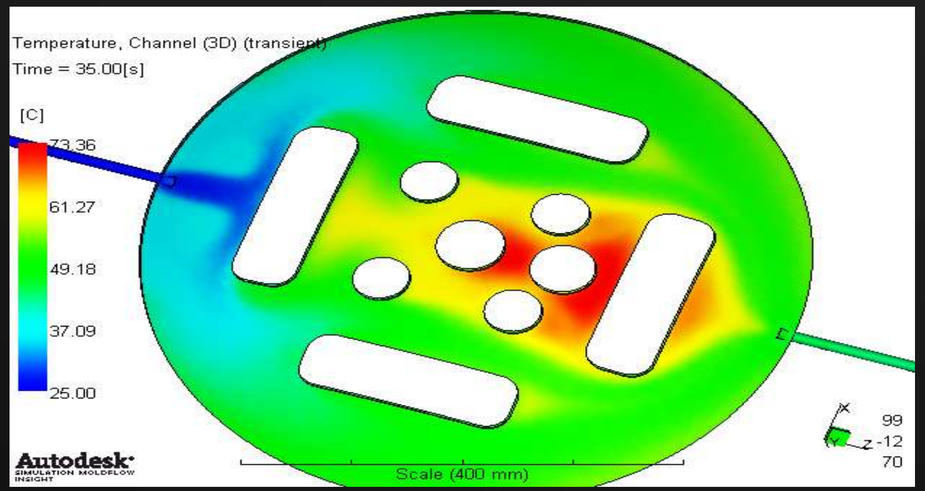



# Coolant Solution from CFD

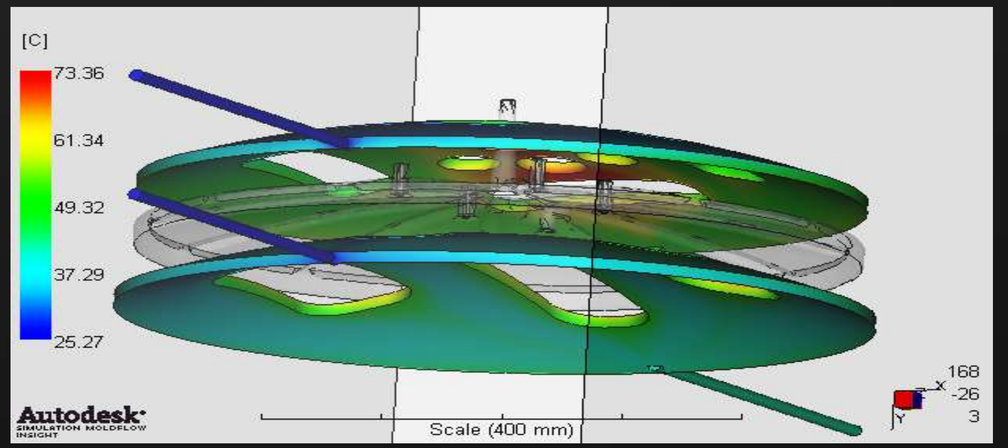



Coolant Flow – Dead zone

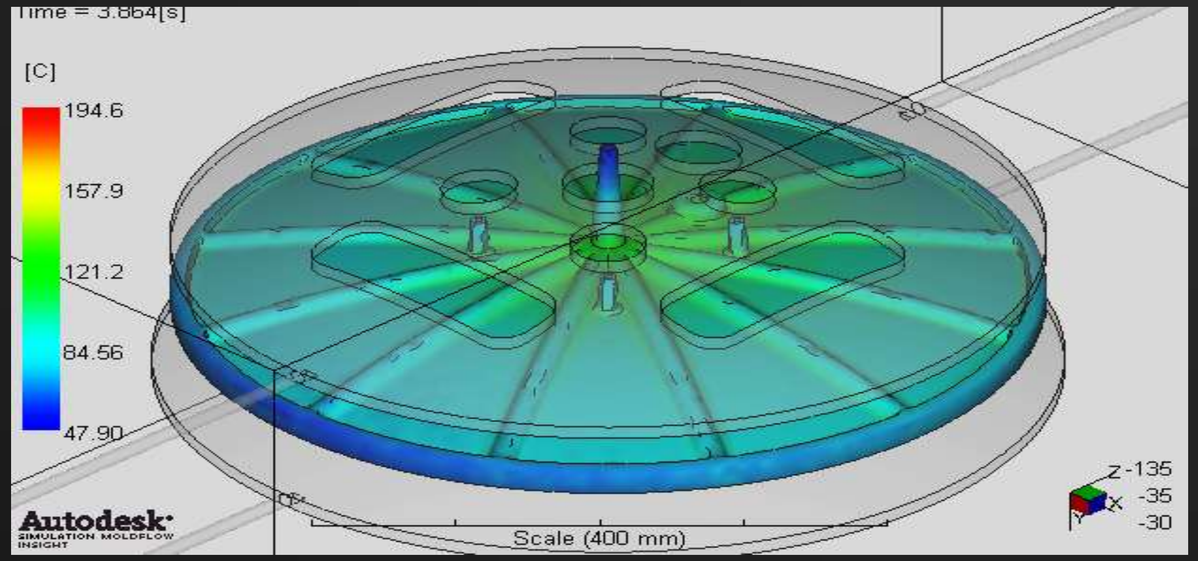


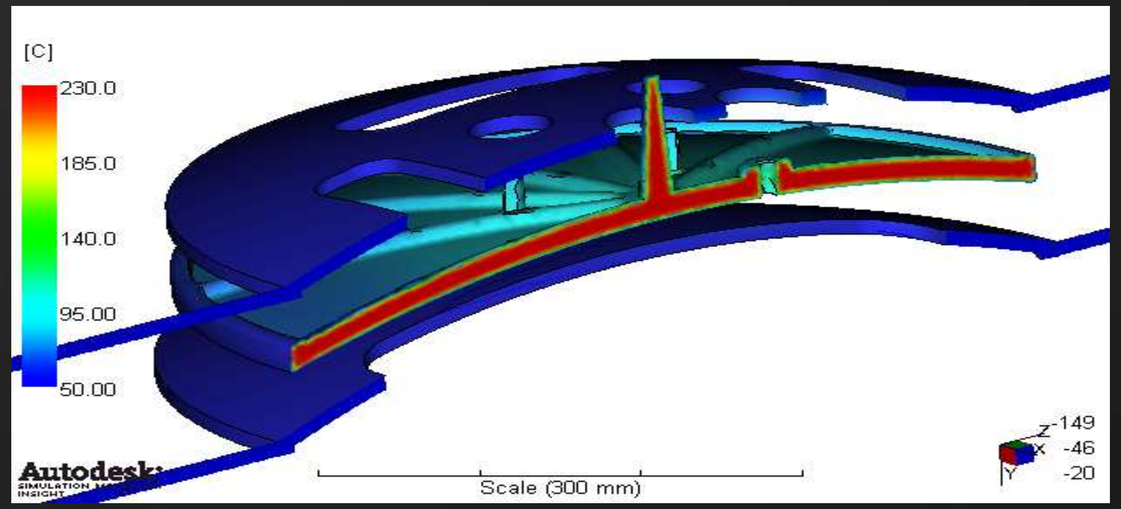

Coolant Temp – Hot Spot




Mold Temperature – Hot Spot

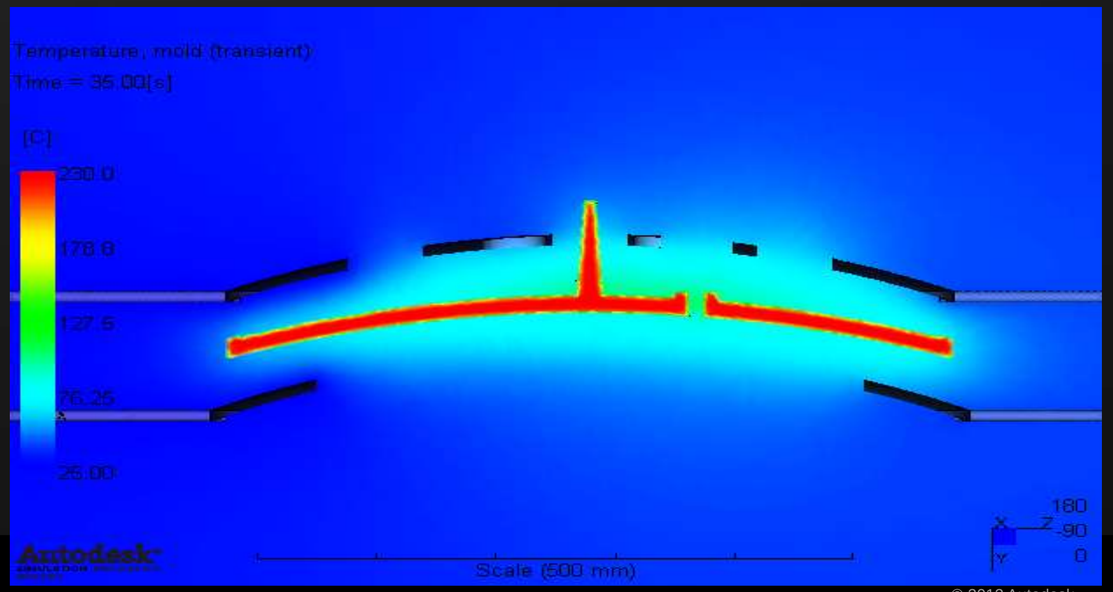
# Integrate 3D Coolant CFD into Moldflow



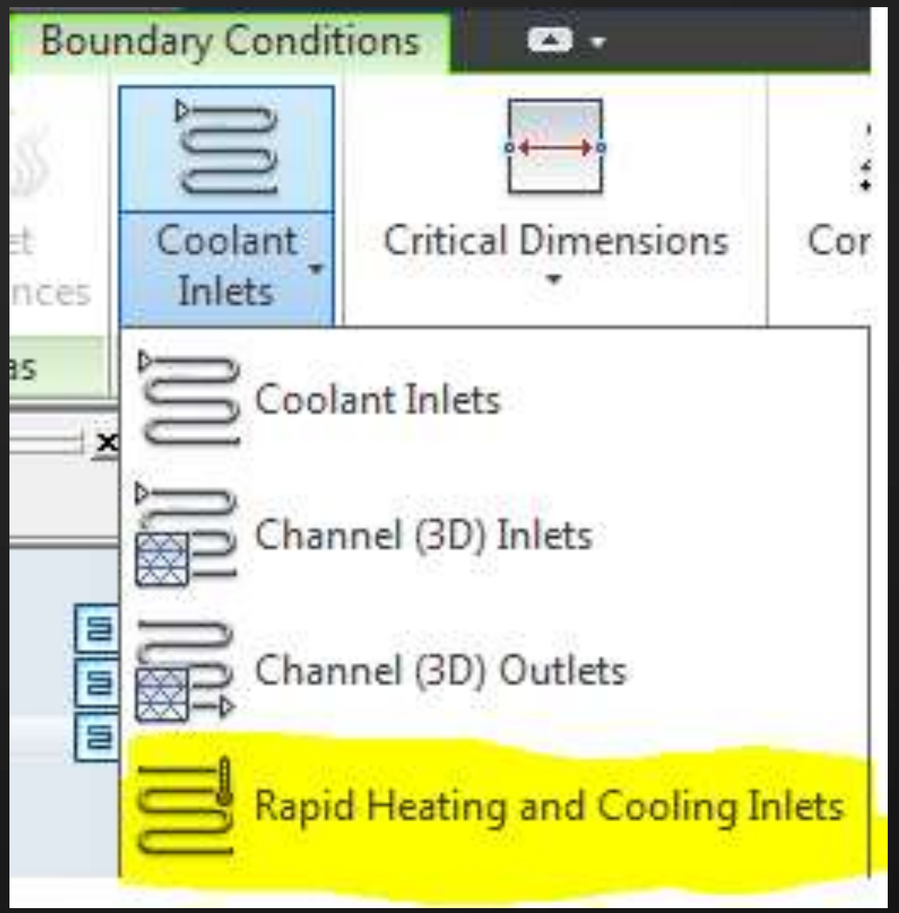

Cavity surface temperature

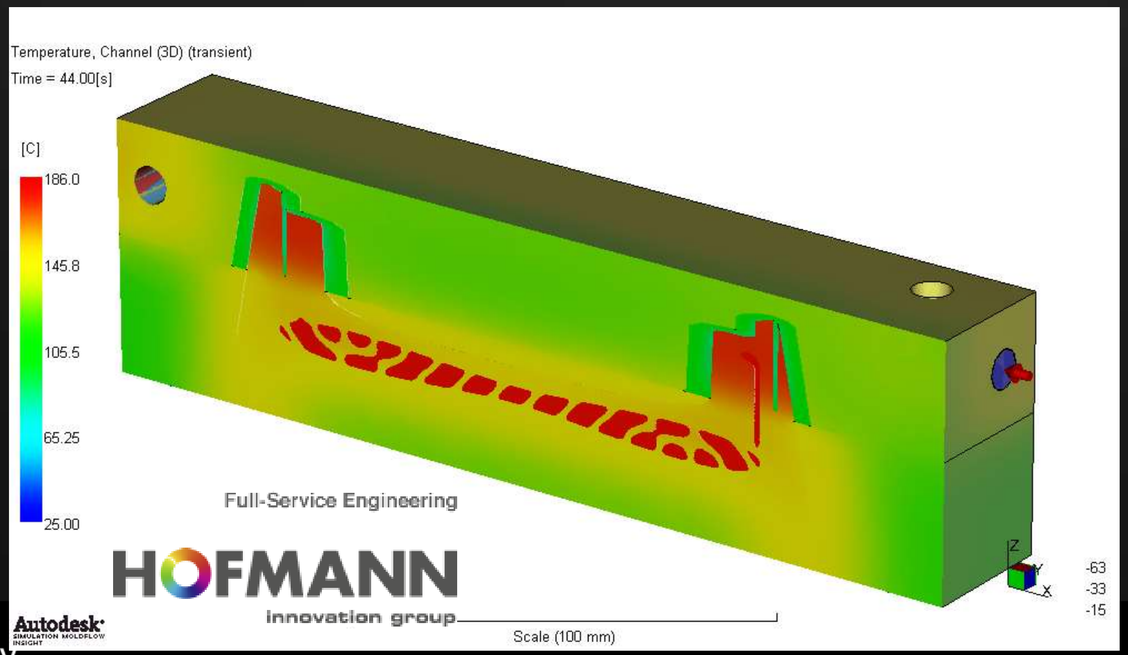
Coupled Mold, Coolant and Part Temperature solutions



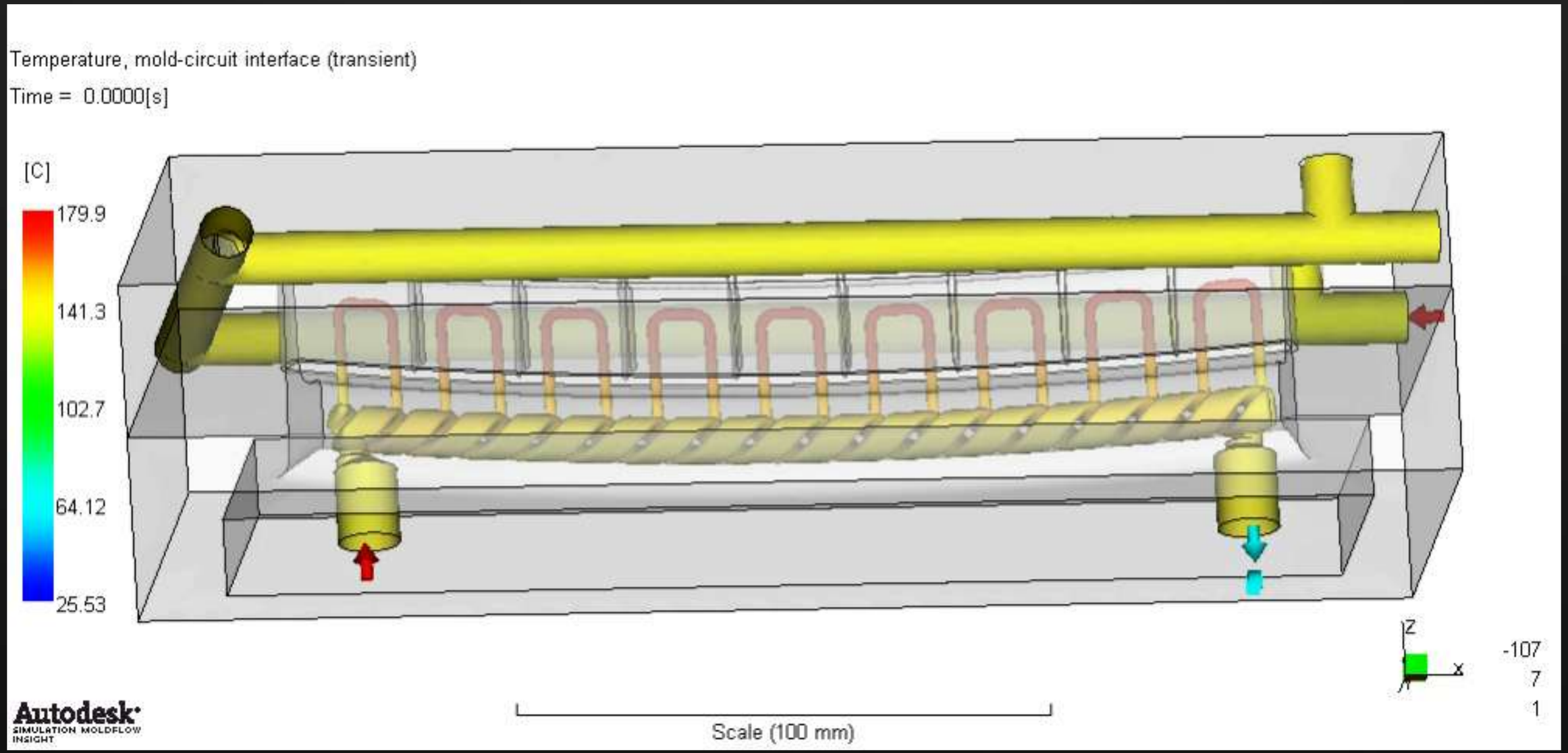
# Conformal Channels with RTC

- Future Version:
  - Allow Rapid Heating and Cooling on 3D Channels
  - Specify Rapid Heating and Cooling process parameters as normal



# Conformal Channels with RTC



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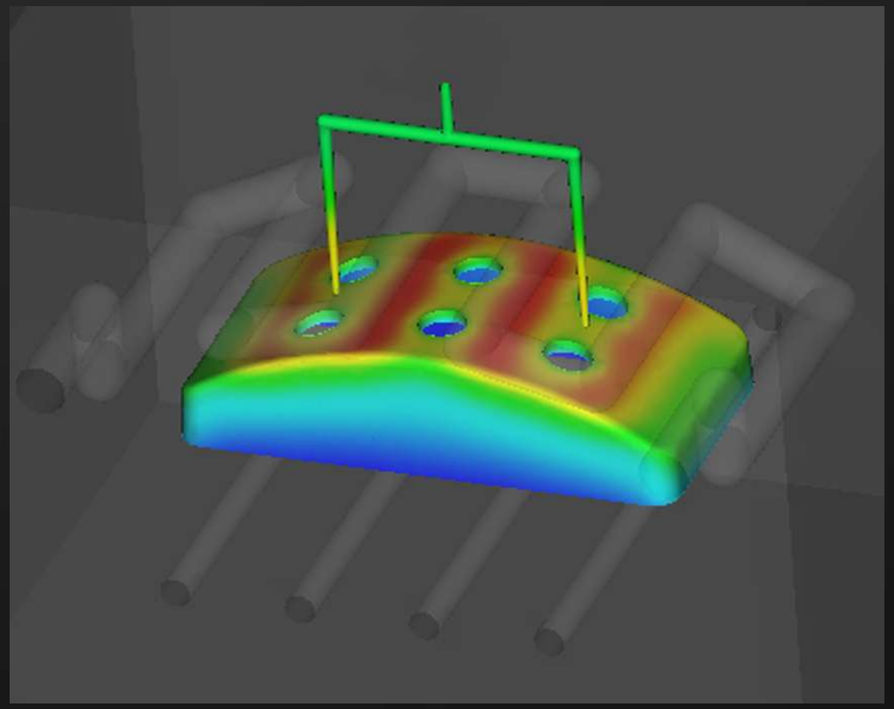
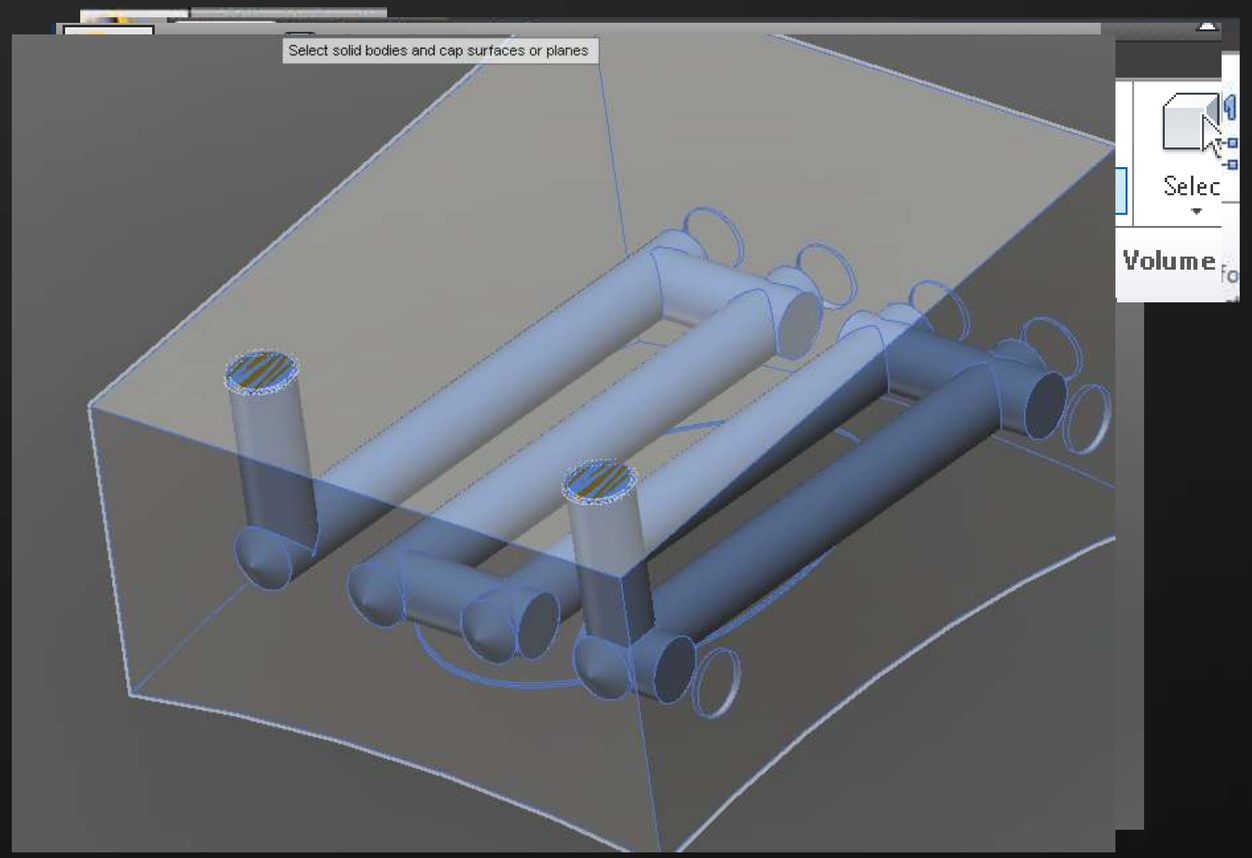


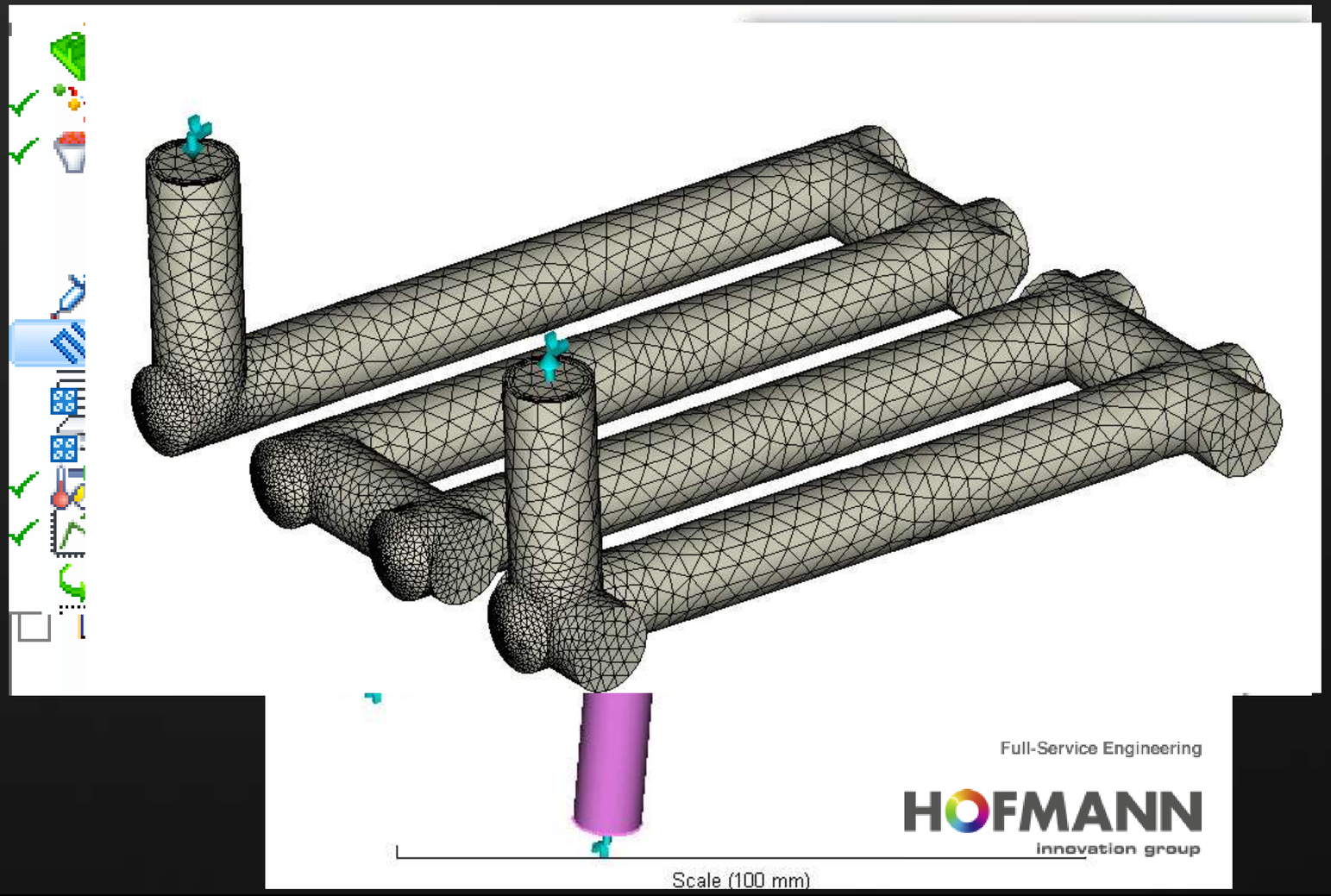
# Creating channel geometry from the mold

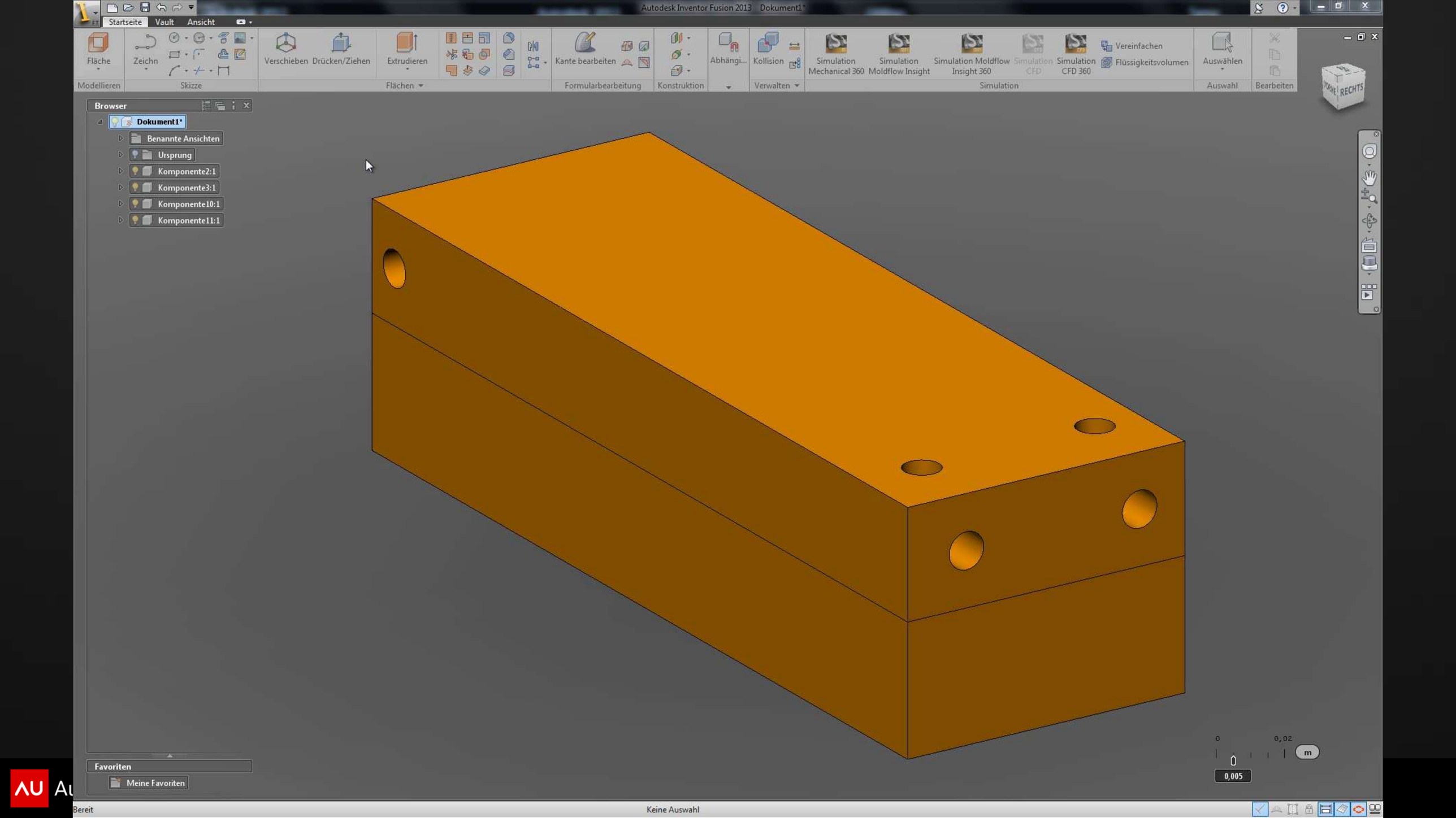
- Switch to surface mode
- Select Patch tool
  - Select lip of hole to patch
  - Patch surface created
- Fluid Volume Tool
  - Select Internal Volume
  - Select surrounding blocks and patch surfaces
  - Prompts to fill the void with a new solid body



# Meshing the 3D Channel Bodies

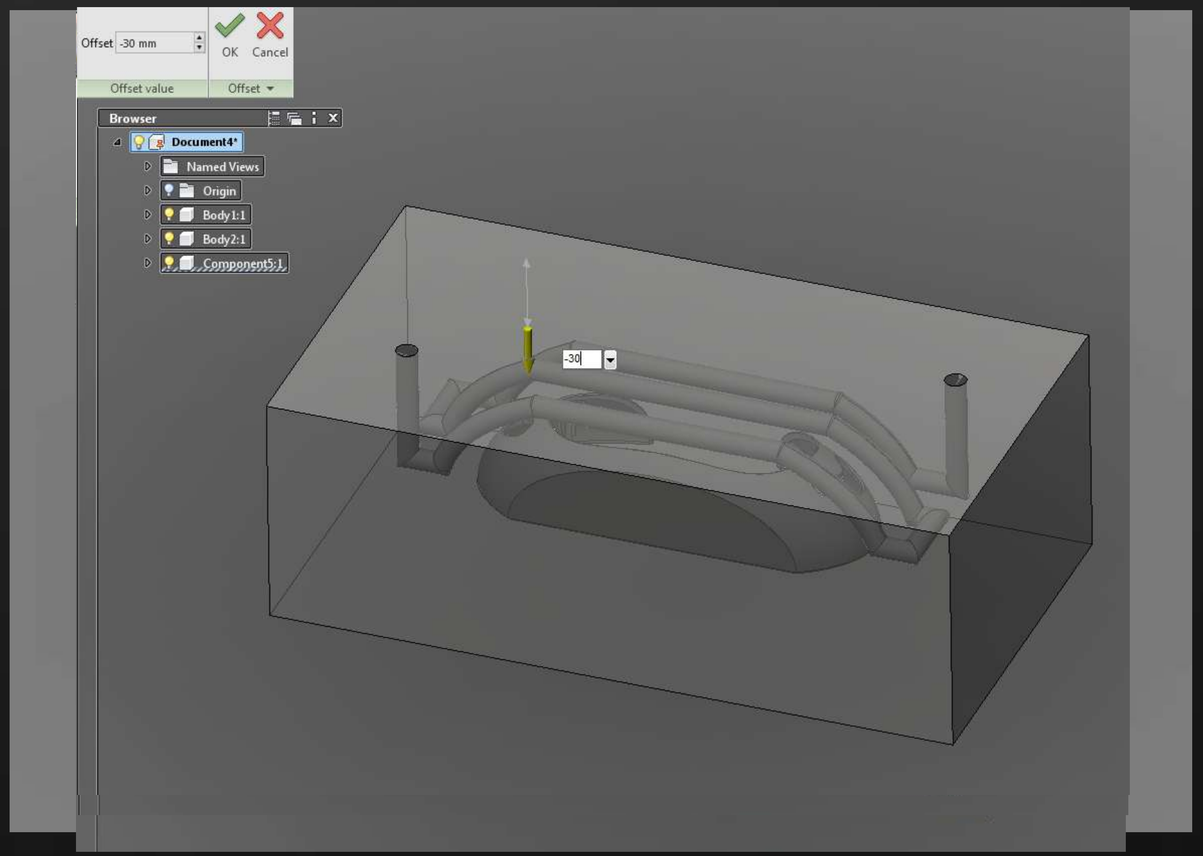
- Assign Channel (3D) property
- Assign Channel Inlets and Outlets
- Create Channel Mesh




Autodesk Inventor Fusion 2013 Dokument1*
Startseite
Vault
Ansicht
Fläche
Zeichn
Verschieben
Drücken/Ziehen
Extrudieren
Kante bearbeiten
Abhängi...
Kollision
Simulation Mechanical 360
Simulation Moldflow Insight
Simulation Moldflow Insight 360
Simulation CFD
Simulation CFD 360
Vereinfachen
Flüssigkeitsvolumen
Auswählen
Modellieren
Skizze
Flächen
Formularbearbeitung
Konstruktion
Verwalten
Simulation
Auswahl
Bearbeiten
Browser
Dokument1*
Benannte Ansichten
Ursprung
Komponente2:1
Komponente3:1
Komponente10:1
Komponente11:1
Favoriten
Meine Favoriten
RECHTS
0
0,02
m
0,005
Bereit
Keine Auswahl

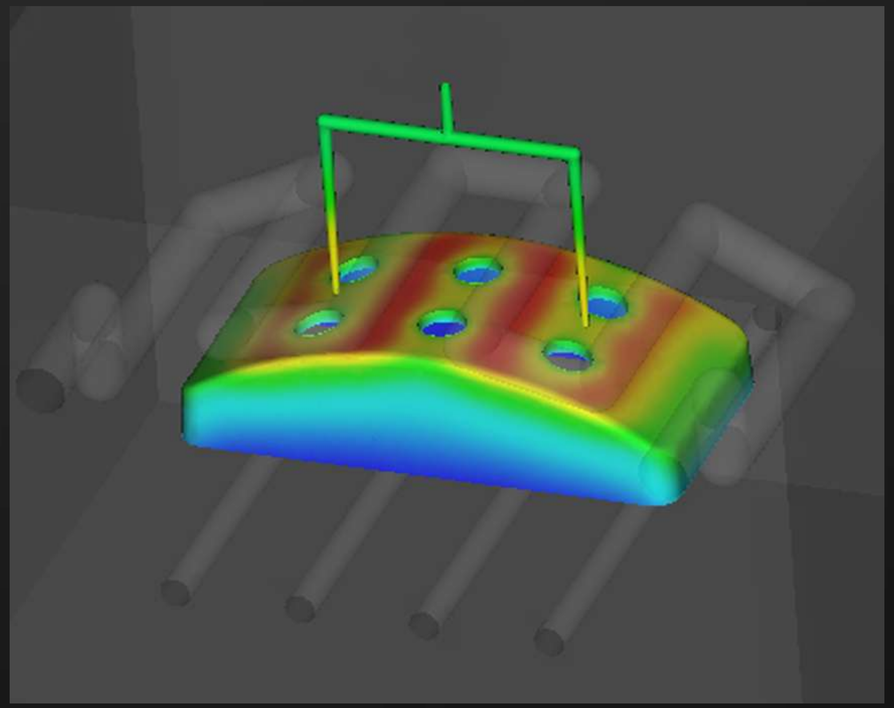
# Creating Mold Geometry in Inventor Fusion

- Only part and channel geometry supplied
- “Fluid Volume” – External
  - Specify a uniform offset all around
- Adjust any faces back to channel extremities



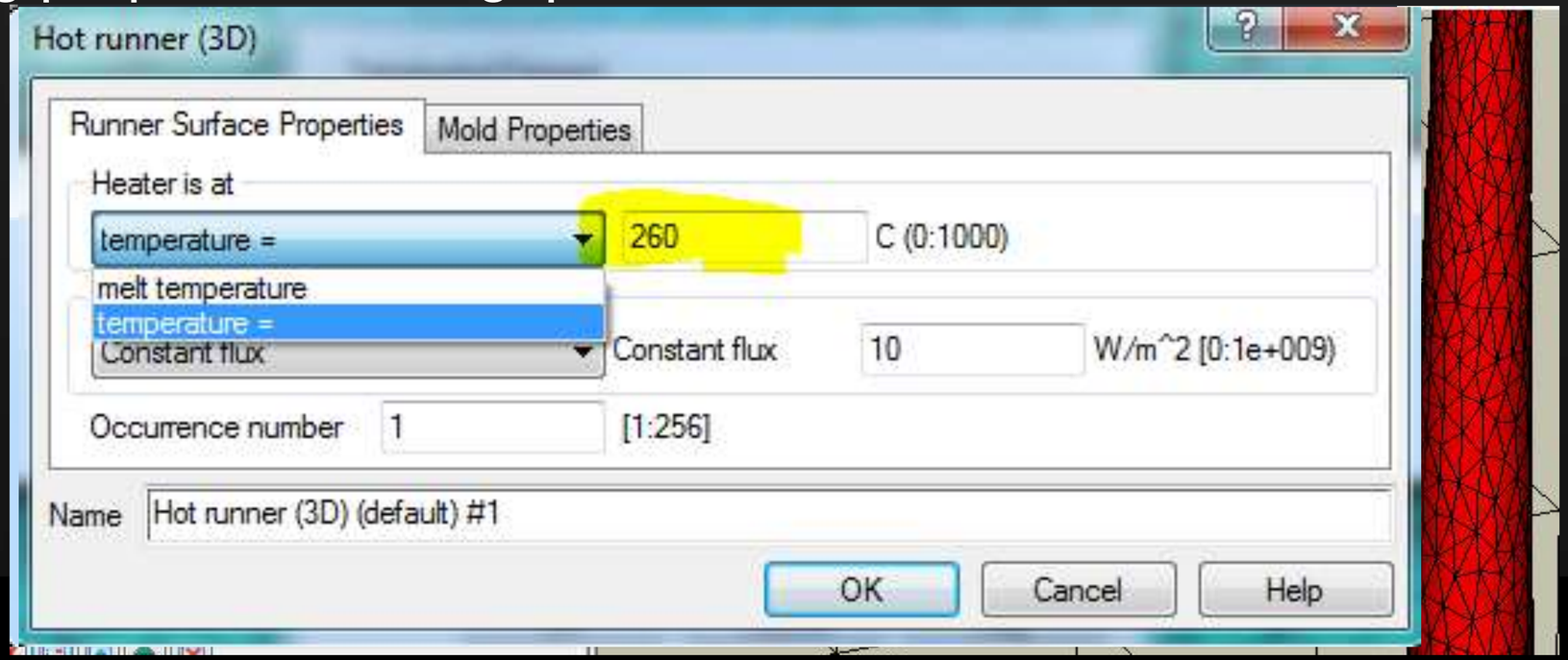
# Contents: Transient Mold Temperature Solution

- Features in Moldflow Insight 2013
  - Rapid Temperature Cycling
  - Geometry tools
- Preview
  - Conformal Cooling / 3D Channels
  - Geometry tools
- Hot Runner Component Analysis



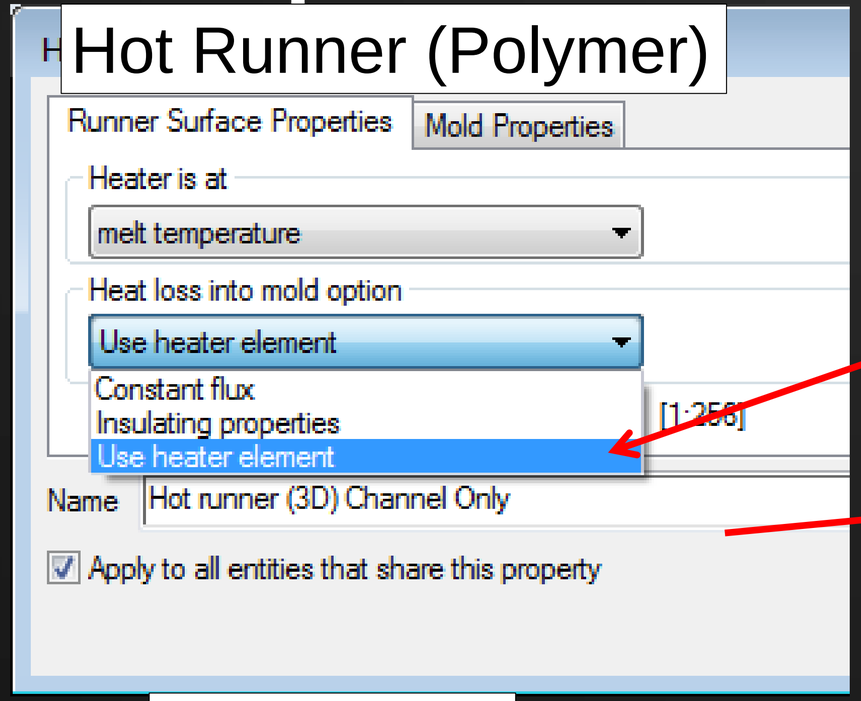
# Modeling of Hot Runners

- Normally:
  - Polymer sees the set heater temperature
  - Mold sees fixed heat passed to it from hot runner manifold:
    - Fixed flux (Default = 10 W/m^2 ), or
    - Insulating properties of air gap

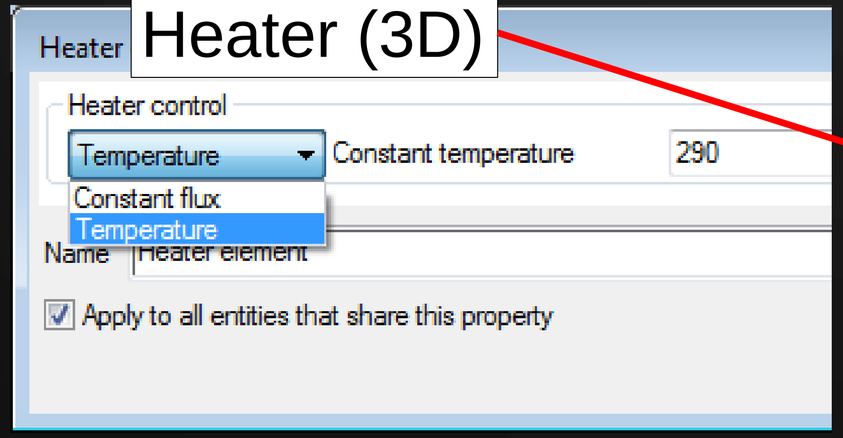


# Component Modeling of Hot Runners

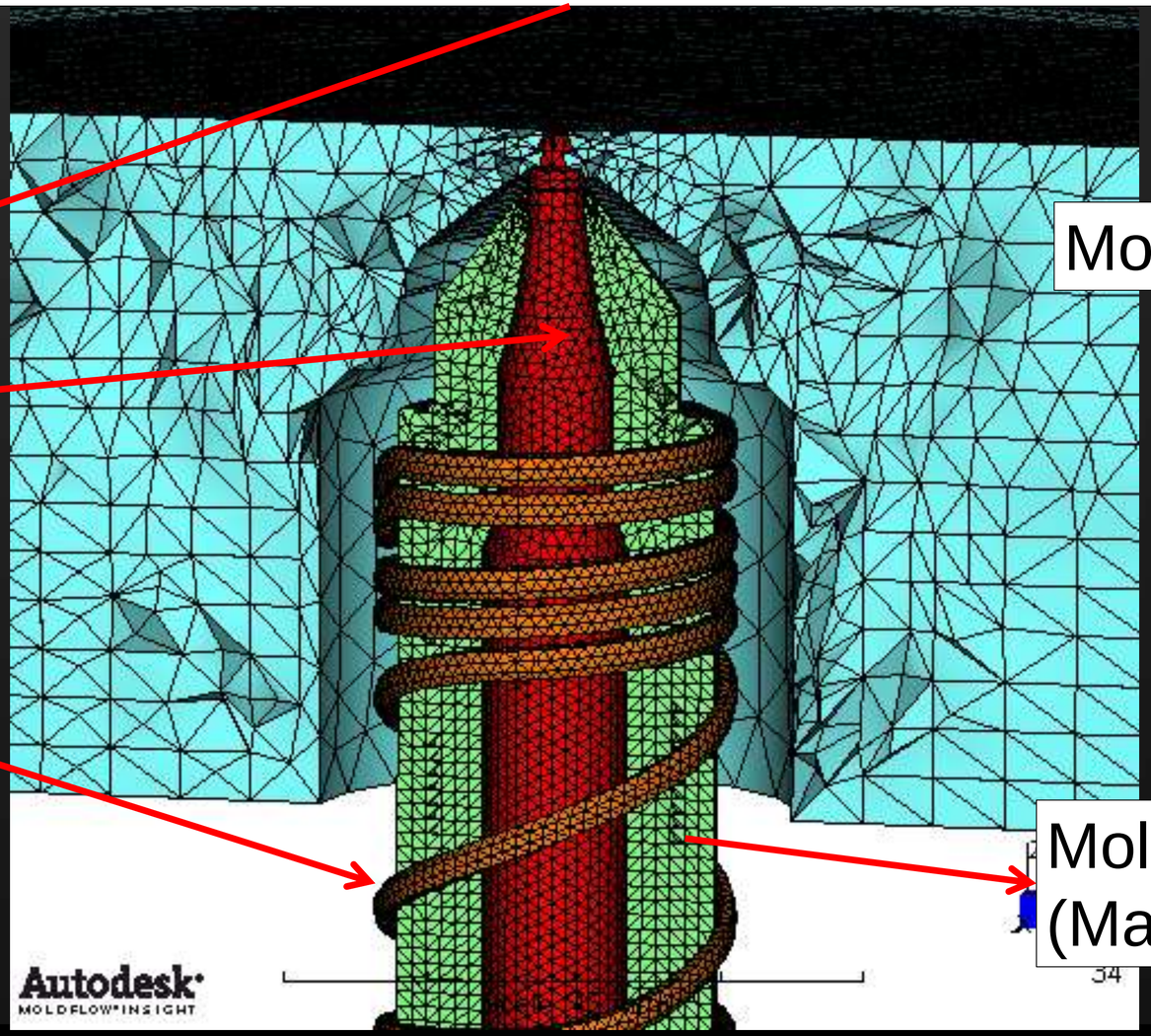
## Hot Runner (Polymer)



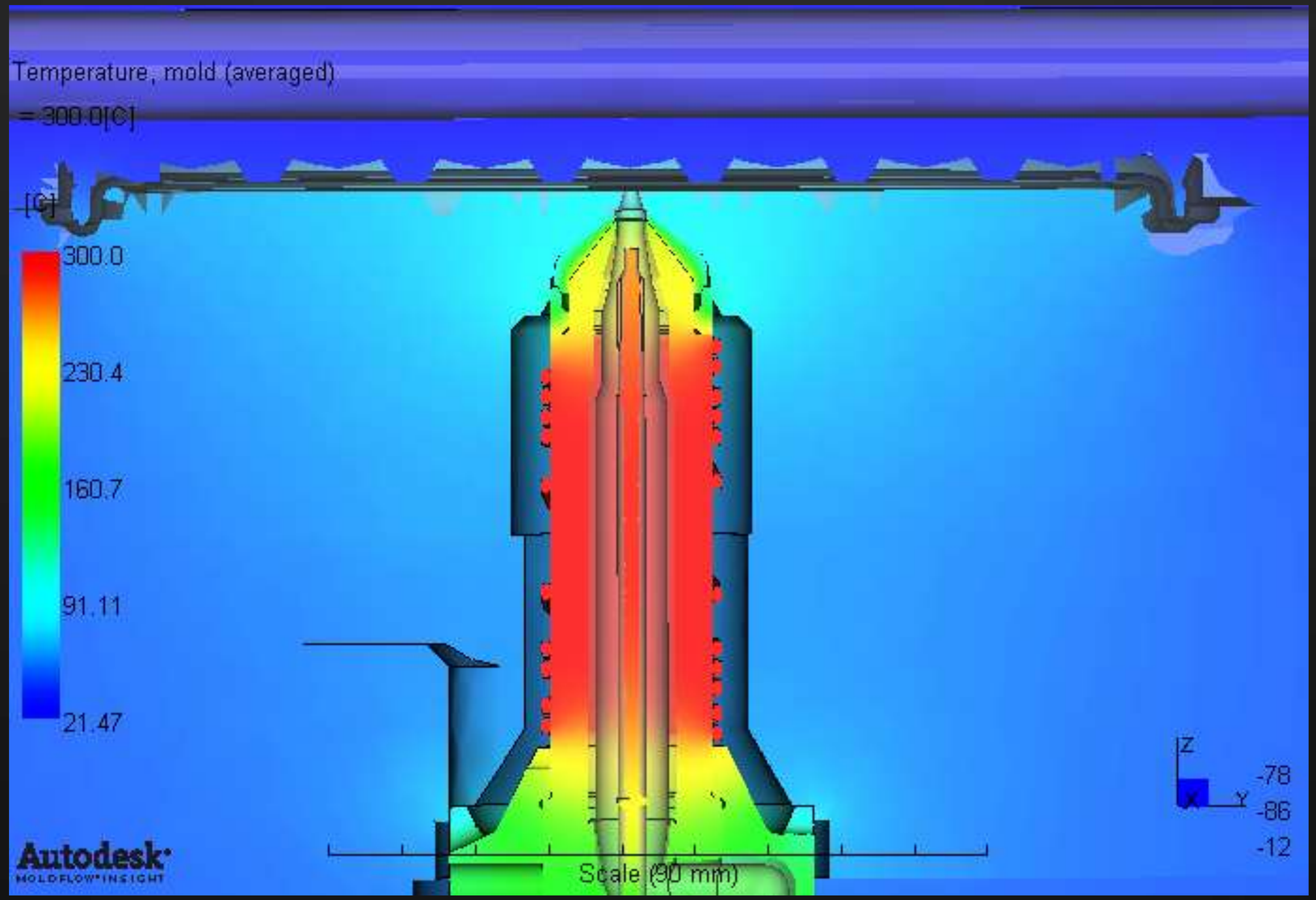

## Heater (3D)




New Hot Runner Property: “Use Heater Element”

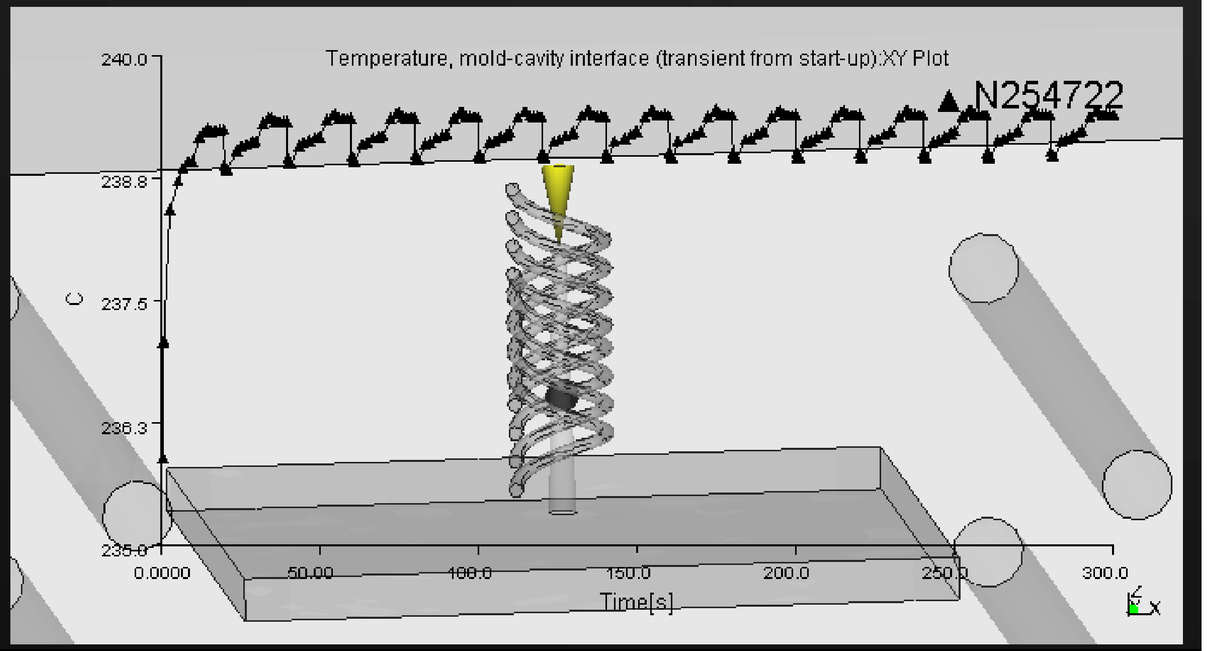


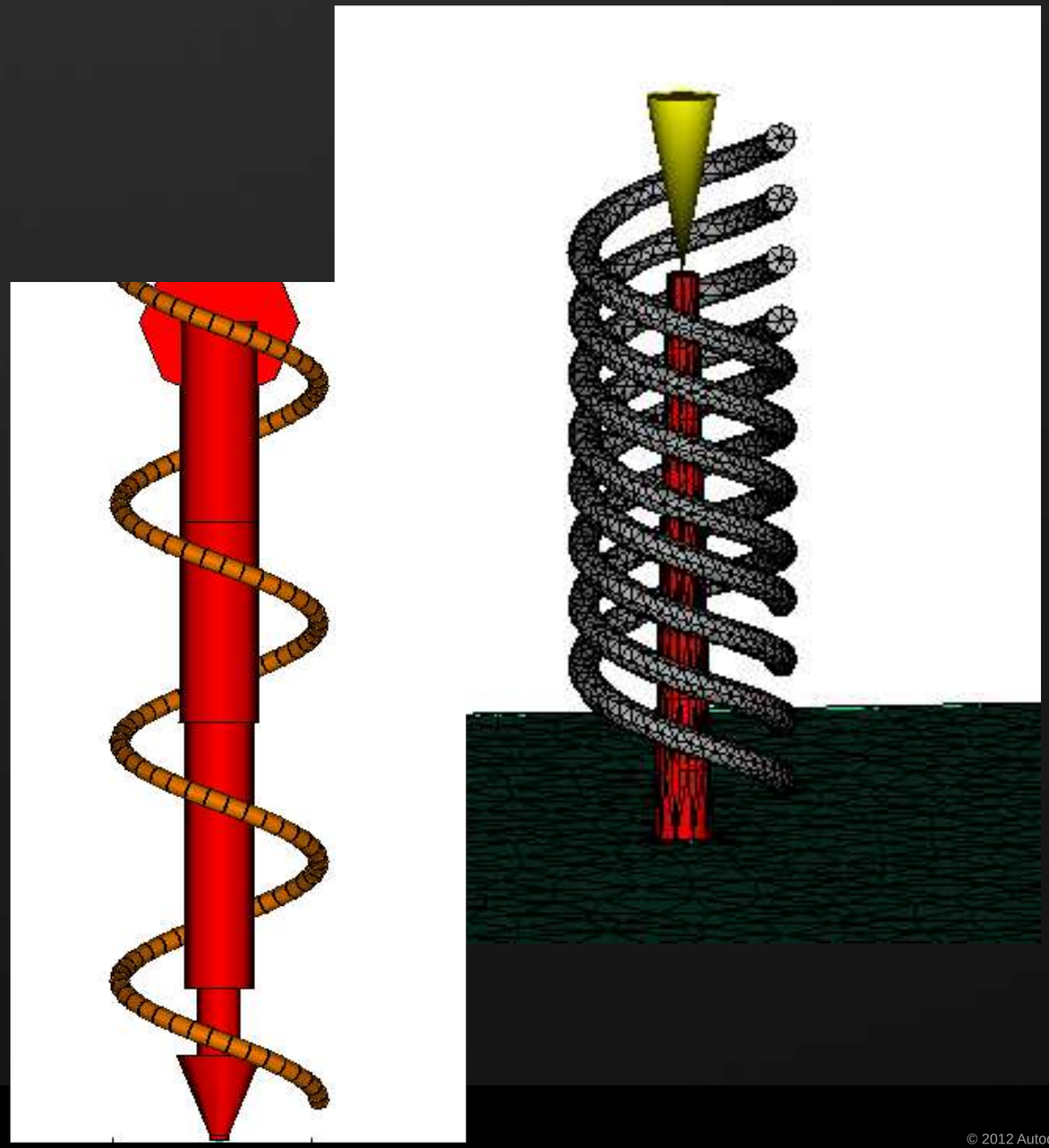
# Component Modeling of Hot Runners



# Heater Wire

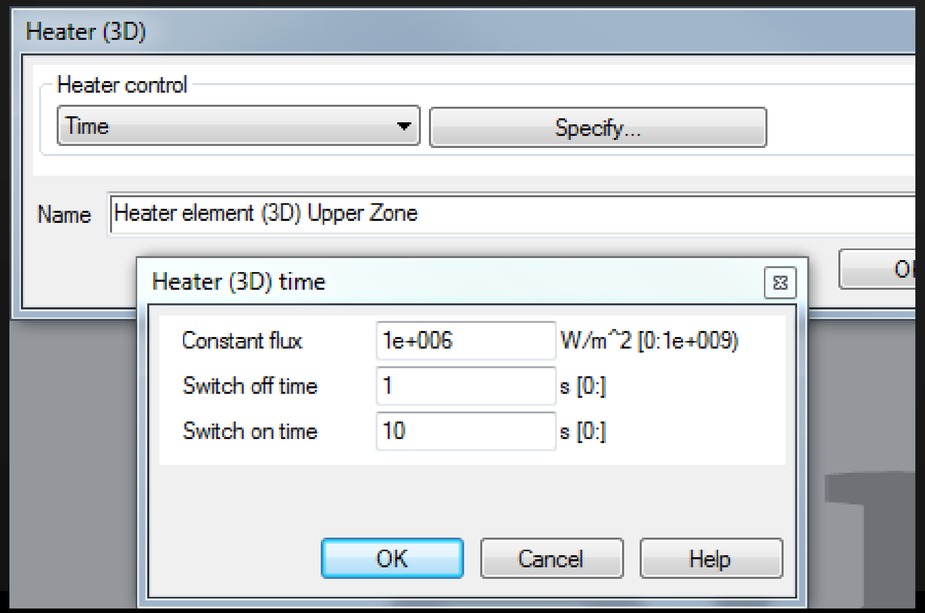
- Model by:
  - 3D Tetrahedral Elements
  - Beam Elements
    - Cartridge Heater Property

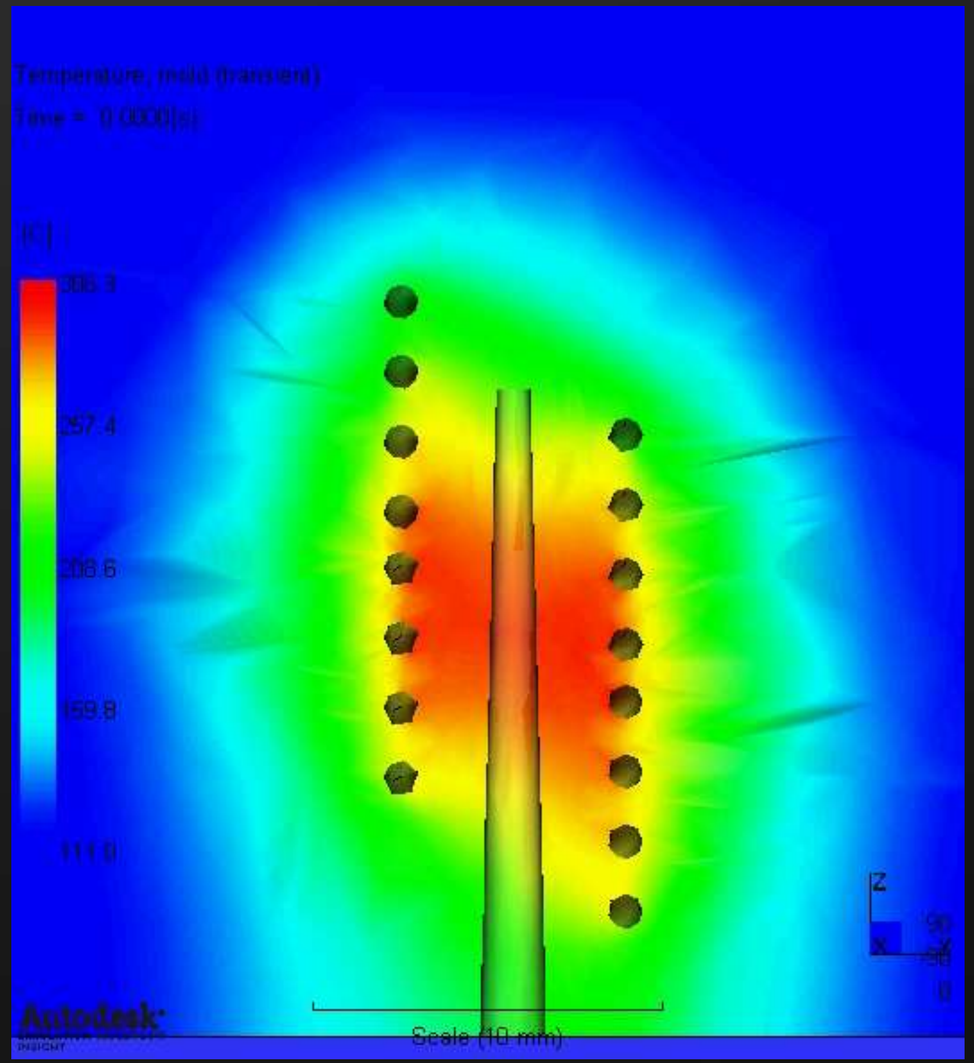


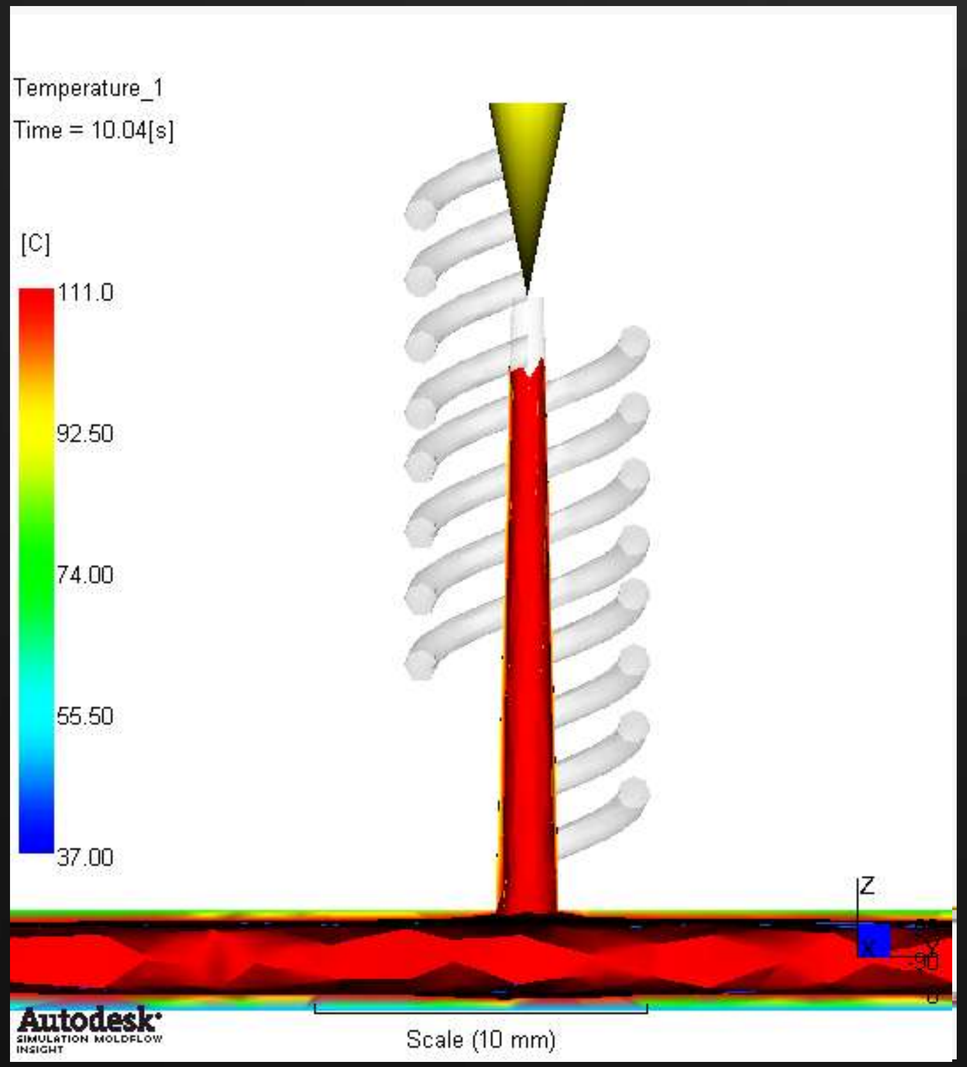
# Examine Transient Manifold Temperatures

- Manifold heat coming from heater elements
- Use Time control to switch heating on/off during cycle
- Examine manifold temperature cycle

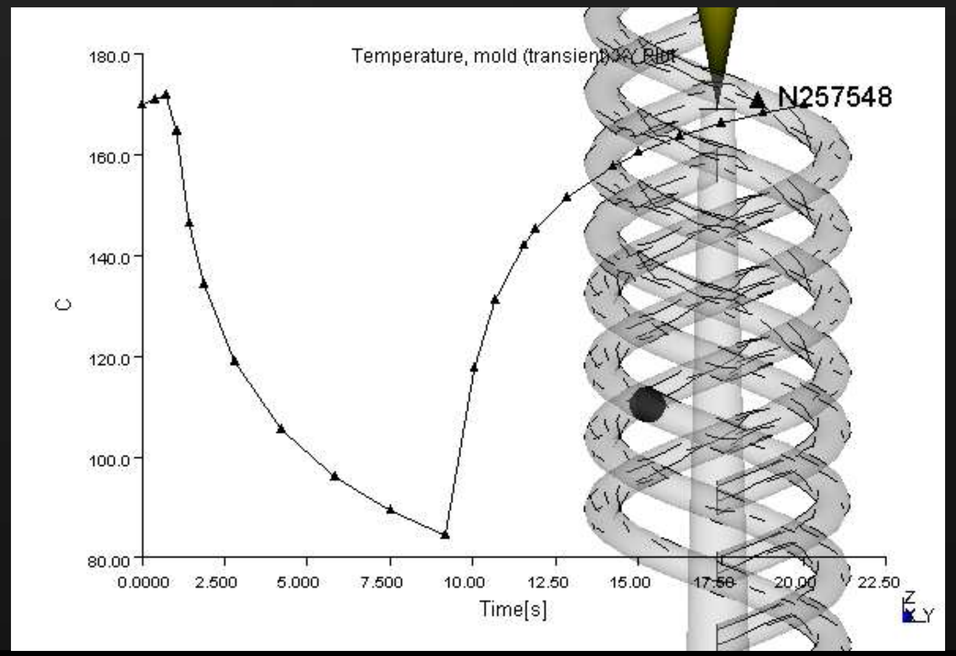


# Frozen layer in hot runner




- Examine part & hot runner temperature result
- Limit plot to show only the frozen layer

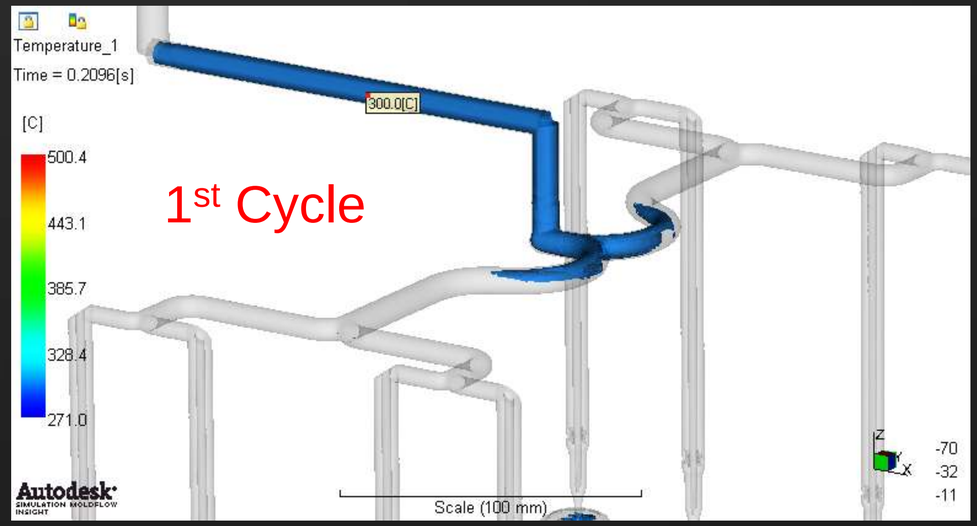


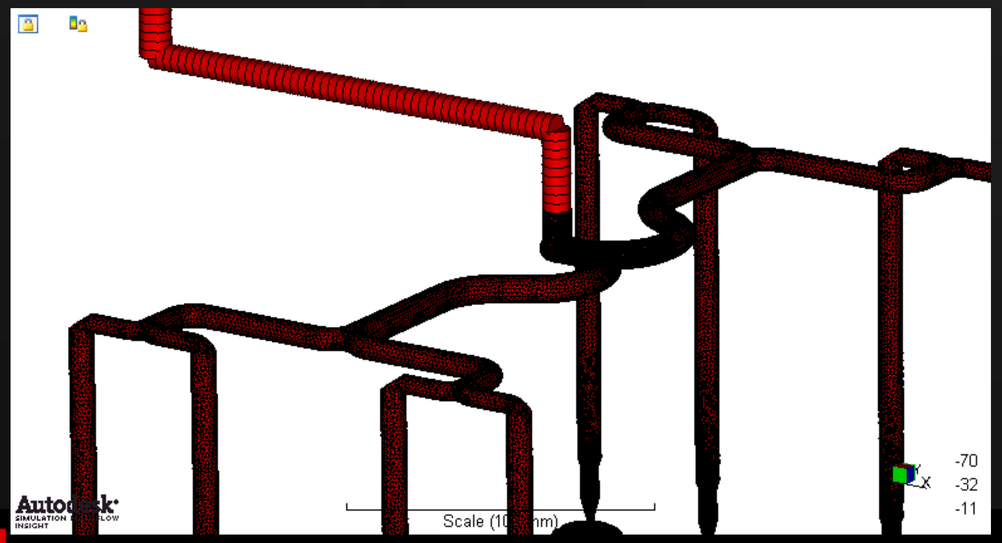

Temperature on heater wire

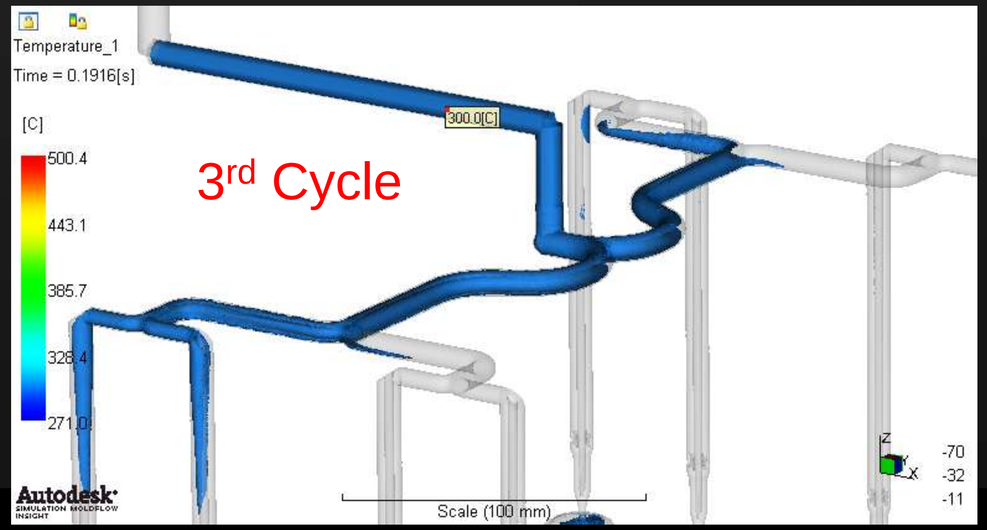
# Polymer temperature is carried from cycle to cycle

- Hot runner material temperatures carried over from previous cycle
- See shear induced temperature build up

Temperature contour at 300°C at 0.2sec



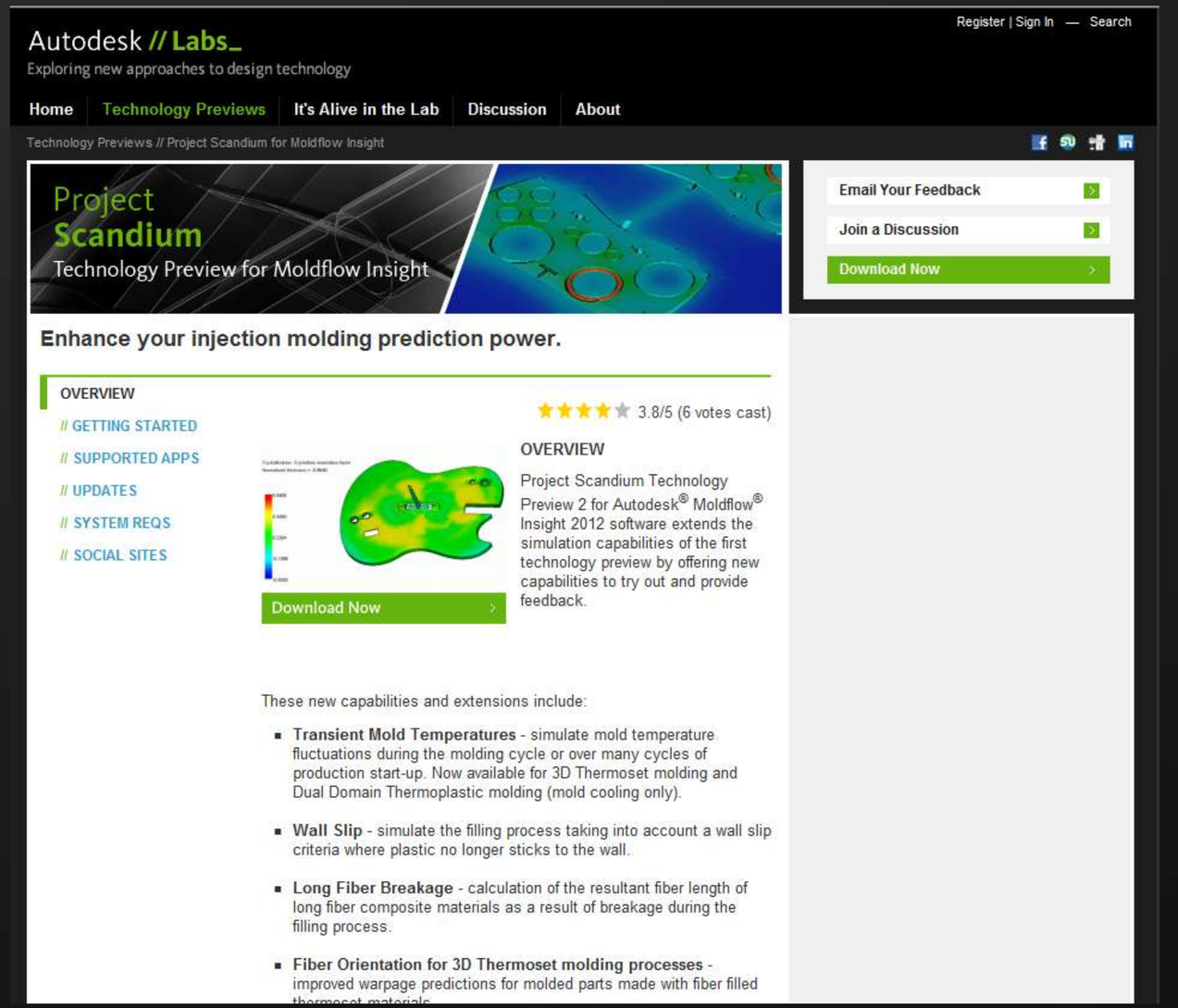



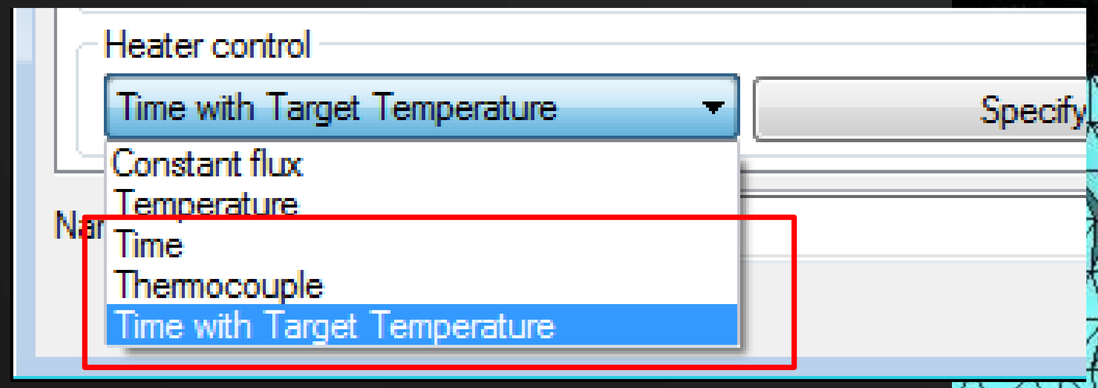
# Scandium Technology Preview

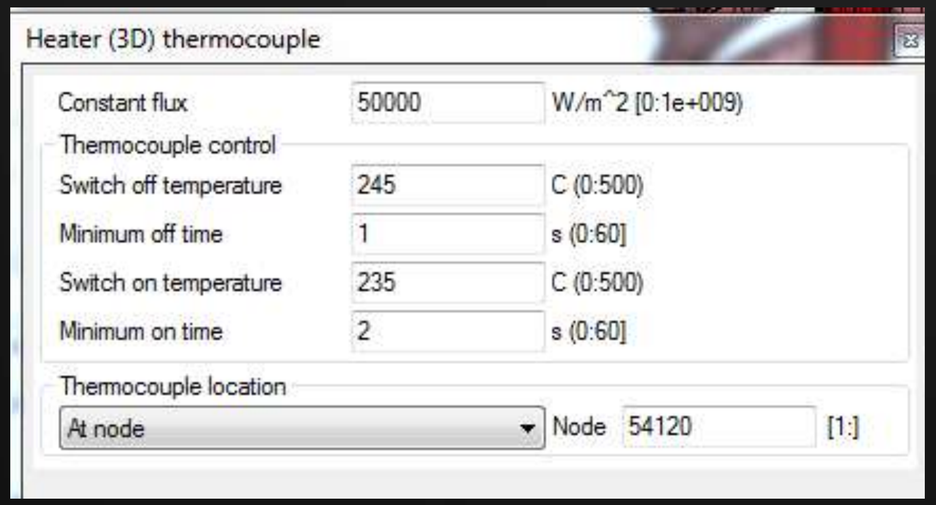
- Free download
  - //labs.autodesk.com/utilities/scandium
- English, Windows only
- Requires current Autodesk Moldflow Insight license
- Provides extended functionality and new prototype features for testing and user feedback

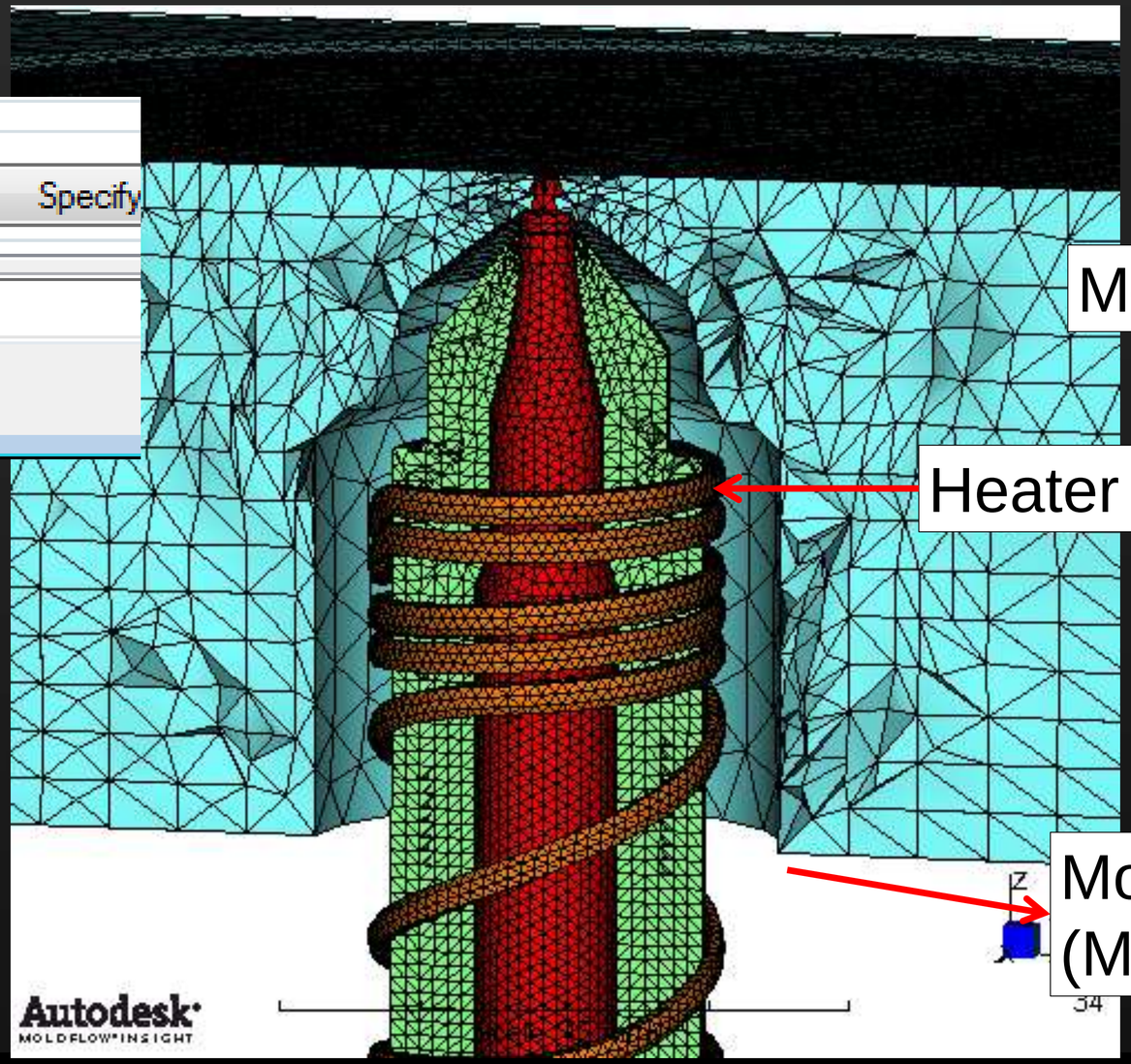
No guarantee that these features will survive or graduate to the official release



# Additional Controls for Tetrahedral Heater Wire

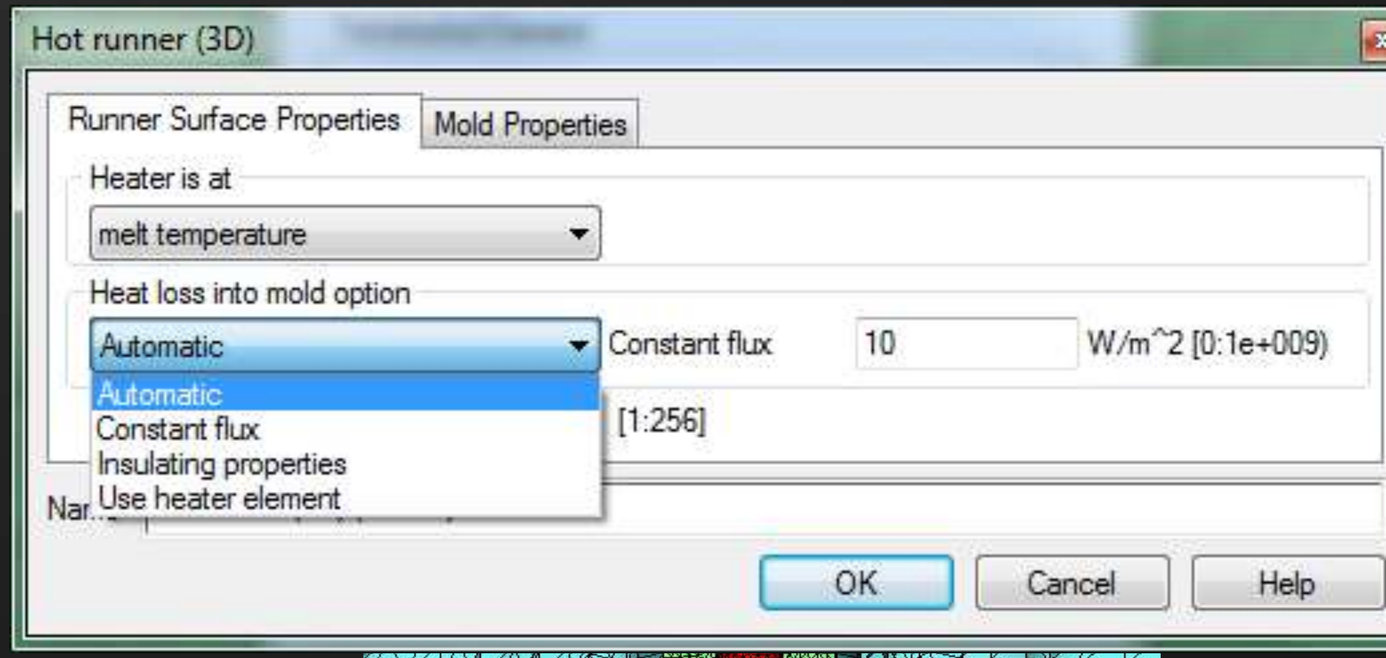


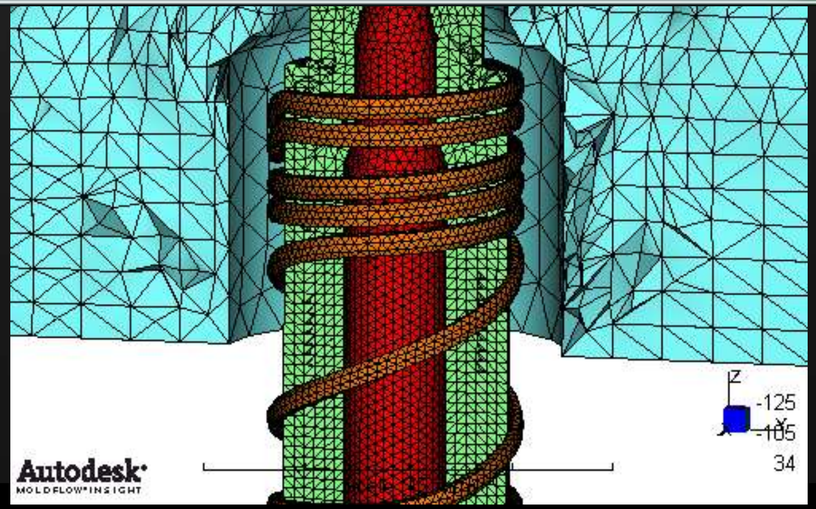



# Automatic Heater Analysis Detection

- New Default Option: Automatic
  - Enables “Use heater element” automatically if heater wire is present in Cool (FEM) analysis
  - Otherwise, uses “Constant flux”
    - Always uses “Constant flux” for BEM Cool
    - “Constant flux” was the previous default



# Q & A

- Features in Moldflow Insight 2013
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- Hot Runner Component Analysis