Using Computer Simulation to Drive the Design of Feeding Systems for Investment Castings

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The Design Process

- Simulation of the ‘Naked’ Casting
- Gate Sizing and Feeding Design
- Rigging Geometry Creation
- Verification via CFD/Solidification Simulation

Naked(Unrigged) Casting Simulation

- Select alloy type from database
- Select shell material and preheat from database
- Import the casting shape from an STL file
- Mesh the model
- Run Radiation View Factor(RVF) analysis to adjust shell HTCs
- Run the simulation
- Open the Riser Design Wizard
- Calculate the number of Feed Zones
- Plot Modulus values to see the location of Feed Zones
- Calculate the gate and feeder bar sizes for each Feed Zone

Full Simulation with Gates & Feeder Bars

- Select shell material(s) from database
- Import the casting(s) and tree configuration from STL
- Mesh the model
- Run Radiation View Factor(RVF) analysis to adjust surface HTCs
- Run the simulation
  - Simple Filling for Speed and Temperature Losses
  - CFD-Based Filling for best accuracy and filling defect predictions
- Plot results
  - Critical Fraction Solid Time(progression of solidification/feeding)
  - Material Density (macroporosity)
  - FCC Criterion (microporosity)
  - Niyama Criterion (centerline shrink)

Investment Casting Simulations

- Select a specific shell material for your mold material. Set the Initial Temperature of the shell to your Preheat Temperature. Use the HTC Calculator to calculate and set the base shell external HTC, based on shell preheat and ambient temperatures.

- To create the shell, you have two options:

  1 – When meshing, select Shell Mold Type

  2 – Use the Shell Maker utility program to create an STL file representing the shell

- After meshing, be sure to use View Factor calculator to account for radiant heat exchange. Select Mesh… View Factor Calculation.

- Why use the Shell Maker? If you have things which are external to the shell such as insulating wrap on the gating, or a bed of sand or vermiculite in which the shell is submerged, creating a shell as part of the model makes it easier to accurately create the model.

Basics of Feeder Design

Chvorinov's Rule:

$$t = B\,(V/A)^2$$

t = Time to complete solidification

B = Mold Constant

V = Volume of a section of the casting

A = Surface area of the same section of the casting

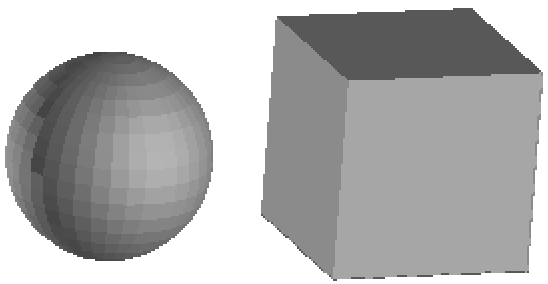
Basics of Feeder Design

(V/A) is referred to as the
Casting Modulus

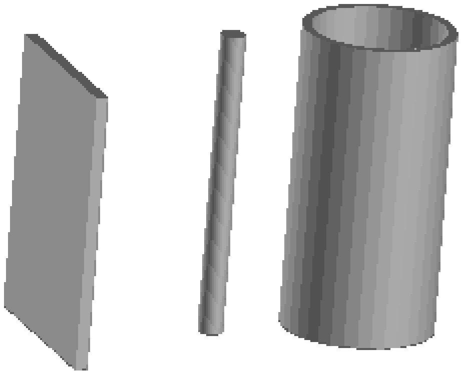
Casting sections with low modulus solidify first.

Casting sections with high modulus solidify last.

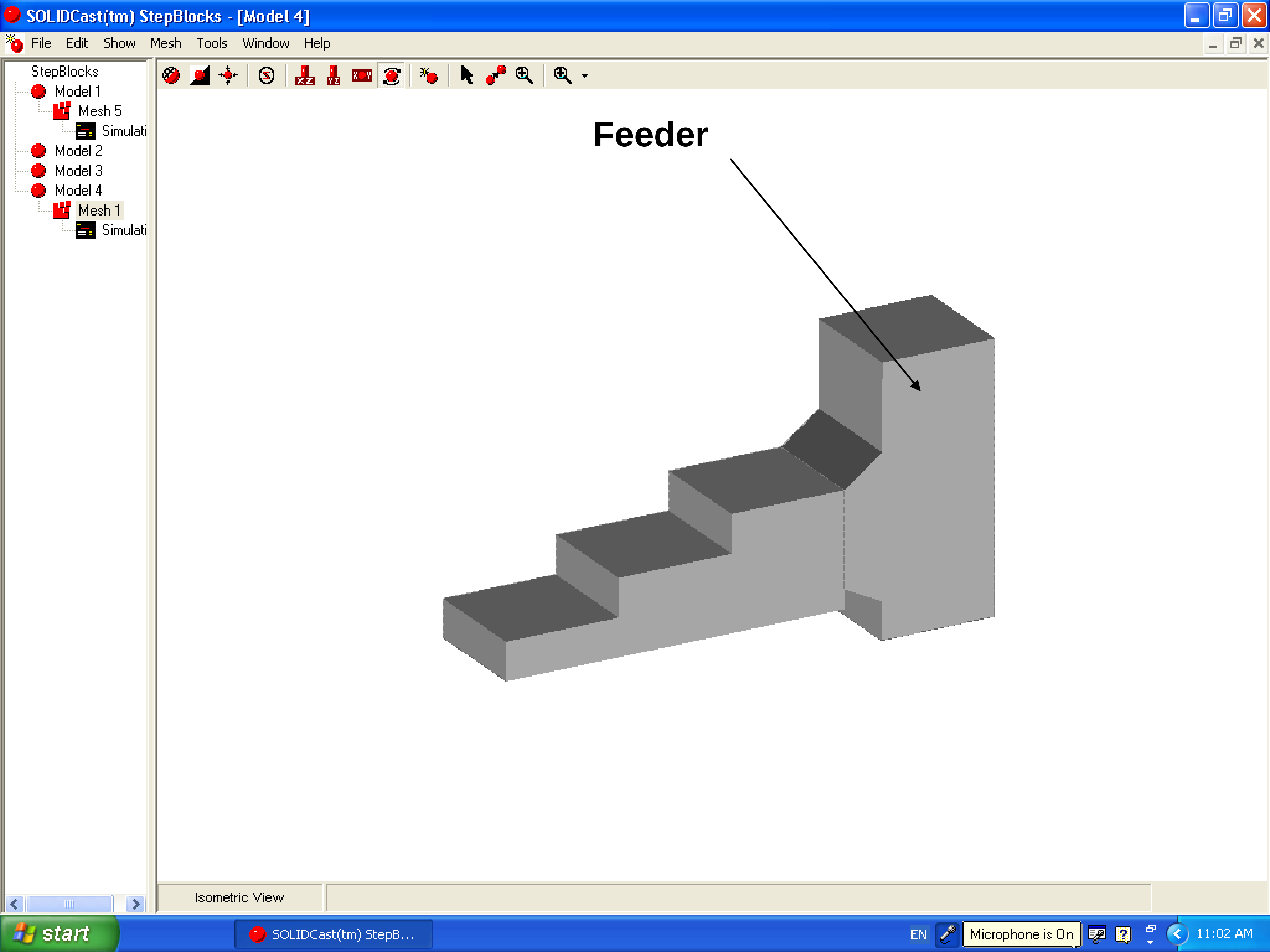
Basics of Feeder Design



Shapes with high Modulus



Shapes with low Modulus


SOLIDCast(tm) StepBlocks - [Model 4]
File Edit Show Mesh Tools Window Help
StepBlocks
Model 1
Mesh 5
Simulati
Model 2
Model 3
Model 4
Mesh 1
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Feeder
Isometric View
start
SOLIDCast(tm) StepB...
EN
Microphone is On
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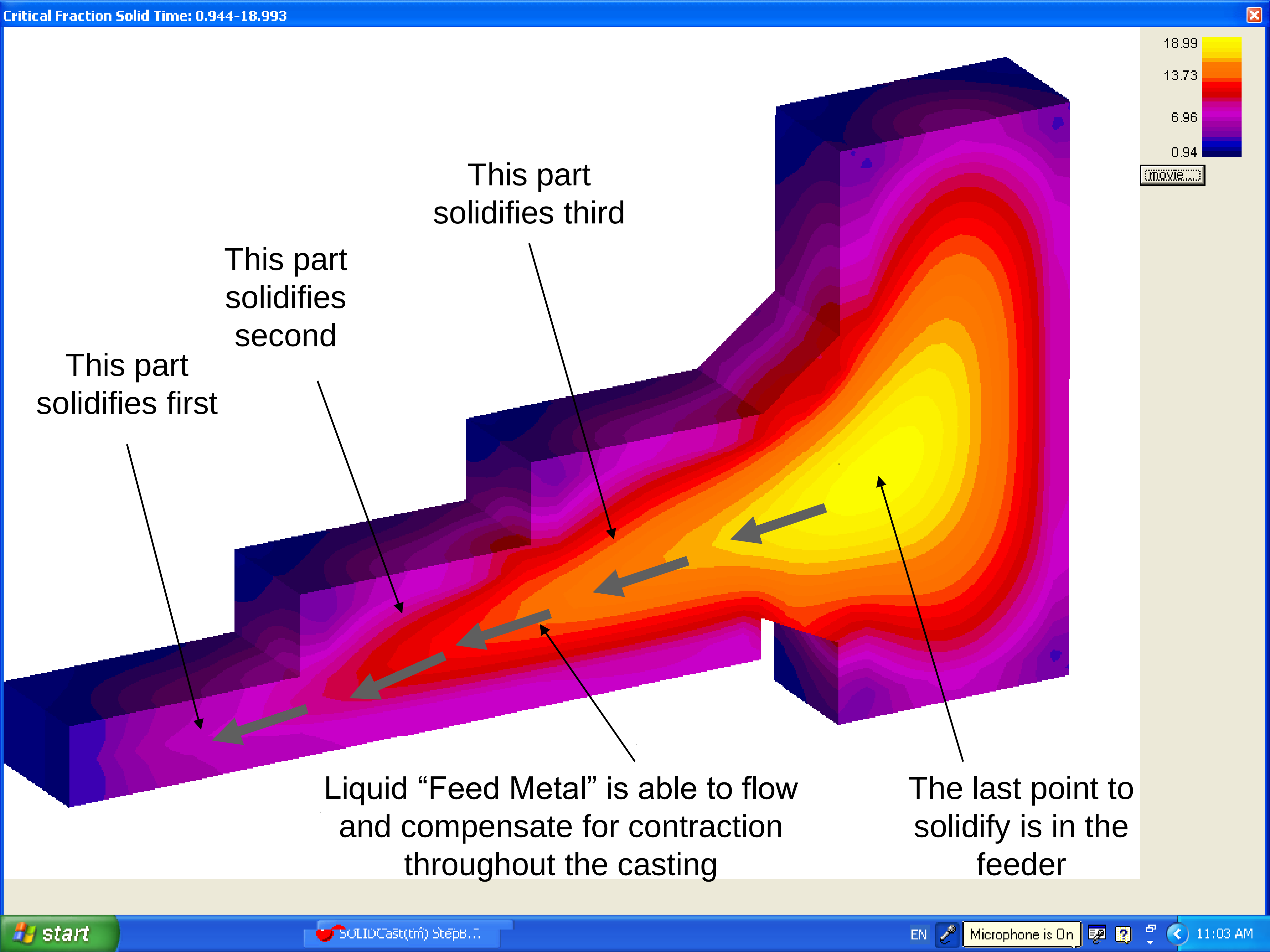
Critical Fraction Solid Time: 0.944-18.993
18.99
13.73
6.96
0.94
movie...
This part solidifies third
This part solidifies second
This part solidifies first
Liquid "Feed Metal" is able to flow and compensate for contraction throughout the casting
The last point to solidify is in the feeder
start
EN
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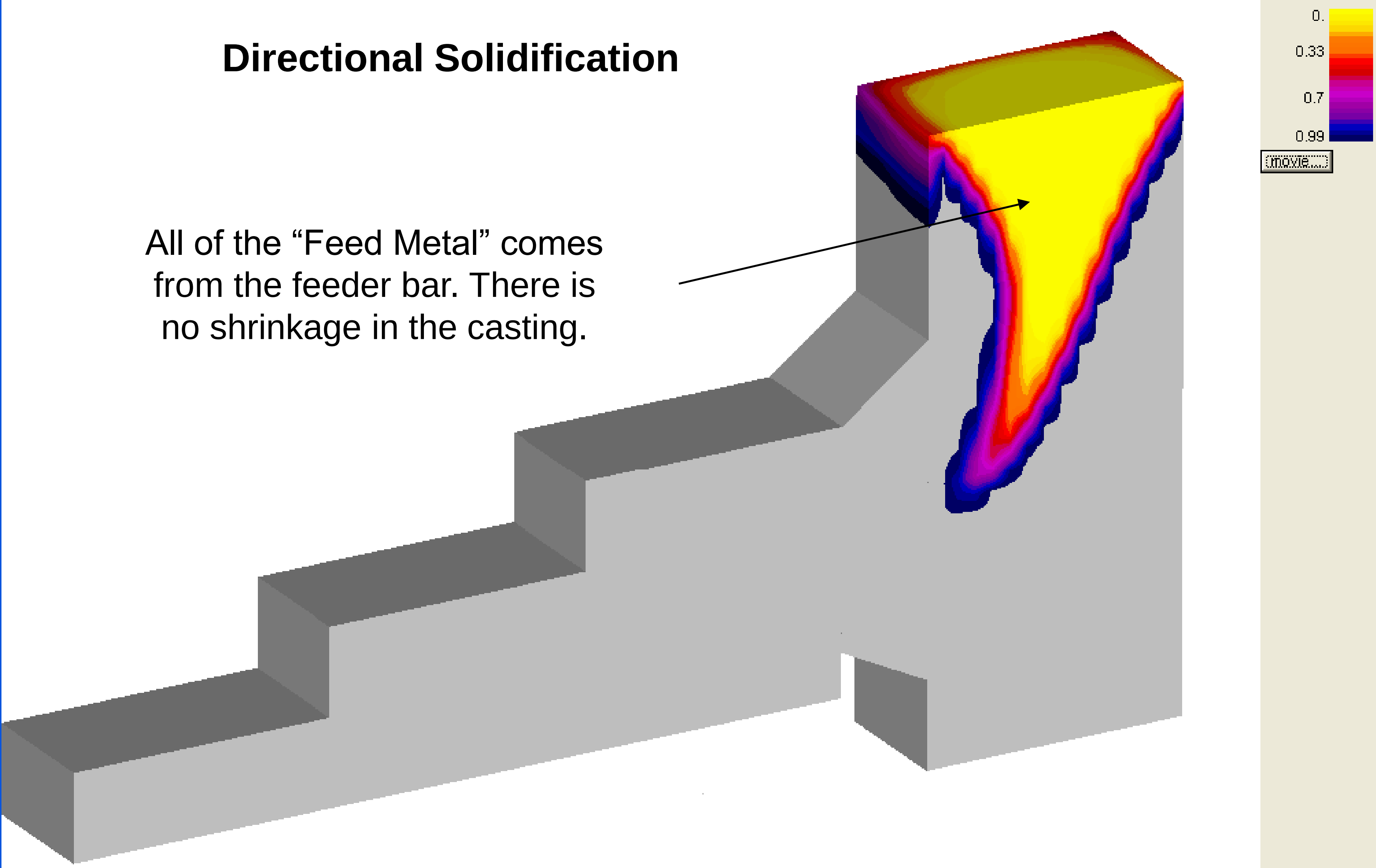
Material Density: 0-0.99

Directional Solidification

All of the “Feed Metal” comes from the feeder bar. There is no shrinkage in the casting.

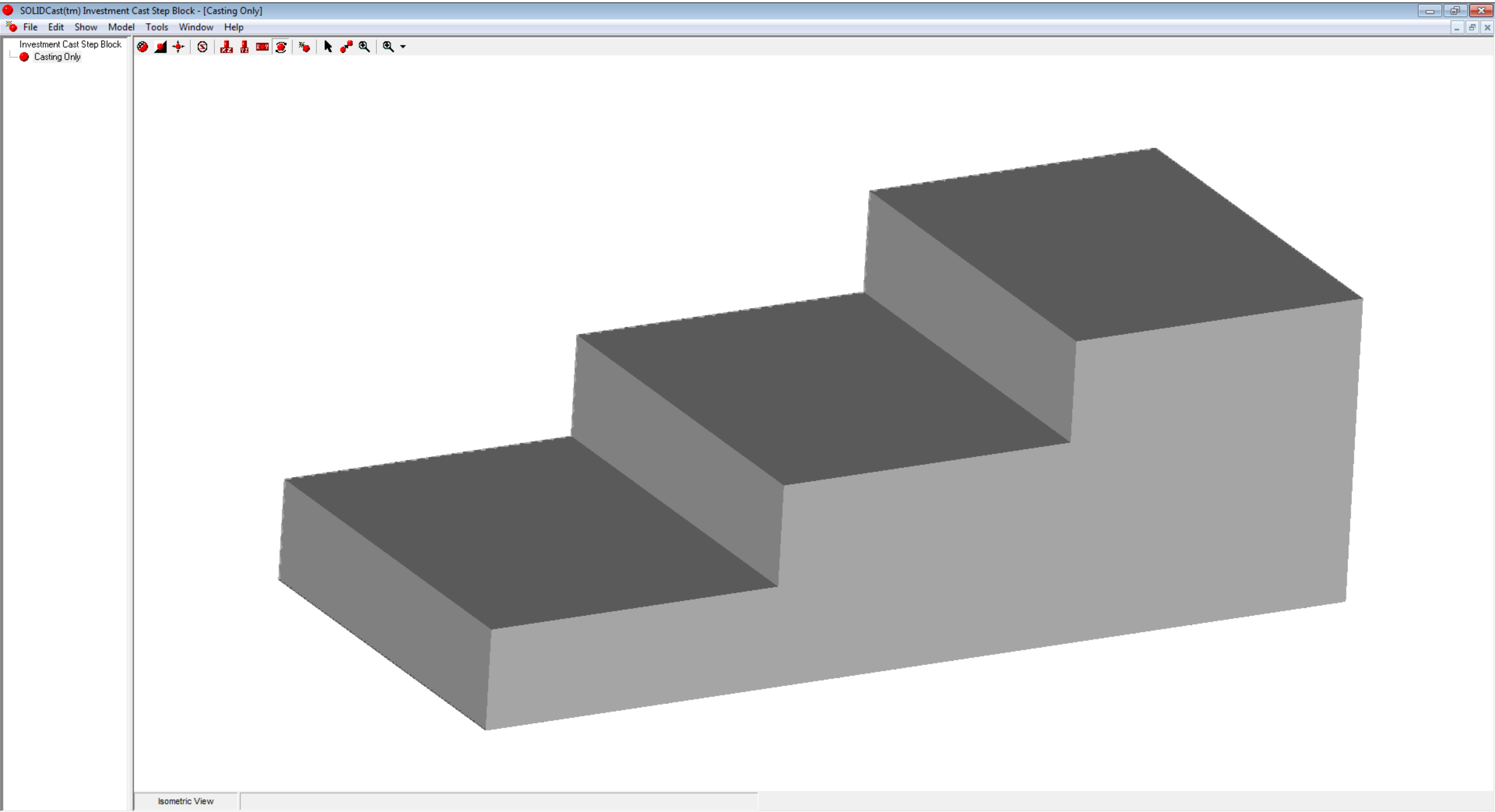


start   Pizazz 5 Capture c:\.....   SOLIDCast(tm) StepB...   EN   Microphone is On   11:03 AM

Gate and Feeder Bar Sizing

- From the Riser Design Wizard, calculate the maximum modulus of the feeding zone.
- The 2-D modulus of the casting end of the gate will be equal to the maximum modulus.
- The 2-D modulus of the feeder bar end of the gate will be 1.2 times the maximum modulus.
- The 2-D modulus of the feeder bar will ALSO be 1.2 times the maximum modulus.
- For a square cross-section, the modulus is the edge length/4.

Step Block Casting



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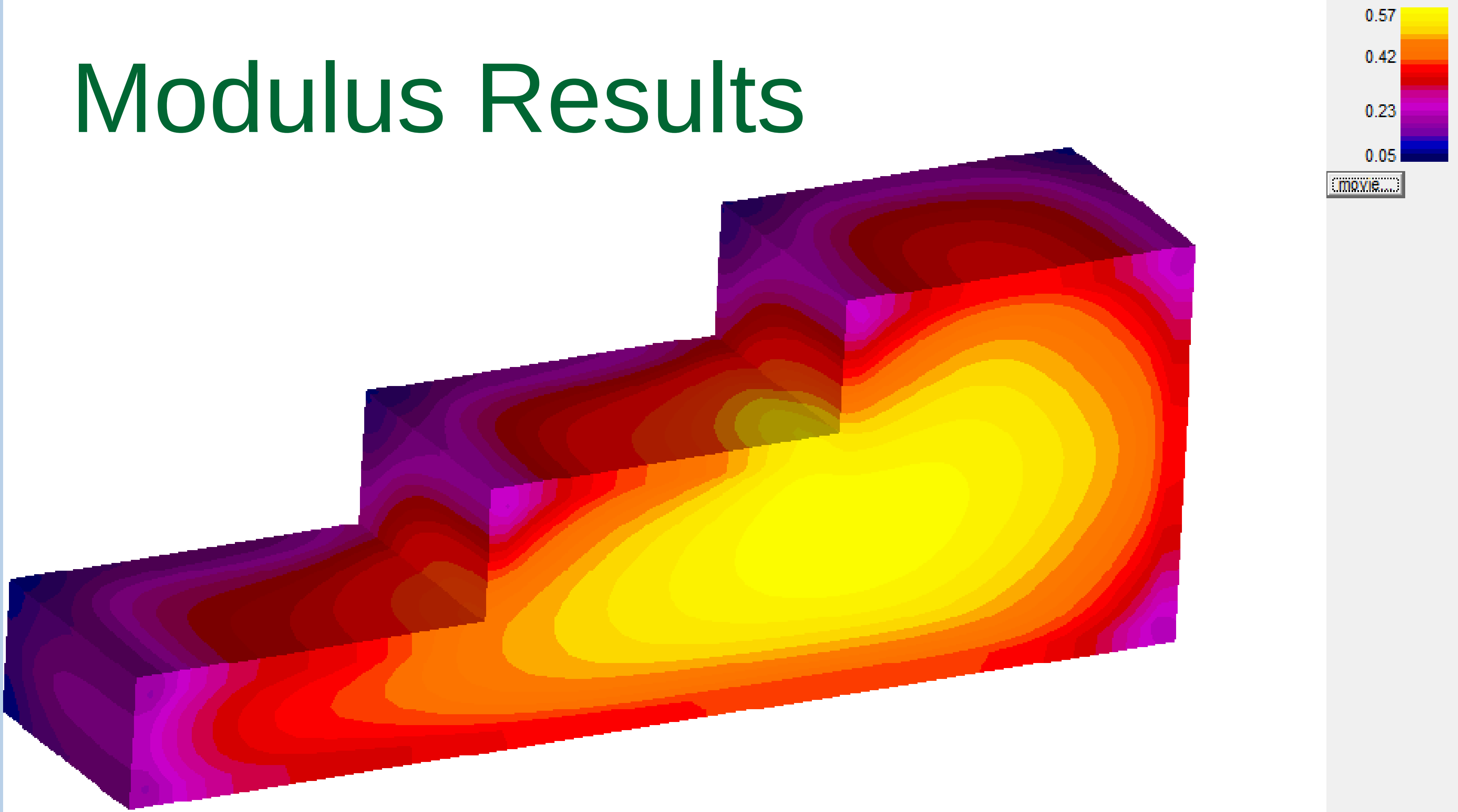
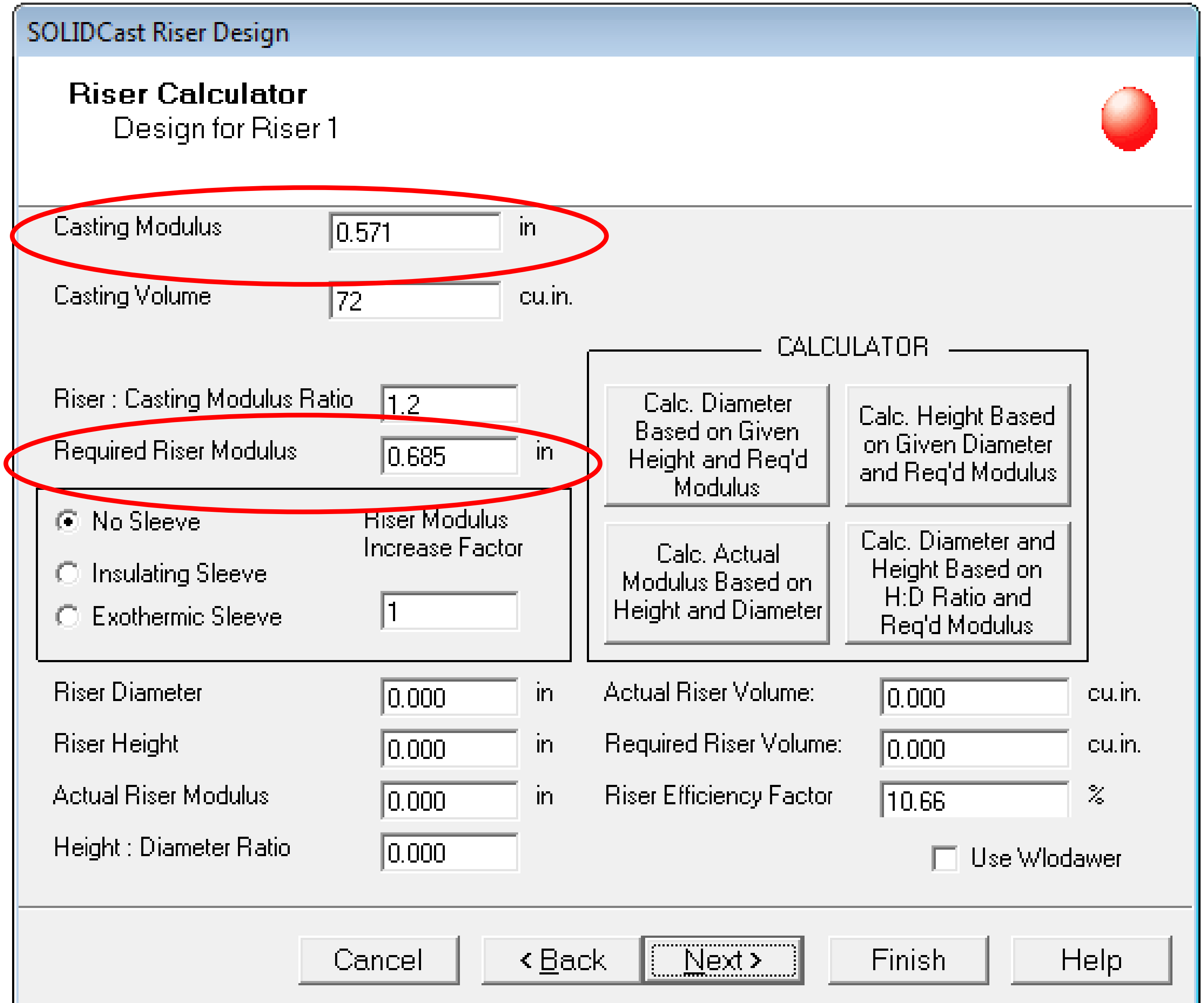
Modulus Results



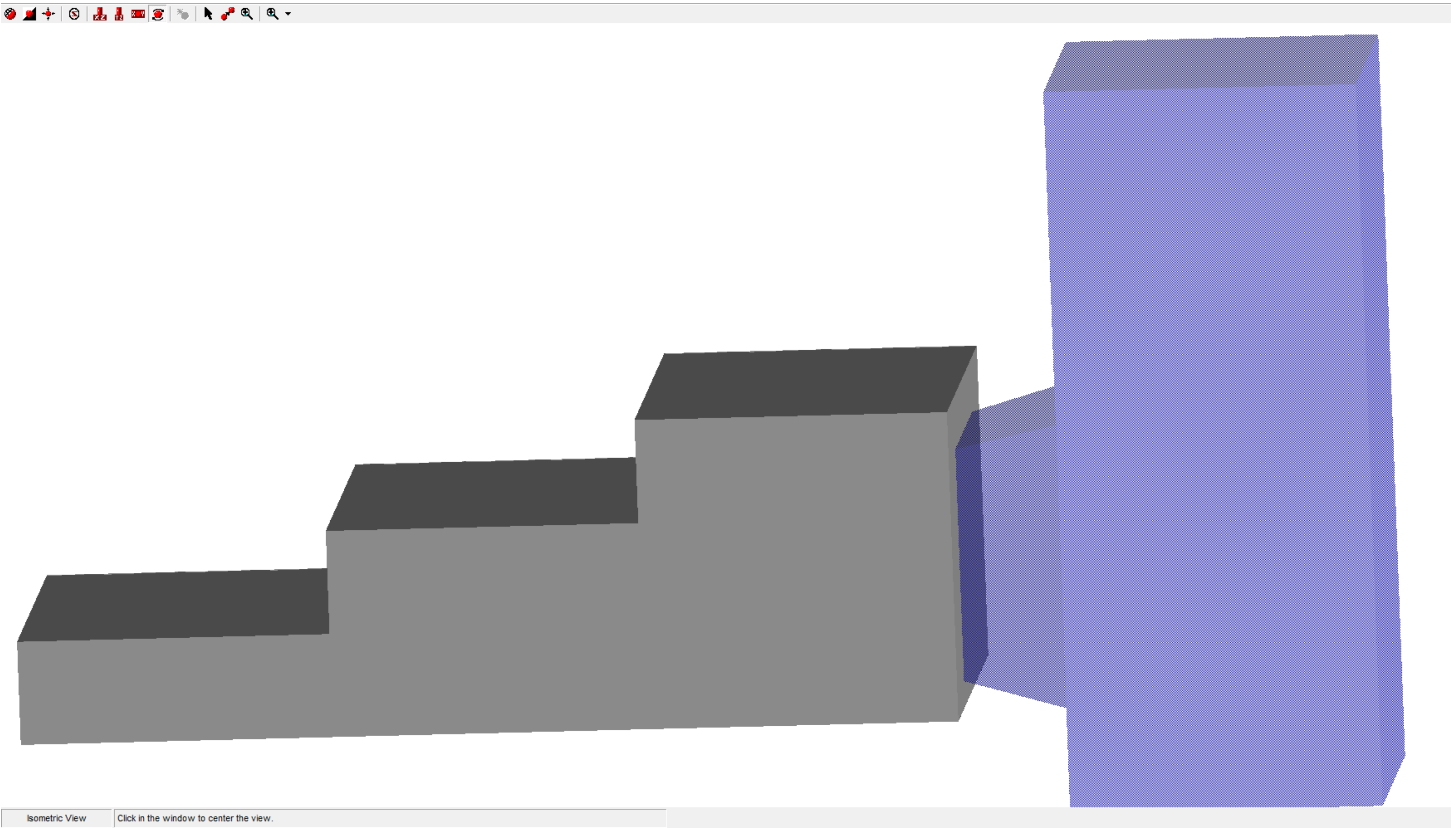
Modulus Values for Gates & Feeder Bar



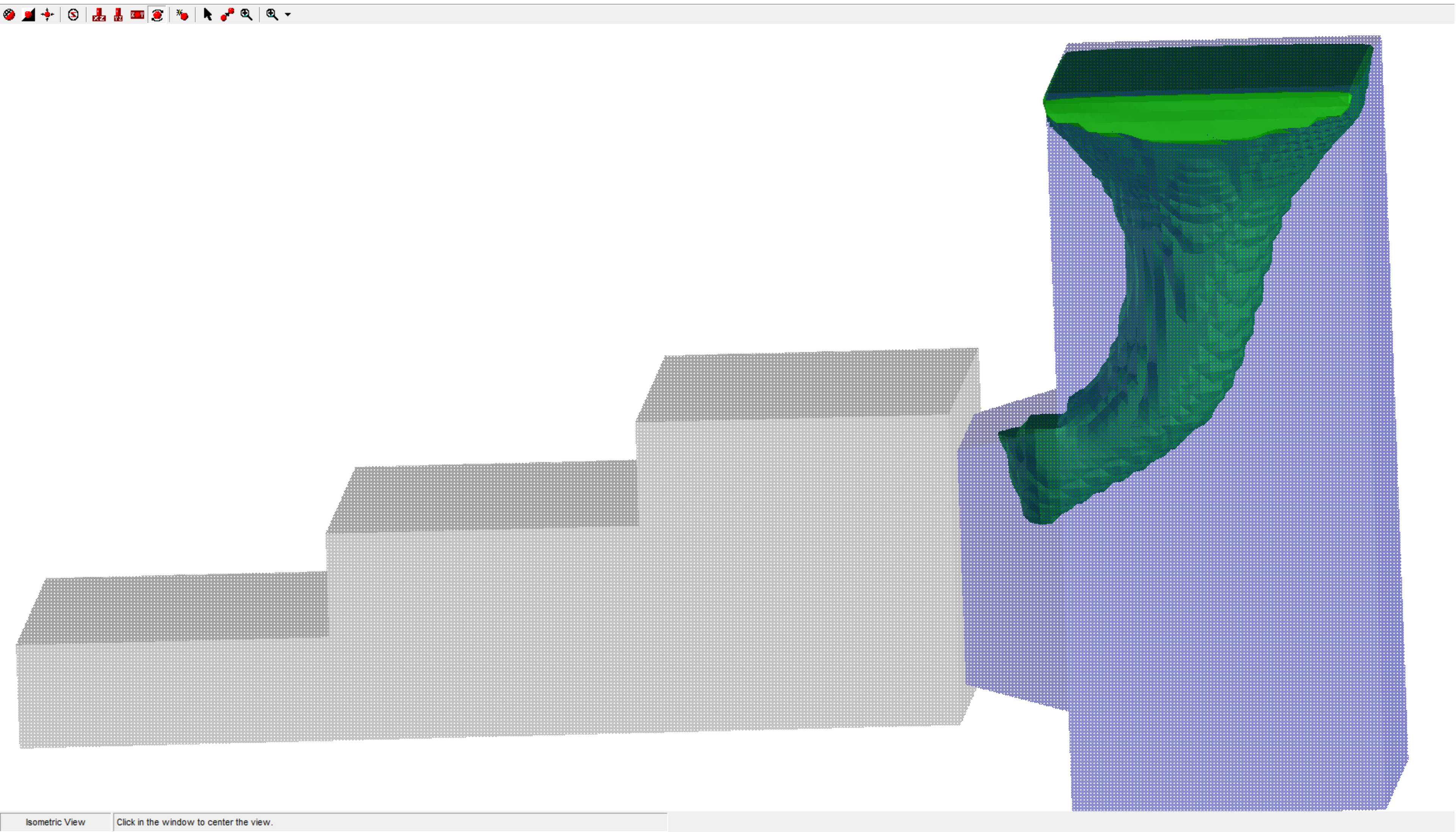
Gate & Feeder Bar Sizing

- At casting, 0.571x4 = 2.284in. edge length
- At feeder bar, 0.685x4 = 2.74in. edge length
- Feeder bar edge length 2.74in. minimum

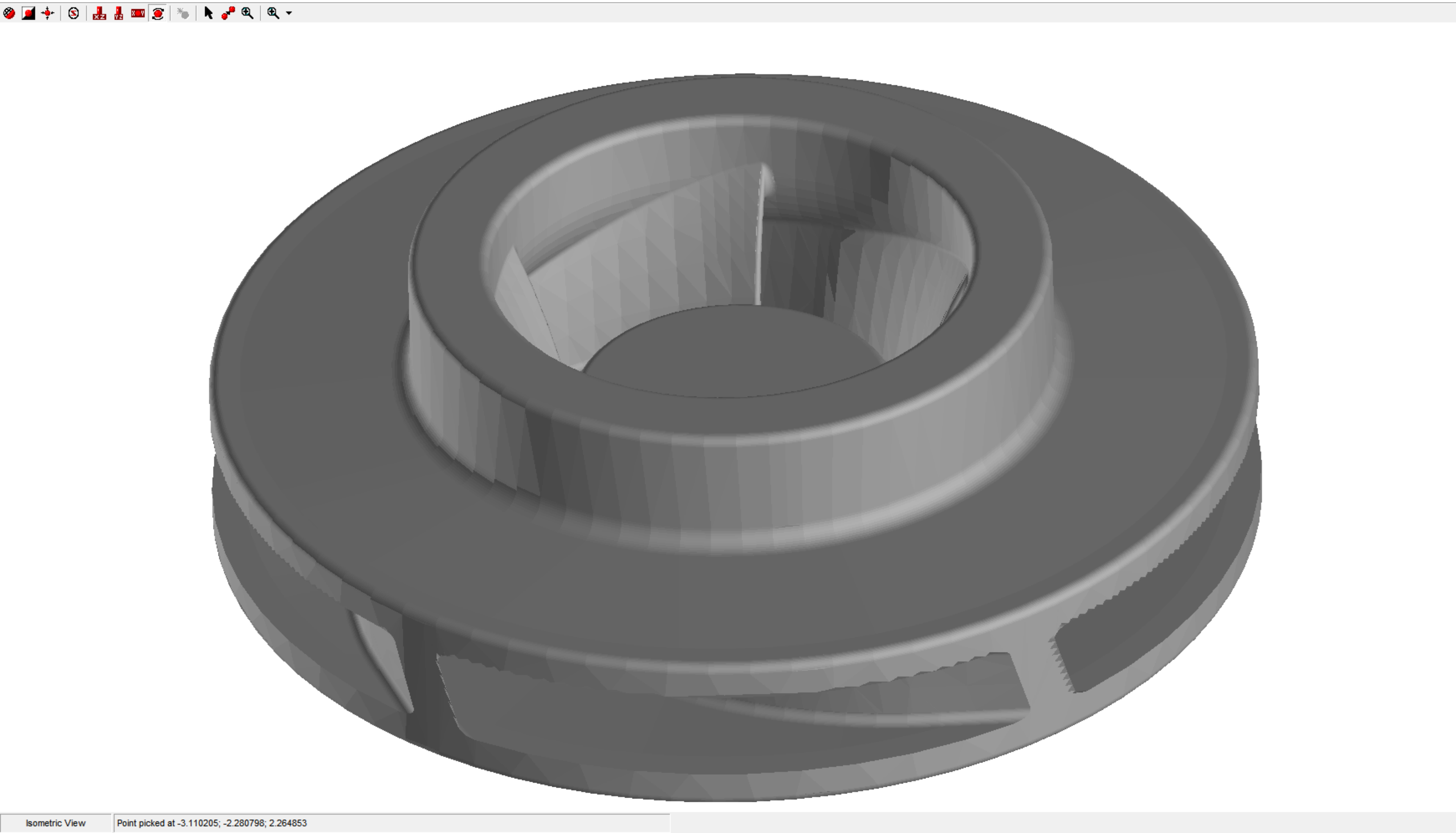
Rigged Casting Model



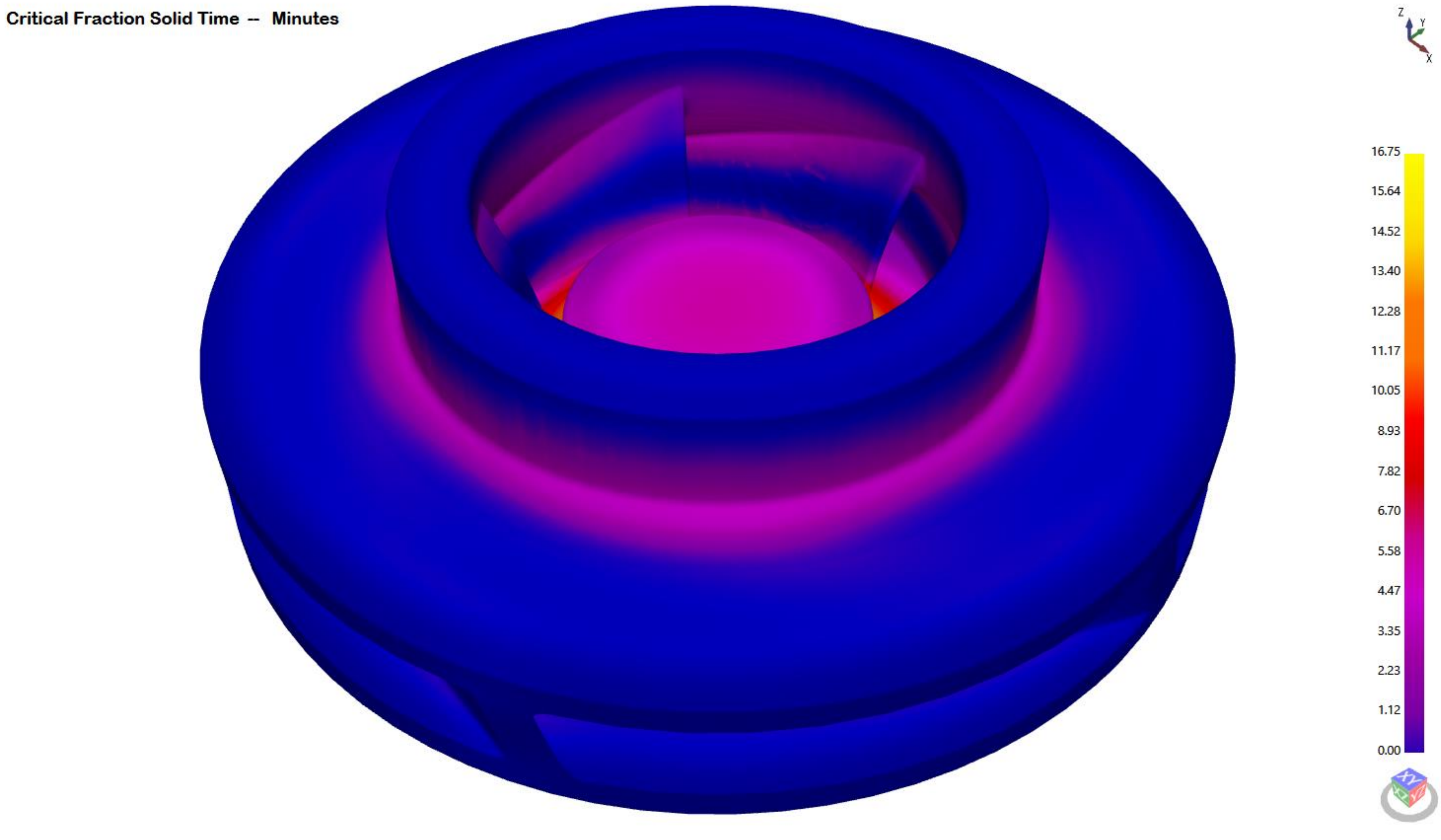
Feeding Results



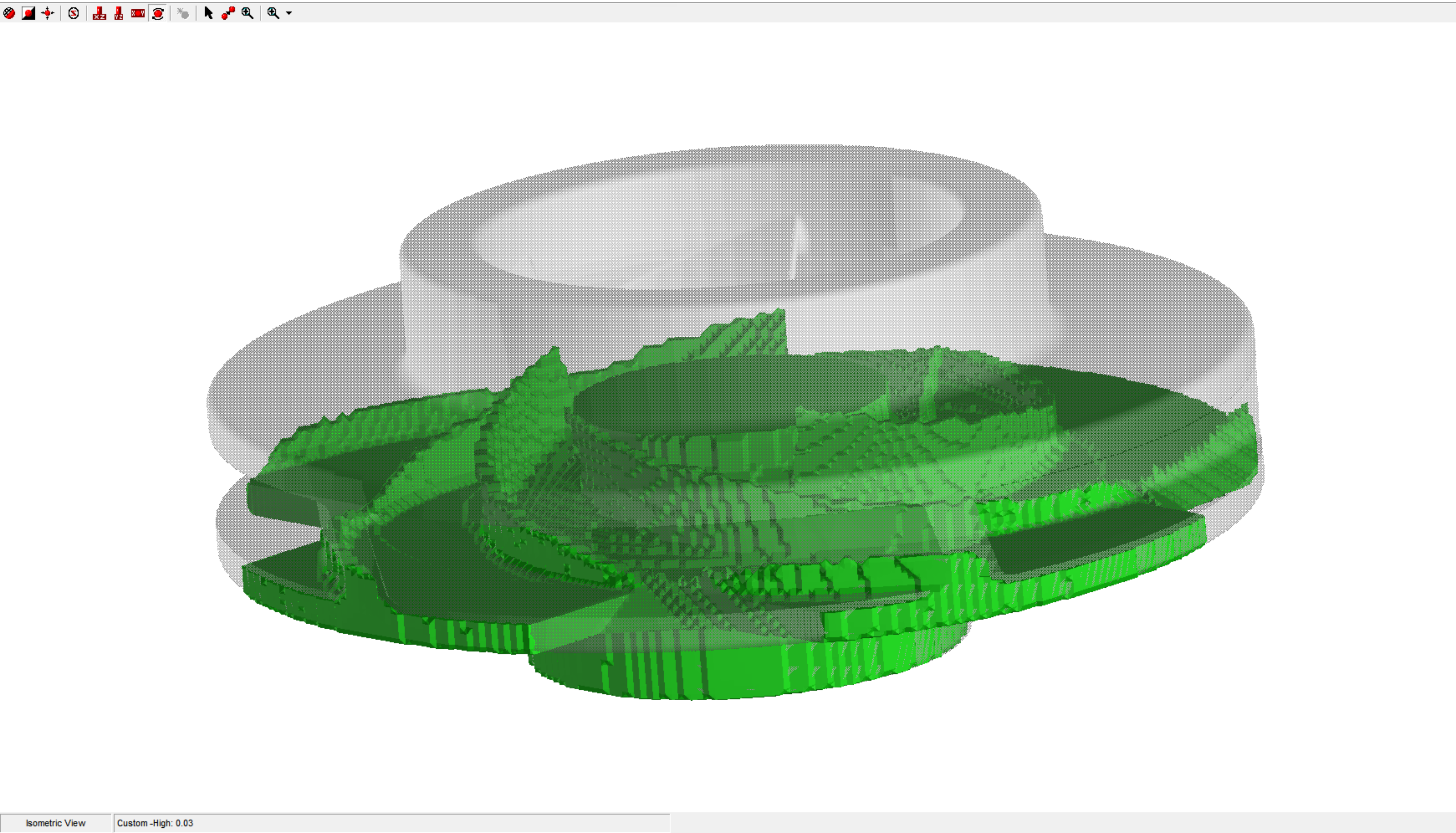
Case Study – Impeller Casting



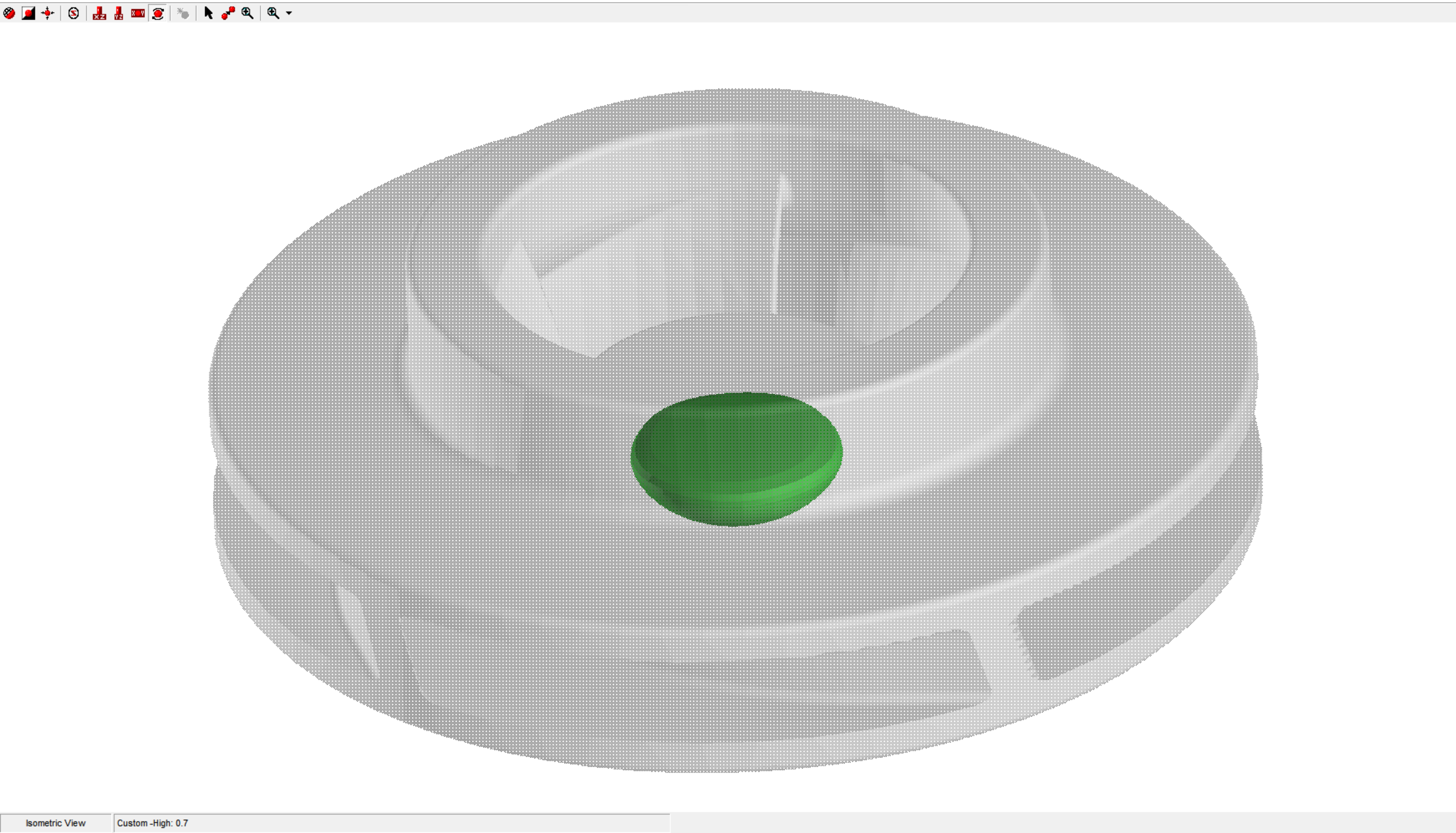
Unrigged Simulation Results



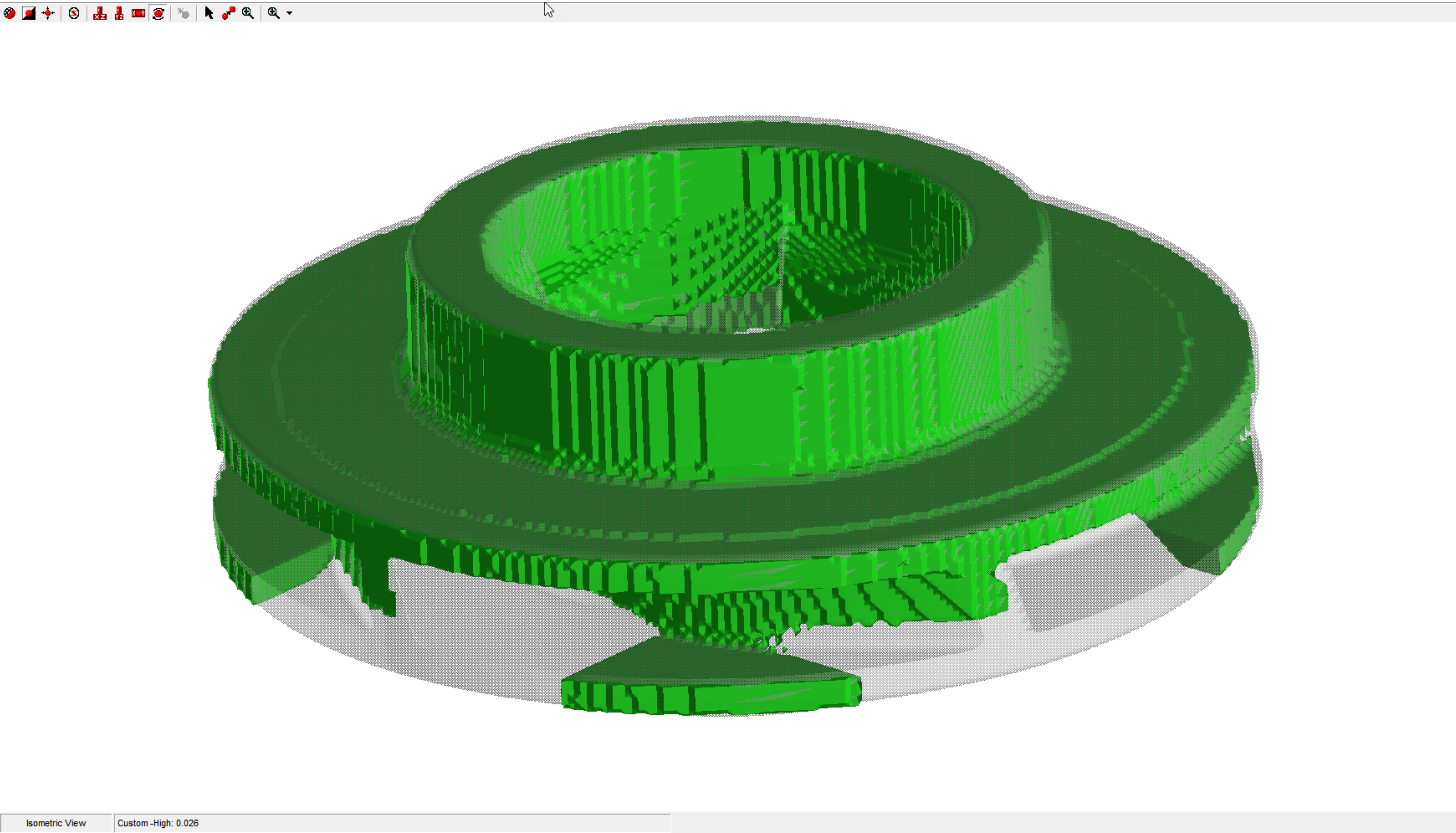
Feeding Zone 1



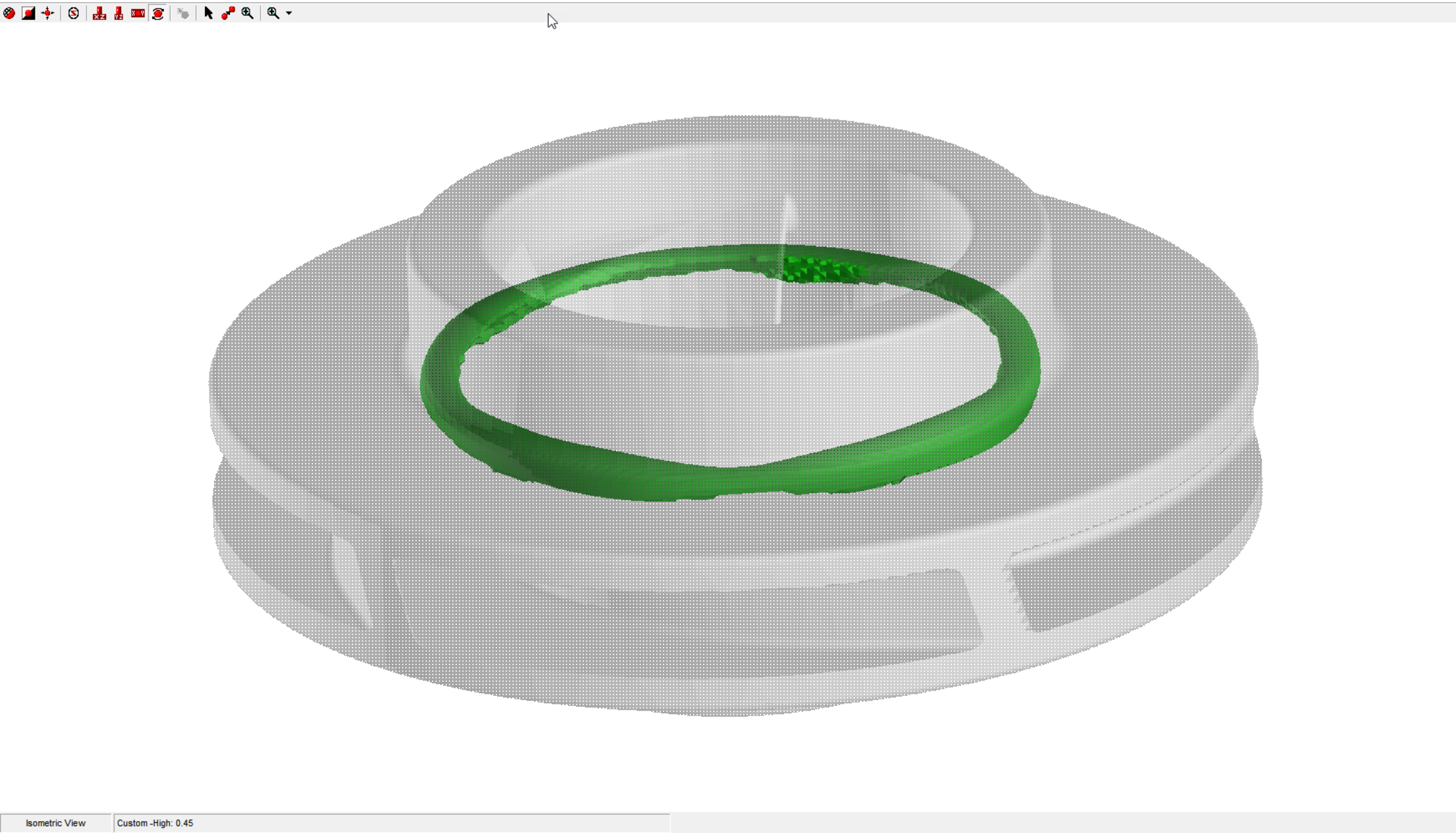
Last Point to Freeze on Zone 1



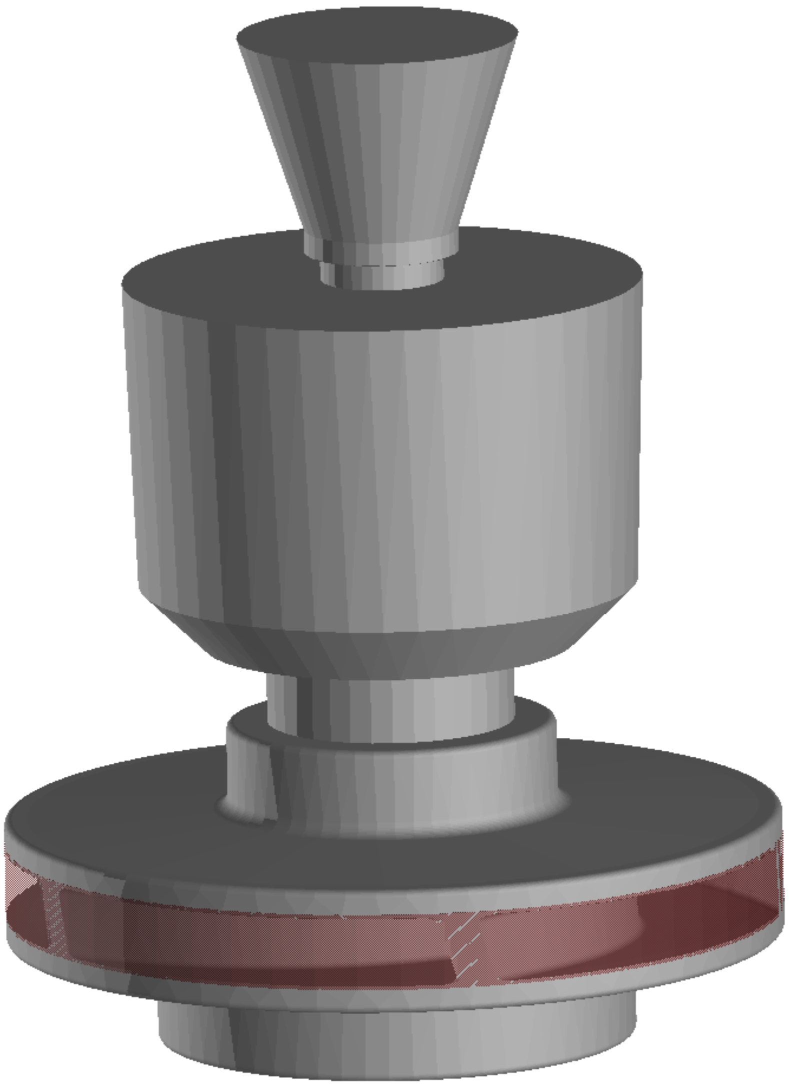
Feeding Zone 2



Last Point to Freeze on Zone 2

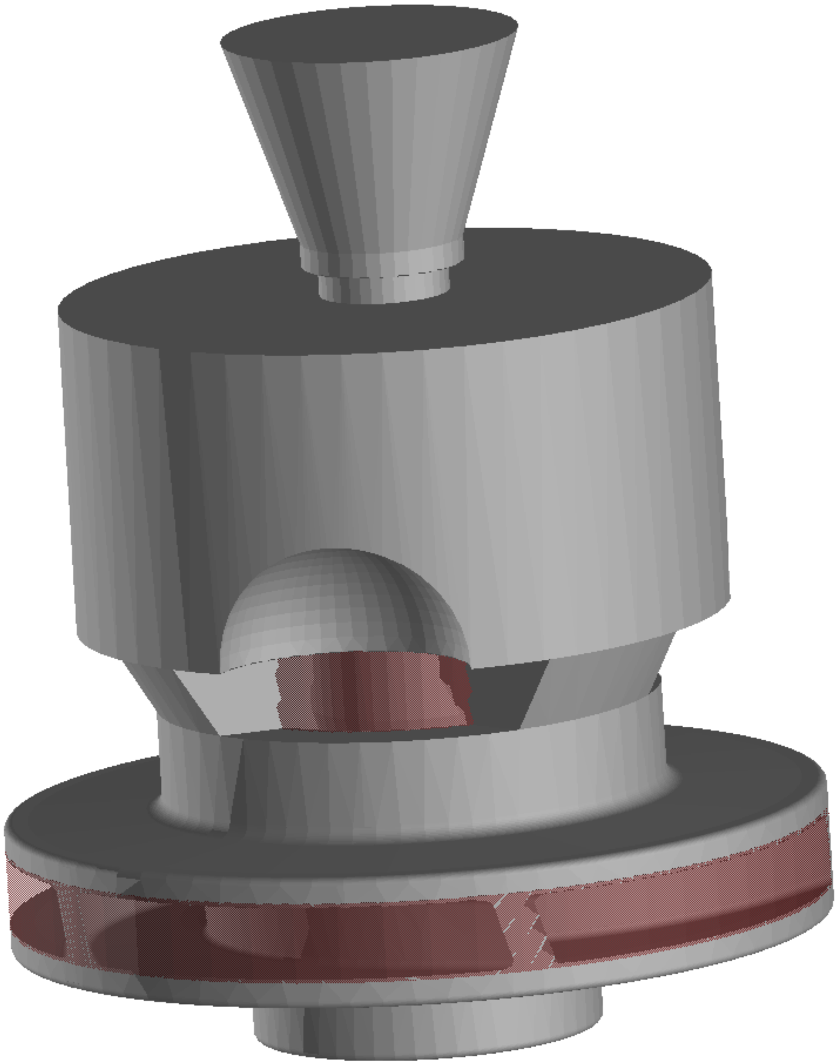


Iteration 1 – Casting inverted with a top feeder

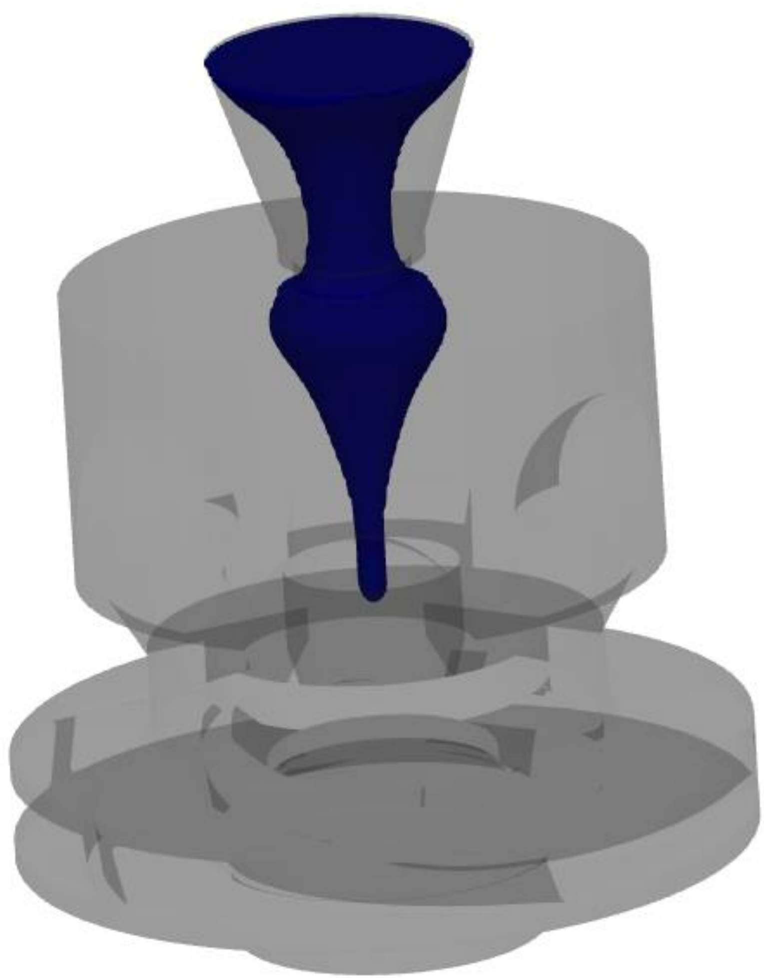


Shrinkage areas in vanes

Iteration 2 – Original orientation with 3 flange gates



The casting is clean!



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