CCC Report
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3D Simulation of Mold Heat Flow

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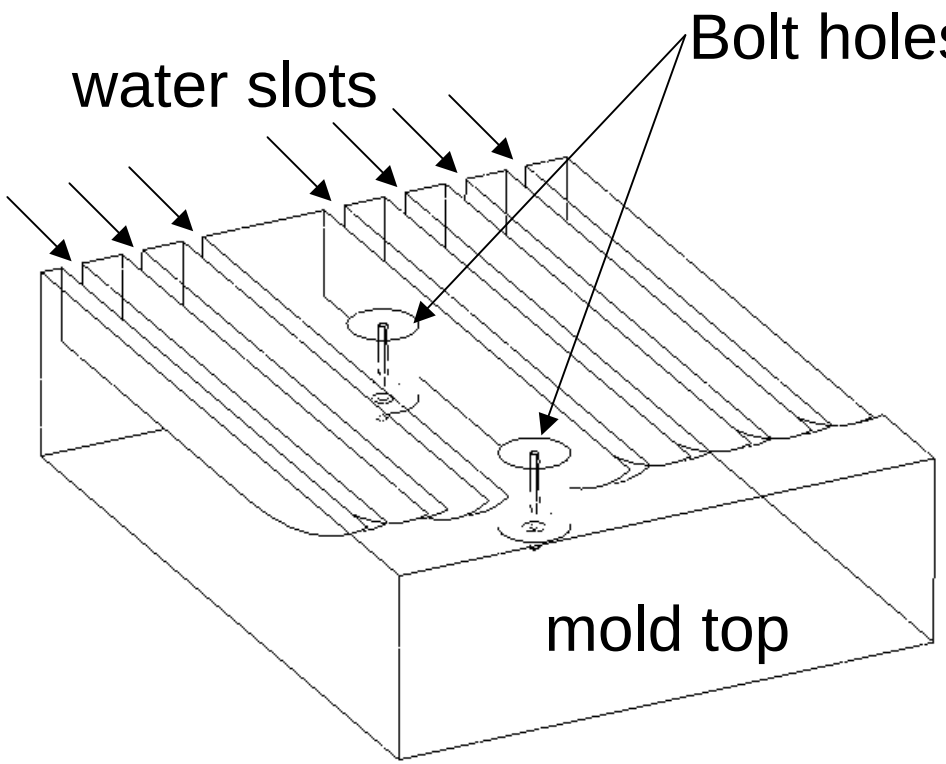
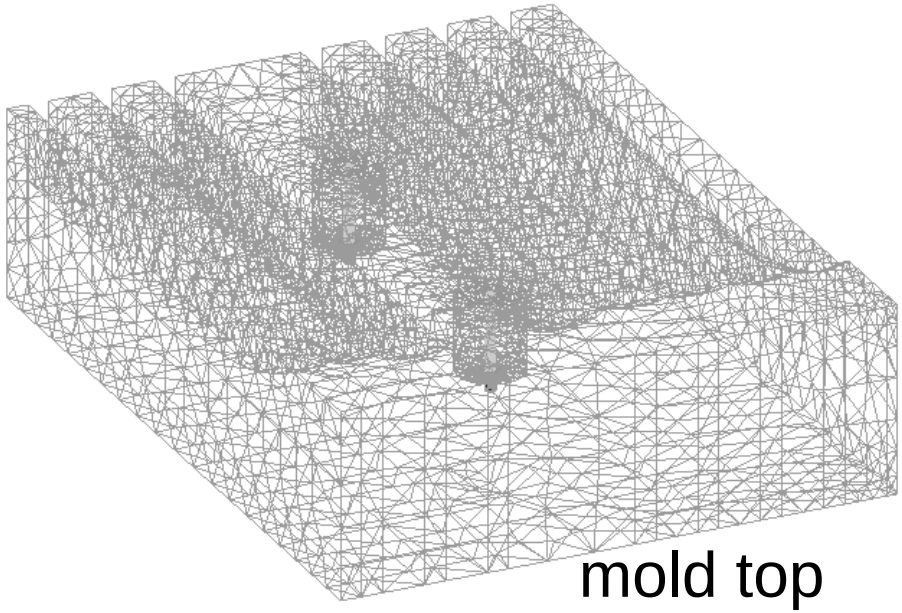
Consulting Project: Columbus Stainless

3-D Model of Mold Temperature Near Meniscus



Domain (showing slots)



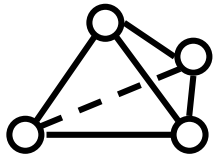
Finite Element Mesh
(4-node tetrahedrons)

Finite Element Model

Solve 3-D heat conduction equation:

$$\frac{\partial}{\partial x} k_x \frac{\partial T}{\partial x} + \frac{\partial}{\partial y} k_y \frac{\partial T}{\partial y} + \frac{\partial}{\partial z} k_z \frac{\partial T}{\partial z} = -Q$$

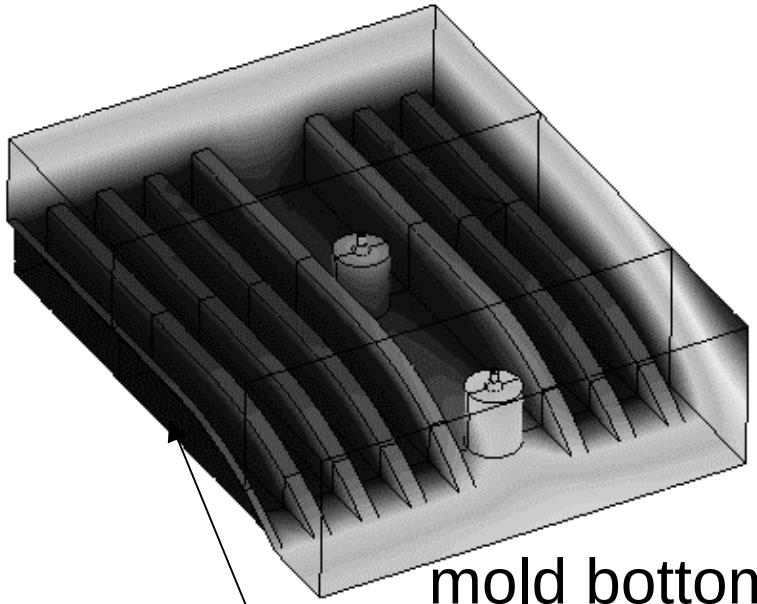
Using 4-node tetrahedral elements:



Using 8457 node - 41266 elements (small mesh)

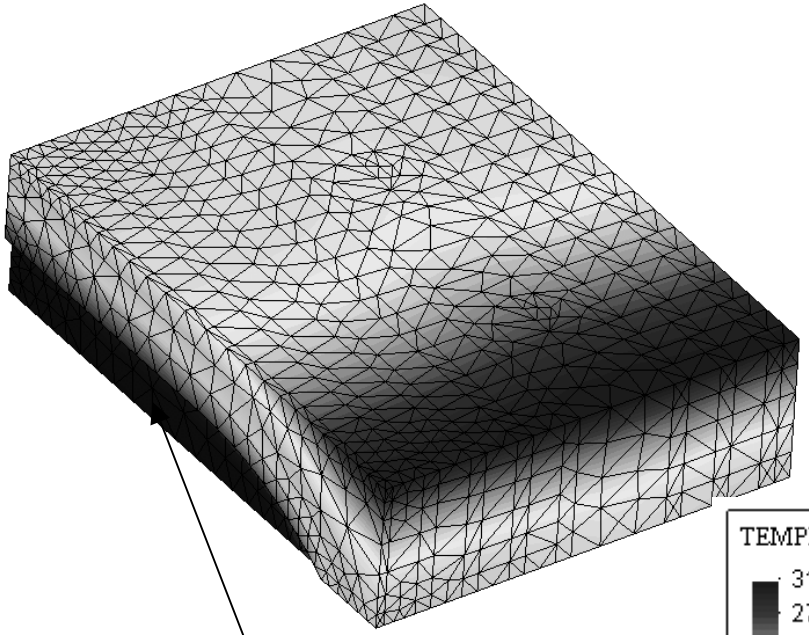
3-D Model of Mold Temperature Near Mold Bottom

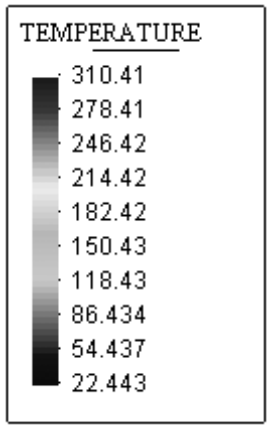
constant q=1.75 MW/m^2



mold bottom

water slot

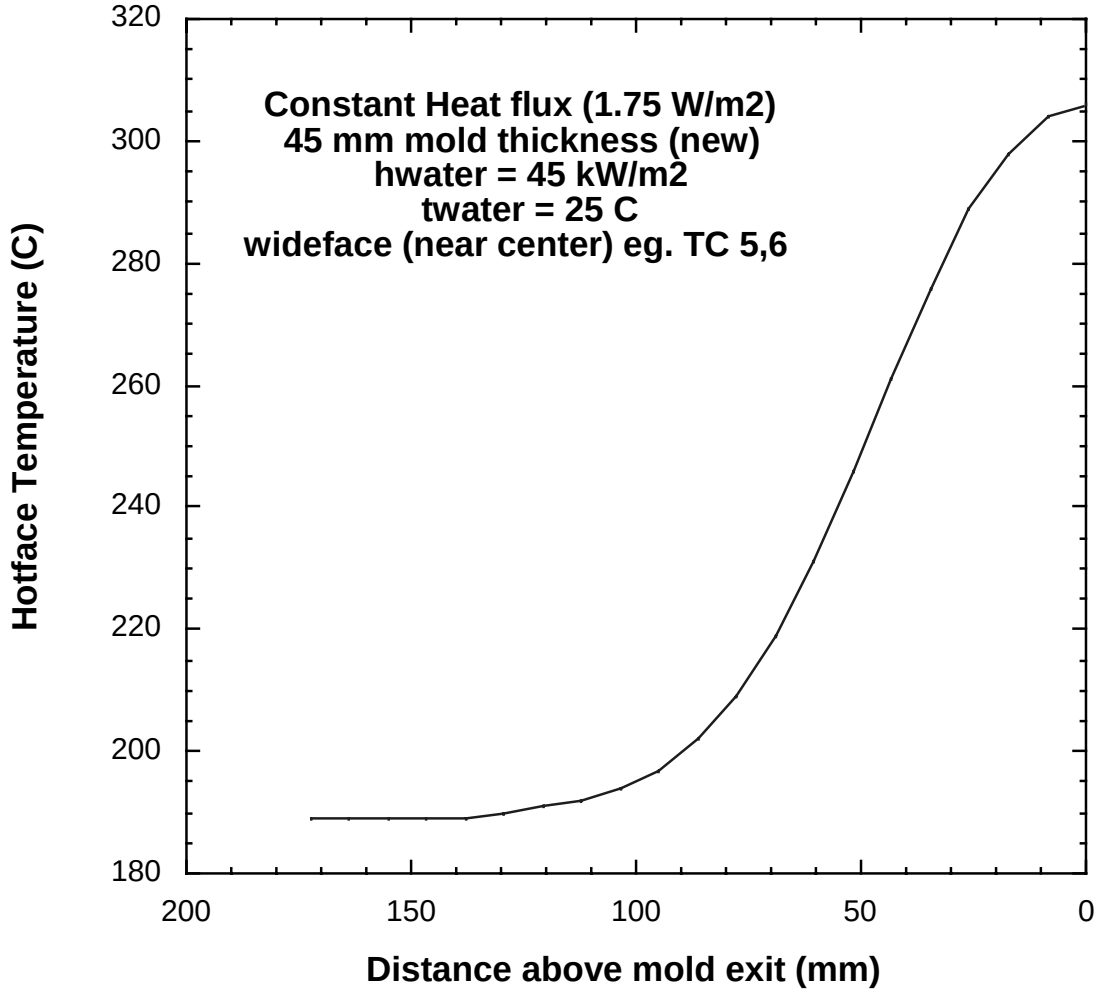




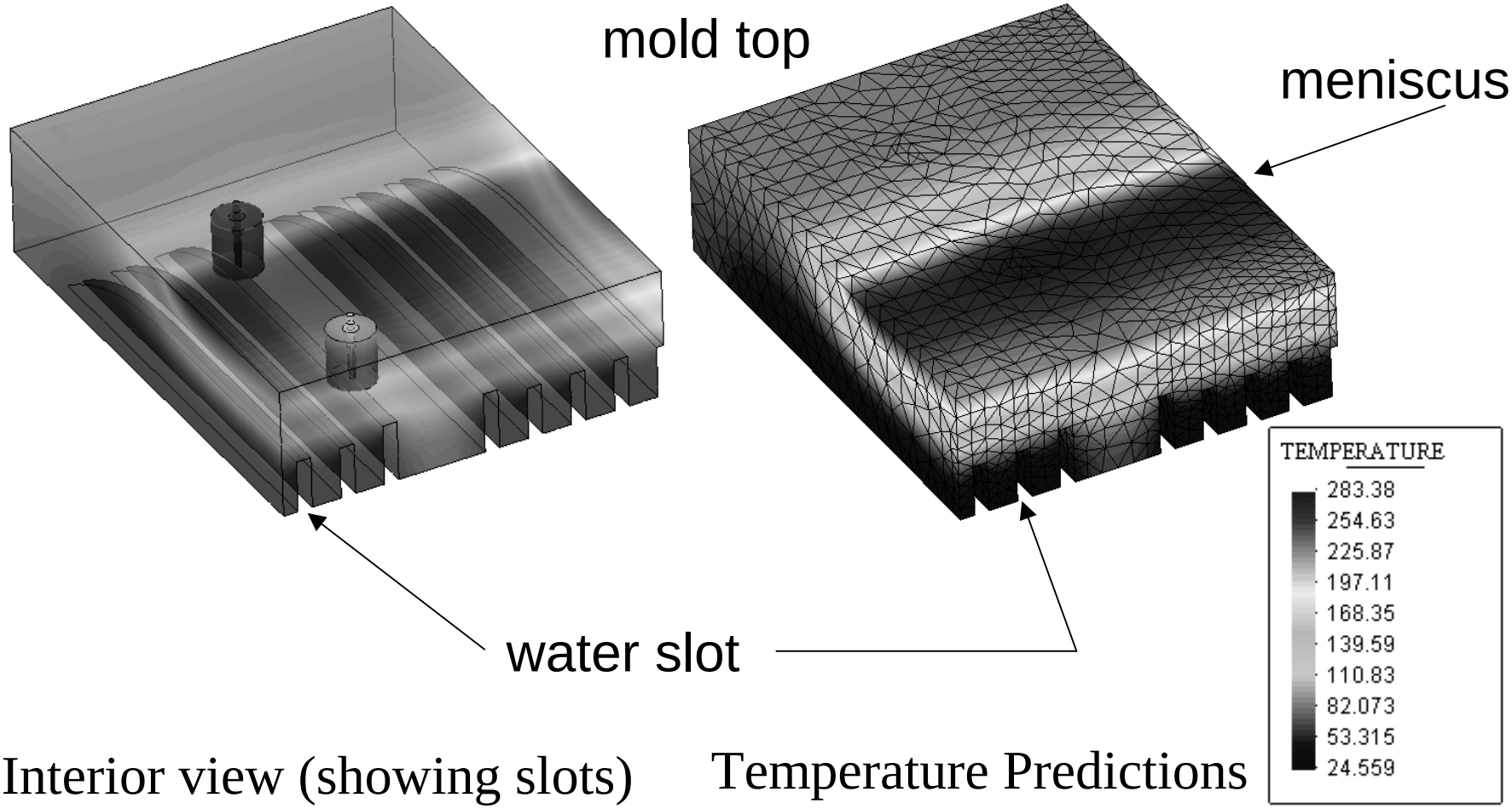
Interior view (showing slots)

Hotface Temperature

Heat Flux Profiles From Calibrated Model



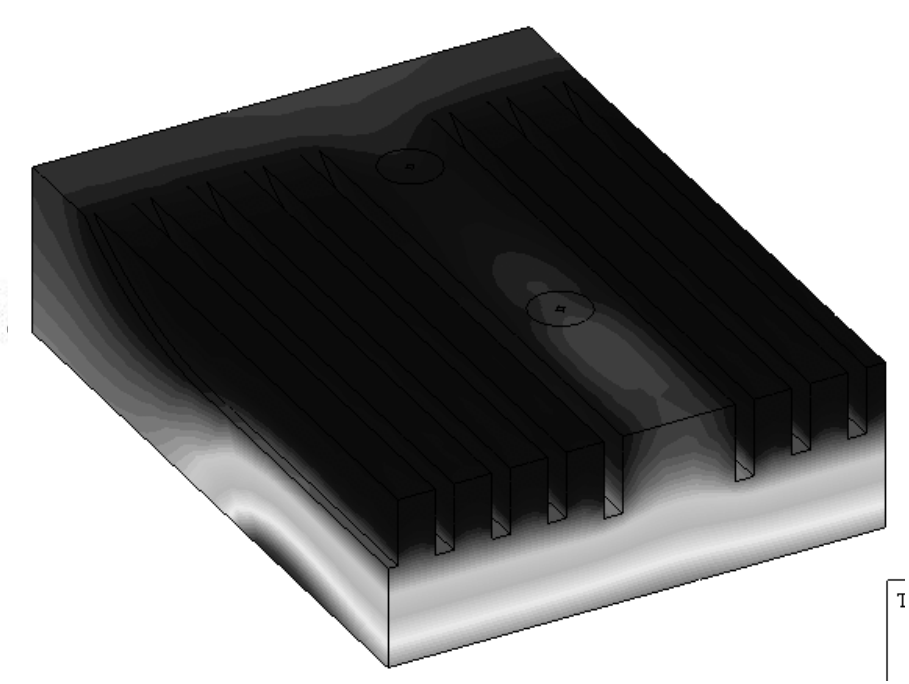
3-D Model of Mold Temperature Near Meniscus



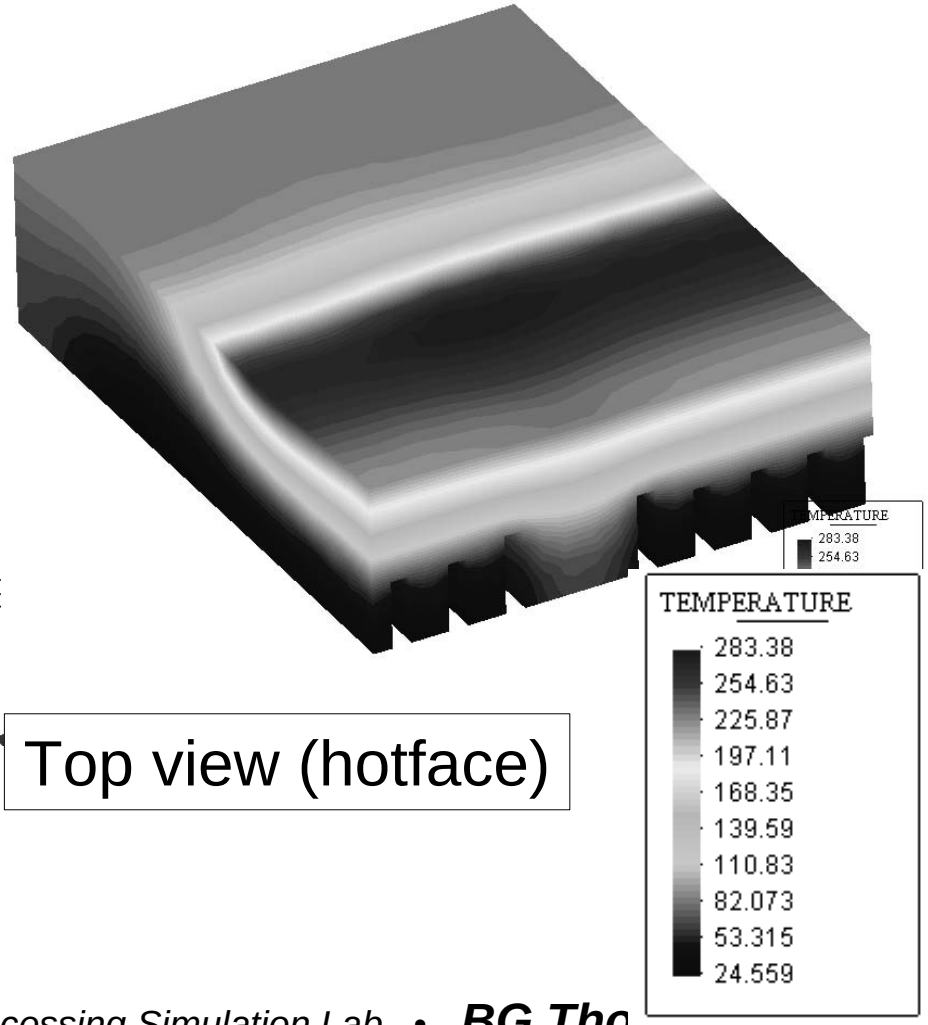
Interior view (showing slots)

Temperature Predictions

3-D Model of Mold Temperature Near Meniscus

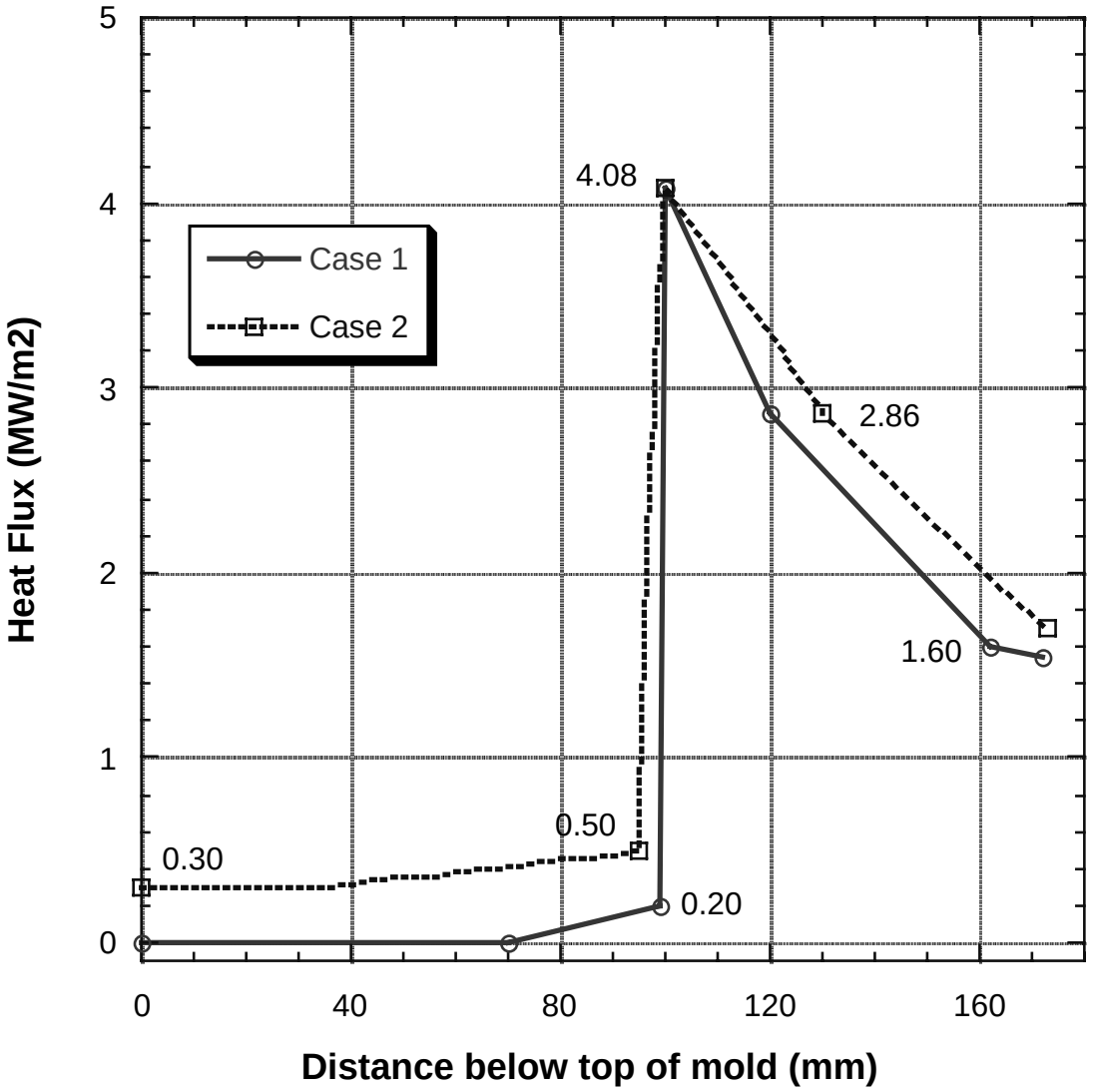


Bottom view (water slots)

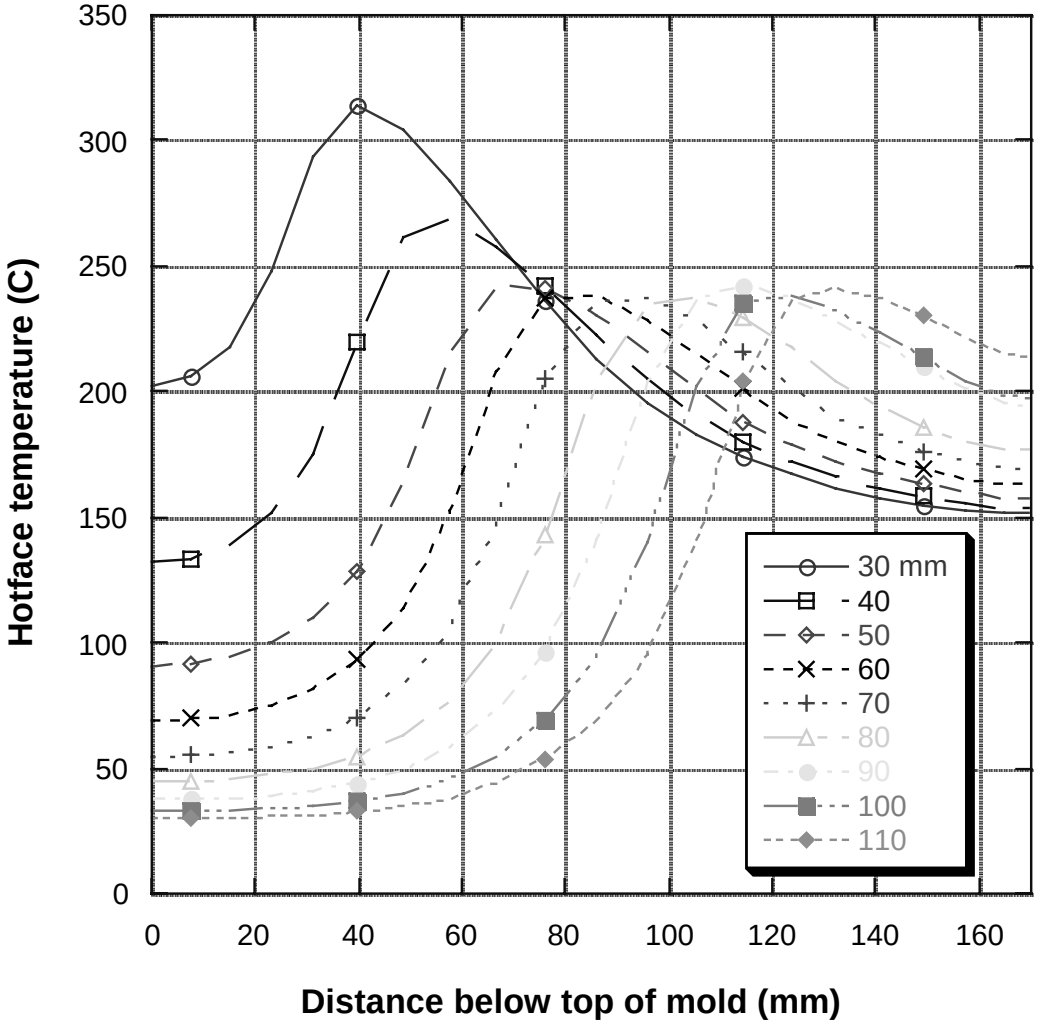


Top view (hotface)

Heat Flux Profiles From Calibrated Model

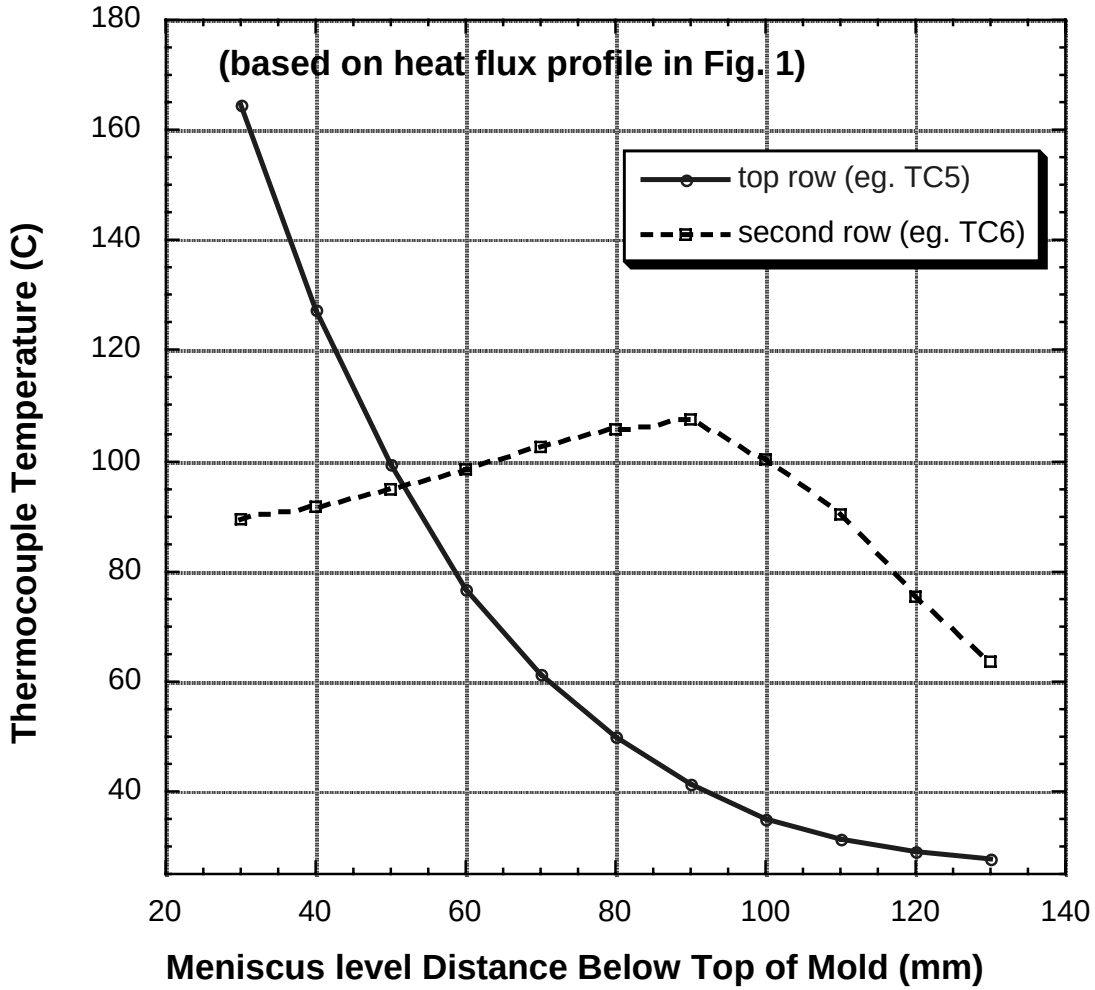


3D Model Application: Meniscus Level Monitoring



Effect of meniscus level on mold temperature

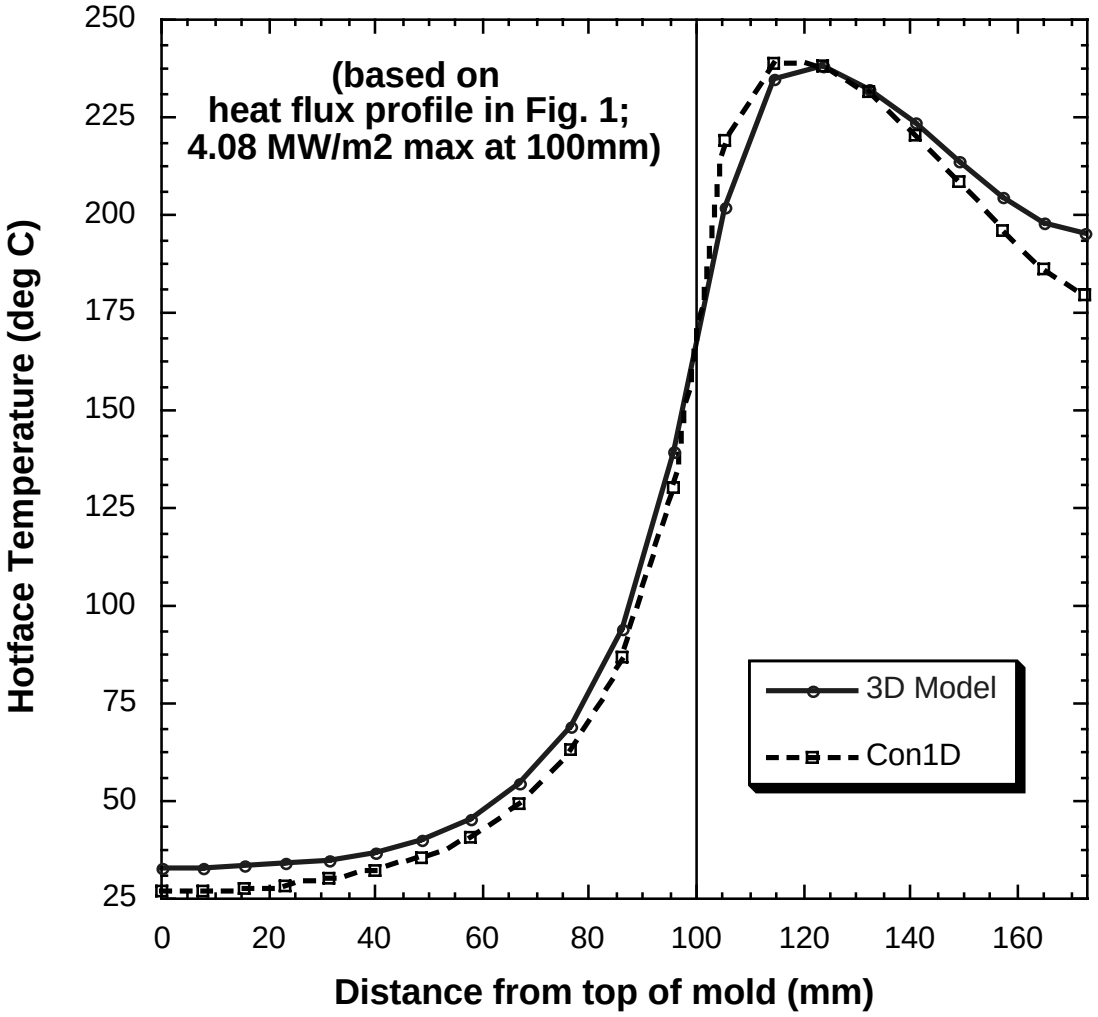
Effect of Meniscus Level on Thermocouple Temperature



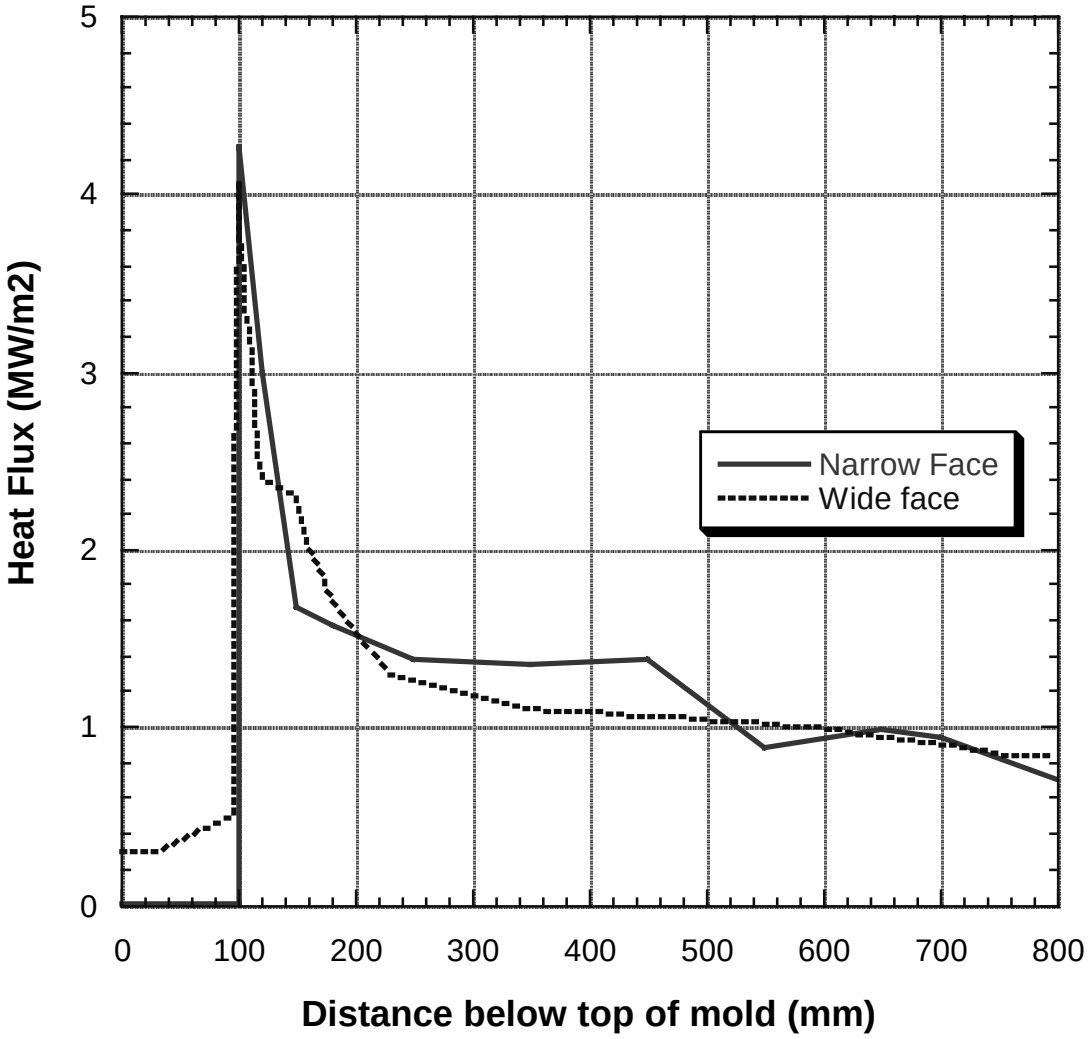
Meniscus level can be inferred from thermo-couple temps.

Effect of meniscus level on thermocouple temperature

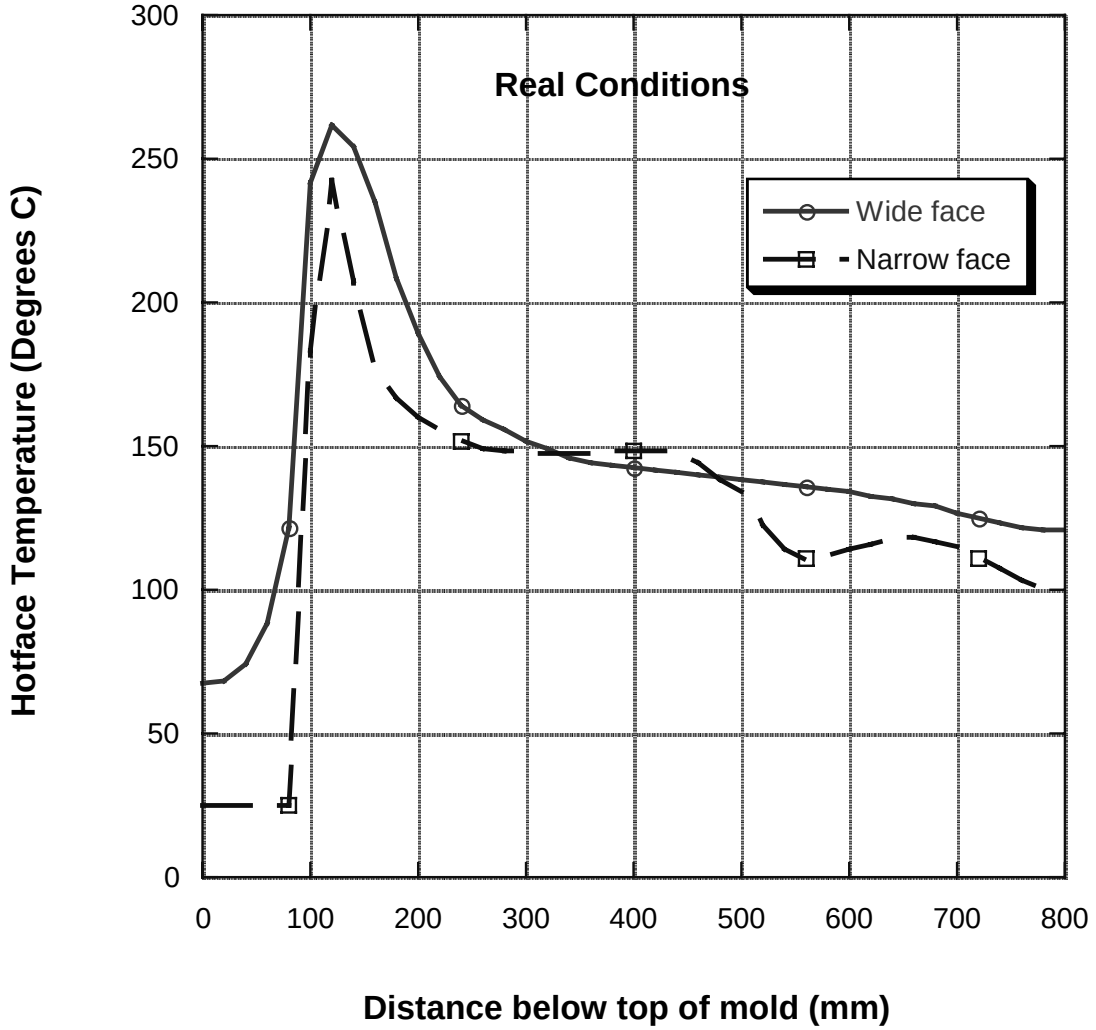
Solidification Model (CON1D): Validation with 3D model



Heat Flux Profiles From Calibrated Model



Heat Flux Profiles From Calibrated Model



Conclusions

1. Efficient and accurate 3D model has been developed. The model features complete copper geometry including details of the thermocouple rod, paste, and hole, and the curved water slot geometry in each symmetric section of the mold.

Offset distances for CON1D can be determined from the 3D model results

CON1D model matches within 10˚C of the real 3D model temperature predictions for both hotface and thermocouple predictions (based on the constant-heatflux offsets). The more the heat flux profile deviates from a constant, and axial heat conduction through the mold becomes important, the less accurate the offset method becomes.

CON1D model predictions might be used to determine metal level and its fluctuations if:

* Several rows of thermocouple data can be measured and evaluated simultaneously
* The 5-10 ^{o}C accuracy problem above the meniscus can be reduced.
* The heat flux profile can be determined reliably
* Transient effects can be taken into account