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Heat Transfer and Distortion of a Beam Blank Mold: Plant Measurements and Model Computations

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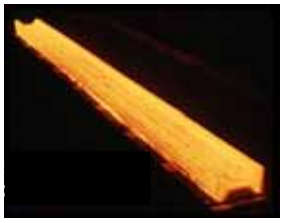
Processes for Beam Blank Mold

Beam Blank Mold

Casting

Semi-Finished

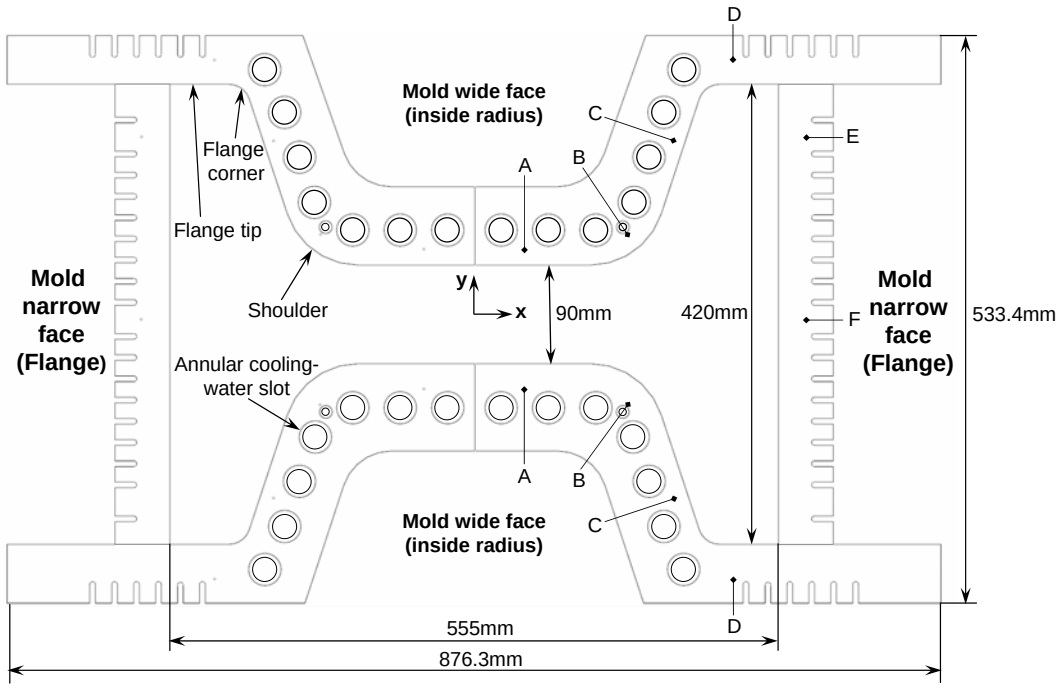


Reheating

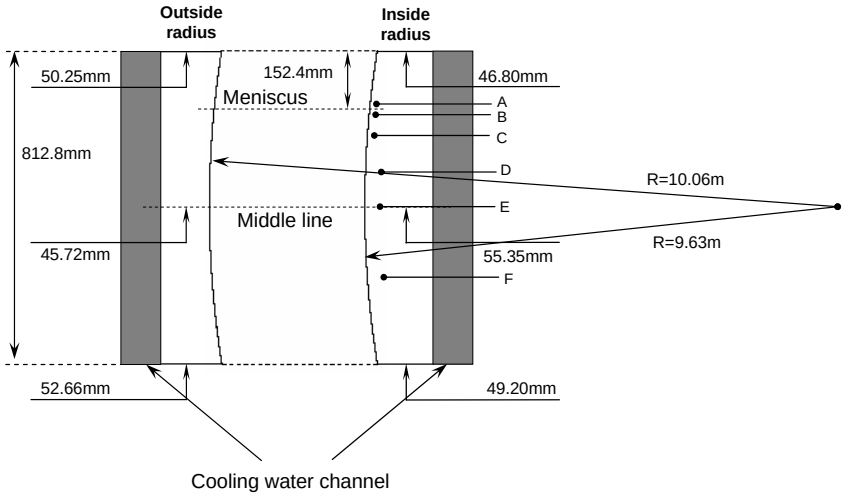
Rolling

Final Product

Top view of Beam Blank Mold



Side view of Beam Blank Mold



Experimental Measurements by Mold Thermocouples

Conducted by SDI and Accumold

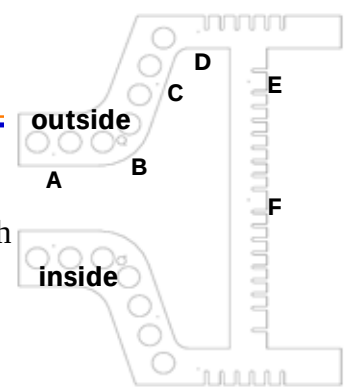
3 columns of 6 in "cove", 1 Column of 3 on flange tip: 21 TCs per wide face

2 Columns on narrow face, 3 on outside column, 2 in center column: 5 TCs on narrow face

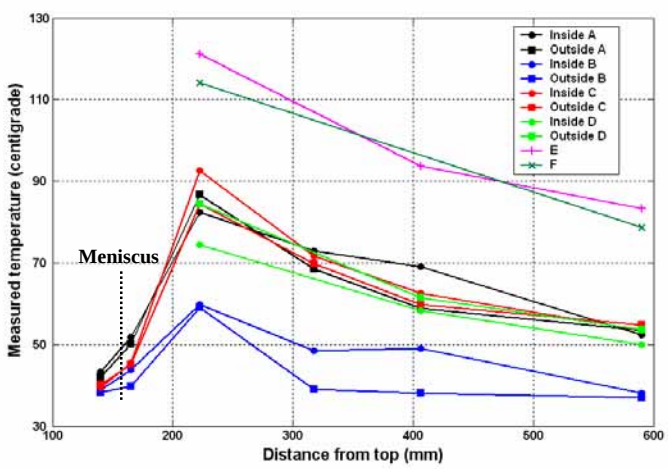
47 total thermocouples

TCs drilled between water slots to 1/10 inch past tangent line through water slots closest to hot face (centered between slots)
1/8 inch diameter Cr-Al (K-type) TCs
Close contact fit (no thermal paste)

Experimental Results



Averaged temperatures over 30 min of steady casting
Cast at 0.92 m/min; 812.8mm mold; 660.4mm working length



Material Properties & Water Heat Balance Measurements

A 992 structural steel: 0.071%C, 1.31%Mn, 0.012%Ph, 0.026%S, 0.17%Si, 0.36%Cu, 0.06%V, 0.02%Nb, 0.0116%N, 0.0017%Al

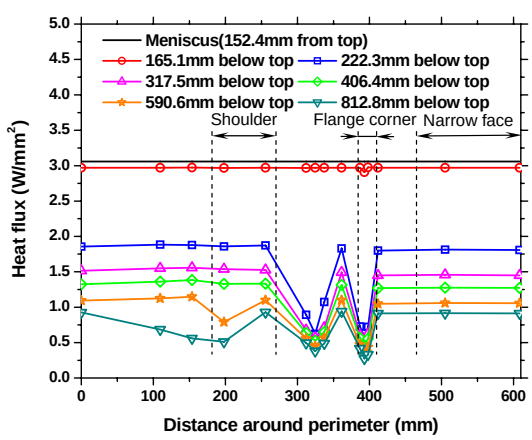
Copper thermal conductivity 350W/mK

	Water Flow (kg/s)	Inlet temp (°C)	Outlet temp (°C)	Flow velocity (m/s)	Heat loss (10^3W)
Front	43.34	31.87	34.91	9.73	551.3
Back	46.04	31.87	34.78	10.34	561.1
Left	14.77	31.87	37.23	7.79	331.8
Right	15.00	31.87	36.96	7.91	319.6
Total	119.16				**1763.8**

Wide face: $T_{ref} = 33.35^o C$, $h = 45\text{kW/m}^2\text{K}$

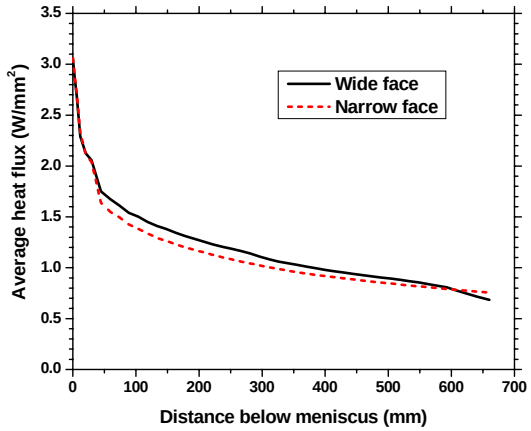
Narrow face: $T_{ref} = 34.48^o C$, $h = 34\text{kW/m}^2\text{K}$

Heat flux along perimeter for meniscus, measured slices and end of mold



Starting from the middle point on the wide face to the middle point on the narrow face

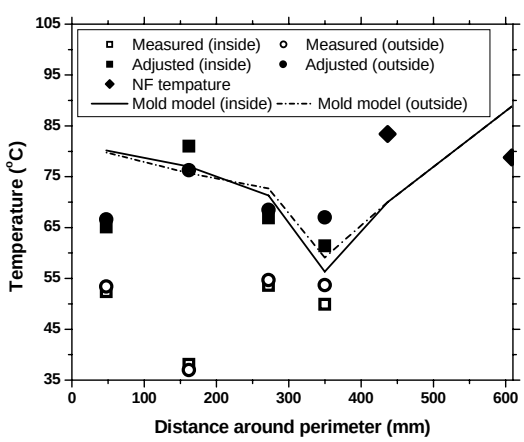
Average heat flux around the perimeter



Comparison of total heat loss

	Experimental	Mold model	error
Wide face	1112.4KW	1204.7KW	+8.30%
Narrow face	651.4KW	634.2KW	-2.64%
Total faces	1763.8KW	1838.9KW	+4.26%

Comparison of measured, adjusted and numerical temperatures for slice 590.6mm below top



On the wide face

$d_{gap} = 0.01mm$

$h_{air} = 60W/m^2K$

$h_{mixed} = 3000W/m^2K$ for the mixed air and water on the shoulder

$T_{ref} = 25^oC$

$k_{air} = 0.026W/mK$

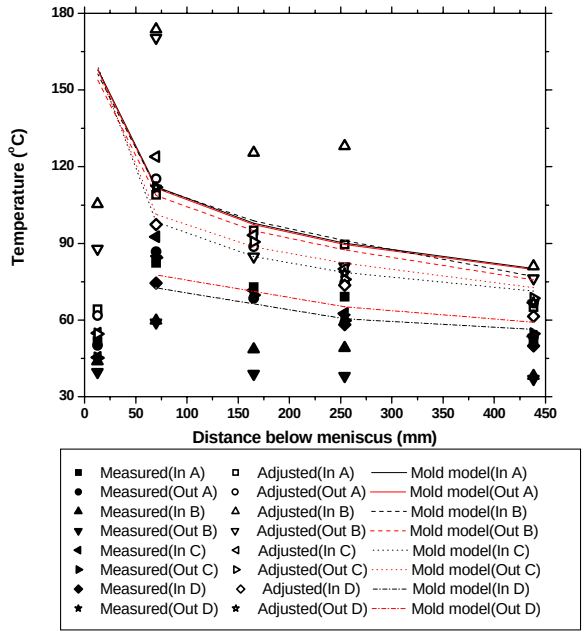
For chromel-slumel thermocouples

$D = 3.175mm, k_{TC} = 19.2W/mK$

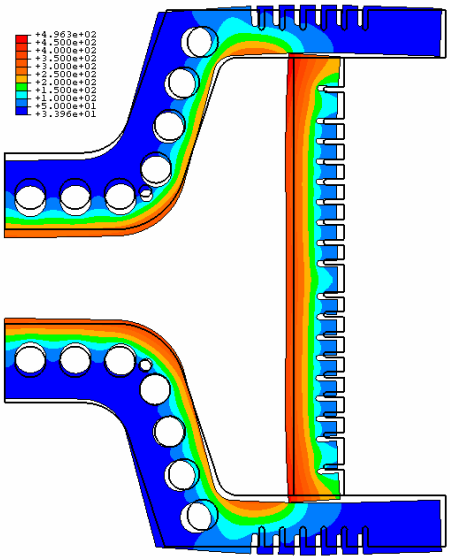
Offset method gives $T_{adj} = T_{mea} + 2\sqrt{\frac{hk_{TC}}{D}}\frac{(T_{mea} - T_{ref})d_{gap}}{k_{air}}$

No adjustment on narrow face

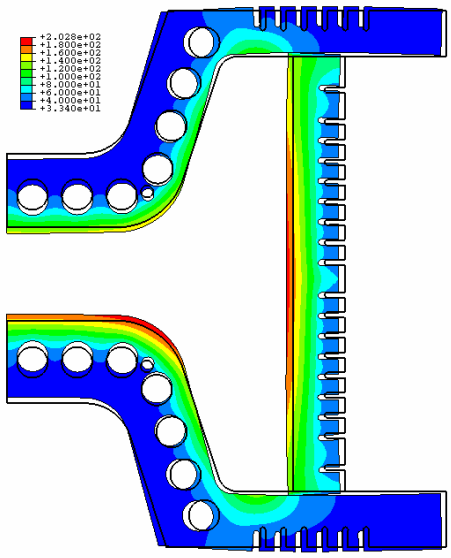
Comparison of measured, adjusted and numerical temperatures for measured slices on wide face



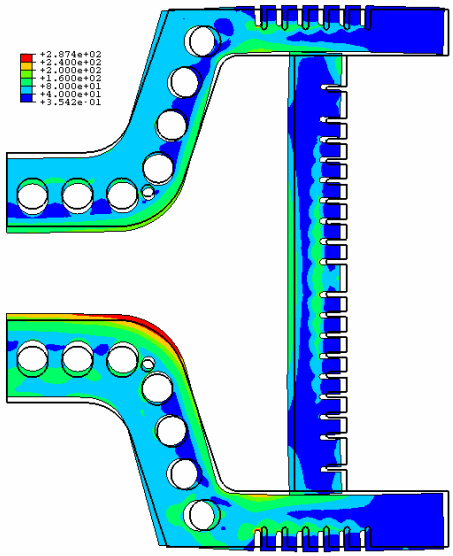
Mold temperature contour for meniscus (uniform heat flux)

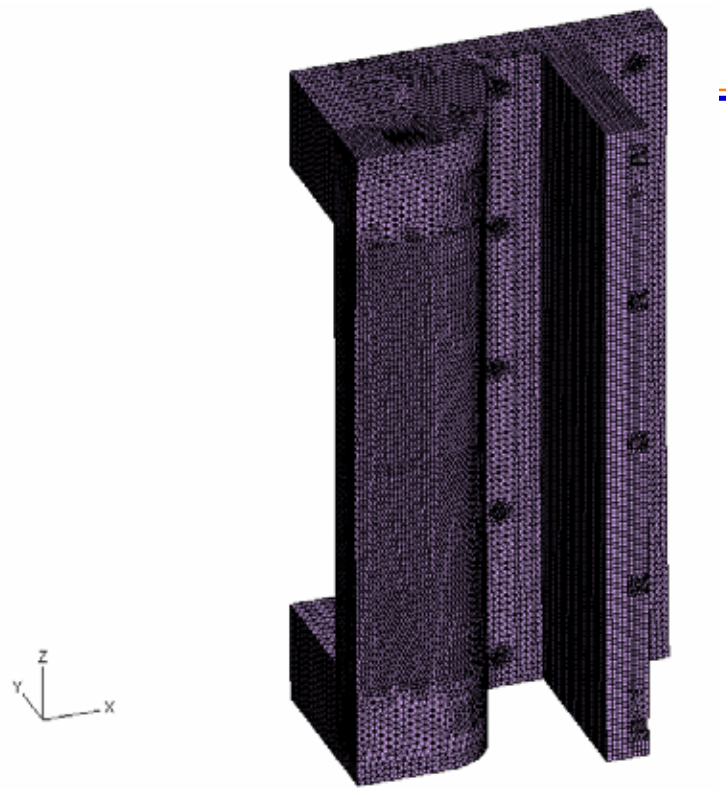


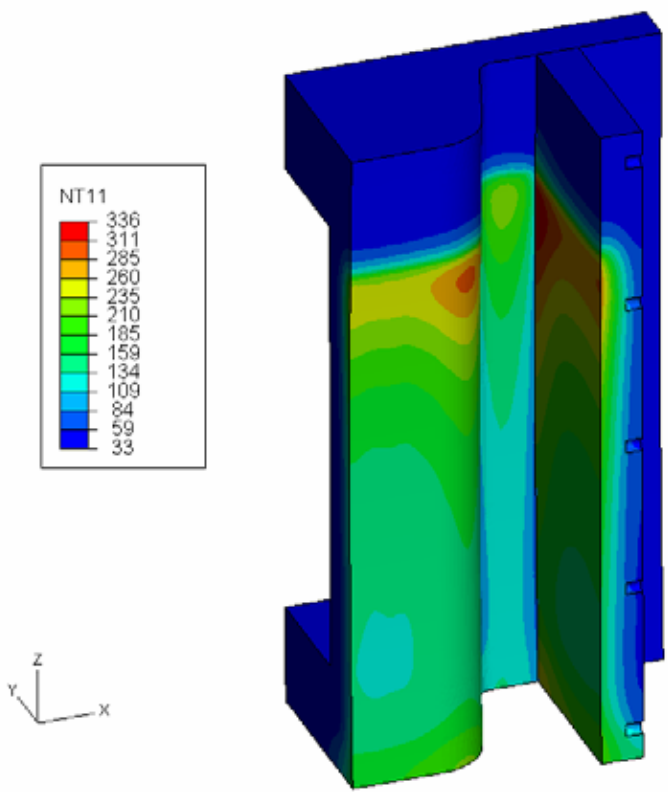
Mold Temperature contour for middle slice from the top



Stress contour and deformation for middle slice from the top




Z
Y
X


NT11
336
311
285
260
235
210
185
159
134
109
84
59
33
Z
Y
X

Conclusions

- Offset method considering the thermal resistance from the air gap or the mixed water and air gap between the thermocouple and mold can explain the decrease of measured temperature with real mold temperature well
- The total heat loss from the water temperature measurements and the chosen numerical heat flux match well
- 2-D distortion simulation shows that wide face distorts inward in the middle and outward for both ends and narrow face has like a total outward translation. It encourages us to adjust temperatures just on the wide face.
- It is recommended that future mold TC measurements use thermal paste to minimize the resistances

Acknowledgements

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- Prof ***B.G.Thomas***
- *Continuous Casting Consortium*