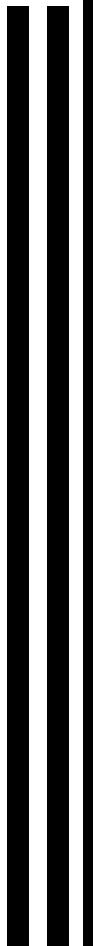




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## Billet Casting Analysis by CON1D



By

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**Continuous Casting Consortium**

**Report**

**Submitted to**

**Allegheny Ludlum  
AK Steel  
Columbus Stainless  
Inland Steel  
LTV  
Stollberg, Inc.**

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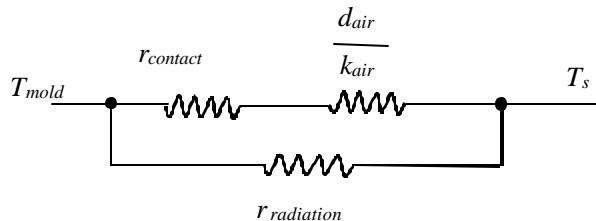
## Introduction

One difference between billet casting and slab casting is the lubrication material. Oil is the lubricant for casting billets while slab casting uses mold powder as lubricant. This difference leads to the different models for calculating gap heat flux between strand and mold.

Heat transfer and solidification model for continuous casting, CON1D has combined both mold powder casting and oil casting heat flux model. The new developed oil-casting model was validated by plant-measured data<sup>[1]</sup>.

## Model Description

For oil billet casting, heat flux extraction from the steel is decided by the air gap thickness between strand and mold, contact resistance and radiation. Figure 1 illustrates this gap heat conduction model.



**Figure 1. Thermal resistance used in the interface model**

The heat flux transferred across gap can be calculated:

$$q_{int} = (h_{rad} + h_{conv})(T_s - T_{mold}) \quad (1)$$

$$h_{rad} = \frac{s(T_s + T_{mold})(T_s^2 + T_{mold}^2)}{\frac{1}{e_{steel}} + \frac{1}{e_{mold}} - 1} \quad (2)$$

$$h_{conv} = \frac{1}{r_{contact} + \frac{d_{air}}{k_{air}}} \quad (3)$$

where

$q_{int}$  = heat flux transferred across gap ( $\text{W}/\text{m}^2$ )

$h_{rad}$  = effective radiation heat transfer coefficient ( $\text{W}/\text{m}^2\text{K}$ )

$h_{conv}$  = effective convection heat transfer coefficient ( $\text{W}/\text{m}^2\text{K}$ )

$T_s$  = surface temperature of the steel shell ( $^\circ\text{C}$ )

$T_{mold}$  = surface temperature of the mold (outermost coating layer) ( $^\circ\text{C}$ )

$r_{contact}$  = strand/mold contact resistance( $\text{m}^2\text{K}/\text{W}$ )

$d_{air}$  = thickness of the air gap (mm)

$k_{air}$  = conductivity of the air gap ( $\text{W}/\text{mK}$ )

$\sigma$  = Stefan Boltzman constant ( $5.67\text{e-}8\text{W}/\text{m}^2\text{K}^4$ )

$\epsilon_{steel}, \epsilon_{mold}$  = steel, mold surface emissivity (-)

This oil casting gap heat flux model has been incorporated into a user-friendly FORTRAN program, CON1D that is a solidification and heat transfer model with 1-D transient finite-difference model of solidifying steel shell and 2-D steady-state heat conduction within the mold wall.

### **Model Validation**

Table 1 provides some simulation parameters used in CON1D for calibrating billet-casting model, the casting condition and mold geometry came from reference [1], refer to attachment 1 for complete input file. The solidus and liquidus temperature is calculated based on Clyne-Kurz microsegregation model<sup>[2]</sup>, which has been incorporated into CON1D. The contact resistance used in CON1D simulation is  $5.6\text{e-}4\text{ m}^2\text{K}/\text{W}$ , including the resistance due to oscillation mark and mold/strand contact resistance. It is larger than expected, but the results based on this turns out to match the measurement data well.

**Table 1. Simulation parameters**


---

Casting condition:	
Casting speed:	2.2 m/min
Superheat:	20 °C
Meniscus level:	100 mm
Cooling water flow rate:	1100 l/m
Cooling water velocity:	6.6 m/s
Inlet cooling water temperature:	30 °C
Steel properties:	
Carbon content:	0.1 wt%
Liquidus temperature:	1517.8 °C
Solidus temperature:	1468.4 °C
Mold geometry and properties:	
Strand dimension:	120 mmx120mm
Mold length:	800 mm
Mold thickness:	6 mm
Mold taper:	0.75 %/m
Mold thermal conductivity:	360 W/mK
Others:	
Air conductivity:	0.1 W/mK
Contact resistance:	5.6e-4 m <sup>2</sup> K/W

---

*Mold cooling water temperature rise and heat flux*

The plant trial measured mold cooling water temperature rise is 8°C, while CON1D predicts a 7.65 °C cooling water temperature increase at mold exit.

Figure 2 gives the comparison of heat flux. It shows that CON1D predicts instantaneous heat flux agrees with measured data. Also, the predicted average heat flux for this 700mm work mold length is 1722.7KW/m<sup>2</sup>(refer to attachment jpi1.ext) which fits the measured average heat flux curve.

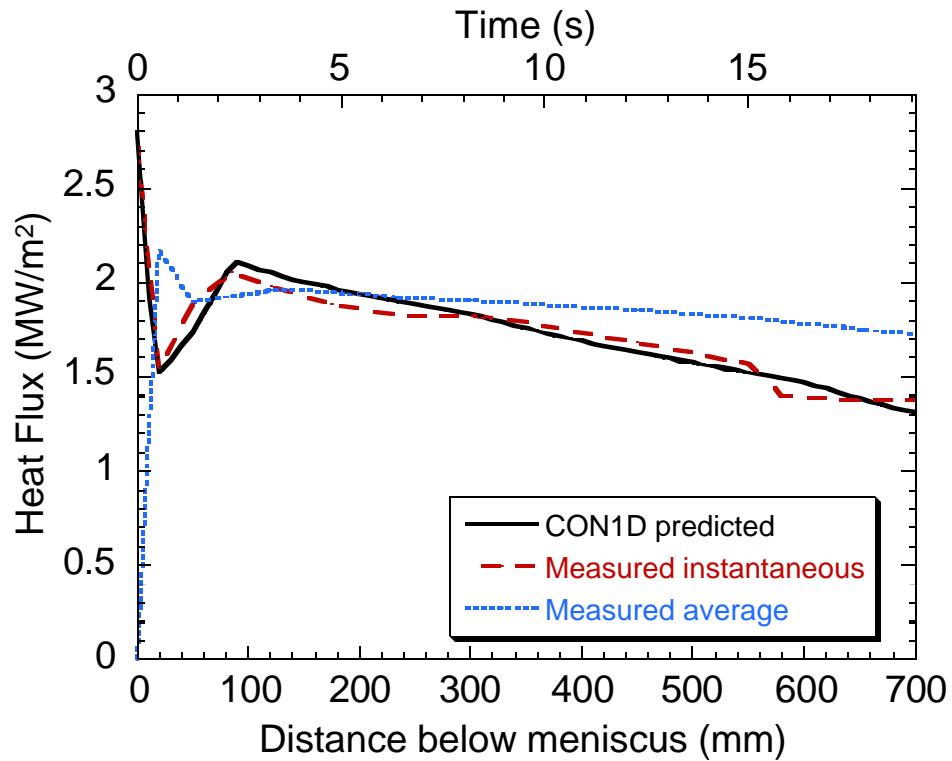


Figure 2. Heat flux down the mold

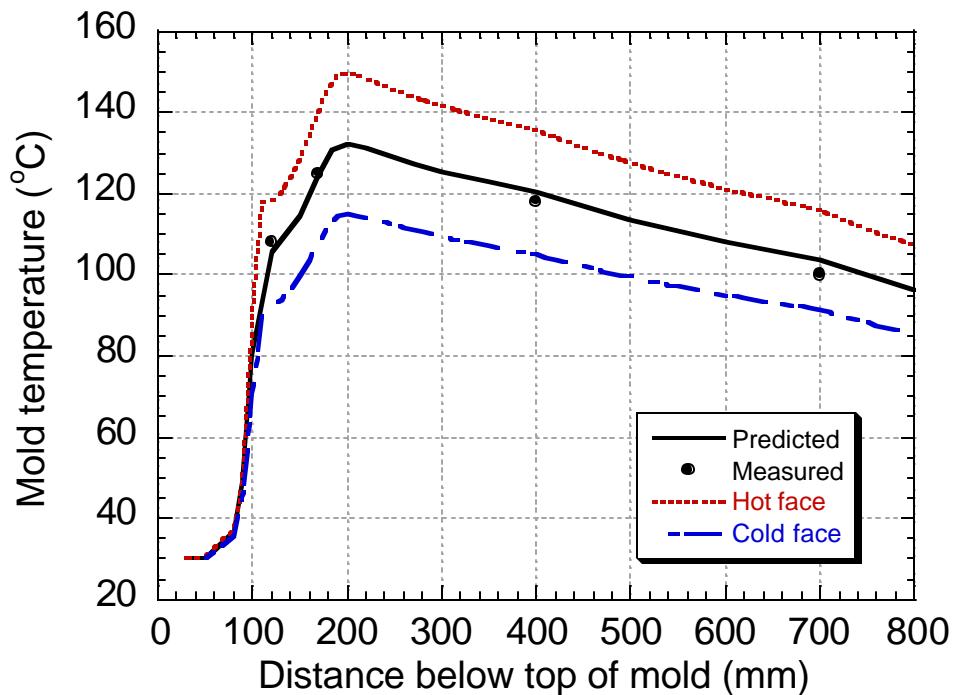


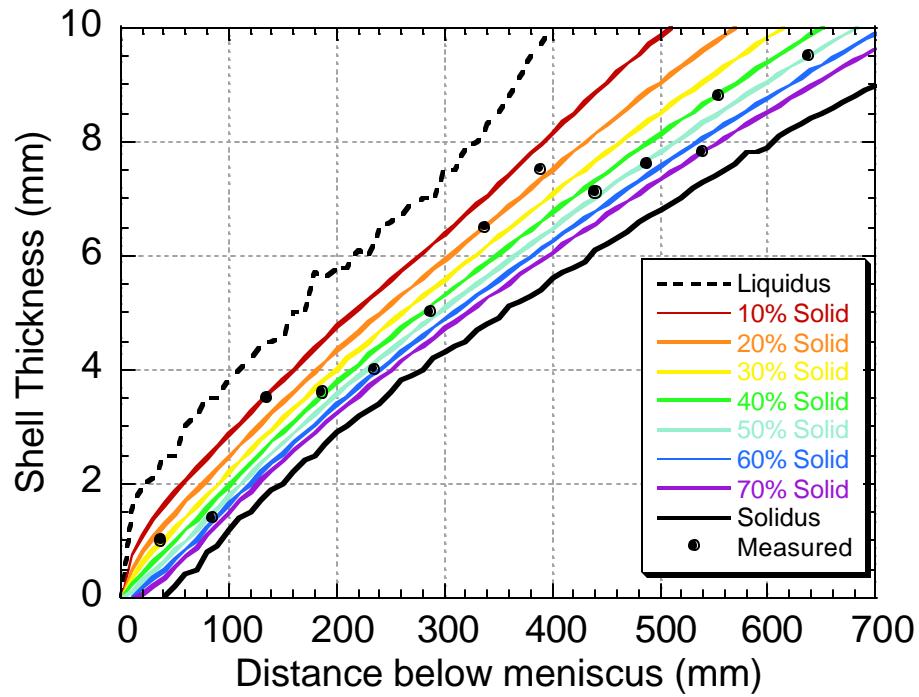
Figure 3. Mold temperature down the mold

### Mold temperature

Figure 3 shows that the predicted thermocouple temperatures in mold match with measured data. It also plots the predicted mold hot face and cold face temperature.

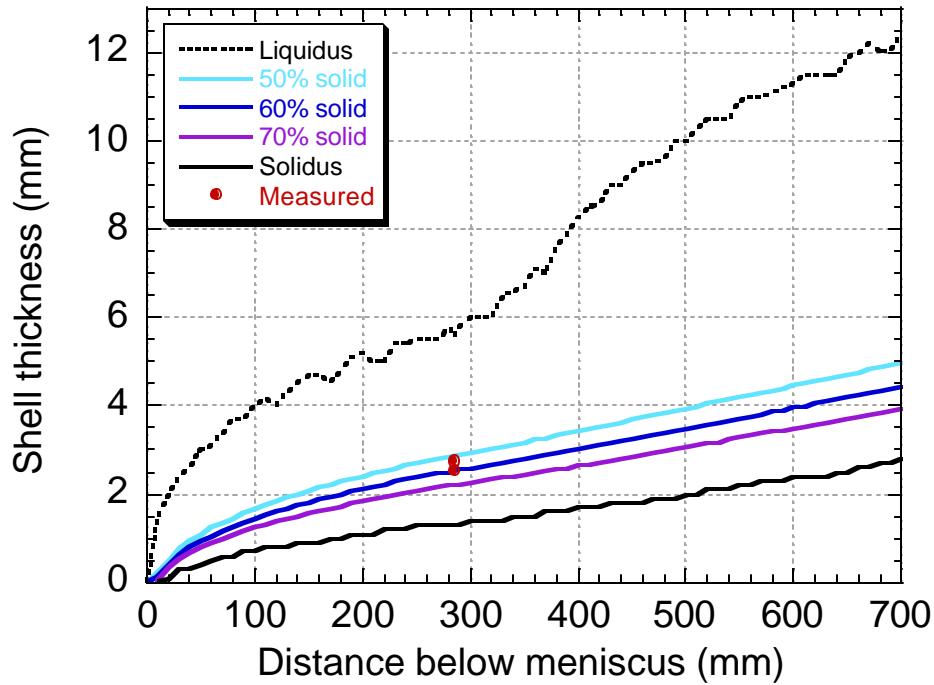
### Shell thickness

Figure 4 shows the CON1D predicted shell thickness down the mold, compared with the plant trial measurements by tracer test. Shell thickness is defined in the model by linearly interpolating the position between the liquidus and solidus isotherms corresponding to the specified solid fraction. The plot shows that the measured data vary in the range of predicted shell thickness between 10% and 70% solid fraction. This may because the depth of tracer penetration varies.



**Figure 4. Shell thickness down the mold: Center**

CON1D was also run for a strand corner simulation with an assumption of big air gap at corner. Figure 5 shows the calculated shell thickness down the mold. It predicts a 2.53mm shell thickness (60% solid) at 285mm below meniscus, which agrees with measured data.



**Figure 5. Shell thickness down the mold: Corner**

### Discussion

The detail at mold-strand interface is plotted in figure 6. Mold distortion due to thermal expansion  $\Delta x_{mold}$  is calculated from:

$$\Delta x_{mold} = \alpha_{mold} \cdot \frac{\text{mold width}}{2} \cdot \frac{T_{cold} + T_{hotc}}{2} \quad (4)$$

where,

$\alpha_{mold}$  = mold thermal linear expansion coefficient ( $1.6e-5 K^{-1}$ )

$T_{cold}$  = mold cold face temperature ( $^{\circ}C$ )

$T_{hotc}$  = mold hot face temperature (without coating) ( $^{\circ}C$ )

Mold taper is 0.75%/m, so the mold wall deflection due to taper  $\Delta x_{taper}$  is:

$$\Delta x_{taper} = 0.75\% \cdot \frac{\text{mold width}}{2} \cdot z \quad (5)$$

where  $z$  = distance below meniscus (m)

Shell shrinkage  $\Delta x_{shell}$  is calculated based on Dippenaar method<sup>[3,4]</sup>, and output by CON1D (refer to attachment .shl files). So the final air gap  $\Delta x_{gap}$  between strand and mold should be:

$$\Delta x_{gap} = \Delta x_{mold} - \Delta x_{taper} + \Delta x_{shell} \quad (6)$$

This air gap represents the gap likely to be found in the mold corner. In real caster, the ferro-static pressure from liquid steel pushes the solidified steel shell close to the mold, decreases the air gap of the interface.

Figure 7 gives the mold distortion due to the thermal expansion and the air gaps used in CON1D simulation for both the positions at center of the strand and in the corner. The simulation results show this estimation is fairly reasonable.

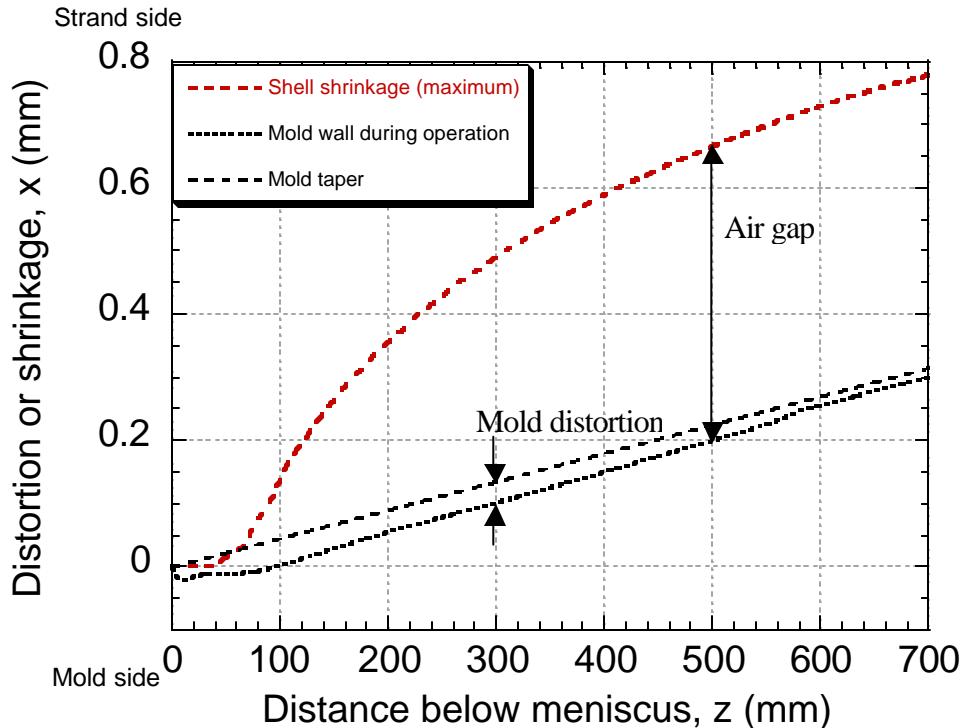


Figure 6. Mold wall and interface gap prediction

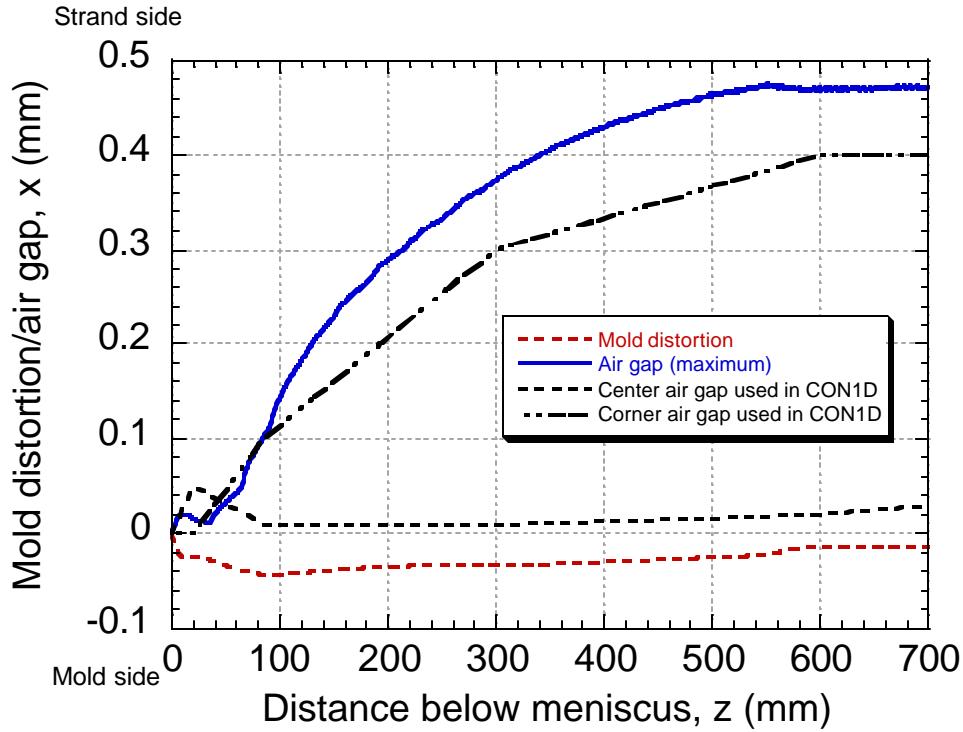


Figure 7. Mold distortion and air gap used in CON1D

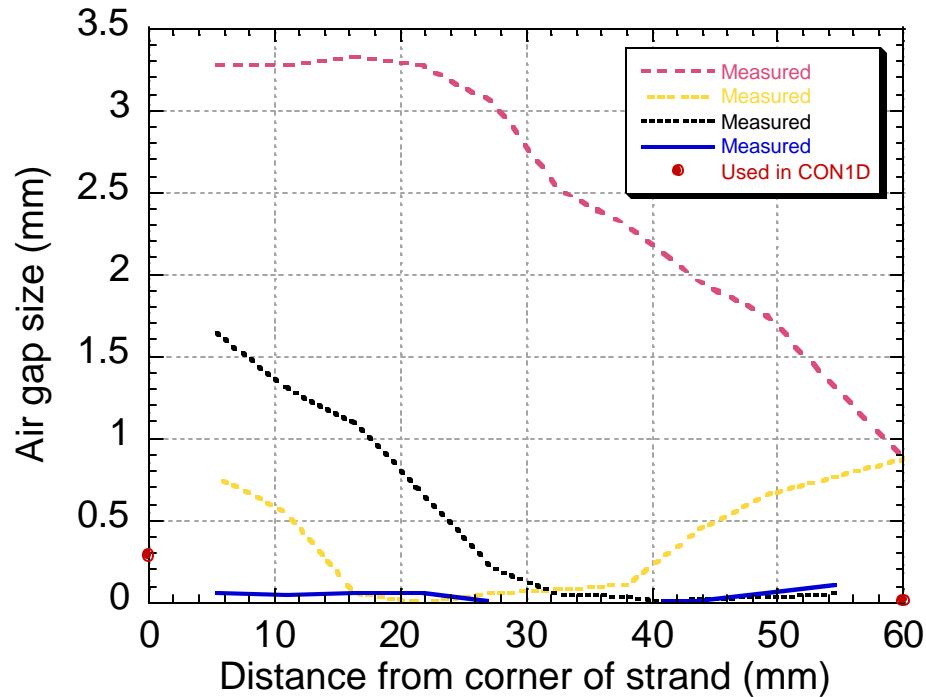
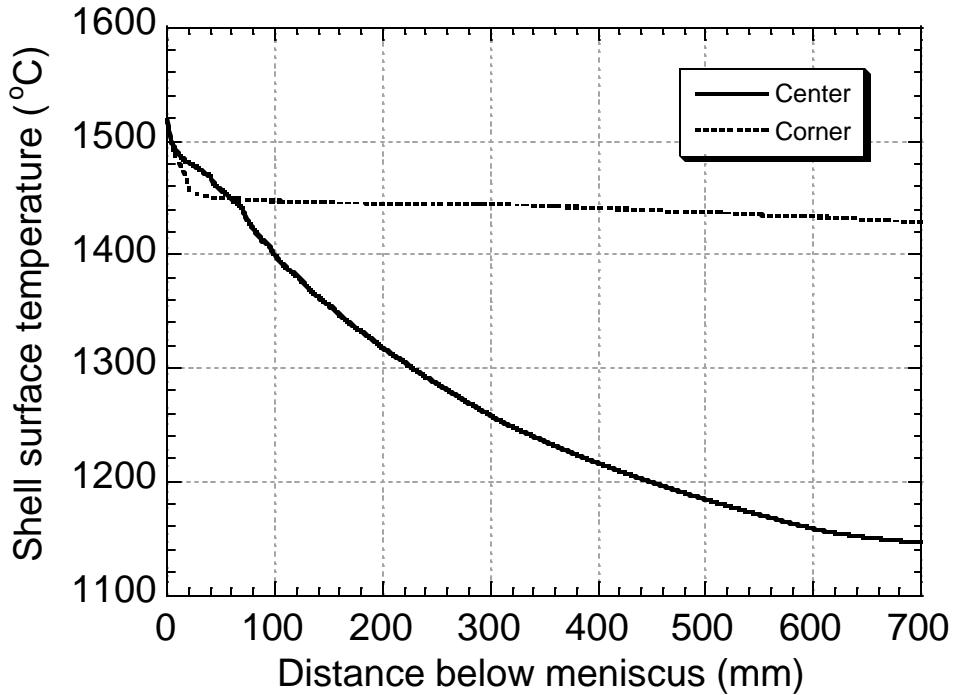


Figure 8. Air gap at 285mm below meniscus

The air gap between stand and mold is one of the input parameters in CON1D. Figure 8 compares the input air gap and measured data at 285mm below meniscus. The result shows the real air gap varies greatly, but the trend is that the corner has the maximum air gap, and it decreases with the distance from the corner.

Figure 5 plots the predicted shell temperature at center of strand and corner. This prediction can also be used for calibration of the model, if measurements from optical pyrometers located just below mold exit are available.



**Figure 9. Shell temperature down the mold**

### Conclusion

From above discussion, the comprehensive heat transfer and solidification model of the continuous slab-casting mold CON1D, specifically the heat flow model for billet casting, has been calibrated with measurements on operating casters, including cooling water temperature rise, mold thermocouple temperatures, and shell thickness. The model predicts a 60% solid fraction for shell thickness, which matches the tracer test.

In addition to heat transfer, the model predicts ideal mold taper, after calculating mold distortion based on mold thermal expansion, the air gap profile at both center and corner can be obtained. The output cooling water temperature provides boundary conditions for 2D simulation.

### **Future Work**

- Parametric study
- 2D Simulation

### **Reference**

- [1] J. K. Park, unpublished report, Feb. 6, 2001
- [2] Y.M. Won, B.G. Thomas, Metall. & Materials Trans. B, submitted Sep. 28, 2000
- [3] Dippenaar R.J., Samarasekera I.V., and Brimacombe J.K., ISS Transactions Vol. 7, 1986, pp31-43
- [4] Chandra S., Brimacombe J.K., and Samarasekera I.V., Ironing and Steelmaking, Vol. 20, 1993, n.2, pp.104-112

**Attachment**

- [1] Center of strand, CON1D input file, jpi1.inp
- [2] Center of strand, CON1D output file, jpi1.ext:
  - condition at mold exit, mold thermocouple temperature
- [3] Center of strand, CON1D output file, jpi1.shl:
  - shell thickness, temperature and taper history
- [4] Center of strand, CON1D output file, jpi1.mld:
  - mold temperature, heat flux and water heat transfer coefficient
- [5] Corner of strand, CON1D input file, jpi2.inp
- [6] Corner of strand, CON1D output file, jpi2.ext:
  - condition at mold exit, mold thermocouple temperature
- [7] Corner of strand, CON1D output file, jpi2.shl:
  - shell thickness, temperature and taper history
- [8] Corner of strand, CON1D output file, jpi2.mld:
  - mold temperature, heat flux and water heat transfer coefficient

## [1] Center of strand, CON1D input file, jpi1.inp

```

CON1D-6.2 Slab Casting Heat Transfer Analysis
University of Illinois, Brian G. Thomas, 2001
JKPark billet Center of Strand           Input Data           INP

(1) Casting Conditions:
 1          Number of time-cast speed data points
            (If=1, constant speed)
 Next 2 lines contain time(s) and vc(m/min) data points
 0.
 2.2
1540.000    Pour temperature (C)
120.0000    Slab thickness (mm)
120.0000    Slab width (mm)
700.0000    Working mold length (mm)
699.0000    Z-distance for heat balance(mm)
127.0000 *   Nozzle submergence depth (mm)

(2) Simulation Parameters:
 0          Which shell to consider? (0=wide face; 1=narrow face)
 2          Which mold face to consider(0=outer, 1=inner,
            2=straight mold or narrow face)
 2          Calculate mold and interface (=0 flux casting, or 2 oil casting )
            or enter interface heat flux data (=-1)
 15         Number of z and q data points (if above = 1 or -1)
            Next 2 lines contain z(mm) and q(kW/m2) data
 0. 20. 50. 85. 120. 175. 230. 300. 350. 450. 550. 580. 650. 840. 870.
2800. 1540. 1885. 2060. 1980. 1880. 1830. 1820. 1785. 1680. 1570. 1400. 1375. 1365. 1350.
 1.0000    Is superheat treated as heatflux?
            0=no; 1=yes (take default);-1=yes (enter data)
 17         Number of z and q data points (if above = -1)
            Next 2 lines contain z(mm) and q(kW/m2) data
10. 45. 100. 200. 300. 400. 500. 675. 720. 770. 980. 1120. 1370. 1470. 1575. 1700. 2000.
20. 40. 58. 57. 28. 36. 88. 384. 408. 406. 321. 303. 98. 58. 38. 25. 20.
 1          Do you want (more accurate) 2d calculations
            in mold? (0=no; 1=yes)
 400.0000  Max. dist. below meniscus for 2d mold calcs (mm)
4.000000E-03 Time increment (s)
120          Number of slab sections
10.000      Printout interval (mm)
0.000000E+00 Start output at (mm)
 710.000    Max. simulation length (mm)
 60.00000   Max. simulation thickness (mm)
            (smaller of max. expected shell thickness &
            half of slab thickness)
100000     Max. number of iterations
 3          Shell thermocouple numbers below hot face (less than 10)
            Next line gives the distance below surface of thermocouples(mm)
 10.0    12.5  25
 0.7000000 Fraction solid for shell thickness location (-)

(3) Steel Properties: (Plain medium Carbon Steel)
 0.100  0.48  0.001  0.026  0.39    %C,%Mn,%S,%P,%Si
 0.0    0.02  0.02   0.02   0.01    %Cr,%Ni,%Cu,%Mo,%Ti
 0.003  0.026  0.056  0.010  0.0000  %Al,%V,%N,%Nb,%W
 0.020  0.0000 0.0000 0.0000 0.0000  %Co,(additional components)
 1000    Grade flag (1000,304,316,317,347,410,420,430,999)
            (carbon steels...AISI stainless steels...,user subroutine)
  1        If CK simple Ansys. Seg. Model wanted for default Tliq,Tsol
            (1=yes,0=no)
  10       Cooling rate used in Seg, Model(if above =1) (K/sec)
            Override defaults with following constants(-1=default)
-1.00000  Steel liquidus temperature (C)
-1.00000  Steel solidus temperature (C)
-1.00000  Steel density (g/cm^3)
-1.00000  Heat fusion of steel (kJ/kg)
-1.00000  Steel emissivity (-)
-1.00000  Steel specific heat(kJ/kg deg K)
-1.00000  Steel thermal conductivity(W/mK)

```

-1.00000 Steel thermal expansion coefficient (-)

0 Use segregation model?(0=no,1=yes)  
(not yet implemented)

(4) Spray Zone Variables:

25.00000	Water and ambient temperature in spray zone(Deg C)
	spray zone condition:(heat tran.coeff.funct:h=A*C*W^n(1-bT))
	(Nozaki Model:A*C=0.3925,n=0.55,b=0.0075)
1.570000	A(0=off)
5.500000E-01	n
7.500000E-03	b
8.700000	minimum convection heat trans. coeff. (natural) (W/m^2K)
5	Number of zones

No.	zone	rolls#	roll	water	spryzone	spryzone	contact	Frac.of	q	spray	conv	amb.
starts	inzone	radius	flowrate	width	length	angle	thru	roll	coeff	coeff	coeff	temp.
(mm)		(m)	(l/min/row)	(m)	(m)	(deg)			(W/m^2K)			(DegC)
1	700.0	1	.0750	18.882	0.984	.904	0.000	.010	.250	8.7	25	
2	2000.	1	.0750	9.1872	0.984	.050	10.00	.080	.250	8.7	25	
3	2710.	1	.0950	5.1955	0.984	.050	10.00	.220	.250	8.7	25	
4	8700.	5	.0950	3.8966	0.984	.050	10.00	.200	.250	8.7	25	
5	13640.	1	.1075	2.9044	0.984	.050	10.00	.360	.250	8.7	25	
	14000.0			End of last spray zone (mm)								

(5) Mold Flux Properties: (M662-C20)

39.2	38.4	3.4	2.0	0.6	%CaO,%SiO <sub>2</sub> ,%MgO,%Na <sub>2</sub> O,%K <sub>2</sub> O
0.0	0.70	0.0	1.3	0.0	%FeO,%Fe <sub>2</sub> O <sub>3</sub> ,%NiO,%MnO,%Cr <sub>2</sub> O <sub>3</sub>
5.0	0.0	0.0	0.0	1.4	%Al <sub>2</sub> O <sub>3</sub> ,%TiO <sub>2</sub> ,%B <sub>2</sub> O <sub>3</sub> ,%Li <sub>2</sub> O,%SrO
0.0	9.3	1.8	2.6	2.8	%ZrO <sub>2</sub> ,%F,%free C,%total C,%CO <sub>2</sub>
	1135.0				Mold flux solidification temperature(C)
	0.8300				Solid flux conductivity(W/mK)
	1.43000				Liquid flux conductivity(W/mK)
	2.00000				Flux viscosity at 1300C (poise)
	2700.000				Mold flux density(kg/m <sup>3</sup> )
	200.0000				Flux absorption coefficient(1/m)
	-1.0000				Flux index of refraction(-)
					( -1 = take default f(composition) )
	0.9				Slag emissivity(-)
	3.089508				Exponent for temperature dependency of viscosity
	1				Form of mold powder consumption rate
	0.48				Mold powder consumption rate
	0.0000E+00				Location of peak heat flux (m)
	0.0040000				Slag rim thickness at metal level (m)
	1.0000E-02				Slag rim thickness above heat flux peak (m)

(6) Interface Heat Transfer Variables:

13	Number of distance-ratio data points (1=constant ratio of solid flux velocity to casting speed)
	Next 2 lines contain z(mm) and vratio (-) data
0.	10. 60. 100. 190. 300. 400. 410. 450. 600. 800. 1000. 1096
.18	.31 .35 .31 .29 .2 .29 .41 .41 .39 .3 .2 .15
5.600E-04	Flux/mold contact resistance(m <sup>2</sup> K/W)
0.500000	Mold surface emissivity(-)
5.99999E-02	Air conductivity(W/mK)
0	Osc.marks simulation flag(0=average,1=transient)
0.20000000	Oscillation mark depth (mm)
1.500000	Width of oscillation mark (mm)
3.942	Oscillation frequency (cps)
	(-1 = take default cpm=2*ipm casting speed)
8.0000	Oscillation stroke (mm)

(7) Mold Water Properties:

-1	Water thermal conductivity (W/mK)(-1 = default = f(T))
-1	Water viscosity (Pa-s)(-1 = default = f(T))
-1	Water heat capacity (J/kgK)(-1 = default = f(T))
-1	Water density (kg/m <sup>3</sup> )(-1 = default = f(T))

(8) Mold Geometry:

11.78700	Mold thickness including water channel (mm),(outer rad.,top)
----------	--

11.78700 Mold thickness including water channel (mm),(inner rad.,top)  
 100.0000 Distance of meniscus from top of mold (mm)  
 120.0001 Distance between cooling water channels(center to center)(mm)  
 360.0000 Mold thermal conductivity(W/mK)  
 30.00000 Cooling water temperature at mold top(C)  
 0.620000 Cooling water pressure(MPa)  
 5.7870 Cooling water channel depth(mm)  
 120.0000 Cooling water channel width(mm)  
 694.44 Total channel cross sectional area(mm<sup>2</sup>)  
     (served by water flow line where temp rise measured)  
 2 Form of cooling water flowrate/velocity(1=m/s ; 2=L/s)  
 4.583 Cooling water flowrate per face/velocity  
     (> 0 cooling water from mold top to bottom  
     < 0 cooling water from mold bottom to top)  
 5.0  
 5.0 Machine radius(m) (outer &inner radius)  
 6 Number of mold coating/plating thickness changes down mold

No.	Scale	Ni	Cr	Others	*Air gap	Z-positions	unit
1	0.000	0.000	0.100	0.000	0.00	0.000	(mm)
2	0.000	0.000	0.100	0.000	0.05	20.000	(mm)
3	0.000	0.000	0.100	0.000	0.01	85.000	(mm)
4	0.000	0.000	0.100	0.000	0.01	300.000	(mm)
5	0.000	0.000	0.100	0.000	0.02	600.000	(mm)
6	0.000	0.000	0.100	0.000	0.03	700.000	(mm)
	0.550	72.100	67.000	1.000	0.10	Conductivity	(W/mK)

0.250000 \*Factor to approximate nonlinear heat flow at  
     meniscus,(first guess for 2d analysis)  
 4.999999E-03  
 6.499998E-02 Equivalent inner and outer radius

(9) Mold Thermocouples:

No.	Distance beneath hot surface(mm)	Distance below meniscus(mm)	Measured:
10	0.0	285.00	
11	1.0	285.00	
12	3.0	285.00	
13	6.0	285.00	
14	9.0	285.00	
21	0.0	20.00	
22	6.0	20.00	
1	3.0	20.00	108
2	3.0	70.00	125
3	3.0	300.00	118
4	3.0	600.00	100 (DeltaT=8 DegC)

## [2] Center of strand, CON1D output file, jpi1.ext:

CON1D-6.2 Slab Casting Heat Transfer Analysis

University of Illinois, Brian G. Thomas, 2001

EXIT

Calculated Conditions

EXT

Initial casting speed: 36.67 (mm/s)  
 Carbon content: 0.1000 (%)  
 Wide face simulation:

### Steel Properties:

The following 3 temperature from Y.M.Won Segregation Model

Liquidus Temp:	1517.80	Deg C
Solidus Temp:	1468.40	Deg C
Peritectic Temp:	1471.74	Deg C

AE3 Temp:	894.67	Deg C
AE1 Temp:	734.35	Deg C
<b>Parameters Based on Derived Mold Values:</b>		
Carbon equivalent:	0.1919	(%)
(using initial casting speed:)		
Negative strip time:	0.10	(s)
Positive strip time:	0.16	(s)
Velocity amplitude of mold oscillation:	99.07	(mm/s)
Pitch(spacing between oscillation marks):	9.30	(mm)
% Time negative strip:	37.93	(%)
Average percent negative strip velocity:	72.01	(%)
Cooling water velocity:	6.60	(m/s)
Cooling water flow rate per face:	4.5830	(L/s)
Average mold flux thickness:	0.0649	(mm)
(based on consumption rate)		
(assuming flux moves at casting speed)		
min. heat trans. coeff. on mold cold face	22.74	kW/m <sup>2</sup> K
max. heat trans. coeff. on mold cold face	27.37	kW/m <sup>2</sup> K
Water boiling temperature:	150.0000	Deg C
Max cold face temperature:	115.1255	Deg C
Max hot face temperature(copper only):	149.8655	Deg C
Max hot face temperature(w/coating):	156.1307	Deg C
Mold water temp diff(in hot channel):	7.6528	Deg C
Mold water temp diff(over all channels):	7.6528	Deg C
Mean heat flux in mold:	1722.70	(kW/m <sup>2</sup> )
<b>Friction Values:</b>		
Average absolute shear stress in Mold:	10.1561	(kPa)
Average friction force in Mold:	0.8531	(kN)
Max. shear stress in Mold:	10.1561	(kPa)
Max friction force in Mold:	0.8531	(kN)
Min. shear stress in Mold:	-10.1561	(kPa)
Min friction force in Mold:	-0.8531	(kN)
shear stress in Mold when Vmold=0:	10.1561	(kPa)
Friction force in Mold when Vmold=0:	0.8531	(kN)
<b>Heat Balance at 699.02mm:</b>		
Heat Extracted:	32.86	(MJ/m <sup>2</sup> )
Heat Input to shell inside:	2.85	(MJ/m <sup>2</sup> )
Super Heat:	0.06	(MJ/m <sup>2</sup> )
Latent Heat in mushy region:	3.69	(MJ/m <sup>2</sup> )
Latent Heat in Solid region:	17.55	(MJ/m <sup>2</sup> )
Sensible Cooling:	9.32	(MJ/m <sup>2</sup> )
Total Heat:	33.48	(MJ/m <sup>2</sup> )
Error In Heat Balance:	1.88	(%)
<b>Heat Balance at Mold Exit( 700.04mm):</b>		
Heat Extracted:	32.89	(MJ/m <sup>2</sup> )
Heat Input to shell inside:	2.85	(MJ/m <sup>2</sup> )
Super Heat:	0.06	(MJ/m <sup>2</sup> )
Latent Heat in mushy region:	3.72	(MJ/m <sup>2</sup> )
Latent Heat in Solid region:	17.55	(MJ/m <sup>2</sup> )
Sensible Cooling:	9.34	(MJ/m <sup>2</sup> )
Total Heat:	33.51	(MJ/m <sup>2</sup> )
Error In Heat Balance:	1.90	(%)
<b>Variables Calculated at Mold Exit( 700.04mm):</b>		
taper (per mold, narrow face):	1.30	(%)
taper (per mold per length, narrow face):	1.85	(%/m)
Shell thickness:	9.64	(mm)
Liquid flux film thickness:	0.0000	(mm)
Solid flux film thickness:	0.0000	(mm)
Total flux film thickness:	0.0000	(mm)
Shell surface temperature:	1146.12	Deg C
Mold hot face temperature:	109.18	Deg C
Heat flux:	1.3076	(MW/m <sup>2</sup> )
<b>Predicted Thermocouple Temperatures:</b>		
No.	distance beneath	distance below
		temperature

	hot surface(mm)	meniscus(mm)	Deg C
1	0.00	285.00	136.39
2	1.00	285.00	131.25
3	3.00	285.00	120.97
4	6.00	285.00	105.57
5	9.00	285.00	90.18
6	0.00	20.00	118.31
7	6.00	20.00	92.38
8	3.00	20.00	105.54
9	3.00	70.00	124.25
10	3.00	300.00	120.16
11	3.00	600.00	103.73

### [3] Center of strand, CON1D output file, jpi1.shl:

```

# CON1D V6.2 Slab Casting Heat Transfer Analysis
# University of Illinois, Brian G. Thomas, 2001

# SHELL          Output Shell Temperature, Taper Histories      SHL
# Posi    time   LiqLoc   SolLoc shell Thermo- Surf   EndWall   Taper   Taper   Oldtaper
# #       s        mm       mm     mm   coupl T   Temp   Defl   Instan   Cumul   Cumul
# #       mm       s        mm       mm     mm   C      C      mm     %/m     %/m     %/m
#
#       0.00    0.00    0.0    0.0    0.00  1518.3  1518.3  0.00    0.00    0.00    0.00
# 10.12   0.28    1.5    0.0    0.00  1518.3  1488.4  0.00    0.00    0.00    0.00
# 20.09   0.55    2.0    0.0    0.06  1518.3  1480.9  0.00    0.00    0.00    0.00
# 30.07   0.82    2.1    0.0    0.21  1518.3  1475.1  0.00    0.00    0.00    0.00
# 40.04   1.09    2.5    0.0    0.36  1518.3  1468.7  0.00    0.00    0.00    0.00
# 50.01   1.36    2.5    0.2    0.54  1518.3  1457.0  0.01    1.80    0.49    0.49
# 60.13   1.64    3.0    0.4    0.73  1518.3  1448.6  0.03    1.79    0.71    0.71
# 70.11   1.91    3.2    0.5    0.88  1518.3  1440.3  0.04    3.75    0.93    0.93
# 80.08   2.18    3.5    0.8    1.11  1518.2  1422.5  0.08    4.70    1.58    1.90
# 90.05   2.46    3.5    0.9    1.30  1518.2  1411.3  0.10    4.35    1.89    2.41
# 100.03  2.73    3.8    1.2    1.49  1518.2  1399.3  0.14    6.44    2.31    3.00
# 110.00  3.00    4.0    1.4    1.71  1518.2  1389.0  0.17    4.84    2.59    3.53
# 120.12  3.28    4.2    1.5    1.87  1518.2  1381.4  0.19    2.93    2.69    3.66
# 130.09  3.55    4.4    1.7    2.06  1518.2  1371.2  0.22    4.10    2.83    3.56
# 140.07  3.82    4.5    1.9    2.25  1518.2  1362.4  0.24    3.56    2.90    3.45
# 150.04  4.09    4.6    2.0    2.40  1518.1  1355.5  0.26    5.06    2.94    3.33
# 160.01  4.36    5.0    2.2    2.59  1518.1  1346.9  0.29    3.14    2.98    3.24
# 170.13  4.64    5.0    2.4    2.76  1518.1  1338.8  0.30    2.84    2.98    3.16
# 180.11  4.91    5.7    2.5    2.90  1518.1  1332.1  0.32    2.68    2.97    3.07
# 190.08  5.18    5.6    2.7    3.08  1518.1  1325.1  0.34    2.60    2.99    2.99
# 200.05  5.46    5.8    2.9    3.25  1518.1  1317.7  0.36    2.40    2.97    2.93
# 210.03  5.73    5.8    3.0    3.38  1518.1  1311.2  0.37    2.26    2.94    2.86
# 220.00  6.00    6.1    3.2    3.54  1518.1  1305.1  0.39    3.10    2.93    2.79
# 230.12  6.28    6.0    3.3    3.71  1518.0  1298.3  0.40    2.09    2.92    2.74
# 240.09  6.55    6.5    3.4    3.85  1518.0  1292.0  0.41    1.98    2.88    2.68
# 250.07  6.82    6.6    3.6    3.98  1518.0  1286.3  0.43    2.72    2.85    2.63
# 260.04  7.09    6.7    3.8    4.16  1518.0  1280.4  0.44    2.49    2.84    2.58
# 270.01  7.36    6.9    3.9    4.30  1518.0  1274.5  0.46    1.78    2.81    2.53
# 280.13  7.64    7.0    4.0    4.42  1518.0  1268.8  0.47    1.69    2.78    2.49
# 290.11  7.91    7.0    4.2    4.57  1518.0  1263.6  0.48    2.20    2.75    2.44
# 300.08  8.18    7.5    4.3    4.73  1518.0  1258.2  0.49    2.09    2.73    2.40
# 310.05  8.46    7.5    4.4    4.85  1518.0  1253.0  0.50    1.53    2.70    2.36
# 320.03  8.73    7.9    4.5    4.97  1518.0  1248.3  0.51    1.88    2.67    2.32
# 330.00  9.00    8.0    4.7    5.13  1517.9  1244.0  0.52    1.81    2.64    2.28
# 340.12  9.28    8.3    4.8    5.28  1517.9  1239.5  0.53    1.72    2.62    2.24
# 350.10  9.55    8.5    4.9    5.39  1517.9  1235.2  0.54    1.67    2.59    2.21
# 360.07  9.82    8.8    5.1    5.51  1517.9  1231.2  0.55    1.59    2.56    2.17
# 370.04  10.09   9.1    5.2    5.68  1517.9  1227.4  0.56    1.55    2.53    2.14
# 380.02  10.36   9.5    5.3    5.81  1517.9  1223.5  0.57    1.48    2.51    2.10
# 390.14  10.64   9.7    5.4    5.93  1517.8  1219.7  0.58    1.44    2.48    2.07
# 400.11  10.91   10.0   5.6    6.05  1517.8  1216.1  0.59    1.71    2.45    2.04

```

410.08	11.18	10.5	5.7	6.21	1517.7	1212.6	0.60	1.36	2.43	2.01
420.06	11.46	10.7	5.8	6.33	1517.5	1209.2	0.61	1.31	2.40	1.98
430.03	11.73	11.0	5.9	6.45	1517.3	1205.8	0.61	1.26	2.38	1.95
440.00	12.00	11.2	6.1	6.57	1516.9	1202.5	0.62	1.49	2.35	1.92
450.12	12.28	11.5	6.2	6.73	1516.6	1199.3	0.63	1.16	2.33	1.90
460.10	12.55	11.7	6.3	6.85	1516.2	1196.1	0.64	1.17	2.31	1.87
470.07	12.82	12.0	6.4	6.96	1515.8	1193.0	0.64	1.13	2.28	1.85
480.04	13.09	12.2	6.6	7.08	1515.4	1190.0	0.65	1.32	2.26	1.82
490.02	13.36	12.4	6.7	7.23	1514.9	1187.1	0.66	1.27	2.24	1.80
500.14	13.64	12.5	6.8	7.35	1514.3	1184.2	0.67	1.30	2.22	1.78
510.11	13.91	12.5	6.9	7.46	1513.8	1181.4	0.67	1.02	2.20	1.75
520.08	14.18	12.9	7.0	7.57	1513.2	1178.6	0.68	1.27	2.18	1.73
530.06	14.46	13.0	7.2	7.72	1512.5	1175.9	0.69	1.14	2.16	1.71
540.03	14.73	13.1	7.3	7.84	1511.8	1173.3	0.69	1.10	2.14	1.69
550.00	15.00	13.5	7.4	7.95	1511.1	1170.7	0.70	1.12	2.12	1.67
560.12	15.28	13.5	7.5	8.06	1510.3	1168.1	0.71	0.91	2.10	1.65
570.10	15.55	13.8	7.6	8.19	1509.4	1165.6	0.71	1.04	2.08	1.63
580.07	15.82	14.0	7.8	8.31	1508.6	1163.2	0.72	0.99	2.06	1.61
590.04	16.09	14.0	7.8	8.42	1507.6	1160.8	0.72	1.01	2.04	1.59
600.02	16.36	14.0	7.9	8.52	1506.6	1158.4	0.73	0.98	2.03	1.58
610.14	16.64	14.4	8.1	8.64	1505.6	1156.4	0.73	0.94	2.01	1.56
620.11	16.91	14.5	8.2	8.77	1504.5	1154.8	0.74	0.88	1.99	1.54
630.08	17.18	14.6	8.3	8.88	1503.3	1153.3	0.75	0.83	1.97	1.52
640.06	17.46	14.8	8.4	8.98	1502.1	1152.0	0.75	0.83	1.95	1.50
650.03	17.73	15.0	8.5	9.09	1500.8	1150.8	0.76	0.80	1.94	1.48
660.00	18.00	15.1	8.6	9.21	1499.5	1149.7	0.76	0.91	1.92	1.46
670.12	18.28	15.0	8.7	9.33	1498.1	1148.7	0.77	0.72	1.90	1.44
680.10	18.55	15.5	8.8	9.43	1496.6	1147.8	0.77	0.68	1.89	1.43
690.07	18.82	15.5	8.9	9.53	1495.1	1146.9	0.77	0.68	1.87	1.41
700.04	19.09	15.8	9.0	9.64	1493.6	1146.1	0.78	0.66	1.85	1.39
710.02	19.36	15.8	9.1	9.75	1492.0	1197.1	0.77	-0.84	1.81	1.21

#### [4] Center of strand, CON1D output file, jpi1.mld:

```
# CON1D V6.2 Slab Casting Heat Transfer Analysis
# University of Illinois, Brian G. Thomas, 2001

# MOLD                               Mold Output                         MLD
#   Z      Mold   TSurf          Mold Temp          Heatflux qcold    hwater     hw      twater
#   thick   Deg C       hot      hotcu cold        MW/m^2   MW/m2   W/m^2K   W/m^2K   Deg C
#   mm     mm   (Deg C)           (Deg C)          MW/m^2   MW/m2   W/m^2K   W/m^2K   Deg C
#
#   0.0   6.0  1518.3   98.7   90.3   71.2   2.802   1.038  25204.8  26184.9  30.00
10.1   6.0  1488.4  123.7  118.0   89.7   1.932   1.525  25594.9  26184.9  30.15
20.1   6.0  1480.9  122.9  118.3   92.4   1.523   1.586  25526.8  26184.9  30.26
30.1   6.0  1475.1  125.0  120.3   93.7   1.589   1.617  25501.3  26184.9  30.35
40.0   6.0  1468.7  129.0  124.0   96.4   1.663   1.676  25427.5  26184.9  30.46
50.0   6.0  1457.0  133.9  128.7   99.7   1.738   1.751  25315.5  26184.9  30.56
60.1   6.0  1448.6  139.7  134.3  103.8   1.832   1.839  25162.1  26184.9  30.68
70.1   6.0  1440.3  146.1  140.3  108.1   1.940   1.931  24978.6  26184.9  30.80
80.1   6.0  1422.5  152.1  146.0  112.2   2.050   2.015  24792.6  26184.9  30.92
90.1   6.0  1411.3  155.7  149.4  114.7   2.109   2.064  24680.6  26184.9  31.06
100.0  6.0  1399.3  155.9  149.7  115.1   2.085   2.071  24679.3  26184.9  31.19
110.0  6.0  1389.0  155.3  149.1  114.7   2.066   2.062  24724.3  26184.9  31.32
120.1  6.0  1381.4  154.4  148.3  114.1   2.052   2.049  24782.0  26184.9  31.45
130.1  6.0  1371.2  153.4  147.3  113.4   2.033   2.034  24844.1  26184.9  31.58
140.1  6.0  1362.4  152.4  146.4  112.8   2.018   2.019  24905.6  26184.9  31.71
150.0  6.0  1355.5  151.5  145.5  112.1   2.005   2.005  24964.0  26184.9  31.84
160.0  6.0  1346.9  150.6  144.7  111.5   1.990   1.991  25021.8  26184.9  31.96
170.1  6.0  1338.8  149.7  143.8  110.9   1.976   1.977  25079.0  26184.9  32.09
180.1  6.0  1332.1  148.9  143.1  110.4   1.964   1.964  25132.5  26184.9  32.21
190.1  6.0  1325.1  148.1  142.3  109.8   1.951   1.951  25184.9  26184.9  32.34
200.1  6.0  1317.7  147.4  141.6  109.3   1.938   1.939  25236.7  26184.9  32.46
210.0  6.0  1311.2  146.7  140.9  108.8   1.927   1.927  25286.4  26184.9  32.58
```

220.0	6.0	1305.1	146.0	140.2	108.3	1.916	1.916	25334.7	26184.9	32.70
230.1	6.0	1298.3	145.3	139.6	107.9	1.904	1.905	25383.4	26184.9	32.83
240.1	6.0	1292.0	144.6	139.0	107.4	1.893	1.894	25430.1	26184.9	32.95
250.1	6.0	1286.3	144.0	138.4	107.0	1.883	1.883	25475.4	26184.9	33.07
260.0	6.0	1280.4	143.4	137.8	106.6	1.873	1.873	25520.1	26184.9	33.18
270.0	6.0	1274.5	142.8	137.2	106.2	1.863	1.863	25564.4	26184.9	33.30
280.1	6.0	1268.8	142.2	136.6	105.8	1.853	1.853	25608.6	26184.9	33.42
290.1	6.0	1263.6	141.6	136.1	105.4	1.844	1.843	25652.4	26184.9	33.54
300.1	6.0	1258.2	140.9	135.4	104.9	1.835	1.831	25698.9	26184.9	33.65
310.1	6.0	1253.0	140.0	134.6	104.3	1.818	1.817	25750.2	26184.9	33.77
320.0	6.0	1248.3	139.1	133.8	103.7	1.802	1.802	25803.4	26184.9	33.88
330.0	6.0	1244.0	138.2	132.9	103.1	1.787	1.787	25856.1	26184.9	34.00
340.1	6.0	1239.5	137.3	132.0	102.5	1.772	1.772	25908.8	26184.9	34.11
350.1	6.0	1235.2	136.5	131.2	101.9	1.758	1.758	25959.5	26184.9	34.22
360.1	6.0	1231.2	135.6	130.4	101.4	1.743	1.744	26008.8	26184.9	34.34
370.0	6.0	1227.4	134.8	129.7	100.8	1.730	1.730	26056.8	26184.9	34.45
380.0	6.0	1223.5	134.0	128.9	100.3	1.716	1.717	26103.5	26184.9	34.55
390.1	6.0	1219.7	133.3	128.2	99.8	1.703	1.704	26148.7	26184.9	34.66
400.1	6.0	1216.1	132.6	127.6	99.5	1.690	1.696	26185.4	26184.9	34.77
410.1	6.0	1212.6	131.8	126.8	98.8	1.677	1.677	26241.4	26230.0	34.88
420.1	6.0	1209.2	131.0	126.1	98.3	1.665	1.665	26284.9	26273.5	34.98
430.0	6.0	1205.8	130.3	125.4	97.9	1.653	1.653	26327.7	26316.3	35.09
440.0	6.0	1202.5	129.6	124.7	97.4	1.641	1.641	26369.6	26358.2	35.19
450.1	6.0	1199.3	129.0	124.1	97.0	1.629	1.629	26411.1	26399.7	35.30
460.1	6.0	1196.1	128.3	123.5	96.5	1.617	1.617	26451.5	26440.1	35.40
470.1	6.0	1193.0	127.7	122.9	96.1	1.606	1.606	26491.3	26479.8	35.50
480.0	6.0	1190.0	127.0	122.3	95.7	1.595	1.595	26530.4	26518.9	35.60
490.0	6.0	1187.1	126.4	121.7	95.3	1.584	1.584	26568.7	26557.2	35.70
500.1	6.0	1184.2	125.8	121.1	94.9	1.573	1.573	26606.9	26595.4	35.81
510.1	6.0	1181.4	125.2	120.6	94.5	1.562	1.562	26644.1	26632.7	35.91
520.1	6.0	1178.6	124.7	120.0	94.2	1.552	1.552	26680.8	26669.3	36.00
530.1	6.0	1175.9	124.1	119.5	93.8	1.541	1.541	26716.8	26705.3	36.10
540.0	6.0	1173.3	123.5	119.0	93.4	1.531	1.531	26752.2	26740.7	36.20
550.0	6.0	1170.7	123.0	118.5	93.1	1.521	1.521	26787.2	26775.7	36.30
560.1	6.0	1168.1	122.5	117.9	92.7	1.512	1.512	26822.2	26810.7	36.39
570.1	6.0	1165.6	121.9	117.4	92.4	1.502	1.502	26856.3	26844.8	36.49
580.1	6.0	1163.2	121.4	117.0	92.1	1.493	1.492	26889.8	26878.2	36.58
590.0	6.0	1160.8	120.9	116.5	91.8	1.483	1.483	26922.8	26911.3	36.68
600.0	6.0	1158.4	120.4	116.0	91.5	1.474	1.474	26955.5	26943.9	36.77
610.1	6.0	1156.4	119.3	115.0	90.7	1.454	1.454	27003.9	26992.4	36.87
620.1	6.0	1154.8	118.3	114.0	90.0	1.436	1.436	27049.9	27038.3	36.96
630.1	6.0	1153.3	117.2	113.0	89.4	1.418	1.418	27094.0	27082.4	37.05
640.1	6.0	1152.0	116.3	112.1	88.8	1.401	1.401	27136.5	27125.0	37.14
650.0	6.0	1150.8	115.4	111.2	88.2	1.384	1.384	27177.6	27166.0	37.23
660.0	6.0	1149.7	114.5	110.4	87.6	1.368	1.368	27217.3	27205.7	37.31
670.1	6.0	1148.7	113.6	109.5	87.0	1.352	1.352	27256.3	27244.7	37.40
680.1	6.0	1147.8	112.7	108.7	86.5	1.337	1.337	27293.5	27281.9	37.49
690.1	6.0	1146.9	111.9	108.0	85.9	1.322	1.322	27329.7	27318.0	37.57
700.0	6.0	1146.1	111.1	107.2	85.4	1.308	1.308	27364.8	27353.2	37.65

## [5] Corner of strand, CON1D input file, jpi2.inp

```

CON1D-6.2 Slab Casting Heat Transfer Analysis
      University of Illinois, Brian G. Thomas, 2001
JKPark billet   Corner of Strand           Input Data          INP
                                                              
(1) Casting Conditions:
  1      Number of time-cast speed data points
        (If=1, constant speed)
  Next 2 lines contain time(s) and vc(m/min) data points
  0.
  2.2
  1540.000    Pour temperature (C)
  120.0000    Slab thickness (mm)

```

120.0000 Slab width (mm)  
 700.0000 Working mold length (mm)  
 699.0000 Z-distance for heat balance(mm)  
 127.0000 \* Nozzle submergence depth (mm)

(2) Simulation Parameters:

0 Which shell to consider? (0=wide face; 1=narrow face)  
 2 Which mold face to consider(0=outer, 1=inner,  
 2=straight mold or narrow face)  
 2 Calculate mold and interface (=0 flux casting, or 2 oil casting )  
 or enter interface heat flux data (=-1)  
 15 Number of z and q data points (if above = 1 or -1)  
 Next 2 lines contain z(mm) and q(kW/m<sup>2</sup>) data  
 0. 20. 50. 85. 120. 175. 230. 300. 350. 450. 550. 580. 650. 840. 870.  
 2800. 1540. 1885. 2060. 1980. 1880. 1830. 1820. 1785. 1680. 1570. 1400. 1375. 1365. 1350.  
 1.0000 Is superheat treated as heatflux?  
 0=no; 1=yes (take default);-1=yes (enter data)  
 17 Number of z and q data points (if above = -1)  
 Next 2 lines contain z(mm) and q(kW/m<sup>2</sup>) data  
 10. 45. 100. 200. 300. 400. 500. 675. 720. 770. 980. 1120. 1370. 1470. 1575. 1700. 2000.  
 20. 40. 58. 57. 28. 36. 88. 384. 408. 406. 321. 303. 98. 58. 38. 25. 20.  
 1 Do you want (more accurate) 2d calculations  
 in mold? (0=no; 1=yes)  
 400.0000 Max. dist. below meniscus for 2d mold calcs (mm)  
 4.000000E-03 Time increment (s)  
 120 Number of slab sections  
 10.000 Printout interval (mm)  
 0.000000E+00 Start output at (mm)  
 710.000 Max. simulation length (mm)  
 60.00000 Max. simulation thickness (mm)  
 (smaller of max. expected shell thickness &  
 half of slab thickness)  
 100000 Max. number of iterations  
 3 Shell thermocouple numbers below hot face (less than 10)  
 Next line gives the distance below surface of thermocouples(mm)  
 10.0 12.5 25  
 0.7000000 Fraction solid for shell thickness location (-)

(3) Steel Properties: (Plain medium Carbon Steel)

0.100 0.48 0.001 0.026 0.39 %C,%Mn,%S,%P,%Si  
 0.0 0.02 0.02 0.02 0.01 %Cr,%Ni,%Cu,%Mo,%Ti  
 0.003 0.026 0.056 0.010 0.0000 %Al,%V,%N,%Nb,%W  
 0.020 0.0000 0.0000 0.0000 0.0000 %Co,(additional components)  
 1000 Grade flag (1000,304,316,317,347,410,420,430,999)  
 (carbon steels,,AISI stainless steels,,user subroutine)  
 1 If CK simple Ansys. Seg. Model wanted for default Tliq,Tsol  
 (1=yes,0=no)  
 10 Cooling rate used in Seg, Model(if above =1) (K/sec)  
 Override defaults with following constants(-1=default)  
 -1.00000 Steel liquidus temperature (C)  
 -1.00000 Steel solidus temperature (C)  
 -1.00000 Steel density (g/cm<sup>3</sup>)  
 -1.00000 Heat fusion of steel (kJ/kg)  
 -1.00000 Steel emissivity (-)  
 -1.00000 Steel specific heat(kJ/kg deg K)  
 -1.00000 Steel thermal conductivity(W/mK)  
 -1.00000 Steel thermal expansion coefficient (-)

0 Use segregation model?(0=no,1=yes)  
 (not yet implemented)

(4) Spray Zone Variables:

25.00000 Water and ambient temperature in spray zone(Deg C)  
 spray zone condition:(heat tran.coeff.funct:h=A\*C\*W^n(1-bT))  
 (Nozaki Model:A\*C=0.3925,n=0.55,b=0.0075)  
 1.570000 A(0=off)  
 5.500000E-01 n  
 7.500000E-03 b  
 8.700000 minimum convection heat trans. coeff. (natural) (W/m<sup>2</sup>K)  
 5 Number of zones  
 No. zone rolls# roll water spryzone spryzone contact Frac.of q spray conv amb.

	starts inzone	radius	flowrate	width	length	angle	thru	roll	coeff	coeff	temp.
	(mm)	(m)	(l/min/row)	(m)	(m)	(deg)			(W/m^2K)		(DegC)
1	700.0	1	.0750	18.882	0.984	.904	0.000	.010	.250	8.7	25
2	2000.	1	.0750	9.1872	0.984	.050	10.00	.080	.250	8.7	25
3	2710.	1	.0950	5.1955	0.984	.050	10.00	.220	.250	8.7	25
4	8700.	5	.0950	3.8966	0.984	.050	10.00	.200	.250	8.7	25
5	13640.	1	.1075	2.9044	0.984	.050	10.00	.360	.250	8.7	25
				14000.0	End of last spray zone (mm)						

(5) Mold Flux Properties: (M662-C20)

39.2	38.4	3.4	2.0	0.6	%CaO,%SiO <sub>2</sub> ,%MgO,%Na <sub>2</sub> O,%K <sub>2</sub> O
0.0	0.70	0.0	1.3	0.0	%FeO,%Fe <sub>2</sub> O <sub>3</sub> ,%NiO,%MnO,%Cr <sub>2</sub> O <sub>3</sub>
5.0	0.0	0.0	0.0	1.4	%Al <sub>2</sub> O <sub>3</sub> ,%TiO <sub>2</sub> ,%B <sub>2</sub> O <sub>3</sub> ,%Li <sub>2</sub> O,%SrO
0.0	9.3	1.8	2.6	2.8	%ZrO <sub>2</sub> ,%F,%free C,%total C,%CO <sub>2</sub>
1135.0					Mold flux solidification temperature(C)
0.8300					Solid flux conductivity(W/mK)
1.43000					Liquid flux conductivity(W/mK)
2.00000					Flux viscosity at 1300C (poise)
2700.000					Mold flux density(kg/m <sup>3</sup> )
200.0000					Flux absorption coefficient(1/m)
-1.0000					Flux index of refraction(-)
					( -1 = take default f(composition) )
0.9					Slag emissivity(-)
3.089508					Exponent for temperature dependency of viscosity
1					Form of mold powder consumption rate
0.48					Mold powder consumption rate
0.0000E+00					Location of peak heat flux (m)
0.0040000					Slag rim thickness at metal level (m)
1.0000E-02					Slag rim thickness above heat flux peak (m)

(6) Interface Heat Transfer Variables:

13					Number of distance-ratio data points
					(1=constant ratio of solid flux velocity
					to casting speed)
					Next 2 lines contain z(mm) and vratio (-) data
0.	10.	60.	100.	190.	300. 400. 410. 450. 600. 800. 1000. 1096
.18	.31	.35	.31	.29	.2 .29 .41 .39 .3 .2 .15
5.600E-04					Flux/mold contact resistance(m <sup>2</sup> K/W)
0.500000					Mold surface emissivity(-)
5.99999E-02					Air conductivity(W/mK)
0					Osc.marks simulation flag(0=average,1=transient)
0.20000000					Oscillation mark depth (mm)
1.500000					Width of oscillation mark (mm)
3.942					Oscillation frequency (cps)
					(-1 = take default cpm=2*ipm casting speed)
8.0000					Oscillation stroke (mm)

(7) Mold Water Properties:

-1					Water thermal conductivity (W/mK)(-1 = default = f(T))
-1					Water viscosity (Pa-s)(-1 = default = f(T))
-1					Water heat capacity (J/kgK)(-1 = default = f(T))
-1					Water density (kg/m <sup>3</sup> )(-1 = default = f(T))

(8) Mold Geometry:

11.78700					Mold thickness including water channel (mm),(outer rad.,top)
11.78700					Mold thickness including water channel (mm),(inner rad.,top)
100.0000					Distance of meniscus from top of mold (mm)
120.0001					Distance between cooling water channels(center to center)(mm)
360.0000					Mold thermal conductivity(W/mK)
30.00000					Cooling water temperature at mold top(C)
0.620000					Cooling water pressure(MPa)
5.7870					Cooling water channel depth(mm)
120.0000					Cooling water channel width(mm)
694.44					Total channel cross sectional area(mm <sup>2</sup> ) (served by water flow line where temp rise measured)
2					Form of cooling water flowrate/velocity(1=m/s ; 2=L/s)
4.583					Cooling water flowrate per face/velocity < 0 cooling water from mold bottom to top)
5.0					

5.0 Machine radius(m) (outer &inner radius)  
 6 Number of mold coating/plating thickness changes down mold

No.	Scale	Ni	Cr	Others	*Air gap	Z-positions	unit
1	0.000	0.000	0.100	0.000	0.00	0.000	(mm)
2	0.000	0.000	0.100	0.000	0.00	20.000	(mm)
3	0.000	0.000	0.100	0.000	0.10	85.000	(mm)
4	0.000	0.000	0.100	0.000	0.30	300.000	(mm)
5	0.000	0.000	0.100	0.000	0.40	600.000	(mm)
6	0.000	0.000	0.100	0.000	0.40	700.000	(mm)
	0.550	72.100	67.000	1.000	0.10	Conductivity	(W/mK)

0.250000 \*Factor to approximate nonlinear heat flow at meniscus,(first guess for 2d analysis)  
 4.999999E-03  
 6.499998E-02 Equivalent inner and outer radius

(9) Mold Thermocouples:  
 11 Total number of thermocouples (space here for t.c. location)

No.	Distance beneath hot surface(mm)	Distance below meniscus(mm)	Measured:
10	0.0	285.00	
11	1.0	285.00	
12	3.0	285.00	
13	6.0	285.00	
14	9.0	285.00	
21	0.0	20.00	
22	6.0	20.00	
1	3.0	20.00	108
2	3.0	70.00	125
3	3.0	300.00	118
4	3.0	600.00	100 (DeltaT=8 DegC)

## [6] Corner of strand, CON1D output file, jpi2.ext:

CON1D-6.2 Slab Casting Heat Transfer Analysis  
 University of Illinois, Brian G. Thomas, 2001

EXIT	Calculated Conditions	EXT
Initial casting speed:	36.67	(mm/s)
Carbon content:	0.1000	(%)
Wide face simulation:		
Steel Properties:		
The following 3 temperature from Y.M.Won Segregation Model		
Liquidus Temp:	1517.80	Deg C
Solidus Temp:	1468.40	Deg C
Peritectic Temp:	1471.74	Deg C
AE3 Temp:	894.67	Deg C
AE1 Temp:	734.35	Deg C
Parameters Based on Derived Mold Values:		
Carbon equivalent:	0.1919	(%)
(using initial casting speed:)		
Negative strip time:	0.10	(s)
Positive strip time:	0.16	(s)
Velocity amplitude of mold oscillation:	99.07	(mm/s)
Pitch(spacing between oscillation marks):	9.30	(mm)
% Time negative strip:	37.93	(%)
Average percent negative strip velocity:	72.01	(%)
Cooling water velocity:	6.60	(m/s)
Cooling water flow rate per face:	4.5830	(L/s)

Average mold flux thickness: (based on consumption rate)	0.0649	(mm)	
(assuming flux moves at casting speed)			
min. heat trans. coeff. on mold cold face	22.64	kW/m <sup>2</sup> K	
max. heat trans. coeff. on mold cold face	26.76	kW/m <sup>2</sup> K	
Water boiling temperature:	150.0000	Deg C	
Max cold face temperature:	119.3907	Deg C	
Max hot face temperature(copper only):	158.4988	Deg C	
Max hot face temperature(w/coating):	166.1601	Deg C	
Mold water temp diff(in hot channel):	3.4314	Deg C	
Mold water temp diff(over all channels):	3.4314	Deg C	
Mean heat flux in mold:	773.59	(kW/m <sup>2</sup> )	
Friction Values:			
Average absolute shear stress in Mold:	10.1561	(kPa)	
Average friction force in Mold:	0.8531	(kN)	
Max. shear stress in Mold:	10.1561	(kPa)	
Max friction force in Mold:	0.8531	(kN)	
Min. shear stress in Mold:	-10.1561	(kPa)	
Min friction force in Mold:	-0.8531	(kN)	
shear stress in Mold when Vmold=0:	10.1561	(kPa)	
Friction force in Mold when Vmold=0:	0.8531	(kN)	
Heat Balance at 699.02mm:			
Heat Extracted:	14.76	(MJ/m <sup>2</sup> )	
Heat Input to shell inside:	2.85	(MJ/m <sup>2</sup> )	
Super Heat:	0.06	(MJ/m <sup>2</sup> )	
Latent Heat in mushy region:	5.47	(MJ/m <sup>2</sup> )	
Latent Heat in Solid region:	5.51	(MJ/m <sup>2</sup> )	
Sensible Cooling:	1.81	(MJ/m <sup>2</sup> )	
Total Heat:	15.71	(MJ/m <sup>2</sup> )	
Error In Heat Balance:	6.47	(%)	
Heat Balance at Mold Exit( 700.04mm):			
Heat Extracted:	14.77	(MJ/m <sup>2</sup> )	
Heat Input to shell inside:	2.85	(MJ/m <sup>2</sup> )	
Super Heat:	0.06	(MJ/m <sup>2</sup> )	
Latent Heat in mushy region:	5.49	(MJ/m <sup>2</sup> )	
Latent Heat in Solid region:	5.51	(MJ/m <sup>2</sup> )	
Sensible Cooling:	1.82	(MJ/m <sup>2</sup> )	
Total Heat:	15.73	(MJ/m <sup>2</sup> )	
Error In Heat Balance:	6.48	(%)	
Variables Calculated at Mold Exit( 700.04mm):			
taper (per mold, narrow face):	0.12	(%)	
taper (per mold per length, narrow face):	0.17	(%/m)	
Shell thickness:	3.94	(mm)	
Liquid flux film thickness:	0.0000	(mm)	
Solid flux film thickness:	0.0000	(mm)	
Total flux film thickness:	0.0000	(mm)	
Shell surface temperature:	1428.03	Deg C	
Mold hot face temperature:	61.77	Deg C	
Heat flux:	0.5103	(MW/m <sup>2</sup> )	
Predicted Thermocouple Temperatures:			
No.	distance beneath hot surface(mm)	distance below meniscus(mm)	temperature Deg C
1	0.00	285.00	65.94
2	1.00	285.00	64.20
3	3.00	285.00	60.75
4	6.00	285.00	55.56
5	9.00	285.00	50.37
6	0.00	20.00	157.62
7	6.00	20.00	119.23
8	3.00	20.00	137.79
9	3.00	70.00	89.88
10	3.00	300.00	60.18
11	3.00	600.00	56.66

## [7] Corner of strand, CON1D output file, jpi2.shl:

CON1D V6.2 Slab Casting Heat Transfer Analysis University of Illinois, Brian G. Thomas, 2001												
#	SHELL	Output Shell Temperature, Taper Histories										SHL
#	Posi	time	LiqLoc	SolLoc	shell	Thermo-	Surf	EndWall	Taper	Taper	Oldtaper	
#	mm	s	mm	mm	mm	coupl	T	Temp	Defl	Instan	Cumul	
#	mm					C		C	mm	%/m	%/m	
	0.00	0.00	0.0	0.0	0.00	1518.3	1518.3	0.00	0.00	0.00	0.00	
	10.12	0.28	1.5	0.0	0.02	1518.3	1482.4	0.00	0.00	0.00	0.00	
	20.09	0.55	2.0	0.1	0.34	1518.3	1458.7	0.01	5.28	1.05	1.04	
	30.07	0.82	2.4	0.3	0.52	1518.3	1452.6	0.02	0.66	1.14	1.14	
	40.04	1.09	2.6	0.3	0.68	1518.3	1450.6	0.02	0.27	0.96	0.96	
	50.01	1.36	3.0	0.4	0.80	1518.3	1449.8	0.02	0.11	0.81	0.81	
	60.13	1.64	3.1	0.5	0.90	1518.3	1449.5	0.02	0.03	0.68	0.68	
	70.11	1.91	3.4	0.6	0.99	1518.3	1448.0	0.03	0.51	0.64	0.63	
	80.08	2.18	3.7	0.6	1.09	1518.2	1447.6	0.03	0.14	0.59	0.56	
	90.05	2.46	3.7	0.7	1.18	1518.2	1447.5	0.03	0.19	0.54	0.50	
	100.03	2.73	4.0	0.7	1.25	1518.2	1447.0	0.03	0.17	0.51	0.46	
	110.00	3.00	4.2	0.8	1.32	1518.2	1446.5	0.03	0.15	0.47	0.43	
	120.12	3.28	4.0	0.8	1.39	1518.2	1446.2	0.03	0.12	0.44	0.40	
	130.09	3.55	4.3	0.8	1.45	1518.2	1446.0	0.03	0.10	0.42	0.37	
	140.07	3.82	4.5	0.9	1.50	1518.2	1445.8	0.03	0.08	0.40	0.35	
	150.04	4.09	4.7	0.9	1.56	1518.1	1445.6	0.03	0.07	0.37	0.33	
	160.01	4.36	4.7	0.9	1.62	1518.1	1445.5	0.03	0.06	0.35	0.31	
	170.13	4.64	4.5	1.0	1.68	1518.1	1445.4	0.03	0.05	0.34	0.29	
	180.11	4.91	4.8	1.0	1.73	1518.1	1445.3	0.03	0.33	0.32	0.28	
	190.08	5.18	5.1	1.1	1.78	1518.1	1444.6	0.04	0.15	0.32	0.27	
	200.05	5.46	5.2	1.1	1.84	1518.1	1444.3	0.04	0.10	0.31	0.26	
	210.03	5.73	5.0	1.1	1.89	1518.1	1444.2	0.04	0.08	0.30	0.25	
	220.00	6.00	5.0	1.2	1.93	1518.1	1444.1	0.04	0.07	0.29	0.24	
	230.12	6.28	5.4	1.2	1.98	1518.1	1444.0	0.04	0.06	0.28	0.23	
	240.09	6.55	5.4	1.2	2.02	1518.1	1444.0	0.04	0.06	0.27	0.22	
	250.07	6.82	5.5	1.3	2.07	1518.1	1444.0	0.04	0.04	0.26	0.21	
	260.04	7.09	5.5	1.3	2.11	1518.0	1444.0	0.04	0.04	0.25	0.20	
	270.01	7.36	5.5	1.3	2.15	1518.0	1444.0	0.04	0.03	0.24	0.20	
	280.13	7.64	5.8	1.3	2.19	1518.0	1444.0	0.04	0.03	0.23	0.19	
	290.11	7.91	5.8	1.3	2.23	1518.0	1444.0	0.04	0.03	0.23	0.18	
	300.08	8.18	6.0	1.4	2.26	1518.0	1444.1	0.04	0.02	0.22	0.18	
	310.05	8.46	6.0	1.4	2.30	1518.0	1443.9	0.04	0.06	0.21	0.17	
	320.03	8.73	6.0	1.4	2.33	1518.0	1443.7	0.04	0.06	0.21	0.17	
	330.00	9.00	6.5	1.4	2.37	1518.0	1443.4	0.04	0.06	0.21	0.16	
	340.12	9.28	6.6	1.5	2.40	1518.0	1443.2	0.04	0.07	0.20	0.16	
	350.10	9.55	6.7	1.5	2.43	1518.0	1442.9	0.04	0.06	0.20	0.16	
	360.07	9.82	7.1	1.5	2.47	1518.0	1442.7	0.04	0.19	0.19	0.15	
	370.04	10.09	7.0	1.6	2.51	1518.0	1442.1	0.04	0.16	0.19	0.16	
	380.02	10.36	7.6	1.6	2.55	1517.9	1441.6	0.04	0.14	0.19	0.16	
	390.14	10.64	7.9	1.6	2.59	1517.9	1441.1	0.04	0.13	0.19	0.16	
	400.11	10.91	8.3	1.7	2.64	1517.9	1440.7	0.05	0.12	0.19	0.16	
	410.08	11.18	8.5	1.7	2.68	1517.9	1440.4	0.05	0.12	0.19	0.16	
	420.06	11.46	8.6	1.7	2.72	1517.9	1440.0	0.05	0.11	0.19	0.16	
	430.03	11.73	9.0	1.8	2.76	1517.9	1439.6	0.05	0.11	0.18	0.16	
	440.00	12.00	9.0	1.8	2.80	1517.9	1439.3	0.05	0.11	0.18	0.16	
	450.12	12.28	9.3	1.8	2.85	1517.9	1439.0	0.05	0.11	0.18	0.16	
	460.10	12.55	9.5	1.8	2.89	1517.8	1438.6	0.05	0.11	0.18	0.16	
	470.07	12.82	9.5	1.9	2.93	1517.8	1438.3	0.05	0.10	0.18	0.16	
	480.04	13.09	9.6	1.9	2.97	1517.8	1438.0	0.05	0.10	0.18	0.16	
	490.02	13.36	10.0	1.9	3.01	1517.8	1437.7	0.05	0.10	0.17	0.16	
	500.14	13.64	10.0	2.0	3.05	1517.8	1437.3	0.05	0.10	0.17	0.16	
	510.11	13.91	10.3	2.0	3.09	1517.8	1437.0	0.05	0.10	0.17	0.16	
	520.08	14.18	10.5	2.1	3.14	1517.8	1436.6	0.05	0.16	0.17	0.16	
	530.06	14.46	10.5	2.1	3.18	1517.7	1436.0	0.05	0.14	0.17	0.16	
	540.03	14.73	10.5	2.1	3.23	1517.7	1435.6	0.06	0.13	0.17	0.16	
	550.00	15.00	10.9	2.2	3.28	1517.6	1435.1	0.06	0.12	0.17	0.16	
	560.12	15.28	11.0	2.2	3.32	1517.5	1434.7	0.06	0.13	0.17	0.16	
	570.10	15.55	11.0	2.3	3.37	1517.4	1434.3	0.06	0.13	0.17	0.16	

580.07	15.82	11.1	2.3	3.41	1517.3	1434.0	0.06	0.13	0.17	0.16
590.04	16.09	11.2	2.3	3.45	1517.2	1433.6	0.06	0.13	0.17	0.16
600.02	16.36	11.3	2.4	3.49	1517.1	1433.3	0.06	0.12	0.17	0.16
610.14	16.64	11.5	2.4	3.54	1517.0	1432.9	0.06	0.13	0.17	0.16
620.11	16.91	11.5	2.4	3.58	1516.9	1432.4	0.06	0.14	0.16	0.16
630.08	17.18	11.5	2.4	3.63	1516.7	1432.0	0.06	0.14	0.16	0.16
640.06	17.46	11.5	2.5	3.67	1516.6	1431.6	0.06	0.15	0.16	0.17
650.03	17.73	11.9	2.5	3.71	1516.5	1431.1	0.06	0.20	0.16	0.17
660.00	18.00	12.0	2.6	3.76	1516.4	1430.5	0.07	0.19	0.16	0.17
670.12	18.28	12.2	2.6	3.81	1516.3	1429.8	0.07	0.19	0.17	0.17
680.10	18.55	12.0	2.7	3.85	1516.1	1429.2	0.07	0.18	0.17	0.17
690.07	18.82	12.1	2.7	3.90	1516.0	1428.6	0.07	0.18	0.17	0.17
700.04	19.09	12.5	2.8	3.94	1515.9	1428.0	0.07	0.17	0.17	0.18
710.02	19.36	12.5	2.8	3.98	1515.7	1432.4	0.07	-0.41	0.15	0.14

## [8] Corner of strand, CON1D output file, jpi2.mld:

```
# CON1D V6.2 Slab Casting Heat Transfer Analysis
# University of Illinois, Brian G. Thomas, 2001

# MOLD
# Mold Output
# MLD

# Z Mold TSurf      Mold Temp      Heatflux qcold hwater    hw      twater
# thick          hot   hotcu cold      MW/m^2     MW/m2    W/m^2K   W/m^2K   Deg C
# mm   mm   Deg C      (Deg C)          

# 0.0  6.0  1518.3  109.7  101.3  79.5  2.782  1.284  25928.0  26498.6  30.00
10.1 6.0  1482.4  157.2  149.4  111.6  2.613  2.011  24702.4  26498.6  30.17
20.1 6.0  1458.7  165.3  157.7  119.3  2.543  2.160  24285.0  26498.6  30.33
30.1 6.0  1452.6  151.4  145.3  111.6  2.053  2.005  24714.4  26498.6  30.48
40.0 6.0  1450.6  135.4  130.2  100.9  1.743  1.776  25252.4  26498.6  30.60
50.0 6.0  1449.8  122.2  117.6  91.9  1.526  1.568  25627.9  26498.6  30.70
60.1 6.0  1449.5  111.8  107.7  84.8  1.361  1.397  25860.3  26498.6  30.79
70.1 6.0  1448.0  103.9  100.2  79.5  1.234  1.264  25997.7  26498.6  30.87
80.1 6.0  1447.6  97.9   94.5   75.4  1.132  1.160  26081.6  26498.6  30.95
90.1 6.0  1447.5  93.6   90.4   72.5  1.065  1.085  26133.5  26498.6  31.02
100.0 6.0  1447.0  90.5   87.5   70.4  1.020  1.029  26168.6  26498.6  31.08
110.0 6.0  1446.5  88.0   85.1   68.7  0.979  0.985  26195.6  26498.6  31.15
120.1 6.0  1446.2  85.8   83.0   67.3  0.942  0.946  26218.4  26498.6  31.21
130.1 6.0  1446.0  83.9   81.2   66.0  0.909  0.912  26237.8  26498.6  31.27
140.1 6.0  1445.8  82.2   79.5   64.9  0.879  0.881  26254.9  26498.6  31.32
150.0 6.0  1445.6  80.6   78.0   63.9  0.851  0.853  26270.3  26498.6  31.38
160.0 6.0  1445.5  79.1   76.7   62.9  0.825  0.827  26284.4  26498.6  31.43
170.1 6.0  1445.4  77.8   75.4   62.0  0.802  0.803  26297.6  26498.6  31.48
180.1 6.0  1445.3  76.5   74.2   61.2  0.780  0.781  26309.8  26498.6  31.53
190.1 6.0  1444.6  75.4   73.1   60.5  0.759  0.761  26321.3  26498.6  31.58
200.1 6.0  1444.3  74.3   72.1   59.8  0.740  0.742  26332.2  26498.6  31.63
210.0 6.0  1444.2  73.4   71.2   59.2  0.723  0.724  26342.7  26498.6  31.68
220.0 6.0  1444.1  72.4   70.3   58.6  0.706  0.707  26352.8  26498.6  31.72
230.1 6.0  1444.0  71.6   69.5   58.0  0.691  0.692  26362.7  26498.6  31.76
240.1 6.0  1444.0  70.8   68.8   57.5  0.677  0.677  26372.1  26498.6  31.81
250.1 6.0  1444.0  70.0   68.1   57.0  0.663  0.664  26381.4  26498.6  31.85
260.0 6.0  1444.0  69.3   67.4   56.6  0.650  0.651  26390.4  26498.6  31.89
270.0 6.0  1444.0  68.7   66.8   56.1  0.638  0.639  26399.3  26498.6  31.93
280.1 6.0  1444.0  68.1   66.2   55.7  0.627  0.628  26408.1  26498.6  31.97
290.1 6.0  1444.0  67.5   65.7   55.4  0.616  0.618  26416.7  26498.6  32.01
300.1 6.0  1444.1  67.0   65.2   55.1  0.606  0.609  26425.3  26498.6  32.05
310.1 6.0  1443.9  66.7   65.0   54.9  0.602  0.603  26434.0  26498.6  32.09
320.0 6.0  1443.7  66.5   64.7   54.8  0.599  0.599  26442.8  26498.6  32.13
330.0 6.0  1443.4  66.3   64.6   54.7  0.595  0.595  26451.7  26498.6  32.16
340.1 6.0  1443.2  66.2   64.4   54.6  0.591  0.591  26460.6  26498.6  32.20
350.1 6.0  1442.9  66.0   64.2   54.4  0.588  0.588  26469.3  26498.6  32.24
360.1 6.0  1442.7  65.8   64.1   54.3  0.584  0.584  26478.1  26498.6  32.28
370.0 6.0  1442.1  65.6   63.9   54.2  0.581  0.581  26486.7  26498.6  32.31
380.0 6.0  1441.6  65.5   63.8   54.1  0.577  0.577  26495.4  26498.6  32.35
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390.1	6.0	1441.1	65.3	63.6	54.0	0.574	0.574	26504.1	26498.6	32.39
400.1	6.0	1440.7	65.1	63.4	54.0	0.571	0.572	26512.7	26498.6	32.42
410.1	6.0	1440.4	65.0	63.3	53.9	0.567	0.567	26521.1	26509.6	32.46
420.1	6.0	1440.0	64.8	63.2	53.8	0.564	0.564	26529.5	26518.1	32.49
430.0	6.0	1439.6	64.7	63.0	53.7	0.561	0.561	26538.0	26526.5	32.53
440.0	6.0	1439.3	64.5	62.9	53.6	0.558	0.558	26546.3	26534.9	32.57
450.1	6.0	1439.0	64.4	62.7	53.5	0.555	0.555	26554.8	26543.3	32.60
460.1	6.0	1438.6	64.3	62.6	53.4	0.552	0.552	26563.1	26551.7	32.64
470.1	6.0	1438.3	64.1	62.5	53.3	0.549	0.549	26571.4	26559.9	32.67
480.0	6.0	1438.0	64.0	62.4	53.3	0.546	0.546	26579.6	26568.2	32.71
490.0	6.0	1437.7	63.9	62.2	53.2	0.543	0.543	26587.8	26576.4	32.74
500.1	6.0	1437.3	63.7	62.1	53.1	0.541	0.540	26596.1	26584.7	32.77
510.1	6.0	1437.0	63.6	62.0	53.0	0.538	0.538	26604.2	26592.8	32.81
520.1	6.0	1436.6	63.5	61.9	52.9	0.535	0.535	26612.3	26600.9	32.84
530.1	6.0	1436.0	63.3	61.7	52.9	0.532	0.532	26620.4	26608.9	32.88
540.0	6.0	1435.6	63.2	61.6	52.8	0.529	0.529	26628.4	26616.9	32.91
550.0	6.0	1435.1	63.1	61.5	52.7	0.527	0.527	26636.4	26624.9	32.94
560.1	6.0	1434.7	62.9	61.4	52.6	0.524	0.524	26644.5	26633.0	32.98
570.1	6.0	1434.3	62.8	61.3	52.6	0.522	0.521	26652.4	26640.9	33.01
580.1	6.0	1434.0	62.7	61.2	52.5	0.519	0.519	26660.3	26648.8	33.04
590.0	6.0	1433.6	62.6	61.1	52.4	0.517	0.517	26668.1	26656.7	33.07
600.0	6.0	1433.3	62.5	60.9	52.4	0.514	0.514	26675.9	26664.5	33.11
610.1	6.0	1432.9	62.5	61.0	52.4	0.514	0.514	26684.1	26672.6	33.14
620.1	6.0	1432.4	62.5	61.0	52.4	0.513	0.513	26692.1	26680.6	33.17
630.1	6.0	1432.0	62.5	61.0	52.4	0.513	0.513	26700.1	26688.6	33.20
640.1	6.0	1431.6	62.5	61.0	52.4	0.513	0.513	26708.0	26696.6	33.24
650.0	6.0	1431.1	62.5	61.0	52.5	0.512	0.512	26716.0	26704.5	33.27
660.0	6.0	1430.5	62.5	61.0	52.5	0.512	0.512	26724.0	26712.5	33.30
670.1	6.0	1429.8	62.5	61.0	52.5	0.512	0.512	26732.1	26720.6	33.33
680.1	6.0	1429.2	62.5	61.0	52.5	0.511	0.511	26740.0	26728.5	33.37
690.1	6.0	1428.6	62.5	61.0	52.5	0.511	0.511	26748.0	26736.5	33.40
700.0	6.0	1428.0	62.5	61.0	52.5	0.510	0.510	26755.9	26744.4	33.43