Annual Report

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Heat Transfer Analysis of a Refractory Nozzle Assembly

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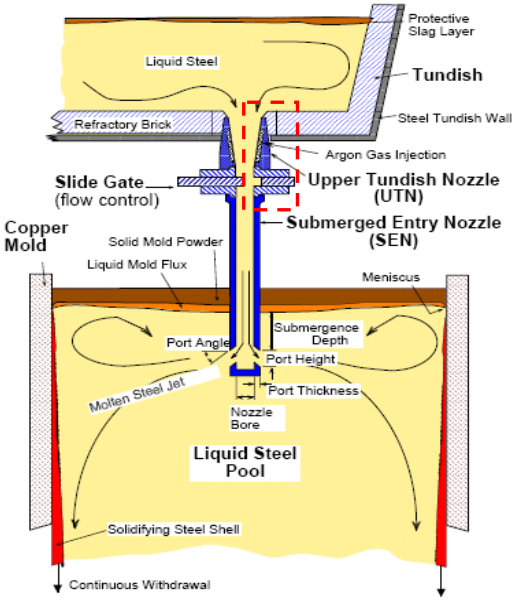
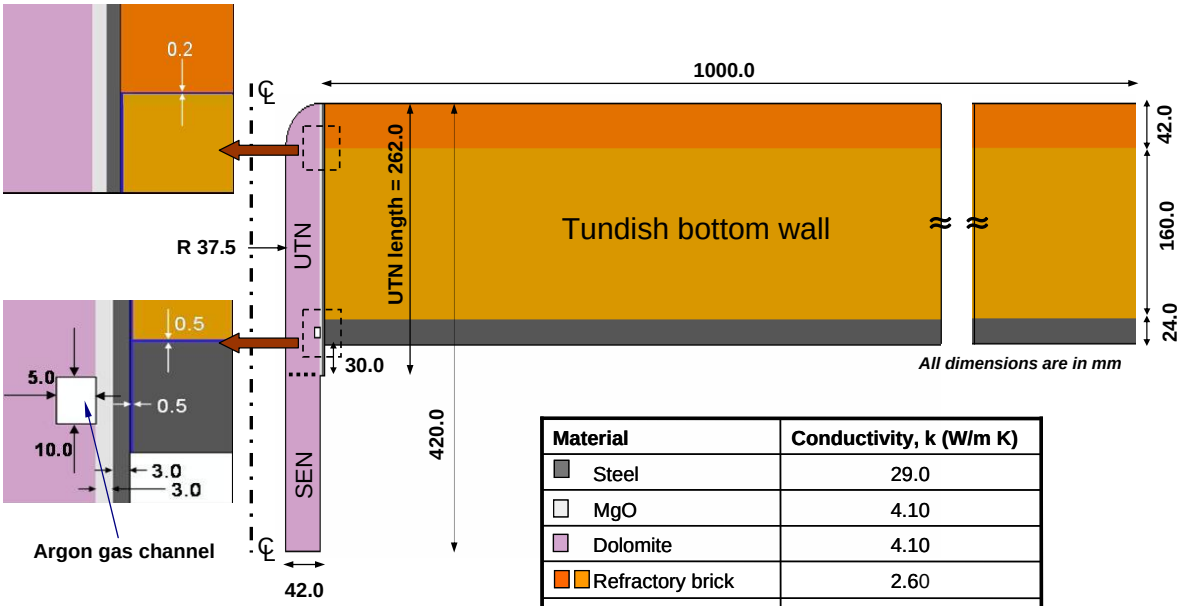
Objectives

- Determine effect of tundish refractory on temperature distribution in UTN
- Develop a 2-D thermal model of the nozzle assembly (UTN + SEN) and tundish bottom steel and refractory layers
- Determine effect of air gaps



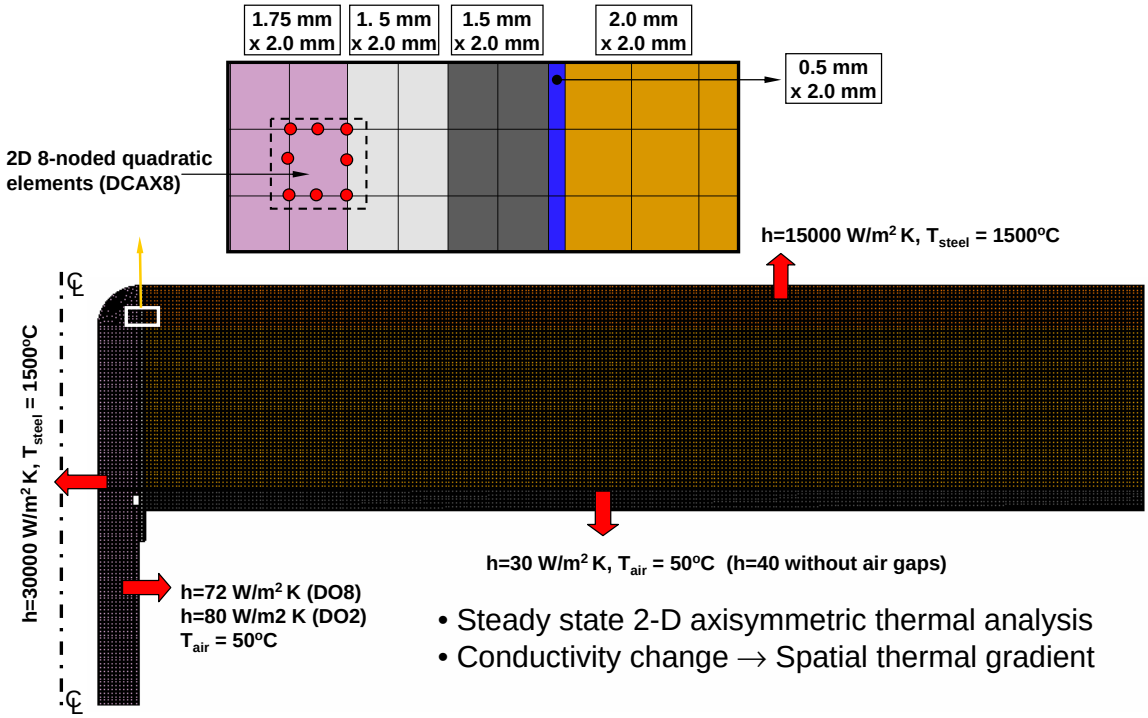
Location of nozzles on the continuous casting machine

Geometry of Nozzle Assembly



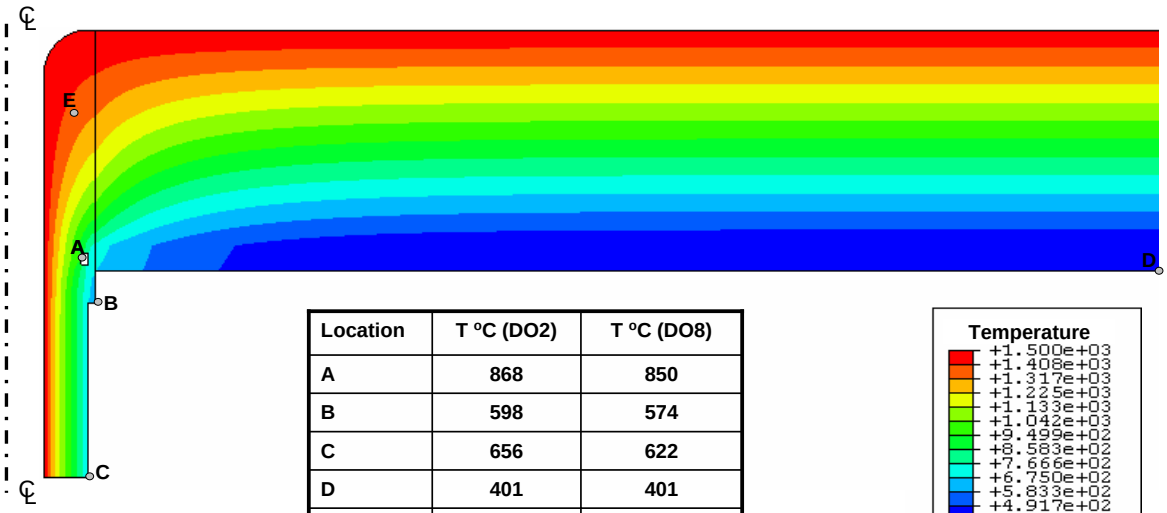
Material	Conductivity, k (W/m K)
Steel	29.0
MgO	4.10
Dolomite	4.10
Refractory brick	2.60
Air	0.01

FE Discretization (Mesh) & Thermal Boundary Conditions



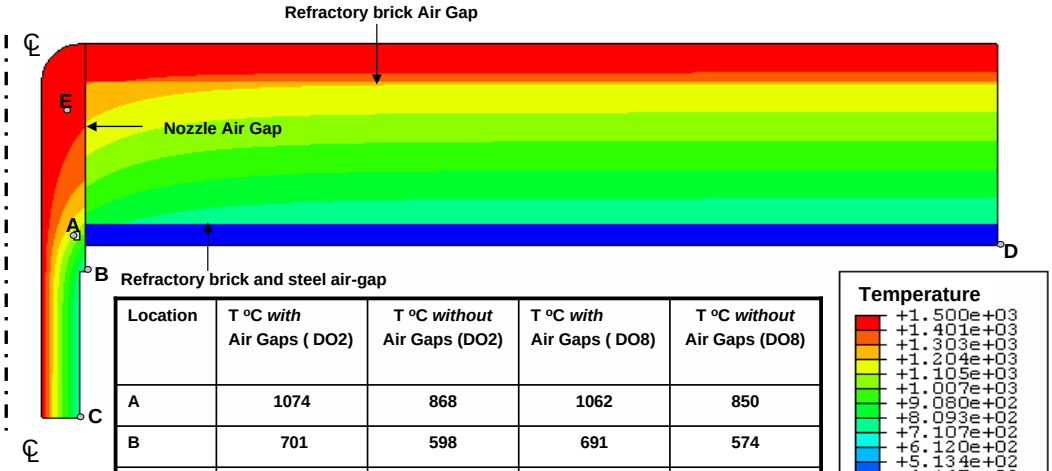
- Steady state 2-D axisymmetric thermal analysis
- Conductivity change → Spatial thermal gradient

Temperature Distribution with no air gaps (DO8)



Location	T °C (DO2)	T °C (DO8)
A	868	850
B	598	574
C	656	622
D	401	401
E	1282	1271

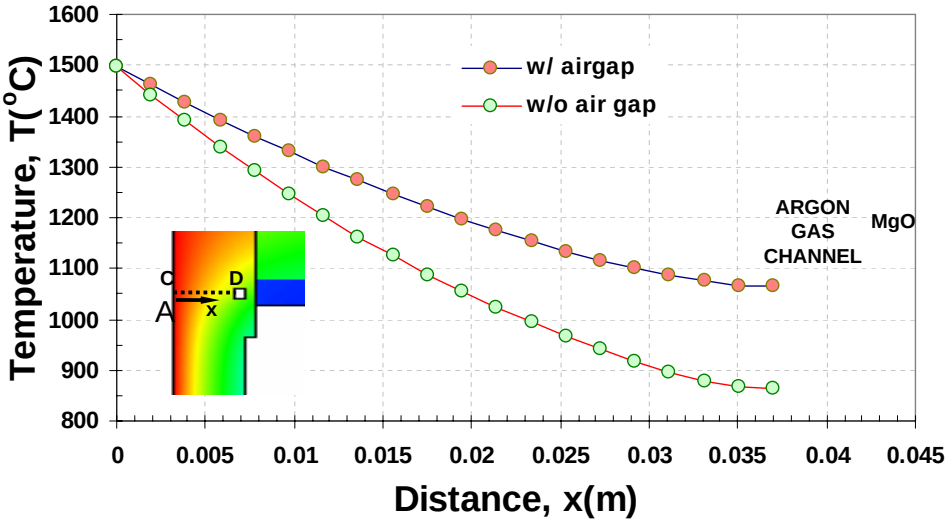
Temperature distribution with air gaps



Location	T °C *with* Air Gaps (DO2)	T °C *without* Air Gaps (DO2)	T °C *with* Air Gaps (DO8)	T °C *without* Air Gaps (DO8)
A	1074	868	1062	850
B	701	598	691	574
C	656	656	622	622
D	316	401	316	401
E	1390	1282	1380	1271

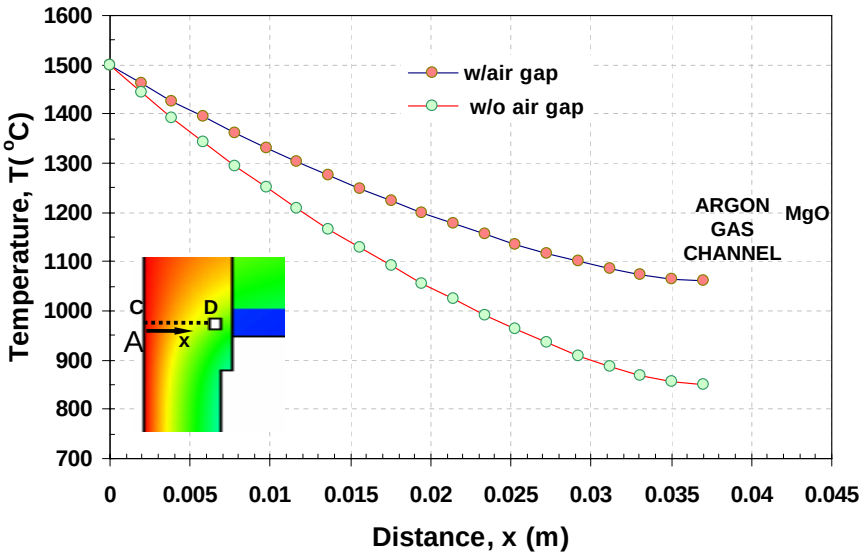
- Air gap provides increased resistance to radial heat flow
- Nozzle air gap calculated using: gap = $\alpha_{steel}\ \Delta T \times R$ (mm) with $\alpha_{steel} = 12 \times 10^{-6}$ /°C

Temperature Distribution along CD (DO2)



• Gradual temperature decrease from surface to argon gas channel

Temperature Distribution along CD (DO8)



• Gradual temperature decrease from surface to argon gas channel

Temperature distribution along AB

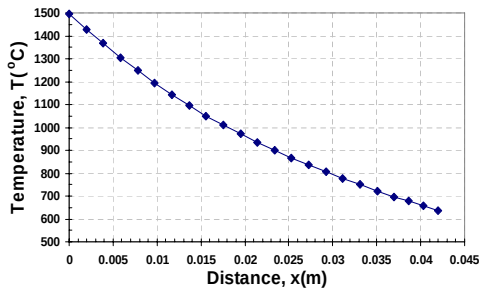
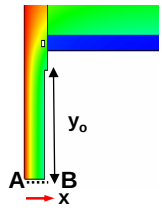


Fig:1 DO2



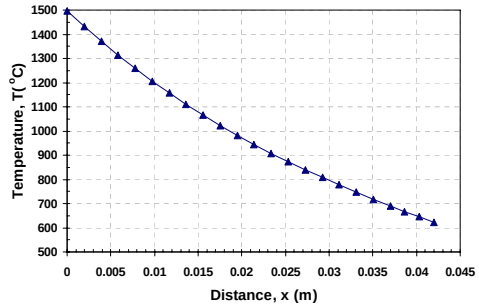


Fig:2 DO8

- At a distance > y_o (90 mm) below the UTN bottom, T_B for DO2 = 656°C & TB for DO8 = 622°C
- And gradient across thickness remains 1-D and constant (+/- 1°C)

Conclusions

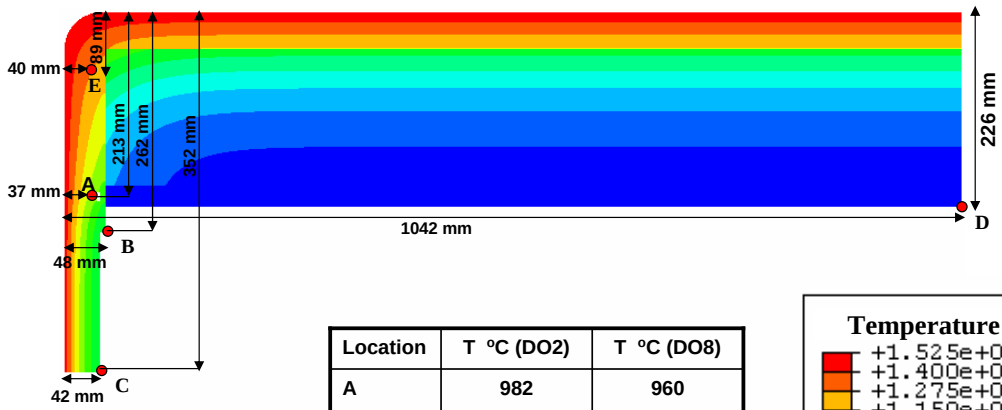
- Tundish refractory has significant effect on nozzle wall temperatures above the point of injection of argon gas.
- Lower than ~120 mm beneath steel bottom of tundish, temperature gradient across nozzle wall thickness remains constant (+/- 1°C) and one dimensional
- Air gaps significantly increase temperature in the UTN by decreasing the heat transfer through it.
- The tundish steel bottom reaches 300-400 °C at steady state, indicating that ***transient effects*** are very important.

Transient Analysis

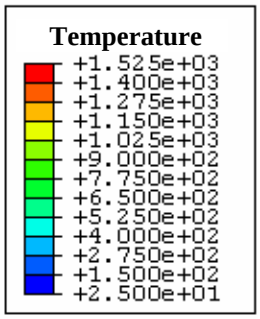
Material Properties used in the model for the Transient Analysis

S.No	Material	Properties	Temperature dependent data				Temperature-independent data
			343°C	593°C	843°C	1232°C	
1	Dolomite (DO2)/ (DO8)	Specific Heat (J/Kg K) Same for DO2 & DO8	1007	1053	1083	1117	-
		Density (kg/ m^3)	-	-	-	-	2940/2820
		Conductivity (W/ m K)	5.3/3.2	4.3/3.2	3.9/3.0	3.0/2.6	-
2	Steel	Specific Heat (J/Kg K)	-	-	-	-	690
		Density (kg/ m^3)	-	-	-	-	8000
		Conductivity (W/ m K)	-	-	-	-	29
3	Brick	Specific Heat (J/Kg K)	-	-	-	-	1000
		Density (kg/ m^3)	-	-	-	-	1840
		Conductivity (W/ m K)	-	-	-	-	2.6
4	MgO	Specific Heat (J/Kg K)	1189	1240	1281	1327	-
		Density (kg/ m^3)	-	-	-	-	2600
		Conductivity (W/ m K)	5.5	4.4	3.5	2.8	-
5	Air	Specific Heat (J/Kg K)	-	-	-	-	1000
		Density (kg/ m^3)	-	-	-	-	1290
		Conductivity (W/ m K)	-	-	-	-	0.01

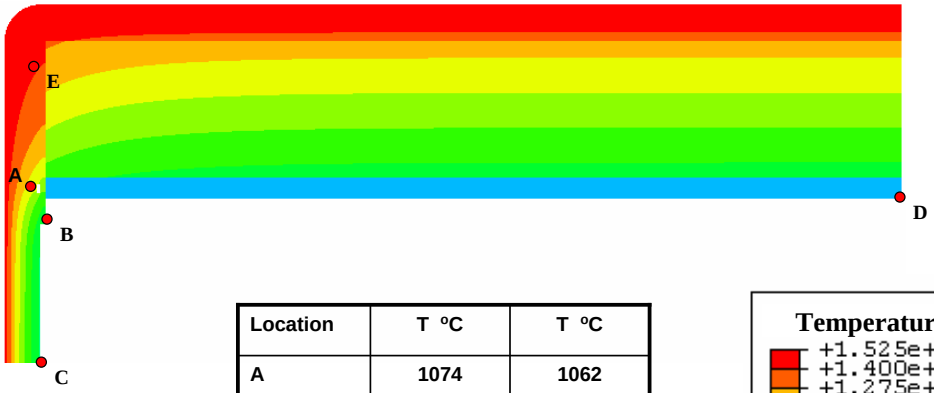
Temperature Distribution after one hour of operation



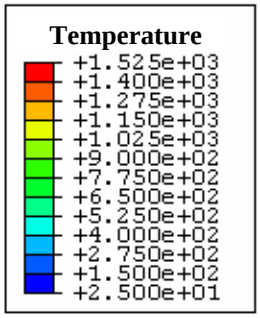
Location	T °C (DO2)	T °C (DO8)
A	982	960
B	664	639
C	655	621
D	46	46
E	1217	1182



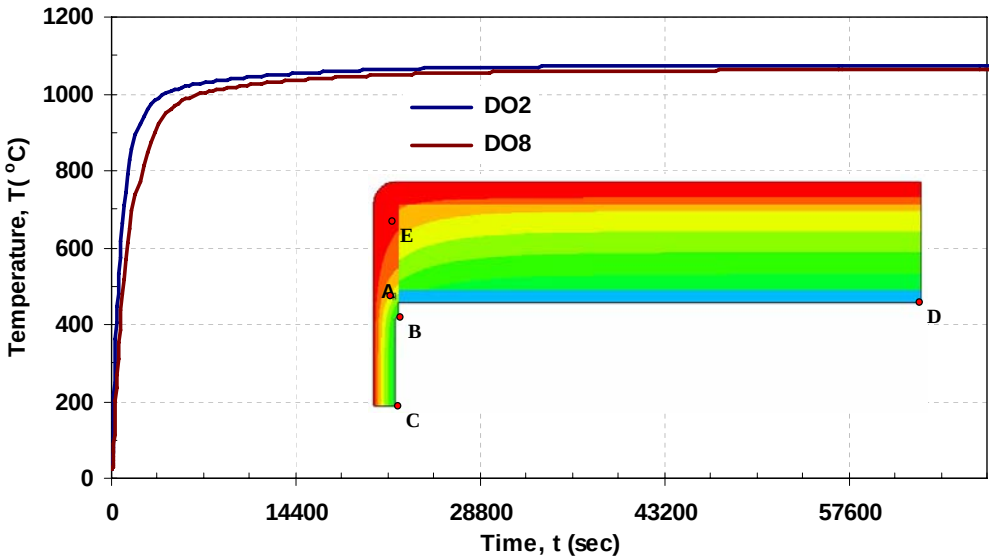
Temperature Distribution at Steady State



Location	T °C	T °C
A	1074	1062
B	702	691
C	656	622
D	316	316
E	1391	1380

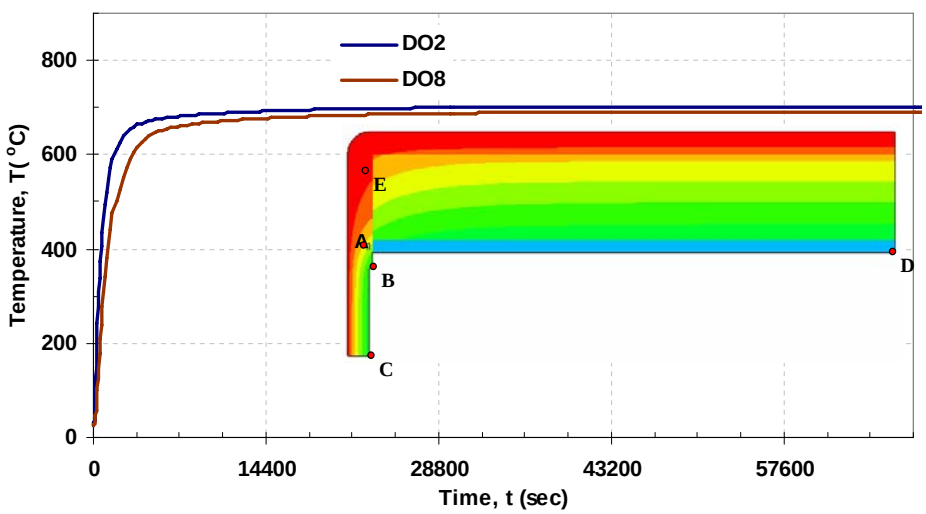


Temperature vs. Time at point A



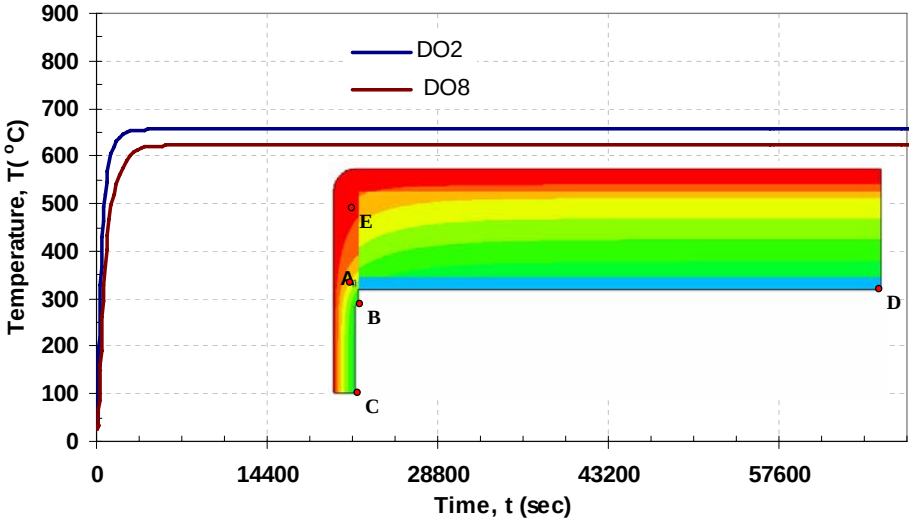
- Temperature reaches steady state after 13 hours – DO2
- Temperature reaches steady state after 16 hours – DO8

Temperature vs. Time at point B



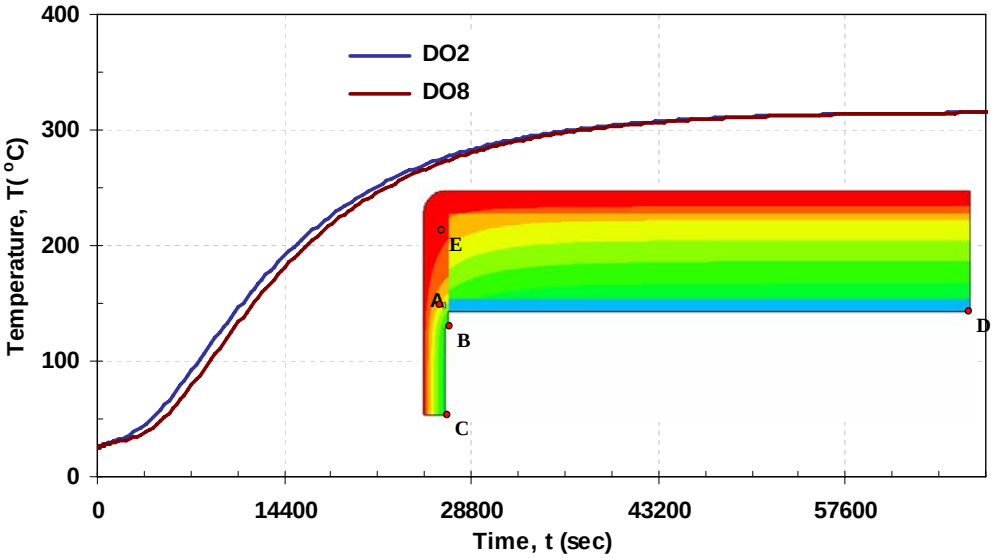
- Temperature reaches steady state after 11 hours – DO2
- Temperature reaches steady state after 14 hours – DO8

Temperature vs. Time at point C



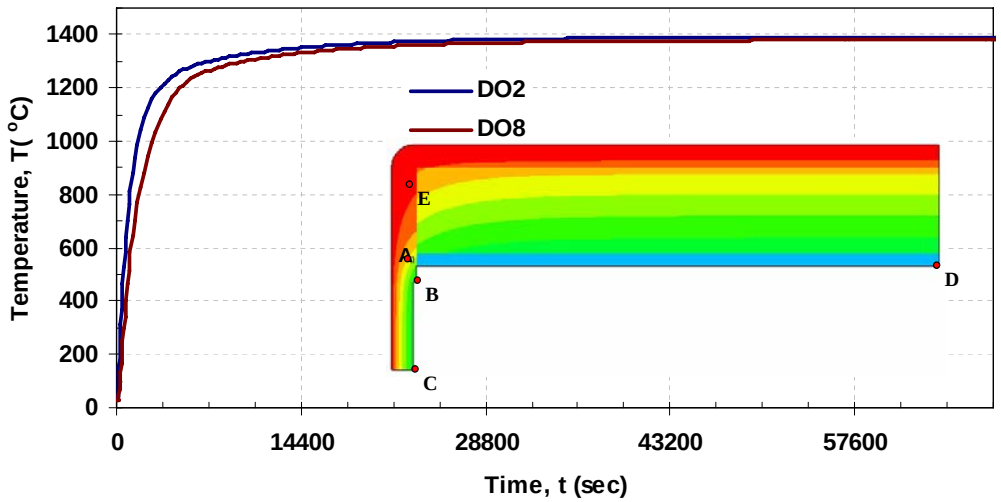
- Temperature reaches steady state after 1 hour – DO2
- Temperature reaches steady state after 1:40 hours – DO8

Temperature vs. Time at point D



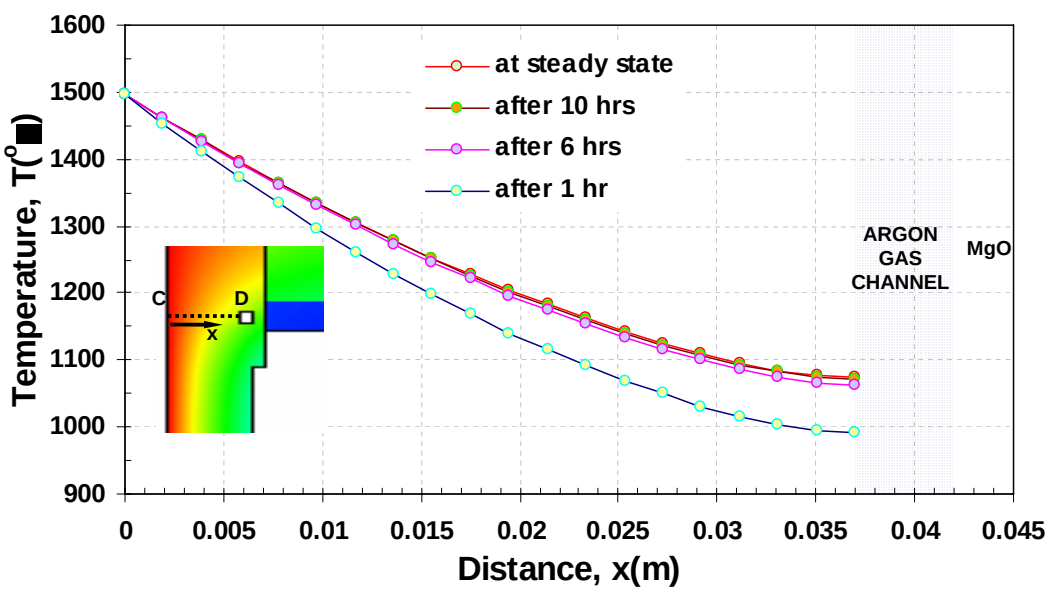
- Temperature reaches steady state after 20 hours – DO2
- Temperature reaches steady state after 22 hours – DO8

Temperature vs. Time at point E

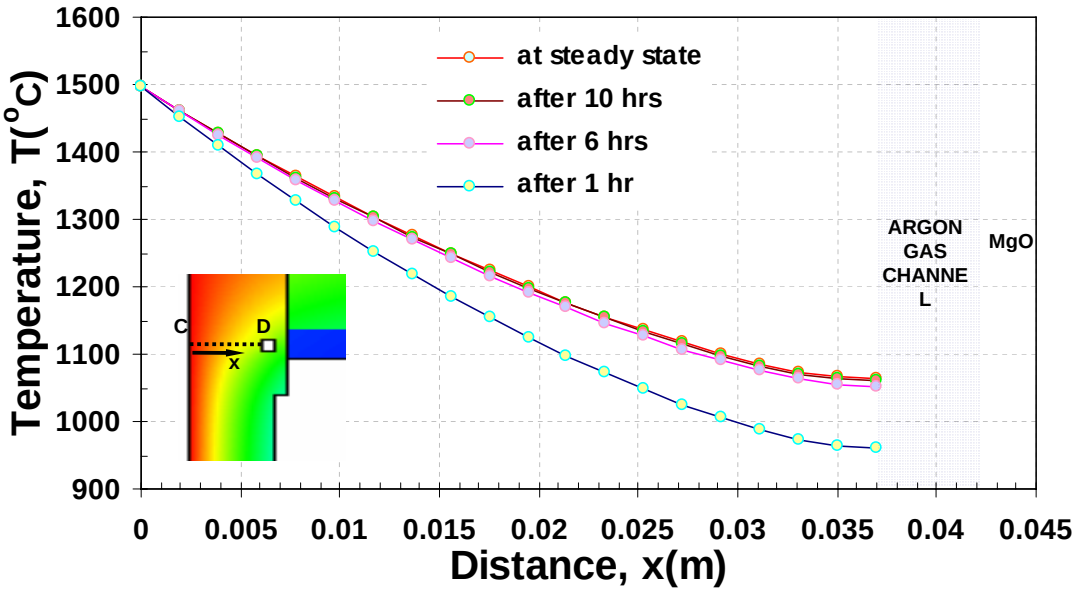


- Temperature reaches steady state after 15 hours – DO2
- Temperature reaches steady state after 17 hours – DO8

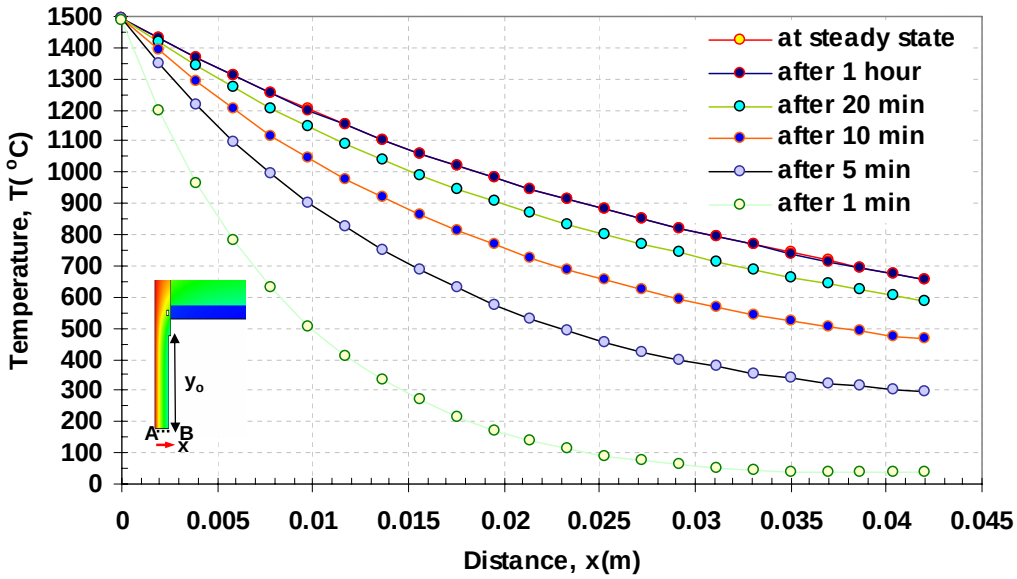
Temperature distribution along CD at different times (DO2)



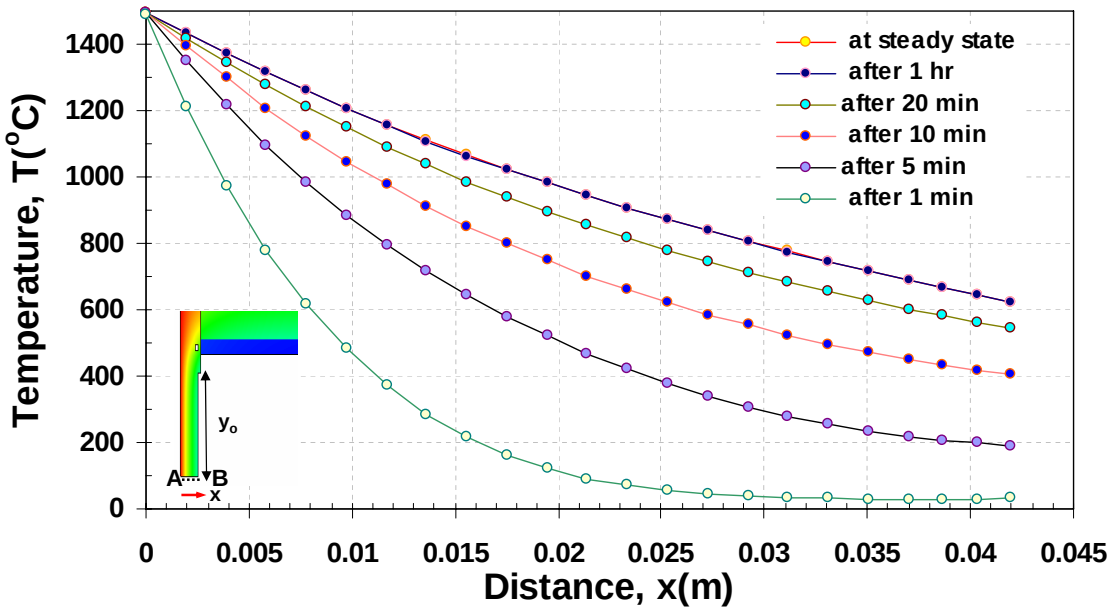
Temperature distribution along CD at different times (DO8)



Temperature distribution along AB at different times (DO2)



Temperature distribution along AB at different times (DO8)



Conclusions

- Tundish steel bottom (point D) reaches a steady state temperature of 316 °C after 20 hours (for DO2) of operation.
- This clearly proves that, in reality, the process is always transient.
- Use of DO8 instead of DO2 increases the time required to reach steady state and further decreases the tundish wall temperatures.

Acknowledgements

- Continuous Casting Consortium Members (Nucor, Postech, LWB Refractories, Algoma, Corus, Labein, Mittal Riverdale, Baosteel, Steel Dynamics)
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