Heat transfer, fluid flow & solidification modeling of Twin Roll Casting process

Yuvaraj G. Patil and Ajay K. Shukla

Department of Metallurgy and Materials Engineering,

Indian Institute of Technology Madras, 600036

patilyuvrajg@gmail.com and shukla@iitm.ac.in

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Introduction

Horizontal Twin Roll Casting (HTRC) is an energy efficient process. HTRC process is modeled to get thin strips of alloy like Al, Mg, steel etc.

The transport phenomenon is applied to Twin Roll Casting (TRC) domain, in order to understand fluid flow, heat transfer and solidification behavior of metal flow. The governing equations of continuity, momentum and energy are solved with help of ANSYS® FLUENT® software package. The focus of this study is to predict Temperature of solidified strip at outlet of domain by changing various input/process parameters. Changes in input parameters like inlet Temperature, roll velocity, setback distance etc. having its effect on changes in mushy zone length, outlet temperature etc.

Geometry and computational domain

Figure 1 shows 2D schematic of a horizontal twin roll caster

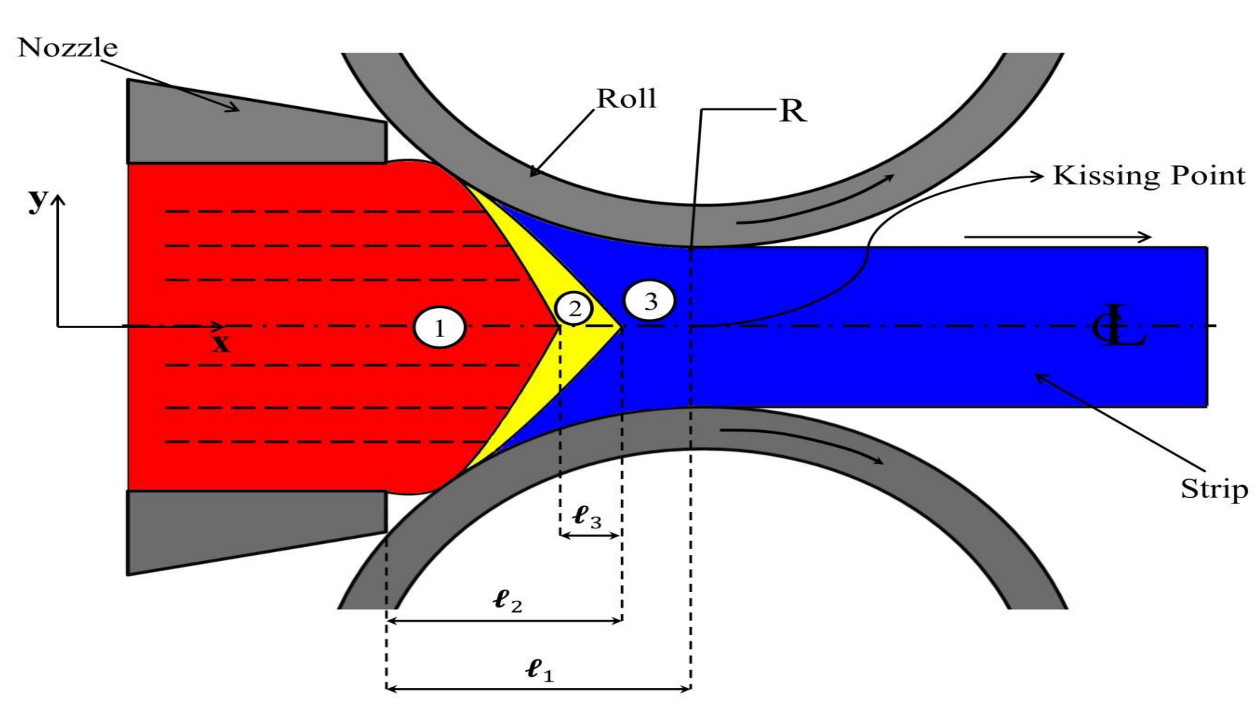

Fig. 1 Schematic of the twin roll casting process; region 1 is the liquid metal, region 2 is the mushy zone and region 3 is the solid strip, ℓ1, ℓ2 and ℓ3 are set-back distance, sump depth and mushy zone thickness, respectively. Note: The perspective of the TRC is not to scale and the nozzle size and position are magnified with respect to the rolls.

Governing equation's

- Mass conservation equation:

$$\frac{\partial}{\partial x_j}(\rho u_j) = 0$$

- Momentum conservation equation :

$$\frac{\partial}{\partial x_j}(\rho u_i u_j) = \rho g_i + \frac{\partial}{\partial x_j}\left(\mu \frac{\partial u_i}{\partial x_j}\right) - \frac{\partial p}{\partial x_i}$$

- Energy conservation equation :

$$\frac{\partial}{\partial x_j}(\rho u_j C_P T) = \frac{\partial}{\partial x_j}\left(k \frac{\partial T}{\partial x_j}\right)$$

- Enthalpy-porosity sink term :

$$-C\frac{(1-f_l)^2}{f_l^3+\varepsilon}(u_j - u_{r,j})$$

- Latent heat formulation :

$$H = H_{ref} + \int_{T_{ref}}^{T} C_P \, dT$$

where the subscripts i and j show directions,
u : velocity vector (m/s),
ρ : density (kg/m³),
g : gravity vector (m/s²),
μ : dynamic viscosity (Pa.s),
p : pressure (Pa),
Cp : specific heat capacity(J/kg°C),
k : thermal conductivity (W/m°C),
T : temperature (°C),
H : the enthalpy (J/kg),
H_{ref} : latent heat of fusion (J/kg),
T_{ref} : solidus temperature (°C),
C : Mushy zone parameter,
f_l : liquid fraction,
$u_{r,j}$: Pull velocity,

Thermo-physical properties & process parameters

Property	Value/ function	Parameter	Value/ function
Density ρ (kg/m³)	$(\rho_s - \rho_l) * f_s + \rho_l$	Roll diameter (m)	0.355
latent heat of fusion H (J/kg)	3,40,000	Inlet Temperature (K)	930
specific heat capacity Cp (J/kgK)	$C_l + L/(T_s - T_l)$	Exit strip thickness (m)	0.006
Thermal conductivity k (W/mK)	$(K_s - K_l) * f_s + K_l$	Roll velocity (m/min)	1.7
T_{sol} (K)	848	Length of cast-roll zone (m)	0.0375
T_{liq} (K)	903	Heat transfer coefficient (w/m²K)	20,000

Boundary conditions

- Inlet :

  $V_x = V_{in}$, $V_y = 0$, $T = T_{melt}$

- Inlet Nozzle surface :

  $V_x = V_y = 0$,

  $\partial T/\partial y = 0$,

- Roll interface :

  Convection heat transfer with HTC = 20,000 W/m°K ,

  Roll surface temperature T_{roll}= 333 K ,

  V_{roll} = Roller velocity (Rad/s) ,

- Outlet :

  $V_x = V_{roll}$, $V_y = 0$,

Predicted Temperature plots

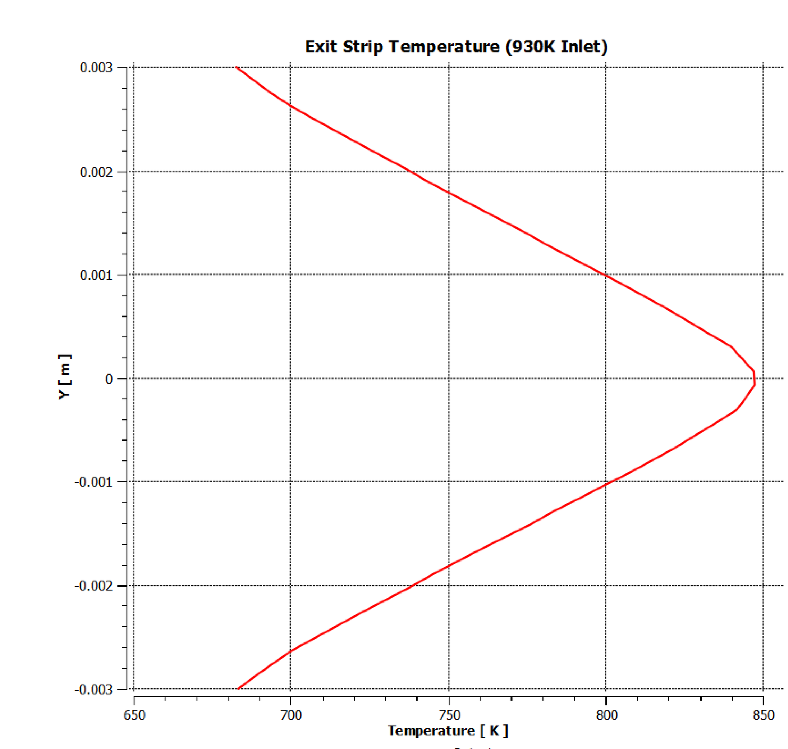

Fig.2 : Temperature distribution at roller exit

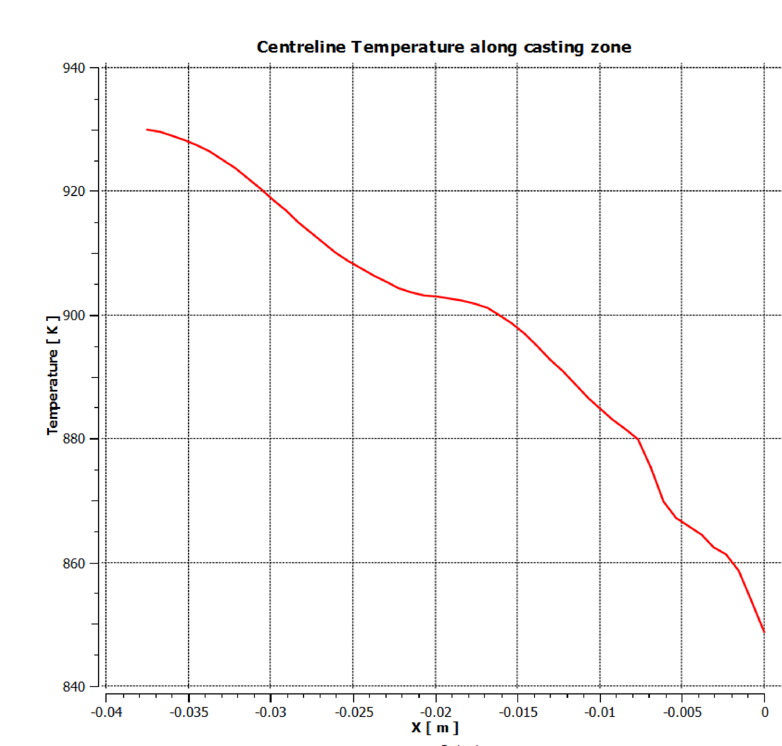

Fig.3 :T emperature distribution along centreline of casting zone

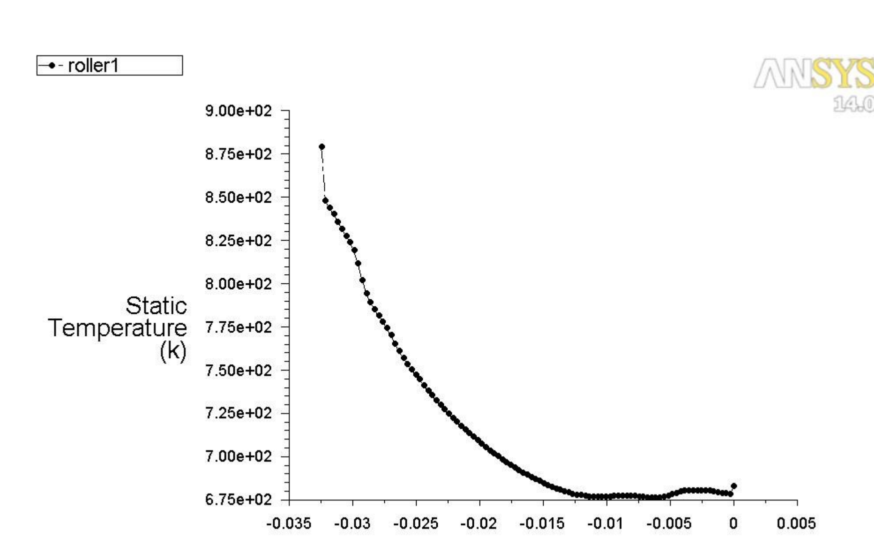

Fig.4 : Temperature distribution along roller surface

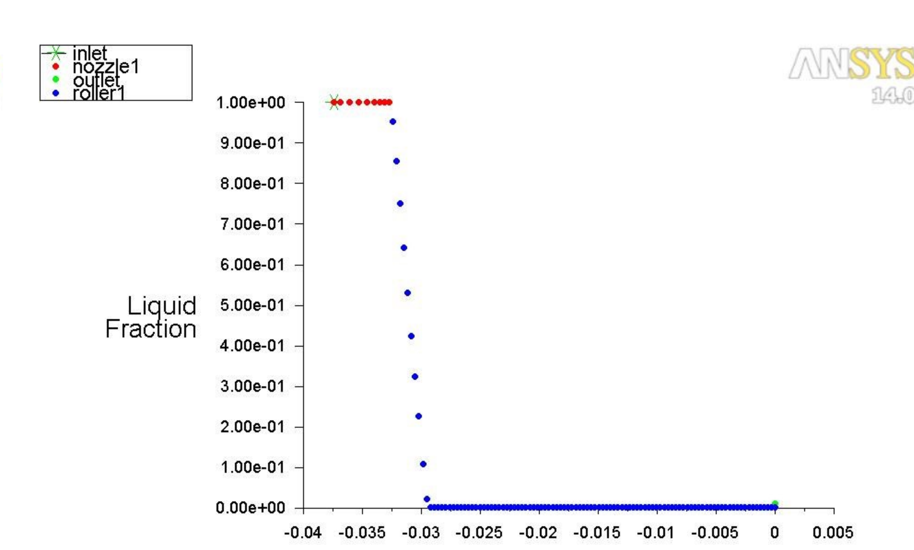

Fig.5 : Fraction of liquid before solidification.

Conclusion & Future work

Conclusion :

The prepared numerical model works according to experimental data obtained from literature. The input parameters like melt temperature, setback distance and rolling velocity has impact on outlet strip temperature and therefore controls microstructural properties.

Future work:

Numerical result's will be correlated with input parameters, to find how it controls segregation, microstructure and secondary arm spacing of cast strip.

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