MSE629
Physical and Mathematical modelling of steelmaking processes

ASSIGNMENT-4
Metallurgical Performance Analysis in Steelmaking Tundish Using CFD

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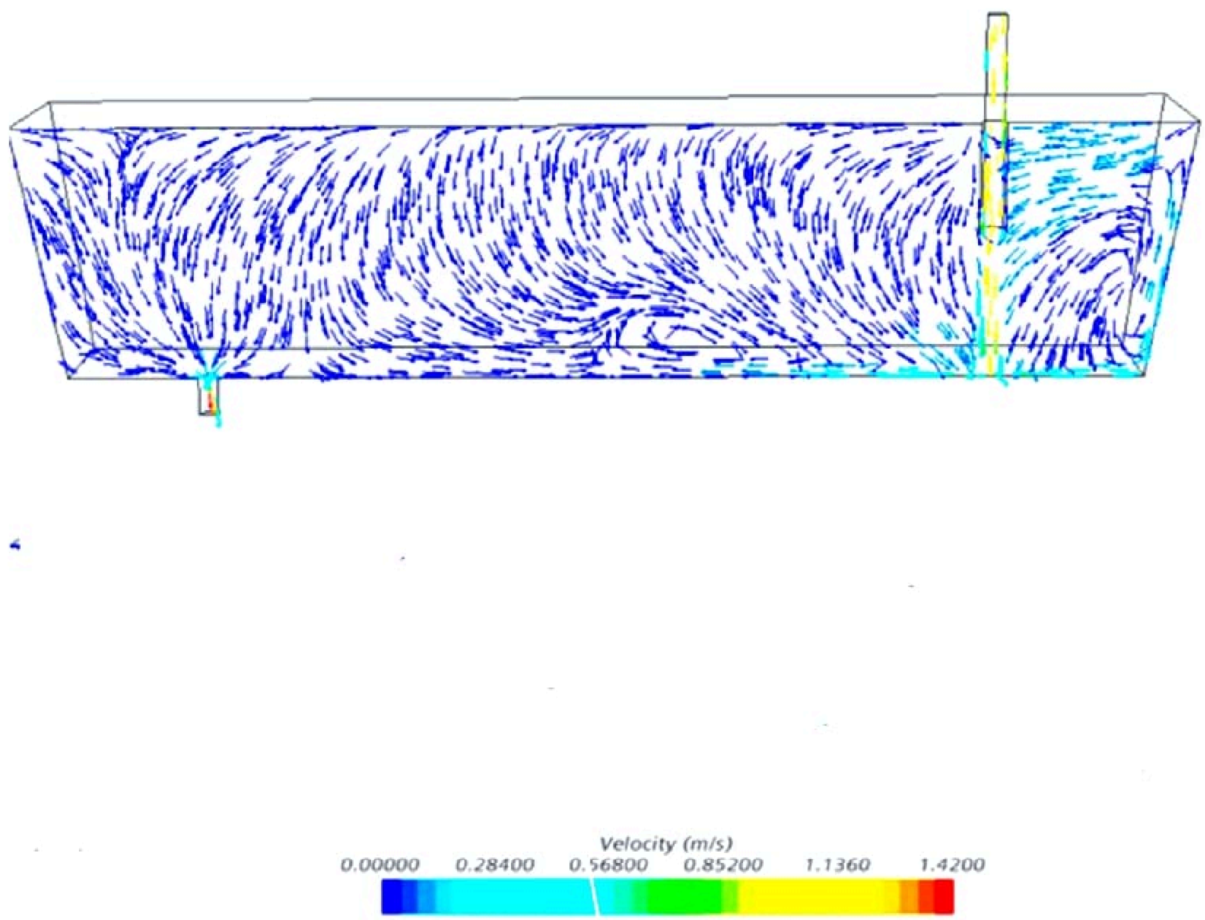
Objective:

1. Understand how water moves through a scaled-down tundish model to represent the flow of molten steel in the actual steelmaking tundish
2. Calculate how long the water stays inside the tundish to assess whether the flow allows for proper mixing and processing.
3. Identify areas of poor or ideal flow, which can impact the quality of steel by affecting thermal control and impurity removal.
4. Use the flow and residence time data to suggest design improvements or flow modifiers that can enhance steel quality and processing efficiency.

1. Estimate the volume of liquid in the tundish at steady state and hence, calculate theoretical or nominal residence time (= volume of tundish/ volumetric flow rate) numerically



Boundary Conditions

- **Inlet Conditions**:

  Velocity: Uniform inlet velocity of 0.1273 m/s .

  Temperature: Inlet temperature of 25C

- **Outlet Condition**:
  - **Velocity**: Uniform inlet velocity of 0.0425 m/s .
  - **Temperature**: Inlet temperature of 25C.

- **Fluid Domain**:
  - Newtonian, incompressible fluid with constant density and viscosity.The flow is assumed to be laminar and steady, so the velocity and pressure

Height of liquid = 17.5cm

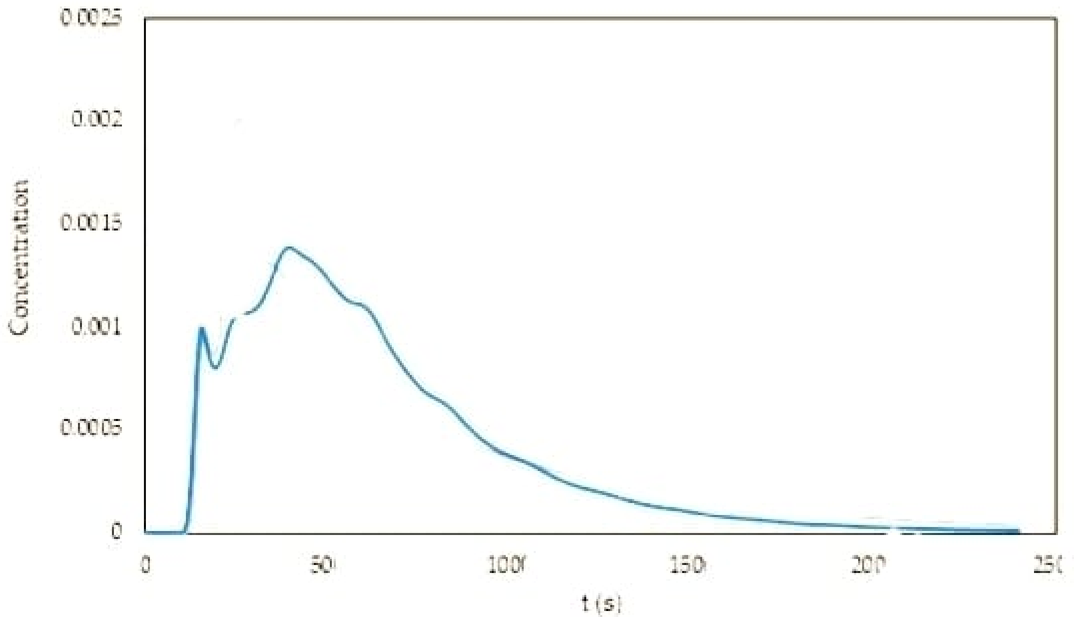
Volume of Liquid at steady state = 0.18x0.12x0.63 = 0.01332m^3

volumetric flow rate = pi x r^2 x v = 0.000224 m^3/sec

theoretical residence time = 89 sec

nominal residence time = 57sec

II.For the given problem, plot concentration (exit) as a function of time and note the minimum break through time (i.e., the time taken by the tracer to reach the probe tip) as well as the time at which the probe registers maximum concentration.



Minimum break through time = 9.8 sec
Time at which the probe registers maximum concentration= 48 sec

(iii) . Approximate the curve suitably and integrate (upto 2 times the mean residence time τav. to determine the numerical mean residence time.

1. **Estimate the Curve:** We can approximate the shape of the concentration vs. time curve by assuming a mathematical function that resembles its form. A commonly used approximation is an exponential decay function, especially since the concentration gradually decreases after a peak. However, if you have a specific function form or data points, we can use those for a better fit.

Exponential decay function form:

C(t)=C’e−λtC(t)

Where:

C(t) is the concentration at time ttt,

C’ is the initial concentration,

λ is the decay constant, and

t is time.

2. **The mean residence time** is generally calculated by integrating the area under the concentration vs. time curve from to infinity and then dividing by the total concentration (or mass).

   By calculation **mean residence time = 58 sec**

IV.. From 2 and 3 above, calculate the proportions of dead, well mixed and dispersed plug flow volumes

1. The **dead volume** is the area under the concentration vs. time curve from **0 to 9.8 seconds**. In this period, the concentration remains close to zero or negligible.

2. **Dispersed Plug Flow Volume** = 2 × τ_av = 2 × 58 sec = 116 sec

3. **Well-Mixed Volume: =** 0.3293

   This is the area between the breakthrough time (9.8 sec) and the peak concentration time (48 sec)

Summary of Proportions:

1. **Dead Volume**: 8.45%
2. **Well-Mixed Volume**: 32.93%
3. **Dispersed Plug Flow Volume**: 58.62%

V. Based on steps 2, 3 and 4 draw some inferences on the metallurgical performance of the industrial scale tundish system.

Dead Volume (8.45%):

- **Impact**: Poor inclusion removal, inefficient slag removal, and potential temperature gradients.
- **Recommendation**: Minimise dead zones using flow modifiers to improve mixing and inclusion removal.

Well-Mixed Volume (32.93%):

- Fluid in this region is well-mixed, ensuring uniform temperature and composition.
- **Impact**: Better inclusion float-out, effective slag emulsification, and stable thermal conditions.
- **Recommendation**: Aim to maximise the well-mixed volume for better steel quality and efficient slag removal.

Dispersed Plug Flow Volume (58.62%):

- Steady but slightly dispersed flow, suitable for consistent movement towards the mold.
- **Impact**: Allows for smooth flow but with reduced mixing, potentially leading to slower inclusion removal.

- **Recommendation**: Improve mixing to ensure faster inclusion removal and better temperature uniformity.

Observation:

1. Focus on enhancing well-mixed regions and reducing dead zones by optimizing tundish design with baffles and dams.
2. Improve thermal mixing to avoid temperature gradients and improve solidification consistency.
3. Ensure better inclusion and slag removal by promoting more uniform flow throughout the tundish.

Comparison of Values:

As the fluid flows through the pipe, it absorbs heat from the wall, leading to a gradual increase in temperature until it approaches the wall temperature. Initially, there is a significant temperature gradient; however, as the fluid continues to travel, its average temperature asymptotically approaches the wall temperature. Ultimately, the exit temperature stabilises around 347 K.