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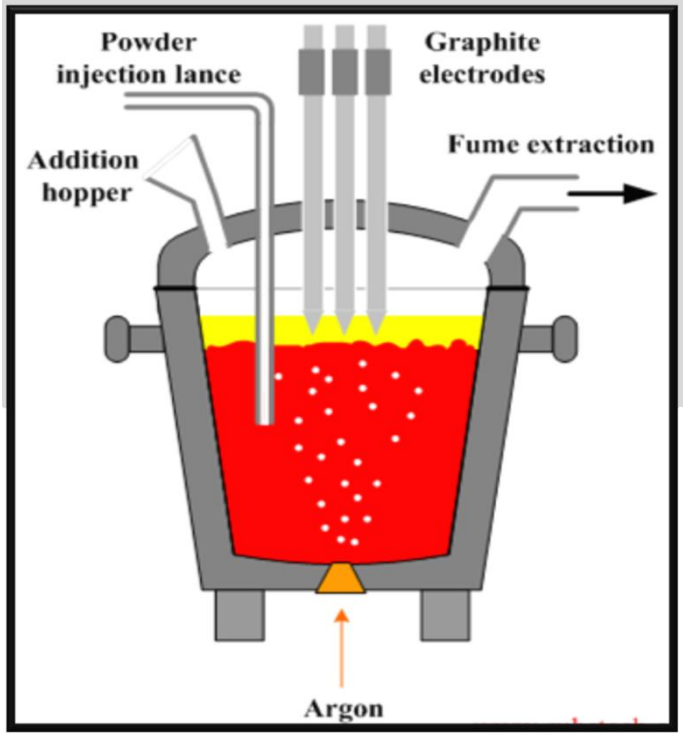
Implementation of Double Porous Plug Gas Stirring in Steel Ladles to Improve Gas Stirring Efficiency and Increase Ladle Lining Life



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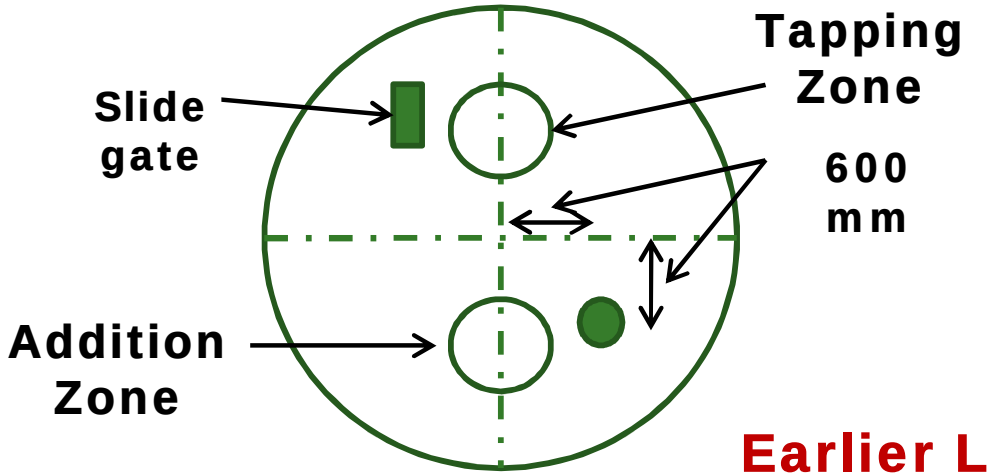
Background

- Durgapur Steel Plant uses a 120T ladle with single porous plug for gas stirring
- To improve steel quality feasibility of 2 porous plug for gas stirring was explored.
- Improvement in refractory ladle life with introduction of second porous plug expected
- Numerical and physical modeling techniques used for finalization of position of second porous plug.
- Plant trial carried out with modification in one steel ladle to ascertain the results.



Earlier Layout

Gas Stirred Ladle Refining

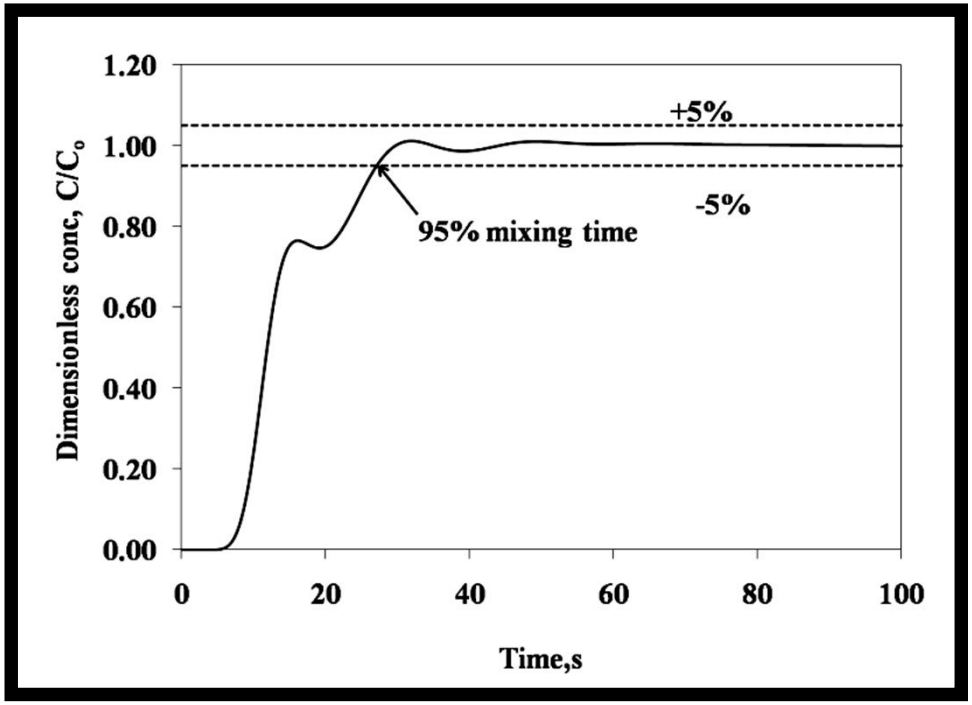
- **Ladle refining technique employs metallurgical processes of**
  - **Control of alloy melting process in the liquid bath to improve its recovery**
  - **Mixing and homogenization of liquid bath**

- **Gas purging through the bottom of the steel ladle is an effective method employed to enhance**
  - **Melting and dissolution of alloys**
  - **Improve chemical reaction rates, mixing and homogenization**
  - **Remove inclusions to produce clean steel**

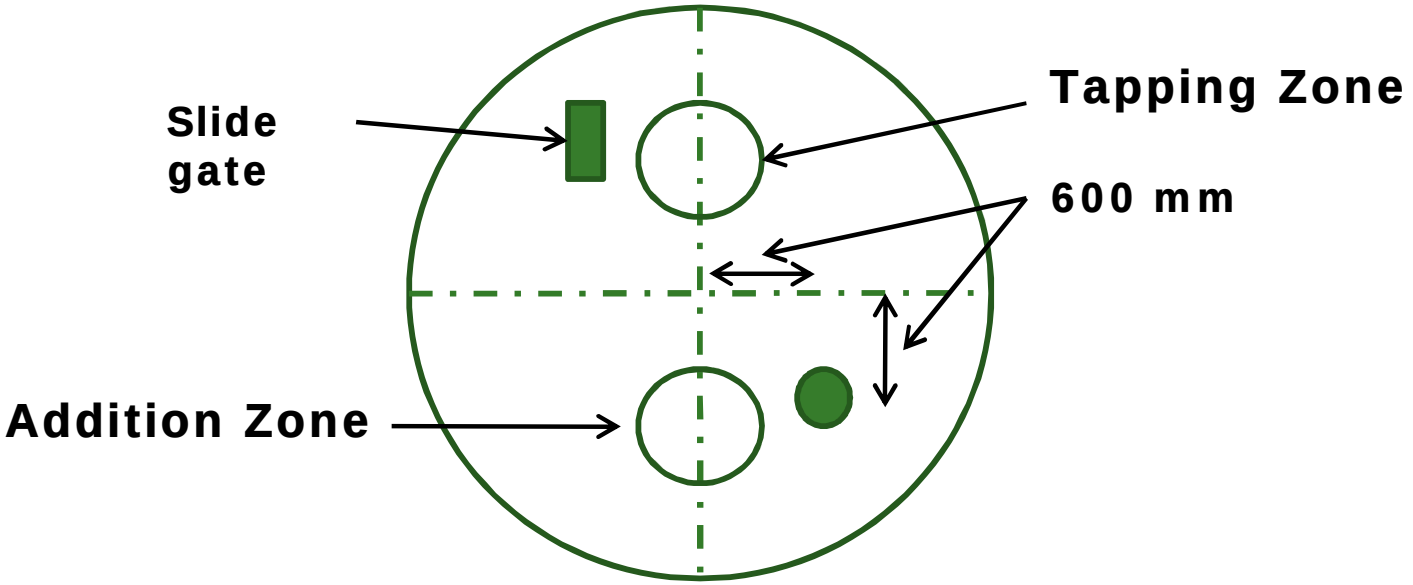
Melting and Mixing in Ladle

- **Alloy addition and melting process in the liquid steel consists of two main parts**
  - **Melting of solid alloy substances in the liquid steel.**
  - **Mixing of the molten and dissolved alloy within the liquid steel**

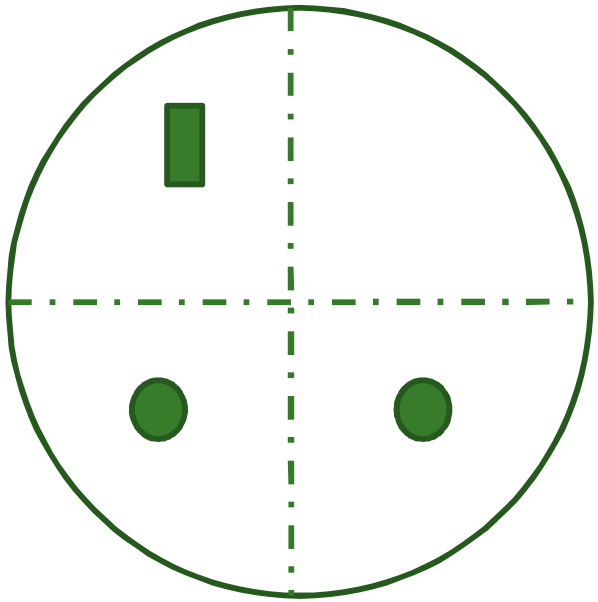
- **The efficiency of a gas stirred ladles can be quantified in terms of "mixing time" which is defined as**
  - **The time required for achieving 95% homogeneity in the ladle due to flow conditions.**



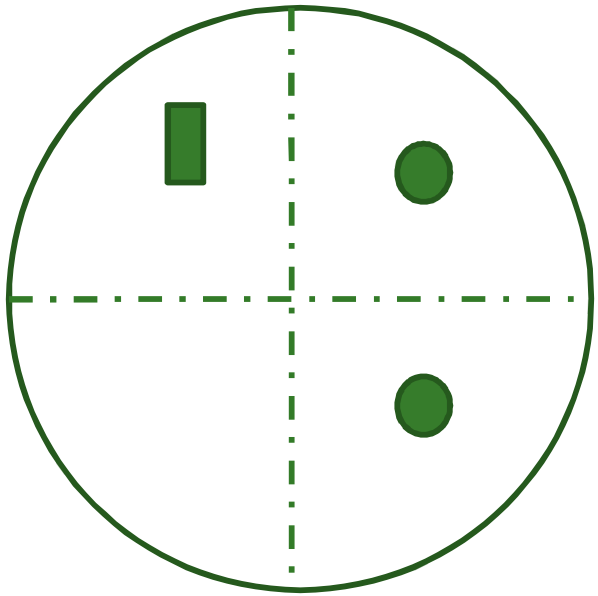
Single vs Double Porous Plug



Current Layout



Double Porous Plug layout Option 1

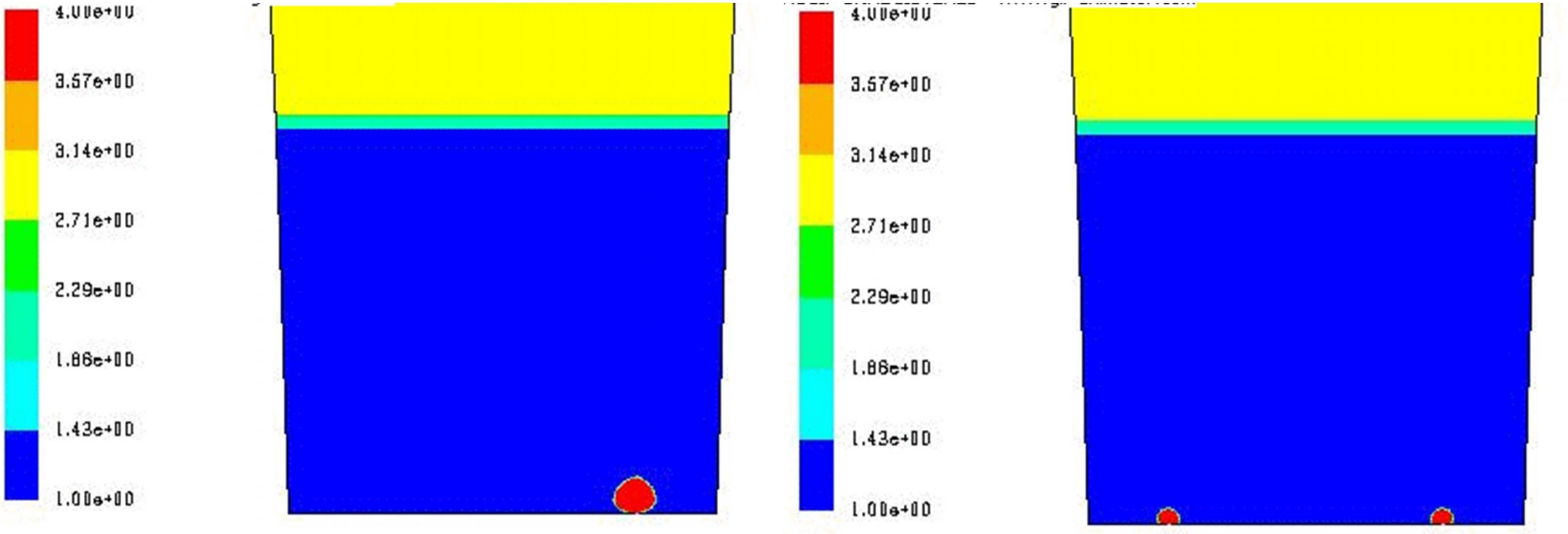


Double Porous Plug layout Option 2

Porous Plug Arrangement

- Double PP Layout Option 2 can result in adverse effect of refractory of tapping zone. Not considered for further analysis.
- Physical and Mathematical modeling technique applied to ascertain differences between single and double porous plug layout for Option 1.
- Wall Shear stress profiles in numerical model has been monitored to determine possible effect of ladle wall refractory life.
- Total flow rate of gas going inside ladle in case of both single and double porous plug is kept constant.
- The current arrangement allows for introduction of gas with asymmetric flow conditions

Mathematical Model – Distribution of Phases

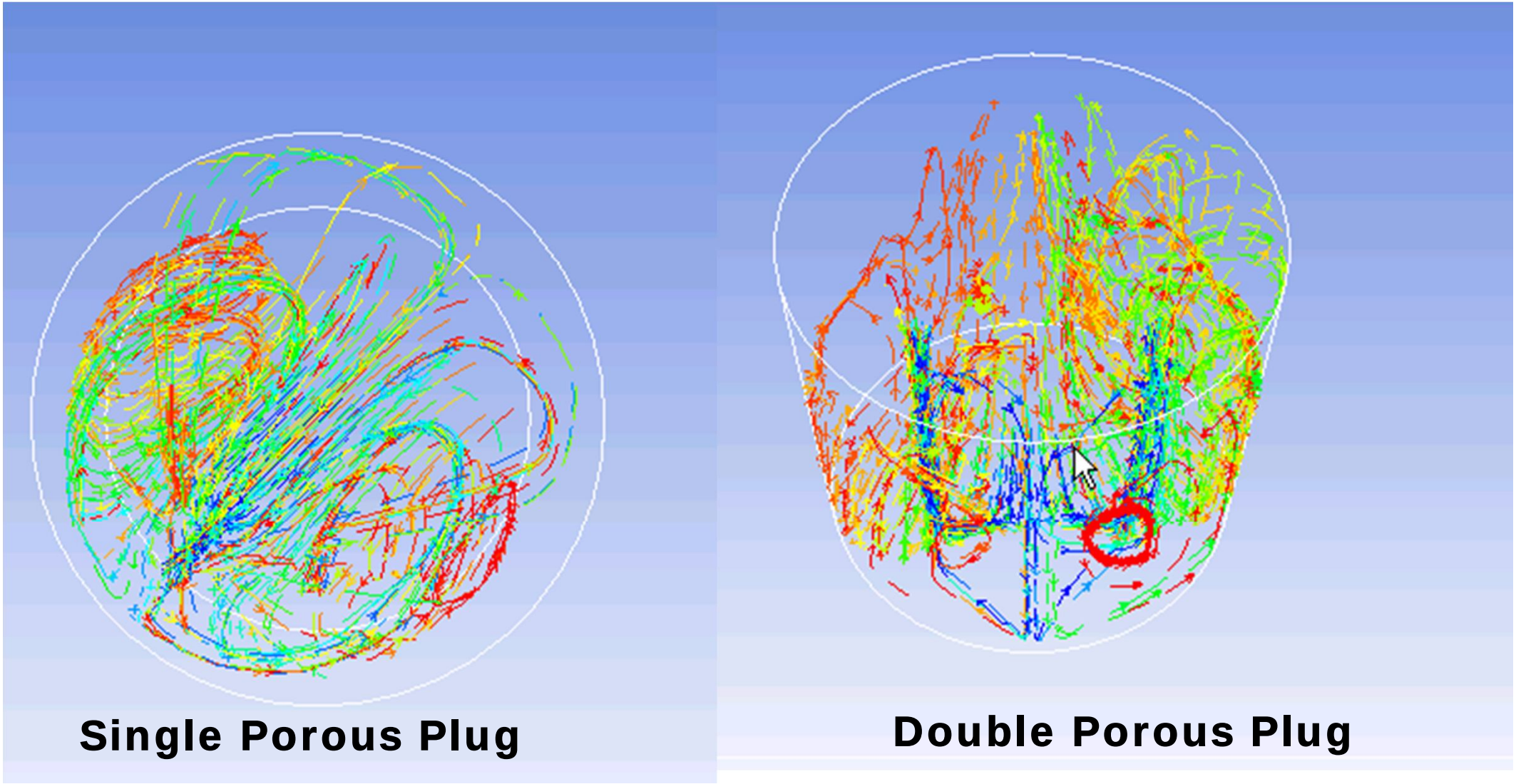


Single Porous Plug **Double Porous Plug**

Steel **Slag** **Argon** **Air**

Slag layer (Light Blue – color) pushed towards one side in Single Porous Plug configuration

Mathematical Model – Streamlines

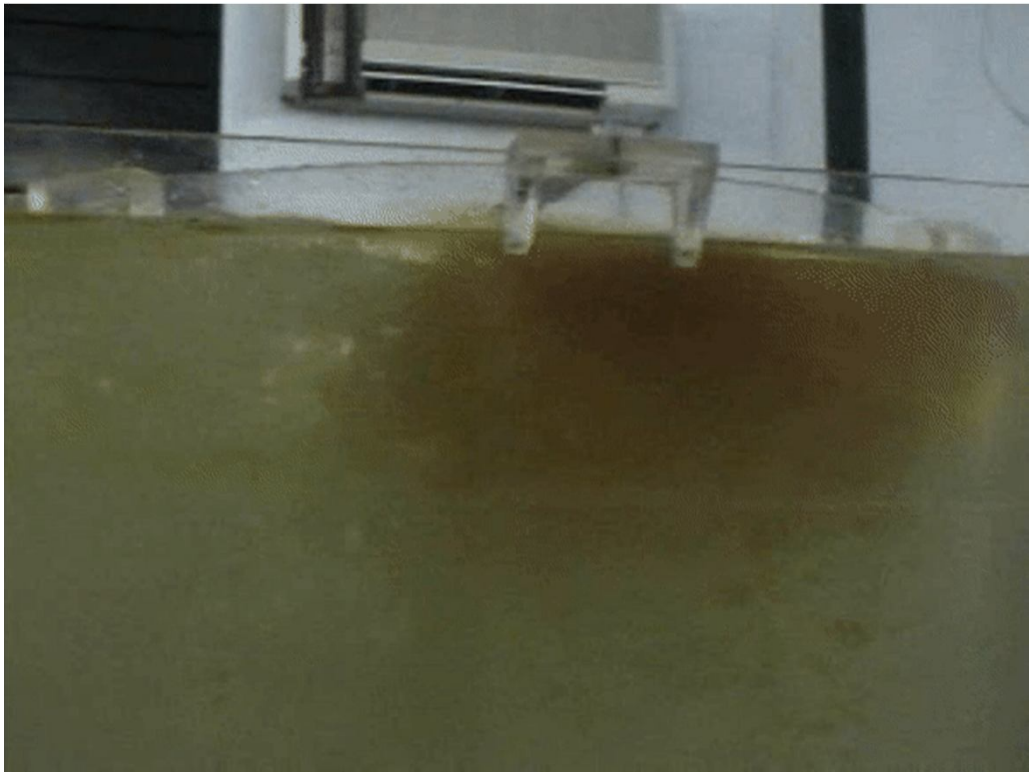


Single Porous Plug

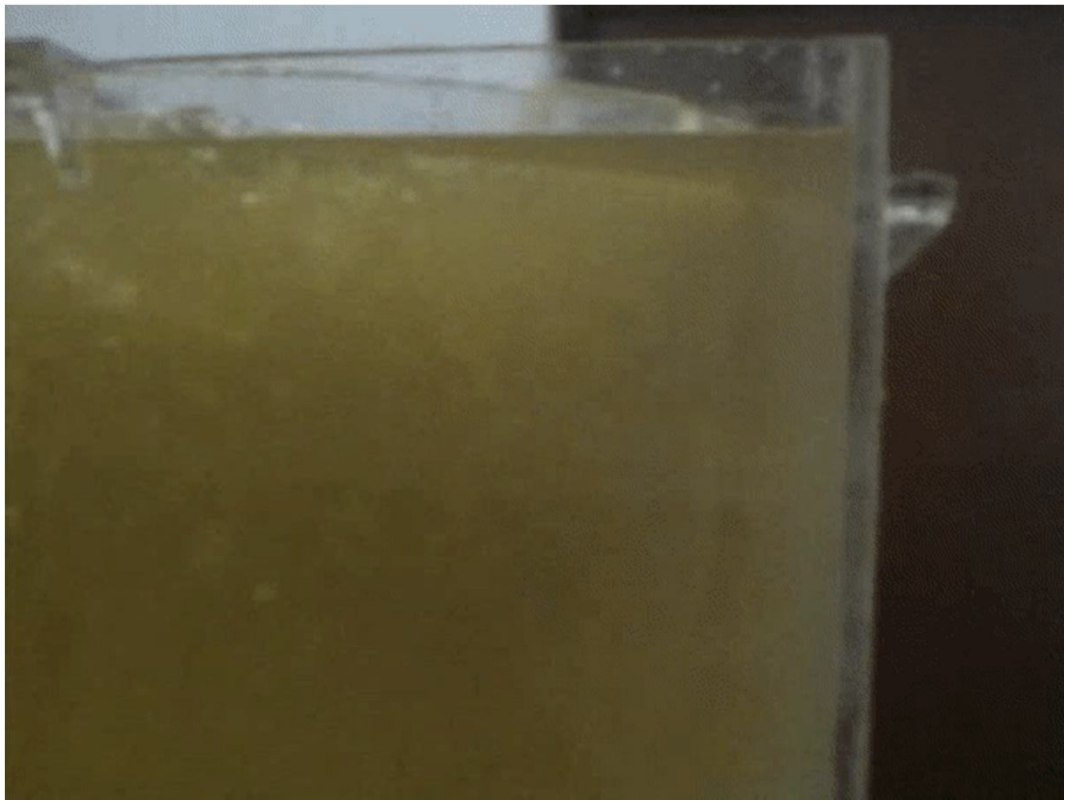
Double Porous Plug

Flow separation in two separate recirculating loop in Single Porous Plug.

Physical Modeling- Results



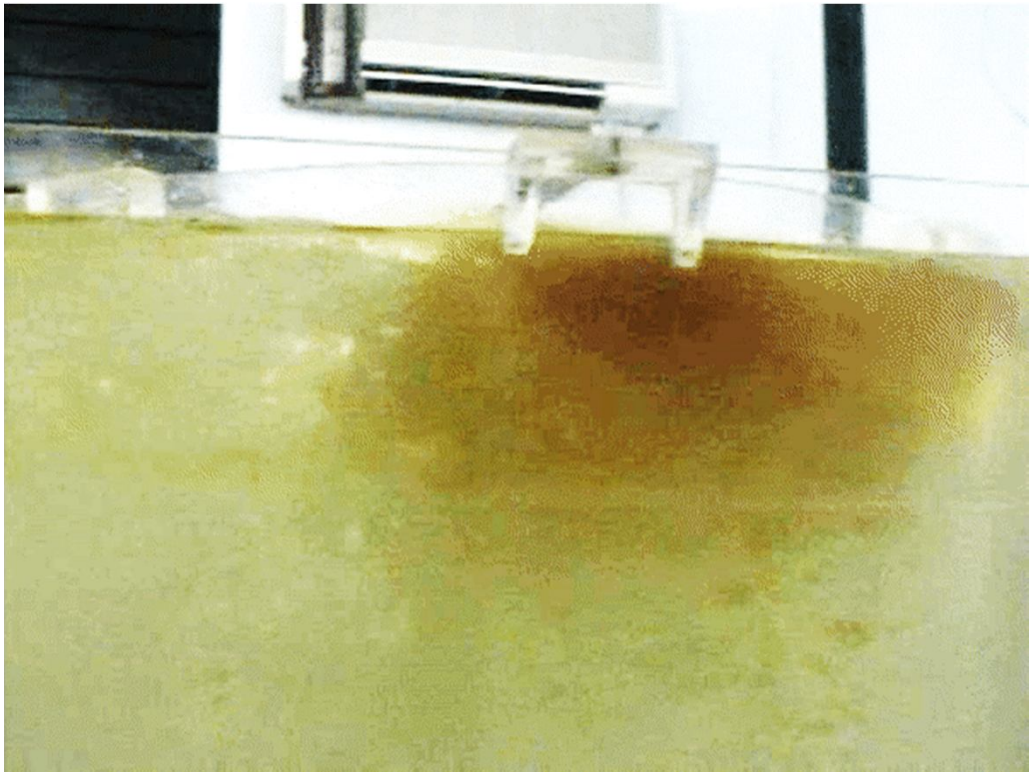
Single Porous Plug



Double Porous Plug

Slag (Dark patch) pushed towards one side in Single Porous Plug configuration

Physical Modeling- Results

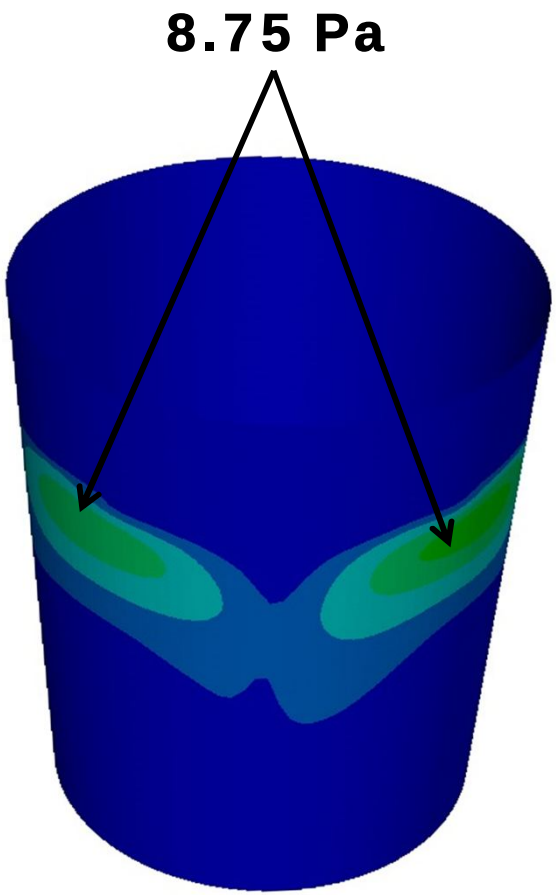


Single Porous Plug

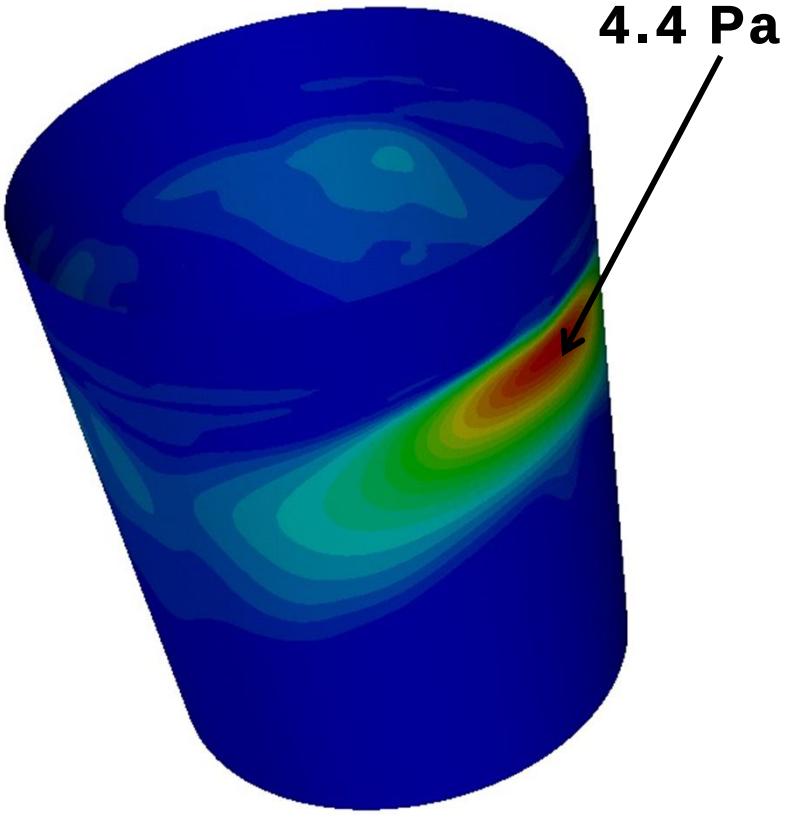
Double Porous Plug

Slag (Dark patch) pushed towards one side in Single Porous Plug configuration

Wall Shear Stress – Lining Erosion



Single Porous Plug



Double Porous Plug

Higher shear stress is an indication of higher refractory erosion and lower lining life.

Modification in Steel Ladle

Modified Steel Ladle with both Porous Plugs at Durgapur Steel Plant

Results: Ladle Life

Refractory Supplier	Ladle Life
S1	55
S1	51
S1	52
S1	54
S2	71

Average lining life recorded 56.6 heats in 5 campaigns

Results: Inclusion Volume Fraction

Ladle with Double Porous Plug		Ladle with Single Porous Plug	
Heat No	Incl. Vol. Frac	Heat No	Incl. Vol. Frac
01a	0.13	01b	0.32
02a	0.32	02b	0.31
03a	0.18	03b	0.28
04a	0.08	04b	0.32
05a	0.11	05b	0.33
Average	**0.16**	**Average**	**0.31**

Less inclusion volume fraction → Cleaner Steel

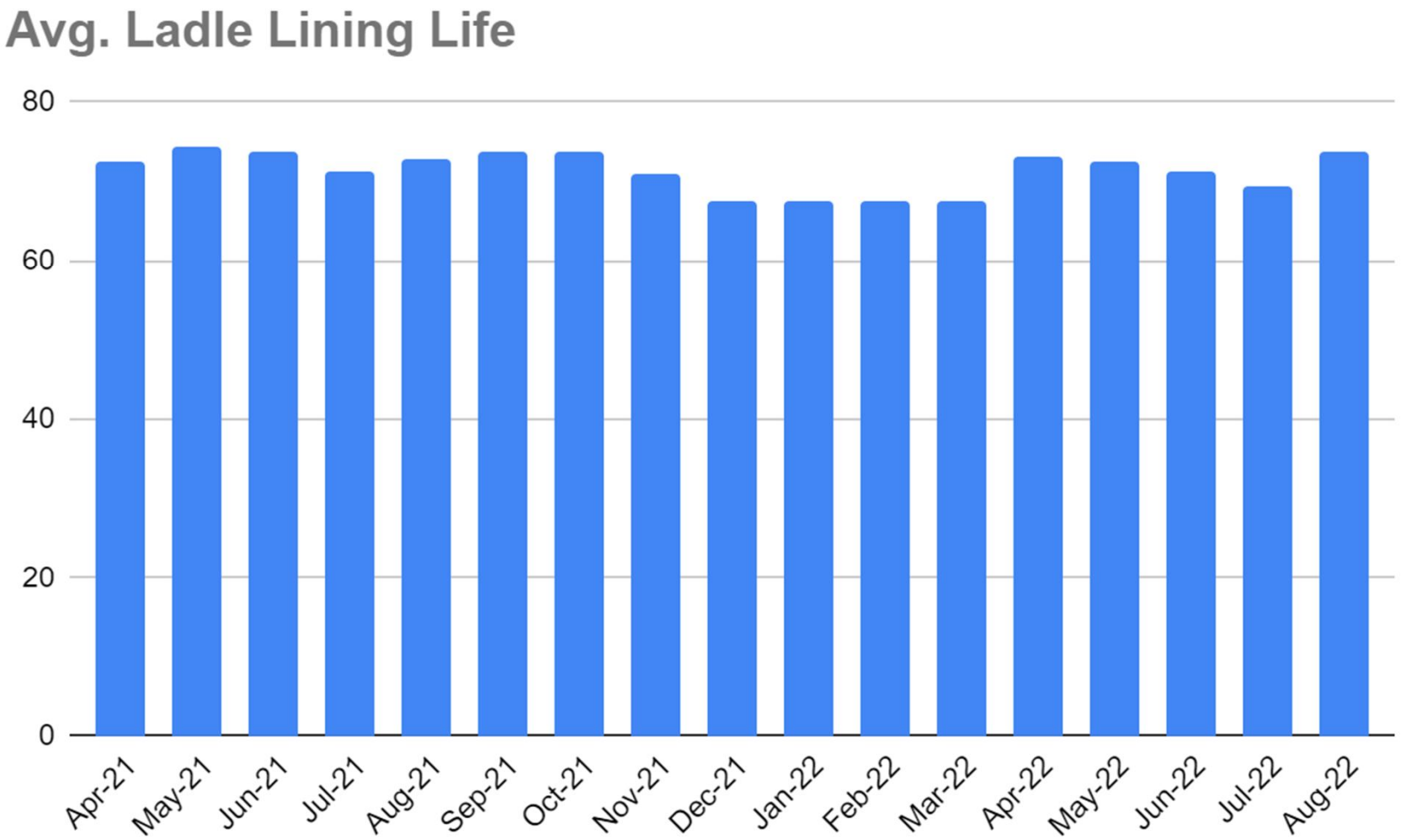
Results: Thermal Homogeneity

Uniformity of steel bath in ladle ascertained using tundish temperature variation

Range	Double Porous Plug ladle	Single Porous plug ladle
Less than 5°C	50.0 % ↑	29.9 %
5 to 10 °C	34.8 %	42.5 %
Greater than 10°C	15.2 % ↓	27.6 %

Higher incidence of lower thermal variations → Better mixing in ladle

Average Ladle Life Over Last Year



Conclusion

- Average ladle treatment time decreased to 45 mins (double PP) compared to 52 mins (single PP).
- Average ladle refractory life in steel ladle increased to 56 heats compared to 44 heats.
- Significant drop in inclusion volume fraction and uniformity in steel bath temperature observed

The present double plug arrangement with asymmetric gas flow leads to better mixing, cleaner steel and improved ladle life


" THANK YOU "
Best replacement of steel is
BETTER STEEL
There's a little bit of SAIL in everybody's life