Characterisation and optimisation of ladle stirring systems for The steelmaking industry
DISSTECH WORK SHOP
Kista 2017-05-23
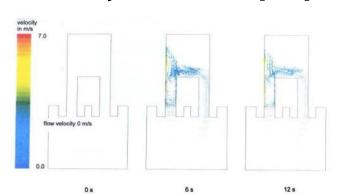
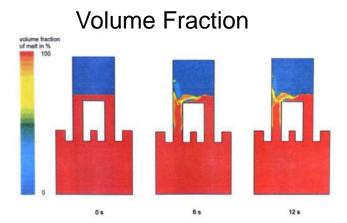jonas.alexis@swerea.se
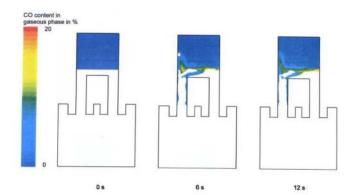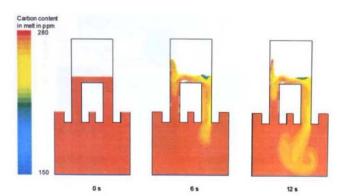
Jonas Alexis

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Control of inclusions in RH degassing processes

Velocity Vector Field [m/s]

Volume Fraction

CO Content in gaseous phases

Carbon content in the melt [ppm]

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Control of inclusion, slag foaming and temperature in vacuum degassing
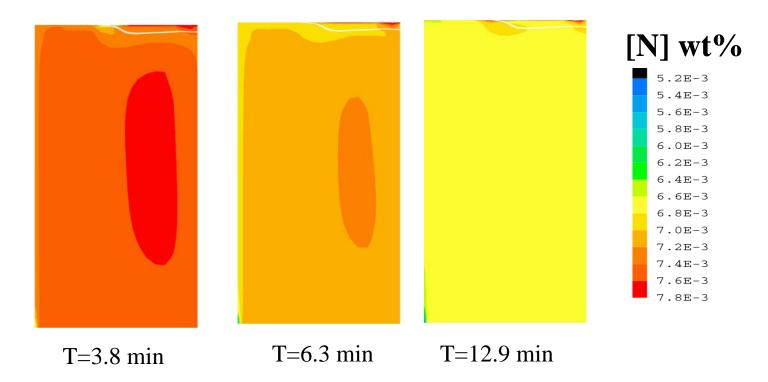
- Open eye size vs. Slag viscosity and flow rate:

Case	Flow rate [l/min]	Slag Thickness [cm]	Slag viscosity [Pa.s]
1	80	10	4.3e-4
2	80	25	4.3e-4
3	80	10	8.0e-3
4	120	10	8.0e-3

$$k_r^N = \frac{0.015 \cdot f^2{}_N}{1 + 161 \cdot a_O + 63.4 \cdot a_S}$$

Q=80 l/min, Slag Thickness: 10 cm, slag viscosity: 4.3e-4 Pa.s

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Production of EAF steels with low content of N2 and S through vacuum treatment
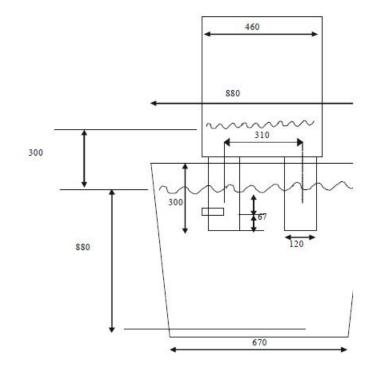
- Concentration profile of nitrogen

[N] wt%

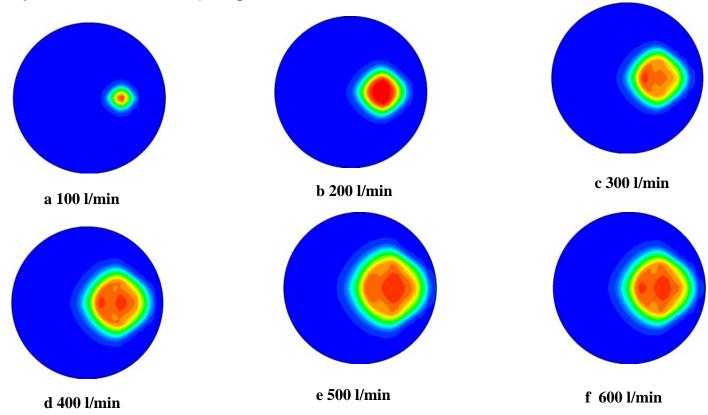|	
■	5.2E-3
	5.4E-3
	5.6E-3
	5.8E-3
	6.0E-3
	6.2E-3
	6.4E-3
	6.6E-3
	6.8E-3
	7.0E-3
	7.2E-3
	7.4E-3
	7.6E-3
	7.8E-3

T=3.8 min   T=6.3 min   T=12.9 min

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Improvment of inclusion floatation during RH treatment

- Geometry and its schematic:

Development of advanced methods for the control of ladle stirring process
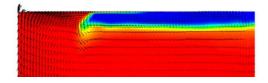
- Open eye for ecentric plug

a 100 l/min

b 200 l/min

c 300 l/min

d 400 l/min

e 500 l/min

f 600 l/min

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Development of advanced methods for the control of ladle stirring process
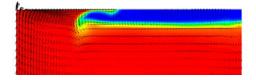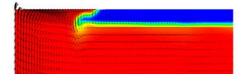
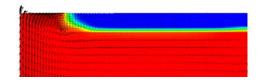- Effects of viscosity on the size of the open eye:
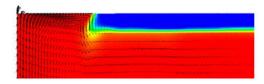
Q=200 l/min, υ (slag) = 4.6e-5 m2s-1
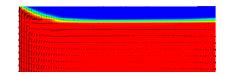

Q=200 l/min, υ (slag) = 4.6e-2 m2s-1

Q=200 l/min, υ (slag) = 4.6e-4 m2s-1

Q=200 l/min, υ (slag) = 4.6e-1 m2s-1

Q=200 l/min, υ (slag) = 4.6e-3 m2s-1

Q=50 l/min, υ (slag) = 4.6e-1 m2s-1

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Development of advanced methods for the control of ladle stirring process
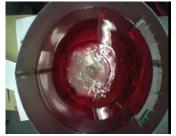
- Water model:
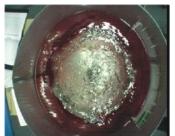
| Q=3.6 l/min | Q=9.2 l/min | Q=25.2 l/min |

oil height: 2 cm, centric plug

| Q=3.6 l/min | Q=7.0 l/min | Q=20.2 l/min |
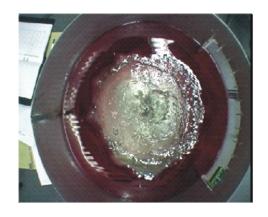
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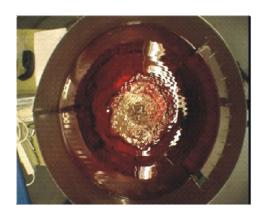
Development of advanced methods for the control of ladle stirring process

- Open eye size vs. Oil height
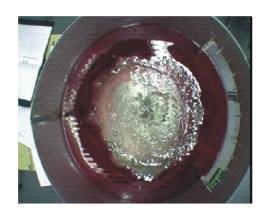
H = 20 mm
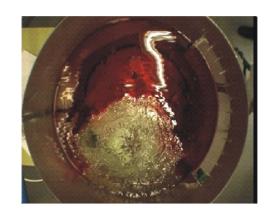
H = 40 mm

gas flow: 3.6 l/min, centric plug

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- Open eye vs. Plug position and number
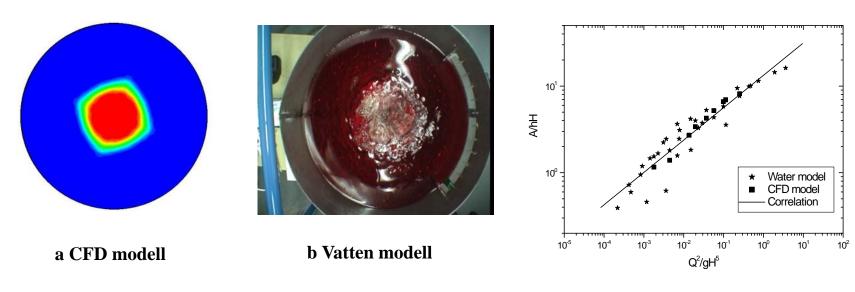
Centric

Eccentric

Double lance
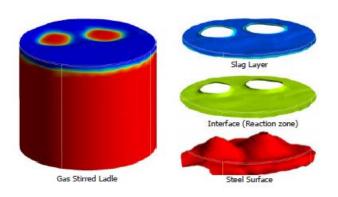
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Development of advanced methods for the control of ladle stirring process

- CFD vs. Water model

a CFD modell

b Vatten modell

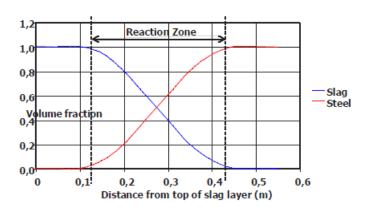gas flow: 7 l/min, centric plug, oil height: 6cm

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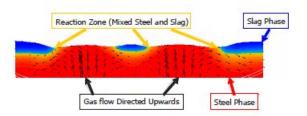
Improved control of inclusion chemistry and steel cleanness in the ladle furnace
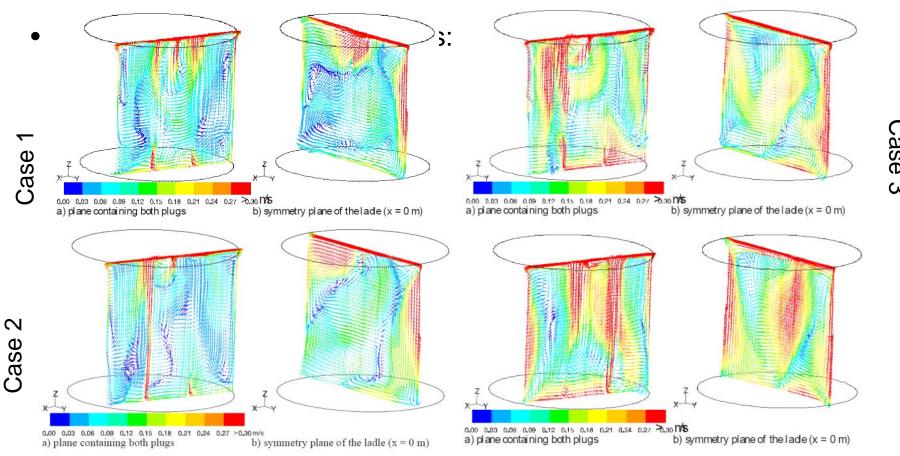
- Slag-metal interface modelling:

Improved control of inclusion chemistry and steel cleanness in the ladle furnace

- Flow profile for different variants:

Case	Plug 1 [l/min]	Plug 2 [l/min]
1	60	60
2	120	120
3	200	200
4	60	200
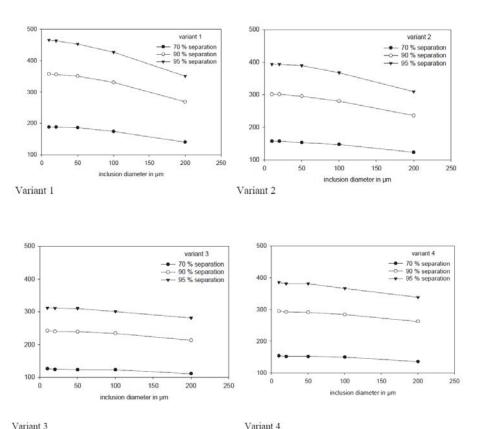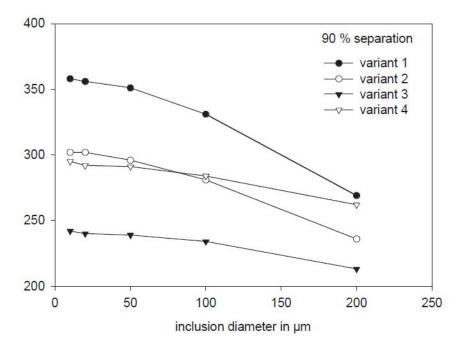
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Improved control of inclusion chemistry and steel cleanness in the ladle furnace

Case 1

Case 2

Case 3

Case 4

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Improved control of inclusion chemistry and steel cleanness in the ladle furnace

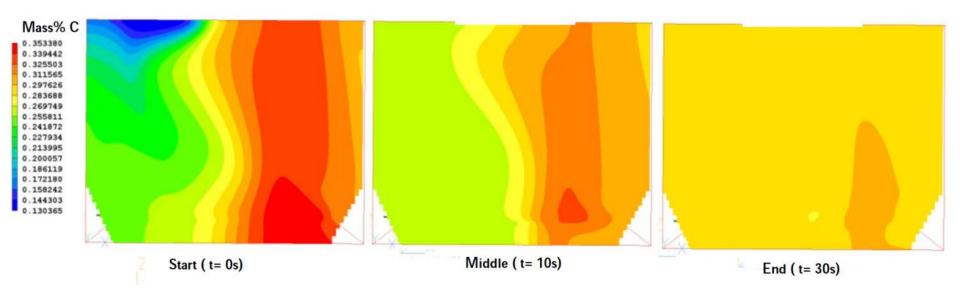- Inclusions separation:

Variant 1

Variant 2

Variant 3

Variant 4

Resource-saving operation of stainless steel refining in VOD and AOD processes

- Distribution of carbon concentrations in % for an AOD heat at start of inert gas blowing, after 10s and after 30s.

Mass% C

0.353380
0.339442
0.325503
0.311565
0.297626
0.283688
0.269749
0.255811
0.241872
0.227934
0.213995
0.200057
0.186119
0.172180
0.158242
0.144303
0.130365

Start (t= 0s)   Middle (t= 10s)   End (t= 30s)

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Summary

- RH degasser:
  - Melt conposition
  - Inclusion model
  - Temperature profile and heat transfer
- Ladle:
  - Stirring: gas and/or industion
  - Arc heating
  - Homogenization
  - Melt composition
  - Inclusion model
- AOD and VOD:
  - Melt composition
  - Temperature profile
  - Decarburization
- The newest simulation work is at least 6 years old!

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Why stirring?

- Improves the kinetics so that equilibrium conditions are met faster
- Homogenization with respect to dissolved elements as well as temperature
- Promote the separation of inclusions to slag

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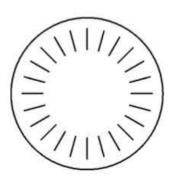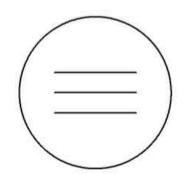
Porous plugs

Slot plug   Segment plug   Hybrid plug

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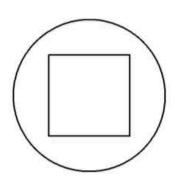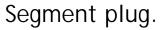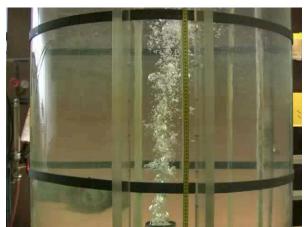
Bubble columns

Slot plug   Segment plug.   Hybrid plug

Homogenization Times

Slot plug
Medel=85 s
Std.av=14 s
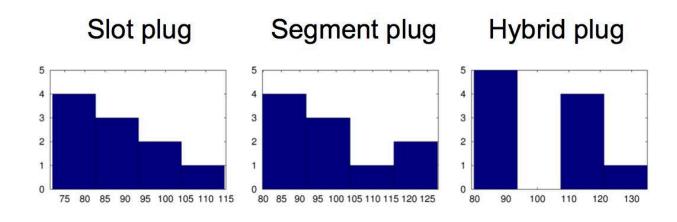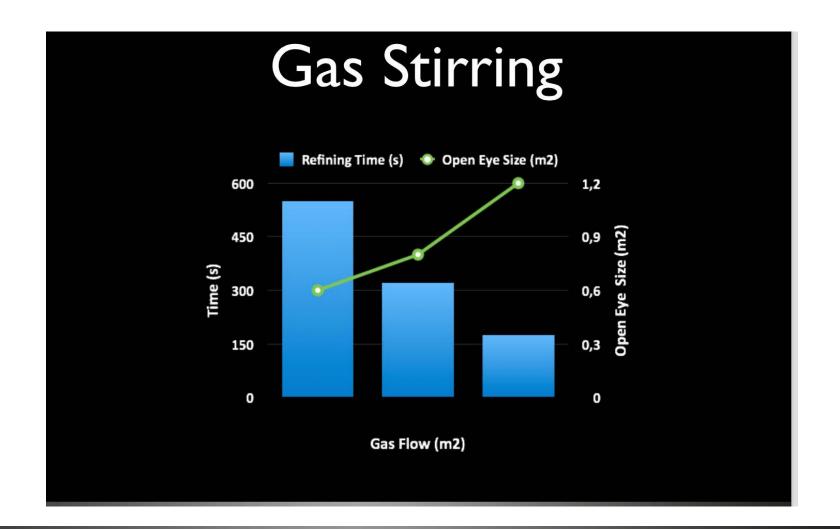
Segment plug
Medel=99 s
Std.av=16 s

Hybrid plug
Medel=102 s
Std.av=19 s

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Symmetric gas flow

150x150   180x180   210x210

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Asymmetric gas flow

150x210   180x210   210x210

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Effect on flow

Steel velocities

Open eye size
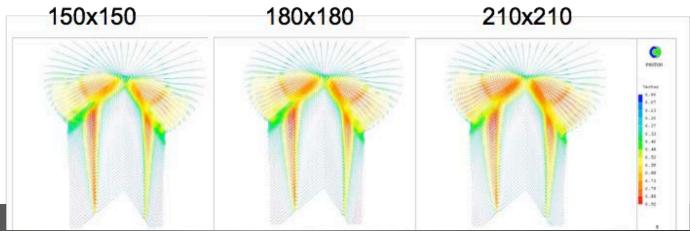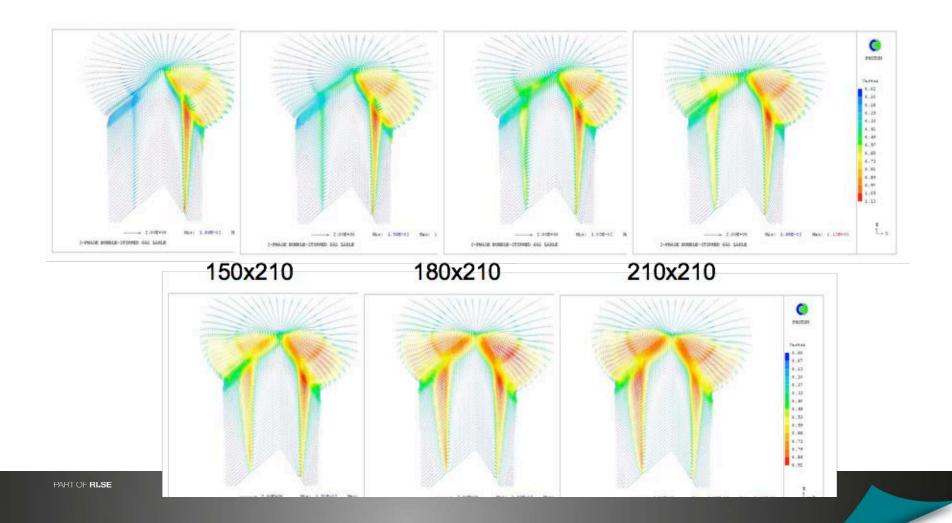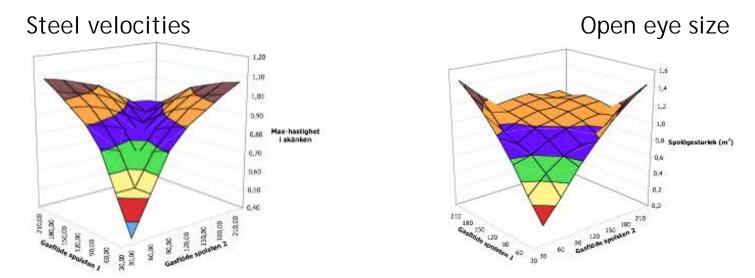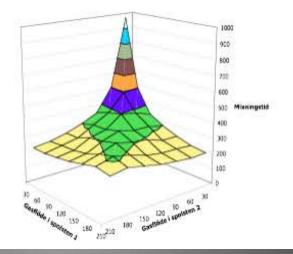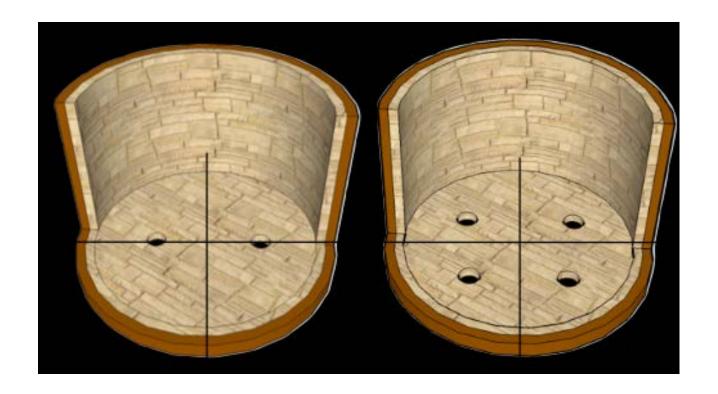
Homogenization time

Number of plugs

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Refining times

Ladle age

Stirrer

🟨	New Ladle
🟥	Half Worn Ladle
🟩	Worn Ladle
🟦	Extra Worn Ladle

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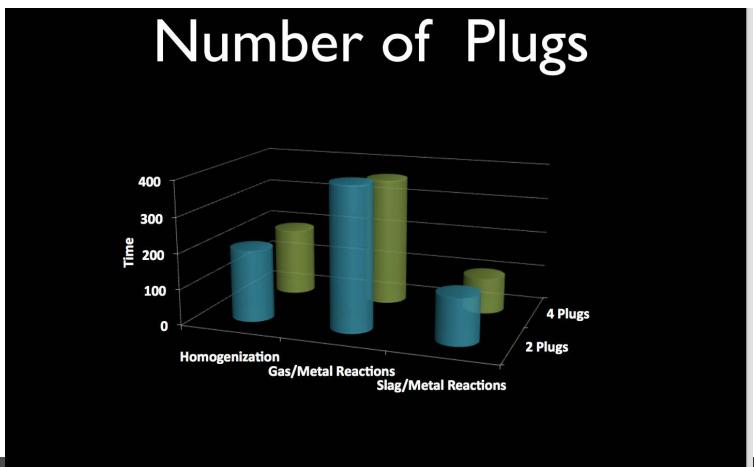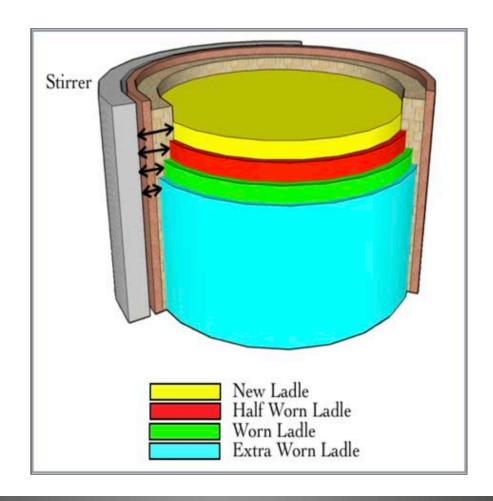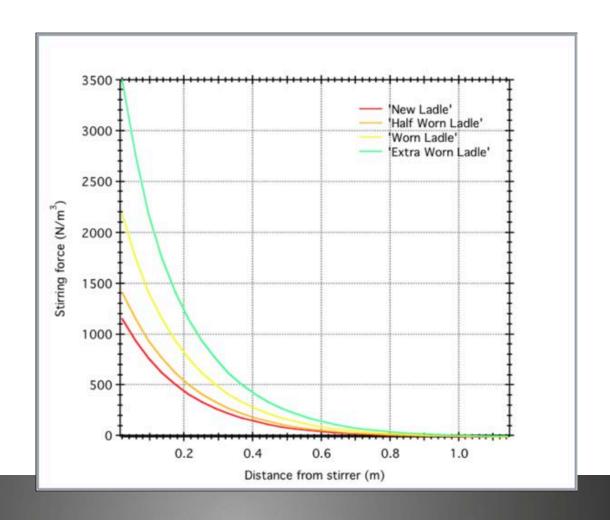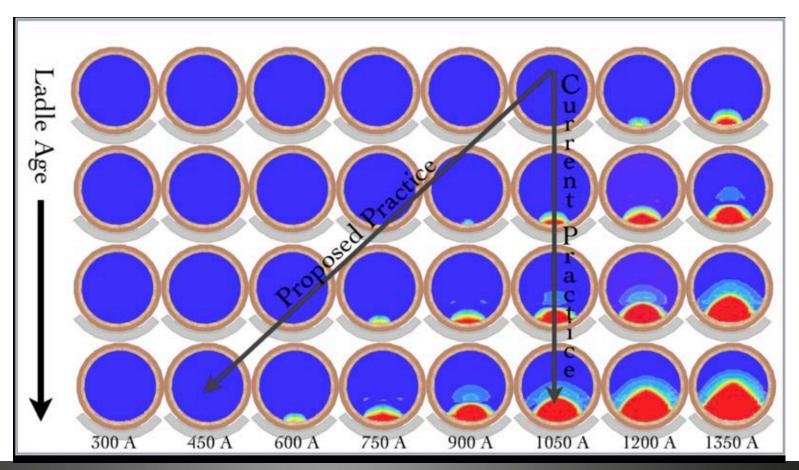
Electromagnetic stirring forces

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Open eye size

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Geometries

H/D =   1   2   0,5

H/D = Height/Diameter

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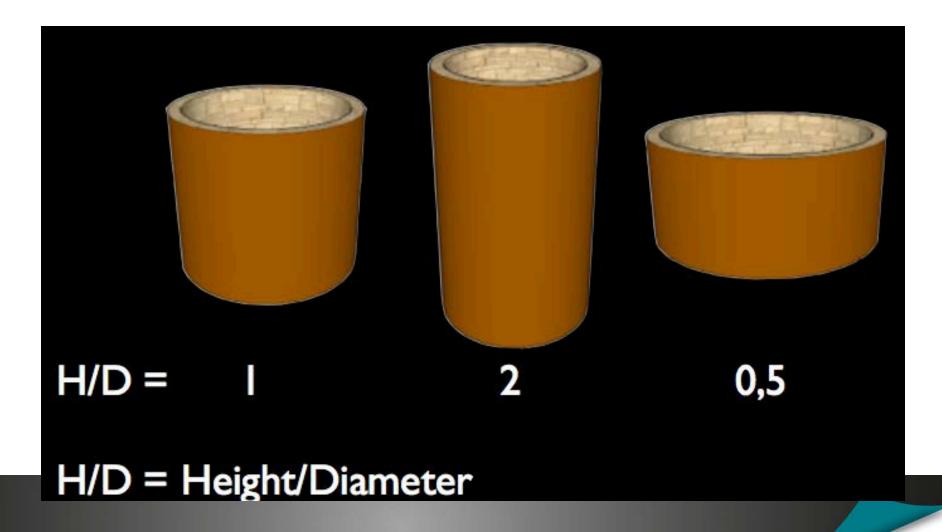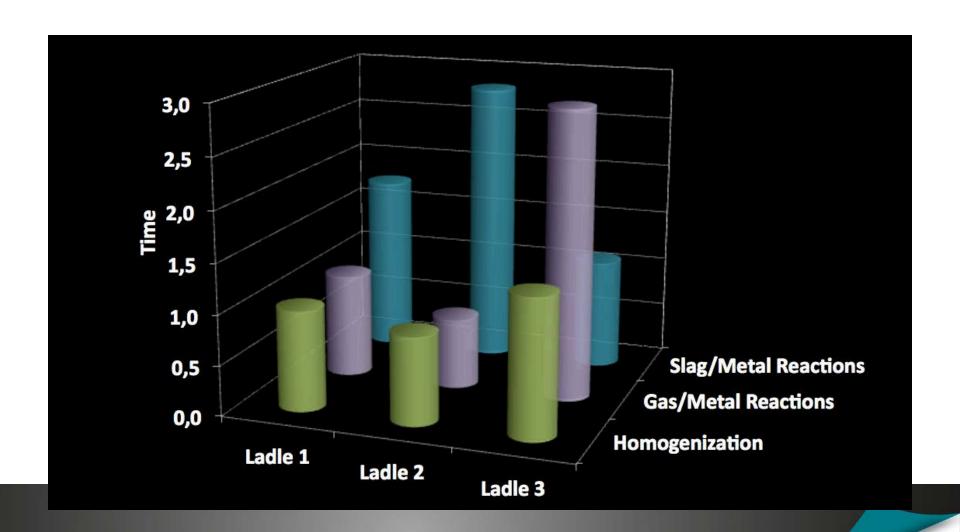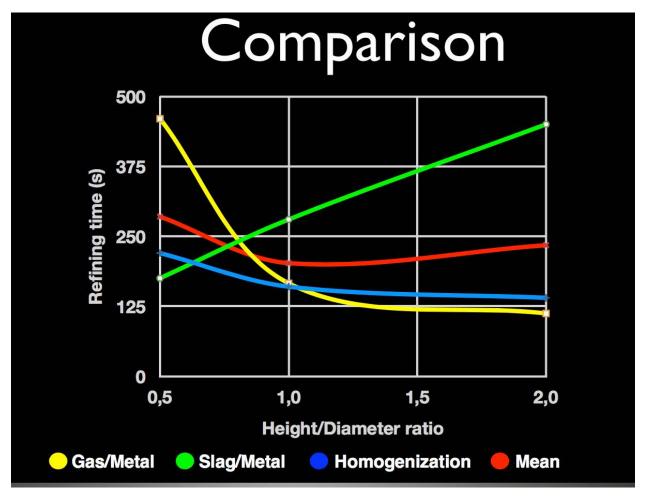
Refining operations
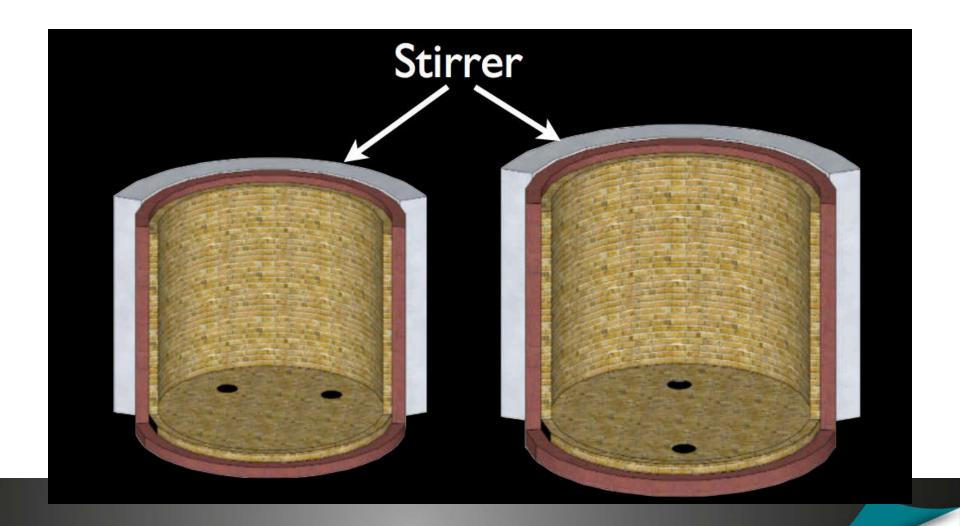
Ladle geometry

Plug placement

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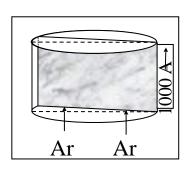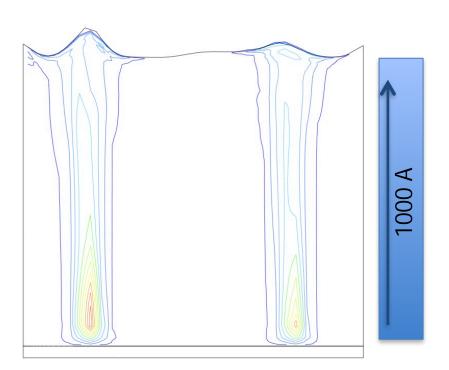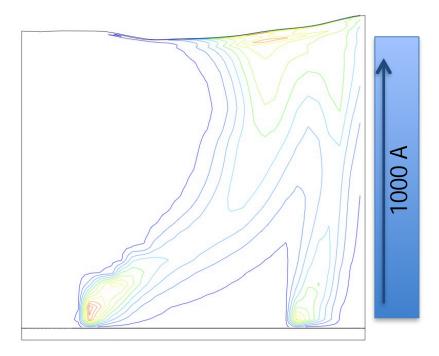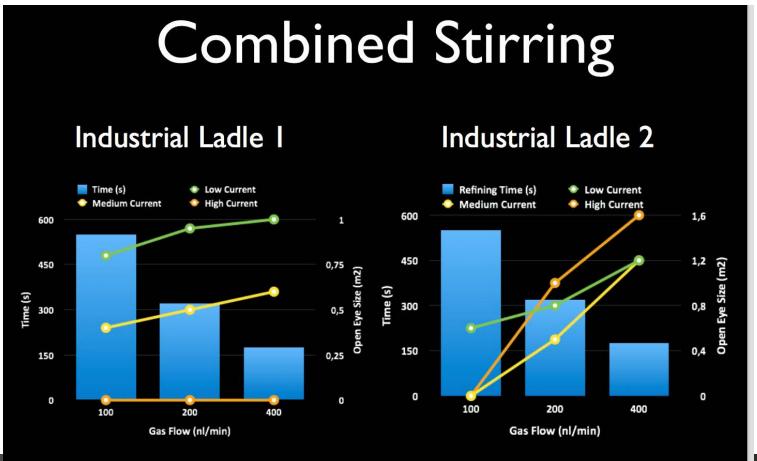
Gas plumes

Industrial ladles

Scientific Work for Industrial Use
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