VDEh-Betriebsforschungsinstitut GmbH

Simulation of Slag/Gas and Slag/Iron Interface Tilting in Blast Furnace Hearth during Slag Tapping

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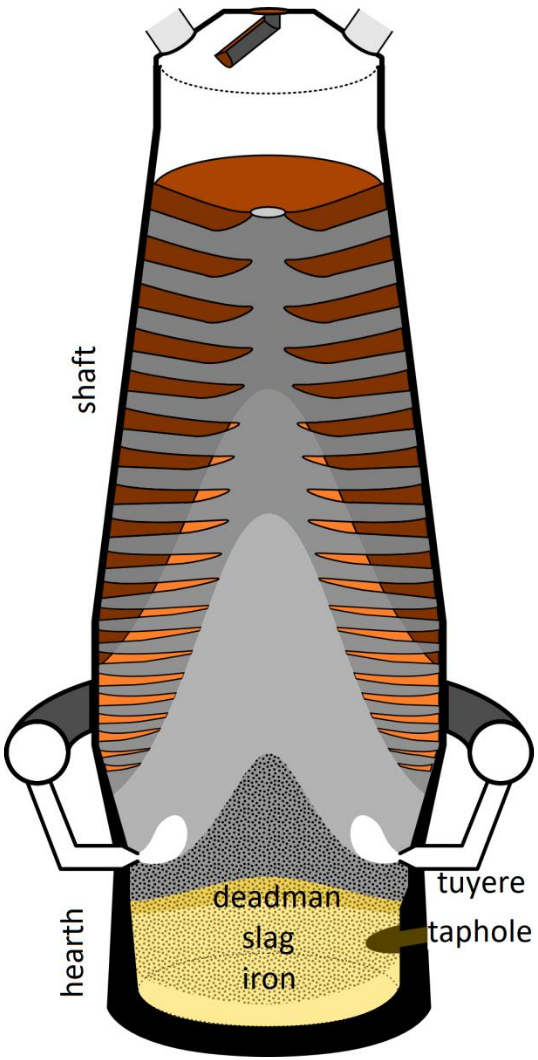
Stahl

Introduction

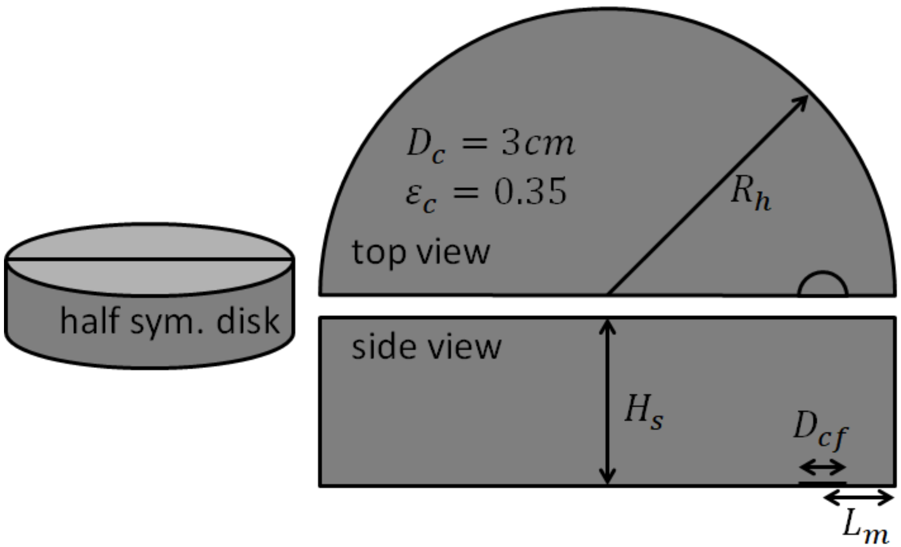


The blast furnace is a type of counter current shaft furnace used for iron ore reduction and smelting to produce industrial liquid iron.

The end products are molten iron and slag phases tapped from the bottom, and flue gases leaving from the top of the furnace.

The blast furnace hearth drainage constitutes a major part of the blast furnace operation. The <u>operational target</u> is usually not only to <u>empty the blast furnace as far as possible</u> but also to <u>keep the slag below a critical level</u> to prevent flooding of the tuyeres where the hot blast is injected into the furnace.

Computational Methods:
Flow in Porous Media



$$\kappa = \frac{\varepsilon_c^3 \cdot D_c^2}{150(1-\varepsilon_c)^2}$$

$$\beta_F = \frac{3.5(1-\varepsilon_c) \cdot \rho_s}{2 \cdot \varepsilon_c^2 \cdot D_c}$$

where

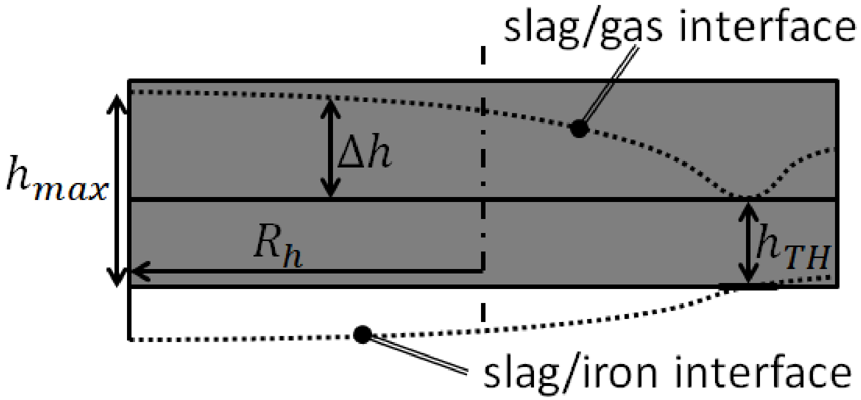
$D_c = 3\ \mathrm{cm}$	coke particle diameter
$\varepsilon_c = 0.35$	deadman porosity
$\rho_i = 6700\ \mathrm{kg/m^3}$	molten iron density
$\rho_s = 2800\ \mathrm{kg/m^3}$	molten slag density
$\mu_i = 0.006\ \mathrm{Pa \cdot s}$	molten iron viscosity
$\mu_s = 0.435\ \mathrm{Pa \cdot s}$	molten slag viscosity

The molten slag has a much higher viscosity than the molten iron. Thus, practically only the flow of molten slag through the coke bed (deadman) is restricted and it governs the interface tilting phenomena.

Hence, a single phase slag flow in porous bed with moving interfaces at top and bottom has been formulated and implemented

Initial porous bed geometry is a half disk as shown here. The permeability and Forchheimer drag terms are computed by the given equations (see model library v3.5a example).

Computational Methods:
Moving Mesh (ale)



The slag/gas and iron/slag interface movements are modelled using the "Moving Mesh (ale)".

The sloshing tank example in model library v4.3b is used as a template.

The motion of the interfaces (mesh motion) are coupled to the fluid flow normal to the surface as well as production and tapping rates.

$$v_n = \frac{n_x u + n_y v + n_z (w + w_{s0} + w_i)}{\varepsilon_c}$$

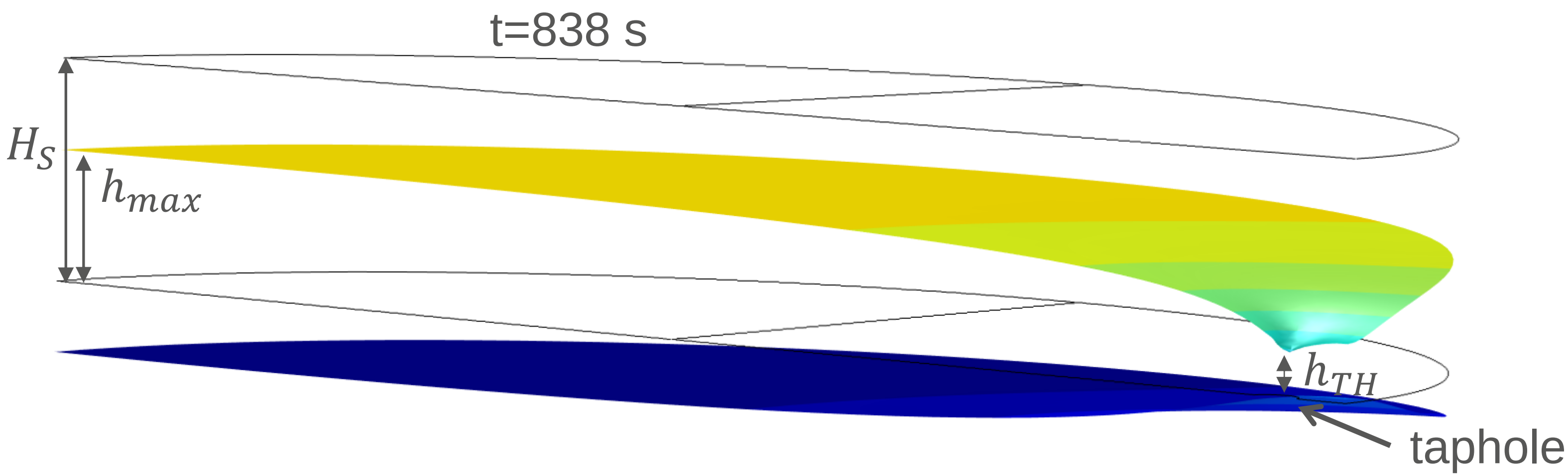
n_x, n_y, n_z : the unit surface normal

u, v, w : the flow in the porous bed

$w_{s0} = \frac{\dot{V}_s}{\pi R_h^2}$: slag level increase due to slag production

$w_i = -\dot{V}_i \cdot \frac{\Delta h}{2 \int_S \Delta h \, dS}$: slag level decrease due to iron level decrease (slag/iron interface tilting due to non-uniform slag weight)

Results:
Movement of the interfaces

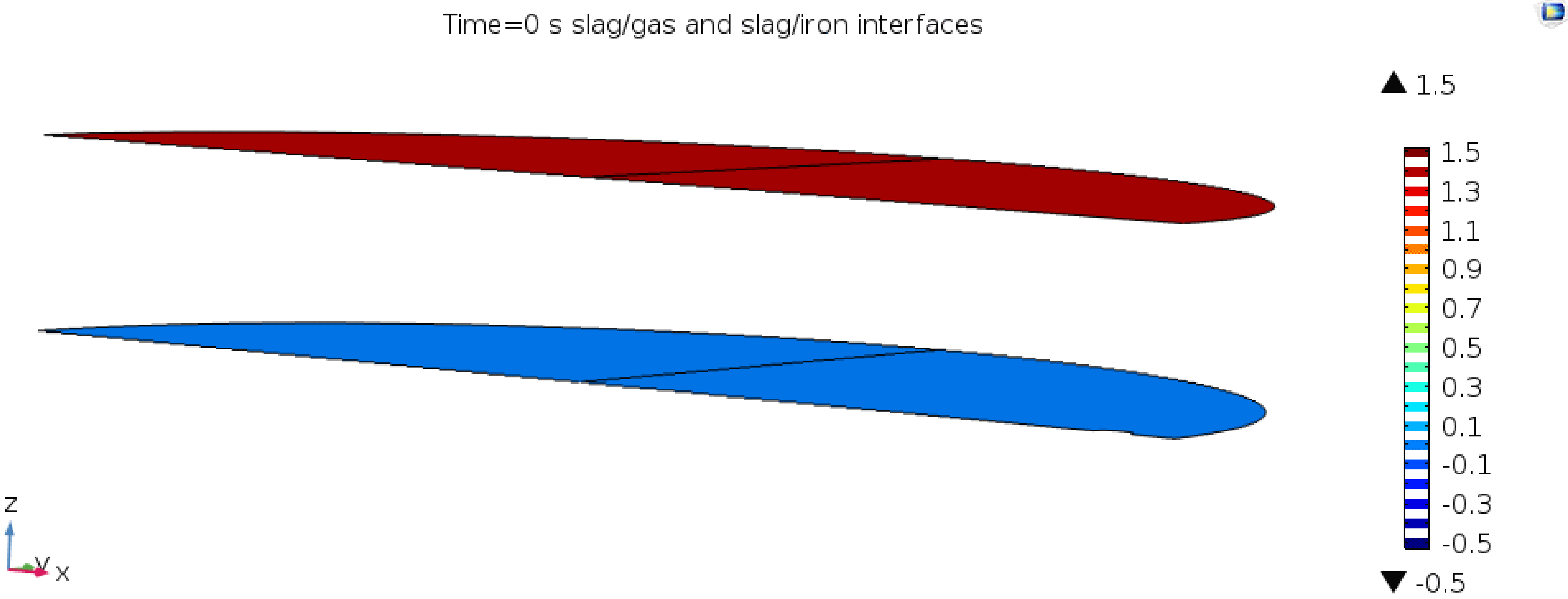


Typical shape of the slag/gas and slag/iron interface at the end of tapping

The main results, which are most useful to the plant operation, are:
maximum slag level h_{max} occurring opposite to the taphole
minimum slag level h_{TH} occurring at the taphole entrance

Influences of the initial thickness of the slag layer H_S at slag arrival and slag viscosity μ_S on the slag tapping duration are discussed in next slide.

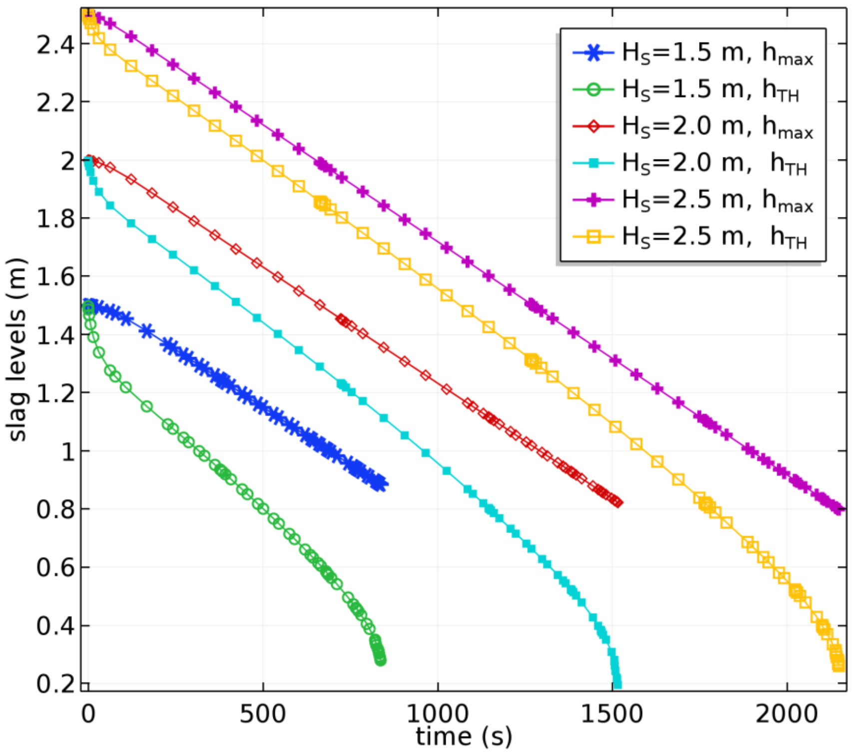
Results:
Movement of the interfaces (movie)

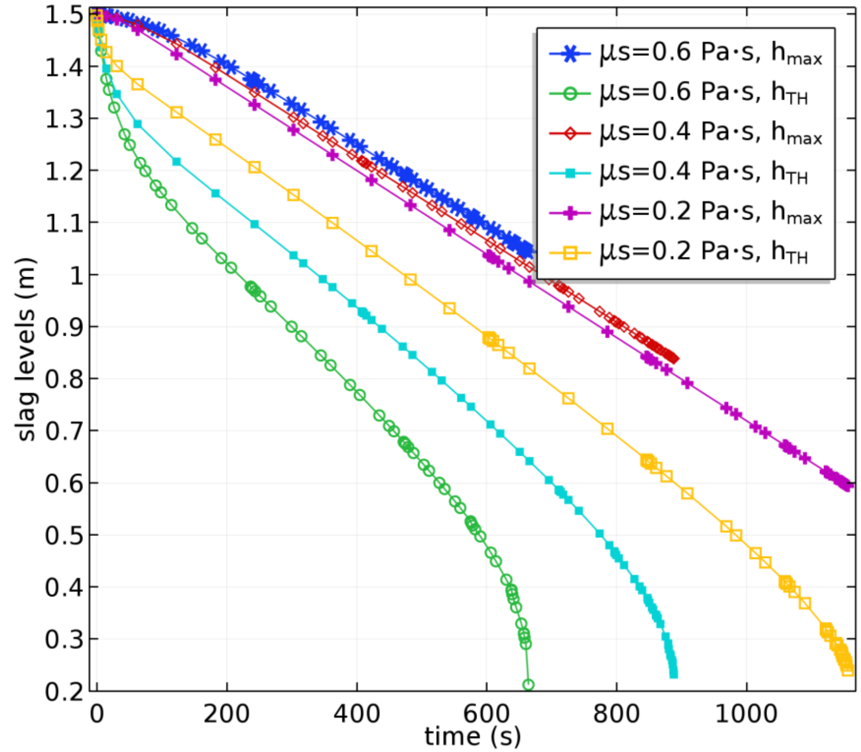


Results:

Slag Tapping Duration

initial slag layer thickness H_S v.s. slag viscosity μ_S





H_s	$\Delta t_{tapping}^{slag}$	μ_s	$\Delta t_{tapping}^{slag}$
1.5 m	840 s	0.6 Pa·s	665 s
2.0 m	1510 s	0.4 Pa·s	890 s
2.5 m	2150 s	0.2 Pa·s	1150 s

Conclusions

- A 3D tilting model is developed to estimate the shape of slag/gas and slag/iron interfaces during tapping process of blast furnace.
- The slag/gas and slag/iron interface movements are modelled with moving mesh physics.
- The so-called viscous fingering (penetration of gas to the taphole) is estimated, which signals the end of the tapping cycle.
- This model can be used to investigate the influence of model parameters on boundary conditions, hearth geometry, dead man properties, slag properties, tapping rates, etc.
- Two case studies are performed to demonstrate the influence of the initial slag level and of the slag viscosity on tapping duration.

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