EX MENTE

Assessing the Performance of a PGM Smelting Furnace

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Background

Background
Shift to Lower-grade Ore Bodies

Renewable and Sustainable Energy Reviews
Volume 204, October 2024, 114821

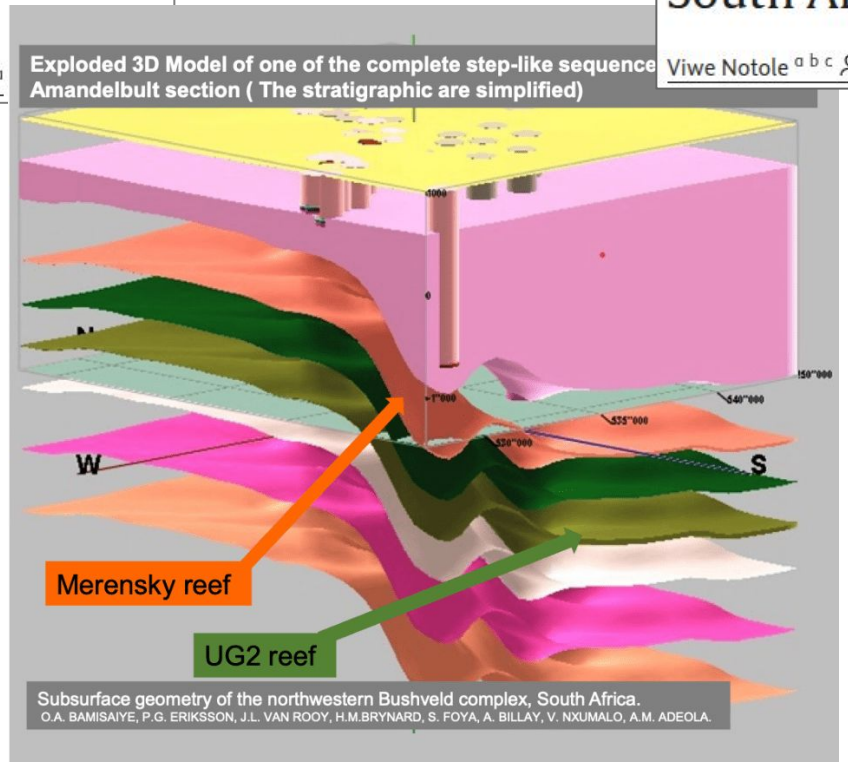
Supply and demand of platinum group metals and strategies for sustainable management

Shengen Zhang [a b], Xuefeng He [a], Yunji Ding [a c d], Zhisheng Shi [a], Boyu Wu [a]

Minerals Engineering
Volume 234, December 2025, 109682

Investigating mineral composition of PGE low-grade ore in Bushveld igneous complex, South Africa ☆

Viwe Notole [a b c], Glen T. Nwaila [b], Mehdi Safari [b d], Sehliselo Ndlovu [a e]



Decrease
Sulphide content
Base metals

Increase
Chromite content

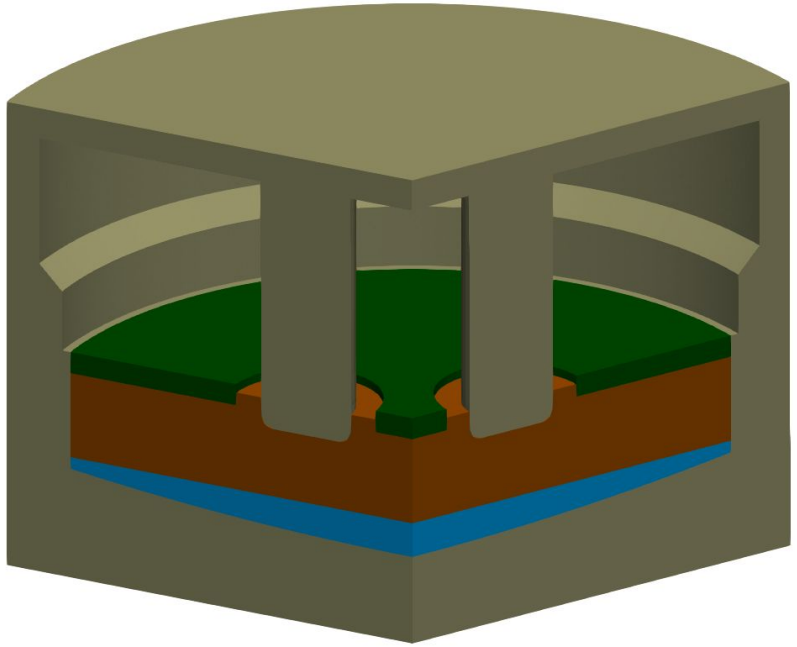
Background
Determine the Influence

Determine the influence on existing technology

Slag and Matte properties and behaviour
Changes in operating conditions
Matte fall
Energy requirement
Heat losses
Throughput
Containment
Many other aspects

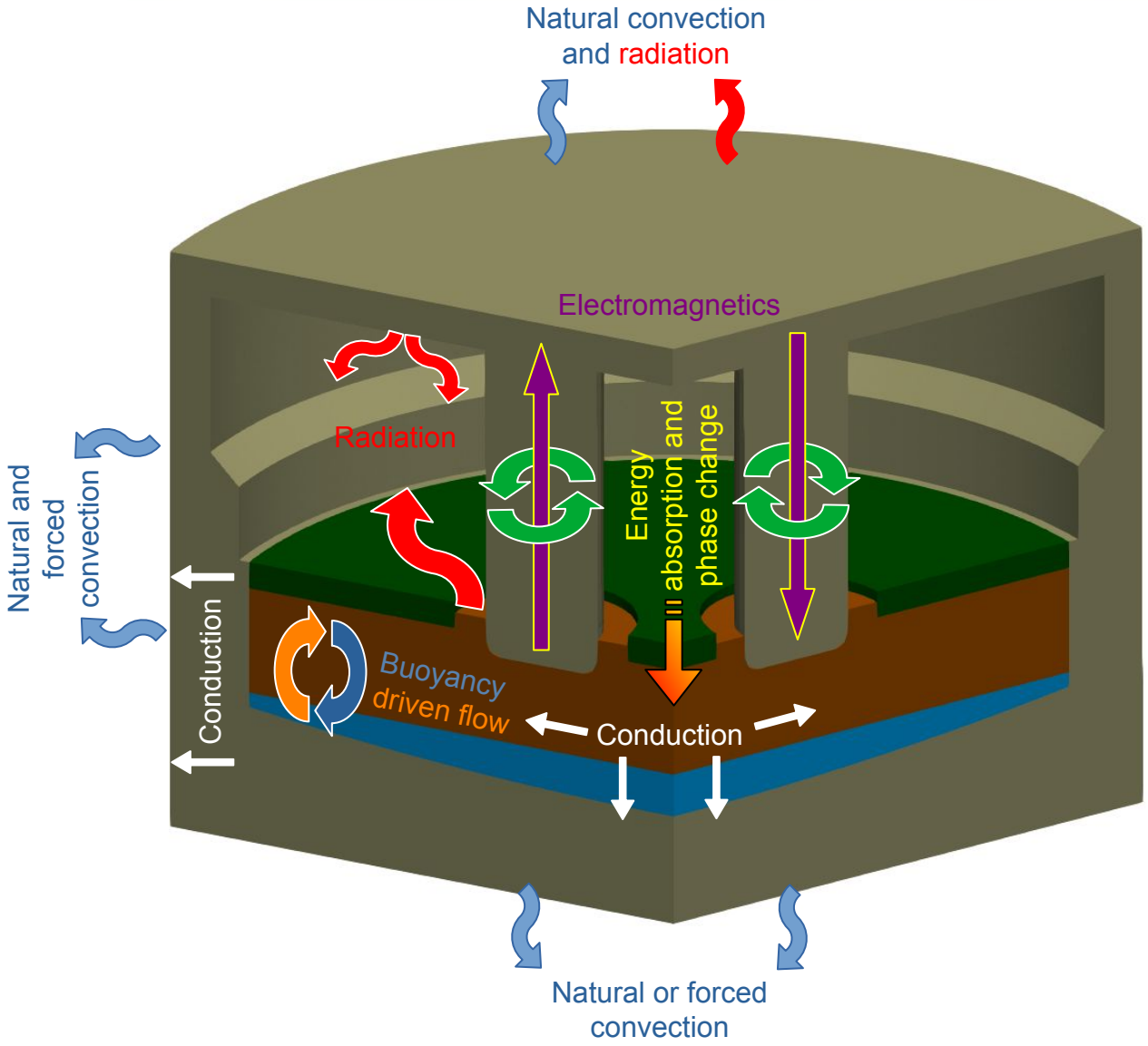
Computational models

Computational thermochemistry
Process models
Multiphysics models



Multiphysics Model

Multiphysics Model
What Are They?



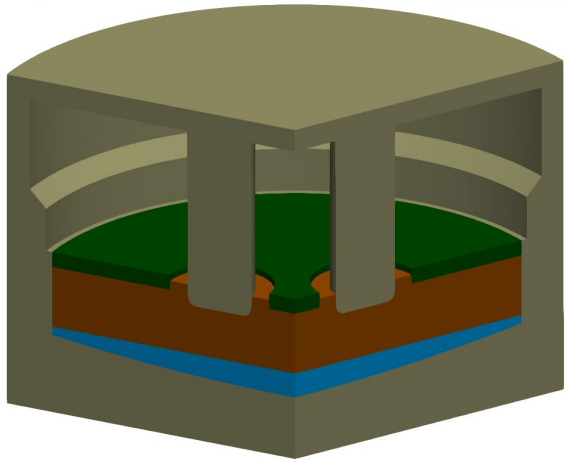
Spatial representation the furnace

Incorporate detailed physical phenomena

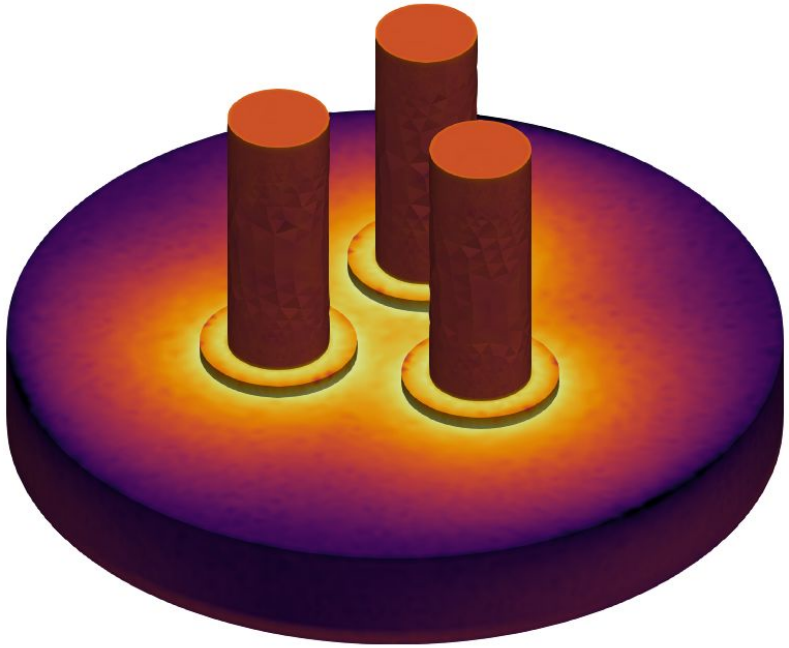
Apply material property Descriptions

κ, ρ, $C_{p,}$ σ, μ

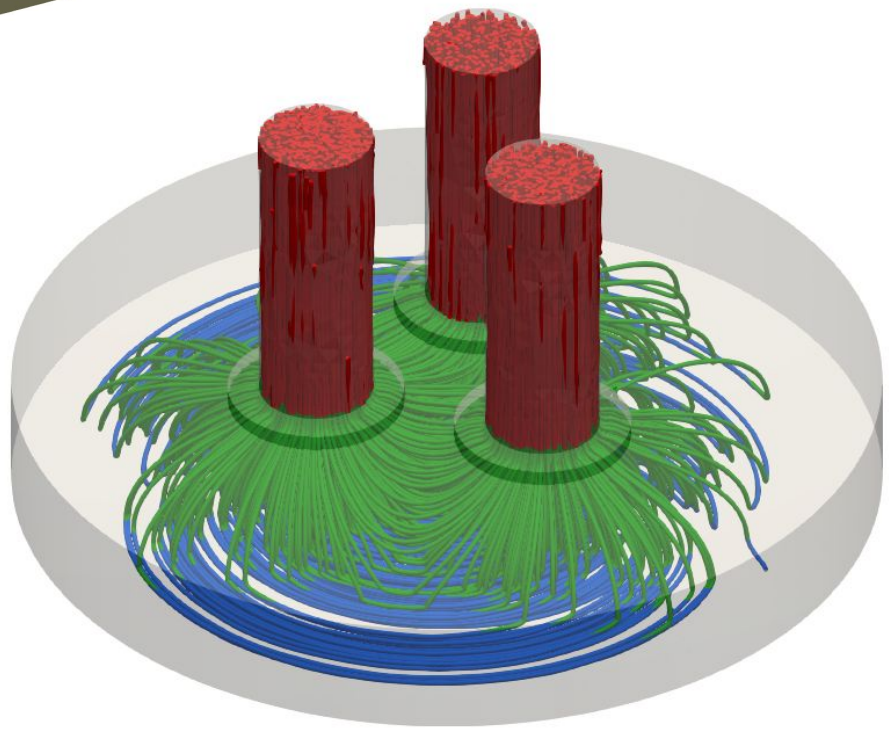
Multiphysics Model
Electrical System



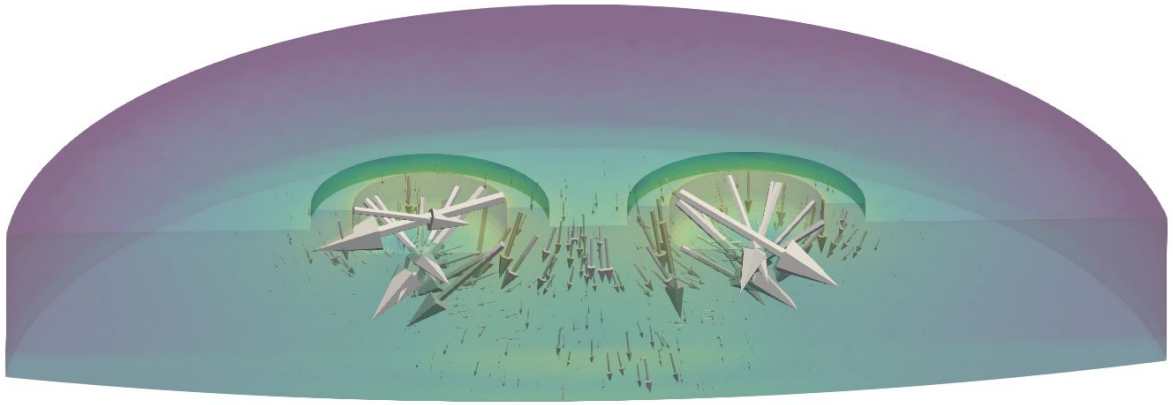
Joule heating distribution



Electrical current flow

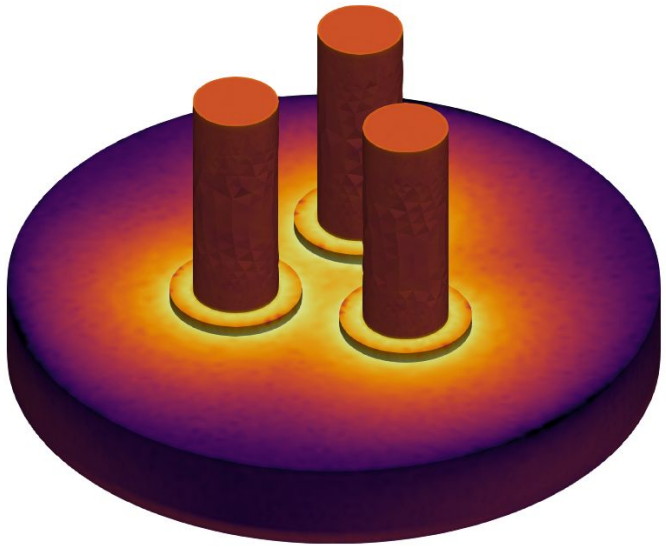


Electromagnetic forces

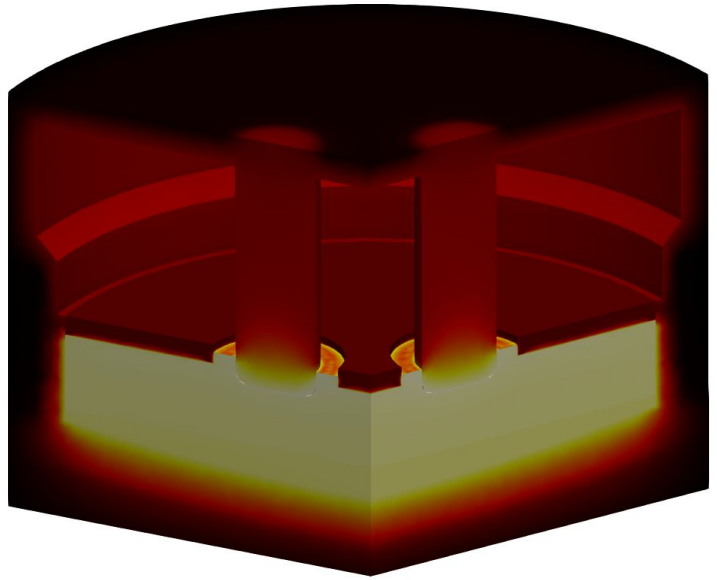


Multiphysics Model
Heat and Fluid Flow

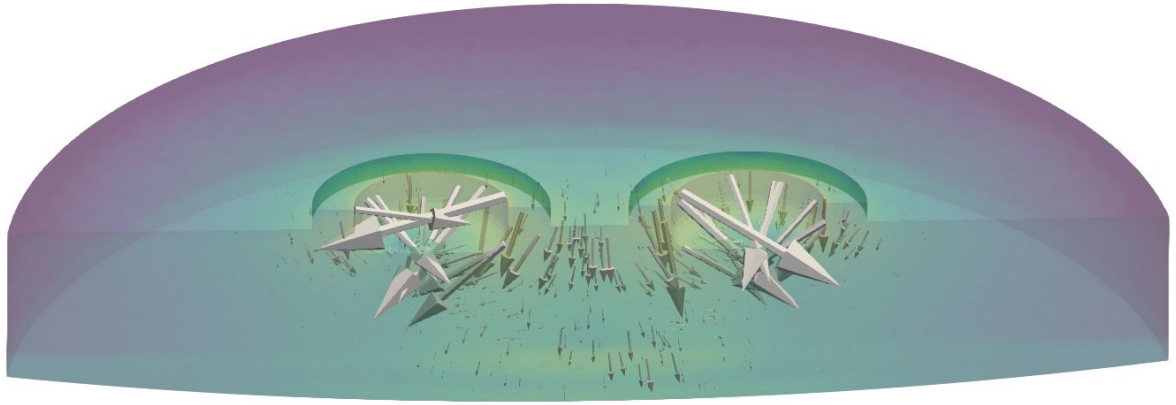
Electric current flow and Joule heating



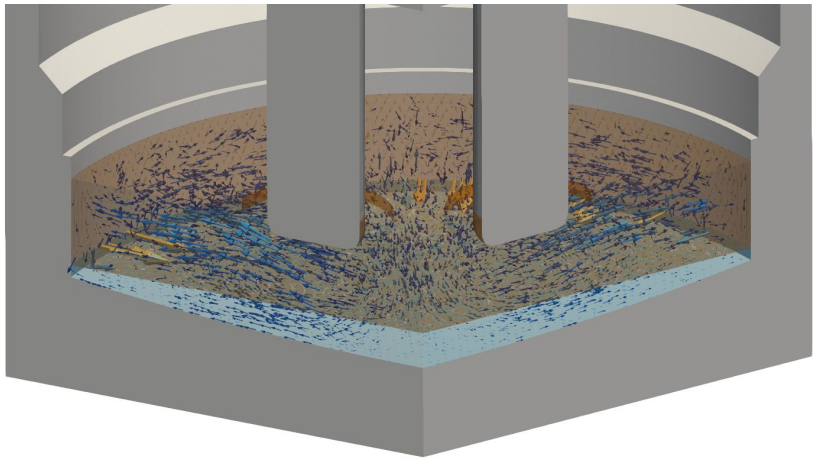
Heat transfer



Electromagnetic forces

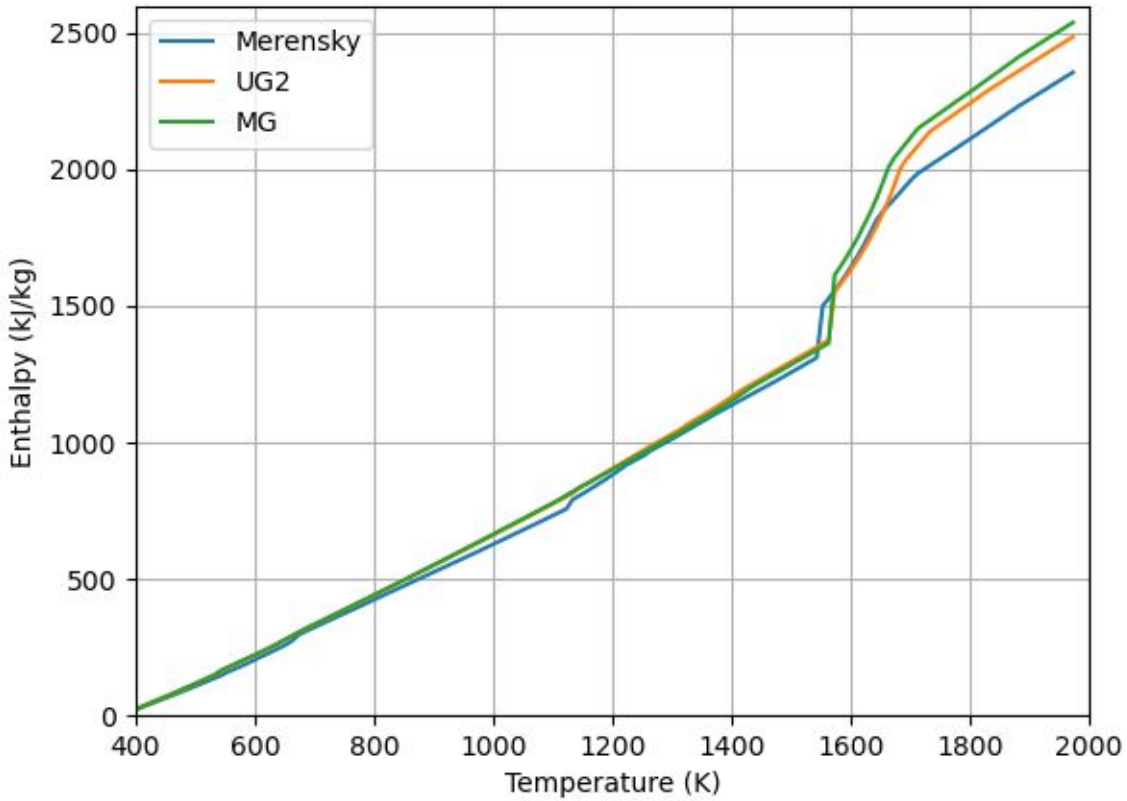


Flow in molten baths

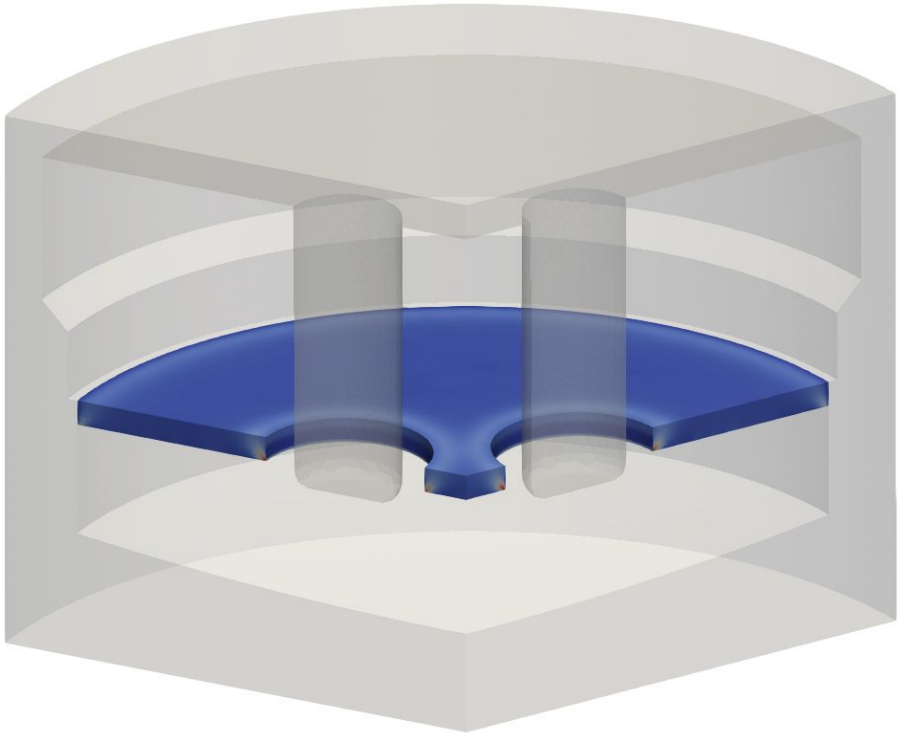


Multiphysics Model
Smelting Rate / Throughput

Thermochemistry data from FactSage



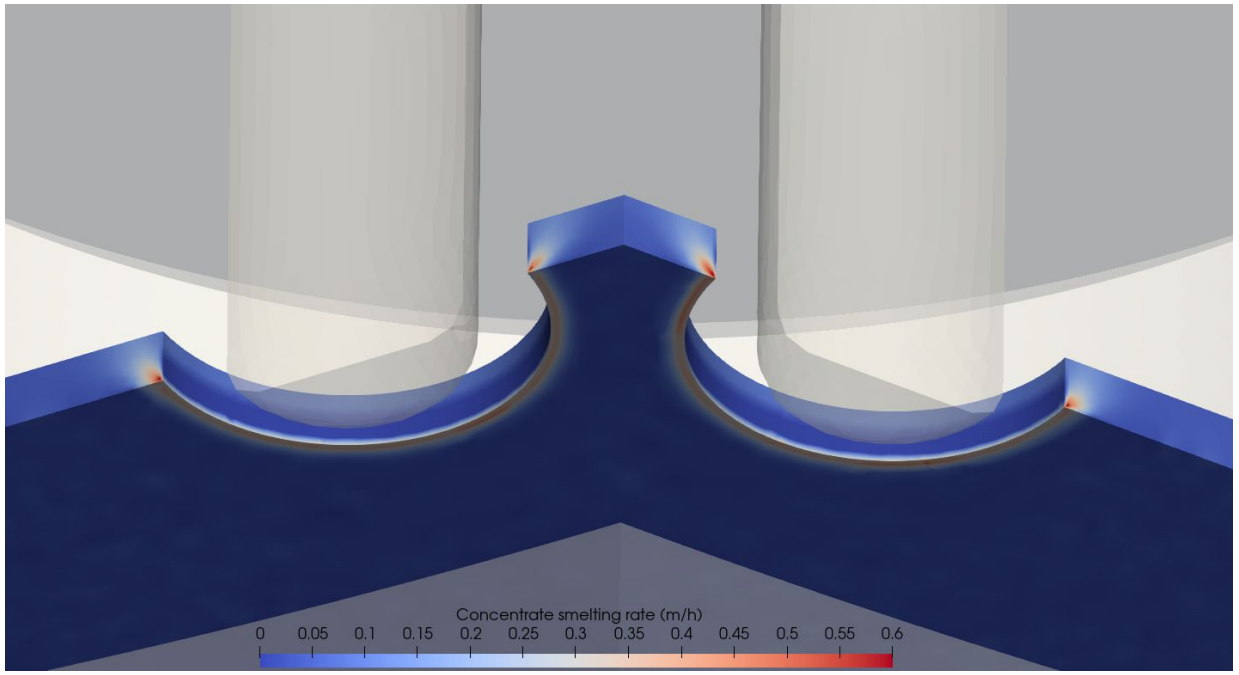
Material movement description



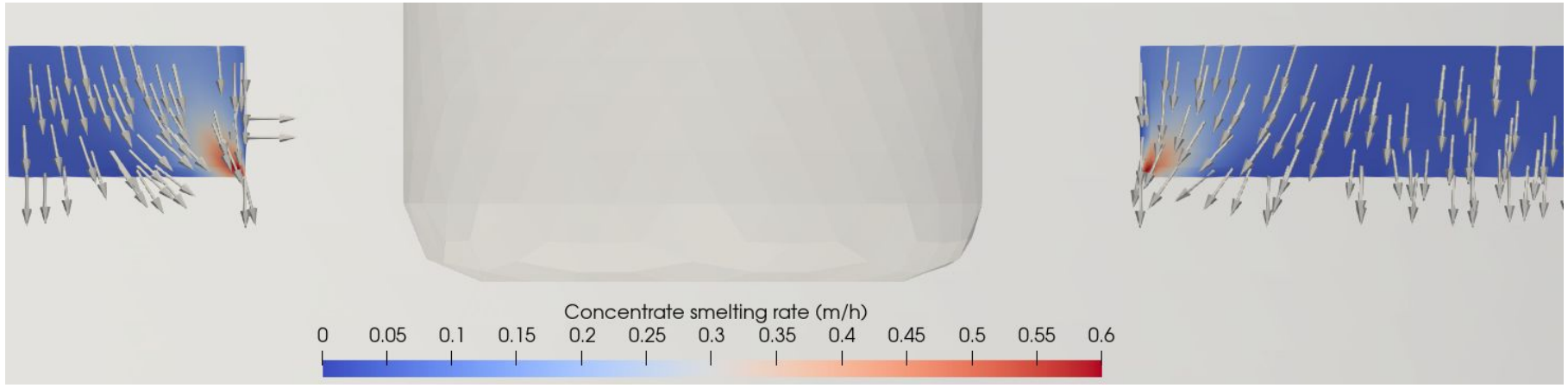
Not only the smelting rates at different locations

But also the local direction of movement

Multiphysics Model
Smelting Rate / Throughput



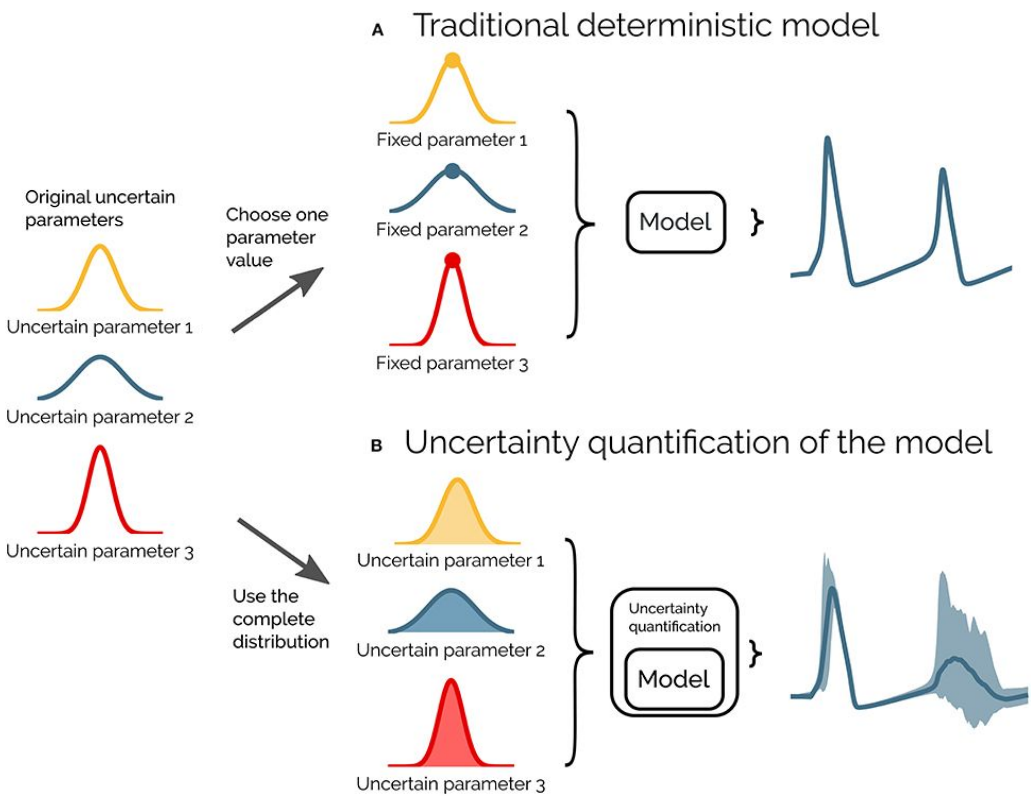
High local smelting rates around electrodes

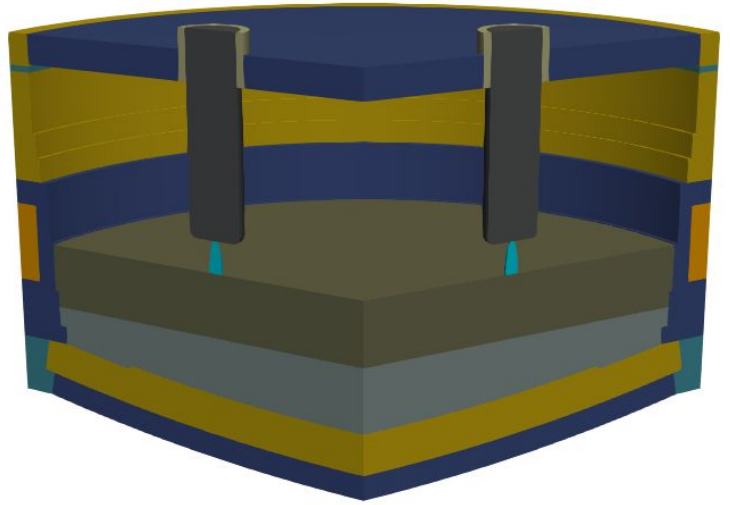


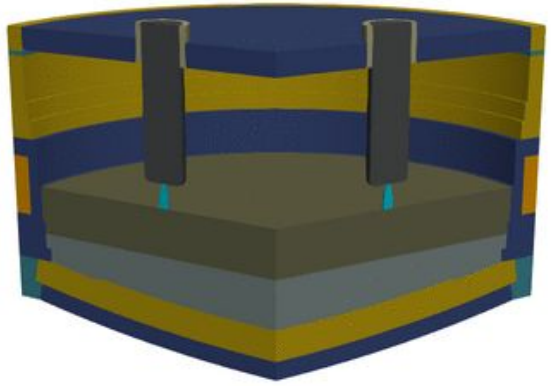
Inward movement around electrodes

Sensitivity Analysis

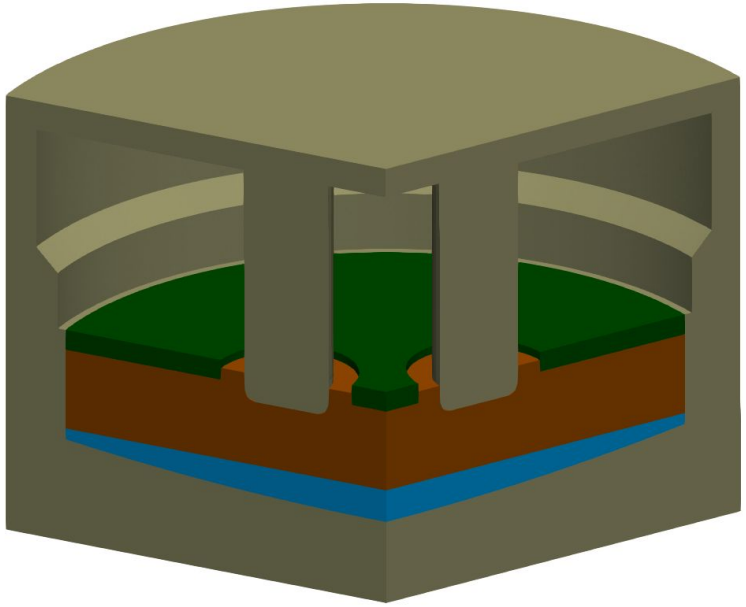
Sensitivity Analysis
Investigate Influential Parameters







Sensitivity Analysis
Parameter Details

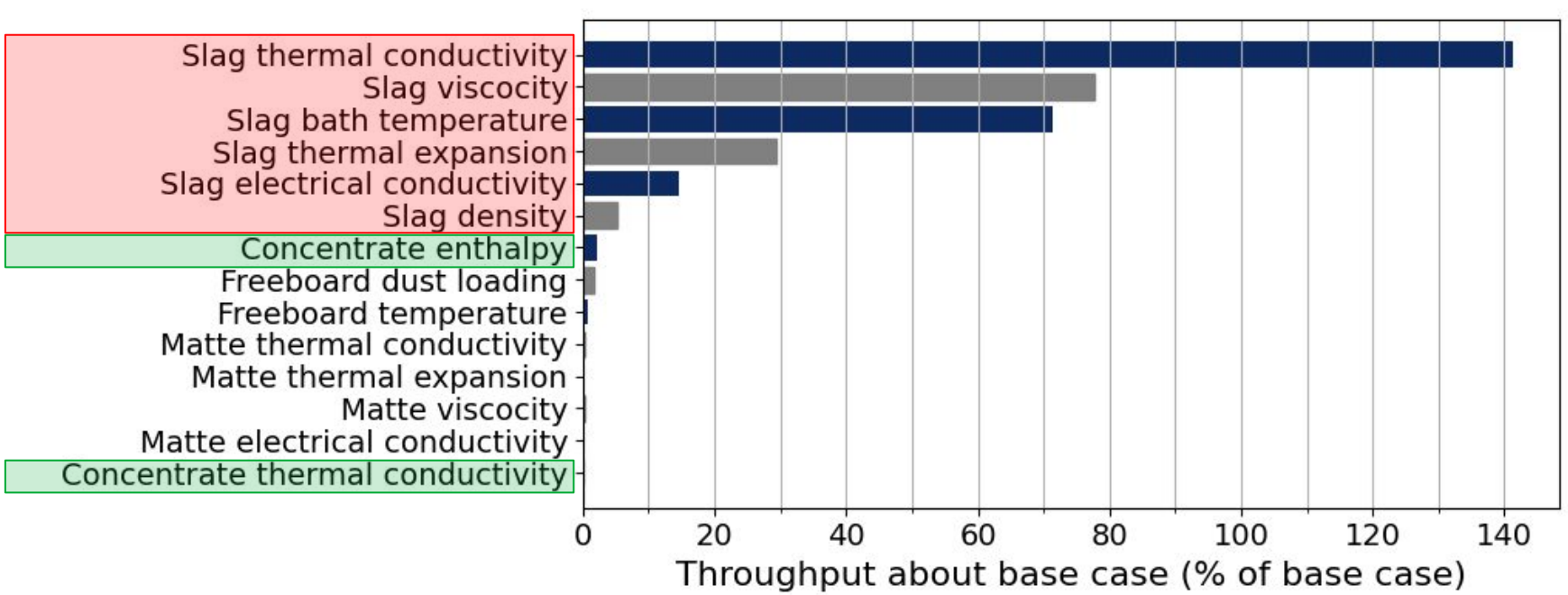


Established layout

Uncertainties about operation and *material properties*

Parameter	Unit	Minimum	Maximum	Uncertainty
Slag bath temperature	°C	1600	1680	medium
Freeboard temperature	°C	400	700	medium
Freeboard dust scattering	-	0.1	2.5	medium
Slag thermal conductivity	W/m/°C	0.5	2.5	high
Slag density	kg/m3	2800	3200	medium
Slag thermal expansion	1/°C	2×10^{-4}	4×10^{-4}	medium
Slag viscosity	Pa.s	0.1	2.0	medium
Slag electrical conductivity	S/m	20	80	high
Matte thermal conductivity	W/m/°C	5	25	high
Matte thermal expansion	1/°C	1×10^{-4}	5×10^{-5}	medium
Matte viscosity	Pa.s	0.001	0.005	medium
Matte electrical conductivity	S/m	1000	20000	medium
Concentrate thermal conductivity	W/m/°C	0.5	5.0	medium
Concentrate enthalpy	kJ/kg	Merensky, UG2, MG		low

Sensitivity Analysis
Furnace Throughput Importance Matrix



Influence

Uncertainty

Concentrate properties

Low-medium uncertainty

Low influence

Low risk

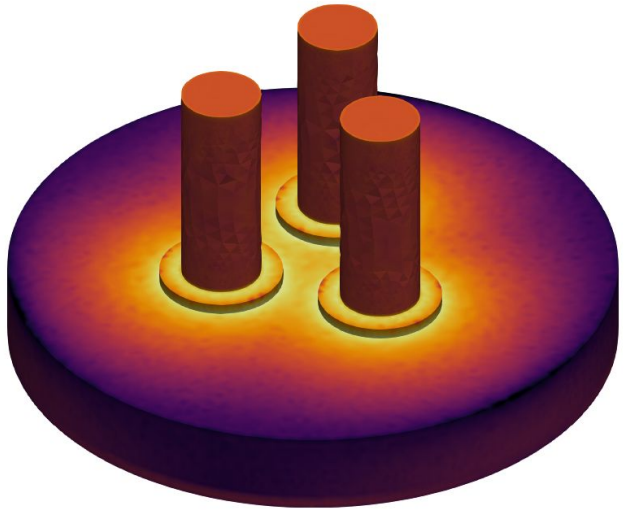
Slag properties

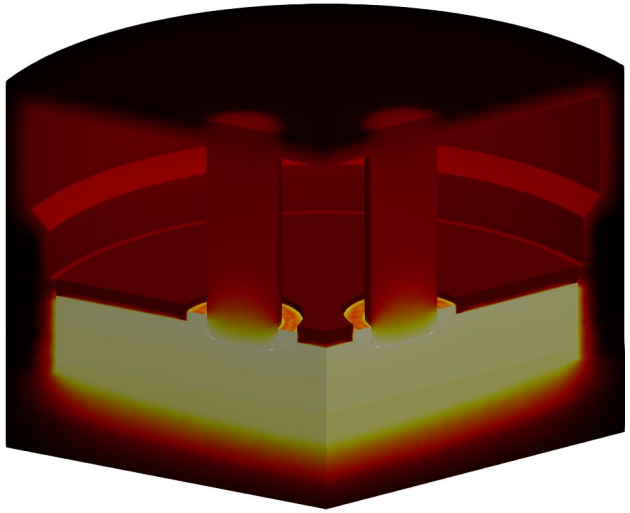
High uncertainty

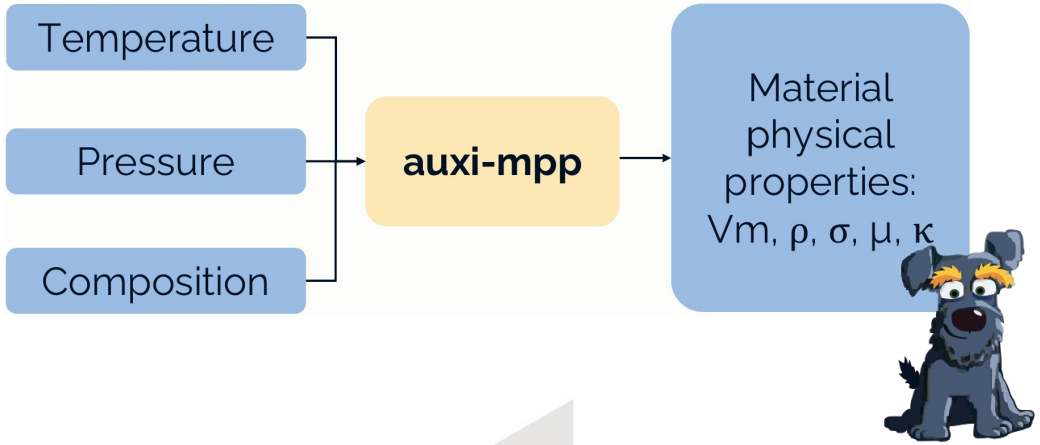
High influence

Substantial risk

Sensitivity Analysis
Importance of Material Properties





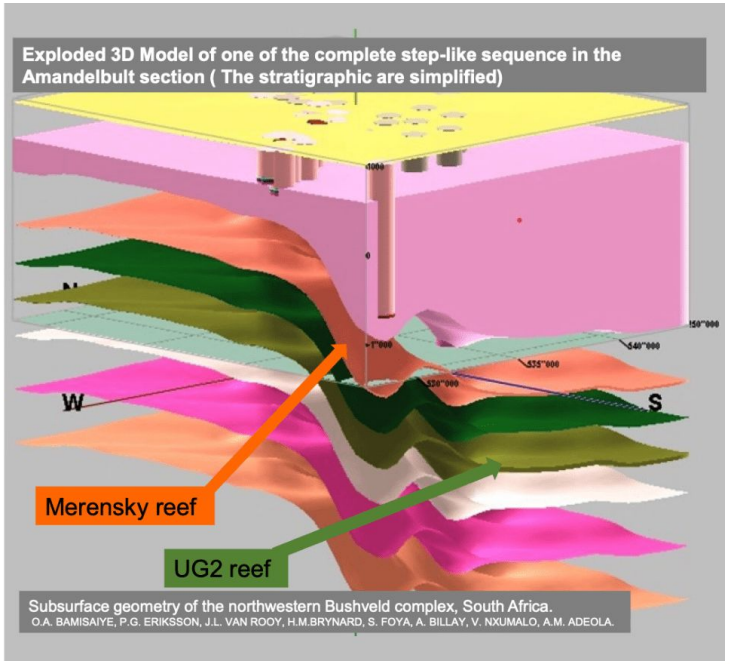


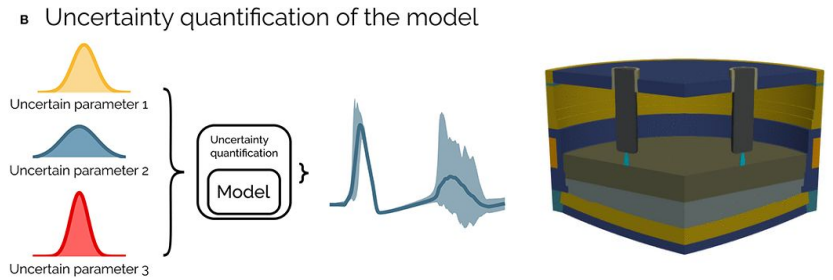
Furnace is a heat transfer and melting reactor
Highly dependent on material properties
Especially slag

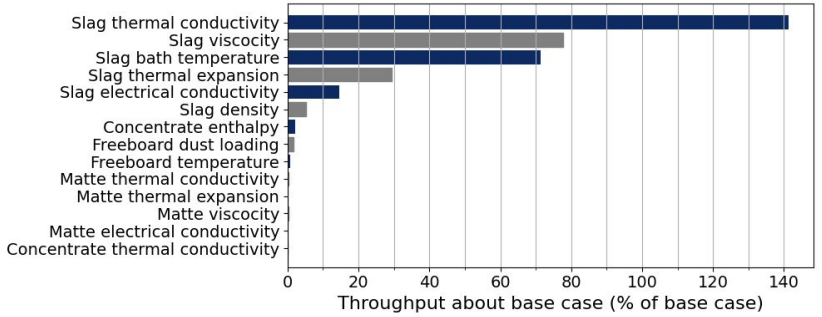
Reduce uncertainty
Improve evaluation accuracy
More insight into behaviour of the furnace

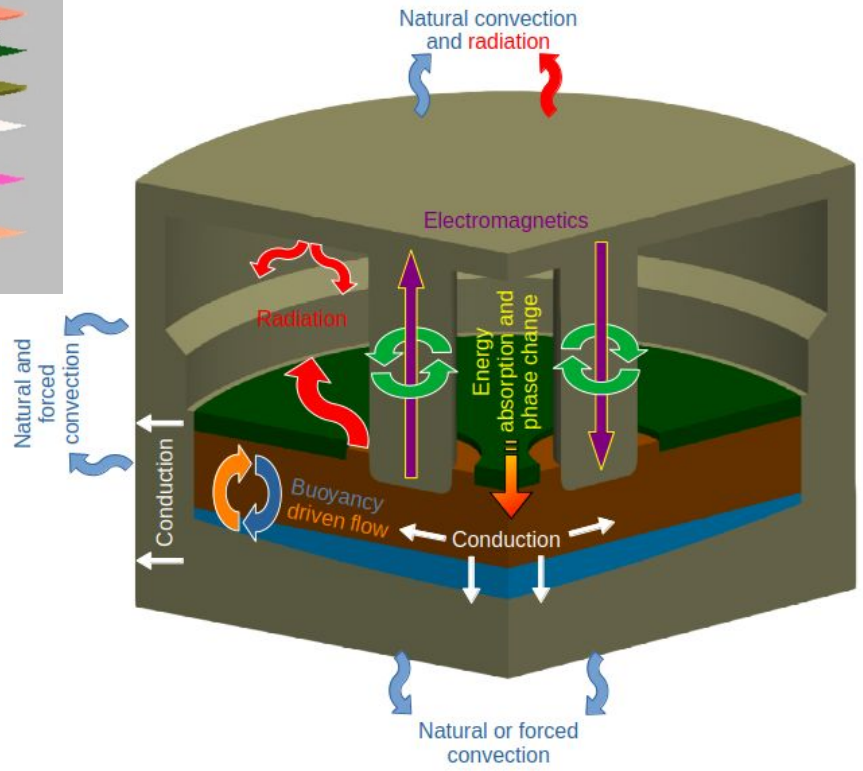
Conclusion

Conclusion


Exploded 3D Model of one of the complete step-like sequence in the Amandelbult section (The stratigraphic are simplified)
W
S
Merensky reef
UG2 reef
Subsurface geometry of the northwestern Bushveld complex, South Africa.
O.A. BAMISAIYE, P.G. ERIKSSON, J.L. VAN ROOY, H.M.BRYNARD, S. FOYA, A. BILLAY, V. NXUMALO, A.M. ADEOLA.


B Uncertainty quantification of the model
Uncertain parameter 1
Uncertain parameter 2
Uncertain parameter 3
Uncertainty quantification
Model


Slag thermal conductivity
Slag viscocity
Slag bath temperature
Slag thermal expansion
Slag electrical conductivity
Slag density
Concentrate enthalpy
Freeboard dust loading
Freeboard temperature
Matte thermal conductivity
Matte thermal expansion
Matte viscocity
Matte electrical conductivity
Concentrate thermal conductivity
0
20
40
60
80
100
120
140
Throughput about base case (% of base case)

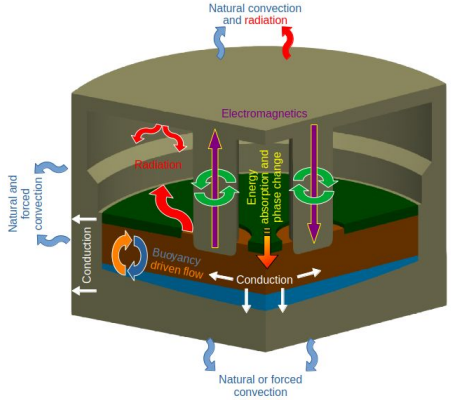

Natural convection and radiation
Electromagnetics
Radiation
Energy absorption and phase change
Natural and forced convection
Conduction
Buoyancy driven flow
Conduction
Natural or forced convection

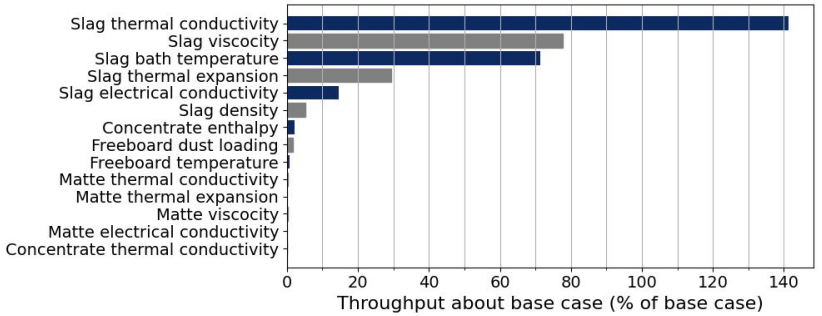
Conclusion

SO WHAT?

Insight into which levers to pull
Stable operation
Reduce energy requirement
Increase throughput

Prepare operations for different blends
OR
Prepare blends for desired operations






Thank You