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# Application of Multiphysics in the Simulation of Metallurgical Processes

Mattias Ek[1,*] and Du Sichen[1]

[1]Department of Materials Science and Engineering, Royal Institute of Technology

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# Stirring in Metallurgical Processes

- Argon or Nitrogen Stirring
- Thermal and Chemical Homogeneity
- Process time gains
- Refractory wear and material costs
- Importance of CFD

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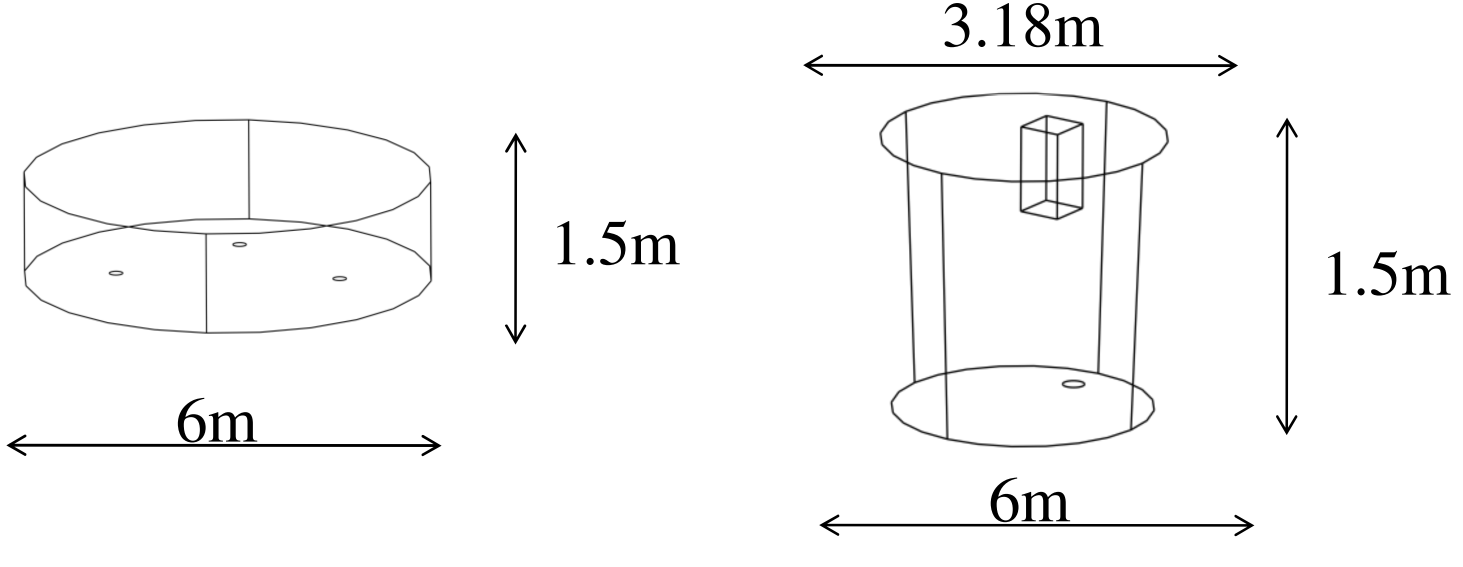
# Vessels

- 300 ton converter vessel, stirring 400-800$Nm^3h^{-1}$
- 180 ton ladle vessel, stirring 20-40$Nm^3h^{-1}$



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# Assumptions

**General assumptions**

- Only 2 phases present, gas and metal.
- Constant temperature and stirring rate
- The K-$\varepsilon$ model is employed to calculate turbulent flow.
- Surface is assumed flat and no top phase is present.

- **Ladle specific assumptions**
- Flow is assumed to stabilized.
- All alloying material is present within a small sub domain at beginning.
- No loss of alloying element

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# Modelling

- Comsol Multphysics 3.5
- Chemical Engineering module
  - Bubbly flow model
  - Convection and Diffusion model

Momentum equation $$\phi_l\rho_l\frac{\partial u_l}{\partial t}+\phi_l\rho_l u_l\nabla u_l=-\nabla p_l+\phi_l\rho_l g+F+\nabla\left[\phi_l(\eta_l+\eta_T)\left(\nabla u_l+\nabla u_l^T-\frac{2}{3}(\nabla u_l)I\right)\right]$$

Continuity equation $$\frac{\partial}{\partial t}\left(\rho_l\phi_l+\rho_g\phi_g\right)+\nabla\cdot\left(\rho_l\phi_l u_l+\rho_g\phi_g u_g\right)=0$$

Mass transfer $$\frac{\partial c_i}{\partial t}+\nabla(-D_i\nabla c_i)=R_i-u\nabla\cdot c_i$$

# Boundary conditions

Bubbly flow mode

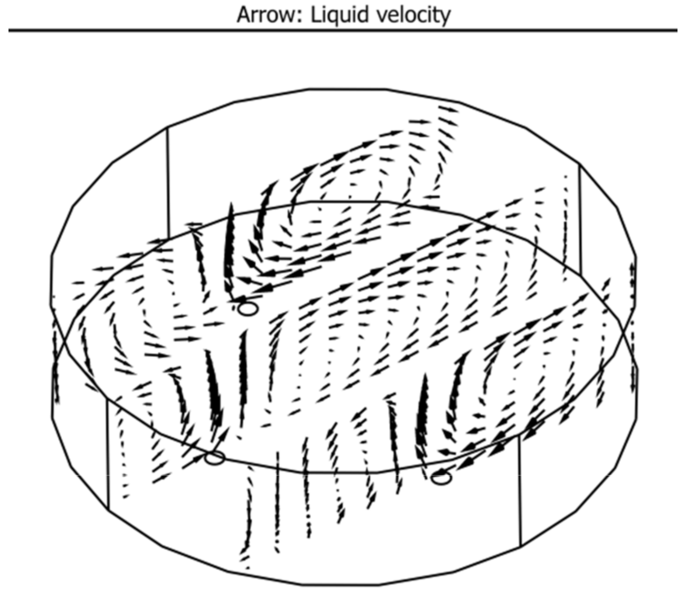
- Logarithmic wall function
- Gas influx [$kgm^{-2}s^{-1}$]
- Outlet of gas

Mass transfer

- All walls insulating

# Solving method

- Paradiso solver
- Time dependent




# Converter results

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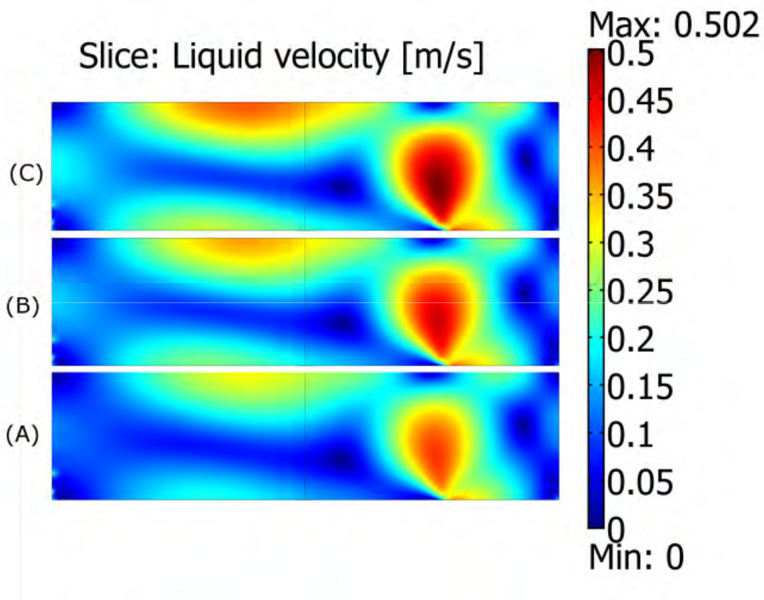


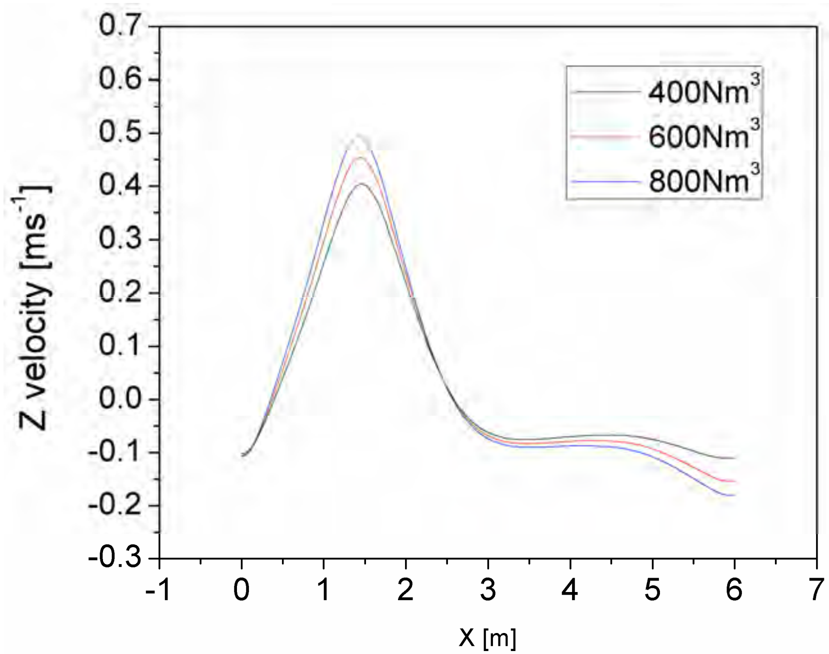

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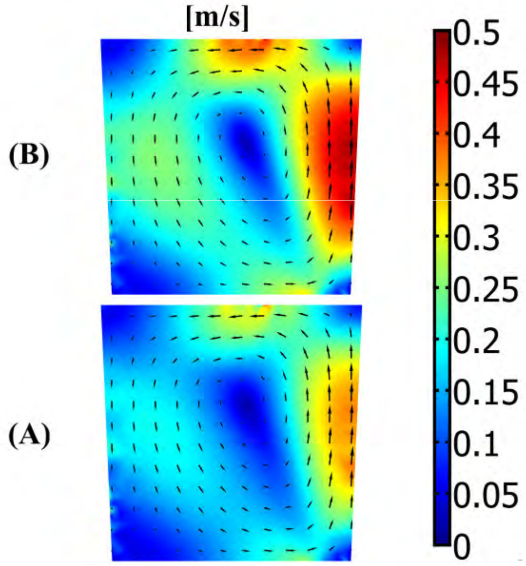
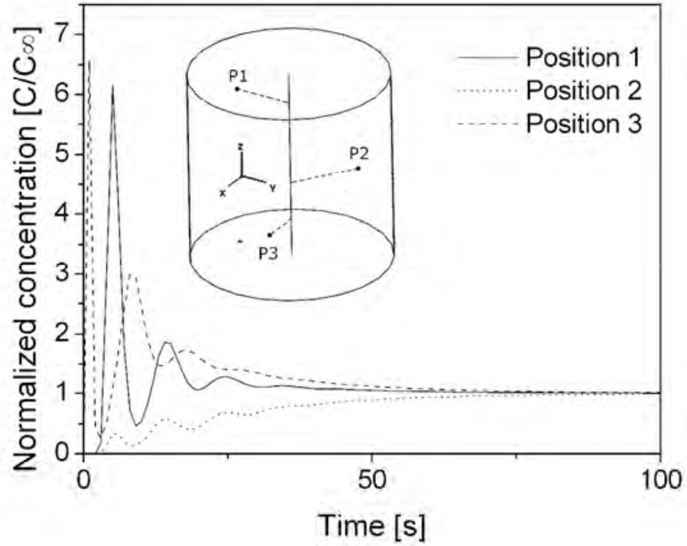
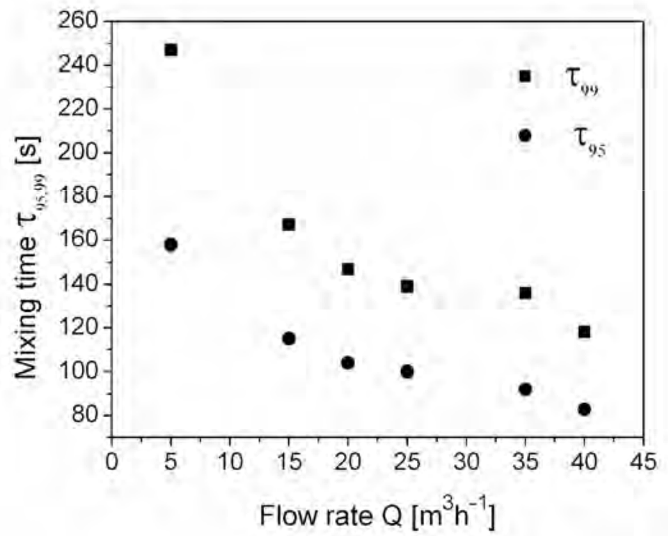
# Ladle results

Mixing time criteria $\tau_{95,99} = \frac{|c|}{c_\infty}$



# Conclusion

- A simplified model of two metallurgical processes were developed using Comsol Multiphysics 3.5
- Flow and mixing time in the ladle was calculated.
- The flow profile within the converter was calculated.

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# Thank you for listening