Progress Report Meeting

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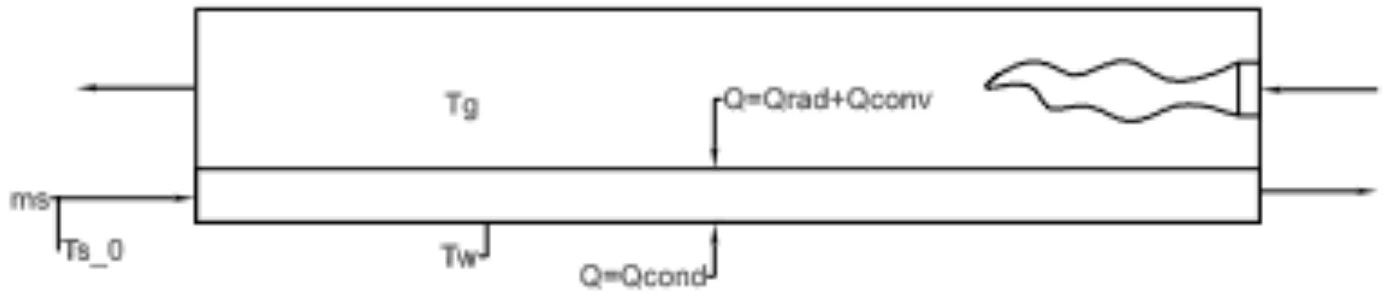
1-D PFR Model (ODE)

Why use a simplified model?

- It may give good results due to the low loading of the kiln
- It can be used as an aid for decisions in the re-design of the operation unit, e.g. the temperature of the feed can be changed easily and the computation time is seconds (to evaluate preheating of the feed for example)
- It will be used for an initial solution for further models

1-D/2-D Sketch of the Kiln

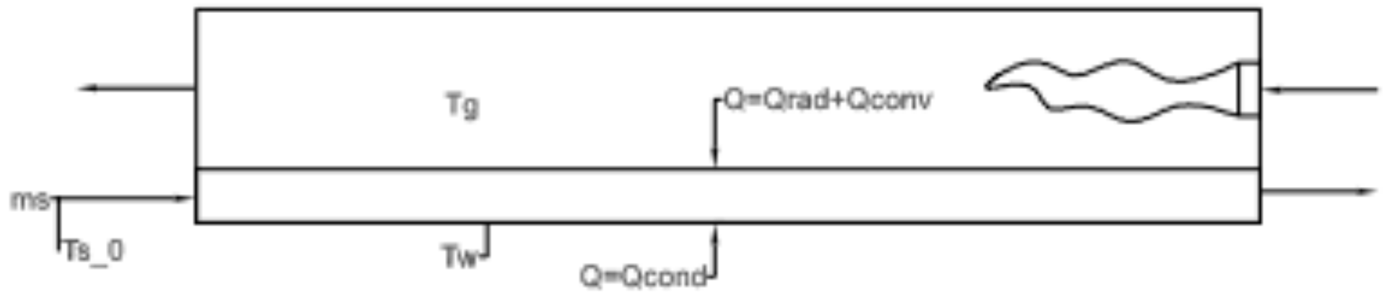


Assumptions of the Model

- The freeboard gases are homogeneously mixed in the transversal direction,
- The granular material is perfectly mixed in the transversal direction,
- The granular material flows in a PFR-like manner.

One must note that indeed the approach is a simplification of the actual phenomena.

1-D/2-D Sketch of the Kiln



Governing Equations

$$\dot{m}_s c_{ps} \frac{dT_s}{dz} = Q_{radiation,g\rightarrow s} + Q_{convection,g\rightarrow s} + Q_{conduction,w\rightarrow s}$$

$$Q_{gas\rightarrow wall} + Q_{radiation\rightarrow wall} + Q_{solids\rightarrow wall} = Q_{shell\rightarrow ambient}$$

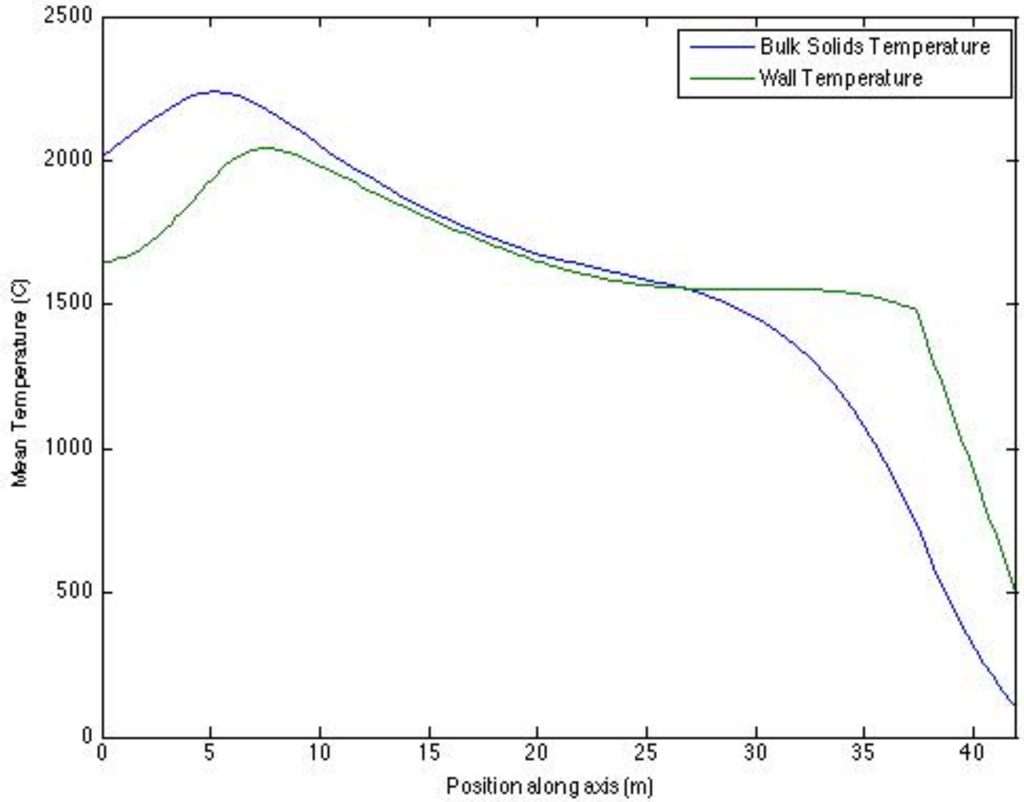
Governing Equations

$$\dot{m}_s c_{ps} \frac{dT_s}{dz} = Q_{radiation,g \to s} + h_{conv} A_{g \to s} (T_g - T_s) + h_{cond} A_{w \to s} (T_w - T_s)$$

$$h_{conv} = 0.4 G_g^{0.62} \qquad Nu = \frac{h_{cond} R \xi}{k_b}$$

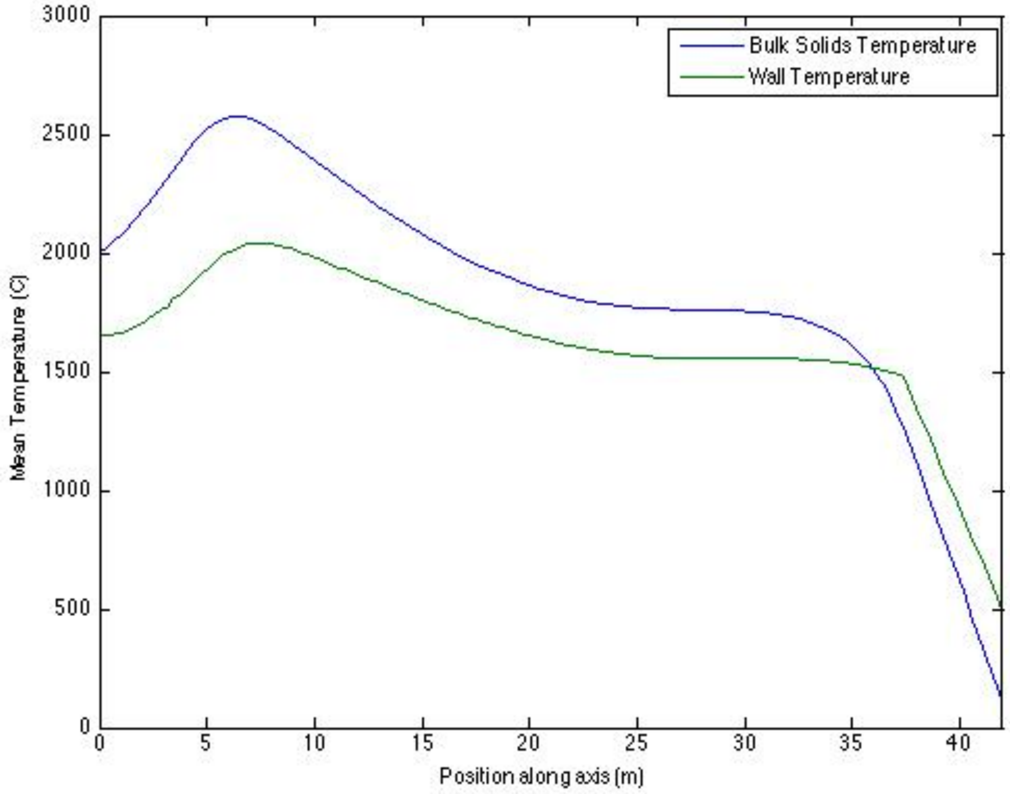
$$Nu = 11.6 Pe^{0.3} \qquad Pe = \frac{R^2 \xi \omega}{\alpha_b}$$

Preliminary Results



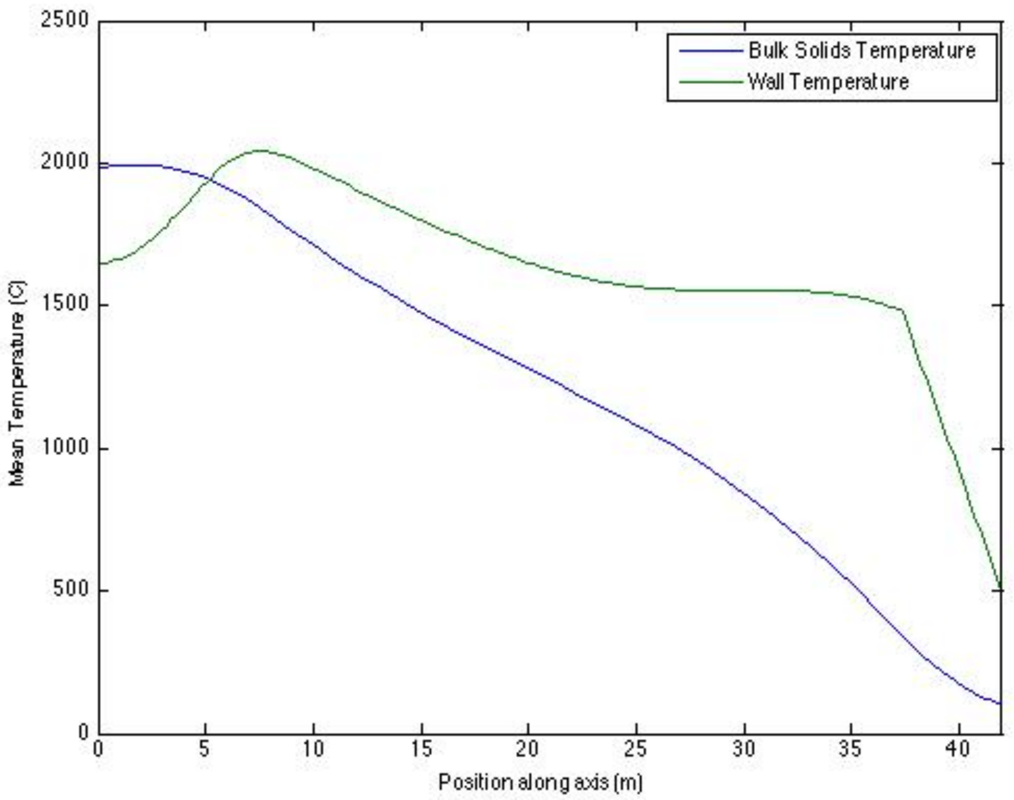
Base Case: 4500 kg/h, 500 Nm3/h, 100 C

Preliminary Results



High gas velocity

Preliminary Results



Higher Kiln loading/Lower Gas Velocity

Further work on 1-D model

- Calibration with data calculated by M. Pisaroni
- Selection of convective heat transfer correlation
- Validation with data from the Kiln, thermocouples and discharge end temperatures
- Sensibility analysis on Gas velocity, Mass Flow and Solids initial Temperature.

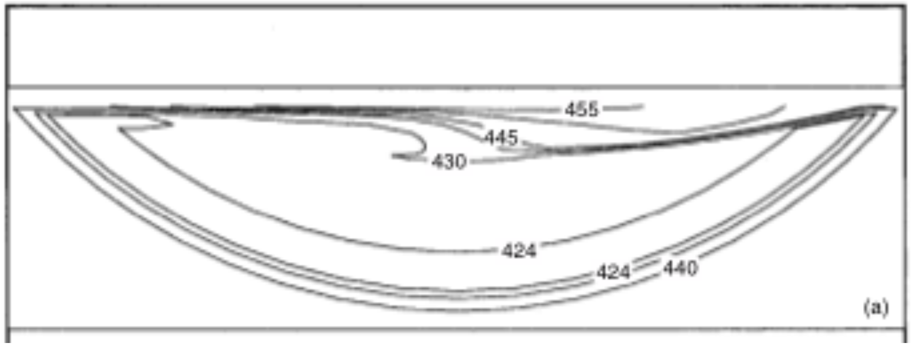
What comes next?

- 1-D Model
  - Calibration and Validation
- Transversal Flow Model (DEM)
  - Calibration and Scale Up to actual kiln size
- PDE Heat Transfer Model
  - Setup, calibration and validation

PDE Heat Transfer Model

- Model described by Boateng,
- Uses Input from a Transversal Flow model which in our case is a DEM simulation,
- Uses same physical correlations as 1-D model and similar governing equations

Sample Output



$$\frac{\partial}{\partial x}\left(k_{\mathrm{eff}}\frac{\partial T}{\partial x}\right)-\rho c_p u_x\frac{\partial T}{\partial x}+\frac{\partial}{\partial y}\left(k_{\mathrm{eff}}\frac{\partial T}{\partial y}\right)-\rho c_p u_y\frac{\partial T}{\partial y}+\dot{m}_b c_{p_b}\frac{\mathrm{d}T_{\mathrm{ba}}}{\mathrm{d}z}=0$$

*Images from Boateng

Thank you for your Time!

Questions?