Modelling and Analysis of Electrothermal Fluidized Bed Reactors: A Case Study on COS decomposition via direct resistive heating

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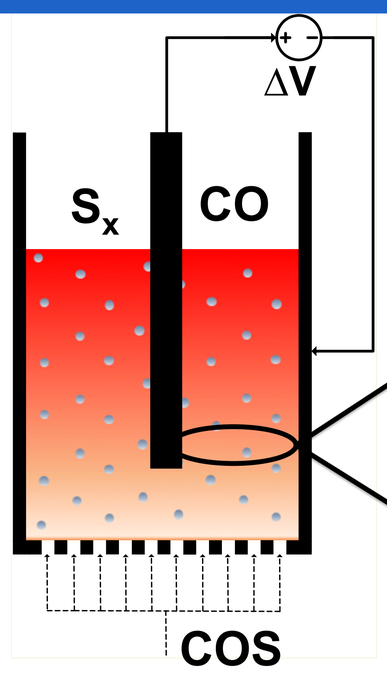
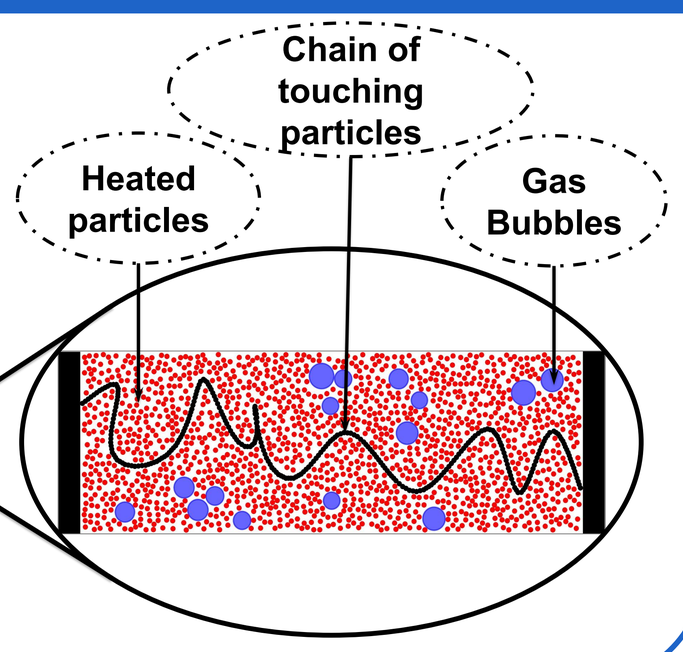
Introduction

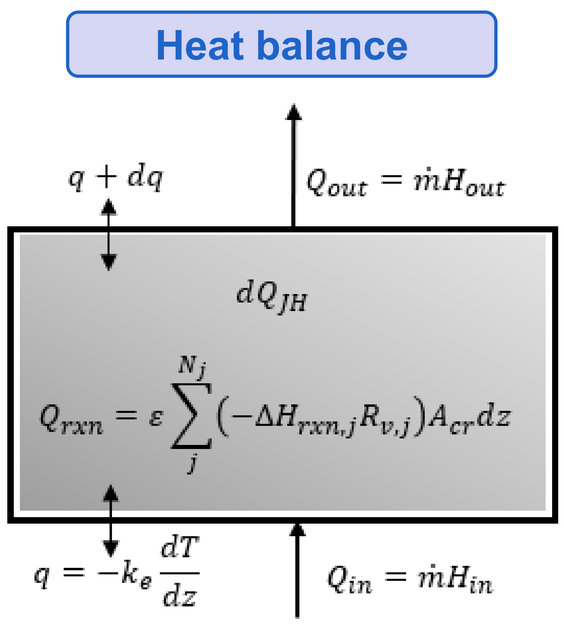
- **Electrothermal Fluidized Bed (ETFB):** Electric potential **(ΔV≈5-150V[1])** across electrodes drives electric current **(I≈10-100A[1])** via conductive particle bed through **chains of touching particles**, generating Joule/resistive heating **(Q_{JH})** while **fluidization** enhances heat/mass transfer.
- **Gap:** the literature lacks a fundamental heat balance model that can utilize the electrical parameters of an ETFB such as **ΔV, I** or **Q_{JH}** to predict temperature and conversion profiles.
- **Contribution:** A steady-state 1-D electrothermal model that utilizes electrical inputs and serves as a design/optimization tool and evaluated on the COS decomposition reaction



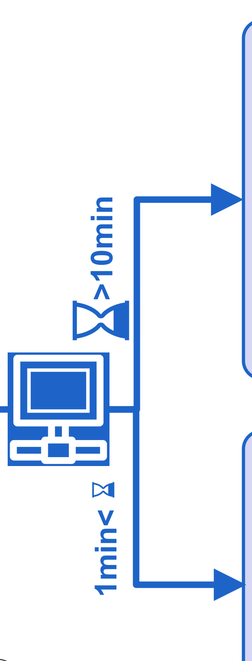


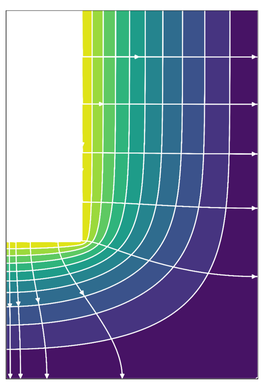
Adiabatic Electrothermal Model of a Coaxial-Electrode ETFB

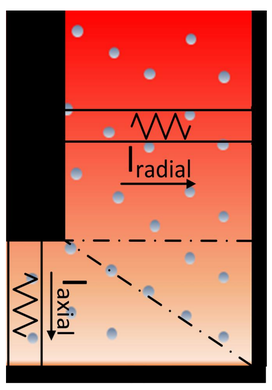
Heat balance



$$u\rho_g Cp_g \frac{dT}{dz} - k_e \frac{d^2T}{dz^2} - \varepsilon \sum_j^{N_j} (-\Delta H_{rxn} R_{v,j}) - \frac{dQ_{JH}}{dz A_{cr}} = 0$$



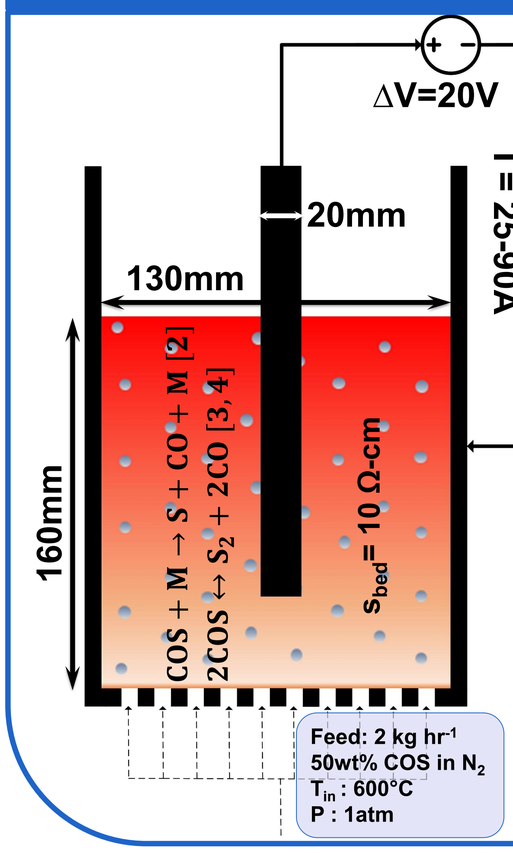


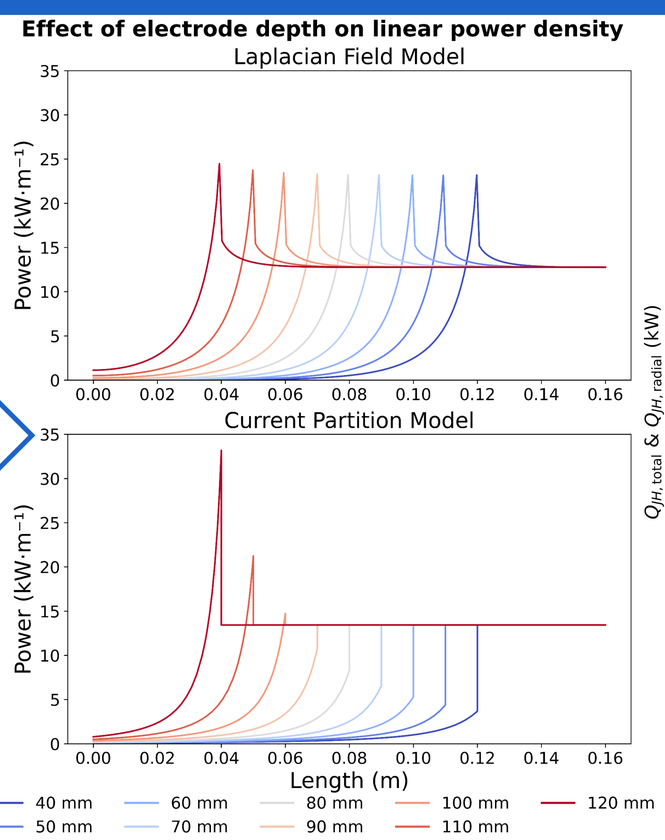


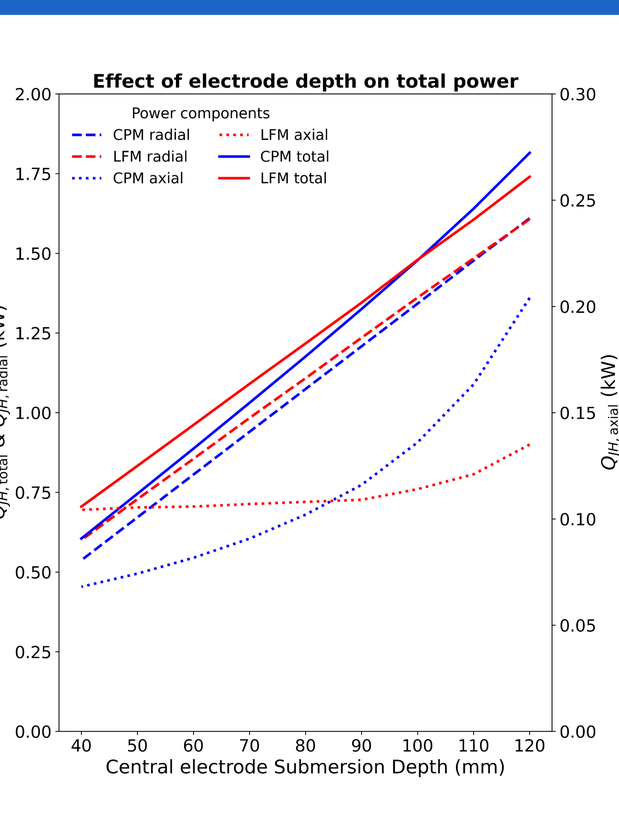
- 2D spatially resolved Laplace equation for electric potential field description
- Accounts for the curvature of the electric field
  - $\frac{dQ_{JH}}{dz} = \int_{0/r_1}^{R} \int_0^{2\pi} -\frac{1}{s_{bed}} \left(\left(\frac{d\Delta V}{dr}\right)^2 + \left(\frac{d\Delta V}{dz}\right)^2 \right) r dr d\Theta$

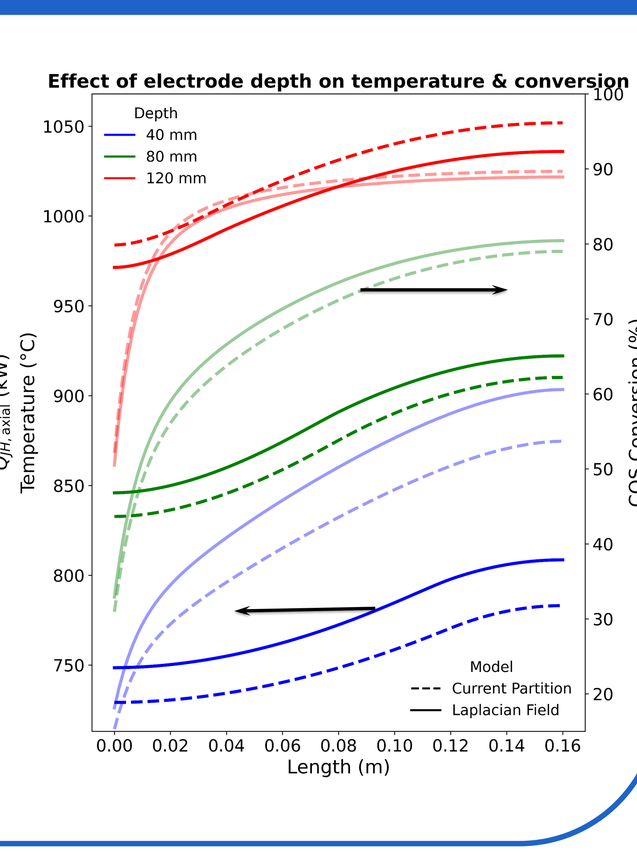
- Identifies dominant current direction region
- Divides the bed into distinctive resistive regions
  - $\frac{dQ_{JH,radial}}{dz} = \frac{\Delta V^2 2\pi}{s_{bed} \ln\left(\frac{R}{r_{electrode}}\right)}$; $\frac{dQ_{JH,axial}}{dz} = \frac{I_{axial}^2 s_{bed}}{\pi r^2}$

The case of COS decomposition









Conclusions

- **LFM** provides **full-field spatial resolution** of the bed's electric behavior (gradients and **power-density spikes**); **CPM** gives a ~10× cheaper approximation.
- The model is a practical tool to select **electrode configuration**, **ΔV**, and **bed properties** for target operating points.
- **Future work:** transients, non-ideal hydrodynamics, and experimental validation.

Acknowledgements

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