

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

K. Jacobs¹, S. Zareghorbaei¹, J. Lauwaert², J. Thybaut^{1*}

¹Laboratory for Chemical Technology (LCT), Ghent University, Ghent, Belgium;

²Industrial Catalysis and Adsorption Technology (INCAT), Ghent University, Ghent, Belgium;

*Joris Thybaut: Joris.Thybaut@UGent.be

Keywords: ElectroThermal Fluidized Bed reactor; Joule heating; Electrical resistance; COS decomposition
Background and motivation.

ElectroThermal Fluidized Bed reactors (ETFB) are a promising technology for the electrification of high-temperature endothermic reactions. However, modeling efforts on ETFBRs are scarce, and to our knowledge, no basic differential heat balance model for it is available in the literature. Consequently, the objective is to develop a basic design tool for ETFBRs, utilizing available solvers at minimal computational cost.

Materials and methods.

COS decomposition into CO and elemental S in an ETFB with a coaxial electrode configuration (Figure 1 (left)) is simulated as a case study. The mass balances of a two-phase bubbling fluidized bed are detailed elsewhere^[1], and the kinetics of COS decomposition are derived from previous works^[2]. The resistive heating term of an adiabatic ETFB, isothermicity between low and high-density phases, radial uniformity, and steady state conditions was derived from conceptual electric resistances in the annulus (CAR) and below the tip region (TCR) of the bed (Figure 1 (middle)).

Results and discussion.

The resistive heating term ($dQ_{JH} dz^{-1} \text{Ac}^{-1}$) for each conceptual resistor is incorporated into the heat balance, resulting in the following expression for a one-dimensional adiabatic ETFBR:

$$u\rho_g C p_g \frac{dT}{dz} - k_e \frac{d^2T}{dz^2} - \varepsilon \sum_j (-\Delta H_{rxn} R_{v,j}) - \frac{dQ_{JH}}{dzAc} = 0; 0 < z < Z_1: \frac{I_{TCR}^2 s_{bed}}{\pi r_1 r_2 Ac}; Z_1 < z < Z_2: \frac{\Delta V^2 2\pi}{s_{bed} \ln\left(\frac{r_2}{r_1}\right) Ac} \quad (1)$$

The model captures the impact of electrode position on bed temperature and reaction conversion as seen in Figure 1 (right) while maintaining the applied voltage constant. Future work includes developing a 2-phase heat balance with resistive heating occurring in the high density phase as well as capturing non-ideal hydrodynamics.

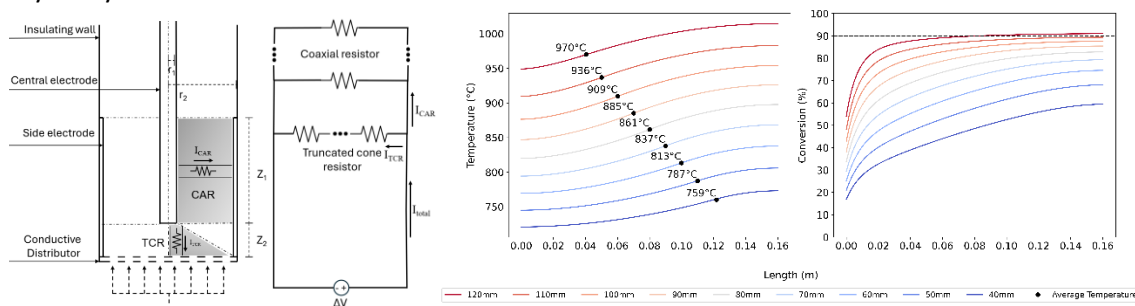


Figure 1. Left: Coaxial ETFBR configuration. Middle: Equivalent mixed resistors circuit. Right: Impact of the electrode position on Temperature and COS Conversion

Acknowledgments

This research is being supported by the project e-CODUCT under Horizon Europe Agreement No. 1012058100.

References

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