

A User-Defined Electrothermal Fluidized Bed Reactor Model for Direct Joule Heating with Application to Non-Oxidative Coupling of Methane

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Highlight

- Developed an axially resolved two-phase reactor model for electrically heated fluidized beds
- Axial energy balance quantifies internally generated electrical heating demand
- Preliminary reactor-level energy demand is ~19.1 kJ per mol of methane feed

1. Introduction

Electrothermal fluidized bed reactors (EFBRs) are promising for high-temperature gas–solid endothermic reaction systems, including methane coupling, because of their high heat-transfer rates and precise temperature control. Within EFBR designs, direct Joule heating delivers electrical energy by passing current through electrically conductive bed particles, generating heat internally through electrical resistance [1]. This enables uniform bed temperatures and high electrical heating efficiency. However, there is no built-in reactor model available in commercial process simulators for electrothermal fluidized bed reactors with direct Joule heating. Consequently, a user-defined EFBR reactor model is required to enable realistic process-level assessment of EFBRs with direct Joule heating.

2. Methods

Within the CAMELEON project, a preliminary one-dimensional reactor model for an electrothermal fluidized bed reactor with direct Joule heating is being developed. The model is based on an axially resolved two-phase bubble–emulsion description of the fluidized bed. The governing equations describing mass and energy transport in the fluidized bed are implemented and solved in MATLAB. The model is designed to be coupled with Aspen Plus as a CAPE-OPEN–compliant user-defined unit operation, enabling the exchange of material and energy streams at the flowsheet level. Application to a non-oxidative methane coupling (NOCM) system is considered as a case study, using gas-phase chemistry described by the AramcoMech 3.0 mechanism [2] and surface reactions based on established literature models [3].

3. Results and discussion

The model provides detailed axial profiles for the bubble and emulsion phases, capturing the impact of interphase mass transfer on methane conversion and product selectivity. The framework calculates the axial energy requirement of the reactor, quantifying the electrical power needed to sustain the endothermic NOCM reaction, with preliminary reactor-level results indicating an energy demand of approximately 19.1 kJ per mol of methane feed. In addition, it provides a predictive tool to assess how variations in superficial gas velocity and electrical input affect reactor efficiency.

4. Conclusions

Overall, this work presents a process-oriented modeling framework for directly Joule-heated electrothermal fluidized bed reactors that can be integrated into industrial process simulation environments. The proposed approach provides a foundation for assessing and further developing electrified fluidized bed concepts for NOCM applications, as well as for future techno-economic and sustainability studies.

References

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Keywords

Methane conversion, Electrified reactors, Two-phase fluidization modeling, User defined function

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