

# Binary particle wetting and backmixing in an Archimedes packed bed reactor with helical tube coil

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## Highlights

- Helical screw reactor intensifies gas-liquid-catalyst contact in trickle beds.
- Alternating gas/liquid segments enable near plug-flow with low backmixing.
- Model and tracer studies predict flow, residence time, and mixing behavior.

## 1. Introduction

Trickle bed reactors (TBR) are among the most commonly used contact devices for heterogeneous catalytic gas-liquid reactions. The mass transfer of the gaseous reactant is often the limiting step [1], which must be compensated operating at high pressure.

In recent years, various concepts for intensifying the limiting heat and mass transfer steps have been proposed. The main goal of these concepts is to improve the mass transfer of the gaseous reactants to the catalyst. Periodic operation of TBRs is suitable for improving gas mass transfer [2]. However, the success of this method is limited to narrow laboratory reactors with plug-flow-like behavior [3]. Existing intensification concepts aimed at achieving local variations in wetting, e.g., siphon reactor, inclined rotating reactor [4,5]; however, they are not sufficiently flexible and complex interactions among the geometric and operational parameters impede scale-up and industrial use.

## 2. Methods

A more promising approach is the concept, which involves a tubular reactor with an Archimedean screw in the form of helical tube coils, integrated with a catalyst bed (Figure 1). Alternating portions of liquid and gas are drawn from a reservoir at the reactor head or reactor sump into the helix and transported axially according to the rotational direction of the reactor. The alternating fluid portions at the macroscopic scale resemble Taylor flows, which could previously only be realized in thin channels. The catalyst bed is subjected to wetting and de-wetting, and the gaseous and liquid-phase reactants are alternately brought into direct contact with the catalyst. By separating the individual gas and liquid portions during their transport through the reactor, a plug-flow-like behavior with low backmixing is achieved. Yet, this new intensification concept lacks geometric and operational design principles.

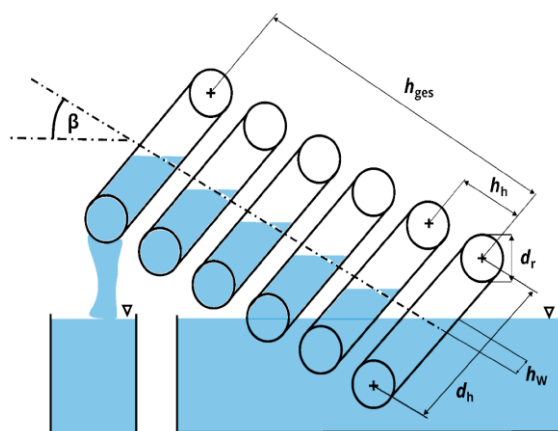
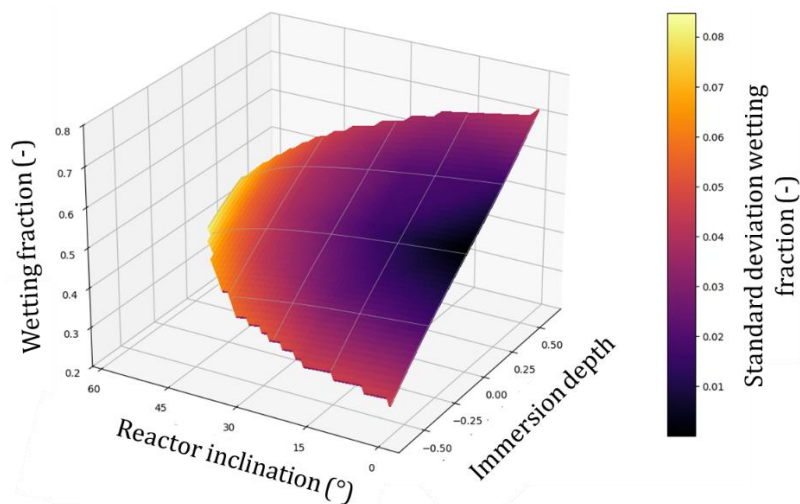


Figure 1. Principle of the Archimedes packed bed reactor with helical tube coil.

### 3. Results and discussion

In this contribution, a geometry model is presented as a design tool based on a representative tube coil, which provides liquid flow rate, liquid filling level in the coil, wetting duration per rotation (Figure 2), and the total residence time as a function of tilt angle, coil pitch, tube and helix diameter, rotational speed, and reservoir immersion depth. Hydrodynamic studies were conducted to assess the deviation of the flow rate for empty and packed reactor comparing model predictions and experiment data.



**Figure 2.** Particle wetting fraction depending on inclination angle and reservoir immersion depth for  $d_h:d_r = 3:1$ .

Additionally, conductivity tracer studies were performed to investigate the degree of axial backmixing and the mean residence time as a function of geometric and operational parameters. The quantification of the degree of backmixing is performed through tracer mass balance with the residence time model for a CSTR with partial recirculation and dead zones. Deviations from plug-flow result from the drainage behavior within the catalyst bed and the retention of liquid in the packing due to capillary forces and the liquid-catalyst drag.

### 4. Conclusions

Trickle bed reactors often suffer from gas-phase mass-transfer limitations, making process intensification essential. A novel concept uses a tubular reactor with an Archimedean screw and helical coils to alternately transport gas and liquid, creating Taylor-flow-like segments, periodic wetting/dewetting of the catalyst, and near plug-flow behavior with low backmixing. A geometry model and tracer studies were used to predict flow, residence time, and deviations caused by drainage and capillary retention.

### References

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### Keywords

Archimedes reactor; geometric model; packed bed; periodic wetting; backmixing