PINCH TUBE FLOW REACTOR FOR EXOTHERMIC MULTIPHASE REACTIONS

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Abstract

A novel reactor concept that used the straight tube as a flow reactor modified by means of pinching it periodically at different locations and at different angles is presented. A detailed hydrodynamic study (pressure drop, residence time distribution and mass transfer) involving single and two phase flow is done for pinched tube helical coils of different sizes and compared with the straight tube of identical length. CFD simulations were carried out to explore the effect of pinching length and pinching angle on mixing and flow profile inside the reactor for different tube cross sections and compared with experimental data. In all cases decreasing the pinching length increases pressure drop compared to straight tube for single and two phase flow. The performance of the pinched tube reactor is verified by successfully carrying out two phase highly exothermic reaction without employing micromixer.

Keywords

Novel, hydrodynamics, simulations, Pressure drop.

Introduction

Continuous flow reactors are known to have several advantages over the conventional batch reactors. The tubular form of flow reactors are common and a variety of configurations of tubular reactors, viz. coils, serpentine configuration, spiral etc. are used for different applications (C. Petschacher et. al., 2013). Among few of the ways to improve the mixing, heat transfer and mass transfer in a tubular reactor are by enhancing the surface roughness or inserting a static mixer (X. NI et al., 2003). The static mixer needs to be inserted inside the channel or tube, and is suitable only for straight tubes. In view of this limitation, a novel tubular flow reactor is presented here.

In general, a typical flow reactor includes a good micromixer followed by a residence time section. For the case of miscible fluids undergoing a fast and exothermic reaction, the role of micromixer is important as it helps to achieve good mixing. The dimension of the residence time section is chosen such that the heat transfer requirement for conducting the specific reaction is met. However for the gas-liquid as well as liquid-liquid immiscible reactive systems the previous configuration is of limited use as the interfacial area available for mass transfer remains limited by the slug size. While it is possible to enhance this area by changing the flow regimes by changing the flow rates, the flow rate ratio of the two fluids is largely dictated by the reaction chemistry. Thus, it is necessary to develop a reactor that will allow retaining excellent mixing or dispersion throughout the length without affecting the area available for heat transfer. In order to achieve these phenomena, a straight tube was modified by pinching it externally in a periodic manner at fixed pitch, such that it decreases the cross-sectional area locally by as much as 70% while the perimeter remains the same. The extent of pinch can also be varied to achieve different levels of shearing inside the tube. The pitch between two subsequent pinch locations was varied as a function of tube diameter viz. 5D, 10D, 15D, etc. Importantly, the direction was pinch or angle was changed periodically to achieve an

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internal change of flow direction in addition to periodic shearing. Thus, between two subsequent pinched sections there would be a straight non-pinched section, which would generate a sequence of converging-diverging segments with change of flow direction. Such a tube after pinching can be used in any form viz. straight tube, helical coil, spiral etc. which would not affect the nature of flow due to periodic high and low shear zones in the reactor.

**Experimental Procedure**

Different pinched tube reactors were fabricated by pinching SS316 tubes of 6.2 mm o.d. and 3.52 mm o.d. at different intervals (3D to 10 D). Pinching was performed such that every subsequent pinching was perpendicular to the previous one. Initially, the hydrodynamics of the pinched tubes was studied by monitoring the pressure drop at different flow rates. Two syringe pumps were employed to pump the fluid in the reactor. Single phase and two phase pressure drop experiments were performed for kerosene-water system. To measure the residence time distribution inside the reactor tracer pulse of salt solution was given at the inlet and conductivity was measured at the outlet with the help of conductivity meter and data is recorded using an in-line data acquisition system. The nature of flow was studied using computational fluid dynamics (using COMSOL Multiphysics software) and the data was used for choosing the optimal pinching protocol. Further the pinched tube reactor was used for carrying out liquid-liquid extraction as well as exothermic liquid-liquid reactions.

**Result**

Decreasing the pinching interval increases the pressure drop for two phase and single phase flow. Pinching the tube significantly enhances the mixing during the flow inside the tube by means of contraction and expansion of cross section over the length which provides the resistance during the flow increasing the pressure drop.

**References**

