

THERMOGRAPHIC INVESTIGATIONS OF A MICRO STRUCTURED THIN FILM REACTOR FOR GAS/LIQUID CONTACTING

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Summary

Information about the liquid distribution as well as the mass transfer at the gas-liquid interface can be inferred from thermographic measurements taken of a thin film micro reactor performing an exothermic test reaction.

Keywords

Multiphase reactor, Novel reactor technologies, Micro-reactors.

Introduction

Micro thin film reactors are interesting devices for gas/liquid reactions due to their exceptional heat and mass transfer characteristics. However, compared to conventional reactors, the equal distribution of flow is both more important and at the same time more difficult to achieve, which can complicate characterization of the transport within these devices [1]. Wille et al. [2] characterized the liquid distribution at start up conditions in a micro structured falling film reactor with thermographic measurements of the liquid film. They demonstrated the excellent heat transfer characteristics of a falling film micro reactor when performing the reaction of gaseous CO₂ with aqueous NaOH solution, achieving near isothermal conditions.

In this contribution, however, we chose not an isothermal, but a near adiabatical approach to analyse the processes occurring within the thin film. The analysis of the evolving temperature distribution allows for both the characterization of liquid flow distribution as well as characterization of the gas-liquid mass transfer.

Experimental Methods

The set-up consists of a micro structured thin film contactor, which has been developed to perform highly exothermic gas-liquid reactions, gas and liquid dosing systems, and a thermographic camera. The reactor is shown in Figure 1. For the purpose of the reported investigations, the heat exchange module has been removed and replaced with a window allowing for the collection of thermographic measurements on the reverse side of the thin, micro structured foil, which is blackened

to provide a homogeneous heat emitting surface. The foil is structured with 33 microchannels 1000 µm wide, 600 µm deep, separated from each other by 600 µm, where the length of the channel open for contact to the gas is 197.5 mm. There is a large gap for gas flow between the microchannels and the glass observation window above. The liquid entrance consists of closed microchannels, which forces the liquid into the microchannels and is intended to provide a good distribution of the liquid. Liquid flows downward through the open channels, where it is exposed to gas and reacts. Calibration of the setup using hot water showed that the heat conductivity of the metal foil is sufficiently high to give a reliable temperature signal, and the length of the temperature path is small.

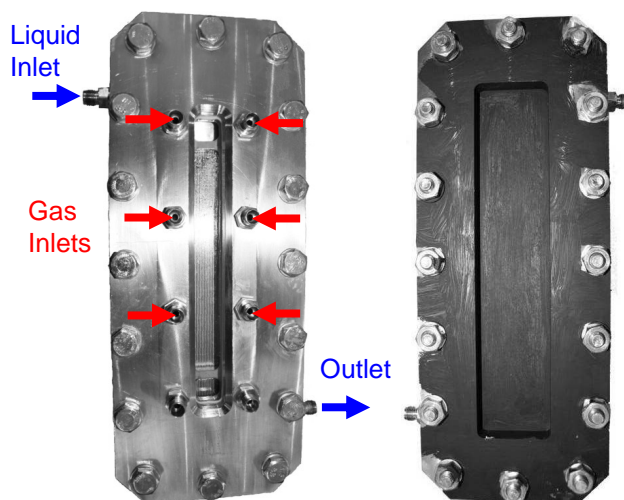


Figure 1: thin film microreactor for thermographic investigations

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The reactor can be operated either with gas-liquid separation performed in the bottom portion and liquid and gas exiting through separate ports analogous to the inlets or, as was done in this study, the two phase flow can exit through a single outlet.

Results

The equipartition of the fluids can be observed when operating the device properly. Improper operating conditions lead to an asymmetrical heat evolution that can immediately be detected. Thus, the equal distribution of flows can be characterised. Figure 2 shows thermographic images for a reaction with good distribution of the fluids in micro structured channels and a poor liquid distribution on an unstructured foil.

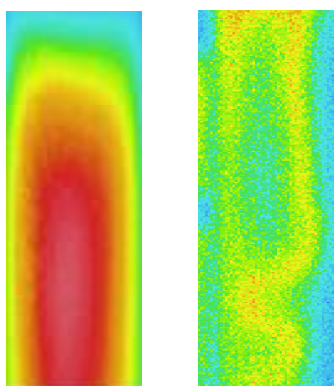


Figure 2: Thermographic images for the thin film micro reactor demonstrating (left) good distribution of both fluids and (right) maldistribution of liquid

The reaction was performed using varying concentrations of reactant in the gas. As can be seen in Figure 3, the amount of heat as well as the rate of the heat evolution, which is directly proportional to the rate of reaction, depend on the gas concentration and can easily be monitored by the thermographic measurements, taking into account the heat loss as calibrated before. The profiles as shown in Figure 3 reflect that along the channel the temperature is constant at the inlet, since the liquid is not contacted with the gas. As soon as the fluids are contacted the temperatures rise linearly, the steepness reflecting the extent of the reaction.

Increasing the flow rates at a constant stoichiometric ratio resulted in a higher overall temperature in the reactor; although the residence time decreased, the overall enthalpy released due to reaction was higher when more reactants were present.

It is interesting to note that at high gas partial pressure, the reaction is limited to the first half of the reactor. Thus, mass transport determinations can be complicated not only by high conversion but also because the reaction rate is not

constant along the reactor length under these conditions. This situation represents a poor utilization of the reactor volume. However, using the data obtained by the thermographic method, it should be possible to optimize the reactor design, or to identify the optimal reaction parameters for a given reactor. An even distribution of the

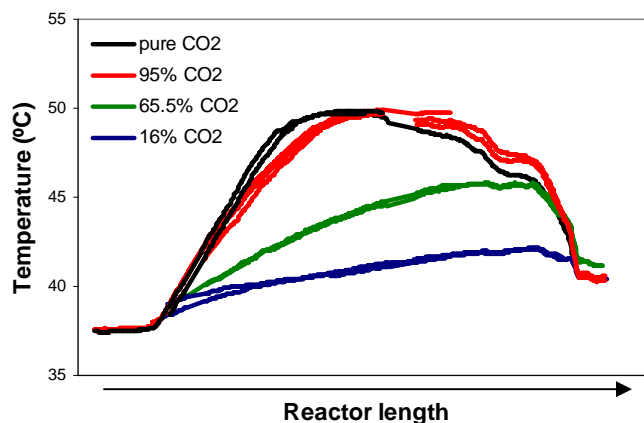


Figure 3: Temperature profile along reactor length for various gas reactant concentrations

reaction rate and thus energy release over the reactor length can be accomplished by diluting the reactant gas so that the transport through the gas controls the reaction rate or by introducing the gas reactant in stages through various gas inlet ports.

As has been shown, the thermographic images and resulting temperature profiles allow for a quantitative analysis of the extent of reaction along the reactor profile. Direct observation of the reaction via the heat evolution thus enables the investigation of mass transfer effects and optimization of the reactor design.

References

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