**Control of Temperature Uniformity for Exothermic Liquid Reaction in Structured Passages**

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**Highlights**

* Spatially-resolved temperature measurement using a fine-wire thermocouple
* Computation predicts the measured temperature profiles
* Buoyancy significant for the 5 mm passage size and flow rates used

**1. Introduction**

Exothermic reaction may cause temperature to exceed limits associated with preventing unwanted product formation or runaway reaction. Yet for efficient use of reactor volume it is important to operate as near to the temperature limit as possible to maximize reaction rate. Thus, an important engineering objective is minimizing temperature non-uniformity during the reaction process.

Reactors employing small-scale passages to increase relative heat transfer area have been widely advocated1 but structuring the passage geometry to get the best performance out of a given size has received little attention. The present approach uses spatial temperature measurements within the flow passages, by traversing a fine-wire thermocouple, to assess the capability of predictive computation, thereby allowing probing at other scales and for other geometries than those used in the experiments. Spatial temperature measurement has not been attempted within the flow in small passages. Those reported are either of exterior temperature of the device, e.g. using infrared thermometry 2, or require sensor size approaching that of the passage, therefore not local and only at the passage walls3,4.

The ‘F’ mixer geometry5,6 shown in Fig. 1a is considered here. Only the first four elements of a multi-element reactor are studied as the first few elements are where the reactant streams mix, the largest concentrations prevail and hence the greatest challenge to thermal control occurs. The experiment uses relatively large passage size to enable accurate local resolution of temperature by the measurement. The size is large enough for buoyancy to be significant, although at the smaller size passages envisioned for best thermal control, buoyancy will have reduced importance.

  

**Figure 1.** (a) Reactor geometry and (b) temperature measurement arrangement.

 **2. Methods**

In the experiment, two separate streams are supplied at uniform temperature to four F elements placed in series. The element passages are milled from PEEK, covered top and bottom by 1 mm stainless steel sheets coated on the passage side with a thin PFA layer and sandwiched between two copper plates containing cooling water passages. Temperature profiles are measured along linear paths passing through the passages by traversing a 75 micron diameter butt-welded K-type thermocouple (Fig. 1b). Calculations of wire temperature in a flow with sinusoidal fluid temperature variation along the wire suggest conduction error is less than 1% of field temperature difference with this wire size. Computations use ANSYS 16 to solve the Navier-Stokes, energy and species equations in the experimental geometry, the domain including the solid regions surrounding the passage. Boundary conditions are uniform temperature, composition and velocity at the inlets, uniform temperature at the top and bottom boundaries (although with a heat transfer coefficient representing the thermal resistance of the PFA-coated cover sheet) and zero heat flux at other external boundaries. The apparatus is design to deliver these with good approximation.

**3. Results and discussion**

Fig. 2a shows a typical result for computed and measured temperature profile with water flow (no reaction). In this case a warm inlet (46 °C) is cooled by the top and bottom plates (25 °C). The importance of buoyancy is clear from the computed result with gravity switched off (dashed line). Fig. 2b shows successful measurement of temperature with reaction occurring (18 °C adiabatic temperature rise) from inlet reagent streams at 25 °C with plates at (35 °C). Computations of the reacting cases are underway and could provide a route to deducing models for reaction kinetics.

(a) (b) 

**Figure 2.** Temperature along wire path (a) in Element 2 for water flow with heating and (b) reaction of 0.35 M sodium chlorite and 0.10 M potassium tetrathionate with 0.002 M sodium hydroxide.

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