DECHEMA FORSCHUNGSINSTITUT

Chemical Technology

Determination of mixing efficiency of micro structured mixers by isothermal heat balance calorimetry

A. Pashkova, J.-F. Drillet
e-mail: pashkova@dechema.de
Funded by: BMWi via AiF
Period: 01.05.2012 - 30.04.2014

ALLIANZ INDUSTRIE FORSCHUNG
Gefördert durch: Bundesministerium für Wirtschaft und Technologie

Project idea

Use the enthalpy of mixing ($h_{E,id}$) as a reference point for determination of mixing efficiency (G) of micro mixing devices

$G = h_{E,eff} / h_{E,id}$

$h_{E,id}$
- Measure for ideal mixing of two fluids on molecular scale
- Available in databases
- Accessible by isothermal calorimetry

$h_{E,eff}$
- Obtained from continuous heat balance calorimetry for the case when mixing takes place inside a micro mixing device

Benefits
- No need for optically transparent devices
- No need for knowledge of mixer channel geometry
- Well defined reference point / High reproducibility
- Possible wide variation of fluid viscosity

Types of experiments

ChemiSens CPA202 reaction calorimeter - "true heat flow" principle

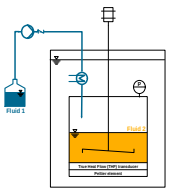
BATCH / $h_{E,id}$

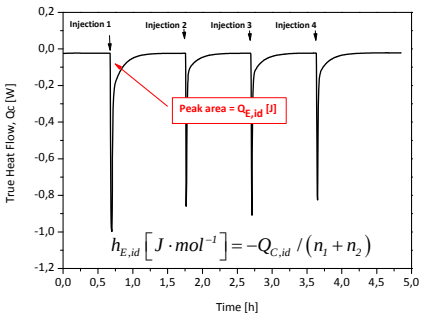
Model substances ethanol / acetone

Reference point T = 25 C

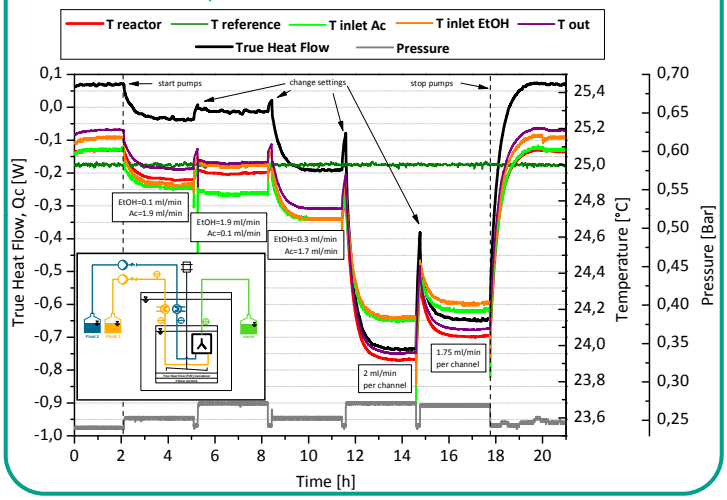
Heat transfer loop 22 ml

Injection syringe pump



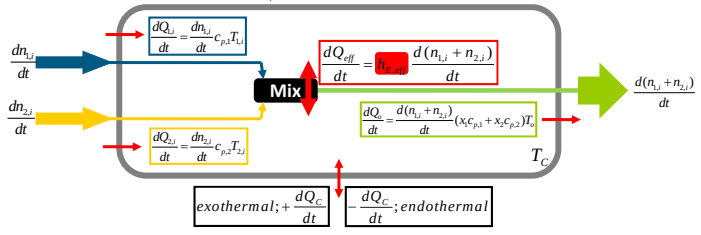


CONTINUOUS / $h_{E,eff}$



Heat balance of continuous mixing

dn/dt – mole flows [mol min^{-1}] | T – temperature [K] | i – inlet | eff – effective
dQ/dt – heat flows [W] | c_p – heat capacity [J K^{-1} mol^{-1}] | o – outlet | c – calorimeter

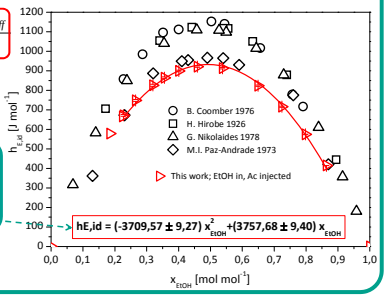


Heat flow balance

$$0 = \left[\left(\frac{dQ_{1,i}}{dt} + \frac{dQ_{2,i}}{dt}\right) - \frac{dQ_o}{dt}\right] - \frac{dQ_C}{dt} + \frac{dQ_{eff}}{dt}$$

$$G = \frac{h_{E,eff}}{h_{E,id}} = \frac{-\frac{dQ_{eff}}{dt} / \frac{d(n_{1,i} + n_{2,i})}{dt}}{h_{E,id}}$$

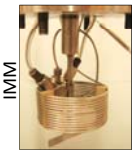
Polynomial fit of batch data

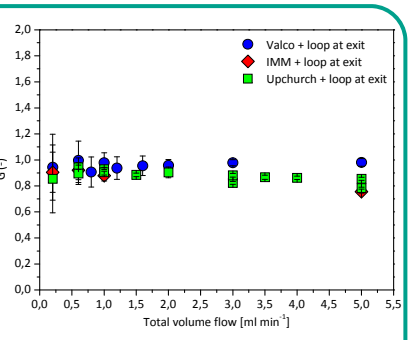


Mixer characterisation

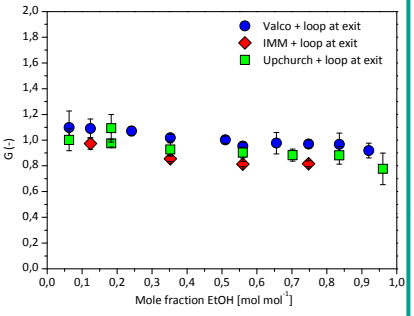
Reference point ($h_{E,id}$; G=1) determination ⇒ mixer with residence coil at exit

- Continuous experiments
- EtOH / Ac = 1 / 1
- T(reactor) = 25 C
- Stirrer = 500 rpm



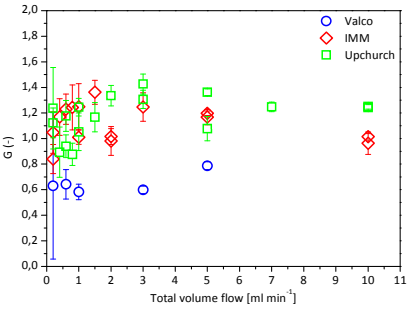


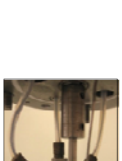
- Continuous experiments
- F(total) = 2 mL min^{-1}
- T(reactor) = 25°C
- Stirrer = 500 rpm

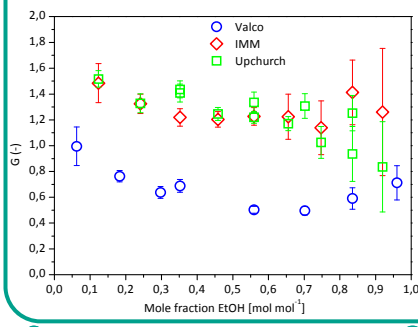


Net performance of mixer (without residence coil)

- Continuous experiments
- EtOH / Ac = 1 / 1
- T(reactor) = 25°C
- Stirrer = 500 rpm







- Continuous experiments
- F(total) = 2 mL min^{-1}
- T(reactor) = 25 C
- Stirrer = 500 rpm

Summary

- G is suitable for experimental determination of mixing efficiency
- $h_{E,id}$ is accessible continuously
- Preliminary results: A. Pashkova, L. Greiner *Chem. Eng. Sci.* 76 (2012) 45-48

Outlook

- Identify reasons for deviation of G
- Variation of fluid viscosity
- Test of reactive systems (acid/base)
- Change mixer types / peripherials
- Dimension analysis