Coflore ACR

Update and Results

AM Technology
Gilda Gasparini

17th PIN Meeting
30th June 2009, Newcastle University





Batch Reactors

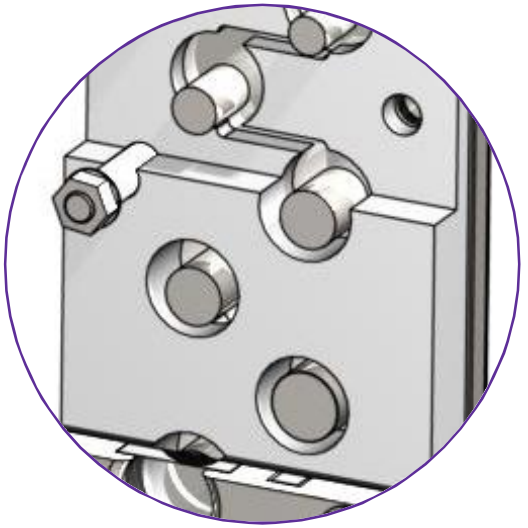
Coflux®

- On-line monitoring
- Better temperature Control
- Faster heating and cooling
- Improved energy efficiency

Continuous Reactors

Coflore™ ACR

- R&D and pilot plant
- Development tests
- Small productions for trials
- Small scale manufacture for high value products



Continuous Processes

EuC 2009

Maison Européenne des Procédés Innovants (MEPI)

INP ENSIACET

Summary of some results ....

Type of reaction	Phase system	Objective	Ancient Process	Intensified Process
Organometallic	monophasic	Continuous process feasibility Safety	Batch 100 L 3h30 fed-batch T = -70°C	- Volume reduction (150 mL) and duration(180 s) - Change in temperature (-40 to -20°C)
Synthesis of a carbonate	diphasic liquid-liquid	Selectivity	Batch 4m³ Low selectivity Excess of reactant 4h fed-batch	- Volume reduction (100mL) - Increase of selectivity - Decrease of reactant and solvent
Ionic liquid synthesis	monophasic, then diphasic G/L and 3-phase G/L/L	Exothermicity and mass transfer limitation	Batch 10 L 10h fed-batch 10 Kg/week	- Volume reduction 50 mL - Duration reduction : 1 min. - Productivity : 2 to 6 Kg/h
Hydrazine synthesis	Diphasic G/L	Continuous process feasibility	Adiabatic plug reactor	- Volume : 80 mL - Duration < 1 min. - Conversion increase

EFCE

GPE-EPIC Congress, Venice, Italy, 14-17 June 2009

le LABORATOIRE DE GÉNIE CHIMIQUE

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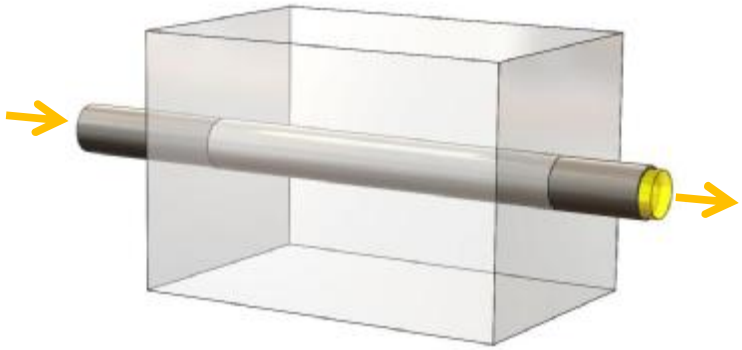
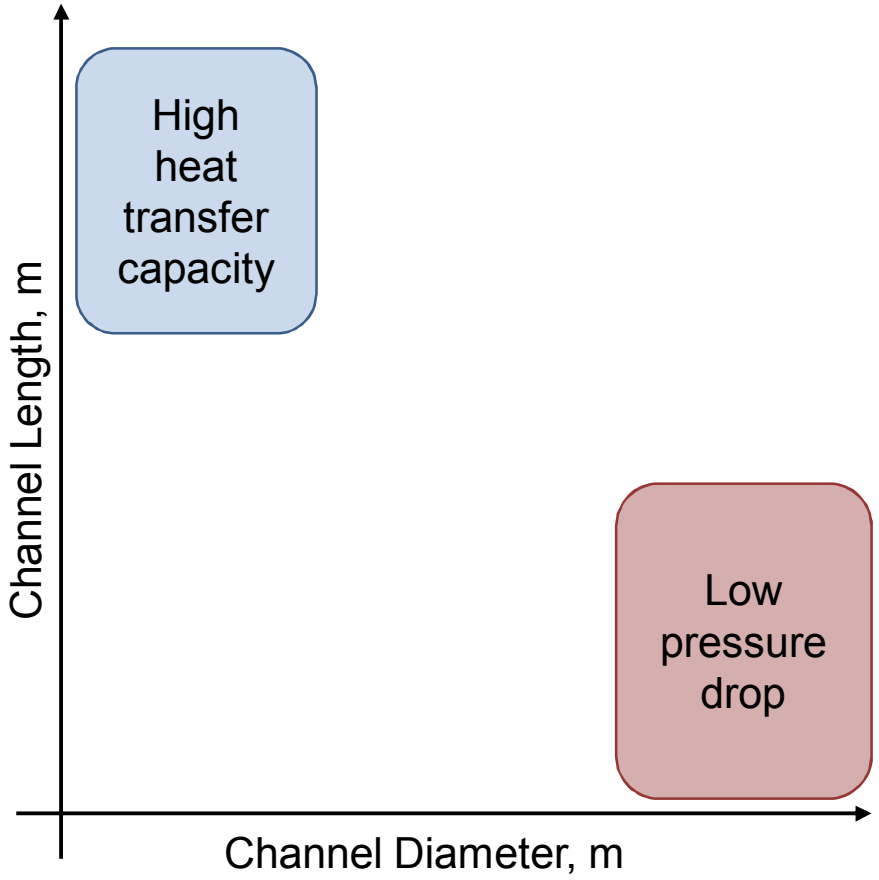
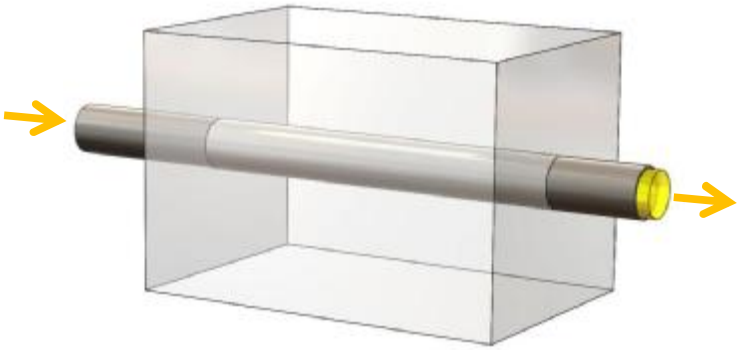
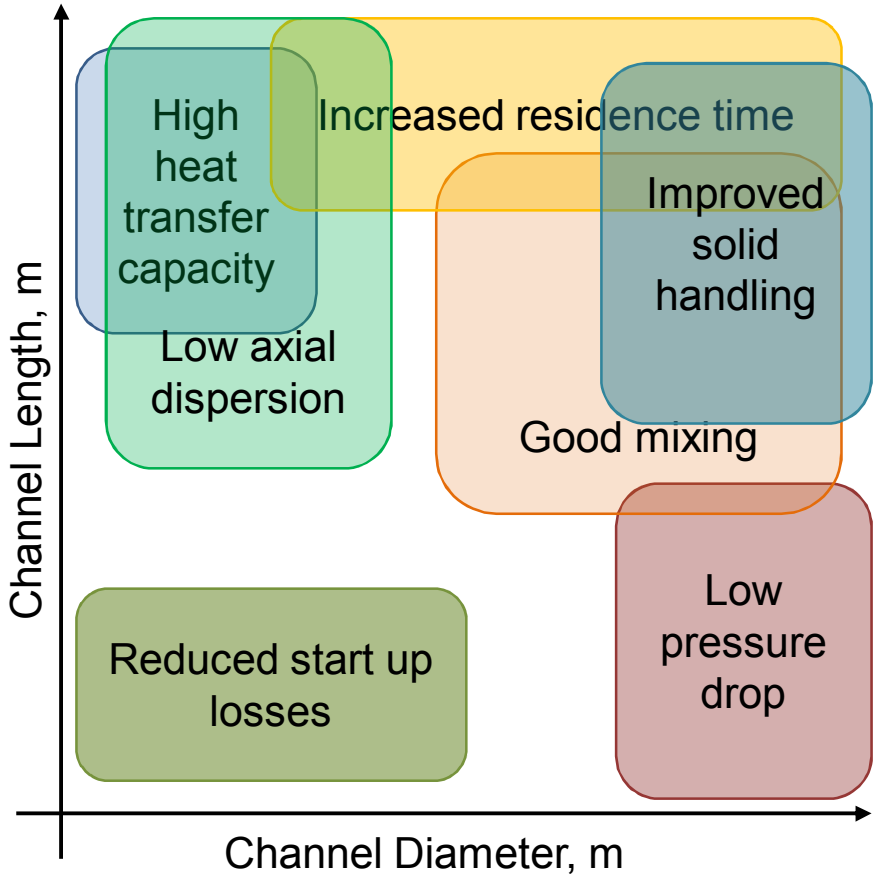


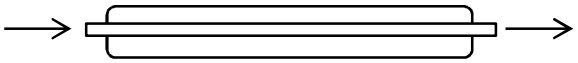
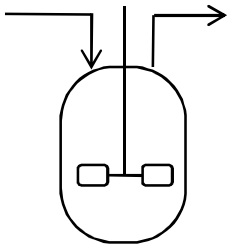


Continuous Processes



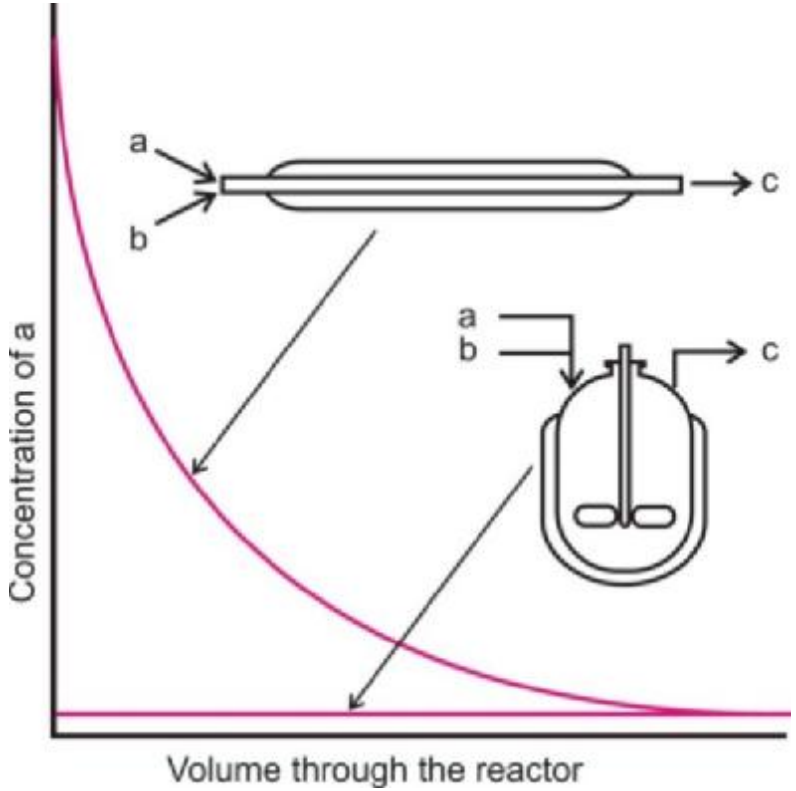


Continuous Processes

Static mixing		Dynamic mixing
		
O	Flexible throughput/residence time	P
O	Good mixing at low throughputs	P
P O	Low pressure drop	P
O	Good solids handling	P
P	Plug flow at low throughputs	O

Plug Flow

Plug flow is important for controlling reaction time and minimising dilution of reactants



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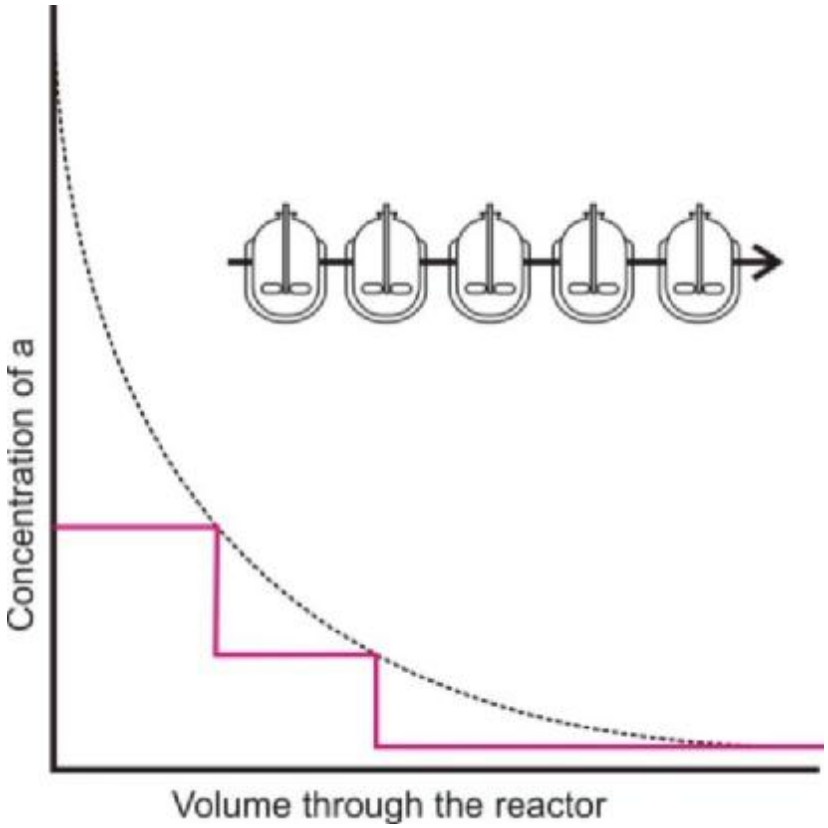

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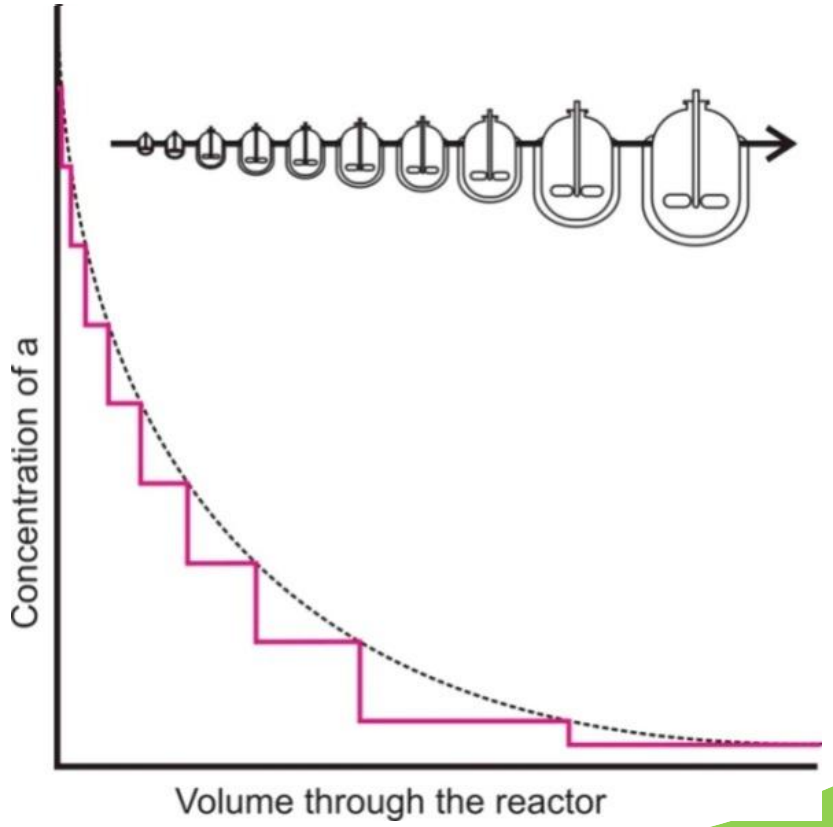
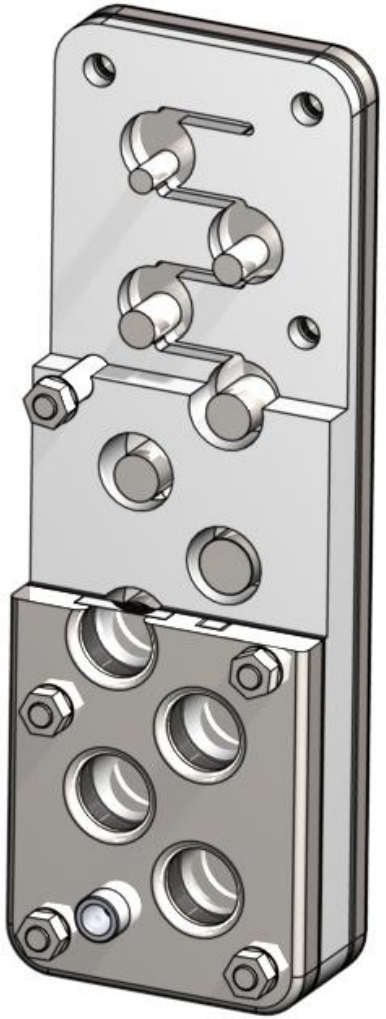


ACR / 1

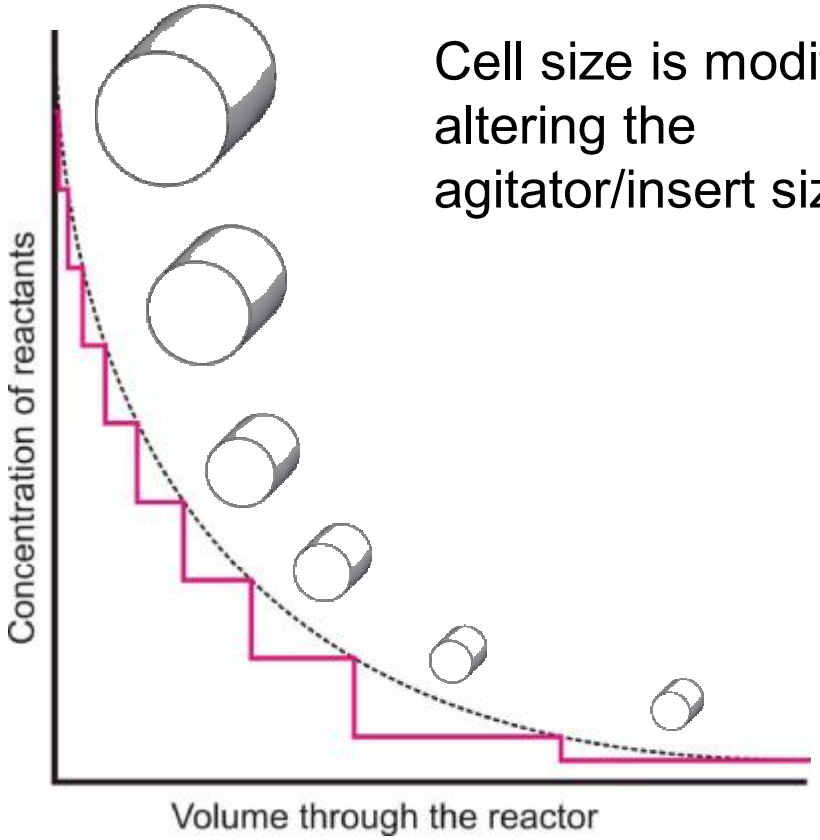
- Multi-stage CSTR with 10 cells in series
- Variable volume
- Minimal backmixing
- Constant heat transfer requirement
- Monitoring glass windows

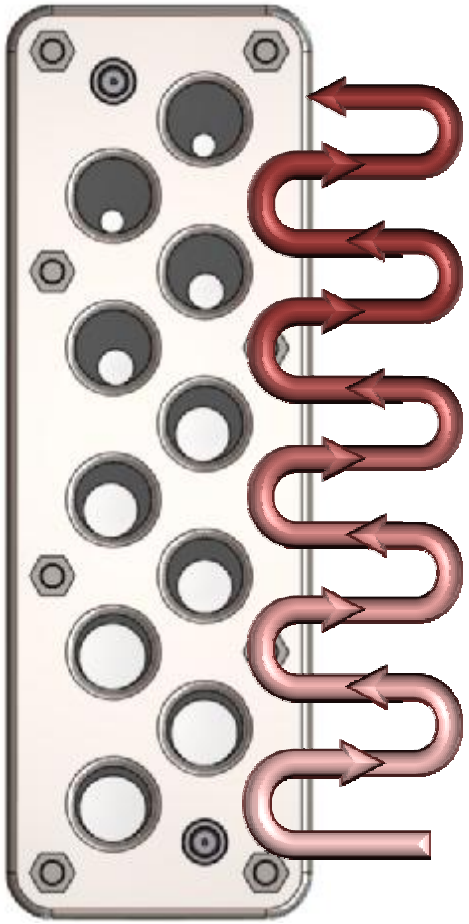


ACR / 2

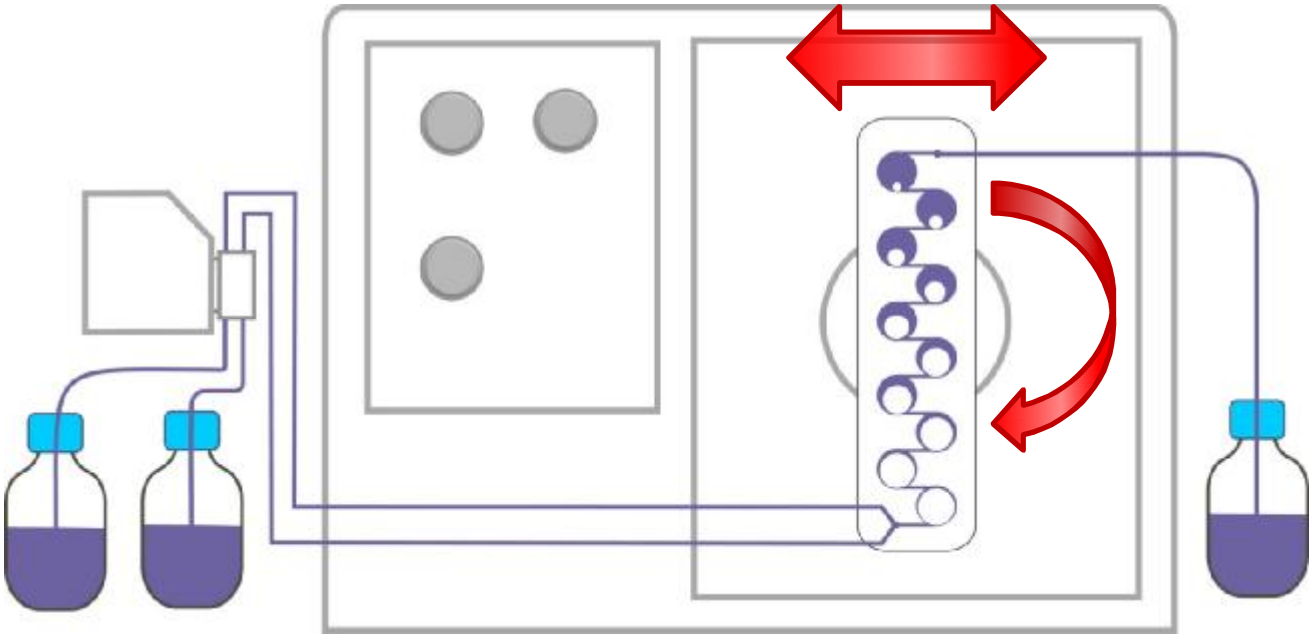
Agitator role #1:

Cell size is modified by altering the agitator/insert size

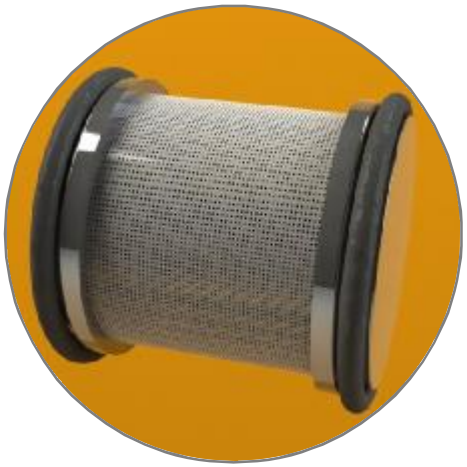




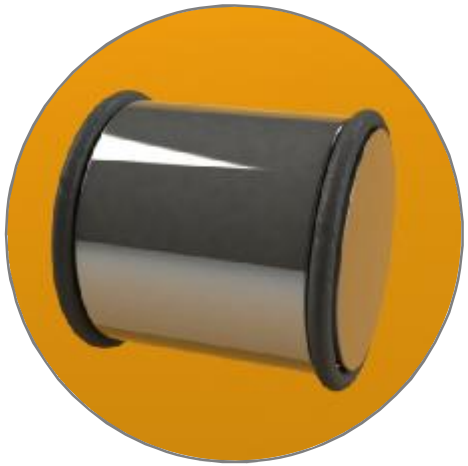
Agitator role #2:
The reactor block is mounting on an oscillating support.
The loose elements provide good mixing to each cell



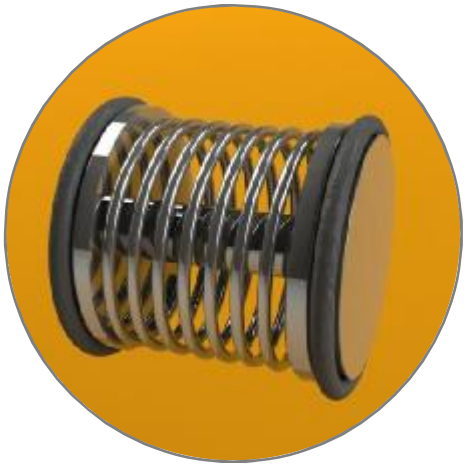
Agitator role #3:
Design optimized to promote mixing and flow for different systems



Catalyst basket

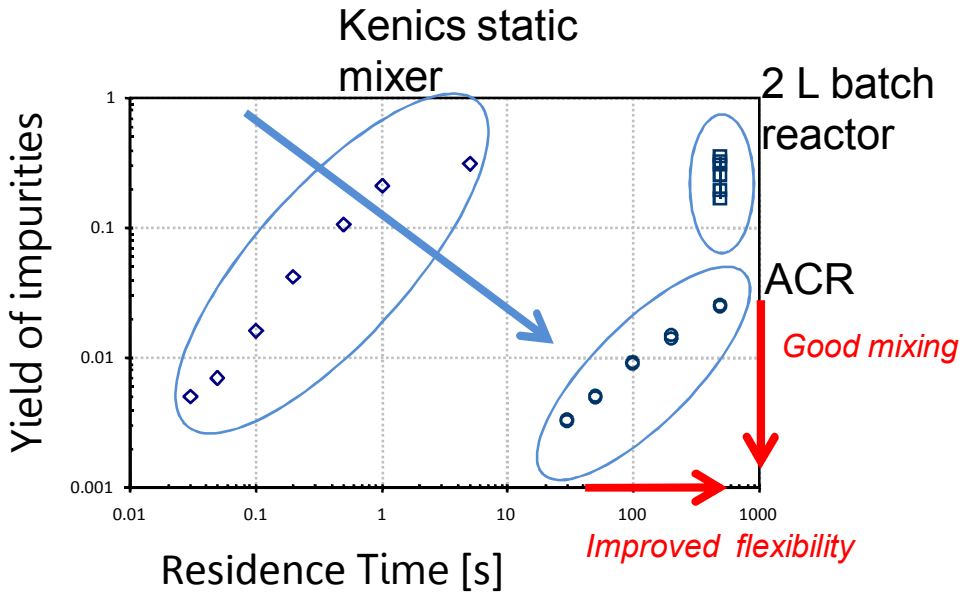


Agitator for solids



High shear mixing

Results - Mixing



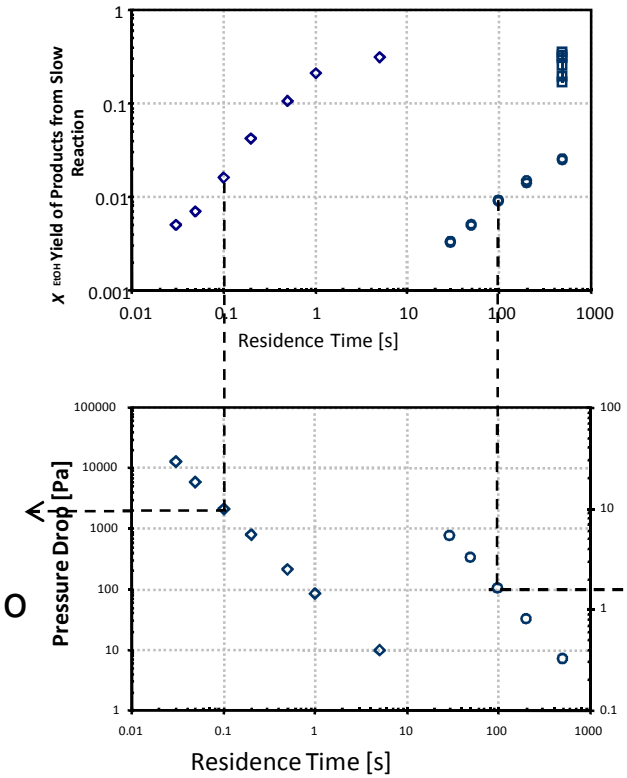
Bourne reactions:
Mixing sensitive reactions where low levels of impurities indicate good mixing

Conclusion 1:

The ACR exhibits a higher level of mixing efficiency over a wide range of throughput.

By permission of Imperial College

Results - Pressure Drop



Kenics Static mixer

For a reaction time o 100 seconds DP is 30 bar

Conclusion 2:

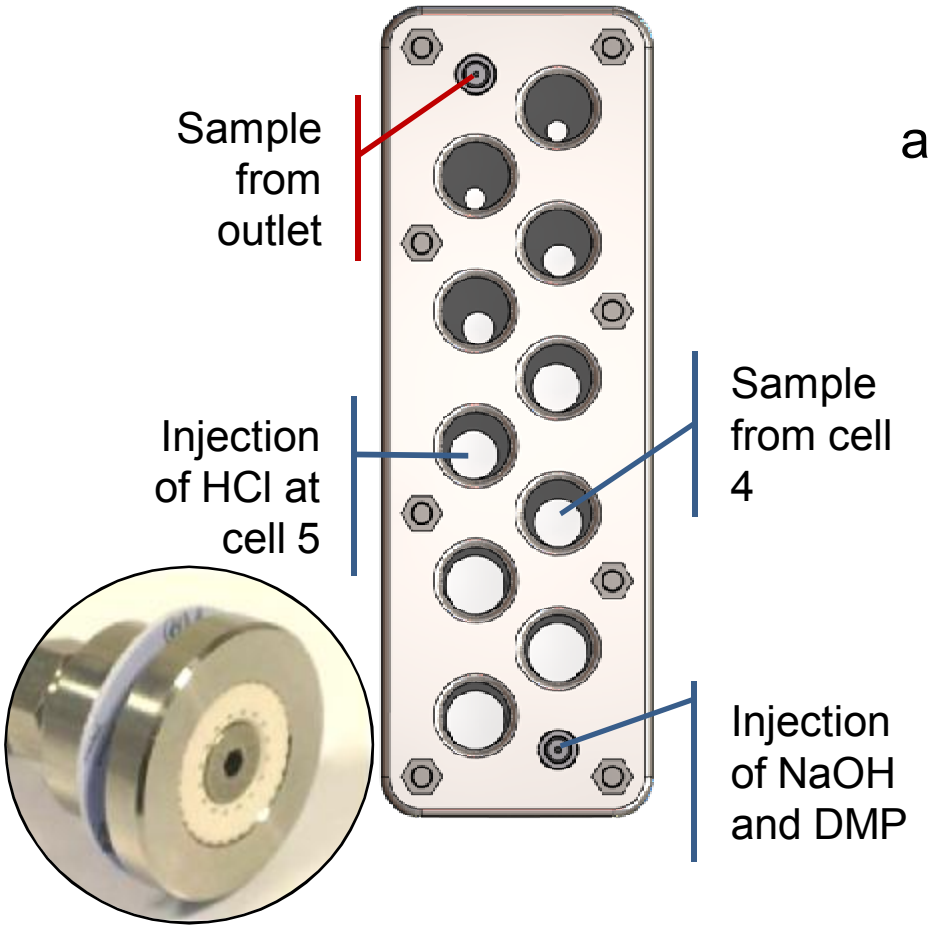
Thanks to its cellular design, the pressure drop across the ACR is up to a 3 order of magnitude lower than a tubular reactor.

ACR

At 100 seconds better mixing and DP is <0.01 bar

By permission of Imperial College

Results - Plug Flow



By permission of Imperial College

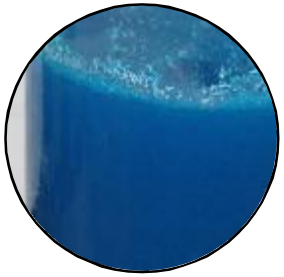
Good plug flow requires:
good mixing
a reasonable number of reaction cells
no back mixing between cells

Conclusion 3:

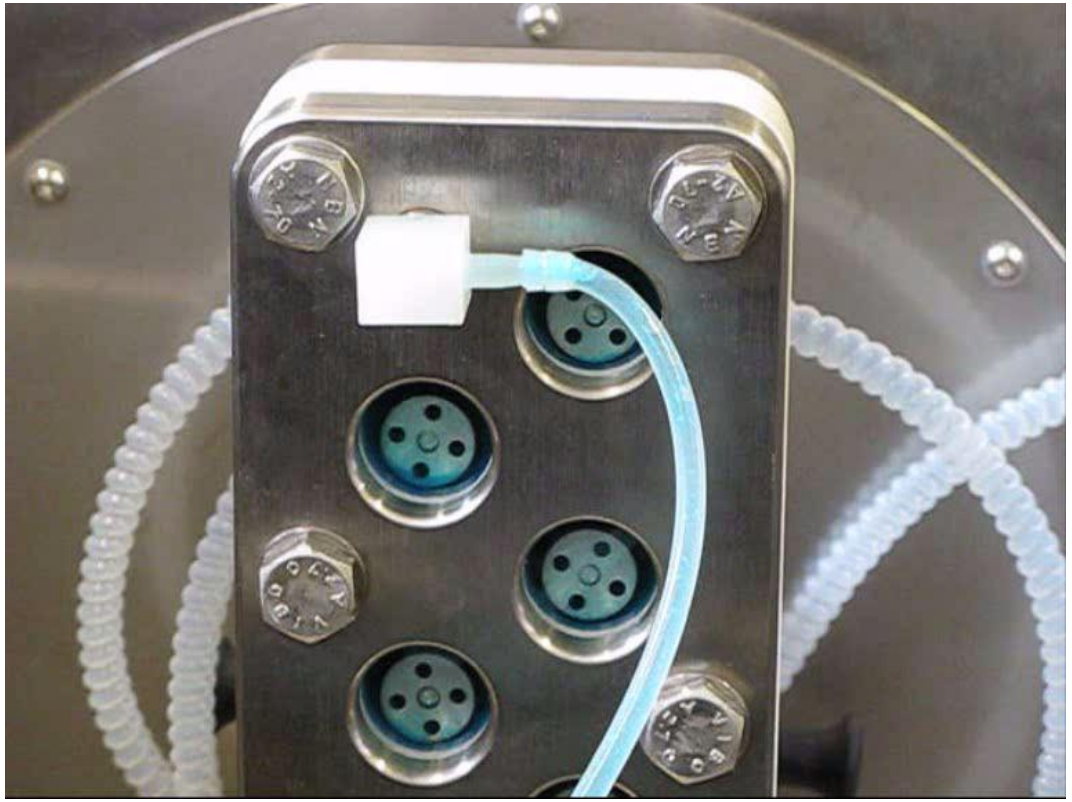
Negligible back mixing has been validated hence the ACR delivers good plug flow behaviour.

Results - Solid Flow

PVA, 50-200 µm, 1.4 g/cm^3



Approx 30% PVA in water



Conclusion 4:

Slurries can flow through the reactor in a controlled manner

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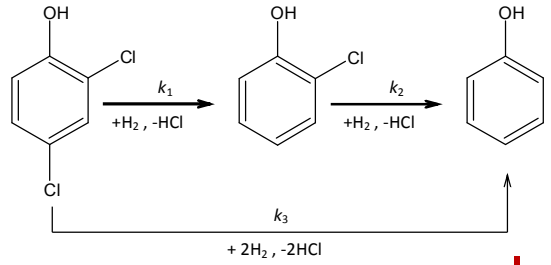
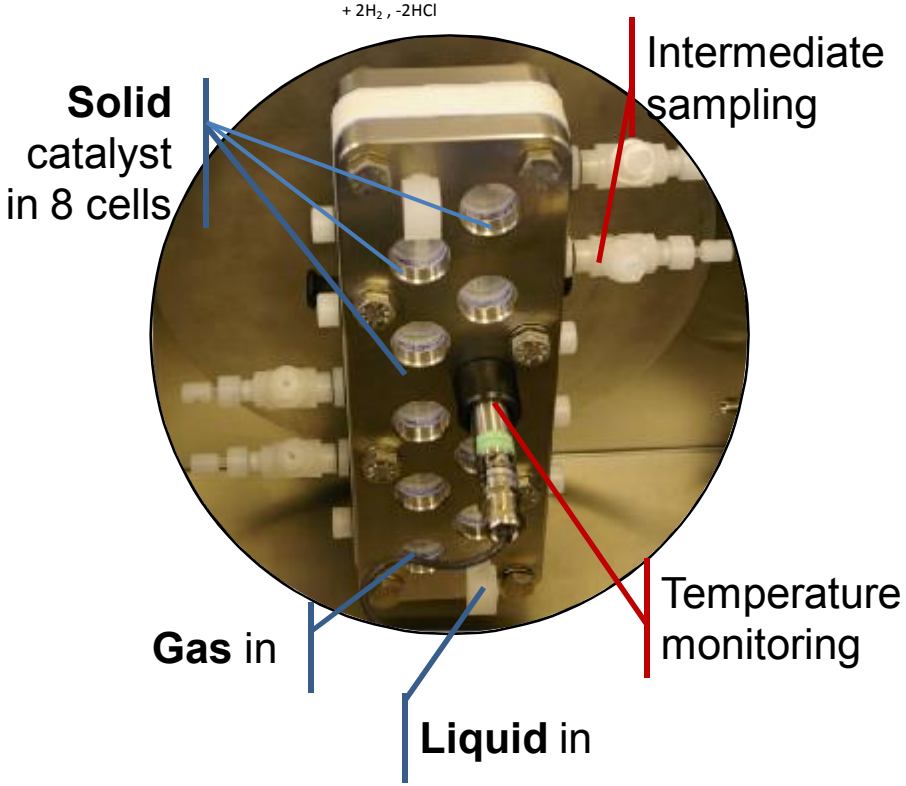
Results - Solid Catalyst





By permission of Heriot - Watt

Conclusion 5:

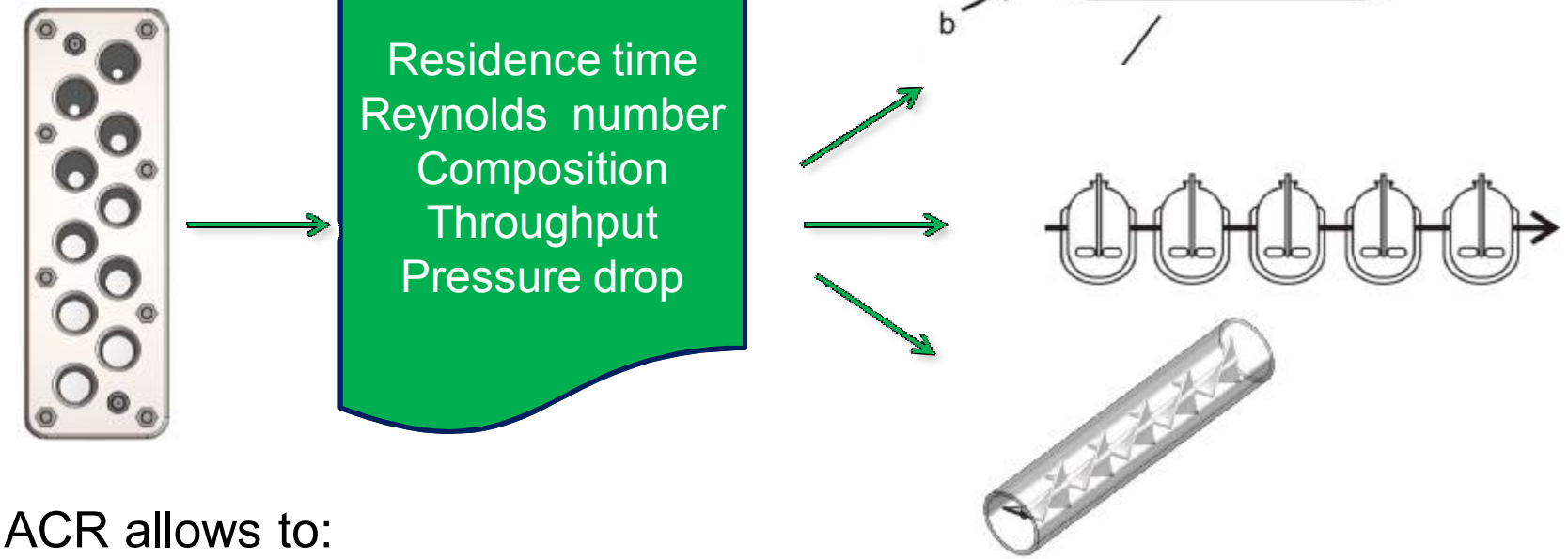
Five times higher efficiency in terms of H_2 usage

Greater hydrodechlorination rates: 35 *vs.* 65 $mmol_{Cl}\ g_{Pd}^{-1}\ min^{-1}$

Enhanced phenol formation *via* simultaneous Cl removal

Prolonged catalyst life

Scale up



The ACR allows to:

- Efficiently test a wide variety of operating conditions
- Optimize the chemistry
- Choose the most suitable manufacturing scale reactor.

ACR - Summary

ACR - A development reactor which allows the user to vary, throughput/residence time without affecting mixing

- Wide flow range: ***5 - 5000 grams per hour***
- Reaction time: ***10 seconds to >100 hours***

üg to kg production

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- Wide flow range: ***5 - 5000 grams per hour***
- Reaction time: ***10 seconds to >100 hours***

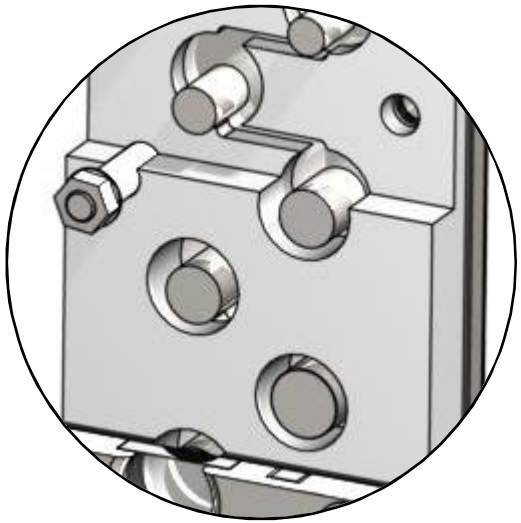
→ **ü** g to kg production

- Fluid types: ***Liquids, slurries, immiscible fluids, gas/liquids***
- Low pressure drop: ***<0.001 bar at 5 l/hr for water***
- Low minimum throughput: ***1 reactor volume***

→ **ü** Development studies

Many thanks to:

Prof. Mark Keane	Heriot-Watt University
Santiago Gòmez-Quero	Heriot-Watt University
Prof. John Atherton	Huddersfield University
Dr Nick Powles	Huddersfield University
Prof. Nilay Shah	Imperial College
Mayank Patel	Imperial College
Dr Mike Stillwell	Micropore Technologies



THANK YOU

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