Integrated Project IMPULSE

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Outline

- The IMPULSE Project
- What is **Structured Multiscale Processing**?
- What **Vision** for the process industries does it support?
- How do we get there?

Situation in the process industries

Pressures on the process industries

- Emergence of low cost producers in developing nations
- Increasing costs in meeting the Environment, Safety and Health regulations
- Markets where agility of manufacture is critical to performance
- Commoditisation of products, manufacturing technologies and design capabilities;
- Public and political concerns over the use of “chemicals” in society.

Shortcomings

- Traditional processing equipment often does not deliver conditions that are ideal for the process, compromising yield, efficiency;
- Traditional equipment and supply chains often hold large quantities of materials that present safety and environmental risks;
- Traditional approaches to scale-up of manufacture rely on a partly heuristic approach, and more reliable scale-up is desirable

Vision of multiscale processing

Fact: Industrial uptake of PI has been disappointingly slow, and the potential benefits in risk reduction, processing efficiency and lower costs have not been accessed;

It is clear that innovation will only take hold if business drivers are being met.

Vision: Multiscale processing, as developed and promoted by IMPULSE extends and refocuses the PI approach, and equally is fully consistent with the ideas of operational excellence. Instead of starting from a device focus, the philosophy is

To match process systems closely to the needs of the process, commerce and society – "precision processing".

The IMPULSE Project :

a European response to a global challenge

Integrated
Multiscale
Process
Units with
Locally
Structured
Elements

Project goal :

Effective **targeted integration of innovative process equipment** (such as microreactors, compact heat exchangers, thin–film devices and other micro and / or meso–structured components) to attain radical performance enhancement for whole process

Industrial leaders : GSK, Degussa, P&G, Siemens

Consortium : **20 partners** from 8 European countries

Project resources : 17 M€ over 4 years
(of which 10,5 M€ from the European Commission)

cefic

6th European Framework Programme for
Research and Technological Development

Consortium

INDUSTRIAL PRODUCERS (4 Partners)

GlaxoSK (UK) :	Pharmaceuticals
Degussa (D) :	Specialty chemicals
P & G (UK) :	Consumer products
Solvent Innov. (D) :	Ionic liquids (*)

INDUSTRIAL SERVICE GROUPS (4 Partners)

Britest (UK) :	Proc. innovation (*)
Siemens (D) :	Proc. design/control
Dechema (D) :	Chem. ind. assoc.
ARTTIC (F) :	Proj. Management (*)

RESEARCH INSTITUTES and UNIVERSITIES (12 Partners)

CNRS (F) :	LSGC–Nancy :	Chem. Proc. Eng.
	LGC–Toulouse :	Chem. Proc. Eng.
	LGPC–Lyon :	Cat. Reac. Eng.
INPL–Nancy (F) :		Chem. Eng.
Univ. of Manchester (UK) :		Process Innov., Proc. Economics
RWTH–Aachen (D) :		Physical Chem.
TNO (NL) :		Eco-efficiency,
IMM–Mainz (D) :		Microreac. Tech.
FZK-Karlsruhe (D) :		Microreac. Tech.
INERIS (F) :		Process Safety
ICPF–Prague (CZ) :		Process Eng.
ICT-Prague (CZ) :		Chem. Tech.
WUT–Warsaw (PL) :		Chem. Eng.
ETSEQ–Tarragona (ES) :		Chem. Eng.

(*) SME

Miniaturization and intensification : a PROCESS DESIGN solution

What we NEED, and WHY it is DIFFERENT !

INTEGRATED MULTISCALE DESIGN

Principle : construction of large–scale systems, but with small–scale inner–structuring at specifically targeted points only (= locally structured elements)

Claim : a « paradigm shift », inspired by numbering–up, that REVERSES traditional engineering practice :

Rather than determining « optimal » global operating conditions to adapt chemistry to equipment limitations, adapt the equipment to IMPOSE the local operating conditions required by the desired chemistry !

Shortcoming : the methodology does NOT (yet) exist !

The IMPULSE Project :

Goals and demands on key deliverables

Project Goals

The key IMPULSE « Deliverables »

⇒ **Design methods and tools = HOW**

⇒ **Decision–making criteria = WHEN**

Conditions for Project Success

The key DEMANDS on the IMPULSE « Deliverables »

Methods, tools and criteria must be :

relevant, reliable, accessible **AND** **« teachable » !!**

Selected Application Areas :

High value added supply sectors

- Key issues
  - **R&D times ↓**
  - **Scale-up risk ↓**
  - **Capital lockup ↓**
  - **Time-to-market ↓**
  - **Manufacturing cost ↓**
  - **Process safety ↑**
  - **Sustainability ↑**
  - **Distributed/on demand manufacuring ✓**

Pharmaceutical Products

- Continuous hydrogenation
- Continuous solids handling
- Integrated primary and secondary manufacturing

Fine Chemicals

- Liquid-liquid alkylation (ionic liquid synthesis)
- Miniemulsion polymerisation
- Electrochemical alkoxylation

Consumer Products

- Sulfonation and sulfation
- Targeted encapsulation (of e.g. perfumes)
- Controlled emulsification

Opportunities

- M**icro and meso-structured components, control and instrumentation techniques** open opportunities for step changes in manufacturing by allowing much more precise control of conditions;

- More precise processing opens opportunities **for new business models** and enhanced sustainability through more efficient, inherently safer processing, distributed manufacture etc.;

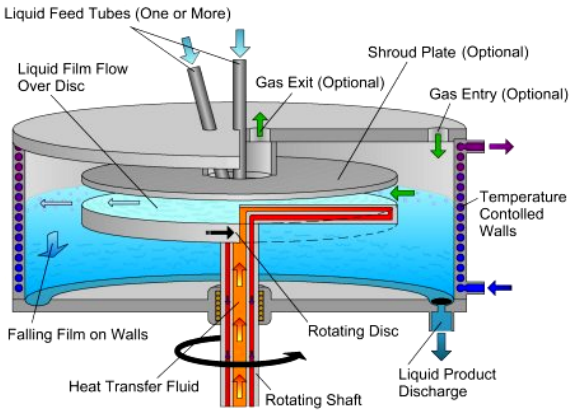
- The delivery of [potentially more extreme] conditions very precisely opens the opportunity for the delivery of new, **previously inaccessible products**;

- An increase in processing precision implies an increase, or at least no decrease of the level of **process understanding** required for process implementation;

- Benefit from deploying new technology can be not only in new process design but also in the **design of multipurpose facilities and retrofitting to existing processes**.

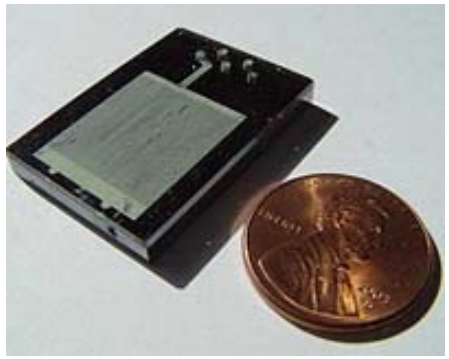
What is Structured Multiscale Processing?

- What is structuring?
  - All of these devices can be thought of as “structured” for some operations.



Spinning disc reactor

Oscillatory baffled reactor



Microreactor technologies developed at LLNL

Printed Circuit Heat Exchangers

What is Structured Multiscale Processing?

- Structured?
  - Using geometric and other features to control the environment of processing **precisely**
- Multiscale?
  - Understanding that different processes have inherently different intrinsic rates, so we should **adapt the scale of the equipment to the duty**
- Processing?
  - A way of transforming materials into products to **meet the needs of society – in time, at cost and without harm**

What is Structured Multiscale Processing?

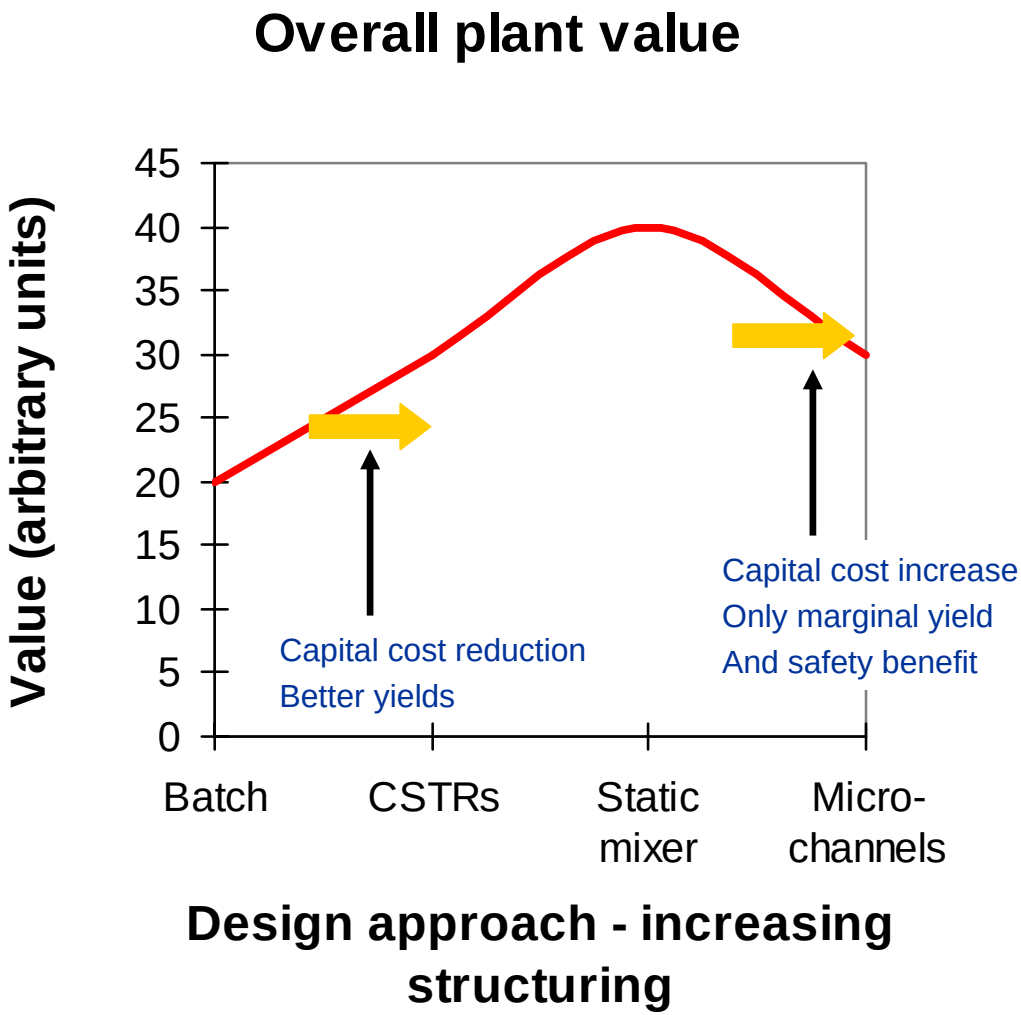
- What is structuring?
  - A **relative** concept not an absolute one
- A process in a microreactor is structured for many flow types
  - Laminar flow controls geometry and concentration field precisely
- A fast reaction in a large agitated vessel is not structured
  - Reaction in a small part of the vessel
  - Turbulence makes local environment unsteady

Technical Benefits of Structuring to Processing

- Intensity
  - Lower inventories of material,
  - Smaller equipment,
  - Ability to use exotic materials,
  - Ability to access extreme conditions
- Precision
  - Much more controlled conditions
  - Higher degree of predictability
- BUT
  - Benefits do not arise in every case
  - Benefits are not of commercial value in every case
  - Benefits do not always improve further with increased structuring

Structured Multiscale Processing

Identifying the appropriate level



- How structured is structured enough?
- e.g. medium-scale nitration of benzene
- TOO structured brings no extra benefit

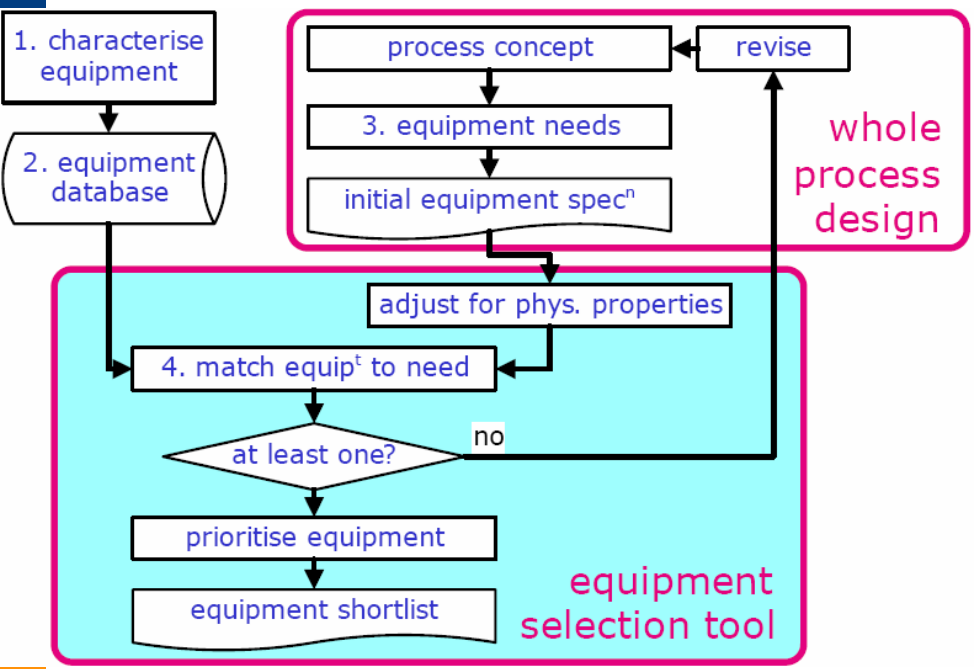
Interaction with IMPULSE

IMPULSE User Group

First targeted group: **Equipment Manufacturers**

Discussion and validation of equipment selection/characterisation methods

Equipment selection process



Equipment characterisation proforma

01		**Equipment name**	
02		**Unique identifier**	

		Material balance & residence time	
03	*	Total mass flow into the device	Range, kg/s
04	*	Volume	Range, m^3
05	*	Residence time gas	Order of magnitude range, s
06	*	Residence time light liquid	Order of magnitude range, s
07	*	Residence time heavy liquid	Order of magnitude range, s
08	*	Residence time solid	Order of magnitude range, s

		Mixing	
09	*	Bulk mixing time to achieve 95% mixing, t_{95}	Order of magnitude range, s
10	*	Micromixing characteristic mixing time	Order of magnitude range, s

etc...

Beyond IMPULSE :

Future challenges for industrial development

1 Major Objective

Overcoming barriers to wide-spread, routine implementation of intensified, multiscale technologies over a broad range of application areas and production scales

2 Key Challenges

– breaking economies of scale

- **– robust, low–cost microcomponents**
- **– a market (and standards) for equipment manufacturers**
- **– new production paradigms for MUCH lower capital investment**

– intensifying PRODUCT engineering

- **– targeted production of end–use properties through local process control**
- **– methods for accelerated scale–up from bench–top to production**

SUMMARY :

Why IMPULSE ? Why now ? and ... What's next ?

CONTEXT

Intensified microstructured process components and devices of proven performance currently available

PROBLEM

Industrial take–up of the new technologies in the chemical process industries slow and unsystematic

NEED

Appropriate design methodology (and corresponding tools) for techno–economic evaluation, decision–making, process development and scale–up

MULTISCALE DESIGN →

Local process control,
Constructal optimization,
Laboratory / process similitude,
Innovative business models

Future CHALLENGES →

Wide–spread implementation,
Reduced capital investment,
Intensified PRODUCT engineering

www.impulse-project.org