Integrated Multiscale Process Units with Locally Structured Elements

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EDITORIAL

The IMPULSE project has emerged as a response to the challenges and opportunities of the modern chemical process industries. The demands on processing are increasing, looking for shorter lead times, lower environmental footprint, increased safety, reconfigurability, greater precision in delivering higher quality products and so on. Indeed, it has become evident that the survival of chemicals manufacturing in the developed world requires new and radical approaches. To meet the challenges, opportunities are arising with new processing devices such as microreactors, structured intensive equipment, better measurement techniques, enhanced modelling capabilities and advanced control. IMPULSE is developing a radical approach that exploits these new technologies in an integrated way.

The IMPULSE approach is one of structured multiscale design; matching the length and time scales delivered by processing equipment to the intrinsic needs of the process. This is done in a context of the need to address both business drivers and the need of society to move towards sustainable processing. The vision is one of smaller, safer, cleaner and more responsive manufacturing facilities with novel processing capabilities.

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To deliver this vision, IMPULSE is dedicated to develop tools and methodologies supporting structured multiscale process design and development. This third issue of the IMPULSE newsletter describes a rational approach to select the appropriate piece of processing equipment to match the needs of the process. Instead of just using standard equipment and adapting process conditions to the capabilities of this device, it starts with the determination of the physico-chemical characteristics of the process to devise process conditions that will deliver the “best” process.

Prof. Paul Sharratt

In this issue

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Select the appropriate process equipment

by Jeremy Double, Britest Ltd.

Early in process development, there is a need rapidly to select appropriate types of process equipment that could be used for carrying out a particular process concept. IMPULSE is currently developing an approach to carrying out this rapid shortlisting of equipment options early in process design.

In the low- to medium-throughput process industries, a typical approach to process development is to assume the type of equipment to be employed — the batch stirred tank — and then to modify the conditions of the process such that the chemistry can be carried out in this equipment. Chemists and chemical engineers working in these industries are comfortable with scaling up processes using batch equipment, and thus this approach is perceived — perhaps falsely — to be a low risk strategy. Many of the resulting processes are in fact inefficient, and by considering a wider range of equipment possibilities then better processes could be generated.

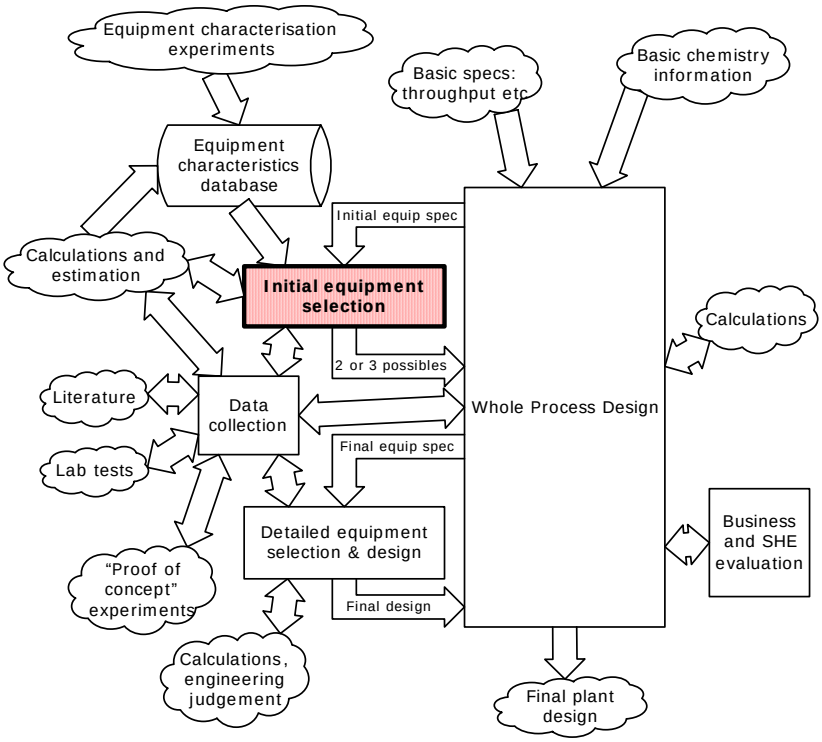

Figure 1: Initial equipment selection within the design process

A more logical approach to process development is to consider the physico-chemical characteristics of the process and from these to devise process conditions that will deliver the "best" process. Once the process has been devised on an equipment-independent basis, then the most appropriate equipment can be designed or selected.

The methodology described here is an element of the process development procedure, and is intended to generate a shortlist of equipment options in which the process could be carried out. After the shortlisting, further development work is needed to optimise the process conditions followed by detailed equipment design.

Figure 1 shows the place of the subsequently described equipment selection methodology in the context of the whole process design process.

Equipment characterisation and selection

The equipment selection methodology developed in IMPULSE is outlined in Figure 2. It is based on standardised characterisation methods, which allow the creation of a database of equipment characteristics representing the typical performance envelope of each type of equipment. In principle, if the needs of the process are known, then equipment that meets these needs can be found using the database.

Table 1 shows a standard set of characteristics that is to be collected for each equipment type. This will be used to structure the equipment selection database. The characteristics to be included in the database are categorised into classes, based on the individual duties that would be required of the equipment.

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In addition to material balance and residence time, mixing, energy (heat) transfer, mass transfer, phase and flow characteristics and operability, associated questions of phases to be processed, flow patterns and operability are also considered. Note that table 1 may be used in two ways:

(i) as a template representing the information needed to characterise equipment for inclusion in the database, as already described; and

(ii) as a template for defining the process needs, which will then be used for equipment selection.

Standard equipment characterisation tests

Standard tests are required to allow the characteristics defined in table 1 to be measured for each item of equipment. Wherever possible, the standard test methods will use process fluids that have small intrinsic hazards, such as water, air and nitrogen. For the inclusion of standard types of equipment (e.g. batch stirred tanks, tubular reactors without internals etc), design information in the literature can be used to calculate the outcomes of the standard tests. This avoids the need to do expensive experimentation on standard equipment.

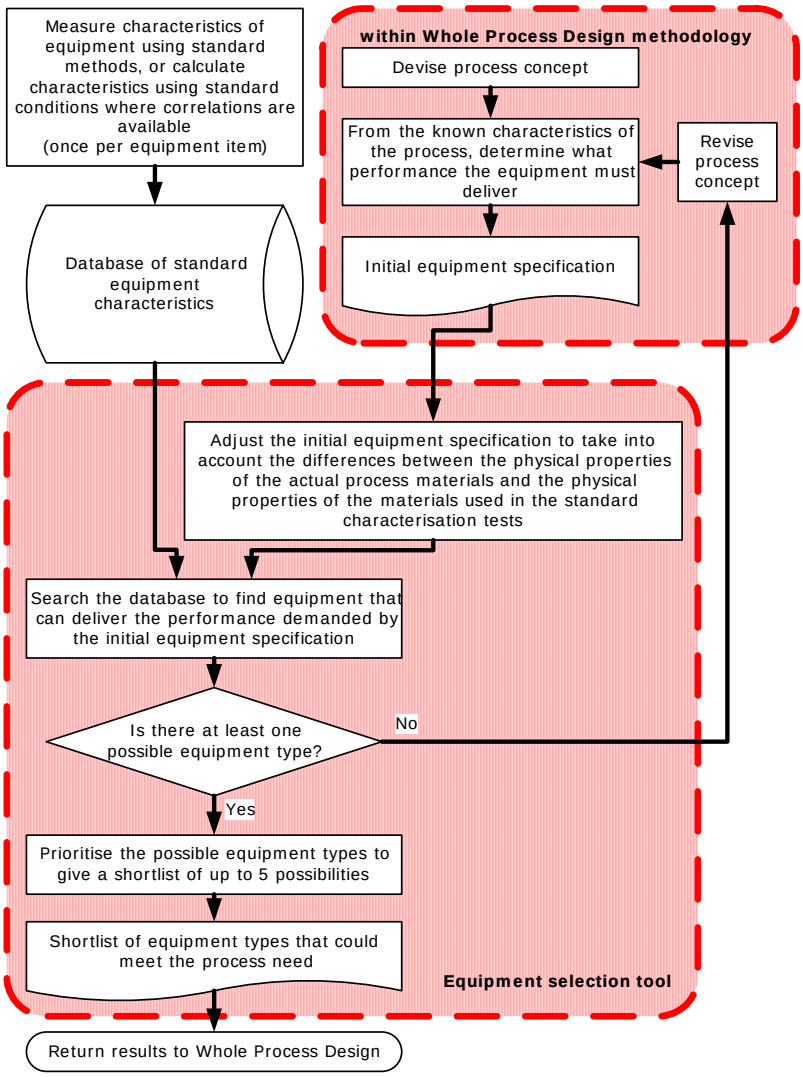

Figure 2: Outline flowchart of initial equipment selection

Using standard characterisation measurements in equipment selection

One potential difficulty with using the results of standard characterisation tests for selecting equipment is that the process fluids in the actual process will have different physical properties from the relatively innocuous materials used in the characterisation tests. Thus, the equipment performance in the real process may be different from the performance in the characterisation experiments.

Ignoring the difference between the real process and test systems, and adopting “fuzzy” boundaries when matching equipment to the process need has the dangers, that unsuitable equipment could be selected for the shortlist or that promising equipment is rejected. More promising are the following two approaches:

(i) Perform process development experiments in lab equipment characterised according to the standard methods, and select equipment that is at least as capable as the lab equipment when scaling up.

(ii) Use knowledge of the fundamental science underlying the equipment capabilities to develop methods for adjusting the process needs to the same basis as that used in the equipment characterisation tests.

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Approach (i) is useful at the stage of process development where significant experimentation has been carried out on the process, but is not appropriate early in process design where only a few experiments at a very small scale have been carried out to prove the chemistry concept. Approach (ii) is the most useful approach, but may be difficult to use where the underlying science of competing types of equipment is significantly different.

Table 1: Standard set of equipment characteristics

01		**Equipment name**	
02		**Unique identifier**	
		Material balance & residence time	
03	*	Total mass flow into the device	Range, kg/s
04	*	Volume	Range, m3
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, t95	Order of magnitude range, s
10	*	Micromixing characteristic mixing time	Order of magnitude range, s
		etc.	

Equipment matching

Once the process requirements have been adjusted to account for the differences in physical properties, a simple search can be used to identify which items of equipment in the database meet all of the requirements of the process. If the equipment matching generates a large list of possible equipment types (for instance, if the process duties are not onerous), then equipment will need to be considered further based on cost and operability factors. The details of this prioritisation process have yet to be finalised.

Upcoming IMPULSE Events

The first meeting of the IMPULSE User Group addressing equipment manufacturers, will be held in **Brussels on 25 January 2007**. IMPULSE representatives will introduce the methods of equipment characterisation and the equipment selection proforma. It is intended to discuss and validate the methodologies and to engage equipment manufacturers to facilitate a knowledge-based equipment selection for the application industries. The IMPULSE consortium believes this to be beneficial for both users and suppliers of process equipment. User Group participants are granted access to a password protected area on the IMPULSE website, in which the workshop material and additional IMPULSE information are available.

How to contact IMPULSE

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For joining the IMPULSE User Group, or questions and comments on the initiative, please contact the IMPULSE Support Team (SupportTeam@impulse-project.org) or visit our website at http://www.impulse-project.org, where we also announce presentations of IMPULSE research results at major conferences in the field of chemical engineering and chemistry.

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