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PROCESS ENGINEERING RESEARCH AND EDUCATION AT THE DEPARTMENT OF PROCESS ENGINEERING – – PAST, PRESENT AND FUTURE

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The aim of this paper and this special issue is to overview the latest developments in process modelling, simulation, control, and process monitoring. The special issue of the Hungarian Journal of Industrial Chemistry will be devoted to 30th Anniversary of the Department of Process Engineering. It is meant primarily to contain papers written by the colleagues working closely with us. Their papers and this overview will illustrate that process engineering covers all the necessary knowledge required for defining, designing, implementing and optimizing any process where physical, chemical and/or biological transformation of materials occur. Nowadays, the task of process engineers is to design, construct and operate complete systems. These tasks are very complex and according to that diversity, the papers of this special issue are grouped to five parts: 1) Modelling and model analysis, 2) Data analysis and data driven techniques, 3) Control, 4) Optimization, and 5) Numerical methods. The aim of this paper is to give a brief overview about how process engineering research and education is effected by the needs of industrial process development, and to highlight how the Department of Process Engineering of the University of Pannonia (former University of Veszprém) adapts to these challenges.

Keywords: Process Engineering, Engineering education, Research and Design

Needs of Industrial Process Development

The term 'Process Systems Engineering' may be traced back at least as far as the early 1960s. Process engineering covers all the necessary knowledge required for defining, designing, implementing and optimizing any process where physical, chemical and/or biological transformation of materials occurs. It is a cross-disciplinary science organized around fundamental subjects (mass and heat transfer, fluid mechanics, chemical reactors theory, mass and heat balances, distillation, filtration and other separation methods). But it is also concerned with the development of specific methods (coupled transport phenomena, modelling, process control, systemic approach). Initially developed in response to the needs of oil industry, the process engineering is concerned with a diversity of other branches today:

- fine chemistry and related activities,
- agri-food, biology, pharmacy and cosmetics industries,
- specialized materials (glass, cement, paper) and materials for microelectronics,
- protection of the environment and water treatment.

Nowadays, the task of process engineers is to design, construct and operate complete systems. By complete systems we mean both processes and plants that produce products that fully meet the customer's needs. Both the needs of customers as well as the society as a whole have an important effect on the process industry and these needs largely determine what products are produced and how they are produced. These needs determine the challenges that chemical and process engineering have to face and the know-how process engineers need to have [1].

In the words of P. V. Danckwerts in 1966: 'It will be a great mistake to think of the content of chemical engineering science as permanently fixed. It is likely to alter greatly over the years in response to the changing requirements of industry and to new scientific discoveries and ideas for their application.'

As an engineering discipline based on scientific principles the chemical (and process) engineering has two main tasks [1]:

a) to model subsystems using the theoretical and methodological scientific knowledge. In this respect, chemical engineering is not different from the natural sciences.
b) to develop methods and procedures which allow real systems in all their complexity to be designed and constructed even if not all of the subsystems have been precisely modelled due to a lack of a thorough knowledge of the underlying physics and chemistry.

Nowadays there is a need for further development both in the descriptions of subsystems and also in the methods and tools for designing overall systems. It is not the purpose of this paper to trace the history and future trends of the development of process systems engineering. The readers interested in these topics should consult the excellent overview papers [1, 2, 3, 4]. Our goal will be to seek to map changes in the education of students of process engineering.

Education in Process Systems Engineering

Trends

In the paper of John Perkins [5] a personal view of the history of the development of the process engineering education is given. Two complementary approaches have been distinguished.

1. On the one hand, pedagogical materials have been developed and courses delivered covering important advances in process systems engineering as they have emerged from the research community. As a result, the teaching of design and control methodologies, techniques and tools has become more systematic and comprehensive in the past four decades (see task *a)* presented in the previous session).
2. The second strand of educational development concerns curricula and courses designed to help students to acquire and adopt a 'systems approach' to engineering problem solving. While there are much broader questions involved in pursuing the educational objectives associated with this strand, and the issues extend well beyond the boundaries of process systems engineering, nevertheless process systems engineers have made pioneering developments here also. Indeed, there is some evidence that the desire to help students to develop the skills needed to tackle complex engineering problems partly motivated the early research in process systems engineering.

Such courses and methodologies are also described in the literature. E.g. in [6] an advanced process control course to undergraduates, in [7] an introductory course in computer aided process engineering, in [8] an integrated process design instruction are presented, while in [9] the integration of knowledge management tools is discussed.

The Role of the Industry

The successful further development of the body of knowledge available to the process engineer will in future only be possible if the needs of industry are addressed, and to do this engineers in universities and in companies have their respective roles to play in extending the scientific foundations necessary to meet these needs [1]:

1. The universities must train highly qualified engineers who will then be able to go into industry and address the problems awaiting them by using the tools and methods of science. These chemical engineers – when necessary – must be able to work closely together with their colleagues at universities and research institutes.
2. The second prerequisite is that although university research and education is guided by the problems encountered in industry, university scientists should not focus narrowly on meeting the needs of industry rather on extending our fundamental knowledge. Such a research and training network requires an understanding on the part of industry that the source of many innovation processes lies in fundamental research. Furthermore, research and development departments within companies have to recognize that the goal of developing progressive and competitive technologies can be reached only by being fully aware of the pioneering research being carried out elsewhere.

Brief Description of the Department

Historical Background

Since the beginning of sixties, teaching of chemical technology, based on a unified treatment of technological knowledge segmented in accordance to the branches of industry, as well as teaching of unit operations with an integrative foundation of the fundamental principles has gone on parallel in chemical engineering education. At our university, the former were taught by the technological departments founded simultaneously with the university, while the latter was represented by the Department of Chemical Engineering Science, founded by *Professor Antal László* in 1963. *Professor Pál Benedek* and *Professor Antal László* worked out the first course of unit operations at the university. *Professor Rezső Mohilla* completed the course of unit operations by introducing process dynamics, clearing a way also for teaching automation becoming more and more important in the chemical industry. Owing to the development of computers and computing methods, however, decomposition of chemical technologies has not been the stopped on the level of operational units, what has been indicated also by appearance of a new department. On 1 July 1977, the Autonomous Departmental Group of Chemical Cybernetics was founded by *Professor Péter Árva*, which was developed into the Department of Chemical Engineering Cybernetics in 1990. Since 1993, the Department, together with the Department of Chemical Engineering Science and with the Department of Hydrocarbon and Coal Processing, has formed the Institute of Chemical Engineering, which has become responsible for the education of students in chemical engineering. Since 1995, *Professor Ferenc Szeifert* has served in the capacity of the Head of the Department.

Research and Development Strategy

In Hungary, chemical engineering field represented by the department was born around the end of sixties and the beginning of the seventies and it is being fulfilled these days as the technical environment including microelectronics enables the direct application of the theory in real working processes. Parallel with the advance of the field in Hungary, key researchers of the department always studied the typical problems: mathematical modelling and simulation of unit operations, simulation of the entire process system, complete description of the chemical processes (from the molecules to the production), coordination-level control of processes, application of chemical engineering models in the design, control (model-based control) and development (model-based process development) of technological systems; along with these the solution of problems of numerical methods, computer techniques, information technology, artificial intelligence; techniques of computer process control and the employment of application software.

The department provides an ideal background for establishing the harmony of theoretical and practical problems by connecting closely the academic projects and the application ones. The primary function of the basic research in field of chemical engineering cybernetics (systems engineering) and process engineering is the development of methods and tools for the selection and integration of the necessary knowledge from natural sciences (description of transport processes, complex reaction mechanism and kinetics, description of biochemical processes, determination of phase structures, etc.) and economics (profit, market limitations, etc.) in order to analyze (modelling), design and control chemical processes operating at economic optimum.

The department is open for the quick introduction and application of the newest methods (fuzzy techniques, artificial neural networks and other artificial intelligence tools, etc.) and engineering tools (mainly software packages). E.g. at the 90's our most important OTKA (National Scientific Research Fund) basic research topics of the past and present periods were the following:

- Design and control of chemical processes using crisp and fuzzy information (supervisor: Péter Árva)
- Hierarchical modelling and control of chemical processes (supervisor: Péter Árva)
- Evolutionary structures and learning logic programs (supervisor: Béla Csukás)
- Model-based control of crystallizers (supervisor: Béla Lakatos)
- Design and control of flexible chemical processes (supervisor: Ferenc Szeifert)

All of the basic research topics are associated with R&D projects. Researchers of the department in the sixties developed simulators of an ammonia plant and of the Bayer process. The direct application of these simulators in the process development and control was quite new in that time. The department was among the firsts applying artificial intelligence methods in solving chemical engineering problems (fuzzy algorithms and neural networks in process control). The fundamental principle of the departmental research is that in case of every basic research topic the possibility of application is sought after, while in case of development projects the possibility of generalization is looked for too. By now, the teaching and research activities of the Department of Process Engineering cover mainly the topics of process system engineering, including:

- modelling and simulation of chemical processes,
- process control of chemical processes and computer controlled systems,
- computer-aided design, development and operation of process systems,
- analysis of historical process and business data (Data Mining).

Co-operation with Industry and Academics

The information requirement of process engineering methods and tools used in process analysis, control and development is very high and it is almost impossible to be satisfied inside the limits of a university department. Therefore the close working relationships to the industrial firms have an important role both in the educational and the research activities of the department.

At the end of the seventies, in cooperation with the companies of Hungarian Trust of Aluminium Industry (MAT) a simulation system for the Bayer cycle was developed at the department.

Based on this simulator a coordination-level control strategy, which is still in use, was formulated. The cooperation with TVK Rt. and BorsodChem Rt. has been going on for several decades and is mainly related to the polymerization plants. The development is based on the hierarchical models of polymerization developed at the department. There is a continuous cooperation in the development of the control structure of flexible chemical plants and in the formulation of the closed information loop of process development including scale-up with CHINOIN Rt. since 1990. The quality assurance (validation) of process control systems was studied in cooperation with Richter Rt. Joint projects in the development of process control of batch systems are going on in cooperation with Batch Control Kft. and ComForth Kft. Important parts of different projects were elaborated for the invitation of BVM Rt., Dunastyr Rt., Nitroil Rt., Nitrokémia Rt. and Paks Nuclear Power Plant.

Cooperation is maintained with several academics departments of MUKKI and Budapest Technical University among the Hungarian institutes. Inside the University of Veszprém there are working relationships with the following departments: Chemical Engineering Science, Physical Chemistry, Environmental Engineering and Chemical Technologies, Earth and Environmental Sciences, Computer Science. Of course, we also work

with institutes, like, UMIST (UK), Bulgarian Academy of Sciences (Bu), University of Bradford (UK), Babes-Bólyai University (Ro), Katholieke Universiteit, Leuven, (Be), Universitat Politechnica de Catalunya (ES), Berty Reaction Engineers, Ltd. (USA), Delft University of Technology (NE).

Process Engineering Education at the Department of Process Engineering

Courses taught by our Department

In teaching, the department covers the whole range of process engineering, while, regarding its research activity, the main research areas include modelling, model-based process control, design and development as well as process informatics.

The department is linked strongly to the *training of chemical engineers*. A significant part of the topics taught by the staff of the department, however, is invariant under the engineering fields; therefore the department participates also in teaching programs of the *environmental engineering*, *engineering management* and *material engineering* courses. Since the chemical industry is one of the most important fields of applications of information systems, and the implementation of information systems are attached strongly to the process control, we expect that the subjects taught by the department will also be included into the program of information technology, and the department will have opportunity of teaching these subjects as well.

The department plays important role in the *PhD education* as well. Professor Péter Árva is the leader of the ChE-2 Process Engineering PhD Program, while Professor Béla Lakatos and Professor Ferenc Szeifert and dr. János Abonyi participate in that program as project supervisors. So far, 9 students have finished or have been carrying out their PhD research projects at the department in the framework of this program. The department also teaches a number of courses in the framework of other programs.

Infrastructure used in Education

In education, the department, besides laying intensive theoretical foundation of engineering knowledge, also emphasizes the practical applications of that knowledge. A continuously improved process engineering laboratory has been developed for that purpose, which includes some operational units and technological systems of smaller size, operated and controlled by means of computers.

The departmental local network of some 50 computers connected to the worldwide network through the network of the university assures efficient utilization of the modern hardware and software tools. The system make possible also work of the staff at home. This integrated system of teaching tools involves software packages for simulation, control, design and documentation of technological systems.

Figure 1: (left) Batch process unit at our laboratory *(right)* Computer room at our department

Our Philosophy

The above presented system plays a key role in our education, since the courses focus to the *application of methods and tools of information technology for solution of process engineering problems*, – process analysis and modelling, process design and process control –, where

- wide selection of software packages are available,
- general solution is not available,
- tools cannot be simply integrated,
- application requires good engineering background.

Hence, our main educational objectives are to:

- prepare students to accept and use these tools,
- develop the necessary skill for the application of computer aided process engineering (CAPE),
- understand the background and operation of the methods,
- be able to learn the new and appropriate software packages,
- critically evaluate the results obtained,
- have some experience in real application.

As can be seen, in our philosophy, CAPE is not a single subject rather a set of carrier ones which contains more or less foundation and application.

The Curriculum

The Chemical Engineering Curriculum is accredited by the IChemE (The Institution of Chemical Engineers which is the leading professional body for chemical and process engineers with an international membership across more than 80 countries.)

Lecturing and research activities are co-ordinated by a coherent team highly concerned with industrial applications. This Lecturing – Research – Application approach implies that students are in closer contact with industry (internships and projects) during their studies.

Graduates in chemical engineering become aware of the technical, economic, social and human dimensions of companies and jobs. Their training leads to:

- acquiring a solid scientific and technical knowledge and learning to adapt to the constant evolution in process engineering,
- knowing how to apply these concepts to real professional situations,
- developing contacts with industry, with foreign cultures and languages,
- developing individual personalities and personal projects and becoming proficient communicators,
- being more and more autonomous.

Students are trained to deal with area of process engineering, are prepared to adapt to a diversity of life and work patterns and are prepared to work within a team. They easily take part in the following activities:

- defining and designing production units (choosing processes, studying and optimizing mass and energy balances, implementing environmental impact studies, clean technologies and recycling wastes),
- calculating these units and their dimensions,
- monitoring the setting up and operation of these units.

The laboratory exercises made in the last two years at our department, the compulsory one month practical engineering summer training following the 8th term (semester), the design project in semesters 8-9, and the accompanied consultations with industrial and academic experts, are considered as the first steps of the students' engineering practical career. During these studies students are required to solve various engineering problems, use procedures, collect data and write reports. In addition they can undertake scientific activities, solving independent research exercises in preparation for their research career.

Conclusions

(Computer Aided) Process Engineering (CAPE) tools are widely applied in industry. The Department of Process Engineering at the University of Veszprém is active in the research and development of new CAPE tools and it often contributes to the technological development of local firms in need of technical aid. Our services include consulting, analyses, diagnoses, design, and software development. According to our Lecturing-Research-Application approach the results of these projects are directly used in the education as case-studies, illustrative examples, or as problems for design projects. The up-to-date course materials and internships and design projects ensure that our students are in close contact with industry during their studies.

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