ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ
ΣΧΟΛΗ ΧΗΜΙΚΩΝ ΜΗΧΑΝΙΚΩΝ

ΕΠΙΤΡΟΠΗ ΣΕΜΙΝΑΡΙΩΝ, Καθηγητής Α. Κοκόσης

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ΣΕΜΙΝΑΡΙΟ ΧΗΜΙΚΗΣ ΜΗΧΑΝΙΚΗΣ

Πέμπτη 1 Οκτωβρίου, 13:00

Αίθουσα Σεμιναρίων «Ν. Κουμούτσου»

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Process Systems Engineering: From Solvay to the 21st Century

A History of Development, Successes and Prospects for the Future

The term Process Systems Engineering (PSE) is relatively very recent, but the Engineering of Processing Systems is as old as the beginning of the chemical industry. Ernest Solvay can be arguably seen as the first Process Systems Engineer. His continuous soda process is the first modern process taking into account production specs, economics, and environmental impact. At the beginning, the practice of PSE was informal and as time went on it was progressively formalized, until in our days it is solidly founded on an array of systems theoretical foundations. In this lecture I will try to provide an overview of PSE's origin and evolution, illustrate its tremendous accomplishments in the development of modern chemical industry, and outline some future prospects.

PSE is the field of chemical engineering that encompasses the activities involved in the Engineering of Systems involving physical, chemical, and biological processing operations. It is also very important to keep in mind that the approach of Systems Engineering is driven by two important considerations: (a) The interest is on the "behavior" of the system as a whole, and (b) the emphasis is on studying how the components of the system and their interactions contribute to the overall "behavior" of the system.

The period between 1860s and 1920s can be seen as the Formative Period of PSE. During this period the focus is on Process Development and the ideas and techniques introduced by Solvay were expanded and enriched. Rudolf Knietz, Herbert Dow, Charles Hall, Carl Bosch, Burton and Dubbs, created a series of creative processing schemes and established the general framework of process development activities, based on the following premises: (i) A manufacturing system is a system of interconnected operations. (ii) The components of a manufacturing system, e.g. the chemistries at the core of the process and the separation units were determining the behavior of the system as a whole, i.e. economics and environmental impact. In other words, during the period 1860s to 1920s, the activities that today we characterize as Process Development (the core of Process Systems Engineering), define the central character of what is evolving to become Chemical Engineering; during this period a Chemical Engineer is largely a Process Systems Engineer.

The 1926 famous book "Principles of Chemical Engineering" by Walker, Lewis, and McAdams organized and provided elementary quantification for physical unit operations but omitted chemical reactors and, more to our subject, an overall view of a chemical process. In parallel and outside the disciplinary domain of chemical engineering, a series of important developments are taking and will have a profound effect on the explosive growth of PSE from the late 1950s to today. These developments are: (a) Servo-regulator theory, which addresses the instrumentation needs for monitoring and controlling chemical process operations. (b) The advent of computational machines, towards the end of this period, is feeding developments on numerical methods for the simulation of physico-chemical processes. (c) The laying of the foundations of Mathematical Programming in Linear, Nonlinear and Combinatorial optimization; all of which will play a profound role in subsequent periods of PSE.

During the period 1960-1975 several factors aligned for the Explosive Growth period of PSE: (i) Rapid expansion of the chemical industry on a world-wide scale. (ii) Large jumps in energy and petrochemical raw materials costs in 1970s demanded new more efficient processes. (iii) A science-based description of the basic physico-chemical phenomena in the unit operations is vigorously pursued, enriching our skills for fairly reliable quantitative descriptions. (iv) The digital computer nters industrial life in a very determined way and affects all aspects of process systems engineering.
As a result, in the area of Process Design we see the onset of (a) steady-state simulators, and (b) systematic methods for process synthesis. In process control we witness (a) a shift from unit to plant-wide control, (b) model-based control, and (c) digital computer-based control strategies. The consequences have been profound and long-lasting. Also, during this period and the ensuing years optimization became ubiquitous in chemical engineering and was applied in: Process Design; Process Synthesis; Process Control; Planning and Scheduling of Process Operations; Supply-chain Management; Development of Models from Data; Product Design; Metabolic Engineering; Oil and Gas Production; and many other areas.
Environmental devastations such as that caused by toxic leaks from Love Canal and the meltdown of reactor core in Chernobyl, as well as the Bhopal destruction, the 3-mile island incident, and a series of high profile accidents in refineries and chemical plants, sharpened the sensitivities to risk management and process safety. PSE played a very central role in addressing Process Risk Management. First, it pushed a new mindset in dealing with Process Integrity; from "React and Fix" to "Predict/Detect and Prevent". Second, it fostered the development of a comprehensive Process Safety

Management approach: inherently-safer process designs; advanced process safety methodologies and tools, such as, on-line intelligent diagnostic systems, integration of safety instrumentation systems with process control systems, advanced methods for the design of LOPAs, etc.

So, where is PSE today? The "System's" view has been adopted in an increasing range of contemporary chemical engineering activities: Product and Process Design; Multi-process integration; Pharmaceutical products design and manufacturing; Biomedical devices; Technology and Policy; Energy and Environment. Modeling as the ubiquitous tool of PSE addresses situations with millions of modeling equations, has started integrating models at various resolution (atomic, molecular, meso-, and macro-scales), and encompasses statistical in addition to determinist models. Integration of product and process design is becoming the norm, leading to: "Intensification" of commodity processes; rapid development of processes for pharmaceuticals and fine chemicals; chemical plant integration; development and design of micro-processes. Activities surrounding process operations, such as, monitoring, analysis, diagnosis, control, and optimization are integrated at the technical, managerial, and human resources levels, leading to high-integrity plants.

What is next? PSE will continue to expand the scope of what constitutes a "system", e.g. energy and environment, technology and policy, drug discovery and development, integrated "smart" manufacturing, as well as the range of application areas, e.g. biological systems; design of materials, alternative energy sources. Of particular significance will be the following: Modeling for "Discovery" and Technological "Innovation"; from "Macro-Scale" to "Micro-Scale" to "Nano-Scale" Systems; from "Complicated" to "Complex" Systems.