Abstract:

A crucial success factor in a mature market such as the metallurgical industry roots in the ability to develop and interpret new technologies quicker and more effectively than competitors. As a vehicle to achieve the desired advantage, this article advocates mathematical modeling and process simulation for the promotion of corporate know-how and technology development. Opportunities and advantages of computer-aided design tools will be discussed vis-à-vis the life-cycle of a fictitious “low waste process”. The proposed hierarchical decision-making methodology drives technology development according to the economic incentives offered by novel process technologies. Successively refined economic potential estimators discriminate inferior designs and discard process with marginal economic performance early in the design cycle. A bi-level mathematical program for the simultaneous optimization of economic performance and desired technical operability will be presented. Recent trends in computer-aided systems are put in perspective to commercially available tools.
1. Introduction:
The scope of metallurgical businesses ranges from the competitive iron and steel production to the innovative field of "materials science" aiming at the discovery of new alloys or metal-based compounds for space, bio-engineering or microelectronic applications. In both the mature and the emerging markets, continuous improvements of existing process technology combined with original inventions are key to progress and ultimately crucial for the survival. The permanent succession of research, process development, and re-engineering impose a vital cycle on modern enterprises. This on-going evolution is termed the *process life cycle*.

In process engineering, creative R&D efforts generate a continuous stream of new potentially marketable process ideas. At the beginning of the life cycle, the conceptual design phase investigates the technical and commercial feasibility of a new technology. Only a few novel concepts promise enough economic incentive to pursue full-scale process development. Viable conceptual designs advance to the pilot plant tests. Satisfactory pilot plant runs may trigger full-scale process implementation phase. The whole development cycle may absorb five to ten years. This procedure is not only time consuming but highly risky, since only a small number of pilot plants and even less conceptual ideas reach the market establishing a new manufacturing process.

This article will give an overview of a process design driven by economic incentives. Section 2 will introduce with conceptual design and a feasibility study of a new "low waste process". The pilot plant phase and the study of process dynamic are the subject of section 3. In section 4, advanced topics in process automation and control accompany the "low waste process" to industrial size. New challenges in dynamics optimization will briefly be addressed. The lecture closes with conclusions and significance.
2. Conceptual Process Design

The feasibility study decides technical and economic viability of a new process idea at the very beginning of a new process life. *Technical feasibility* determines whether the desired chemical or physical transformations are industrially realizable. Key questions include the search for a chemical reaction network converting cheap raw materials into value-added products. Frequently, multiple reaction routes requiring distinct raw materials and/or different operating conditions are possible. Multiple options leading to the same desired product are known as process alternatives.

The selection from among various process alternatives and assessment of their respective *economic feasibility* is determined by process economics. Usually, engineering companies aim at designs with the highest profitability. Detailed process development is warranted only if the expected return surpasses a certain subjective limit – the *economic potential* of the new technology. The choice of a tolerable risk level is a corporate managerial decision. The computation of the processes expected economic performance is an engineering task.

The ultimate pressure for process profitability justifies a design approach searching for optimal economic trade-offs. The systematic approach aims at eliminating unprofitable process designs as early as possible to keep process development cost at a minimum. It is based on a hierarchy of decision layers for the gradual refinement of relevant technical and economical aspects. The design stages prioritize critical design decisions adding more operational details incrementally [1]. In addition to key process design variables such as reaction rates and selectivity, the relevant cost factors such as total annualized cost of major equipment are computed. The *economical potential (EP)* is an upper limit of the expected benefit of an evolving process. The gradual refinement of the cost estimates leads to a