Batch Process Scheduling Optimization of Multiproduct Plants Under Simultaneous Environmental and Economical Considerations

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A key feature of the batch plant is its inherent operational flexibility, which translates into the potential use of alternative resources such as different equipment, existing utilities, intermediate storages and the different assignment of available production time to processing equipment. However, this feature introduces additional degrees of complexity in the design of such plants, since design considerations are interlinked with operational/scheduling aspects [1]. This fact poses interesting research challenges when considering scheduling, as a basic building block in the more general area of Enterprise-wide Optimization [2].

Recently, environmental aspects are being incorporated into the design of chemical processes due to pressures from regulation policies and the global trend in businesses towards sustainability [3]. Different studies have been carried out in order to identify the most significant environmental effects of a process and to suggest modifications with the aim to achieve environmental improvements. As a result, a wide range of process design frameworks have been proposed: the methodology for obtaining Minimum Environmental Impact process (MEI, or MEI methodology), the waste reduction (WAR) algorithm proposed by the United States Environmental Protection Agency (USEPA) which uses the pollution balance concept, the introduction of "eco-vectors" for the calculation of life cycle inventories for process industries and the environmental fate and risk assessment tool (EFRAT), to cite some representative examples. Most of the former examples embed the concepts of life cycle assessment (LCA), developed to set the Environmental Management System (EMS) through an ISO 1404X series. Within LCA the overall life cycle of process or product is analyzed, taking into account upstream and downstream flow from the process. Consequently, the LCA technique is selected as the environmental tool for process development and optimization. The main reason for this choice is that this technique studies the whole product chain from cradle to grave.

This work aims at analyzing the significant environmental issues associated to production process scheduling. The implementation of a LCA for a given process or product requires the gathering of data regarding process environmental interventions (e.g. raw material consumption, uncontrolled emissions and waste generation). This set of data is organized in a life cycle inventory (LCI) which is the basis for the environmental impact calculation, as specified in the ISO 1404X series. In this work we aim at generating the required process LCI by means of a mathematical programming model. Multicriteria optimization of a mathematical process model representation is considered to obtain the optimal production schedules from both economical and environmental points of view.

Waste generation, fugitive emissions and raw material or utility consumption are the key components for the compilation of LCIs. Specifically in the case of batch industries, the LCI is directly related to product recipes and product changeovers. Therefore, scheduling decisions affect the former environmental considerations. Hence, the mathematical programming model considers product flows, raw material or utility consumption and changeover operations to simultaneously deal with environmental and scheduling features. Multi-objective optimization is carried out in order to shed light over the environmental and economical trade-offs resulting from alternative production schedules. As a consequence, this work highlights the importance of introducing environmental considerations at the scheduling stage, and provides the plant decision maker with a wider and deeper knowledge of both environmental and economical consequences when adopting a particular schedule.

A multiproduct batch plant which produces three acrylic fiber polymers is considered as an illustrative case study [4]. Each product undergoes the same eight processing stages and their operational and environmental considerations are fully detailed in their corresponding recipes. Additionally, the product changeover dependence of time, waste generation, emissions and utility consumption is thoroughly studied and modeled accordingly. The results obtained of this particular case study are examined and discussed towards future work.

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References

1. “Environmental impact considerations in the optimal design and scheduling of batch processes”, S. K. Stefanis, A. G. Livingston and E. N. Pistikopoulos. Computers Chemical Engineering 21 (1997) 1073–1094.

2. “State-of-the-art review of optimization methods for short-term scheduling of batch processes” C. A. Méndez, J. Cerdá, I. E. Grossmann, I. Harjunkoski and M. Fahl. Computers and Chemical Engineering 30 (2006) 913–946.

3. “Sustainable development and its implications for chemical engineering”, R. Clift, Chemical Engineering Science 61 (2006) 4179–4187.

4. “Global strategy for energy and waste analysis in scheduling and planning of multiproduct batch chemical processes” R. Grau, M. Graells, J. Corominas, A. Espuña and L. Puigjaner. Computers and Chemical Engineering 20 (1996) 853–868.