Scheduling in Continuous Process Industry: Models and Solution Procedures

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Abstract

The thesis deals with a class of scheduling problem that occurs quite frequently in refineries and other chemical processing industries. In a refinery set up, for example, streams get split into intermediate products each of which then possibly moves through a network of processing units and blending points before being converted to finished products. As a result, the scheduling of a unit depends on the scheduling of upstream units and influences the scheduling of downstream units. Some of the units in the network may be responsible for producing a range of products. In this situation, the unit usually works in a 'blocked-out' fashion, i.e., at any point of time it processes only one product line or stream. However, arrival of raw materials for other products is simultaneous, being outputted from some upstream unit(s). Inputs for product lines, other than the one currently being processed, must either be stored in tanks for future processing, or it will get 'spilled' or wasted. The spilled amount usually gets downgraded to substantially lower valued products. Spillage can be reduced by quick changeovers. But a changeover from one product line to another has its associated cost and time. Thus, given fixed capacity storage tanks, there is always a trade-off between spillage and changeover while processing multiple products on the same processing unit. Sometimes, these blocked-out units are cascaded one after the other – separated by fixed capacity

storage tanks for each product line – and thus complicates the scheduling decision further. The problem of scheduling gets aggravated by the requirement of meeting the upliftment schedule with its associated penalty for not producing the required amounts of finished products within the due dates. The processing units under consideration are continuous processing units. In a continuous processing unit inputs for a product line are fed in continuously at a fixed rate and the outputs flow out simultaneously at a fixed rate. Here, one product line can be processed in a number of stretches during the scheduling horizon interleaved with the processing of other streams. The length of a stretch is not fixed and each such stretch is called *run-length.* It must be noted, however, that the length of each stretch of run should be greater than a pre-specified *minimum run-length.* That is if a stream is taken up for processing in any time period in any unit, then it should be processed for a minimum number of consecutive time periods called minimum run-length. While longer stretches of run are desirable to reduce changeover cost, shorter stretches may reduce spillage cost and upliftment failure penalty. The scheduling problem aims to find out an optimal mix of product sequences of varying run lengths so as to minimize the total cost/penalty. The objective of the dissertation with respect to the above mentioned scheduling problem is to:

1. Formulate discrete-time mathematical models for the problem. We formulate a mathematical model based on the specifics of the problem. The insights gained from this formulation led us to develop another discrete time mathematical model based on the concept of 'state task network' that can take care of more complex situations. This enhances the generalizability of the model developed earlier.

2. Formulate continuous-time mathematical model for the problem. The limitation posed by the discreteness of the time grain in the case of discrete time models led us to develop a continuous time mathematical model for the problem. Towards this end we extend the concept of global event points for the above mentioned class of problems. Further, our model is more general than other similar such models since we do not pre-fix some of the event variables on the dates of upliftments.

3. Propose a heuristic solution procedure. For realistic scheduling horizons, the complexity of the mathematical models become prohibitively expensive. We,

therefore, suggest a two pass heuristic scheme based on depth first branch and bound mechanism. Here we develop heuristic strategies for upliftment failure and spillage penalties. We also develop efficient node ordering strategies in order to reduce the search time.