Chapter 1
Modeling and Scheduling of Crude Oil Operations in Refinery:
A Hybrid Timed Petri Net Approach

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ABSTRACT

The process of an oil refinery contains both discrete event and continuous variables and can be characterized as a hybrid system. It is extremely challenging to schedule such a system. The short-term scheduling problem of crude oil operations addressed in this chapter is one of the most difficult parts. With jobs to be scheduled being unknown at the beginning, heuristics and meta-heuristics are unable to be applied. Thus, by the existing methods, this problem is formulated as a mathematical programming problem and solved by using exact methods. However, because it is NP-hard in nature, mathematical programming is not computationally efficient and cannot be applied in practice. Up to now, there is no software designed to this problem. In this chapter, for the first time, the problem is studied in a control theory perspective. The problem is modeled by a type of hybrid Petri nets. Based on the model, a two-level control architecture is presented. At the lower level, it solves the schedulability and detailed scheduling problem in a hybrid control theory perspective. At the upper level, it solves a refining scheduling problem, a relative simple problem, with the schedulability conditions as constraints. Consequently, it results in a breakthrough solution such that the large practical application problem can be solved.

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1. INTRODUCTION

With increasingly global competition, the profit and productivity enhancement technology for process industry has attracted more and more research interest in recent years. Oil refinery is one type of such processes. In operating a plant of refinery, there are three levels: production planning, production scheduling, and process control. It is believed that when the plant is well operated it may increase profit by $10 per ton of product or more (Moro, 2003). Thus, for competitiveness, considerable attention has been paid to the development of effective techniques for the operation of refinery for the last two decades. Up to now, at the process control level, advanced control systems have been installed for unit control to optimize production objectives in most oil refineries, leading to significant productivity gains in these units. Nevertheless, the optimization of the production units does not mean the global economic optimization of the plant. Usually the objectives of the individual units are conflicting and thus lead to a suboptimal and sometimes infeasible overall operation.

At the planning level, the potential benefits of optimization for process operations in oil refineries have long been observed, and linear programming has been applied in crude oil blending and product pooling (Symonds, 1955). Oil refineries are increasingly concerned with improving the planning of their operations. Faced with global market competition, companies should assess the potential impact of dynamical changes such as demands for final product specifications, prices, and crude oil compositions. For this purpose, Coxhead (1994) identifies several applications of planning models in the refining and oil industry, including crude selection, crude allocation for multi-refinery situations, and operations planning. With the availability of LP-based commercial software for refinery production planning, such as PIMS (Process Industry Modeling System — Bechtel, 1993), general production plans of the whole refinery can be found. As pointed out by Pelham and Pharris (1996), the planning technology can be considered well-developed and its drastic progress should not be expected. Additional advances in this area may be based on model refinement through the use of nonlinear programming.

Short-term scheduling is at the middle level. As pointed by Shobrys and White (2000), to effectively operate a process plant, the three levels should work together. In fact, the need for integration has been a frequent topic since the 1960s (Mesarovic et al., 1970; Jaikumar, 1974; Baker and Shobrys, 1985; Bodington, 1995; Pinto et al., 2000; and Honkomp et al., 2000). Thus, with the techniques for planning and process control well-developed, it is crucial to develop effective techniques for short-term scheduling.

There are mainly two types of industries: discrete manufacturing industry and process industry. It is believed that scheduling discrete manufacturing operations is well-established (Baker, 1974) and there is a large body of literature on this field. Because of the NP-hard nature for the general scheduling problem, usually heuristics and meta-heuristics, such as simulated annealing algorithms, genetic algorithms, and tabu algorithms, are applied (Sabuncuoglu and M. Bayiz, 1999; Ponnambalam et al., 1999; Mattfeld and Bierwirth, 2004; Yang and Wang, 2001; Czerwinski and Luh, 1994; and Chen et al., 1998).

Process industry can be further divided into two categories: batch and continuous processes. In batch process industry, the materials are processed in batches. These discrete batches can be treated as jobs just as in the discrete manufacturing systems. Nevertheless, the materials are transferred between devices continuously as fluid, and hence, they are characterized as continuous variables. Great effort has been made in scheduling of a batch process by using rule-based algorithms (Kudva et al., 1994; Stephanopoulos and Han, 1996), search algorithms (Ku and Karimi, 1991; and Murakami et al., 1997), and mixed integer programming (Pinto and Grossmann, 1997; Realff