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Integration of generative and evaluative models for production scheduling of lube oil plants in a petroleum refinery

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Abstract

A study was made on the existing practices of production planning, scheduling and prevailing constraints in the six plants of a lube oil section in a petroleum refinery. Based on the data collected from these plants, some generative and evaluative models were developed. The generative models developed were flow network optimisation (FNO) model and binary integer linear programming (BILP) model. The evaluative model developed was simulation. The optimal results obtained from the generative model were fed to the evaluative model to derive the measure of performance. This integration of generative and evaluative models offers an opportunity for better understanding of the subsystem and appropriate decision making.

Keywords: Production scheduling; Generative models; Evaluative models; Petroleum refinery; Lube oil products

1. Introduction

That the oil refining industry is facing a condition characterized by decreasing profit margins due to surplus refining capacity and increasing oil prices is a well-known fact. Simultaneously market competition and rigorous environmental regulations are compelling the industry to make wide ranging modifications in its operations. As a result, there is no refinery nowadays that does not use process optimization tools to improve business results. Such tools are applied widely in production planning and scheduling. Moro [1] stated that many benefits have already been reaped due to the use of these tools, but there is a lot more to be done to achieve their full potential, because they still exhibit many weaknesses. Pinto et al. [2] studied planning and scheduling models for refinery operations, which include non-linear planning models for refinery production and mixed integer optimization models for scheduling. They also analyzed and observed that optimization of the production units did not achieve the global economic optimization of the plant. Usually the objectives of the individual units were conflicting and thus contributed to a sub-optimal, and many times infeasible overall

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operations. Katayama [3] proposed a production planning procedure for multi-item continuous production and an optimal product mix using integer linear programming in a petrochemical plant. For a production planning and scheduling problem in an oil refinery, to satisfy the demand while minimizing production cost and considering storage capacity constraint, Maud et al. [4] proposed a mixed integer linear programming (MILP) model. Artiba and Riane [5] proposed a multi model system integrated with optimization algorithms, discrete event simulation and expert system techniques for production planning and scheduling of process industries. Liza and Pinto [6] proposed a MILP model for optimal scheduling of a lube oil and paraffin production plant. In this work, the authors compared two mathematical formulations for discrete and continuous time representations. Jia and Ierapetritou [7] developed a comprehensive mathematical programming model for scheduling of oil refinery operations by decomposing the overall problem spatially into three domains. Xiong and Nyberg [8] developed a computer integrated manufacturing systems model for a refinery system, and discussed the issues related to production planning and scheduling of the refinery. Alle and Pinto [9] addressed the problem of simultaneous scheduling and optimization of continuous multistage multiproduct plants with intermediate storage. Potter et al. [10] developed a discrete event simulation model to study the dispatch performance in a steel processing industry. They built the simulation model using ARENA simulation software package. Chryssolouris et al. [11] presented a simulation based approach for scheduling crude oils from crude storage tanks to the crude distillation units. Moro and Pinto [12] addressed the problem of crude oil inventory management of a refinery that received several types of oil through a pipeline. Neumann et al. [13] studied scheduling of continuous, semi-continuous and discontinuous production in process industries where storage facilities and resources like processing units and manpower are limited in capacity. They applied Branch and Bound method for solving the problem. De Matta and Miller [14] coordinated the short-term production and inter facility transportation scheduling decisions between a plant that produced intermediate products and a finishing plant that processed the intermediate products into finished goods. They developed an MILP model through which they investigated the variability in plant capacity and costs affecting the coordination of scheduling decisions as well as the choice of transportation modes and carriers. Floudas and Lin [15] presented a review of developments in the scheduling of multiproduct/multipurpose batch and continuous processes.

In this paper we are presenting the development of an optimization model for production scheduling in an oil refinery. Lube oil products are produced in the refinery by distillation of raw material crude. For production scheduling operations of lube oil section in the refinery, a suitable mathematical programming model has been developed by integrating the operations of the plants. An appropriate simulation model has been proposed to take care of the random events in the lube plants. By integrating optimization and simulation models, the generated production schedule has been evaluated for optimal performance. This paper is organized as follows: The process details of the case study organization are presented in Section 2. The framework of the proposed production scheduling model is presented in Section 3. The mathematical model of the flow network optimization (FNO) model and binary integer linear programming (BILP) model for production scheduling are presented in Section 4. The derivation of production schedule from the results of the BILP model is presented in Section 5. Integration of generative and evaluative models is presented in Section 6. Validation of the simulation model is presented in Section 7. Discussion and conclusions are presented in Section 8.

2. Case study

This study was conducted in a public owned petroleum refinery in India, which has a capacity of processing 9.5 million metric tonnes per annum of crude oil and producing a variety of petroleum products. When the raw crude oil is processed in the refinery, it produces 15 different products, namely, sulphur, hexane, naptha, liquefied petroleum gas, petrol, aviation turbine fuel, kerosene, linear alkaline benzene feed stock, diesel, lube base stocks, industrial fuel, asphalt, feed stocks for mex-poly butenes, propylene and paraffin wax. Of these 15 products produced by the refinery, lube based stocks have a higher market value and contribute a major share of revenue for the refinery. The raw crude oil is processed through four stages, namely, distillation, raffination, dewaxing and hydrofinishing to produce lube based stocks. The lube based stocks consist of six products, namely, spindle oil (SP), light neutral (LN), inter neutral (IN), high neutral (HN), 500 neutral (500 N) and