Rajagopalan Srinivasan

Artificial intelligence methodologies for agile refining: an overview

Abstract Agile manufacturing is the capability to prosper in a competitive environment of continuous and unpredictable changes by reacting quickly and effectively to the changing markets and other exogenous factors. Agility of petroleum refineries is determined by two factors – ability to control the process and ability to efficiently manage the supply chain. In this paper, we outline some challenges faced by refineries that seek to be lean, nimble, and proactive. These problems, which arise in supply chain management and operations management are seldom amenable to traditional, monolithic solutions. As discussed here using several examples, methodologies drawn from artificial intelligence – software agents, pattern recognition, expert systems – have a role to play in this path toward agility.

Keywords Petroleum refining · Supply chain management · Decision support · Enterprise-wide optimization · Process supervision · Fault diagnosis · Pattern recognition

1 Introduction

The refining environment today is a fast changing one. Reformulated products are replacing classical distilled ones. Volatile crude prices, imbalance between refining capacity and crude availability, and fluctuating product demands is the name of the game. To survive and prosper in this scenario, refineries are required to be agile. Agility is the ability to proactively respond to a changing environment through responsiveness to customers, product and process innovation, and operational flexibility. Agility of petroleum refining is determined by two factors:
1. Process control: The ability to operate and control the production process to make low-variability products as well as to nimbly and efficiently switch between various products, and

2. Supply chain management: The capability to optimize and manage the supporting services including logistics, inventories, and other supply chain resources so as to take advantage of short-lived market opportunities in product demands or raw material availabilities, as well as to react efficiently to manage disruptions and other supply, production, or demand uncertainties.

In its quest towards agility, the refinery of today has constantly adopted many new technologies. Data is collected in real time, not only from the process but also from the business. Automation applications have been devoted by the industry with the hope of extracting information from data. In the process operations arena, advanced control and unit optimization has become commonplace. Expert systems and neural networks are also being increasingly used. Abnormal situation management has come a long way from a buzzword to near reality. The business operations field also has not been left behind from this incessant push of technology. Vendors are touting systems that integrate different parts of the business, from crude oil acquisition to terminal and depot management, thus cutting across the complex web of logistics, manufacturing, and sales. In such an environment, where it may seem that all that can be solved has been solved, we will outline two areas where artificial intelligence methodologies promise further benefits. The first, as discussed in Section 2, relates to optimization at the enterprise level, and the second to management at the process operations level, as discussed in Sect. 3.

2 Supply chain management

Since most refineries are capable of producing a variety of products and grades, plant personnel have to answer the following questions on a regular basis:

1. What products to sell?
2. When and where should they be produced?
3. What raw materials are needed, when and from whom should they be bought?

These questions lie in the domain of supply chain management (SCM). In the face of highly competitive markets and constant pressure to reduce lead times, enterprises today consider SCM to be the key area where improvements can significantly impact the bottom line. The refinery supply chain spans numerous internal departments and several suppliers and customers. Decision-making is distributed across departments. Figure 1 shows the major supply chain functions in a typical chemical enterprise, and their roles and timescales. Forecasting provides the future requirements of markets or specific customers typically for the next 12–18 months. Based on these, Planning sets the operating targets and provides coordination among the different departments—sales, materials management, production and distribution. The time horizon here is “long,” typically 2–6 months. Various types of uncertainties including those arising from the supply and demand chains as well as from the production are aggregated at this stage. The Scheduling function defines the specific Source and Make activities to be performed over a horizon of a few days to a week. Both the timing and volume of specific activities are specified at this stage. The key drivers are product demand, inventory levels, as well as