CHEMICAL ENGINEERING TRANSACTIONS
VOL. 62, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216
DOI: 10.3303/CET1762233

Optimization of Refinery Production Scheduling Based on Ant Colony Algorithm

Weixiang Jiang

School of Software, Changzhou College of Information Technology, Changzhou 213164, China
343068379@qq.com

In the 21st century, the energy situation is becoming worse and worse. As the oil has been explored continuously, the number of petroleum in the crust and the development of the amount of oil continued to decline, it becomes one of the world's most valuable resources now. Therefore, its price has been rising rapidly. As a typically industry production process, refining process is the pillar industry of the national economy, which is located in the upper reaches of the manufacturing industry. It is also the main driving force for the development of other industries. Only by making scientific and rational production plan of refinery can we make oil refining enterprises get ahead in the fierce market competition. However, there are some problems happening in the process, such as devices and equipment failure, and poor quality of uncertain events. They will change the device products, raw materials, and energy supply and demand, which is difficult to grasp the balance just by artificial experience, and then causes the excessive waste of resources and energy. Then it will result in loss of the interests of the enterprise and even the threat of production safety. These problems need scientific methods to solve urgently. Ant colony algorithm (ACA) is a heuristic search algorithm based on population optimization. As a new bionic algorithm, ant system has attracted the attention of many experts and scholars, and has interpreted many different improved versions. Because the ant colony algorithm has many advantages in solving combinatorial optimization problems, it has been widely applied in academic, industrial and commercial fields. In this paper, the production scheduling of refinery is optimized effectively by using the advantages and disadvantages of ant colony algorithm. First of all, the composition and production process of refinery are paid great attention. Secondly, the advantages of ant colony algorithm are introduced. Finally, the ant colony algorithm is used to optimize the traditional scheduling method. The production scheduling method after optimization can make the refinery satisfy the market demand, and save production costs, too. It can also increase economic efficiency, and improve the technology and management level. Besides, it can enhance the competitiveness of enterprises, which has a great significance for the actual production.

1. Introduction

Recently, petrochemical industry has got a rapid development. Various kinds of petrochemical products and derivatives products are around us everywhere, which are closely related with our work and life. The overall production process in refining enterprise is quite huge and complex, so the importance of production planning is obvious. The optimization of production plan can be solved by mathematical programming method. In early time, linear programming modelling (Simon, 1983) is mainly used to build mathematical programming model to search the optimization of the problem, which is also a research hotspot. It includes mixed integer linear programming and mixed integer nonlinear programming model (Pinto, 1997; Mendez, 2003). The operation mode of production in refinery factory is considered as the decision object, and the production planning and scheduling model is established. In the literature (Neiro, 2004), the petroleum supply chain has been studied, and a general model of production operation plan model has been established, which can be modified and perfected according to different practical problems. In the literature (Liu et al., 2007), a nonlinear function model of variable cost in refinery production planning optimization was proposed. As a new optimization algorithm, Ant Colony Algorithm has been widely used in many industrial fields. Since the Italy scholar Dorigo proposes the ant colony algorithm in 1991, many scholars have come into this field and studied it. In 1992,

Please cite this article as: Weixiang Jiang, 2017, Optimization of refinery production scheduling based on ant colony algorithm, Chemical Engineering Transactions, 62, 1393-1398 DOI:10.3303/CET1762233

Dorigo (1992) further elaborated the core idea of ant colony algorithm. In 1996, Dorigo and Maniezzo, on the basis of these studies, summarized them and put forward Ant Colony Optimization model (ACO), which is a kind of ant algorithm model for combinatorial optimization problems. Johann and Siarryv (2002) used the concept of hierarchy, and then propose a new ant colony algorithm, which aims at optimizing the multi-valued continuous function. Wang (2005) proposes a new ant colony algorithm for assembly sequence planning. Baykasoglu (2006) proposed a novel ant colony algorithm for solving budget constrained and unconstrained dynamic facility layout problems. Nihan (2006) used the ant colony algorithm to optimize the two allocation problem.

ACO has many advantages as a bionic optimization algorithm. In this paper, its global search characteristic is used to improve the scheduling optimization problem in refineries. First of all, we pay full attention to the composition of refinery factory and its production process. Secondly, the advantages of ant colony algorithm are introduced. Finally, it is used to optimize the traditional scheduling method. The production scheduling method after being optimized can make the refinery to meet the market demand. Besides, this method can also save production costs, increase economic efficiency, improve the technology and management level, and enhance the competitiveness of enterprises, which has a great significance in the actual production.

2. Study on the scheduling problems of production in refineries

The production scheduling of oil refining and chemical enterprises are responsible for arranging the storage and transportation of crude oil and the processing ratio of crude oil. They also take the task of refined oil blending, refined oil storage and transportation, oil supply and other work. Production scheduling gives the best proportion of crude oil and process route according to the different raw materials supply, actual production process and product demand situation. At the same time, product oil blending program is also formulated, and it will be conducted directly. Figure 1 is the production process of refinery. Petrochemical industry is a capital and technology intensive industry with continuous process, large processing scale, large quantity of products, wide variety of products and wide market coverage.

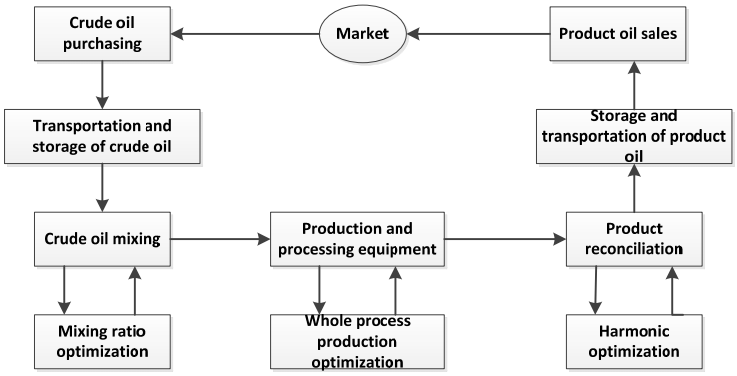

Figure 1: The production process of refinery

2.1 The production process of refineries

Refinery mainly consists of two parts, which are refining process and auxiliary equipment. The production of various petroleum products from crude oil usually involves a number of physical and chemical refining processes. Typically, each refining process consists of an oil refining unit, which is independent with each other. According to the production aim, the devices of oil refining production are classified into the following categories: crude oil separation device, heavy oil becoming lighter device, oil upgrading and oil refining equipment, oil blending device, gas processing plant, atmosphere chemical device, production equipment and product analysis centre. Because of the different production schemes, refinery processes are different in their types, amounts and the degree of complexity. In general, large refineries are more complex, but there are still some large-scale refineries that are not very complex.

As for the production planning and scheduling, the whole refining process can be roughly divided into the following three stages.

(1) The primary process includes the following whole process. Firstly, the crude oil (or the mixed one) is unloaded from an oil tanker at the port terminal to an oil storage tank near the dock. Second, the storage tank is transported from the wharf to the oil supply tank through the dedicated pipeline. Third, the fuel supply tank is allocated to the steam feed tower.

(2) Secondary process contains the following parts. Firstly, a series of processing reactions such as steaming, feeding, cracking and catalysis carried out in the distillation tower and other production and processing units. Secondly, intermediate products are stored together and further processed to become the final product.
(3) The final goods are stored and transported. Various extracted components are mixed into different products according to the market demand, and then they will be sold and delivered

2.2 Production planning and scheduling in refineries

The short-term production plan for crude oil treatment involves discrete event objects such as oil tanks, pipelines and distillation towers, as well as continuous objects like oil, which is a typically mixing system. The distillation column refining scheme is located on the upper level of the system. It will determine when each distillation column will start refining what kind of crude oil, the amount of oil refining, and the rate of refining of the distillation tower. The production planning system of crude oil processing is located in the lower level, which will decide when and how much oil in the port will be unloaded in which oil tank, as well as the oil discharge rate. And decide which oil tank in the refinery will be used to hold the oil, as well as its rate of delivery. In addition, it determines when and how much oil in which oil tank will be delivered to which distillation column to refine it as well as its refining rate. The purpose of the detailed production plan for crude oil treatment is to realize the distillation column refining plan produced by the upper layer. The oil tank is a very important resource and should be operated as efficiently as possible with a minimum tank.

3. Study on ant colony algorithm

3.1 Basic principles of ant colony algorithm

The ant colony algorithm is derived from the characteristics of ant colony, which is searching for food. As we all know, ants are always able to quickly find the shortest path between the nest and the food source. Its basic idea is to simulate the ants' behaviour of looking for food in the real world, in order to obtain the optimal solution. The ant colony algorithm is a swarm intelligence algorithm. It has more superior performance in dealing with a complex optimization problem. It is a simulated evolutionary algorithm. The choice of direction is always based on the information left by ant, and global search is used to get the better solution. Figure 2 describes the operation mechanism of ant colony algorithm through the foraging process of ants.

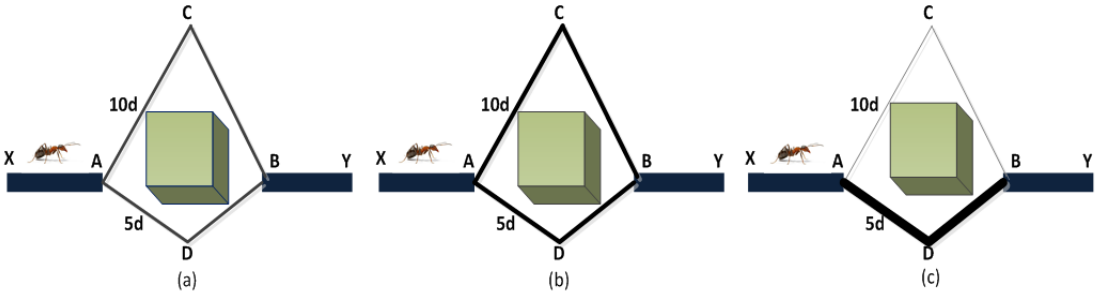

Figure 2: The ant colony foraging process

As is shown in Figure 1 (a), we assume that X is the ant nest, Y is the food and C and D are the obstacles. Firstly, when ants go out of the nest to find food, they will randomly choose ACB and ADB line. However, with time going by, the ants on the two routes will be more evenly distributed, which is shown in the Figure 1 (b) .Since the ADB route is shorter, the ants on this route will return more quickly. Hence, the left pheromones will grow more and more over time. After a period of time, the ant will gradually choose the path with more information. Finally all the ants will choose the path ADB, which is the shortest path from their nest to the food source, which is shown in the Figure 1 (c).

3.2 Ant colony algorithm model

Ant colony algorithm has the characteristics like positive feedback, self-adaptability, robustness and so on. The ant colony algorithm is suitable for many combinatorial optimization problems. Traveling salesman problem (TSP) is a classical application of ant colony algorithm. Formula 1 shows the route choice probabilities of the ant *k* passing between two cities.

$$p_{ij}^{k}(t)=\begin{cases}\dfrac{[\tau_{ij}(t)]^{\alpha}[\eta_{ij}(t)]^{\beta}}{\sum_{s\in allowed_k}[\tau_{is}(t)]^{\alpha}[\eta_{is}(t)]^{\beta}}, j\in allowed_k\\ 0, j\notin allowed_k\end{cases} \quad (1)$$

If the ants go through the connection path between all two cities, the pheromone will be updated, and the method of updating will be formula 2.

$$\tau_{ij}(t+n)=(1-\rho)\tau_{ij}(t)+\Delta\tau_{ij},\Delta\tau_{ij}=\sum_{k=1}^{m}\Delta\tau_{ij}^{k} \quad (2)$$

Fig. 3 is the basic frame chart of ant colony algorithm.

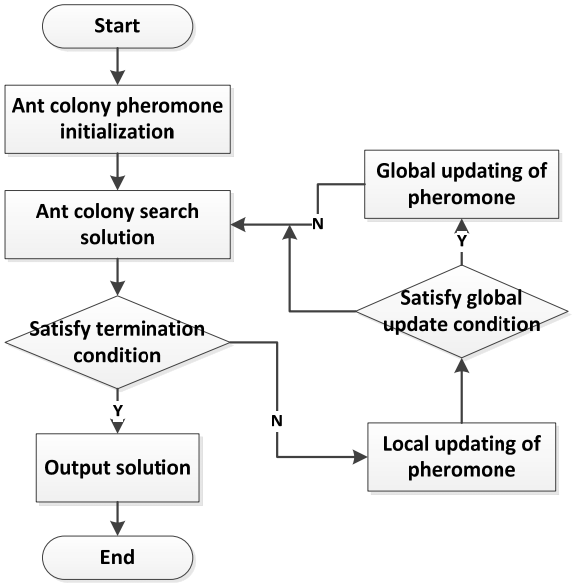

Figure 3: The basic frame chart of ant colony algorithm

4. Optimal design and implementation of production scheduling

In this paper, ant colony algorithm is used to search the optimal solution. All the links between the convergences of production scheduling is optimized to reduce inventory backlog, production consumption and to optimize tank selection strategy. It we assume that a refinery has 5 sets of production equipment, which are atmospheric and vacuum distillation unit, catalytic cracking unit, catalytic reforming unit, delayed coking unit and diesel hydrogenation unit. When using ant colony algorithm to find solution, the processing unit of each process is different from the beginning of processing time and the completion of processing time. Considering that the placement time of the intermediate products is limited, the ants always use the same order when selecting different units of the same process. For each process, you need to set up two pointers, namely, the unit ready pointer Start Point and the unit completion pointer Over Point. The specific steps are as follows.

1) Select a set of production units to start as the foraging beginning for ants.

2) Select the minimum and efficient production as the objective function. Here the objective function is made as the fitness function, and each move will select the solution whose objective function is the smallest in the candidate solution.

3) Select the (Over Point+1) processing unit in each process section for processing. Among all the equipment that can process the unit, we can choose the equipment that completes the processing earliest. Then we assume Over Point=Over Point+1, and check whether the process is the last process. If not, the ready unit pointer values in subsequent processes Ready Point=Ready Point+1.

4) Update the pheromone, when step 3 is accomplished. The reciprocal of the pheromone update quantity is the optimal solution of this iteration.

5) Taboo list. The taboo object chosen in this paper is the current solution, which is the operation model of each production unit in each planned cycle during one month.

6) This method is adopted for each process. Finally, the ant colony algorithm is applied to the whole production process. When the optimal solution is obtained, the algorithm is over.
As forthe processing of various products, the amount of crude oil demand, as well as the processing capacity constraints and inventory constraints, this paper is based on the references and research materials of the actual production data calculation, and they can be debugged and modified in the test. With regard to the parameters related to the optimization algorithm, they are obtained through fixed production parameters within the theoretical feasibility range, which also have been tested several times.

5. Experiment and analysis

5.1 Experiment design

Petrochemical system is a complicated process which has many production units and produces many products. The material flow, energy flow, capital flow, and information flow interact with each other in the enterprise, which is a typically complex system. In order to verify whether this method has a good effect on the optimization of production scheduling of refinery, this paper designs an experiment to make simulation. As for the experimental environment, the hardware environment is the Intel (R), Core (TM), i5-4300M, @2.60GHz, and 4G memory. Besides, the software environment is Windows 7, and the design language is MATLAB.

5.2 Experimental results and analysis

We make a comparison between the production efficiency of traditional refineries and the production efficiency after optimization. As can be seen from Figure 4, when using this method, the refined gasoline and diesel has a larger amount than that of traditional method.

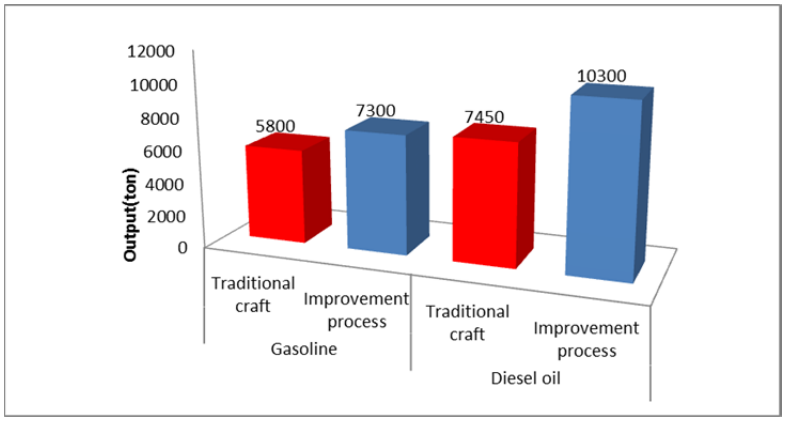

Figure 4: The comparison of product oil production

At the same time, we compare the relationship between the amount of oil and energy consumption during the production cycle of one month. As can be seen from Figure 5, the method of this paper also has very good effect on energy consumption control.

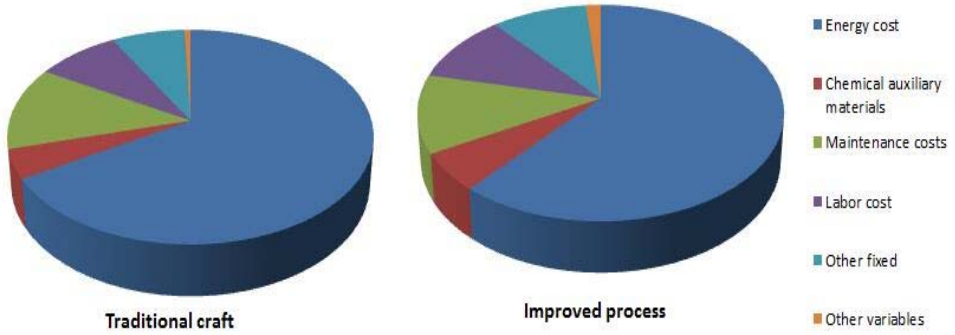

Figure 5: The percentage structure of cost under the same yield

6. Conclusions

In this paper, the characteristics like global search of the ant colony algorithm are used to improve the scheduling optimization problems in refineries. First of all, we focus on the composition and production process of refinery. Secondly, the advantages of ant colony algorithm are introduced. Finally, the ant colony algorithm is used to optimize the traditional scheduling method. The production scheduling method after optimization can make the refinery meet the market demand. Besides, it can also save production costs and increase economic efficiency. What's more, it can improve the technology and management level, and enhance the competitiveness of enterprises, which has a guiding significance for the actual production.

Acknowledgments

Top-notch Academic Programs Project of Jiangsu Higher Education Institutions (PPZY2015A090)

Reference

Adil B., Turkay D., Ibrahim S., 2006, An Ant Colony Algorithm for Solving Budget Constrained and Unconstrained Dynamic Facility Layout Problems, The International Journal of Management Science, 34, 385-396.

Colorni A., Dorigo M., Maniezzo V., 1991, Distributed optimization by ant colonies, Proceedings of the 1st European Conference on Artificial Lift, 134-142.

Demirel N.C., Toksarı M.D., 2006, Optimization of the Quadratic Assignment Problem Using an Ant Colony Algorithm, Applied Mathematics and Computation, 183, 427-435.

Dero J., Siarry P., 2002, A New Ant Colony Algorithm Using the Hierarchical Concept Aimed at Optimization of Multiminima Continuous Functions, 216-221.

Dorigo M., Maniezzo V., Colorni A., 1996, Ant system: optimization by a colony of cooperating agents, IEEE Transation on Systems, Man, and Cybernetics-Part B, 26, 1, 29-41.

Dorigo M., 1992, Optimization, learning and natural Algorithms. Ph.D. Thesis, Department of Electronics, Politecnico di Milano, Italy.

Dorigo M., Gambardella L.M., 1997, Ant Colony System: A Cooperative Learning Approach to the Traveling Salesman Problem, IEEE Transactions on Evolutionary Computation, 4(1), 53-56.

Liu C.W., Li C.F., He X.R., 2007, Optimization model of refinery production planning based on variable processing cost, Journal of Tsinghua University, 47(3), 404-407.

Mendez C.A., Cerda J., 2003, Dynamic scheduling in multiproduct batch plants, Computers and Chemical Engineering, 27(8-9), 1247-1259.

Neiro S.M.S., Pinto J.M., 2004, A general modelling framework for the operational planning of petroleum supply chains, Computers and Chemical Engineering, 28, 871-896.

Pinto J.M., Grossmsmm I.E., 1997, A logic-based approach to scheduling problem with resource constraints, Computers and Chemical Engineering, 21(8), 801-818.

Simon J.D., Azama H.M., 1983, Exxon experience with large scale linear and nonlinear programming applications, Computers and Chemical Engineering, 7(5), 605-614.

Wang J.F., Liu J.H., Zhong Y.F. 2005, A Novel Ant Colony Algorithm for Assembly Sequence Planning, Int J AdvManuf Technol, 1137-1143.