원유하역및 재고관리에 관한 단기일정계획의 MILP 모델

이희만(정), 박선원(정)
한국과학기술원 화학공학과

MILP MODEL FOR REFINERY SHORT TERM SCHEDULING OF CRUDE OIL UNLOADING WITH INVENTORY MANAGEMENT

HEEMAN LEE and SUNWON PARK
Department of Chemical Engineering, KAIST

1. Introduction

Unlike scheduling of batch processes which has received considerable attention in the literature (Reklaitis, 1991, 1992; Rippin, 1992), much less work has been reported in the scheduling of continuous multiproduct plants. Petroleum refinery which has to process different crude oil is one example of continuous multiproduct plants, and many problems involving refinery planning have been studied since the 1950s (Symonds, 1955; Manne, 1956). These problems involved long term supply and production planning of crude oil, and blending schedule for distilled crude oil products. For the short-range scheduling problem, discretizing time is effective in developing MILP models (Kondili et al., 1993). Since the problem addressed in this paper involves transition cost and inventory cost in its objective function, some of the ideas by Sahinidis and Grossmann (1991) and Pinto and Grossmann (1994) on optimal cyclic scheduling of continuous multiproduct plants will also be used.

The scope of this work is to develop a rigorous MILP optimization model for short term crude oil unloading, tank inventory management, and CDU charging schedule. To facilitate the modeling of material balance equations of each oil containers, time will be discretized and nonlinear mixing equations will be reformulated into linear ones. The operating cost in the crude inventory management problem includes inventory cost, crude vessel harboring and sea-waiting cost, and changeover cost for charged oil change in each CDU. Constraints involve quality and quantity specification of mixed crude oil feed to CDU, mixing equations, mass balance for each tank, and capacity limitations of tanks and pumps.

2. Problem Definition

The system configuration of this scheduling problem corresponds to a multistage system consisting of vessels, storage tanks, charging tanks, and CDUs. During a given scheduling horizon, crude vessels arrive in the vicinity of the refinery docking station and, if busy, wait for unloading of the preceding vessel in the docking station. At the docking station, crude oil is unloaded into storage tanks. Crude oil is then transferred from storage tanks to charging tanks which are buffers to produce crude mix of which component compositions were determined at the planning level. Crude oil mix in each charging tank is then charged into a CDU. Given the configuration of the multistage system as well as the arrival times of vessels, equipment capacity limitations, and key component concentration ranges, the problem is then to determine the following operating variables to minimize operating costs:

(a) waiting time of each vessel in the sea
(b) unloading duration time for each vessel
(c) crude unloading rate from vessels to storage tanks

(d) crude oil transfer and mixing rate from storage tank to charging tanks
(e) inventory levels of storage and charging tanks
(f) crude distillation unit charging rates
(g) sequence of mixed crude to be charged into each CDU

Following are operating rules that have to be obeyed in this problem:

(a) In the scheduling horizon, each vessel should arrive and leave the docking station for unloading.
(b) If a vessel does not arrive at the docking station, it cannot unload the crude oil.
(c) If a vessel leaves the docking station, it cannot unload the crude oil.
(d) The vessel should leave the docking station after its arrival.
(e) Vessel cannot arrive at docking station if the preceding vessel does not leave.
(f) While charging tank is charging CDU, crude cannot be fed into charging tank and vice versa.
(g) Each charging tank can feed at most one CDU at one time interval.
(h) Each CDU is charged by only one mixed crude oil at one time interval.

Finally, following are the major operating constraints that must be met:

(a) equipment capacity limitations (tank capacity, pumping rate)
(b) quality limitations on each mixed crude oil (components in mixed crude oil stream)
(c) demand of each mixed oil to be charged into CDU

3. General Mathematical Formulation

The proposed scheduling model is based on a uniform discretization of time in the given scheduling horizon. Selection of the time length of each discretized time span involves trade-off between accurate operation and computational effort. With smaller discretized time size more sophisticated operation is possible since there is more operation changes during the scheduling horizon. However, this increases the computational effort due to increased number of binary variables and constraints. The examples in this paper involve less than 15 time intervals during the scheduling horizon.

4. Solution Method

The branch and bound code OSL (IBM, 1991) was used to solve this problem. In order to reduce the computational expense, several techniques have been employed. Firstly, by specifying a priority to the binary variables according to their contributions to the cost function, the number of nodes in the branch and bound enumeration has been reduced. There are three sets of binary variables in this MILP model. Giving higher priority to the binary variable which contribute to changeover costs reduced the size of the search tree. Secondly, by defining binary variables as special ordered sets (Beale and Tomlin, 1970) considerable reduction in the enumeration has been achieved. For the large size problem a finite value for the relative optimality criterion (OPTCR) was used to reduce the CPU time. The modeling system GAMS (Brooke et al., 1988) was used in order to implement the scheduling model and its solution method.

5. Example

3 vessels, 6 storage tanks which involve crude oil mixing, 4 charging tanks and 3 CDUs.

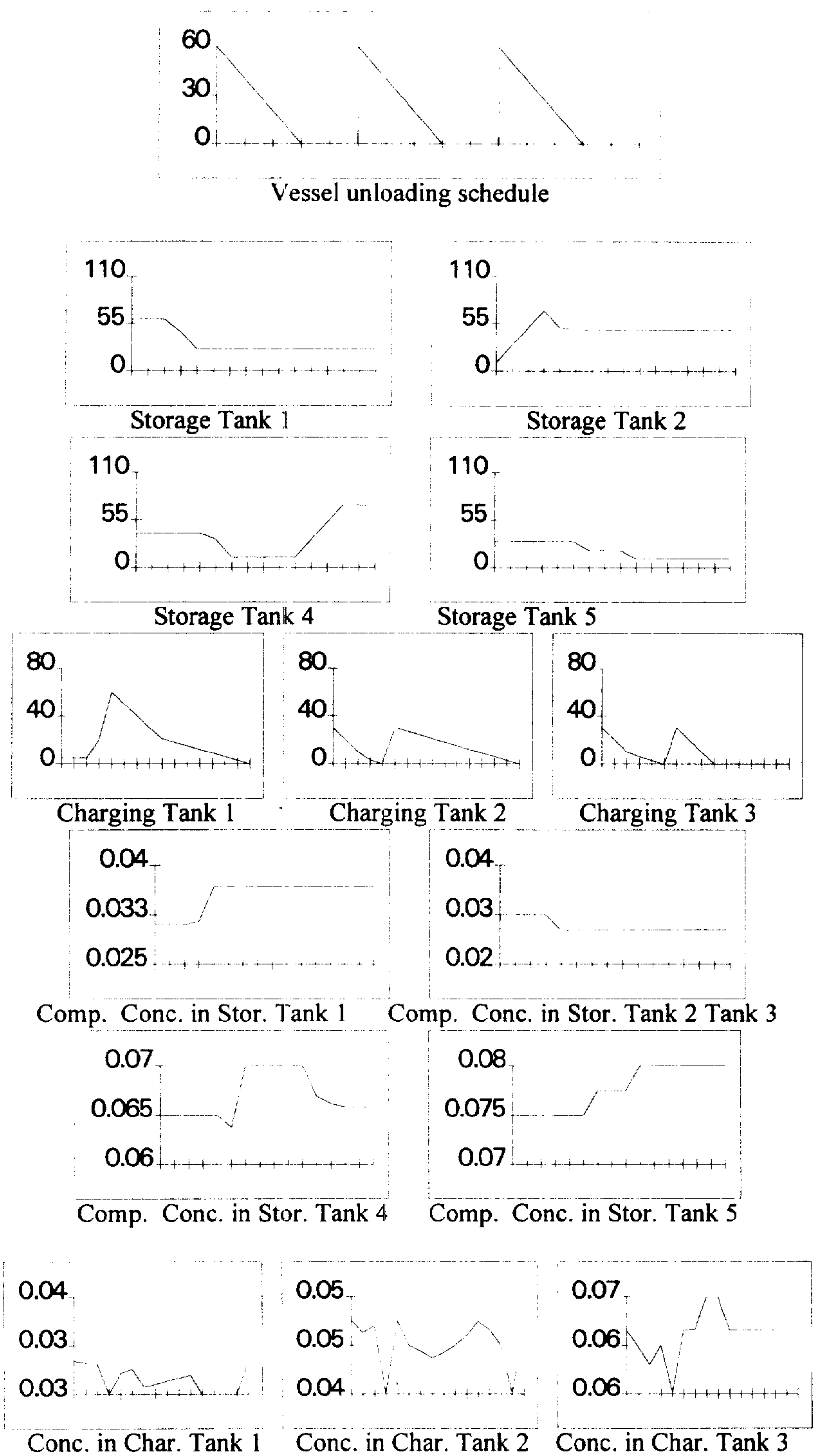
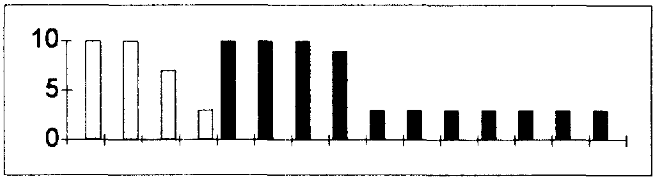
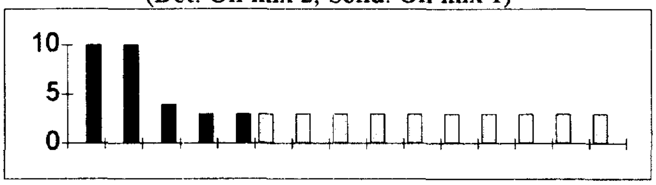


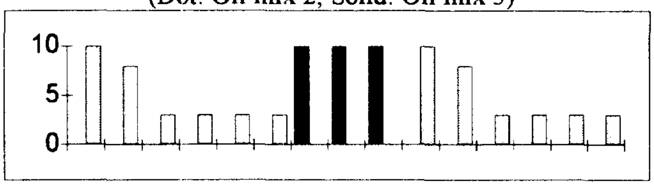
Fig. 1. Optimal inventory schedule for Example.



CDU 1 Charging Schedule
(Dot: Oil mix 2, Solid: Oil mix 1)



CDU 2 Charging Schedule
(Dot: Oil mix 2, Solid: Oil mix 3)



CDU 3 Charging Schedule
(Solid: Oil mix 3, Dot: Oil mix 4)

Fig. 2. Optimal charging schedule for Example.

6.Conclusions

The refinery short term scheduling problem of crude oil unloading with inventory management has been discussed in this paper. This problem can be modeled as a large scale MILP model in which time is uniformly discretized and mass balance equations are applied at each time interval. The bilinear mixing equations were avoided by introducing individual component flows. The LP-based branch and bound method was applied to solve the model, and several techniques have been implemented for the large size problem. Finally, this MILP model has been applied to four examples to show the economic potential and trade-offs involved in the optimization of this problem.

Literature Cited

Pinto, J. M.; Grossmann, I. E. Optimal cyclic scheduling of multistage continuous multiproduct plants. *Computers chem. Engng.* **1994**, 18, 797-816.

Reklaitis, G. V. Overview of scheduling and planning of batch process operations. Presented at NATO advanced Study Institute-batch process system engineering, Antalya, Turkey **1992**.

Rippin, D. W. T. Current status and challenges of batch processing systems engineering. Presented at NATO advanced Study Institute-batch process system engineering, Antalya, Turkey **1992**.

Acknowledgement

한국학술진흥재단과 포항공대 지능자동화 연구센타를 통한 한국과학재단의 부분적 재정지원에 감사드립니다.