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Reception, mixture, and transfer in a crude oil terminal☆

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ABSTRACT

The aim of this work is the modeling and validation of a process of reception, mixture and delivery of crude oil in a terminal. Each tank at the terminal receives different oil qualities from different cargos. Constraints are imposed to ensure material balance and operating rules. Inventory levels in the tanks are discretized. Crude oil should be transferred to the refinery according to a schedule of volumes and qualities. Linear constraints with an adjustment term for composition discrepancies are formulated to force the concentration in a tank to be equal to the concentration of the outlet volume. The problem consists in finding an optimized schedule that meets the constraints. A MILP model is proposed and solved for specific cases. In order to achieve good results in an affordable time, the rolling horizon strategy (RHS) is applied to determine the optimal schedule of crude oil operations over a time horizon.

1. Introduction and motivation

Uruguayan national oil refinery has a crude oil terminal located in José Ignacio, 34° 51′33.5″ S, 54° 43′43.0″ W, 180 km to the east of Montevideo. Crude reception is done through a single buoy mooring, 3.6 km offshore and connected to the tank farm by a pipeline. The tank farm is composed of eight main tanks and one auxiliary tank. During or after crude discharge, an interphase made of water and oil can be sent to a treatment tank. Crude oil can be pumped between tanks and to the main pipeline. The main pipeline connects the terminal with the refinery. Fig. 1 shows the location of the terminal. Fig. 2 depicts a diagram of the terminal. The sketch includes nine tanks, the pipeline for cargo reception from the buoy and delivery to the refinery. A manifold allows the connection between these main input and output points and the tank farm.

The oil refinery receives crude oil feeds through a pipeline, which is linked to the oil terminal and its tanks. Tanker ships unload different oil types through the buoy mooring. Although tanks can be filled with different qualities, the mixing of qualities is not recommended in order to offer extra flexibility. Anyway, some mixtures are allowed between similar qualities, typically in terms of specific gravity or sulfur concentration. Planning requirements determine which mixtures are required to be pumped at specific times due to product demand, quality or operational constraints. Cargo qualities are the result of LP (Linear Programming) optimization. In addition, tanks may undergo maintenance services, not being able to operate during a specific time period. Based on these requirements, it is necessary to determine if the required crude oil schedule can be satisfied or not according to capacity, maintenance, quality and other constraints and, as a result, which schedule arises from the whole set of constraints. Sometimes the required crude oil schedule cannot be modified, i.e. when processing specific mixtures such as asphaltic crude. For these cases, a new maintenance period would be suggested. In other cases the required crude oil schedule is not compatible with tank capacity and quality. Cargos arrive in predefined time windows, usually with an extension of 5 days.

Crude oil scheduling deals with the definition of a detailed schedule for the unloading of crude oil cargos into storage tanks and controlling crude blends and crude flow toward processing units.

The scheduling literature on the subject of crude oil reception, blending and transfer is broad. The work by Oddsdottir et al. (2013) refers to scheduling related to the procurement planning problem for oil refining. The objective is to maximize the profit margin associated with purchasing and refining of crude oil. Lee et al. (1996), Yadav and Shaik (2012) and Castro and Grossmann (2014) consider the scheduling problem that deals with the optimal operation of crude oil unloading from vessels, its transfer to storage tanks and determination of a charging schedule for each crude oil mixture to the distillation units, minimizing crude unloading and inventory costs. Hamisu et al. (2013) introduce the concept of shutdown units penalty and tank to tank transfer. These references consider in

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0098-1354/

Fig. 1. José Ignacio crude oil terminal.

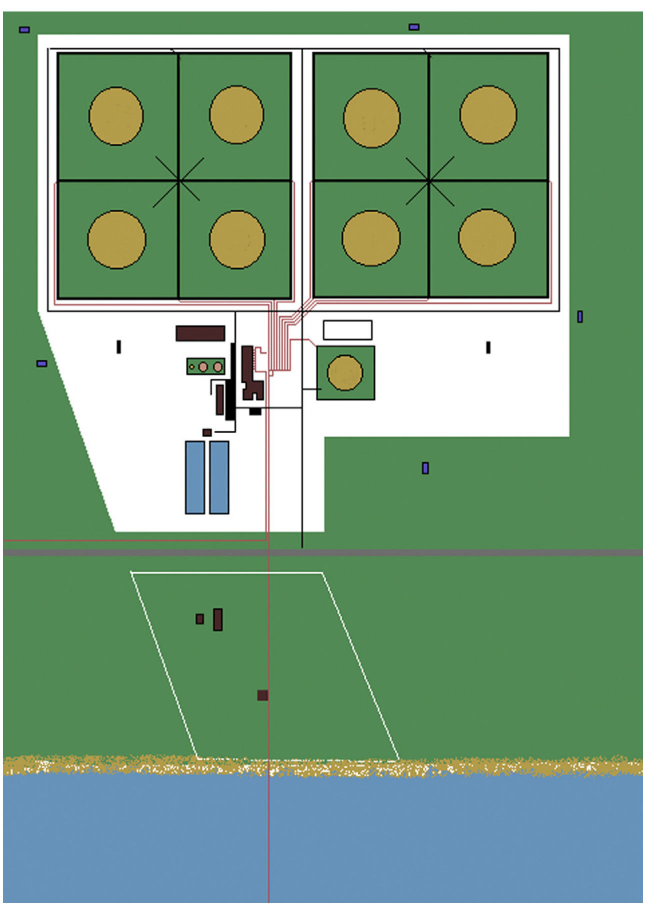

Fig. 2. Crude oil terminal diagram. It consists of nine tanks, a pipeline for cargo reception from the buoy, a manifold, connections between tanks and the main pipeline for delivery to the refinery.

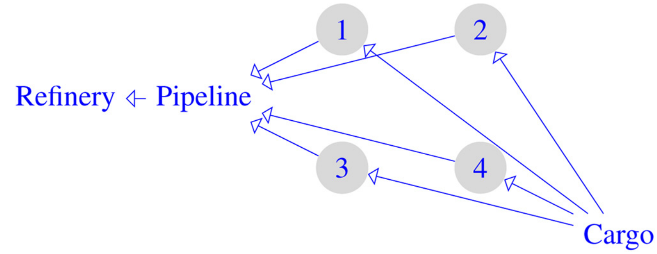

Fig. 3. Graph of the class of problems considered with four tanks.

detail the representation of the unloading process. Moro and Pinto (2004) favor the maximization of the distillation unit feed flow rate while minimizing the cost of tank operation. Crude oil unloading schedule is predefined but operations concerning tanker unloading, storage in the terminal tanks, and transfer through the pipeline are not modeled. Mouret et al. (2009), Li et al. (2011) and Castro and Grossmann (2014) maximize the margins of the distilled crude blends.

The present work discusses the reception, mixture and delivery of crude oil from the terminal to the refinery. It does not consider crude oil processing. Unloading is supposed to be effective in a specific period and allocation of crude, pure or mixed in each tank needs to be determined.

This problem differs from those considered in the literature just mentioned. It does not consider the refinery operations, being focused on the reception of crude oil and the delivery to the pipeline. This work is concerned with the operations at the terminal, which include the allocation of crude oil to the tanks, the mixture of crude oil qualities and the setting of minimum or maximum tank levels due to maintenance requirements. In addition, each tank can be enabled or not for transferring to the refinery.

The problem can be summarized as follows: the terminal comprises several tanks. Each tank can receive different crude oil qualities from different cargos that arrive in predefined periods. In each period, batches of crude oil are pumped through the main pipeline, also referred to as the pipeline, in order to be processed at the refinery. Typically, a component of a blend does not affect blend quality if its concentration is below 10%. There is a previously defined schedule of crude oil qualities and volumes that should be delivered to the refinery. The objective consists in finding the best operations to meet the predefined schedule, accounting for volume and quality constraints. Costs are associated to discrepancies between required and optimized values of volumes and qualities.

It also considers the costs associated to unfilled tanks during cargo unloading, requirements of empty or full tanks and mixture of qualities. Tank filling is preferred during cargo unloading in order to maximize tank usage while minimizing segregation.

As part of the scope of the problem, several questions can be answered that give support to decisions of the operations engineers:

- Is it possible to keep a specific tank out of service during a specific period, fulfilling at the same time the crude oil plan required by the refinery?
- Does the crude oil plan match the tank farm capacity and the quality segregation required to receive the next cargo?
- If not, what is the schedule of daily deliveries which is closest to the original plan required by the refinery?

Fig. 3 presents a graph of a terminal with four tanks and the possible daily operations of crude oil reception from a cargo and the transfer from the tanks to the main pipeline.

Operations planners usually rely on simulation based tools, with a model built in a spreadsheet, in order to plan the daily deliveries