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Optimization of refinery hydrogen network based on chance constrained programming

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ABSTRACT

Deterministic optimization approaches have been developed and used in the optimization of hydrogen network in refinery. However, uncertainties may have a large impact on the optimization of hydrogen network. Thus the consideration of uncertainties in optimization approaches is necessary for the optimization of hydrogen network. A novel chance constrained programming (CCP) approach for the optimization of hydrogen network in refinery under uncertainties is proposed. The stochastic properties of the uncertainties are explicitly considered in the problem formulation in which some input and state constraints are to be complied with predefined probability levels. The problem is then transformed to an equivalent deterministic mixed-integer nonlinear programming (MINLP) problem so that it can be solved by a MINLP solver. The solution of the optimization problem provides comprehensive information on the economic benefit under different confidence levels by satisfying process constraints. Based on this approach, an optimal and reliable decision can be made, and a suitable compensation between the profit and the probability of constraints violation can be achieved. The approach proposed in this paper makes better use of resources and can provide significant environmental and economic benefits. Finally, a case study from a refinery in China is presented to illustrate the applicability and efficiency of the developed approach.

Keywords: Refinery; Hydrogen network; Uncertainty; Chance constraints; Optimization

1. Introduction

During the past decades, crude oil has been getting heavier and contains more sulfur and nitrogen. The shrinking market for heavy fuel oil and stricter legislation on sulfur content in fuels throughout the world are forcing refiners to increase their use of hydrocracking and hydrotreating to upgrade heavy oils to more valuable products and remove sulfur and nitrogen compounds from petroleum products (Towler et al., 1996; Alves and Towler, 2002). As the demand for hydrogen grows, hydrogen is now getting scarce and becoming a critical issue to the refiners worldwide. Hydrogen cost has become the second most important cost after crude oil cost. Thus, it is becoming increasingly more important to reduce hydrogen consumption and improve the utilization ratio of hydrogen (Hallale and Liu, 2001; Liu and Zhang, 2004).

Refineries generally take various measures to improve this situation, such as increasing yield of hydrogen plant, expansion of hydrogen plant, building new hydrogen plants, constructing new hydrogen purifiers, purchasing hydrogen and retrofitting the hydrogen network. The comprehensive benefits obtained by these measures are shown in Table 1 (Qu, 2007). It is not difficult to find that retrofitting the hydrogen network is the best way to gain a better economic and environmental benefit by comparing with these costs listed in Table 1. Therefore, in order to lighten the load of hydrogen production and reduce the hydrogen usage cost in refinery, refiners should retrofit the hydrogen network as far as possible.

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