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Optimization of hydrogen networks with constraints on hydrogen concentration and pure hydrogen load considered

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ABSTRACT

The mathematical model of hydrogen network is developed to minimize the total exergy consumption of the hydrogen utility and compressor work. The constraint on the hydrogen to oil ratio of hydrogen consuming reactor is represented by that on pure hydrogen load of each sink. Instead of reducing the hydrogen concentration and pure hydrogen load to the minimum directly, all the possible combinations of them are considered. Furthermore, the optimal flow rate of each sink is taken as a variable in the model and the matching flow rate constraint is introduced to remove the source-sink match with small flow rate. This method can be applied to target the minimum utility consumption of systems with any number of impurities. In addition, both the hydrogen to oil ratio and hydrogen concentration can be guaranteed not be less than their lower limitations. The proposed method is applied to the hydrogen network of a real installation, and the results show the hydrogen utility saving potential accounts for 16.52% of the current hydrogen utility consumption.

Keywords: Hydrogen to oil ratio; Pure hydrogen load; Hydrogen concentration; Optimization; Compressor work

1. Introduction

Nowadays, there is a worldwide trend of refining heavier crude oils. To convert heavy-end compounds into lighter fractions, refiners must increase the capacity of hydrotreating, and hence result in a significant increase of hydrogen consumption. Meantime, increasingly tight limitations placed by the legislation on the sulfur content of fuels and regulations on gasoline also cause an increase of hydrogen consumption. Because of this, the hydrogen supply in many refineries is becoming a critical problem.

All the hydrogen consuming processes, such as hydrotreating, hydrocracking and isomerization, and the hydrogen producing and by-producing processes, such as catalytic reforming process, compose a hydrogen network with hydrogen containing streams connect them. In a hydrogen network, the hydrogen containing streams can be classified into three types, hydrogen sink stream, hydrogen source stream and hydrogen utility. Hydrogen sinks are the inlet streams of the hydrogen consuming equipments and have a demand for hydrogen. Hydrogen sources are those can supply hydrogen to the hydrogen network. The sources supplied by external suppliers or particularly produced are hydrogen utility (Alves and Towler, 2002).

Generally, hydrogen sink is the inlet stream of hydrogen consuming reactor. To achieve desired oil conversion rate in the reactor, it is necessary to satisfy the constraint on the hydrogen to oil ratio, which is a design parameter that influences product quality. When the reactor is operated at high hydrogen to oil ratio, the product's quality can be improved, but the size of the equipment after the reaction section increases considerably (Munoz et al., 2005; Ancheyta-Juarez et al., 2001). For a given reactor, the lower limit on hydrogen to oil ratio and the inlet hydrogen concentration should be satisfied. At a given throughput, the limit on hydrogen to oil ratio can be represented by that on pure hydrogen load. In a real production, the pure hydrogen load and hydrogen concentration supplied to each hydrogen sink are usually larger than their lower limitations. Therefore, there is the hydrogen-saving potential.

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