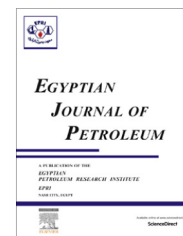




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FULL LENGTH ARTICLE

Automated targeting technique for indirect inter-plant hydrogen integration

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Abstract The increase of hydrogen demand has been one of the focal point recently. Indirect inter-plant hydrogen integration (IPHI) is a new issue for reducing hydrogen consumption and hydrogen discharge, in which hydrogen networks for different plants are integrated indirectly through centralized partitioning regeneration unit where hydrogen is regenerated for further reuse/recycle. This work is an extension of the automated targeting technique that was developed for single hydrogen network and the automated targeting that was developed for inter-plant water integration. The concentration cascade model has been developed to optimize hydrogen networks through partitioning regeneration unit such as pressure swing adsorption (PSA) or membrane separation. Two case studies from literature are studied to illustrate the applicability of the proposed model.

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1. Introduction

Hydrogen management is getting essential in refineries and petrochemical complexes, since refineries face an increasing challenge of meeting the growing demand for clean fuels. Along with the legislation for environment protection higher gasoline and diesel quality specifications have been implemented to reduce pollutants from automotive exhausts. Oil refineries consume hydrogen in large amounts during the past decade to remove sulfur and nitrogen compounds and produce lighter fuel with high quality, since crude oil gets heavier and contains more sulfur and nitrogen. Thus the hydrogen supply in many refineries is becoming a critical problem [1,2].

Hydrogen resources are units that either consume or produce hydrogen. Management of these two resources leads to lower consumption of hydrogen and improves refinery profitability [3,4]. The production sources of hydrogen in refining are catalytic reformers, hydrogen plants, ethylene plants and hydrogen import. Where the most common hydrogen consumption units are hydrocracker and hydrotreaters. The hydrogen demands of hydrogen consumers vary with the changes of operational load mostly and raw material [5–7]. As the demand for hydrogen grows, the management and optimization of hydrogen system in refinery is becoming increasingly important [8]. Development process integration has been proven as a promising approach in maximizing potential resource conservation [9]. The hydrogen network integration optimizes the hydrogen network with all the hydrogen demands and hydrogen supplies. Consequently it can significantly increase the reuse of the process hydrogen and minimize the hydrogen utility consumption. The management of hydrogen network

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Nomenclature

Abbreviations

AF	annualization factor	MINLP	mixed-integer nonlinear programming
A_{MEM}	membrane area, m ²	MP	mega Pascal
AWH	annual working hours	NLP	nonlinear programming
A	fractional interest rate per year	P	maximum pressure of the pipeline in MPa
CCR	continuous catalytic reformer unit	P_n^{feed}	inlet feed pressure to the regenerator
CNHT	cracked naphtha hydrotreater unit	$P_n^{product}$	top product pressure of the regenerator
D	length of the cross-plant pipeline, m	PSA	pressure swing adsorption unit
DHT	diesel hydrotreater unit	SK	sink
$F_{cp,k}$	feed flowrate to the regenerator from network, k	SR	source
$F_{FH,k}^{FIPHI}$	fresh inter-plant hydrogen integration for network, k	TAC	total annual cost measured by US\$
$F_{DH,k}^{FIPHI}$	inter-plant hydrogen discharge flowrate from network, k	UB _{cp}	upper bound of the cross-plant pipeline flowrate
$F_{i,k}^{EXP}$	flowrate exported from source i in network k to the regenerator	US\$	American dollar
$F_{SK,j,k}$	flowrate of sink j for network k	$W_{cost,k}$	unit cost of fresh hydrogen for network, k
$F_{SR,i,k}$	flowrate of source i for network k	$X_{INDIR,k}$	binary variable indicates the existence of a cross-plant pipeline from all sources of network k to the regenerator
$g_{cp,k}$	top product of the regenerator to network k	Y_F	inlet impurity concentration to the regenerator
GPU	cm ³ (STD) * 10 ⁻⁶ /cm ² s cmHg	$y_{H_{2in} feed}$	hydrogen concentration in the feed of the regenerator
HCU	hydrocracker unit	$y_{H_{2in} product}$	hydrogen concentration in the top product of the regenerator
I	is a source in hydrogen networks	Y_i	impurity concentration of source I
IPHI	inter-plant hydrogen integration	Y_p	impurity concentration of the top product of the regenerator
I_{pipe}	capital cost of pipeline, US\$	Y_r	impurity concentration of the bottom product of the regenerator
I_{psa}	capital cost of pressure swing adsorption, US\$	Y_r^{min}	the minimum concentration of all sources in the participating networks when they are regenerated individually
$I_{regenerator}$	capital cost of regenerator, US\$	Y_r^{max}	the maximum concentration of all sources in the participating networks when they are regenerated individually
ISO	isomerization unit	$Z_{INDIR,k}$	binary variable indicate the existence of a cross-plant pipeline from the bottom product of the regenerator to all sinks of network k
J	is a sink in hydrogen network	$\delta_{m,k}$	net material flowrate from level m for network k
JHT	jet fuel hydrotreater unit	$\varepsilon_{m,k}$	residue of impurity load from concentration level m for network k
L	number of years	α_L	hydrogen recovery
LB _{cp}	lower bound of the cross-plant pipeline flowrate		
$L_{cp,k}$	bottom product of the regenerator for network k		
L_{gH_2}	permeability of hydrogen component through membrane		
LP	linear programming		
M	index for concentration levels		
MMSCFd	million standard cubic feet per day		
$N_{INDIR,k}$	binary variable indicates the existence of a cross-plant pipeline from the top product of the regenerator to all sinks of network, k .		

involves two alternatives: reuse and regeneration [10]. For the two alternatives, many researchers focused on the optimization of hydrogen network by graphical or mathematical methods. For graphical optimization, Towler et al. [1] presented a value composite curve method to analyze the hydrogen network. Alves and Towler [2] presented the purity profiles and hydrogen surplus profiles to calculate the minimum fresh hydrogen consumption. Zhao et al. [11] proposed a simple graphical method for determining fresh hydrogen demand at any concentration. El Halwagi et al. [12] presented a rigorous graphical targeting technique to obtain the minimum fresh hydrogen utility. Agrawal and Shenoy [13] proposed a unified conceptual approach for water and hydrogen network. Zhao et al. [14] improved an iterative targeting method considering multiple impurities for hydrogen network.

For mathematical optimization, Liu and Zhang [15] introduced a detailed model of regeneration units by selecting an optimum regeneration unit. Foo et al. [16] presented an algebraic algorithmic method based on concentration intervals. Ng et al. [17,18] introduced the automated targeting technique based on pinch calculation for resource conservation problems for hydrogen reuse and hydrogen regeneration system. Lou et al. [19], presented an improved graphical targeting approach (pinch sliding approach) for water and hydrogen networks with different types of regenerator. The minimum flowrates of utility and regenerator feed are targeted by integrating the triangle rule and the optimal condition theorem. Zhou et al. [20], introduced a systematic modeling methodology for both the economic efficiency and environmental performance of hydrogen network. The economic efficiency is based on the

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