A SYSTEMATIC METHODOLOGY FOR RETROFIT ANALYSIS OF REFINERIES' PREHEAT TRAINS ACCOUNTING FOR VARIABLE HEAT CAPACITIES AND HEAT EXCHANGERS' FOULING

By

Haya Khaled Frez Hussein

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Chemical Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
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Title of Thesis:
A systematic methodology for retrofit analysis of refineries' preheat trains accounting for variable heat capacities and heat exchangers' fouling

Key Words:
Heat Integration; Energy Saving; Fouling; Heat capacity; HEN Revamping

Summary:
Global demand for energy is growing, driven by increasing population and economic growth. Over the past three decades, world energy consumption has more than doubled. Oil refining is an energy consuming process, accounting for about half of all the energy consumed by the oil and gas industry. In order to decrease the energy consumption in the furnace and consequently decrease the overall energy consumption in the refinery, it is required to maximize the temperature of the crude oil before entering the furnace by increasing the efficiency of the preheat train.

Revamping can enhance the energy efficiency to improve productivity, lower the operating costs, and reduce the environmental impacts.

This study proposes a systematic methodology for analyzing the revamping of refinery's preheat train accounting for variable heat capacities and heat exchangers fouling. It introduces two modifications on the case study modification that was published in the article "A new graphical method for Pinch Analysis applications: Heat exchanger network retrofit and energy integration". The first modification, that the assumption of constant heat capacity is to be criticized and analyzed. The second modification is taking fouling into considerations. This will lead to a decrease in the cost of the furnace fuel by approximately 508,718.6 dollars/year.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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Dedication

This thesis is dedicated to my mother.

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I would like to express my deepest appreciation to many people, who have made this work possible. I wouldn't have finished this thesis without their help.

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Nomenclature

HEN	Heat Exchanger Network
Cp	Specific Heat Capacity
ΔTmin	Minimum Temperature Approach
T	Temperature
H	Flow Enthalpy
ΔH	Change in Flow Enthalpy
CC	Composite Curve
GCC	Grand Composite Curve
Q	Heat Duty
Qh	Minimum Hot Utility
Qc	Minimum Cold Utility
Ts	Supply temperature
Tt	Target temperature
PFD	Process Flow Diagram
HPS	High Pressure Steam
MPS	Medium Pressure Steam
LPS	Low Pressure Steam
BFW	Boiler Feed Water
ADU	Atmospheric Distillation Unit
VDU	Vacuum Distillation Unit
LP	Linear Programming
LMTD	Logarithmic Mean Temperature Difference
U_D	Design Overall Heat Transfer Coefficient
U_C	Clean Overall Heat Transfer Coefficient
f	Fouling factor
Tho	Outlet Temperature of Hot Stream
Tco	Outlet Temperature of Cold Stream
A	Area of Heat Flow

Abstract

Global demand for energy is growing, driven by increasing population and economic growth. Over the past three decades, world energy consumption has more than doubled. Oil refining is an energy consuming process, accounting for about half of all the energy consumed by the oil and gas industry. Raw crude oil is heated initially in a preheat train and then enters the furnace, where most of the energy is consumed. In order to decrease the energy consumption in the furnace and consequently decrease the overall energy consumption in the refinery, it is required to maximize the temperature of the crude oil before entering the furnace by increasing the efficiency of the preheat train.

Retrofitting or revamping of existing chemical engineering plant is essential for improving the performance of existing heat exchanger network. Revamping can enhance the energy efficiency to improve productivity, lower the operating costs, and reduce the environmental impacts.

Heat capacity is a function of temperature, which means that it isn't constant, and changes with the change of temperature. Fouling also is important factor in revamping, as adding area without considering the fouling might not give the required duty. Most of retrofit studies in literature ignored the impact of heat capacities and fouling. Consequently, their modifications might not lead to a practical solution as the solution is not accurate as a result of ignoring the heat capacity and fouling effect.

This study proposes a systematic methodology for analyzing the revamping of refinery's preheat train accounting for variable heat capacities and heat exchangers fouling. It introduces two modifications on the case study modification that was published in the article **"A new graphical method for Pinch Analysis applications: Heat exchanger network retrofit and energy integration"** [1]. The first modification, that the assumption of constant heat capacity is to be criticized and analyzed. This will result a temperature difference in the inlet temperature to the furnace from 275.7 ºC to 281.2 ºC. The second modification is taking fouling into considerations, this will affect the temperature, as it will be 281.1 ºC. However, the furnace duty will be decreased by 2 MW. This will lead to a decrease in the cost of the furnace fuel by approximately 508,718.6 dollars/year.

Chapter 1 : Introduction

Energy efficiency has become one of the major factors to consider in the chemical processes design because of the trending energy prices, the fossil fuel limited resources and environmental restrictions being applied worldwide to reduce greenhouse gas emissions which account for climate changes. Therefore, different companies are started to raise the awareness of energy conservation and improve the energy efficiency for their plants to remain sustainable and competitive in the challenging global market.

Heat integration plays an important role in enhancing energy efficiency and reducing operational costs in the process industry. Several methodologies have been developed for heat exchanger network synthesis. Heat integration considers industries and intends to re-use all heat outputs of certain processes, if they can be usable in the moment or later.

Chapter 2 presents a detailed literature review of the energy savings and its importance. On the other hand, the heat integration in preheat train networks, pinch analysis, composite and grand composite curves, retrofit of heat exchangers, heat capacities, and fouling in heat exchangers including the types of fouling and types of fouling rates.

Chapter 3 summarizes the importance of the integration of heat, scope of work, and a statement of the present work.

Chapter 4 focuses on the description of the analysis for the developed model of preheat train in refinery considering the heat capacities and the fouling.

Chapter 5 presents the results of the present work compared with the proposed retrofit in the previous work.

Chapter 6 summarizes the conclusion and the recommendations for this work.