Predictive Modeling and Optimization of Industrial Penex Isomerization unit

By

Mohanad Magdy Menoufi Mohamed Said

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 ENGINEEREING, CAIRO UNIVERSITY

GIZA, EGYPT

2015

"Predictive Modeling and Optimization of Industrial Penex Isomerization unit"

By

Eng. Mohanad Magdy Menoufi Mohamed Said

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

Under the supervision of

Prof. Dr. Tarek Mohamed Mostafa

Chemical Engineering Department

Faculty of Engineering

Cairo University

Dr. Tamer Samir Mohamed

Chemical Engineering Department

Faculty of Engineering

Cairo University

FACULTY OF ENGINEEREING, CAIRO UNIVERSITY

GIZA, EGYPT

2015

"Predictive Modeling and Optimization of Industrial Penex Isomerization unit"

By

Eng.* *Mohanad Magdy Menoufi Mohamed Said

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

Approved by the Examining Committee

Prof. Dr. Tarek Mohamed Mostafa, Thesis Main Advisor

Chemical Engineering Dept., Cairo University, Faculty of Engineering.

Prof. Dr. Mai Mohamed Kamal El-Din, Internal Examiner

Chemical Engineering Dept., Cairo University, Faculty of Engineering.

Eng. Mohamed Ibrahim El-Sayed, External Examiner

Manager of Process Engineering and Studies Department, Process Technology Division, (ENPPI)

FACULTY OF ENGINEEREING, CAIRO UNIVERSITY
GIZA, EGYPT
2015

Engineer: **Mohanad Magdy Menoufi Mohamed Said.**

Date of Birth: **19 / 11 / 1988.**

Nationality: **Egyptian.**

E-mail: **mohanad.magdy12@yahoo.com.**

Phone: **+201001893289.**

Address: **76 Mostafa Hafez, Gesr El Suez, Cairo.**

Registration date: **1 / 3 / 2011.**

Awarding date: **/ / 2015**

Degree: **Master of Science**

Department: **Chemical Engineering Department**

Supervisors:

Prof. Dr. Tarek Mohamed Mostafa.

Dr.Tamer Samir Mohamed

Examiners:

Prof. Dr. Mai Mohamed Kamal El Din (Internal Examiner)

Prof. Dr. Tarek Mohamed Mustafa. (Thesis Main Advisor)

Eng. Mohamed Ibrahim El Sayed. (External Examiner)

Department Manager of Process Engineering and Studies Department (ENPPI) - Cairo -Egypt

Title of Thesis:

Predictive Modeling and Optimization of Industrial Penex Isomerization unit

Keywords:

Isomerization, Penex Process, Kinetic Modeling, Predictive Modeling, Optimization

Summary:

This work presents a model for UOP Hydrogen Once Through (HOT) Penex Process using Aspen HYSYS V7.3. The model relies on routinely taken samples of process streams and normal operating conditions of Penex Unit located in Cairo Oil Refinery. Acquired data sets from the industrial unit have been tested and screened to ensure data validity for building the model and avoiding erroneous results. A reaction network with 20 reactions and 19 components has been used for the reactors model. In addition, rigorous tray by tray simulation of isomerate stabilizer has been utilized to match the performance of plant stabilizer close enough. The model has then been used for studying the effects of process variables on plant performance. Finally, the model has been used in optimizing the operating conditions of the process. Results from optimization scheme showed that considerable savings in isomerate yield and fuel consumption could be accomplished.

Acknowledgement

First of all, I would like to thank Allah for helping me accomplish this work.

I would also like to express my gratitude for my supervisors. My sincere thanks to Dr.Tarek Mostafa for his guidance and valuable advices .Special thanks to Dr.Tamer Samir for his efforts and constant support during the course of this work. They will always be remembered.

My deepest appreciation for my family, especially my mother for their encouragement.

Also, I would like to thank all engineers in Isomerization Sector of Cairo Oil Refining Co. for their cooperation.

Finally, I would like to thank and apologize to anyone who assisted in completing this work and I forgot to mention them.

Dedication

For those who are courageous enough to take risks and make sacrifices seeking the best for their families.

Table of Contents

List of Tables

List of Figures

Nomenclature

A = Exchanger Heat Transfer Area
ASTM=American Society For Testing And Materials
A6 = Benzene
C1 = Methane
C2 = Ethane
C3 = Propane
i-C4 = Isobutane
n-C4 = Normal Butane
i-C5 = Isopentane
n-C5 = Normal Pentane
n-C6 = Normal Hexane
n-C7 = Normal Heptane
CH = Cyclo Hexane
2,2-DMB = 2,2-dimethylbutane
2,3-DMB = 2,3-dimethylbutane
E = Overall Column Efficiency
ETBE = Ethyl Tertiary Butyl Ether
FCC = Fluid Catalytic Cracking
F_T = LMTD Correction Factor
H $factor_i$ = Weight fraction of Hydrogen in component i
I = Parameter for Calculating Refractive Index at 20°C
Isomerate = Liquid Product of Isomerization Process
LHSV = Liquid Hourly Space Velocity
LHV = Low Heating Value
m = Parameter Calculated From Refractive Index and Molecular Weight
MBP7 = Multi Branched Heptanes
MCH = Methyl Cyclohexane
MCP = Methyl Cyclopentane
MON = Motor Octane No.
2MP = 2-Methyl Pentane
3MP = 3-Methyl Pentane
M_w = Molecular Weight
MTBE = Methyl Tertiary Butyl Ether
n = Refractive Index at 20°C
5N5 = Cyclopentane
5N7 = Five Ring, Seven Carbon Naphthene
6N7 = Six Ring, Seven Carbon Naphthene
NP7 = Normal Heptane
PIN = Paraffin Isomerization Number = i-C5/C5 + 2,2-DMB/C6 + 2,3-DMB/C6
PON = Posted Octane No.
PSA = Pressure Swing Adsorption
Q = Duty
Reformate = Catalytic Naphtha Reforming Liquid Product
RON = Research Octane No.
RVP = Reid Vapor Pressure
SBP7 = single branched heptanes

SG = Specific Gravity
TAME = Tertiary Amyl Methyl Ether
ΔT_{model} = Temperature Rise in Reactor Model
ΔT_{plant} = Temperature Rise in Plant Reactor
ΔT_{LM} = Log Mean Temperature Difference (LMTD)
U = Overall Heat Transfer Coefficient
VDU = Vacuum Distillation Unit
w_i = Weighing Factor for Component i
X_i = Mole, Volume or Mass Fraction of Component i
$X_{model-i}$ = Mass Fraction of Component i in Model Outlet Stream
$X_{plant-i}$ = Mass Fraction of Component i in Plant Reactor Outlet Stream
x_n = Naphthenes Volume %
x_p = Paraffins Volume %
y_n = Actual Concentration of Vapor Leaving Plate n
y_n^* = Concentration of Vapor in Equilibrium with Liquid Leaving Plate n
y_{n+1} = Actual Concentration of Vapor Entering Plate n
ψ = property of a petroleum fraction
ψ_i = property of a pure component i
θ = known property of C7+ fraction
η_M = Murphree Efficiency
μ = Viscosity
α =Relative Volatility