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Research Article

Aspen Hysys based Simulation and Analysis of Crude Distillation Unit

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Abstract

Today, distillation of crude oil is an important process in almost all the refineries. Crude distillation is the process of separating the hydrocarbons in crude oil based on their boiling point. The crude oil fractioning is very intensive process. The complexity due to large number of products, side stripper, and pump around made the task of improving energy efficiency into tedious. Aspen One Engineering is a market leading suite of products focused on process engineering and optimization. Process modelling analysis and design tools are integrated and accessible through Aspen HYSYS and Aspen Plus. Steady state simulation of in a real crude plant was performed using Aspen HYSYS.

Keywords: *Crude Oil, Distillation Column, Optimization, Aspen HYSYS*

1. Introduction

The optimization of crude oil separation process is one of the important aspects in the refineries now days due to the high-energy cost and the requirement for quality oil products. Using computer simulations can do the process optimization. The purpose of this paper is to present and analyze the simulation of crude distillation unit in oil refinery using Aspen Hysys. Hysys is used as the simulation tool.

1.1 Crude Distillation Unit

Crude oil is a mixture of light molecular weight hydrocarbons to high molecular weight components. In petroleum refining usually boiling point ranges are used instead of mole fractions. The crude oil refineries are highly non-linear, complex and integrated system used for the refining and production of crude oil into end products such as gasoline, naptha, kerosene, diesel, and vacuum gas oil.

For steady state simulation of petroleum processes, Aspen Technologies provides the tool Aspen Hysys Aspen Hysys is a comprehensive process modeling tool used by the world's leading oil and gas producers, refineries, and engineering companies for process simulation and process optimization in design and operations.

Modeling of a process enables the manufacturers to understand the process behavior and to determine the optimum operating conditions of the process for high output at low cost. Corresponding author

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1.2 Conventional Crude Distillation Unit

In the conventional approach of crude distillation unit (CDU) we use the physical –mathematical model.

The system behavior is completely described by mathematical language. In mathematical modeling the following variables are taken into account decision variables, input variables, state variables, exogenous variables, random variables, and output variables. Usually in multiple stages separation processing which different phases and different components play a role we have to go for iterative solution of hundreds of equations. The design variables have to be specified so that we can find the output variables, which is exactly equal to number of independent variables. The number of equation can be found from mathematical model, which is a theoretical stage method. For each stage we have to write the mass balance of individual components or pseudo components, energy balance, and vapor-liquid equilibrium equation can be written which creates the mathematical model.

Table1 Standard specification of crude oil distilled products

Oil Product	Standard control of distillation temperature curve		
	T 10	T90	T100
Kerosene	-	-	>300⁰C
Diesel	-	290-338⁰C	-
AGO	>280⁰C	-	-

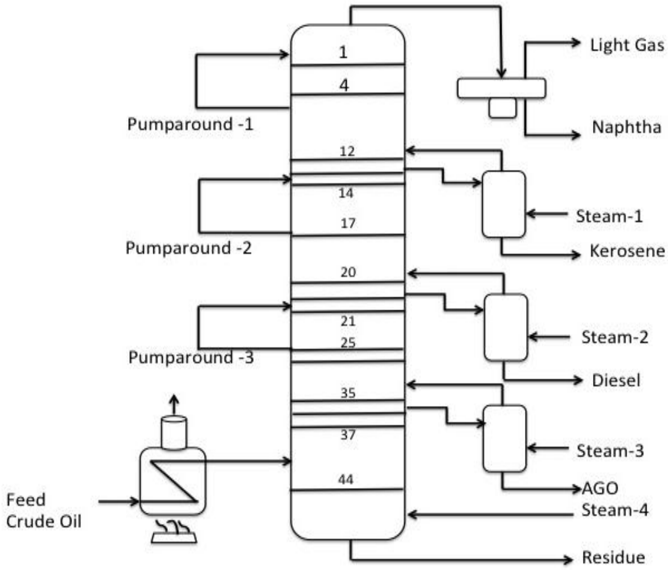

Figure1 Practical configuration of a crude distillation unit

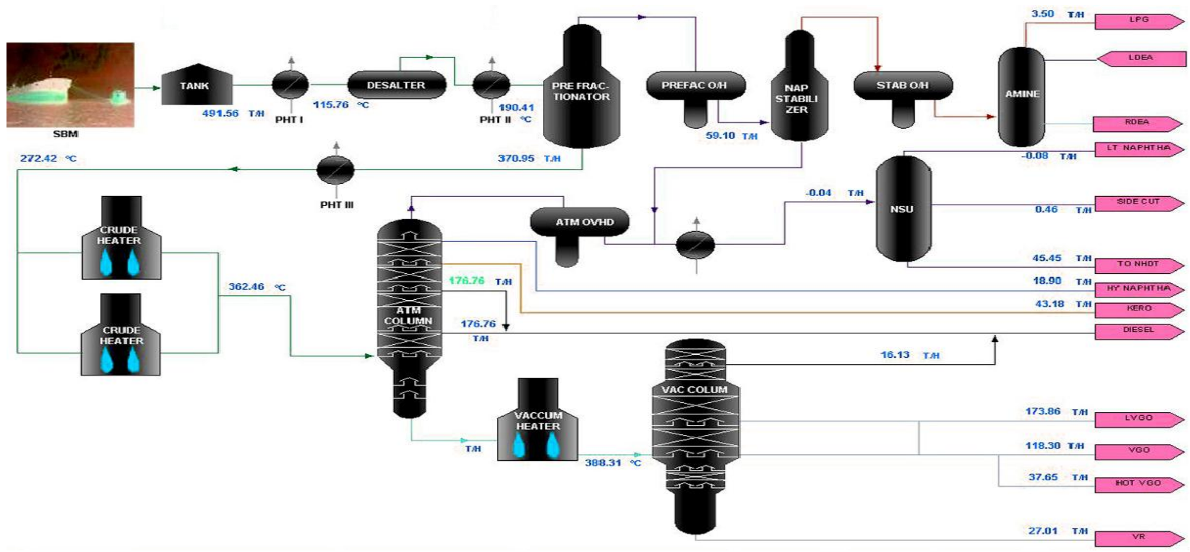

Figure2 The overview of crude oil distillation unit in typical refinery processing Agbami crude

Figure (1) shows the practical configuration of a crude distillation unit. In practical CDU operating condition the major requirement is that all distilled products have to satisfy the specification given in table (1). The temperature distribution of each distilled product cannot be known before hand even if the CDU tower temperature and pressure distributions are well controlled. This is due to the uncertain phenomenon present inside the CDU system.

1.3 Technological knowhow of CDU

Figure (2) depicts an overview of crude oil distillation unit in typical refinery processing Agbami crude. The crude from the submarine is directly fed to a storage tank. The crude is the preheated using hot overhead and product side stream using heat exchanger network and is given to the desalter where all the dissolved salts are removed.

The crude enters a drum and some light ends with water are flashed off the drum.

The high volatile product like LPG is initially obtained. The removed light ends are directly fed to the flash zone of the main column of the CDU. The crude is again heated. Distillate products from the main column are removed from selected trays. These are called Draw off trays. From the tower top of the atmospheric column, full range naphtha (both light and heavy) will leave as a vapor. Eventually, the vapor will be condensed and separated in a phase separator. The separated naphtha product will be partially sent for reflux and the balance sent as reflux stream from the overhead drum. From the atmospheric column the products like kerosene and diesel are also obtained. The bottom products of the atmospheric column is heated and is given to the vacuum column .The vacuum column as the name suggests operates at vacuum temperature, where the products like light vacuum gasoil (LVGO) and high vacuum gasoil (HVGO) are obtained.

2. Input data and characterization of crude oil

The simulation of the typical crude distillation unit using Hysys is the objective of the work. The feed of 491.5 tons/hr of the crude enters into the preflash column. The number of theoretical stages in the column is specified as 13.Thecoloumn pressure was around 2-3 atm. The mass flow of three pre flash column product is given in table (2).

Table 2 Mass flow of preflash column product

Product	Mass flow (ton/hr)
Light Products	3.5
Light Naptha	1.2
Bottom product	370.95

The bottom of the pre flash column was pre heated to 362.4 ^{0}C in a furnace before entering the atmospheric column. The mass flow of atmospheric column is given in table (3).

Table 3 Mass flow of atmospheric column

Product	Mass flow (ton/hr)
Heavy Naptha	45.45
Kerosene	43.18
Atmospheric Residue	176.76

The residue of the atmospheric column is given to the vacuum column where it undergoes distillation under vacuum temperature. The mass flow rate of vacuum column is given in table (4).

Table 4 Mass flow of vacuum column

Product	Mass flow (ton/hr)
LVGO	173.86
VGO	118.30
HVGO	37.65

3. Simulation of crude distillation unit

The first step for a successful simulation is correct choice of the thermodynamic method that will be used in the calculations of the state variables and the physical properties. The Peng-Robinson equation of state is normally accepted for the compounds in the crude distillation unit process stream. The number of theoretical stages of an existing column is estimated, as the product of real number of stages and column efficiency .The equation is applicable to all calculation of all fluid properties in natural gas processes.

The second step is the characterization of crude oil and input data. Refineries usually have multiplicity of crude oils. Refineries go for blending of crude oils due to operational and feed availability.

The input variables are usually crude oil properties and manipulated variables of CDU such as reflux ratio, product flow rates etc. Crude feeds are usually not of one origin but mix that can vary from 2 to 10 different crude types. Usually using ASPEN does the crude oil blending. Simulation package can be used to characterize petroleum fluids if data from laboratory is available, also ready to use characterized crude database are available. The partial simulation of the crude distillation unit in fig (2) is depicted in fig (3) and fig (4) respectively**.**

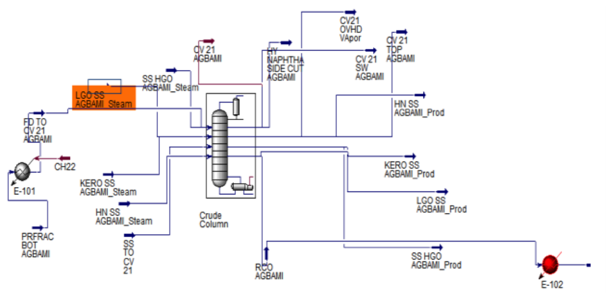

Figure 3 The simulation of typical crude distillation unit

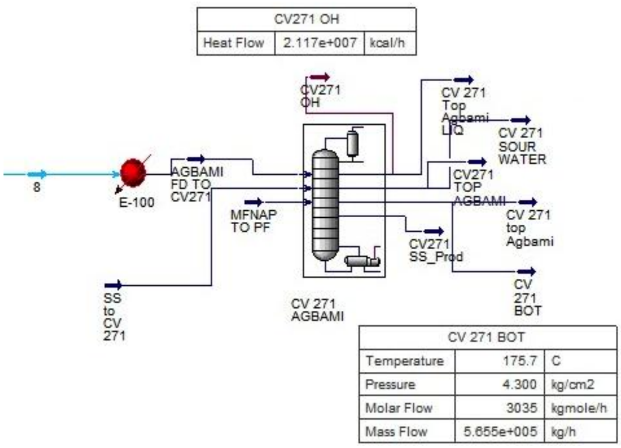

Figure 4 The simulation of typical crude distillation unit

4. Steady State Simulation

The true boiling point data (ASTM D86) for the products like light naphtha, kerosene were available. The initial condition for simulation is set as in real environment. Figure (5) depicts the simulation and experimental result of the kerosene distillate.

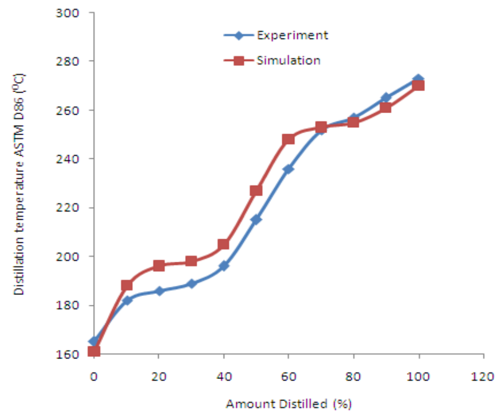

Figure5 Simulated and experimental ASTM D86 curves of Kerosene

Figure (6) depicts the Simulated and experimental ASTM D86 curves of Light gas oil (LGO).

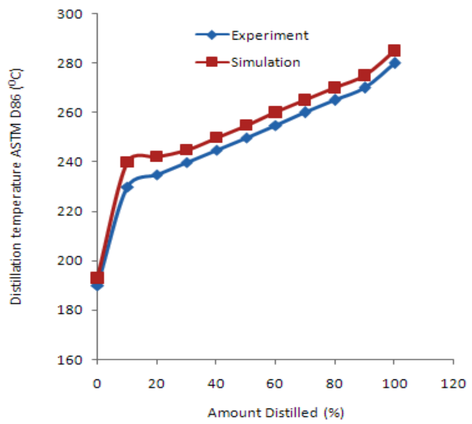

Figure6 Simulated and experimental ASTM D86 curves of Light gas oil (LGO)

Figure (7) depicts the true boiling point curve of the atmospheric crude. The maximum difference between the experimental and simulation results were around 10 ^{0}C.

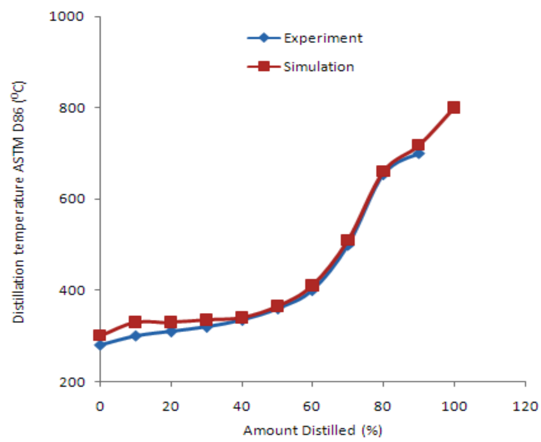

Figure7 Simulated and experimental TBP curves of atmospheric residue

4. Advantages of using Aspen Hysys over Conventional Design Procedure

1. Aspen Hysys is powerful tool for steady state modeling. Theoretically it's very difficult to find the energy balance and mass balance across the crude distillation unit.
2. The process can be easily understood while simulation using Hysys.
3. Aspen Hysys can be used for both steady state an dynamic simulation of complex crude oil distillation system.
4. Aspen Hysys the flexibility contributed through the design combined with un parallel accuracy and robustness leads to the more realistic model.
5. The single model concept of Aspen Hysys increases the Individual Engineers efficiency and efficiency of an organization
6. Aspen Hysys is having its unique feature of its strong thermodynamic foundation

Conclusion

Simulation software is one of the best tools for a crude oil refinery. This can be used during the conceptual design as well during the entire life span of the equipment's. Aspen Hysys enables the simulation of very complex crude distillation systems in an easy manner. The goal is achieved by using Aspen, which provide capability to design the entire process accurately.

For the analysis of the crude distillation unit simulated and experimental curves of kerosene, light gas oil and true boiling point curve of atmospheric residue is taken into account.

The simulation software can be used for debottlenecking, performance and process studies. The optimization can be done very easily, together with the advanced process control tools, make it profitable in the operation in real time. The goal is achieved by using Aspen, which provide capability to design the entire process accurately.

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