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Simulation of Atmospheric Distillation Unit for AL-Diwiniya Crude Oil Refinery by Using Aspen Hysys

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Abstract

This study aims to examine the steady-state modeling of the current performance of the atmospheric distillation column at the Al-Diwiniya refinery, which can process up to 10,000 barrels per day of crude oil. The results of the steady-state simulations run by the Aspen Hysys V14 software were compared to the actual operating parameters of the refinery. These conditions included plant experimental ASTM D86 curves for various products, the flowrate of the refined products, and the temperature of the product trays. The simulation results showed a good agreement with laboratory ASTM D86 curves for all products except heavy Naphtha, which revealed a noticeable difference. The results of the flow rate of Light Naphtha, Heavy Naphtha, Kerosene and Gasoil showed good agreement except Off gas (Relative Error%= 25) and Atmospheric residue (Relative Error%=-0.6). Finally, the simulated temperature of draw trays for refinery products shows good agreement with the refinery data where Relative Error -8.3% for Off gas was the largest variance between the refinery and simulation results.

Keywords: Aspen Hysys, Distillation, Simulation, Refinery, Crude oil.

محاكاة وحدة التقطير الجوي للنفط الخام في مصفى الديوانية باستخدام برنامج اسبن هايسس

الخلاصة:

تم في هذا العمل دراسة محاكاة الحالة المستقرة للأداء الحالي لبرج التقطير الجوي للنفط الخام في مصفى الديوانية والذي تبلغ طاقته 10,000 برميل يومياً. حيث تم الحصول على نتائج محاكاة الحالة المستقرة بواسطة برنامج المحاكاة اسبن هايسس (Aspen Hysys V14) ومقارنتها بظروف التشغيل الفعلية للمصفاة مثل استخدام منحنيات التقطير ASTM D86 للمنتجات المختلفة وكذلك معدل التدفق الحجمي وأيضا درجات الحرارة لصواني السحب للمنتجات. أظهرت نتائج المحاكاة توافقاً جيداً مع منحنيات ASTM D86 المختبرية لجميع المنتجات باستثناء النفثا الثقيلة والتي أظهرت اختلافاً ملحوظاً كذلك أظهرت نتائج معدل تدفق الحجمي للنفثا الخفيفة والنفثا الثقيلة والكيروسين وزيت الغاز توافق مقبول باستثناء الغاز الخامل off gas وزيت الوقود بنسبة خطا بلغت 25% و-0.6% على التوالي. أخيرا، اضهرت نتائج المحاكاة لدرجات الحرارة لصواني السحب للمنتجات توافق مقبول مع القيم الفعلية للمصفى ماعدا الغاز الخامل off gas بنسبة خطا 8.3%- كأعلى قيمة.

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1. Introduction

Crude oil plays a vital part in human daily life, as it is utilized in the refining process to produce a wide range of petroleum-based products and to facilitate the growth of modern industries [1]. An essential part of nearly every refinery is the crude oil distillation unit (CDU). After heating crude oil in a furnace that easily separates its components for different boiling points, it gets the refined oil. Due to its operation at atmospheric pressure, it is sometimes called an atmospheric distillation column. The crude oil refining process begins with this unit, which is also the most significant and core part of the entire facility. CDUs are essential in petroleum refineries for producing the intermediate streams needed by the following units, which are in turn required in the distillation process, the initial step in refining crude oil [2]. Al-Diwaniyah refinery was established in 2008 and is located in the southwestern part of Al-Diwaniyah city. The refinery started with a production capacity 10000 barrel/day, then development began to reach a production capacity 20000 barrel/day by atmospheric distillation units. The existing refinery consist of a heat exchanger network (HEN), furnace, and atmospheric distillation column with one pumps around and two side product strippers. Off gases and Light Naphtha (L.N) are the overhead products. Heavy Naphtha (H.N), kerosene, and atmospheric gas oil are side products while reduced crude residue (R.C.R) is the bottom product. The crude oil used in this refinery comes from Basra fields that has medium gravity of about 29.8 API°. Because models and simulations have grown in importance as a means of learning more about product distribution, ratios, and specifications, this study intends to model the refinery [3]. Steady state simulation of process has used Aspen Hysys (Version 14). Designed to be more accurate and versatile in most working settings, the Aspen Hysys software offers a vast database that covers numerous types of gas and liquid equations of state over a wide range of pressure and temperature. The results are more in line with the actual performance of the separation units due to these features and specifications. Tables and equations including a wealth of experimental data for pure components, solutions, and mixtures are included in the application [4]. Petroleum assay option in Hysys was used to characterize Basra medium crude oil 2021(29.8 API) as required input in the simulation then compared the results with experimental crude assay. Furthermore, refinery process units were simulated to evaluate product specification and operating conditions. Salah M. Ali et al. [5] used aspen hysys V.8 to find optimal operating conditions for an atmospheric distillation column for Al-Dura refinery that distills heavier, moderate, and lighter crude oils. Three crude oil types (Kirkuk light, Basrah light, and Basrah medium) were chosen to assess model validity. Simulation

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results match industrial plant results closely. The suggested model predicted optimal operating conditions for distilling a light-heavy Basrah crude oil blend with varying mixing ratios. Ali Nasir Khalaf [6] showed the possibility of used Aspen hysys software for simulation of the crude distillation tower in Basra refinery at steady state the operation. When compared simulation results with the true plant data, the results showed that the mass flow rates of kerosene, LGO, off Gas, and HGO were found to be identical with those for the real tower condition. While the flow rates for naphtha, residual, and waste water were slightly different, the error difference between the plant and simulated results ranged from (6 - 11) %.

Fatimah A Naji et al. [7] showed the possibility of optimizing the blending process for Iraqi oil. Analytical analysis of oil samples revealed the physical and chemical properties of three different Iraqi crude oils. A unique petroleum assay for each crude oil was used to identify the various boiling points, density, viscosity, and sulfur content of fractions that it could obtain through the atmospheric distillation of crude. authors used Aspen hysys to identify the required blending ratios to obtain or enhance a certain distillation product, which may be a clear opportunity to enhance the prices of final products.

This study focuses on modeling and simulating the atmospheric distillation unit at the Al-Diwiniya refinery in Iraq for the first time. The paper highlighted a noticeable difference between the simulation and actual data for the heavy naphtha product, which provides useful feedback for improving the model or understanding limitations. It also compared the simulation results from Aspen Hysys to the actual operating data, such as draw tray temperatures. This level of validation against real-world refinery performance is not always present in other simulation studies. The paper looked at not just overall product yields but also examined factors like product flowrates and tray temperatures, providing a more comprehensive evaluation of the distillation unit performance. The modelled Crude Oil was processed in Two parts: preheat trains (HEN and furnace) and atmospheric distillation unit.

2. Method:

2.1. Crude Process description

The real existing crude oil has a medium gravity of about 29.8 API° with specifications as shown in Table (1).

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Table (1): Specifications of crude oil

Laboratory test	Result	
API at 15 °C	29.8	
Density(Kg/m^3)	876	
W&Bs (V%)	0.15	
Salt (ppm)	159	
Sulfur content (W%)	3	
Kinematic viscosity(cSt) at 20 °C	12.7	
	Volume %	**Temperature**
Distillation T.B.P. for crude oil	2	40
	3.5	52
	5	62
	7.5	77
	10	95
	12.5	112
	15	128
	17.5	143
	20	159
	25	189
	30	218
	35	249
	40	279
	45	310
	50	342
	55	373
	60	405

10,000 barrels of crude oil per day (66 m^3/hr) is drawn from storage tanks using a feed pump. The first preheat train of the heat exchangers network (HEN) raises the temperature from 25°C to 150°C, and the second train uses a furnace to raise the temperature from 150°C to 300°C. The outlet from the furnace is going to ADC (Atmospheric distillation column). ADC is equipped with

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29 trays and feed is enters flash zone between 3 and 4 trays with temperature and pressure 300°C, 1.5 bar-g respectively. The CDU aims to refine the crude oil to many fractions. These cuts include Naphtha, Kerosene, Gasoil and Atmospheric Residue [8]. The L.N is extracted from the top column, condensed, and then transferred to the reflux drum. From there, the off gas is burned off. In the reflux drum, L.N is returned to the top of the column for further processing, while a portion of it is directed towards the product. H.N I and H.N II have been withdrawn from the 24th and 22nd trays, respectively. Kerosene is withdrawn from tray no. 15 and flows to the stripper column. Gasoil is withdrawn from tray no. 9 and flows to the stripper column then cooled. After Gasoil is cooled, it is pumped around to tray 8 and part of it sent to product. The pump around specifications are provided in Tables (2) and (3) provides the specifications for the side strippers.

Table (2): Pump around of Gasoil

Position between trays	**Volume Flow rate (m^3/hr)**	**Return temperature (°C)**
8 and 9	3	60

Table (3): Side strippers of kerosene and Gasoil

Stripper	Number of Trays	Steam Flowrate(kg/hr)	Product (m^3/hr)
kerosene stripper	4	75	4
Gasoil stripper	4	125	10

The residual components in the atmosphere are removed in the lower part of the distillation column. The lowermost steam enters tray 1 with a flow rate of 300kg/hr at a temperature of 220˚C and a gauge pressure of 5 bar. The pressure at the top of the ADC is 0.75 bar-g, while the pressure at the bottom stage is 1.2 bar-g. Figure (1) shows the crude distillation unit of the AL-Diwiniya refinery, consists of 29 stages, a partial condenser, two side strippers, and one pump around.

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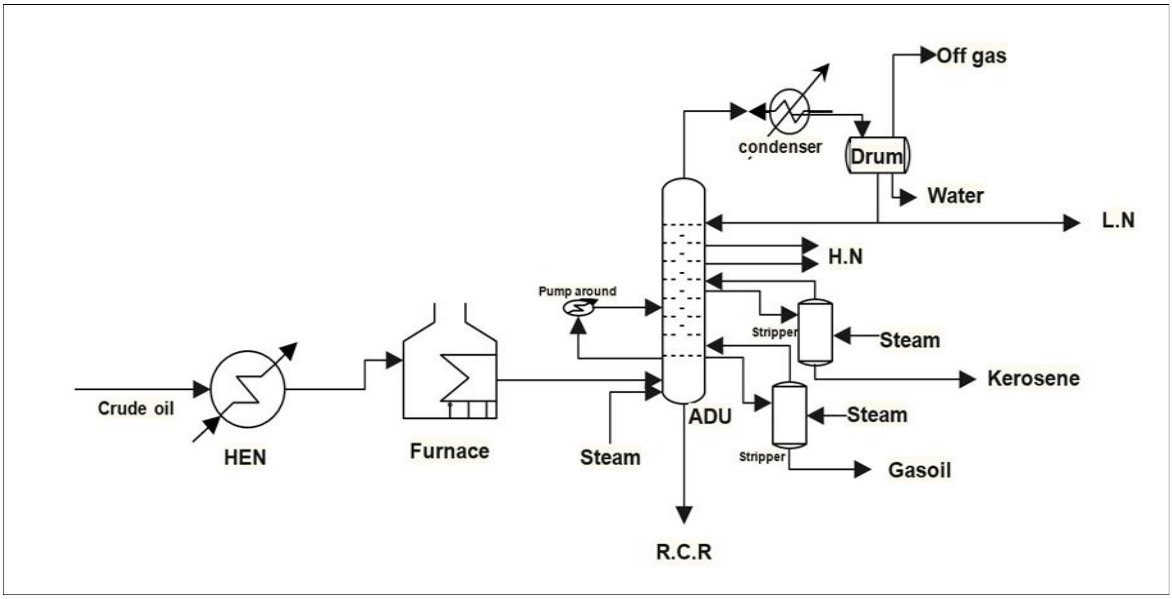

Fig. (1): Typical Crude Distillation Unit and Associated Unit Operations

Through the partial condenser, 8 m^3/hr of Light Naphtha and 0.4 m^3/hr of water stream are generated. 1 m^3/hr is also the off-gas production rate from the partial condenser. The liquid naphtha and gas mixture that exits the overhead condenser at around 60 ˚C can be used as fuel for the furnace or transferred to the flare. From the bottom of the tower, 41 m^3/hr of crude atmospheric residue is produced. The bottom plate of each side stripper produces a straight run output. Using steam to strip the kerosene side stripper allows for a 4 m^3/hr output, while steam stripping the gasoil side stripper yields 10 m^3/hr of gasoil.

2.2. Simulation of Refinery Process flow diagram:

All simulation is conducted using steady-state model developed under Aspen Hysys environment. The precise interpretation of the end product values is achieved using Hysys due to the propagation of petroleum properties throughout the flowsheet. For the thermodynamic fluid, the Peng-Robinson property package is chosen [9].

After the feed, product, and other streams have been defined, the simulation can start by defining the design variables. All product streams' flowrates in the simulation are fixed, including L.N., H.N., kerosene, gasoil, off gas, and residue, but product temperatures are computed after each run. Figure (2) shows an ADU that separates the crude into its straight run products after heating the liquids in a pre-fractionation train. Figure (3) shows the flow diagram of the simulated refinery process.

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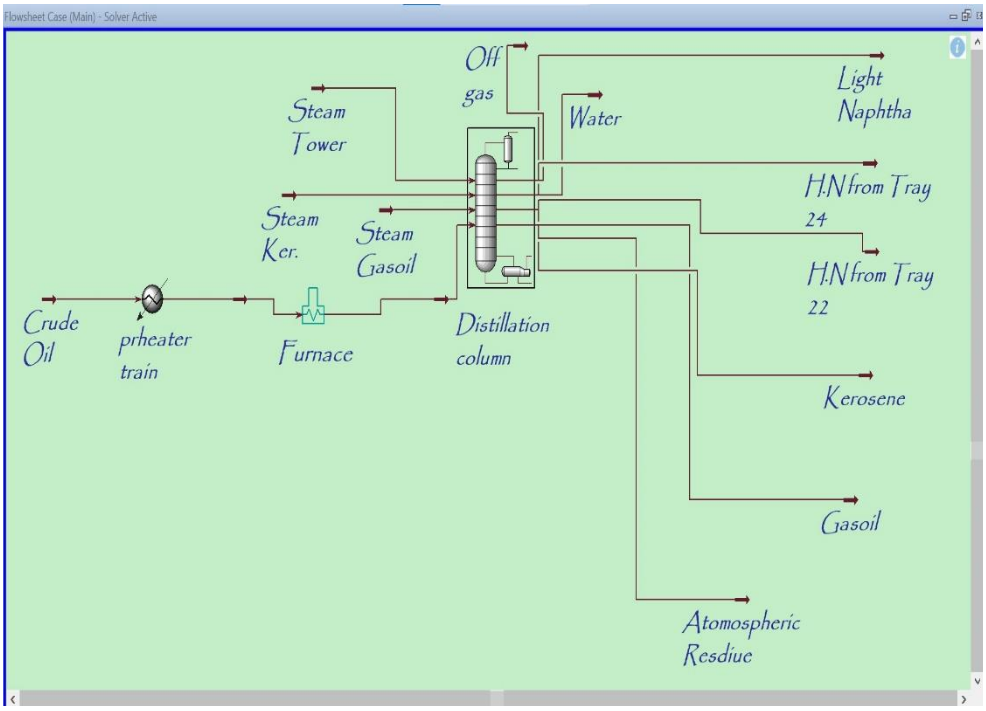

Fig (2): Simulation of preheat trains and CDU

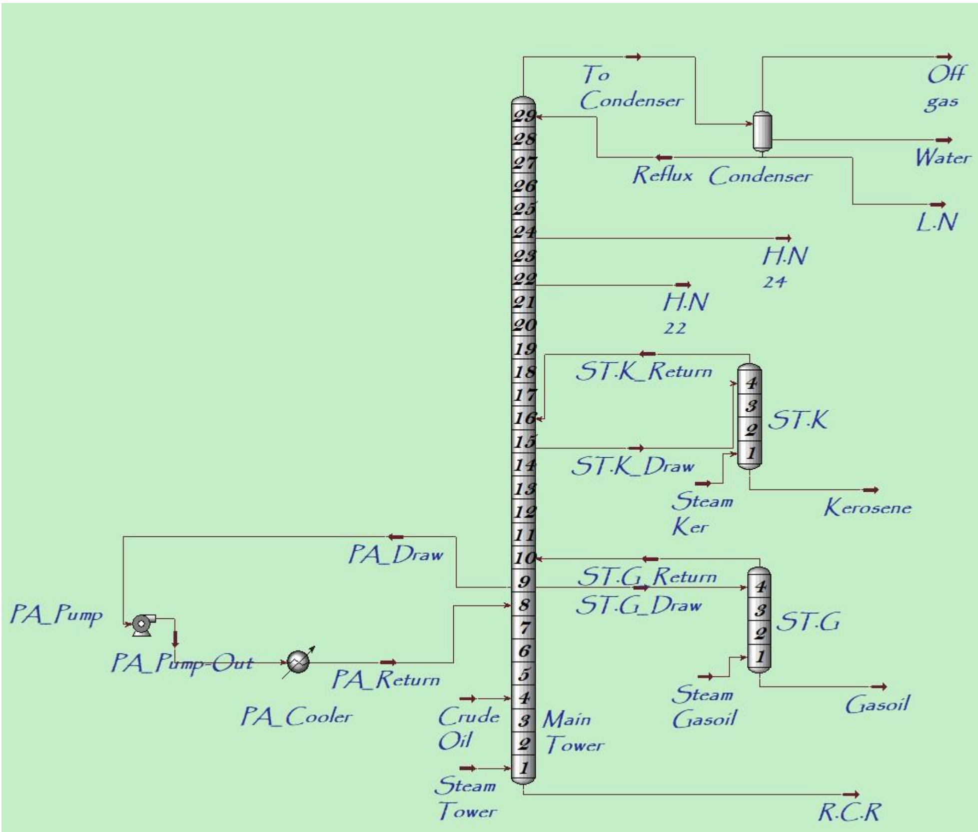

Fig (3): Distillation column sub flow sheet in HYSYS

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3. Results and Discussion

Simulations using the Light Naphtha, Heavy Naphtha, kerosene, and gasoil ASTM D86 distillation curves demonstrated that the product's quality could be considered satisfaction assured [10]. L.N., H.N., kerosene, and gas oil's simulated ASTM D86 curves are shown in Figures (4) to (7), correspondingly.

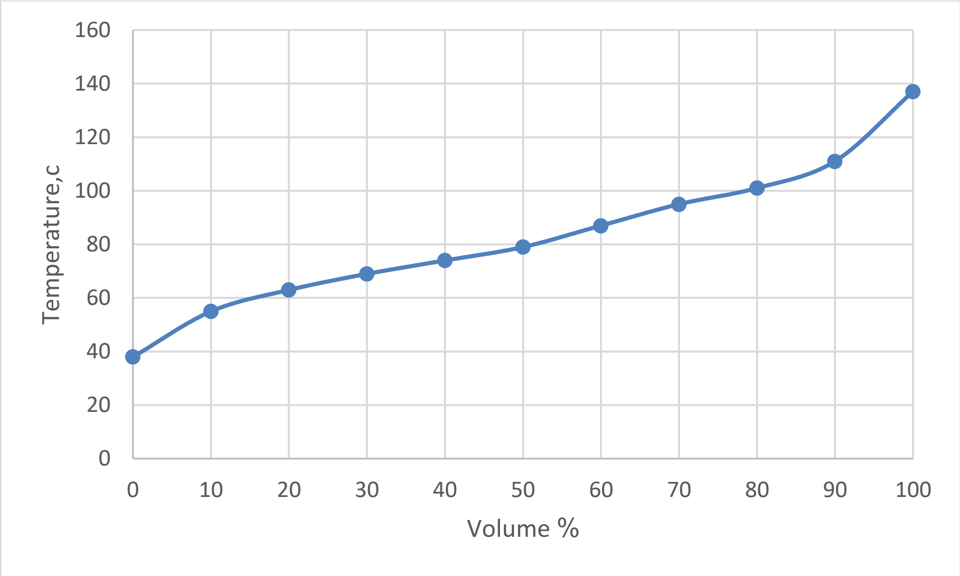

Fig. (4): Simulated ASTM D86 curves of L.N

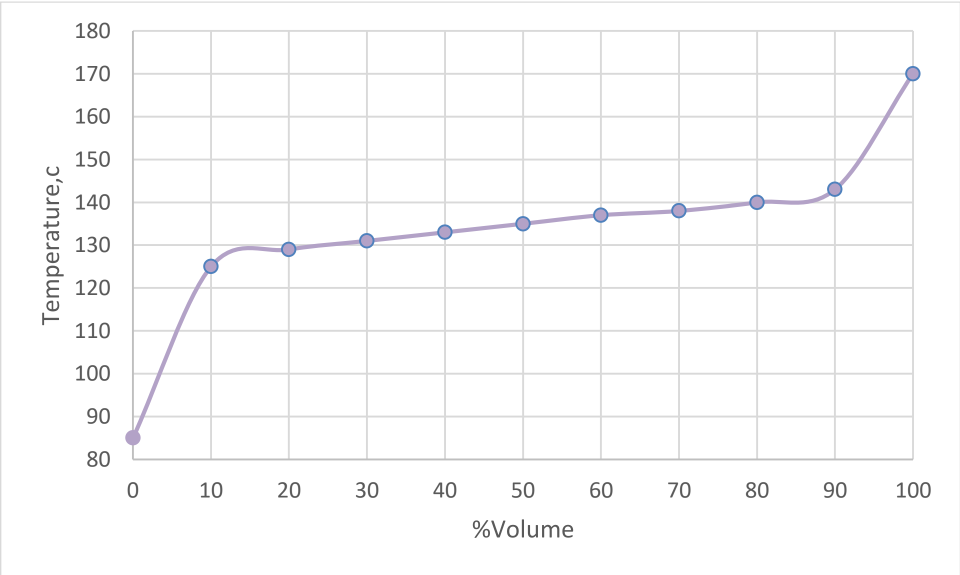

Fig. (5): Simulated ASTM D86 curves of H.N

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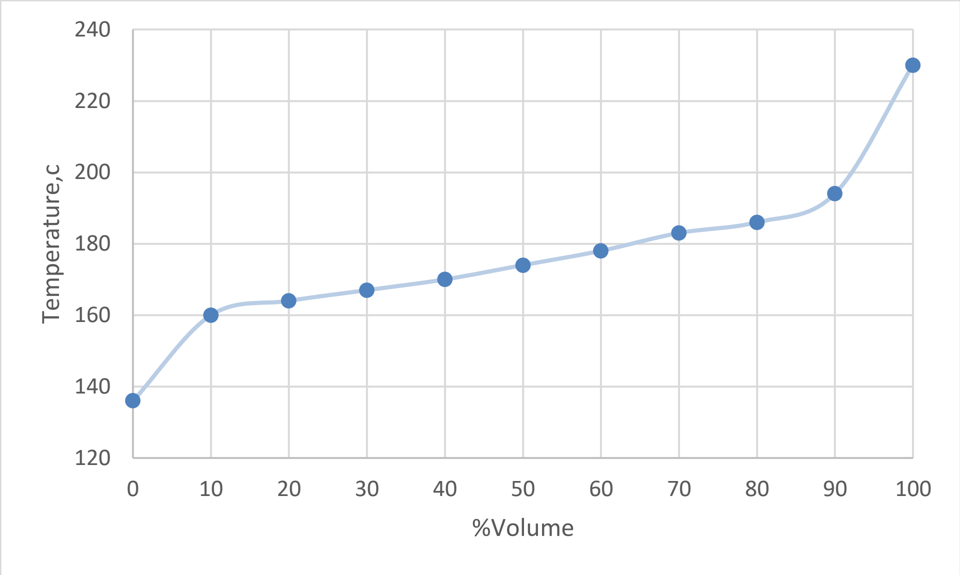

Fig. (6): Simulated ASTM D86 curves of Kerosene

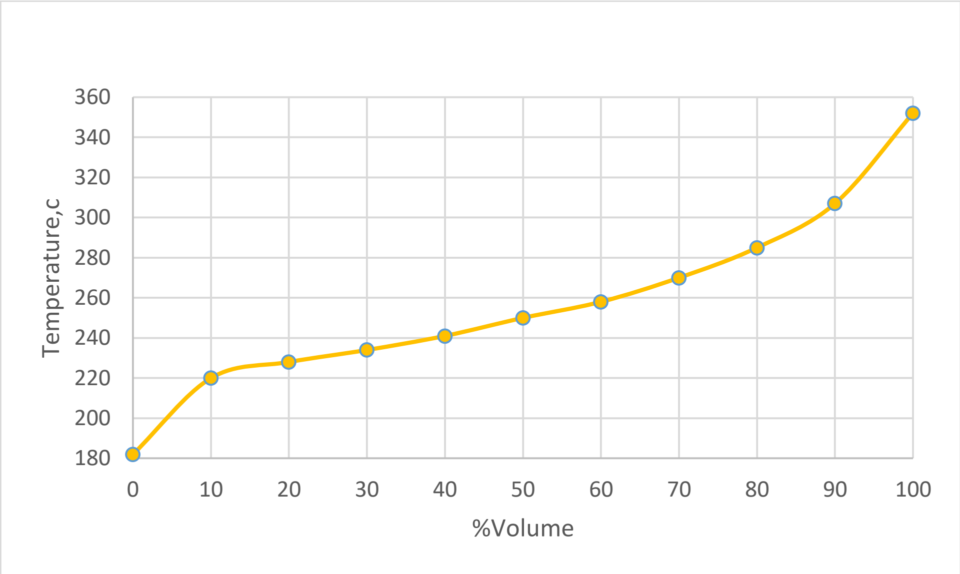

Fig. (7): Simulated ASTM D86 curves of Gasoil

Figures (8) to (11) display the difference between the Real product plant data and the simulated ASTM D86 curve. There was a high degree of agreement between the simulated and experimental plant data using ASTM D86 curves. Except for H.N., the results of the simulations are generally in excellent agreement with the data from the plants. To better understand the changes in the plant products when comparing the simulation results with the ASTM D86 data, it is useful to examine multiple plant measurements. Both variations in laboratory measurements and minor adjustments to plant operations contribute to the observed variability in plant measurements. That there may be variations in lab results and repeatability of ASTM D86 measurements due to sampling

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procedures. The accuracy of temperature measurements within a range of plus or minus 3.3˚C is intended by the ASTM D86 procedure [11].

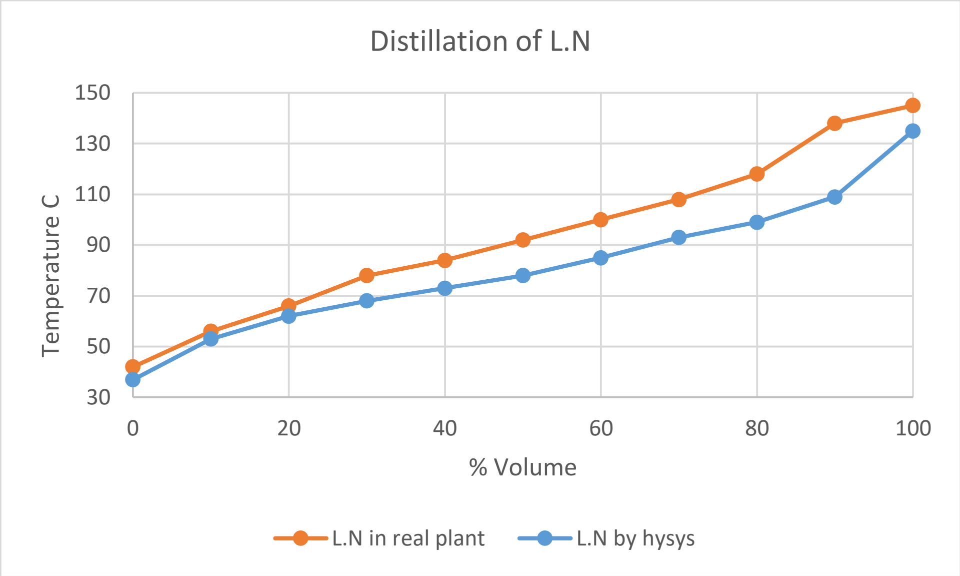

Fig. (8): Simulated and plant data ASTM D86 curves of L.N.

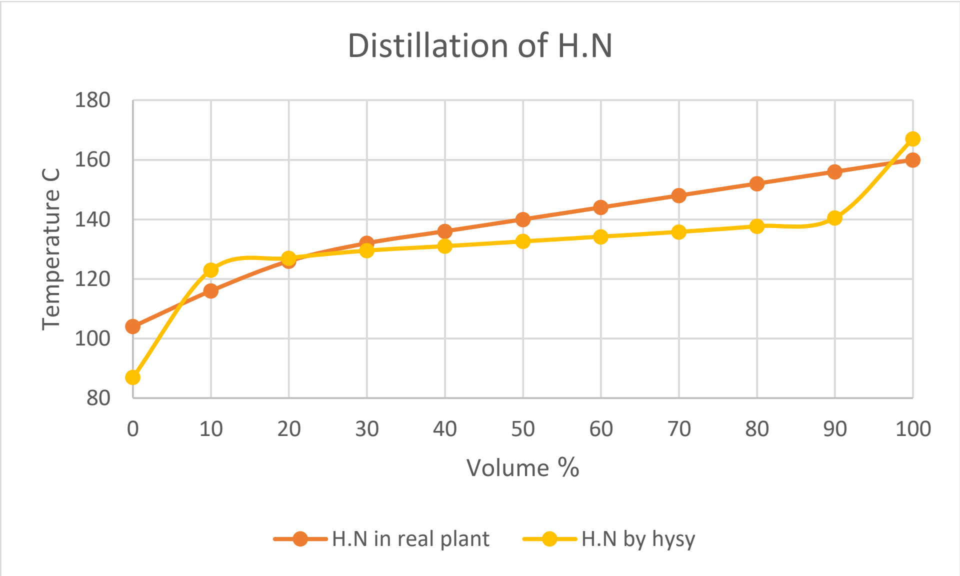

Fig. (9): Simulated and plant data ASTM D86 curves of H.N.

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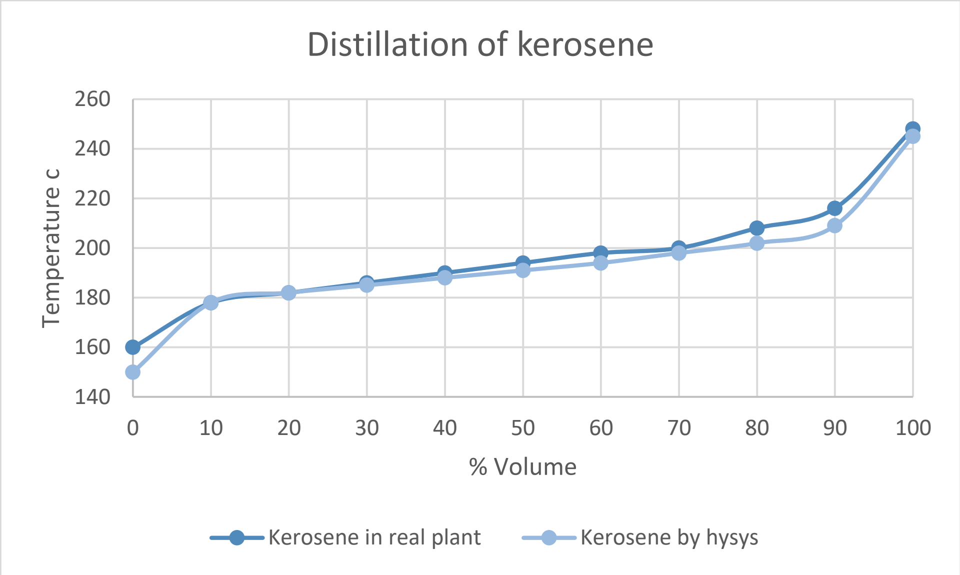

Fig. (10): Simulated and plant data ASTM D86 curves of Kerosene.

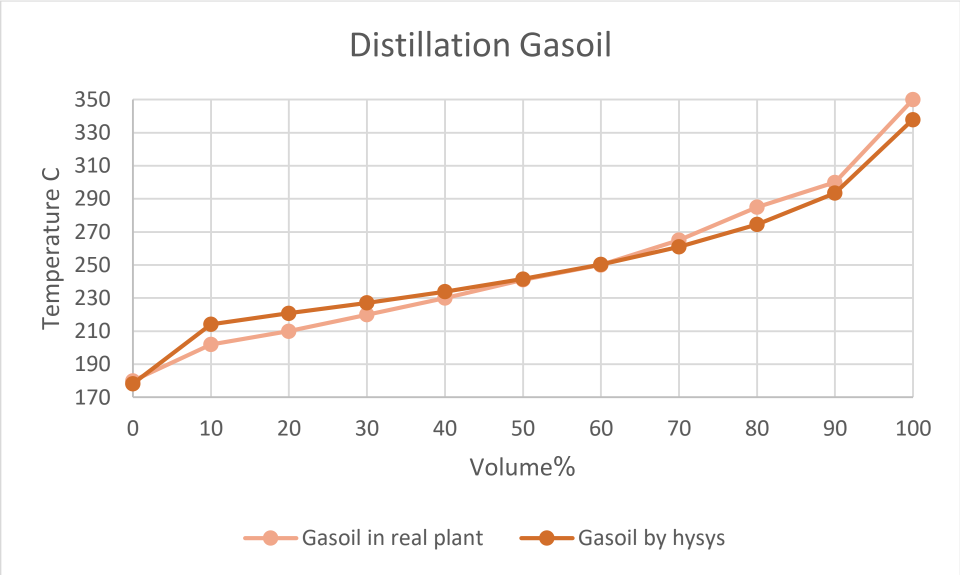

Fig. (11): Simulated and plant data ASTM D86 curves of Gasoil.

The result of the simulation for production rates were also compared with the actual data from the refinery (refer to Table 4). With the exception of off gas (Relative error% 25) where Relative Error =Actual Value-Simulated value /Actual value, the results from the simulation are in very excellent agreement with the data from the plant. Also, a comparison of these results with those of the previous researcher [6] revealed complete agreement, with the exception of atmospheric residue (Relative Error% 11.4) and off-gas (Relative Error% 0).

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Table (4): Results of production rates in real and simulation

Product	Product in real plant (m^3/hr)	Product in hysys (m^3/hr)	Relative Error %
Light Naphtha	8	8	0
Total Heavy Naphtha	2	2	0
Kerosene	4	4	0
Gasoil	10	10	0
Atmospheric residue	41	41.25	-0.6
Off gas	1	0.75	25

Finally, Table (5) displays a comparison of the temperatures for the draw trays in the real plant and the simulation. The results show a significant difference between the two sets of data, with the largest discrepancy being approximately -8.3% for Off gas.

Table (5): Results of production rates in real and simulation

Product	Tray Temp. in real plant (˚C)	Tray Temp. in hysys (˚C)	Relative Error %
Light Naphtha	110	109	0.9
Total Heavy Naphtha	135	140	-3.7
Kerosene	180	190	-5.5
Gasoil	240	235	2
Atmospheric residue	295	295	0
Off gas	60	65	-8.3

4. Conclusions:

The goal of this study is to show that it is possible to model the crude distillation tower at the AL-Diwiniya refinery (which can produce 10,000 barrels of oil per day) in a steady state using Aspen Hysys to provide a virtual representation of a process that can be used to gain insights, test hypotheses, and support decision-making in a variety of domains. The simulation results for the products in the ASTM D86 distillation, volume flow rate, and temperature draw trays are quite similar to the actual plant statistics. The simulation results agree with the plant data for volume flow rate of products and the ASTM-D86 curves from the lab (except for off gas Error% 25). Lastly, the study found that the draw temperature of products differed significantly between the experimental plant data and the simulation, with a maximum variance of around -8.3% for off-gas.

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