Chemical Process Design Vol.3 No.1 (2024) 16-26

University of Sistan and Baluchestan

Chemical Process Design

Available online at http://cpd.usb.ac.ir/



Impact of Blending Basrah and Kirkuk Light Oils on Refining Processes

Esmaeil Koohestanian[1*], Maliheh Ghofran Pakdel[2]

[1]Department of Chemical Engineering, Iranshahr Branch, Islamic Azad University, Iranshahr, Iran
[2]Department of Chemical Engineering, University of Sistan and Baluchestan, P.O.Box 98164-161, Zahedan, Iran

ARTICLE INFO

Article history:
Received: 2023-12-09
Received in revised form: 2024-02-07
Accepted: 2024-03-03
Published online: 2024-03-05

Keywords:
Petroleum refinery; Process design; Basrah light oil; Kirkuk light oil; Crude oil blending; Atmospheric distillation

DOI: *10.22111/cpd.2024.49525.1037*

ABSTRACT

This study aims to investigate the effects of mixing Basrah and Kirkuk light oil and simulate the process using Aspen Plus software. Crude oil blending has gained significant attention recently due to its potential for optimizing oil properties and enhancing refinery efficiency. In this research, a comprehensive analysis is conducted on the physical and chemical characteristics of the resulting mixture. The study begins with a detailed review of the properties and composition of Basrah and Kirkuk light oil, highlighting their strengths and weaknesses. This involves analyzing the impact of blending on key parameters, such as viscosity, density, sulfur content, and API gravity. Subsequently, the Aspen Plus software models the mixing process, considering temperature, pressure, and flow rates. By employing various simulation techniques, the behavior of the mixture under different operating conditions is thoroughly examined. As distillation progresses to approximately 90%, the API gravity of the oil drops by about 10 degrees. To process more than 60% of this oil, a vacuum and superheated steam system is necessary to break down the remaining heavy molecules. When refiners blend crude oils, a higher yield product (about 3%) can be produced from the atmospheric and vacuum distillation units. The findings can assist refinery operators and engineers in making informed decisions regarding crude oil blending strategies, ultimately leading to enhanced operational efficiency and improved product quality.

1. Introduction

Unrefined crude oil is composed of hundreds of different hydrocarbon molecules and organic substances in a liquid state, accompanied by elemental compounds and impurities, which are of limited use and limited value [1]. The sweetening and purification of these compounds and the breaking down of their heavy hydrocarbons into lighter compounds are among the most complex and costly refining processes [2, 3]. Oil refineries consist of units that separate and convert these mixtures into valuable products through distillation towers and reactors [4].

Corresponding author. Tel.: +98 9155118412
E-mail address: koohestanian@pgs.usb.ac.ir (E. Koohestanian).

Crude oil distillation is a major refinery process in which crude oil is converted to valuable and stable products such as gasoline, diesel fuel, heating oil, jet fuel, etc. with desired qualities [5, 6]. Numerous combinations of operational circumstances can be employed to meet the desired qualities dictated by the marketplace [7]. On the other hand, the high energy requirement is one of the disadvantages of crude oil distillation. Crude oil distillation is an energy-intensive process, requiring significant thermal energy to separate its components. However, other methods such as hydrocracking and thermal cracking consume less energy. Reducing energy consumption in this process is of great economic and environmental importance. Furthermore, environmental regulations aimed at reducing CO_2 emissions have created a dilemma for refineries, forcing them to balance their annual profits with the need to comply with these regulations [8]. As a result, enhancing efficiency by reducing operational expenses directly leads to increased profitability. The predominant factors influencing refinery operating costs are the price and composition of crude oil [2].

Furthermore, the sulfur content and gravity of crude oil are the key attributes that impact its market price [9]. Therefore, most petroleum purchase lower-cost crude oils with lower American Petroleum Institute (API) gravity and higher sulfur content and produce crude oil with higher value by mixing them with lighter crude oils with higher API gravity and lower sulfur content [10]. Furthermore, most refineries do not have sufficient tanks to isolate various crude oil. To maximize the yield of the blended crude oil and to decrease the coking and fouling of blended crude oil in petroleum refineries, the compatibility index and dynamic viscosity should be as low as possible [11]. Therefore, optimization of crude oil mixing improves the refineries' annual profits and various academic research has been performed on this issue. Shaoping et al. [12] conducted a study on the blending of crude oil distillation yields and products. According to their findings, when blending Iranian and Saudi crude oil at a ratio of 9:1, the highest total distillation yield was 67.20%. This yield was 1.47% higher than the expected theoretical distillation yield.

Environmental stewardship and sustainable resource management are paramount concerns for businesses worldwide. The oil refining industry, in particular, exerts a significant influence on ecosystems globally [13]. Dai et al. [14] established a data-driven robust optimization for optimizing crude oil mixing in the presence of uncertainties, such as oil properties. The findings indicate that this method enhances the robustness of solutions and effectively safeguards the crude distillation unit by incorporating uncertainty data. It is noteworthy that even in worst-case conditions, the sulfur content of the blended crude oil remains within the safe range, indicating the method's ability to maintain compliance with regulatory requirements pertaining to sulfur content.

The environmental impact assessment (EIA) provides a comprehensive evaluation of the environmental effects of a project or activity throughout its entire lifecycle, from production to disposal. In the context of gasoline refining, EIA offers valuable insights into the environmental impacts of various stages of the process, including crude oil extraction, refining processes, and distribution of the final products [15]. Hou et al. [11] research the six different types of crude oil to predict the properties of mixed crude oil, obtain a better yield of fractions, and reduce the blended crude oil viscosity. Gu et al. [16] established energy optimization of a multistage CDU using mathematical programming and exergy analysis. The results show an increase in heat recovery and a decrease in energy consumption.

In a recent study, Jabbar et al. [17] employed the Aspen Hysys software to analyze the optimal design and simulation of a crude oil distillation system within the context of a refinery process. The research focused on incorporating pre-treatment and mixing of two specific types of crude oil, namely Iraqi Kirkuk-2011 and Basra light-2015. The aim

was to reduce energy consumption and enhance the refinery's annual profit. However, there are several design and computational errors in that design. For example, considering the high number of heat exchangers in their final design, a significant pressure drop occurs, requiring the inclusion of a pump to overcome this pressure drop, and its energy consumption and costs should be considered in the calculations. Optimization is also necessary regarding the location of the pump because the fluid flow is highly viscous, and it is necessary to precondition it before entering the pump to reduce its viscosity and energy consumption. Furthermore, the use of a pre-flash tower before the atmospheric distillation column causes the escape and separation of light components in the pre-flash tower, reducing the size and costs of the atmospheric column [18]. Additionally, the output waste product from the end of the atmospheric tower should enter the vacuum column for further separation, ensuring the complete separation of valuable materials that create high cost-effectiveness in the process. Furthermore, since both oils are light, while this research compared the scenario of light and heavy oils in Basrah. The Aspen Plus software is a powerful simulation tool used in the chemical process industry. It can be used to model and simulate a wide range of processes, including refining, petrochemicals, and pharmaceuticals. Aspen Plus is particularly well-suited for simulating complex processes that involve multiple phases, such as distillation, absorption, and extraction [19].

This research aims to investigate the mixing of Basrah and Kirkuk crude light oil using Aspen Plus, a powerful simulation software widely employed in the oil industry. By employing this sophisticated tool, this research aims to delve into the intricacies of blending these two types of crude oil, exploring their compatibility, properties, and potential synergies. Through a comprehensive analysis, this paper seeks to uncover the effects of mixing Basrah and Kirkuk crude light oil, providing valuable insights for refinery processes and paving the way for more efficient and sustainable oil production practices. This study aims to contribute to the growing body of knowledge in the field, fostering innovation and advancements in the oil industry. The primary objective of this research is to enhance the crude oil refining process by investigating the blending of two types of light crude oils using the Aspen Plus simulation software. The selection of Basrah and Kirkuk crude oils, along with the chosen parameters, is based on their industrial significance and impact on refinery performance. Parameters such as compatibility factor, viscosity, sulfur content, and distillation yield have been selected. Compatibility factor is used to assess the likelihood of phase separation or other undesirable interactions between the two crude oils. Viscosity affects the flow properties of crude oil and influences pumping and processing costs. Sulfur content is a key factor in determining the quality and value of crude oil, as well as its environmental impact. The yield of valuable products from the distillation of blended crude oil is a significant factor in determining its economic value.

2. Simulation details and methods

2.1. Process description

Refinery configurations can indeed differ from one refinery to another based on their specific goals and market demands. It is not uncommon for refineries to have varying orientations towards particular product outputs. For instance, certain refineries may prioritize the production of gasoline, considering the high demand for this fuel in the market. These refineries may dedicate a significant portion of their processing units and infrastructure towards gasoline production. Their configuration might include optimized units such as fluid catalytic crackers (FCC) and alkylation units to maximize gasoline production. On the other hand, some refineries may focus more on producing middle distillates such as jet fuel and gas oil. This orientation could be due to factors like regional demand patterns

or marketing strategies. These refineries may have configurations that allocate more resources to units like hydrocrackers and hydrotreaters to produce higher volumes of middle distillates. It is important to note that refinery configurations are driven by their individual objectives, market conditions, and available feedstock. The choice of configuration allows each refinery to optimize its operations and maximize profitability based on its specific circumstances [20]. Crude oil distillation is a major refinery process, converting crude oil into valuable and stable products like gasoline, diesel fuel, heating oil, jet fuel, and more with desired qualities [21, 22]. The specific product mix and its properties can be adjusted by manipulating various operational parameters, such as temperature, pressure, and feed rate [22, 23]. This flexibility allows refineries to adapt to changing market demands and optimize their product yields.

However, generally crude oil from the storage tank is pumped through a series of heat exchangers where it is preheated to 250 to 300 °F by-products stream from the Crude Distillation Unit (CDU) and vacuum distillation unit (VDU) and 5 to 6 liquid volume percent water is injected into desalting of crude oil [24]. Desalting crude oil before entering the atmospheric distillation column is essential if the level of salts present in crude oil exceeds 10 pounds per 1000 barrels. In many modern refineries, desalting is also carried out for amounts less than the above amount, because salt can not only create deposits but also decompose inside the furnace or other refinery facilities and cause corrosion and damage to refinery equipment.

To reduce the viscosity of crude oil, it is heated before pumping to decrease its viscosity and, consequently, the energy required for pumping. Then, a booster pump is used to increase the pressure of the desalted crude oil, which contains 0.25 to 0.5% water by volume. Fig. 1 illustrates the process flow diagram (PFD) in this study.

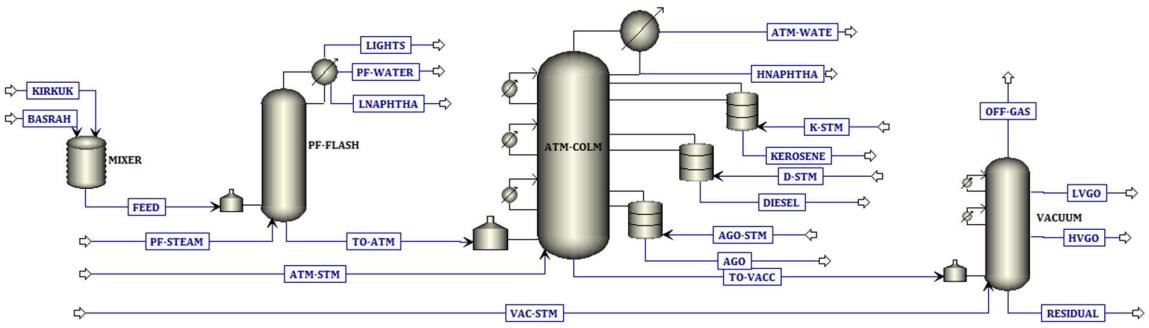


Fig. 1. Process flow diagram

The desalted crude oil, which has been preheated, enters the fired furnace of the CDU for final heating. The outlet temperature of the furnace depends on the specifications and composition[1] of the crude oil [24]. The hot oil mixture from the furnace then flows through a transfer line into the flash zone of the CDU, where it mixes with light hydrocarbons and steam from the column stripping zone. To separate the lightest hydrocarbons from the topped crude product, a sufficient amount of steam is heated and introduced into the stripping zone. Therefore, this process leads to the separation of heated petroleum vapors based on volatilities. The steam used in stripping not only lowers the temperature needed to distill the overhead products from the column feed, but also reduces the partial pressure of the

[1]The composition of any crude oil sample is approximated by a true boiling point (TBP) curve.

hydrocarbons. The heated liquid from the flash zone in effect of gravity force moves downwards through the column's stripping section. In this section, steam is injected into the bottom of the column to strip the liquid of any remaining impurities. The steam provided by the utility unit in the same operating condition (60psi and 400°F) and different flow rates where are summarized in Table 1.

Table 1. The mass flow rate steam

	PF-STEAM	ATM-STM	VAC-STM	AGO-STM	D-STM	K-STM
Mass flow (lb/hr)	7500	12000	20000	800	1000	3300

The hot vapor from the flash zone rises and is contacted by colder reflux flowing down the column where condenses the liquid side products. The reflux is provided by the condenser and pump-around. The pump around takes the hot liquid fluid from the lower tray and returns it to the upper tray after cooling, and they have the following special functions [25]:

- Removing latent heat of evaporation from the existing vapors and assisting in the condensation of the products.
- Creating a reflux flow inside the tower.
- Improving the performance of the heat exchanger network through heat integration, ultimately reducing the required furnace heat capacity.
- Reducing steam flow throughout the distillation tower and ultimately reducing the size of the tower and the required investments.

The pump around specifications in the atmospheric and vacuum columns are summarized in Table 2.

Table 2. Pump around the specification

Pump around position	ATM-COLM		VACUUM	
	1st PA	2nd PA	1st PA	2nd PA
Draw stage	8	14	2	4
Return stage	6	13	1	3
Flow (bbl/day)	49000	11000	20000	49000
Heat Duty (MBtu/hr)	-40	-15	-28.6	-80

It is worth mentioning that when several distillation columns are connected in series so that the output product from the bottom of each distill enters the next column as feed, the thermal load adjustment of each of these distill and the separation of their volatile components is very important. If the thermal load in one of the columns decreases, it can cause an increase in pressure in the next column. This is because, due to the decrease in input heat to the tower, some of the volatile components enter the next tower through the outlet stream from the bottom of the column. If the condenser of the next tower cannot condense these components or does not have enough capacity to handle the extra vapor produced, the dangerous phenomenon of overpressure will occur [26, 27]. Therefore, a certain amount of lighter materials, along with oil cuts, are always drawn out of the tower, causing a decrease in the flash point of the produced materials. The flash point is the lowest temperature at which oil vapors form, which corresponds to the boiling point of its volatile components. Therefore, for safety reasons in storing or transportation, lower-boiling hydrocarbons are removed and the flash point of the product is adjusted to meet requirements [28]. This is done by placing smaller towers, with two to six trays, called strippers column in proximity to the distill to separate the light compounds present in the oil cuts. Superheated steam is injected into these towers, counter-currently colliding with the oil products,

evaporating the present light compounds, and returning to the main tower as a vapor phase through the top of the stripper column. The product is usually in the liquid phase and exits from the bottom of the stripper column. The side stripper specifications are summarized in Table 3.

Table 3. The side stripper specifications

	Kerosene	Diesel	AGO
Number of Stages	4	3	2
Liquid Draw Stage	6	13	18
Overhead Return Stage	5	12	17
Bottem Product (bbl/day)	13000	18000	9000

Additionally, to remove the diesel present at the residual of the tower, superheated steam is injected into the bottom of the atmospheric distillation tower. Re-distillation of the residual effluent from the end of the atmospheric distillation tower requires more heat and, if applied at atmospheric pressure, can cause thermal cracking of molecules. Therefore, the residue product from the atmospheric distillation column is sent to another column with lower operating pressure, called the vacuum distillation column, where separation and division of the residue into other oil cuts are performed. At lower pressure, the boiling point of compounds is reduced, and therefore, the temperature will not be high enough to cause molecule decomposition. This method was invented in the early 20th century and is now widely used in oil refineries. Due to the low pressure in the vacuum distillation column, the volume of steam produced under similar feed conditions is higher compared to the atmospheric distillation column, resulting in more diameter vacuum towers. The pressure of the vacuum distillation columns is determined by the desired cracking and product quality., and is usually operated at a practical minimum vacuum level of 60-110mm Hg [29]. The main objective of vacuum distillation is generally to separate vacuum gas oil (VGO) from reduced crude. The distillation column specifications are summarized in Table 4.

Table 4. The distillation column specifications

	PF-FLASH	ATM-COLM	VACUUM
Number of stages	31	25	6
Feed stage	31-Furnace	22-Furnace	6-Furnace
Steam stage	31-On stage	25-On stage	6-On stage
Condenser type	Partial vapor and liquid	Total	None-Top pump around
Condenser pressure (psi)	39.7	15.7	-
Condenser pressure drop (psi)	10	5	-
Column pressure drop (psi)	3	4	10 mmHg
Furnace type	Stage duty on the feed stage	Single stage flash	Single-stage flash with liquid runback
Distillate rate (bbl/day)	19500	17000	-

It is worth noting that the pressure in the first tower is higher than in the second tower, and in the second tower, it is higher than in the third tower. This is because the process moves towards heavier components that require an increase in temperature or a decrease in pressure. An increase in temperature beyond the permissible level may lead to coking and loss of product and raw materials, in addition to extra costs. Therefore, to facilitate the evaporation and separation of materials and escape components, the pressure has decreased during the process.

2.2. Crude Oil specification

The process of distilling crude oil involves the separation of different fractions based on their boiling ranges by heating the oil to specific temperatures. The composition of any crude oil sample is approximated by a TBP curve or ASTM analysis, which can be represented using corresponding curves or distillation data. The crude oil specifications are summarized in Table 5.

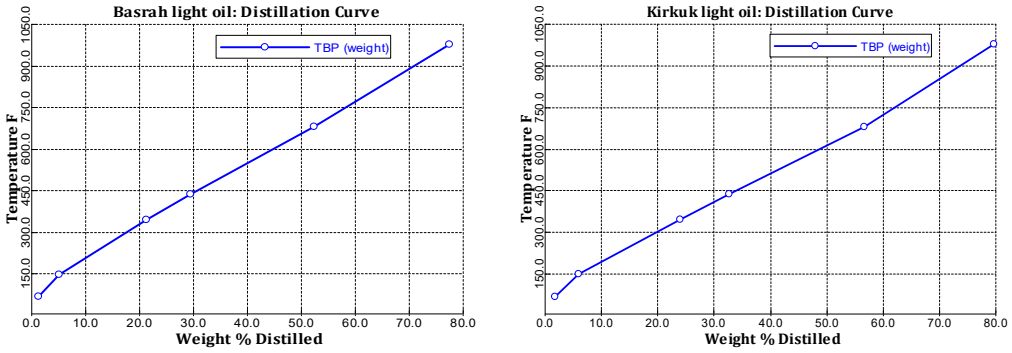
Table 5. The crude oil specification

	Basrah light oil	Kirkuk light oil	Blended crude oil
T (°F)	60	60	60
P (psi)	60	60	60
°API	33.7	35.1	34.40
Density	854.38	847.20	850.79
Specific gravity (kg/m^3)	0.856	0.849	0.853
Stdvol-Flow (bbl/day)	75200	75200	150066
Average MW	215.77	203.21	209.34

Table 5 presents the properties of three crude oils: blended, Kirkuk light, and Basrah light. These properties, measured under standard conditions, include temperature, pressure, API gravity, density, specific gravity, standard volume flow rate, and average molecular weight. This information can be used for various purposes, such as crude oil blending, refining process optimization, pipeline and storage calculations, and economic evaluation. However, it's important to consider other factors like sulfur content, viscosity, pour point, measurement units, and data accuracy.

3. Results and discussion

Fig. 2, illustrates the true boiling point curves of crude Basrah and Kirkuk light oil. According to the figure, more than 80% of Kirkuk oil is distilled at temperatures below 1200°F. In contrast, to achieve this level of distillation in Basra oil, the temperature needs to increase to about 1500°F, indicating that Kirkuk oil contains a larger volume of lighter components.



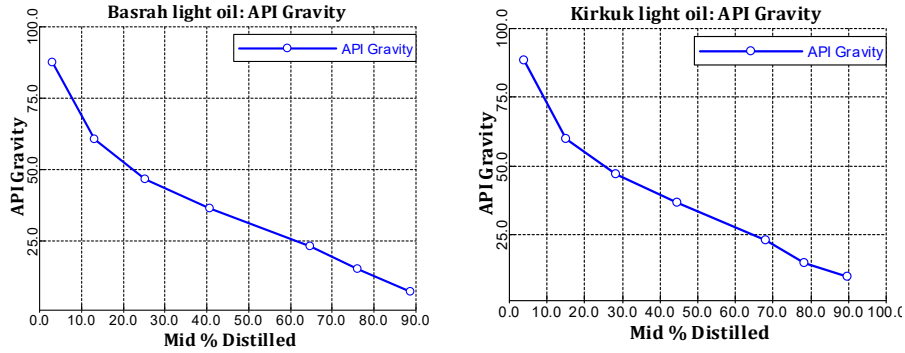
(a) **(b)**

Fig. 2. True boiling point curves of (a) Basrah and (b) Kirkuk light oil

Fig. 3 illustrates Basrah and Kirkuk light oil API gravity. According to this figure, as distillation continues up to about 90%, the API gravity of the oil decreases by about 10, indicating that to further process more than 60% of this oil, the distillation system should use vacuum and superheated steam to break down the heavy oil molecules.

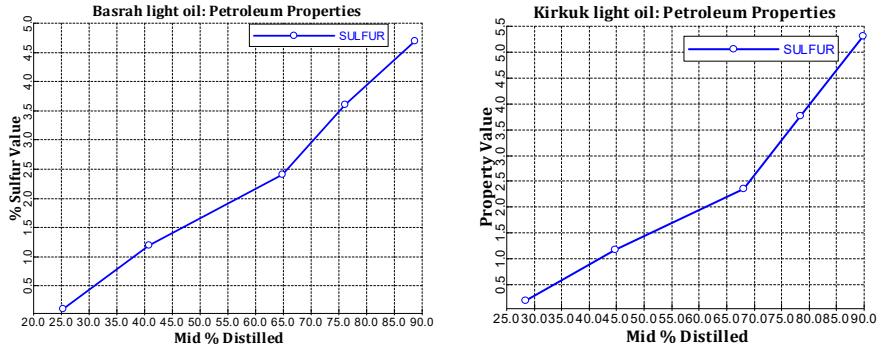
Based on Fig. 4, as the distillation level and progression towards heavier products increase, the sulfur content in the crude components also increases. Considering the low level of sulfur at the initial percentages of distillation,

optimizing an appropriate location for a sulfur removal unit could be a future research topic. As a research proposal, the sulfur removal unit could be placed after the pre-flash unit to process a smaller volume of materials.



(a) (b)

Fig. 3. (a) Basrah and (b) Kirkuk light oil API gravity



(a) (b)

Fig. 4. (a) Basrah and (b) Kirkuk petroleum properties

The boiling point range of crude oil determines the ease of separating it into different fractions (like gasoline, kerosene, diesel, etc.) during distillation (Fig. 5). A wider boiling point range can make separation more challenging, as it requires more energy and can lead to product blending. Oils with a narrower boiling point range might yield higher amounts of specific fractions, while those with a wider range could result in a more balanced product mix. If Basrah oil has a higher proportion of heavier components (with higher boiling points), it might require more severe cracking processes to produce lighter fractions like gasoline. This can increase energy consumption and equipment complexity.

The sulfur and nitrogen content of crude oil can influence the need for hydrotreating to produce cleaner products. If Kirkuk oil has a higher sulfur or nitrogen content, it might require more extensive hydrotreating. the observed differences in boiling points between Basrah and Kirkuk oils can have significant implications for refining operations, including separation efficiency, processing requirements, product quality, and economic factors. Understanding these differences is crucial for optimizing refining processes and maximizing the value of the crude oil. The American Society for Testing and Materials (ASTM) D86 standard test method is utilized to experimentally determine the batch distillation curve of a fuel derived from petroleum at atmospheric pressure [30].

This method provides information on the boiling range of the fuel, which is crucial for understanding its composition, properties, and behavior during storage and usage. The volatility of a hydrocarbon mixture, as determined by the boiling range, is a critical factor in assessing the potential for explosive vapor formation and has a significant impact on both safety and performance considerations[31].

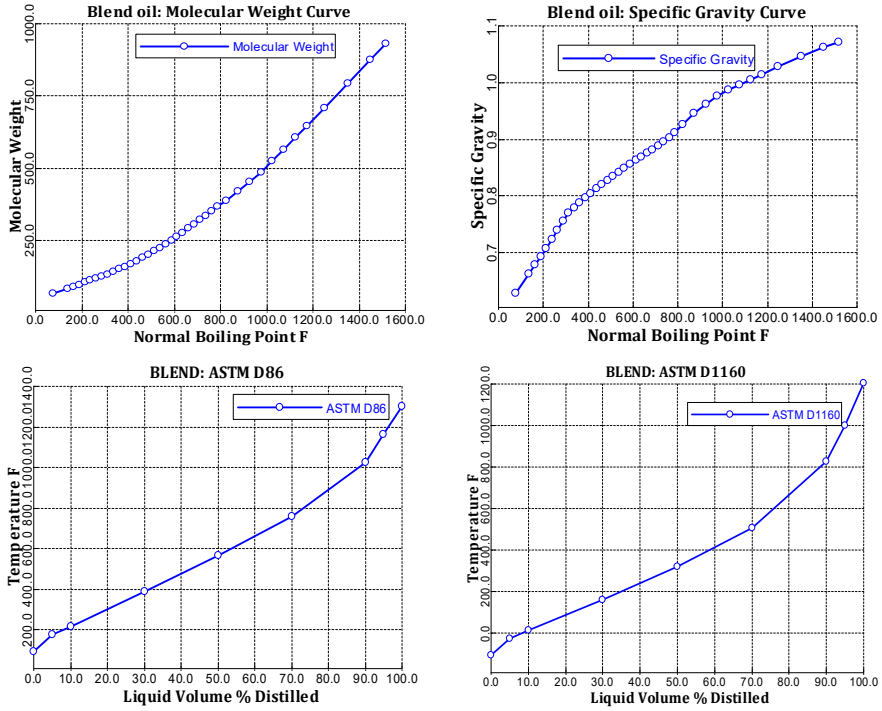


Fig. 5. Blend oil specification

The findings of this research can play a significant role in improving the situation of the Iraqi oil market. By optimizing refining processes and enhancing the quality of petroleum products, Iraq can strengthen its position in the global oil market and generate more foreign exchange earnings. Additionally, this research can contribute to better decision-making regarding investments in the oil and gas sector and can also lead to diversification of exports and a reduction in dependence on a limited number of customers.

4. Conclusion

This paper introduces an optimized design for a system that blends and distills crude oil through rigorous simulations conducted using the Aspen Plus software. The objective was to determine the product quality specifications, optimal operating conditions, and the configuration for crude oil separation. The process comprises three main units: a pre-flash distillation column, an atmospheric distillation tower, and a vacuum distillation column. The distillation column utilized 30 stages and incorporated 3 side strippers. Basrah light and Kirkuk crude oils were employed as the primary feeds in the distillation column. To enhance energy efficiency and maximize the utilization of crude oil, an atmospheric distillation process unit was implemented in the refinery. However, there are still ongoing challenges to overcome to optimize the entire process and yield a more valuable product.

The findings of this study offer valuable insights for refinery operators and engineers seeking to enhance operational efficiency and improve product quality through crude oil blending and distillation. The optimized design and simulation results provide a foundation for future research and can serve as a guide for the development of more

efficient and sustainable crude oil refining processes. In conclusion, the study successfully demonstrates the potential of Aspen Plus simulations in designing and optimizing crude oil blending and distillation systems. It is hoped that the outcomes of this research will contribute to the advancement of the oil refining industry and pave the way for further improvements in energy efficiency and product quality.

However, it is essential to acknowledge that there are still challenges to be addressed to further optimize the entire process and achieve a more valuable end product. The present study successfully demonstrates the potential of Aspen Plus simulations in designing and optimizing crude oil blending and distillation systems. Through rigorous simulations, we identified an optimized configuration comprising a pre-flash distillation column, an atmospheric distillation tower, and a vacuum distillation column, each equipped with 30 stages and 3 side strippers. By employing Basrah light and Kirkuk crude oils as feedstock, we determined optimal operating conditions that maximize product quality and energy efficiency. Simulations have shown that the optimized design results in products with quality equal to or better than industry standards. Furthermore, the integrated atmospheric distillation process significantly improves energy efficiency compared to traditional methods. Additionally, the optimized configuration has the potential to significantly reduce costs by reducing energy consumption and increasing product yield.

References

[1] Al-Khafaji, A.J., Hakimi, M.H., Najaf, A.A., 2018. Organic geochemistry characterisation of crude oils from Mishrif reservoir rocks in the southern Mesopotamian Basin, South Iraq: Implication for source input and paleoenvironmental conditions, Egyptian Journal of Petroleum, 27(1), 117-130. https://doi.org/10.1016/j.ejpe.2017.02.001

[2] Kareem, K.K.H., Abdulla, S.S., 2023. Determination of heavy metals and total petroleum hydrocarbons in soil samples and plant leaves around oil refineries located on erbil-gwer road, Science Journal of University of Zakho, 11(4), 492-498. https://doi.org/10.25271/sjuoz.2023.11.4.1169

[3] Ma, Y., Shi, L., Liu, Y., Lu, Q., 2017. Effects of Neutralization, decoloration, and deodorization on polycyclic aromatic hydrocarbons during laboratory-scale oil refining process, Journal of Chemistry, 2017(1), 7824761. https://doi.org/10.1155/2017/7824761

[4] Emberru, R.E., Patel, R., Mujtaba, I.M., John, Y.M., 2024. A Review of Catalyst Modification and Process Factors in the Production of Light Olefins from Direct Crude Oil Catalytic Cracking, Journal of SCI, 6(1), 11. https://doi.org/10.3390/sci6010011

[5] Muhsin, W., Zhang, J., 2022. Multi-objective optimization of a crude oil hydrotreating process with a crude distillation unit based on bootstrap aggregated neural network models, Journal of Processes, 10(8), 1438. https://doi.org/10.3390/pr10081438

[6] Widyasanti, A., Nurjanah, S., Nurhadi, B., Osman, C.P., 2023. Optimization of the Vacuum Fractional Distillation Process for Enhancing the α-Guaiene of Patchouli Oil with Response Surface Methodology, Journal of Separations, 10(9), 469. https://doi.org/10.3390/separations10090469

[7] Bayomie, O.S., Abdelaziz, O.Y., Gadalla, M.A., 2019. Exceeding Pinch limits by process configuration of an existing modern crude oil distillation unit–A case study from refining industry, Journal of Cleaner Production, 231, 1050-1058. https://doi.org/10.1016/j.jclepro.2019.05.041

[8] Koohestanian, E., Shahraki, F., 2021. Review on principles, recent progress, and future challenges for oxy-fuel combustion CO_2 capture using compression and purification unit, Journal of Environmental Chemical Engineering, p. 105777. https://doi.org/10.1016/j.jece.2021.105777

[9] Demirbas, A., Alidrisi, H., Balubaid, M., 2015, API gravity, sulfur content, and desulfurization of crude oil, Petroleum Science and Technology, 33(1), 93-101. https://doi.org/10.1080/10916466.2014.950383

[10] Nalinakshan, S., Sivasubramanian, V., Ravi, V., Vasudevan, A., Sankar, M.S.R., Arunachalam, K., 2019. Progressive crude oil distillation: An energy-efficient alternative to conventional distillation process, Fuel, 239, 1331-1337. https://doi.org/10.1016/j.fuel.2018.11.033

[11] Hou, J., Li, X., Sui, H., 2015. The optimization and prediction of properties for crude oil blending, Computers & Chemical Engineering, 76, 21-26. https://doi.org/10.1016/j.compchemeng.2015.02.006

[12] Shaoping, L., Luoyong, D., Benxian, S., Lijuan, Z., Feng, T., Xinru, X., Jingyi, Y., Beilei, Z., 2011. The distillation yield and properties of ternary crude oils blending, Petroleum Science and Technology, 29(3), 271-281. https://doi.org/10.1080/10916460902882800

[13] Radelyuk, I., Tussupova, K., Klemeš, J.J., Persson, K.M., 2021. Oil refinery and water pollution in the context of sustainable development: Developing and developed countries, Journal of Cleaner Production, 302, 126987. https://doi.org/10.1016/j.jclepro.2021.126987

[14] Dai, X., Wang, X., He, R., Du, W., Zhong, W., Zhao, L., Qian, F., 2020. Data-driven robust optimization for crude oil blending under uncertainty, Computers & Chemical Engineering, 136, 106595. https://doi.org/10.1016/j.compchemeng.2019.106595
[15] Ramesh, M., Deepa, C., Kumar, L.R., Sanjay, M.R., Siengchin, S., 2022. Life-cycle and environmental impact assessments on processing of plant fibres and its bio-composites: A critical review, Journal of Industrial Textiles, 51(4_suppl), 5518S-5542S. https://doi.org/10.1177/1528083720924730
[16] Gu, W., Wang, K., Huang, Y., Zhang, B., Chen, Q., Hui, C.W., 2015. Energy optimization for a multistage crude oil distillation process, Chemical Engineering & Technology, 38(7), 1243-1253. https://doi.org/10.1002/ceat.201400130
[17] Jabbar, K.J., Zein, S.H., Hasan, A.H., Ahmed, U., Jalil, A.A., 2023. Process design Optimisation, heat integration, and techno-economic analysis of oil refinery: A case study, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 45(2), 4931-4947. https://doi.org/10.1080/15567036.2023.2205365
[18] Ledezma-Martínez, M., Jobson, M., Smith, R., 2018. Simulation–optimization-based design of crude oil distillation systems with preflash units, Industrial & Engineering Chemistry Research, 57(30), 9821-9830. https://doi.org/10.1021/acs.iecr.7b05252
[19] Hazra, S., Morampudi, P., Prindle, J.C., Fortela, D.L.B., Hernandez, R., Zappi, M.E., Buchireddy, P., 2023. Torrefaction of Pine Using a Pilot-Scale Rotary Reactor: Experimentation, Kinetics, and Process Simulation Using Aspen Plus™, Clean Technologies, 5(2), 675-695. https://doi.org/10.3390/cleantechnol5020034
[20] Demirbaş, A., 2012. Fuels for petroleum, coal and biomass, Energy Education Science and Technology Part A-Energy Science and Research, http://openaccess.sirnak.edu.tr/xmlui/handle/11503/1368
[21] Speight, J.G., 2006, The chemistry and technology of petroleum. CRC press, 984 pages.
[22] Gary, J.H., Handwerk, J.H., Kaiser, M.J., Geddes, D., 2007. Petroleum refining: technology and economics. CRC press, 488 pages.
[23] Stout, S.A., Douglas, G.S., Uhler, A.D., 2016. Chemical fingerprinting of gasoline and distillate fuels, in Standard Handbook Oil Spill Environmental Forensics, Elsevier, 509-564. https://doi.org/10.1016/B978-0-12-803832-1.00011-8
[24] Kaes, G.L., 2008. Refinery Process Modeling: A Practical Guide to Steady State Modeling of Petroleum Processes (using Commercial Simulators), Elliott & Fitzpatrick; First Edition, 397 pages.
[25] Koohestanian, E., Sadeghi, J., Mohebbi-Kalhori, D., 2017. Simulation, and design of petroleum, gas, and chemical processes using Aspen Plus, Jahad Daneshgahi Press, 456 pages.
[26] The American Society of Mechanical Engineers (ASME), 2012. Section VIII Div. 1.
[27] Koohestanian, E., Sadeghi, J., Mohebbi-Kalhori, D., Shahraki, F., Samimi, A., 2021. New Process Flowsheet for CO_2 Compression and Purification Unit; Dynamic Investigation and Control. Iranian Journal of Chemistry and Chemical Engineering (IJCCE), 40(2), 593-604. https://doi.org/10.30492/ijcce.2020.37779
[28] Parkash, S., 2003. Refining processes handbook. Gulf Professional Publishing, 728 pages.
[29] Aspen Plus, 2011, Aspen Plus Documentation Version V7. 3. Aspen Tech, Cambridge, MA, USA, 366 pages.
[30] Ferris, A.M., Rothamer, D.A., 2016. Methodology for the experimental measurement of vapor–liquid equilibrium distillation curves using a modified ASTM D86 setup. Fuel, 182, 467-479. https://doi.org/10.1016/j.fuel.2016.05.099
[31] Hosseini, S.M., Soleymani, M., Kelouwani, S., Amamou, A.A., 2023. Energy recovery and energy harvesting in electric and fuel cell vehicles, a review of recent advances. IEEE Access, 11, 83107-83135. 10.1109/ACCESS.2023.3301329