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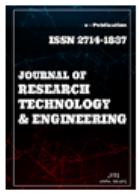

Physical properties of refining products in Najaf refinery

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Abstract: Iraq is considered one of the oil-producing countries and one of the OPEC members. Iraq has storage equivalent to 11% of the global oil and the average daily production is 3.5 million barrels. In this paper, the highlights of the Iraqi crude oil refining products in the Najaf refinery and their statistical analysis were presented in order to determine the physical properties and quality of the refining process products (Naphtha, Kerosene, Gas oil, RCR, and Iraqi crude oil). The study showed that the API for Iraqi oil is 29.3 and is considered heavy oil, and the specific gravity of Naphtha was within the internationally acceptable standard. As for the average initial and end temperatures of Iraqi gas oil, they ranged from (204.79 – 359.73) ° C, This is an important indicator of the presence of a high percentage of impurities in Iraqi gas oil. As for the salts, the percentage was 171 g/m^3 in the crude oil. It was also noted that the average percentage of sodium and water in crude oil was 0.272%, which is a high percentage, which affects the quality of the Iraqi product. As for the average flash point of Iraqi gas oil, it was 75.11 ° C, which is an important indicator of the ease of combustion.Finally, this statistical study confirmed that the Iraqi crude oil refining products in the Najaf refinery are of good quality, so this data can be used for various future studies.

Keywords: API, Flash point, Iraqi crude oil, Naphtha, Oil refining ,Oil Physical properties.

1. INTRODUCTION

Najaf Refinery is one of the external refineries of the MidlandRefineries Company, as its production capacity, consisting of three refining units, reaches 30,000 barrels per day. The Najaf refinery project is considered a major tributary to Najaf Governorate and its neighboring governorates for the production of petroleum products (naphtha , kerosene , gas oil and heavy black oil) to meet the local need, as well as supplying electrical stations, the industrial sector, and other uses. There are 18 refineries in Iraq with different production capacities, the largest of which is the Baiji refinery, with a production capacity of 310,000 barrels per day, which is geographically located in northern Iraq. Iraq contains 11% of the oil wealth in the world, with 145 billion barrels of oil, according to official recorded estimates, and it is rank third in the world after Saudi Arabia and Iran in terms of its oil wealth. It is the third largest oil exporter in the world and possesses resources that qualify it to increase its oil and gas production. Investments in the oil industry in Iraq led to an increase in oil production and its export, and consequently an increase in oil revenues, and this was reflected in the economic situation, approaching other oil countries to restore its role in global markets, and confirming its strong presence in OPEC, and

this makes it a competitor to the Kingdom of Saudi Arabia in oil production and an actor In the global crude oil marketCrude oil consists mainly of carbon and hydrocarbon and thus it is a complex mixture as the hydrocarbons are either gaseous, liquid or solid form stored in the ground for long periods of time (hundreds or millions of years) with different geological and thermal conditions, as well as crude oil contains small amounts of oxygen, sulfur and nitrogen. And trace quantities of minerals and thus the process of refining crude oil is a unique process and has multiple chemical fingerprints results (petroleum derivatives)[1].The basic standard for measuring density gravity is the American Petroleum Institute(API) as a measure of the density of petroleum using the following equation:

$$\text{API gravity} = [\ 141.5/\ \text{density at } 15.6\ C\ ] - 131.5 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Thus, it is considered an important commercial measure to know and rank the quality of crude oil, as heavy crude oil 25API, medium crude oil can be classified from 25API to 35API, and light crude oil from 35API to 45API, inversely proportional to viscosity. The density of crude oil can be measured by the American Society for Testing and Material Method(ASTM)[1].Crude oil is separated by refining it and converting it into oil derivatives that are usable and marketable. Therefore, the process of refining and separating crude oil is very important and it is considered competitive operations according to the requirements required to produce clean energy fuel[2].Although petroleum products make life easier, the life cycle from exploration to final use includes the harm to nature caused by air, water, and soil pollution[3].An oil refinery is an industrial process in which unrefined petroleum is processed and refined into other valuable products such as naphtha, gasoline, diesel, asphalt, heating oil, fuel for lighting, and LPG[4][5], more detailed is shown in Fig. 1.

Fig. 1. Daura refinery in Baghdad

The Kurdistan region of Iraq is an important factor in the oil and gas sector due to the continuous progress made in finding and exploring oil wells. However, there are real problems that the region faces in terms of the costs of exploration, equipment and companies operating in crude oil exploration[6].According to OPEC, the Kurdish region Iraq accounts for 43.7 billion barrels of proven oil reserves. The reserves yet to be proven increased by 25.5 billion barrels, ranging from 3 to 6 trillion cubic meters of natural gas, accounting for 30% of Iraq's proven natural gas Oil reserves and 89% of all natural gas reserves in Iraq[7].There are many pollutants resulting from refining crude oil and have a high environmental impact and replacing them with environmentally friendly alternative energies.

However, the field of fossil fuels remains the promising fuel for humanity in the field of power generation[8].Over consecutive a pair of decades, international demand for oil is calculable to grow to quite 107 Mb/d and also the world energy output by 2030 would account for 32% of the world demand for oil. The contribution from renewables together with wind and solar power is expected to be 4-15% and biofuel is expected to achieve 5.9 billion Mb/dby2030 . These statistics expressly show the continued development and voidance of effluent from the oil sector into giant water sources round the world. The surroundings is influenced by these pollutants. supported the oil type, the plant layout, and operative procedures, PRE are going to be substantially totally different[9].Products resulting from refining crude oil, such as kerosene, gas and petrochemicals, can be used in the energy sector, and this is an important additional financial return[10].The oil refinery is an industrial facility (storage depots, oil treatment units, distillation towers and heat exchanger units) in which oil refining operations are carried out to transform it from its crude form into various oil derivatives.The crude oil distillation system (distillation tower) is the beating heart of the refinery and the crude oil is usually heated in the furnace and converted to oil vapor mixture, which mix with the steam who is injected in the bottom of the tower. Then flows to the towerzoneand passes through thedistillation tower trays. This column is the main part for the distillation of crude oil and the separation of its various petroleum fractionsdepending on boiling point difference of oil fractions. The oil vapor ascends to the top of the distillation tower and while the liquid oil is accumulated at the bottom of the distillation tower and transported using pipelines to the storage tanks in the depot warehouses[11]. The efficiency of distillation of crude oil varies from one refinery to another. There are oil refineries that have the ability to produce nearly 40 types of gasoline with different octane numbers[12]. There are dissolved impuritiesrepresented in minerals such as nickel and vanadium, as well as salts, sediments, and water, as well as solid particles in the residue, as the high percentage of salts has a negative impact on the refining towers, such as corrosion and a decrease in the quality of the refined oil, and thus an increase in the maintenance costs as well as changes in the specifications of the refined oil[12– 15]. The increase in the percentage of water-soluble salts present in crude oil causes major problems in the pipes, valves, tanks, and pumps, as well as the interior parts of the refining tower[16,17].The impurities that have been mentioned in the previous literature lead to serious energy problems represented by blocking the furnace tubes of crude oil unit, thus increasing pressure and temperature and causing an increase in the viscosity and density of crude oil and thus reduces the attractiveness of the API for crude oil and thus becomes a low-quality fuel[19].There are some refineries suffering in heavy oil refining in terms of cost and product quality, and this affects the frequent export of the product to the global and local markets, and thus these problems can be solved by using treatment and purification units for impurities in heavy crude oil, followed by multi-stage desalination and repetition units, thus improving the quality of heavy crude oil[20].The lack of availability of light crude oil over the past few decades has led researchers, developers, and refineries operating to use heavy crude oil to refine it due to its availability and cheapness, and according to recent global estimates, the demand for heavy oil has exceeded 3 trillion barrels, which provides the world's needs for the next fossil energy[21].The problems facing the refineries for the refining of heavy crude oil are represented by viscosity, increased impurities and a decrease in the attractiveness of API compared to light crude oil, and thus it is a complex process to produce some of the products required and consumed continuously such as gasoline and light and medium distillates[21,22].Heavy crude oil is improved by adding hydrogen and removing carbon to produce relatively light crude oil that can be refined in conventional refineries. This technique was applied according to the mentioned literature[24].Most of the traditional refineries are oriented towards mainly producing gasoline, diesel and kerosene, but there are petrochemical products that have popular and desirable markets, such as ethylene, butene, propylene and butadiene, which are important raw materials for the petrochemical industries[25].There are some products that can be produced from heavy crude oil such as naphtha, which is considered a product that can be improved and converted into the gasoline that is required globally in the global and local markets[26].Thermal cracking and water cracking of recurrent crude oil are considered local methods and require high costs and high capital

investments. Therefore, there are modern methods for treating heavy crude oil using the ionizing irradiation method to treat viscosity and sulfur removal, thus a high reduction in capital and operating costs, as well as it is treated with low temperatures and air pressure and without the use of any catalysts. And thus, relatively low energy, high production efficiency, and refining flexibility[27].This paper will shed light on the physical properties of the output of heavy crude oil refining operations from Najaf refinery, which is geographically located in the middle of Iraq.

2. EXPERIMENTAL WORK

Experimental investigations of samples used in Najaf refinery (Naphtha, Kerosene, Gas oil, Black heavy oil and Iraqi crude oil) were conducted for the period 1_Jan – 4_Feb. 2021 to study the physical properties of oil productsresulting from refining operations for Iraqi heavy crude oil according to the specifications of the American Petroleum Institute (API) and the devices used are:

2.1. Distillation Automatic AnalyserAD86 5G2

The automatic distillation analyzer model (SH) works at a voltage of 115 F and a frequency of 50 H, 16 A French made. It consists of a graduated cylinder with a capacity of 100 mm and a distillation flask with a capacity of 100 mm. The device works automatically to distill the hydrocarbons under specific conditions. A certain volume of sample is distilled under suitable conditions. Capacitor temperatures, sizes and times are recorded according to symptoms. Likewise, distillation or volatility is calculated from the resulting data and used in turn to determine the safety and performance of the sample with the international methods that are compatible and applicable within the required specifications (the international standard method ISO 3405) and as shown in the Fig. 2.

Fig. 2. Distillation automatic analyzer AD86 5G2

2.2. Automatic Vapor Pressure Analyzer (HVP 9972)

The device determines the steam pressure with high accuracy for both automotive and aviation gasoline, turbine fuel, other light distilled petroleum products, crude oil, hydrocarbon solvents and chemical compounds.The device provides fast and accurate results of steam pressure up to 1000 kPa in a temperature range from 0 to 100 ° C through its complete automation as shown in the Fig. 3.The device is characterized by its ease of use and thus saves time with strict quality and accurate calibration. It connects to a computer device to store the resulting data.The sample to be tested is withdrawn automatically with a volume of 10 ml by means of a piston. The time measurement period for the

sample to be examined ranges from 10 minutes, and it measures the change of the liquid vapor ratio

Fig. 3. Automatic Vapor Pressure Analyzer (HVP 9972)

from 05 to 4. The device works at a voltage of 100 - 240 V, 50 Hz, and a consumption power of 100 W.

2.3. Automated Multi-Range Capillary Viscometer ASTM D445

The multi-band viscometer determines the kinematic viscosity of clear and opaque fluids through 2 multi-band capillaries. As it requires drawing 18 ml of the sample and thus the device gives accurate results automatically and the spent sample flasks are automatically emptied, allowing new samples to be added at any time until the middle of the test for rapid analysis in the viscosity range from 05 to 600 mm / s and thus provides smart technology. The device operates at temperatures from 20 to 150 degrees Celsius that are programmable by the user and is characterized by accurate control of the relative temperature of 0001 degrees Celsius and a high rotation speed, as shown in the Fig. 4

Fig. 4. Automated Multi-Range Capillary Viscometer ASTM D445

2.4. Flash Point Analyzer FP170 5G: ABEL AUTOMATED

It is a device used to measure the expected flash temperature through a preprogrammed sample test, and it is divided into two basic units, which are the control unit and the test unit. As shown in the Fig. 5. Also able componentsare :

- Heating block,
- Cooling system,
- Stirring system,
- Ignition system,
- Flash detector,
- Sample temperature probe,
- Shutter,
- Diagnostics.

Fig. 5. Flash point analyzer FP170 5G: ABEL AUTOMATED

3. RESULTS AND DISCUSSION

This statistical study was conducted to determine the physical properties of Najaf refinery products (naphtha, kerosene, gas oil, heavy black oil and Iraq heavy crude oil) for study period.Their API averages were respectively (71.8, 47.97, 35.83, 14.39 and 29.3).Standard (API) for the above-mentioned productsas shown in Fig. 6 and the random red points represented the physical properties of (API) for monthly level depending on the refinery characteristics of the Iraqi crude oil.

Fig. 7 clarifies the physical properties of Najaf refinery products (naphtha, gas oil, and black heavy oil), represented by the specific gravity of the products mentioned above, have been determined, and the red points that represent a rise and fall in the specific gravity of naphtha and heavy black oil have been determined while the specific gravity of gas oil remains stable relative, and it is considered an important

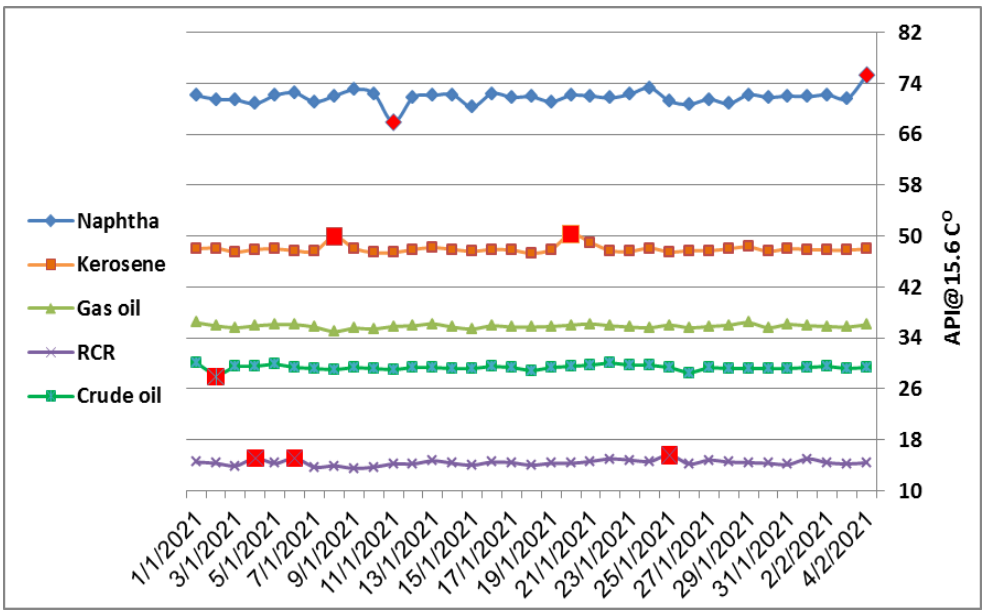

Fig. 6. API comparison of Iraqi crude oil refining products at Najaf refinery

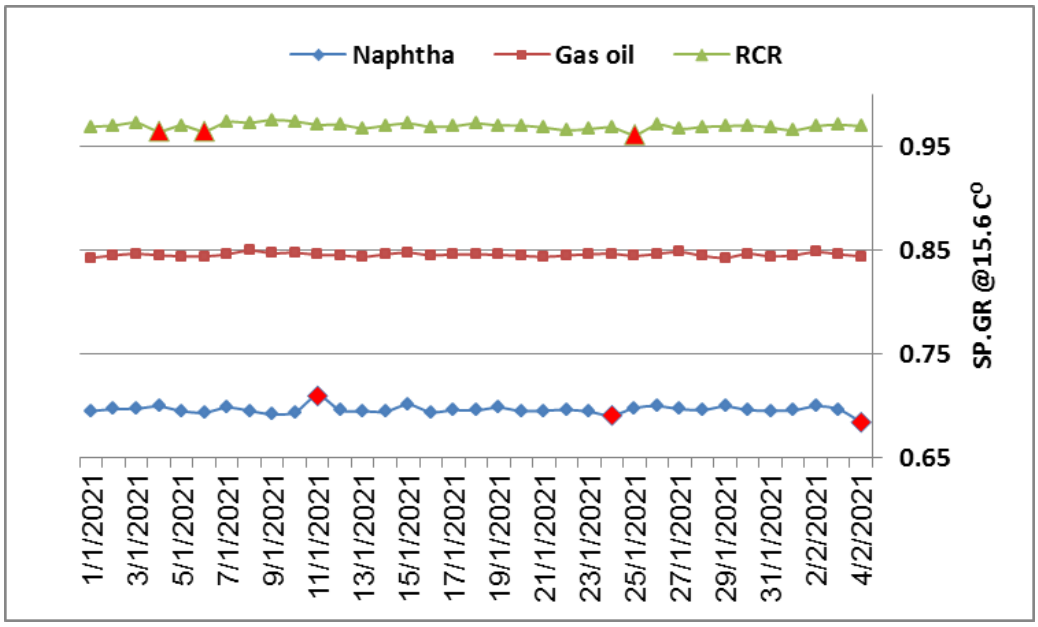

Fig. 7. specific gravity of Najaf refinery products (naphtha, gas oil, and black heavy oil)

indicator depending on the specifications of Iraqi crude oil.

Fig. 8 shows the results represented by the density of the products of Najaf refinery (kerosene, gas oil and black heavy oil) and the red points that show the rise and fall of the above-mentioned products of

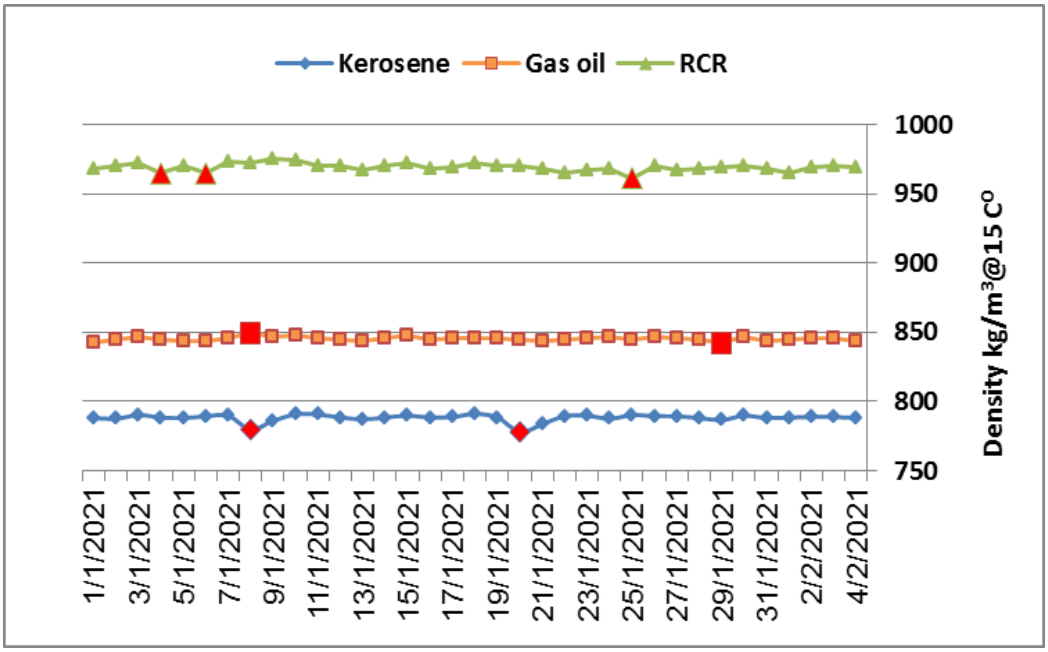

Fig. 8. The density of Najaf refinery products (Gas oil, and Kerosene and RCR)

monthly level depending on the Iraqi crude oil.

The initial and end temperatures for the kerosene and gas oil products are illustrated in Fig. 9. As it was found that the initial and end temperature of the gas oil is higher than the kerosene.The average initial

temperature of the gas oil was 204.79 ° C, while the average end temperature of the same product was 359.73° C.

When the flash point was analyzed statistically, a clear fluctuation was observed for the monthly level of the heavy black oil product (RCR) compared with gas oil and kerosene, as shown in Fig. 10. The highest temperature of the flash point of the RCR was 112 ° C while the average temperature was 95.45° C.

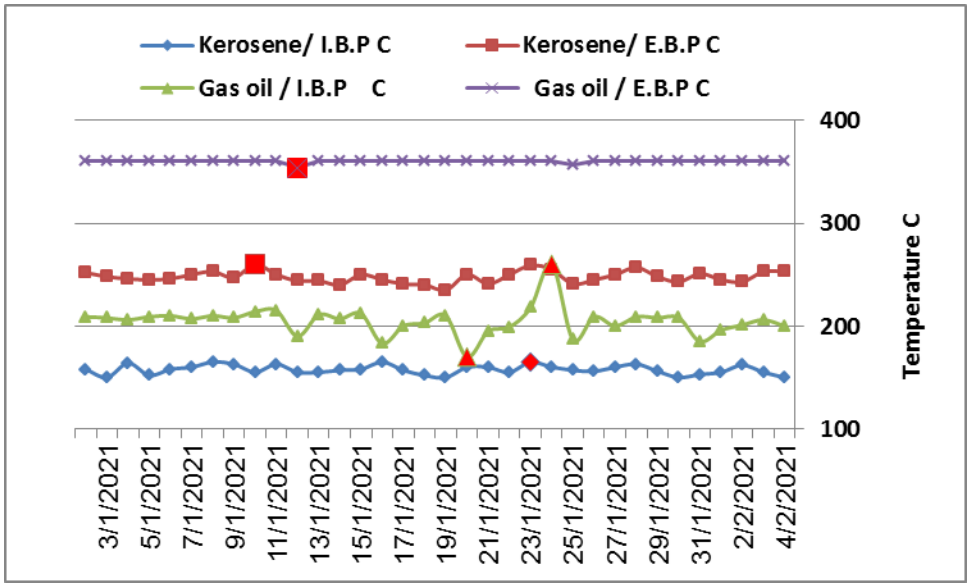

Fig. 9. The initial and end temperatures for the kerosene and gas oil products

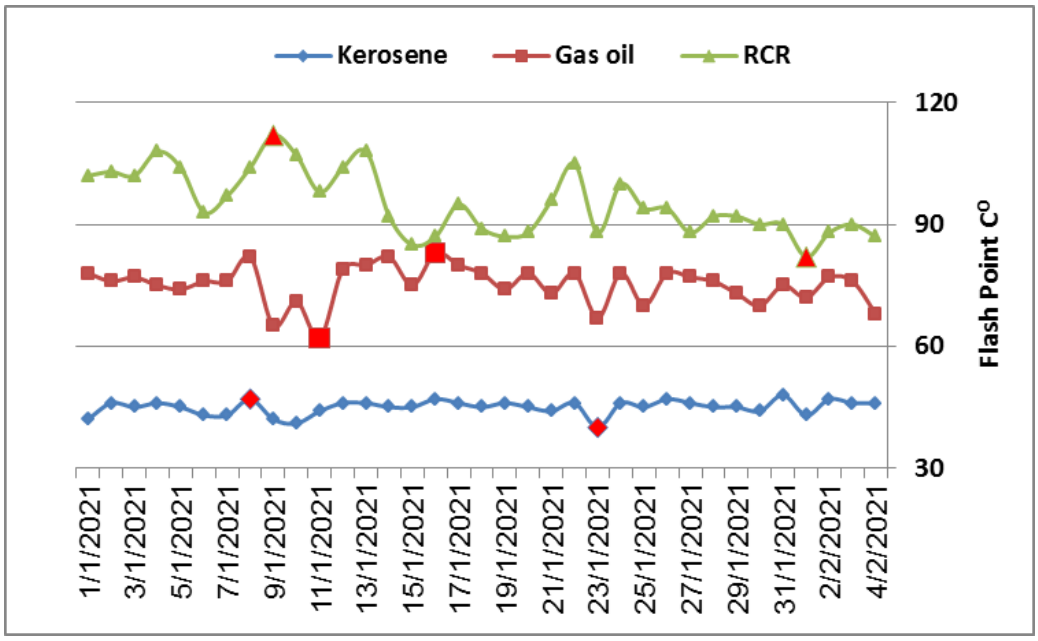

Fig. 10. Flash pointof Najaf refinery products (Gas oil, and Kerosene and RCR)

Salt is an important factor in determining the quality of Iraqi heavy crude oil, as its statistical analysis for the month of January was clearly fluctuating, as shown in Fig. 11. The highest and lowest concentration points were determined (456, 22.8)g/m^{3}respectively, while the mean monthly salts content

were 173.6 g/m^3.The failure to treat crude oil in the production stage led to the crude oil containing a large proportion of salt and water.

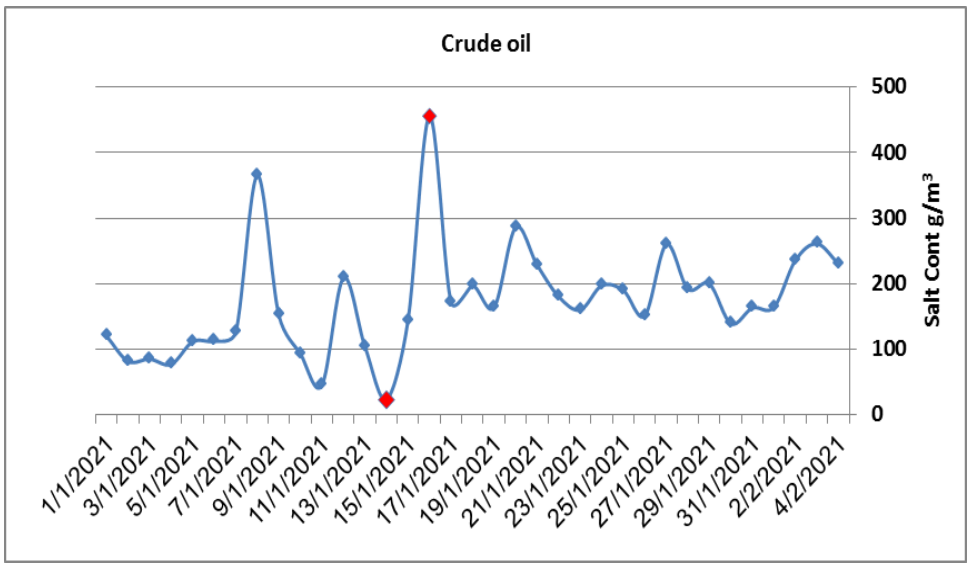

Fig. 11. The salt concentrationin Iraqi crude oil

Viscosity provides a measure of the resistance of an internal fluid to flow. Calculating fluid motion requires the viscosity value. For RCR, the average viscosity during the analysis period was 305.11 mm^2/s at a temperature of 50 ° C, while the highest and lowest viscosity obtained respectively was (395 and 203)mm^2/sat a temperature of 50 ° C as shown in Fig. 12.

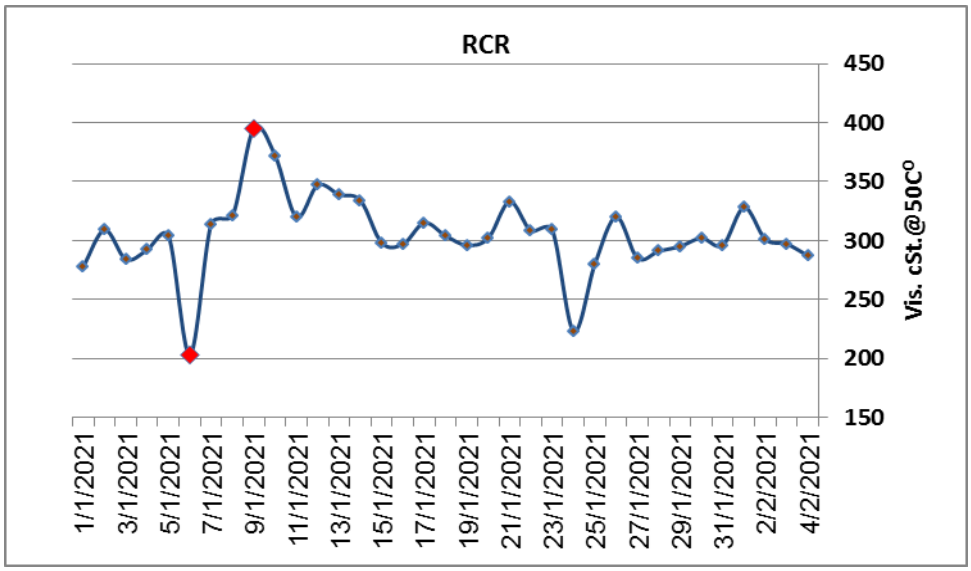

Fig. 12. RCR viscosity

The cetane number (CN) is an indicator of the ignition of Iraqi gas oil fuel, which is considered reliable to describe the quality of the combustion process. The highest value of CN obtained is 54.1 which means ignition delayand at the same time better performance, while the lowest CN was 50 as it causes lower ignition performance and longer time. While the monthly average during the period of statistical analysis for the month of Jan.2021 was 52, as shown in Fig. 13.

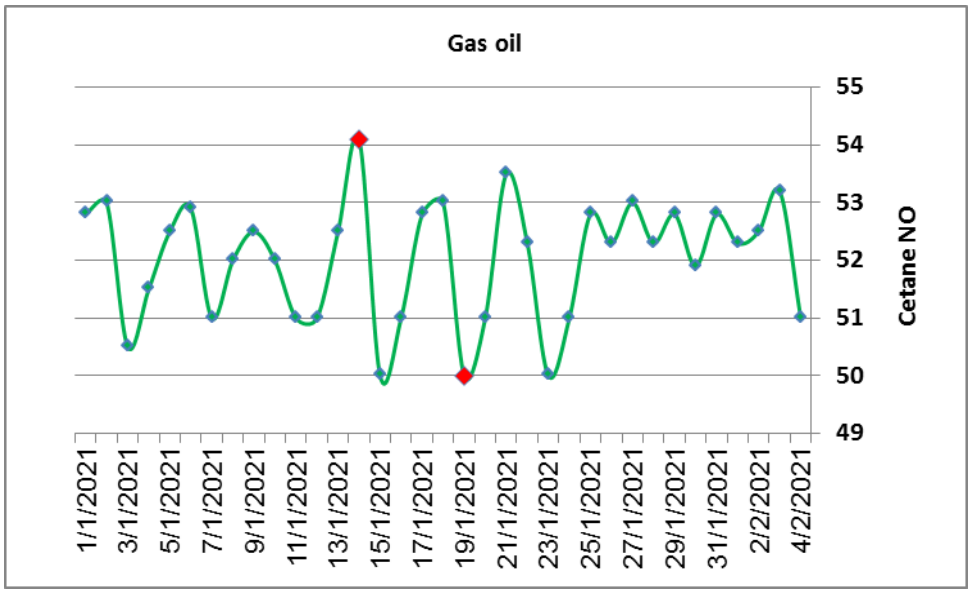

Fig. 13. The cetane number of Iraqi gas oil.

4. CONCLUSION

1- The average Iraqi crude oil API is 29.3, and it is considered heavy oil compared to the international standard, which is about 25.
2- The average specific gravity of the Iraqi naphtha was obtained at a value of 0.696, which is close to the global value of 0.667[28]. This is an important indicator of the quality of refining Iraqi crude oil in the Najaf refinery.
3- The average density of Iraqi kerosene was 788 kg/m3, which is within the range of the international standard from (775-840) kg/m3[28]. The fluctuations in densityat the monthly level represented by the red points in Figure(8) were acceptable and within the global range.
4- The average density of Iraqi gas oil was 845.22 kg/m3, which is less than the international standard of 849 kg/m3[28]. Thus, this type of refined fuel can be used in the relatively hot weather, which represents the weather in Iraq.
5- Higher specificgravity was0.9697for RCR compared with other oil products like Naphtha and Gas Oil (0.6962, 0.8458) respectively.
6- The average temperature of the initial and end boiling point of stander gas oil was (248 - 321) ° C[29], while for Iraqi gas oil (204.79 – 359.73) ° C, respectively due to impurities in the crude oil stocks that affect the quality of the product.In addition, the salt concentration content was 171 g/m3, and the ratio of sodium and water(B.S&W) was 0.272%for the crude oil, which consider very high.
7- The flash point of a gas oil is the lowest temperature at which enough liquid has evaporated to form a flammable gas concentration. The global range was (37.7 – 95.5) ° C[30], while the

average range of Iraqi gas oil was 75.11 ° C. Gas oil with a higher flash point had a low flammability, which is an indication of how easy it is to combust.

5. RECOMENDATIONS

After studying the physical properties of crude oil derivatives in the Najaf Oil Refinery (NOR), the researchers recommend the following:

1. Making a comparative study with different periods for the same derivatives produced from the Najaf refinery.
2. Analyzing the data statistically for different periods to predict the physical properties of crude oil derivatives.
3. Providing sufficient infrastructure to work to benefit from crude oil derivatives (refining units), such as producing gasoline and others.

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