

RESEARCH ARTICLE

COMPARATIVE EVALUATION OF PHYSICAL PROPERTIES OF SOME YEMENI CRUDE AND FUEL OIL

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Abstract

Due to the high significance of crude oil to modern society as a source of energy and as raw material for a wide chemical and petrochemical industries; in this study, we evaluate the characteristics of certain Yemeni crude, and fuel oils specifically Mareb crude oil blend, Masila crude oil blend plus two samples from Sounah and Hijah oil fields in Masila basin. The general specifications of these crudes and fuel oils are determined and compared with some other regional and international types including Brent and West Texas benchmark crudes using the published data in the specialized literature. It is revealed that Mareb crude oil blend is the lightest and sweetest crude oil followed by Sounah crude while Masila is considered Medium crude and Hijah field is the heaviest with medium sulfur content. Mareb, Masila blends, and Sounah field fuel oils are considered low sulfur fuel oils with sulfur content below the 1% standard marketable fuels; while the Hijah fuel oil slightly above, and this is absorbed within the marketable blend.

Keywords: Crude, Fuel oil, Mareb, Masila oil, Characterization.

1. Introduction

The utility of remote sensing data and its integration with other physical and structural data in the GIS domain to demarcate the potential areas of oil and gas exploration. The achieved results have manifested the oil-gas potential zones, which were detected through the use of GIS MCE based Fuzzy logic, and was subsequently validated. The study logically proves that almost all of known oil-gas discovered wells coincided with the extremely favourable zones in the Sauyn – AlMasilah Basin. MCE based fuzzy logic is a new approach that can be applied in oil-gas exploration in the frontier Yemeni Basins [2].

Crude oil is a naturally occurring mixture, consisting predominantly of hydrocarbons, Sulphur, nitrogen and metals. Quality of petroleum products is playing the major role of consumer satisfaction and speaks about the performance of the refineries [3]. To identify and predict the behaviour of crude oil and finished petroleum products in particular circumstances, it is necessary to measure Physic-chemical properties [19]. And to compare the measured values with International Standards. The typical nature of crude oil from different sources is different or less identical. Crude oils are complex but

mainly paraffinic, naphthenic and aromatic. [20]. Crude oils contain all normal alkenes from C1 to C120 [1, 13].

2. Site Description

MasilaMasila Basin is one of the onshore basins in Yemen, which is located in the east part of Yemen (Fig. 1). The Masila Basin is classified as enormous hydrocarbon basins in the Yemen and contains a few, notable hydrocarbon oilfields (Fig. 1A). However, the area of interest of this study is the Masila, Hijah and Sounah oilfield.

These oilfield is one of the most productive oil fields in the Masila Basin, located in the N/W sector from the Masila Basin (Fig. 1A). These oilfield is likewise bordered with a few effective delivering oilfields such as WadiTaribah, Kharir and Tasour oilfields (Fig. 1B).

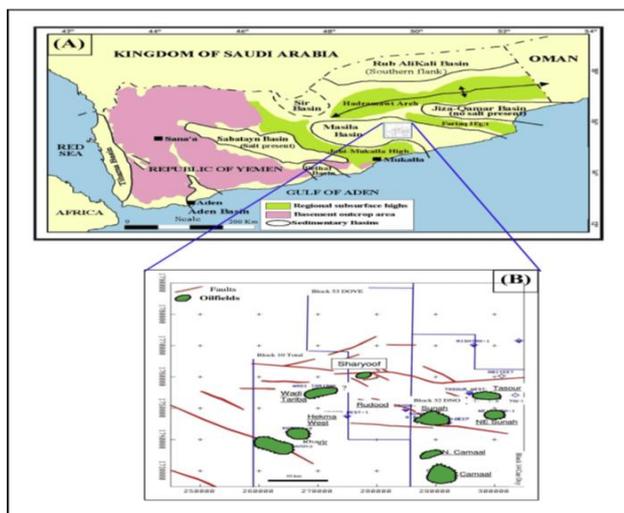


Figure 1: (A) Main sedimentary basins in the Republic of Yemen [4]) and (B) location map of some Masila Basin's Blocks including Sharyoof oilfield (Block 53), Hadramout region of the Republic of Yemen.

The main structures in these areas oilfield are characterized by horst, tilted fault blocks formed during Late Jurassic-Early Cretaceous and developed during the Oligocene-Middle Miocene time as a result of the opening of the Red Sea and the Gulf of Aden during the Tertiary rifting tectonic event [16, 12, 11, 7, 6].

The Masila fields are associated with the Upper Jurassic to Lower Cretaceous Sayoun Masila rift graben basin. Almost 90% of the oil reserves discovered are in the Lower Cretaceous upper Qishn sandstones, Qishn Formation, Tawilah Group. Oil also is found in seven other reservoirs consisting of Lower Cretaceous and Middle to Upper Jurassic elastics and carbonates as well as a fractured granitic basement. The uppermost marine sandstones are more homogeneous because they are texturally more mature. The major field accumulations are tilted, normal-fault block structures located over basement paleohighs and dependent on cross-fault juxtaposition against overlying Qishn Carbonates Member top seal.

Another area of interest in this study is the section in the Mareb and Hijah basin block as shown in Fig (2).

The stratigraphic section in the Mareb-Shabwa Basin is dominated by a thick Mesozoic succession and ranges in age from Jurassic to Cretaceous. Hydrocarbon exploration activity became extensive after 1990 and provided a considerable amount of subsurface data, which allowed the revised synthesis of basin progression in Yemen, such as the work done by [1, 4, 9]. The petroleum geology was summarized in [8]. Two major tectonic periods occurred that formed the tectonic evolution of Yemen.

The first events took place in the Late Jurassic – Early Cretaceous, when three basins developed within Gondwana land: the Mareb-Shabwa, the Sir-Sayoun, and the Jeza-Qamar basin. The second major tectonic activity in the Cenozoic was related to the opening of the Gulf of Aden and the Red Sea and the collision of the Arabian Peninsula with Eurasia, respectively [14]

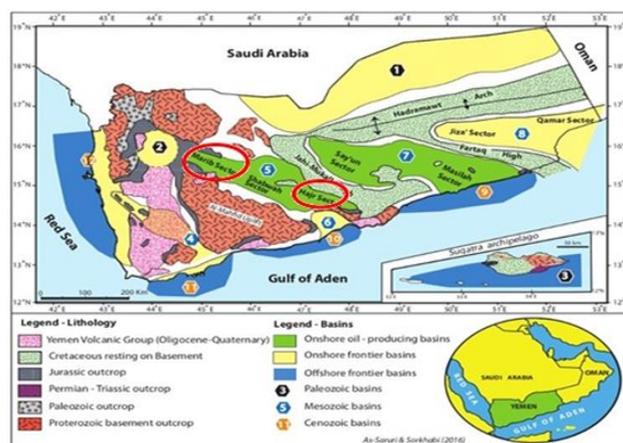


Figure 2: location map of Mareb&Hijah Basin's block.

3. Objectives

Studying the characterization of crude oil and fuel oil (Masila, and MarebShabwa basin), and comparing with other fuel oil and crude oil in the world.

4. Material and Method

Crude oils from Masila, HijahSounah and Mareb-Shabwa were collected and taken from Aden Refinery Company. And prepared for examine such as characterization of crude oils and fuel oil

Characterization of crude oils. And fuel oil

- 1) Density and Specific Gravity: according to (ASTM D-1298) method using hydrometer cylinder, hydrometer and glass stirring.
- 2) Kinematic Viscosity at 40°C: according to (ASTM D-445) method using viscometer measuring (5/4685,5/61315,5/4686,5/4688), Kv-55, Kinematic Bath produced in Tanaka Scientific Limited Company, electric furnace 100°C.
- 3) For determination of total salts content of Crude oil, according to Conductivity Method (IP 265)
- 4) Using thermometer, cylinder, conductivity cell and meter.
- 5) According to the Reid method (ASTM D-323), we determined Vapor Pressure of Crude Oil, and fuel oil using vapor pressure bomb, manometer, Auto Vapor Pressure Tester model AVP-30 D
- 6) Water and Sediment in Crude Oil and fuel oil by the Centrifuge Method: according to (ASTM D-4007) using toluene, Oil Test Centrifuge Model Set A produced in Germany, centrifuge tubes, Interdit Pour TouteMettler PE 600 Transaction and Heating bath.
- 7) Determination of Sulfur in Crude Oil and fuel oil: according to (IP 336), using Sulfur – In Oil analyzer model SLFA- 2800 – Horiba Company.

5. Results and Discussion

Specific gravity or density is an important parameter to measure the quality of crude oils. Low specific gravity indicates good quality of crude oil having lighter fractions

and vice versa. The specific gravity of all Yemeni crude oil (Table 1) shows that highest density was in Haijah crude oil (0.9095 kg/m³ and the lowest was in Mareb crude oil (0.8051 kg/m³). The specific gravity of the crude oil gives a rough measure of the amount of lighter hydrocarbons present in *Yemeni crude oil*.

API gravity 22.30°: Sweet crude oil is considered “sweet” if it contains less than 0.5% sulfur (commodity-trading-today.com). Sour crude oil is that when it contains total sulfur contents greater than 0.5% (commodity-trading-today.com). Sulphur is highly poisonous, cause foul-smelling, corrosion and plant rusting. Sulphur is one of the major concerns of refineries. Certain crudes evolve hydrogen sulphide, low boiling sulphur compound and decomposition products of heavy sulphur compounds during processing. However, most of the sulphur compounds concentrate in the distillation residue. Alkali washing and hydro treating remove the sulphur in the distillate.

Table 1. Indicate that highest specific gravity was in Hijah crude oil (0.9095 kg/m³), the lowest in Mareb crude oil (0.8051 kg/m³) while in Sounah and Masila crude oil was (0.8473 kg/m³, 0.8545 kg/m³ respectively. All samples are under normal value (0.82-0.90 kg/m³) except Hijah crude oil which shows the highest value. The results of statistical analysis showed API values for every sample were significantly different at p<0.05.

Viscosity: measurement helps in the pump design. It also gives a rough idea about the different fractions of the crude oils. If viscosity is low, then the crude oil sample will have more light refractions. Viscosity data at temperature 40°C (table 1) indicate the highest viscosity is in Hijah crude oil (25.348 cst) and lowest in Mareb crude oil (1.781 cst) while in Sounah and Masila crude oil are (5.014 cst, 5.820 cst) respectively . Comparing these values with Syrian crude oil, we found that viscosity of all studied samples was lower than Syrian (Table 3). The results of statistical analysis showed viscosity values for every sample were significantly different at p<0.05.

Sulfur: in Table (1) shows that highest percentage of sulfur is in Hijah crude oil (0.886 %), the lowest is in

Mareb crude oil (0.105 %), while in Sounah and Masila crude oils are (0.4695 % , 0.483 %) respectively.

Sulphur: content in all Yemeni Crude Oils samples in this study is the lowest, it is under the normal value (6- 0.1). International crude oils have Sulphur range 0.14-1.48 wt% and Yemeni crude oils have lower Sulphur as shown in (Tab.3). So Yemen crude oils are better in quality on the basis of sulfur than international crude oils.

Water and sediments: in crude oil lead to the corrosion of the plant. Water in crude oil is either in the form of an emulsion or in large droplets.

Table 1. Shows that the content of water and sediments in Sounah crude oil is the higher (0.70 %) and low content water and sediments in Mareb and Hijah (0.05), while in Masila crude oil is (0.1 %). There is no significant in water content and sediments among Hijah, Mareb and Masila crude oils. As shown in table 1. The results of statistical analysis showed water and sediments values for Sounah and Masila samples were significantly different at p<0.05.

It was found that Highest of total salts of NaCl was in Sounah crude oil (33.0 PTB), the lowest of NaCl was in Masila and Hijah crude oil (2.0 PTB) while in Mareb crude oil was (3.0 PTB). Comparing with Syrian crude oil (Tab.3), it was found that the percentage of NaCl in all studied samples were higher than in Syrian crude oil . Statistically there is no significant at p<0.05 in percentage of NaCl in Hijah, Mareb and Masila crude oil, while there are significantly different at p<0.05 between Sounah and other studied samples of crude oil.

Reid vapor pressure: measurement can be used to estimate the volatile contents and transportation purposes. Table 1. Indicates that the highest vapor pressure is in Mareb crude oil (9.6 psi), and the low vapor pressure is in Hijah crude oil (1.1 psi), while in Masila and Sounah are (5.6 psi and 7.6 psi) respectively.

It was found that vapor pressure of Masila crude oil equivalent of vapor pressure of Syrian crude oil (5.8 psi), statistical analysis showed vapor pressure values in all studied samples are significantly different at p<0.05.

Table 1: Characterization of Yemeni Crude Oil (Mean ± SD)

Property / Sample	Density/ Specific Gravity Kg/m ³	Kinematic Viscosity Cst at 40°C	Sulfur Content%	Vapor Pressure p/inc2 psi	Water and Sediment %	Total salts p/1000 PTB
Marib oil	0.8051±0.0001	1.781±0.001	0.105±0.001	9.0±1	0.05±0.01	3.0±0.1
Masila	0.8545±0.0001	5.820±0.001	0.483±0.001	5.6±0.1	0.10±0.1	2±1
Hijah	0.9095±0.0001	25.348±0.001	0.886±0.001	1.1±0.1	0.05±0.01	2. 0±0.1
Sauna	0.8473±0.0001	5.014±0.001	0.4695±0.0001	7.6±0.1	0.70±0.01	33±1

Yemeni Fuel oil

Heavy fuel oil is chemically very complex consisting of many different compounds. Complete characterization of HFO is impractical if not impossible [15]. However, there are some methods by which the overall composition can be determined by analyzing groups of similar components.[15]

Residual fuel oils are sometimes called light when they have been mixed with distillate fuel oil, while distillate fuel oils are called heavy when they have been mixed with residual fuel oil. Heavy gas oil, for example, is a distillate that contains residual fuel oil.

Fuel oil is made of long hydrocarbon chains, particularly alkanes, cycloalkanes and aromatics. The term fuel oil is also used in a stricter sense to refer only to the heaviest commercial fuel that can be obtained from crude oil, heavier than gasoline and naphtha.

The physical properties of four Yemeni fuel oil Mareb, Masila, Sounah and Hijah were studied .

Table 2 shows that the highest specific gravity was in Hijah fuel oil (0.9649 kg/m³), the low was in Mareb (0.9364 kg/m³) while in a fuel of Sounah and Masila (0.9450 kg/m³ and 0.9460 kg/m³ respectively. Comparing the value of Yemeni fuel oil were highest than Specific gravity of Pennsylvania, Texas, and Iranian fuel oil, while specific gravity of Yemeni fuel oil equivalent to specific gravity of Mexican fuel oil. (Table 4). The results of statistical analysis showed specific gravity values for every sample were significantly different at $p < 0.05$.

Table 2 indicates the highest viscosity was in Hijah fuel oil (615.1 cst) and the low viscosity was in Mareb fuel oil (107.6 cst) while the viscosity of Masila and Sounah fuel oil was (298.7 cst), (343.9 cst) respectively. Comparing these values with the values in (table 4) and under normal

value (180cst), we found that the viscosity of fuel oils of Hijah, Sounah and Masila was higher than normal value. Except in fuel oil of Mareb which is under normal value.

The results of statistical analysis showed viscosity values for every sample were significantly different at $p < 0.05$. According to table 2, the sulphur content in Hijah fuel oil is the highest (1.218 %) and the low content is in Mareb fuel oil (0.469%), while the content in Sounah and Masila is (0.919 %, 0.991 %) respectively. From (Table 4) indicates that the content of sulphur in Hijah fuel oil higher than in Pennsylvania fuel oil, while the other samples are low than Pennsylvania fuel oil

On the other hand, the content of Sulphur in all samples are lower than in fuel oils of Mexico, Texas's and Iranian. Comparing the value of Sulphur in this study, we found that they are under the normal value (3.5 %). The results of statistical analysis showed sulfur values for every sample are significantly different at $p < 0.05$.

Flash Point

The flash point of engine oil is the lowest temperature to which the oil must be heated underspecified conditions to give off sufficient vapor to form a mixture with air that can be ignited spontaneously by a specified flame. The flash point of engine oil is an indication of the oil's contamination. A substantially low flash point of engine oil is a reliable indicator that the oil has become contaminated with volatile products such as gasoline. The flash point is also an aid in establishing the identity of a particular petroleum product. The flash point increases with an increasing molecular mass of the oil. Oxidation would result in the formation of volatile components which leads to decrease the flash point [17].

Table 2: Properties of Yemeni Fuel oil (Mean \pm SD)

Property Sample	Density Kg/m ³	Kinematic Viscosity cst at (50- ° C 60 ° C)	Sulfur content %	Flash point ° C	Pour ° C	Water %
Marib oil	0.9364 \pm 0.0001	107.6 \pm 0.1	0.469 \pm 0.001	132 \pm 2	36 \pm 2	0.05\pm0.01
Masila	0.9460 \pm 0.0001	296.7 \pm 0.1	0.991 \pm 0.001	226 \pm 2	30 \pm 2	0.05\pm0.01
Hijah	0.9649 \pm 0.0001	615.1 \pm 0.1	1.218 \pm 0.001	222 \pm 2	27 \pm 2	N.F
Sounah	0.9450 \pm 0.0001	343.9 \pm 0.1	0.919 \pm 0.001	232 \pm 2	21 \pm 2	N.F

Table 2 shows that the highest flash point was in Souna fuel oil (232°C), the low was in Mareb Fuel oil (132 ° C), while in Hijah and Masila fuel oil were (222 ° C, 226 ° C) respectively. There is no significant between Mareb and Sounah fuel oil samples, and between Masila and Hijah fuel oil, but there are statistical significant between all studied samples at $p < 0.05$. According to the lowest flash point (66 ° C) it was found that all samples have higher value of flash point.

Pour point

The pour point of an engine oil is the lowest temperature at which the oil will remain in a flowing state. Most engine oils contain waxes and paraffin's that solidify at

cold temperatures. Engine oils with high wax and paraffin content will have a higher pour point. Pour point is highly affected by an oil's viscosity, and engine oils with high viscosity are characterized by having high pour points. The pour point of an engine oil is an important variable, especially when starting the engine in cold weather. The oil must have the ability to flow into the oil pump and then pumped to the various part of the engine, even at low temperatures [18].

Table 2 shows the highest pour point was in Mareb fuel oil (36 ° C), and the lowest was in Sounah (21 ° C), while in Hijah and Masila fuel oil was (27 ° C, 30 ° C) respectively. We found that pour point in Sounah fuel oil equivalent with pour point in Syrian fuel oil (table 4), while the other samples higher than Syrian fuel oil.

There is no significant at $p < 0.05$ between pour point in Masila fuel oil and Mareb fuel oil, but there are significant between other studied samples. According to normal value of pour point (24°C) it was found that in Mareb, Masila, Hijah fuel oil was the highest than the normal value, but in Sounah was the lowest.

Table 2 shows that the **water** content in Mareb and Masila fuel oil was (0.05 %), while in Hijah and Sounah the water content didn't found.

Comparing water content in studied samples with Syrian fuel oil, we found that the content of water in Mareb and Masila fuel oil were lower than in Syrian fuel oil. In addition the water content in studied samples under the normal value (0.5 %). Statistically, there is no significant at $p < 0.05$ between all samples.

Table 3: Reported values of physical parameters of some crude oil [10]

Characteristics	Texas Gulf Coast Mtx	Nigerian (Bonney)	Canada (Red water)	Venezuela (Lagemar)	Pakistan (Min-Max)	Syrian	Yemeni (Mareb)
API Gravity	36.5	38.1	34.9	30.7	22.3-47.4	0.9094	0.8051
Viscosity	41.0	38.4	47.8	107.0	-	31.6	1.781
Sulphurwt %	0.16	0.14	0.56	1.48	0.018-0.9	4.08	0.105
Water & Sediments vol. %	0.1	Trace	Trace	Trace	0.018-0.0927	0.670	3.0
Reid vapor pressure	32	6.9	8.4	2.5	3.0-7.0	5.8	9.0

Table 4: Reported values of physical parameters of some International fuel oil

Characteristics	Iran	Pennsylvania	Texas	Mexico	Syria	Mareb	Masila	Hijah	Sounah
Specific Gravity	0.897	0.82	0.982	0.95	0.95	0.9364	0.9460	0.9649	0.9450
Viscosity	88	4.02	176	1500	950	107.6	296.7	615.1	343.9
Sulphur %	1.7	1	1.33	3.27	-	0.469	0.991	1.218	0.919
Flash Point	Above 65	-	71	Above 65	65	132	226	222	232
Pour Point	-	-	-	-	20	36	30	27	21
Water %	-	-	-	-	1	0.05	0.05	trace	trace

6. Conclusion

Based on the physicochemical evaluation of crude and fuel oils of different basins and oil wells in Yemen, Mareb, Masila, Hijah and Sounah, the results show that Mareb field A was the best according to crude oil, followed, Sounah, Masila then Hijah.

According to fuel oil, the results show Mareb fuel oil was the best one, followed Masila, Sounah then Hijah. Obviously it depends on the:

The Qishnclastic reservoir rocks have generally good reservoir properties for oil accumulation with relatively high effective porosity and permeability and low shale contents.

The oil mobility is relatively high and the oil producing can be expected. On the other hand, the characterization of reservoirs by a detailed petro-physical parameter estimation revealed that the dominated of sand bodies as a result of the presence of high values of porosity and permeability as well as high fraction value of Sandstone. Northwestern part of Yemen is a promising area for more prospecting activity.

In general, all tested samples of Yemeni crude, and fuel oils have better quality than the other samples has been reviewed from literature and taken into consideration in this study.

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دراسة مقارنة للخصائص الفيزيائية لعدد من عينات النفط وزيت الوقود اليمني

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المُلخَص

نتيجة لأهمية النفط في الحياة اليومية واستخداماته الواسعة، تم دراسة الخصائص الفيزيائية لأربعة أنواع من النفط الخام وزيت الوقود اليمني (خام وزيت الوقود - مآرب، المسيلة، سونا و هيجا). من خلال المقارنة وجدنا بأن خام نפט مآرب من حيث مواصفاته كان الأفضل يليه نפט سونا فالمسيلة ثم هيجا. أما فيما يتعلق بزيت الوقود فقد كان زيت وقود مآرب هو الأفضل يليه زيت وقود المسيلة ثم سونا وبعدها هيجا. وعند مقارنة النفط الخام وزيت الوقود اليمني مع النفط الخام وزيت الوقود لبعض الدول وجدنا بأن النفط الخام اليمني وزيت الوقود بشكل عام من حيث المواصفات الفيزيائية أفضل من أنواع النفط الخام وزيت الوقود في الدول التي تمت مقارنتها معه. جميع أنواع زيت الوقود تعد مفضلة للاستخدام في عملية التكسير والعمليات الصناعية اللاحقة وذلك لانخفاض كلفة عمليات التحويل اللاحقة. وهذا يدل أن أنواع النفط الخام وزيت الوقود اليمني التي تمت دراستها تمتلك مواصفات عالية تضعها في مرتبة متقدمة عند التقييم.

الكلمات المفتاحية: النفط الخام وزيت الوقود، نפט مآرب والمسيلة، خصائص.

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