



An experimental investigation for flow characteristics of heavy oil in pipe lines using dilution technique with different solvents

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Article information

Article history:

Received: November, 12, 2023

Accepted: December, 24, 2023

Available online: April, 08, 2024

Keywords:

Heavy fuel oil

Viscosity

Dilution

Ethanol

Kerosene

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Abstract

Heavy fuel oil (HFO) is considered as a major fuel in steam power plant in Iraq. High viscosity and high energy requirements for fluid pumping are issues that affect the movement of crude oil via pipelines. A great viscosity is a serious problem in flow and combustion. Viscosity reduction techniques can improve flow. The objective of this work is to reduce the viscosity and enhancing the flow characteristics of heavy fuel oil in pipes using different solvents. The experimental includes oil pump, oil pipe (1.27 cm diameter and 2 m length), pressure gauge, magnetic stirrer, and Brookfield viscometer. Various types of solvents added to Heavy fuel oil to reduce its viscosity and improve heavy fuel oil characteristics; Kerosene (5, 10, 15, 20, 25, 30 vol.%) and ethanol with same adding percent are tested. The experimental results showed that viscosity reduction achieved 26% using 20 vol% ethanol and 53% at 20 vol% of kerosene. This viscosity reduction improves the flow properties as Reynolds number and pressures where the Reynolds increased by 19.25% and pressure drop decrease by 22.58% at 20% of ethanol in addition when adding 20 vol% of kerosene the Reynolds number increased by 51.21% and pressure drop decrease by 56.68%. The findings of this research is considered as a major contribute for heavy fuel oil pumping and hence reduce the environmental impacts. Also the results proved that the dilution at the use percentage is considered as economically feasible since kerosene and ethanol are available at low costs in Iraq.

1. Introduction:

Heavy fuel oils are a significant source of energy. In recent years, there has been a global increase in the requirement for heavy fuel oil processing due to rising petroleum product demand and depleting light crude oil resources. Additionally, the development of better drainage regions through the drilling of multilateral, horizontal, and highly deviated wells in shallow reservoirs has increased commercial interest in heavy oil production systems [1]. Heavy fuel oil production and processing in pipelines and wellbores are more difficult than with light crude oil because of the very high molecular weight of its constituent parts, such as asphaltene, resins, and waxes. Asphaltene is also the most polar polycyclic aromatic hydrocarbon due to the presence of heteroatoms and metals, which causes it to self-associate with the creation of a viscoelastic network of nanoaggregates and results in a high viscosity of heavy fuel oils [2-5]. At room temperature, heavy fuel oils have viscosities between 100 and 10,000 cp, and extra-heavy fuel oils have viscosities beyond 10,000 cp. The typical maximum ideal pipeline viscosity that can be transferred through pipelines is 400 cp for crude oil [6–8]. Due to the polarity of lighter oils, mixing heavy crude oils with lighter oils is the most popular technique used to reduce the viscosity of heavy fuel oil in the pipeline [9–10]. The mobility of heavy fuel oils can be increased by lowering the dynamic viscosity of the oil, which is known to reduce internal friction resistance in the oil [11]. Therefore, for the production, pumping, and transportation of heavy fuel oils, the forecast of diluted viscosity is crucial. Many studies have been conducted to predict the viscosity of diluted heavy fuel oil.

The effect of light oil concentration on viscosity behavior has been studied to lower the Ibrahim et al. (2019) [13] researched the effects of dilution after recent research showed that the electric field has the capacity to lower the viscosity of heavy crude oil. There were various concentrations of acetone employed as a diluent. When acetone (20 wt%) is added, there is a significant viscosity reduction of about 21.98%. With 10% light oil and 20% light oil, respectively, the viscosity of heavy crude decreased from 10,000 to 1200 cp and from 10,000 to 350 cp. Toluene and dimethyl ketone were utilized as diluents (50/50 vol.%) in various dilution ratios by Azeez et al. (2020) [14] to lessen the viscosity of the Iraqi crude oil. When the solvents were present at various temperatures, the viscosity was evaluated. Additionally, the outcomes demonstrate that the mixture of toluene and dimethyl ketone (50/50 vol.) effectively lowers viscosity. However, the highest level of viscosity decrease was found to be around 87.17% at 15 weight percent of the mixture of toluene and dimethyl ketone (50/50 vol%) at 318.15 K and (42 s⁻¹) shear rate. Due toluene's aromatic property, which interferes with asphalt aggregation, is what led to the relevant results. The processing of heavy Iraqi crude oil from the East Baghdad field (22.2 API) was researched by Majeed et al. (2020) [15] and involved the application of many additives to lessen viscosity. Different kinds of additives have been used to reduce viscosity, and studies with a heavy oil sample have also been done using a variety of solvents, including n-propanol, ethanol, and methyl ethyl ketone (MEK). With regard to heavy crude oils, MEK has been the most effective viscosity reducer out of all the types that have been used; the maximum reduction of viscosity is 3.78cSt at 75°C and 26 API at 25°C, while the other solvents

for n-propanol are 5.85cSt at 75°C and 24.61 API at 25°C and 5.96cSt at 75°C and 27 API at 27°C. Martnez-Narro, et al. (2020) [16] utilized 5%, 10%, and 15% of the diluent to dilute polypropylene and polystyrene to lessen the viscosity of Mexican crude oil. The results showed that a viscosity decrease of 96%–97% was achieved at room temperature by employing 15% of the diluent. It was discovered that temperatures between (45° C to 56° C) allowed for the greatest transmission of pipes. The objective of this work is to enhance the properties of HFO using different cost-effective solvents in order to reduce its viscosity and protect the environment from injured gas emissions.

2. Fluid flow governing equations:

Pressure drop, Power consumption, Reynolds number and friction factor Pressure drop Δp (Pa), Flow rate Q (m³/s) , Re Reynolds number(-) , density (m³/s), viscosity (cp) , u velocity (m/s), D diameter of pipe (m) , f friction factor (-) , L length of pipe (m) [17,18]

$$\Delta p = \frac{128\mu L Q}{\pi D^4} \dots\dots\dots(1)$$

$$\dots\dots\dots(2)$$

$$Re = \frac{\rho u D}{\mu} \dots\dots\dots(3)$$

$$f = \frac{\Delta P . D}{2 L \rho . u^2} \dots\dots\dots(4)$$

3. Methodology

3.1 Materials

samples of materials were utilized in the experiment tests:

i- Heavy fuel oil: The tests were carried out on Basra crude oil supplied from Al- Doura refinery. The physical specifications of the proposed Heavy fuel oil are shown in Table (1).

Table (1): Physical properties of Basra crude oil.

Properties	Heavy fuel oil
Sp.gr at 15.6°C	0.9718
API at 15.6°C	14.1
Density at 15°C	0.97
Kinematic Viscosity at 10°C (CSt)	330.9
Asphaltenes content (wt %)	2.527

ii- Ethanol ($\text{CH}_3\text{CH}_2\text{OH}$): ethyl alcohol with purity of 99.9% It was mixed with a heavy fuel oil at a concentration of 1.5% using a magnetic stirrer.

iii- Kerosene: consists of hydrocarbons derived from fractional distilling petroleum between 150 and 275 °C (300 and 525 °F), and is a transparent, low-viscosity liquid with a density of 0.78 to 0.81 g/cm³.

3.2 Experimental system setup configuration

The dilution-based viscosity reduction technology was applied in a closed flow loop system. As seen in Figure (1), the experiment was conducted in a re-circulatory flow facility. The control unit, oil pump, pressure gauge, , 2 m of PVC tubing with a 0.5 inch diameter, additive tank, viscometer, and oil tank are the components of this system.

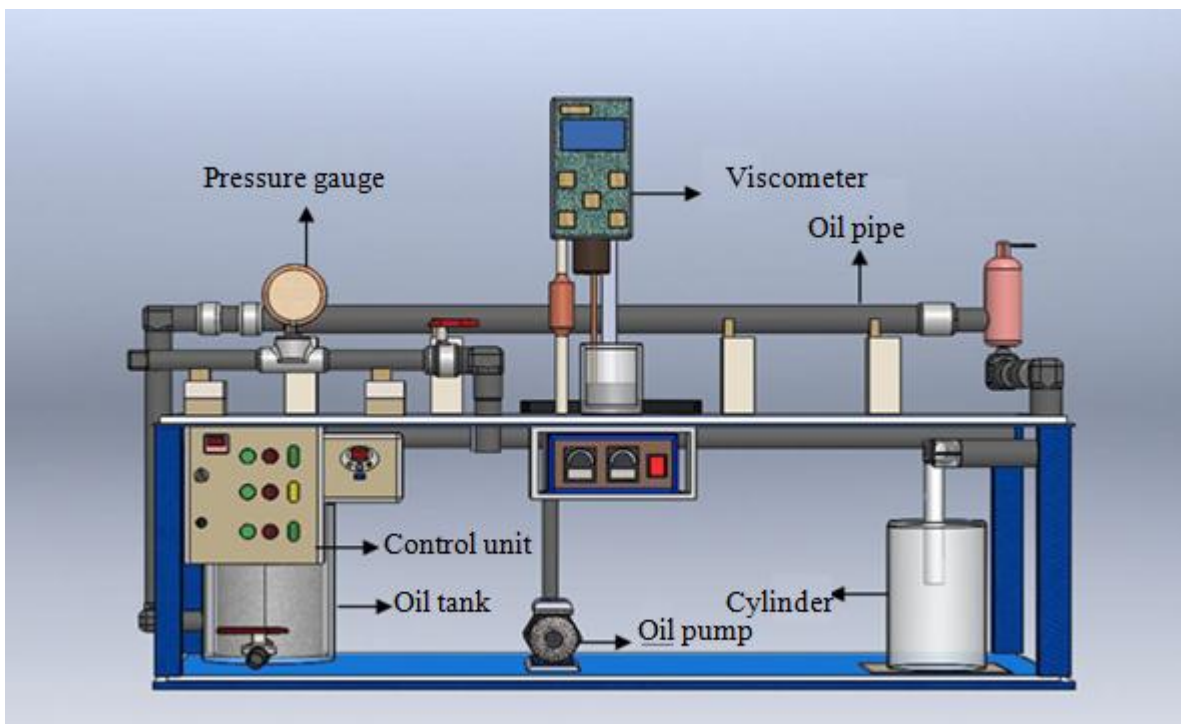


Figure (1): The experimental system is represented schematically.

3.3 Experimental procedure

Seven concentrations of ethanol and kerosene are used respectively (0%, 5%, 10%, 15%, 20%, 25%, and 30%) and (5%, 10%, 15%, 20%, 25%, 30%). These additives were stirred with heavy fuel oil for 2 minutes using a magnetic stirrer, then the mixture was added to the oil tank. The viscosity, Reynolds number, friction factor, pressure drop, and power consumption were calculated before and

after additive.

Table (1) shows the device specifications

Table (1): Device specifications

device	Type	Specifications
Oil pump	WCB75	220/380V,750W,50L/minmax Head 30m,0.3 Mpa (43 psi)
Solenoid valve	S 101001018N	Size ¼, Orifice 1.8mm, Pressure 0-16 bar
Digital Viscometer	BDV-5S	digital display viscometer by adopting the high accuracy driven stepmotor and 16-bit micro- computer control processor with a LCD night visual display

4. Results and Discussion

4.1 Heavy fuel oil with ethanol

Since asphaltene molecules are thought to clump together to create the micelle-like cluster, the viscosity behavior makes sense. The oil's high viscosity is a result of these clusters. The viscosity will decrease when these agglomerates break up. Hence, a deeper drop in viscosity was attained by increasing and accelerating the breakdown of asphaltene agglomerates through an increase in polar solvent concentration. The heavy fuel oil's composition was changed by the addition of ethanol by separating aggregates of asphaltenes and turning them into independent particles. This can result in a reduction in the viscosity of heavy oil. At a temperature of 20 Co, adding 20% by volume of solvent causes heavy oil's viscosity to drop from 620 cp to 460 cp with a ratio of about 26%. It has been demonstrated that ethanol can effectively lower the viscosity of heavy oil. Figure (2) represents the impact of ethanol on HFO viscosity.

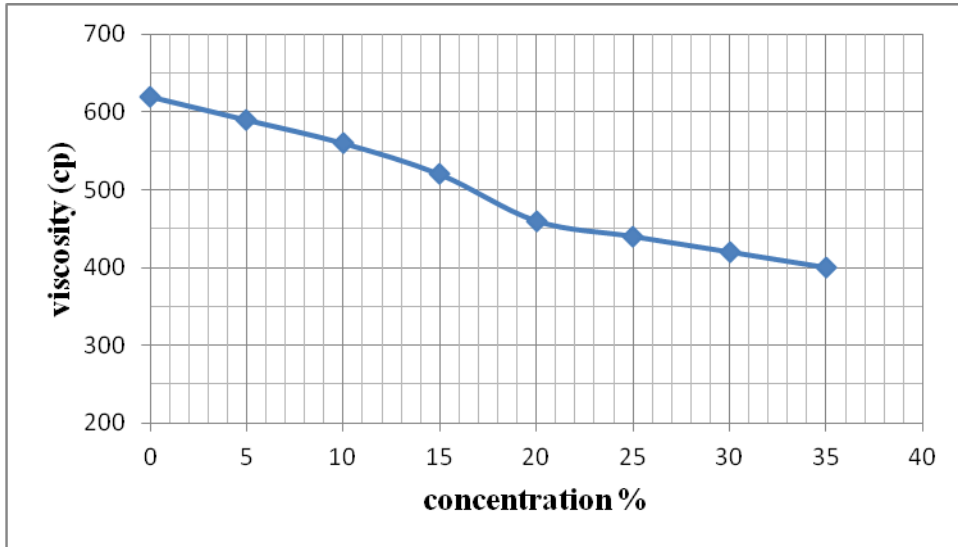


Figure 2: Impact of ethanol addition on HFO viscosity

Figure (3) illustrates that the Reynolds number value increased from 397.387 with no addition to 492.125 when adding Ethanol with a concentration of 20%. Thus, it is possible to increase the viscosity of heavy fuel oil inside the pipe by around 23.8% when employing the solvent.

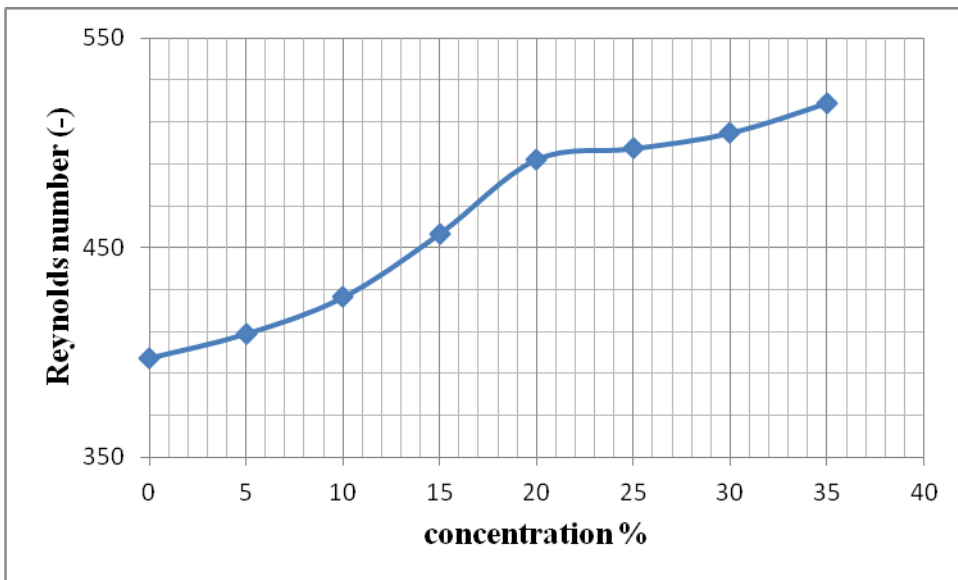


Figure 3: Influence of Ethanol addition on Reynolds number

Figure (4) illustrates how ethanol affects friction by acting as a lubricant, increasing the amount of slippage between crude oil molecules as well as between the oil molecules and the pipe wall. As a result, it was discovered that adding 20% ethanol caused a 19.22% decrease in friction, from 0.161 to 0.130048.

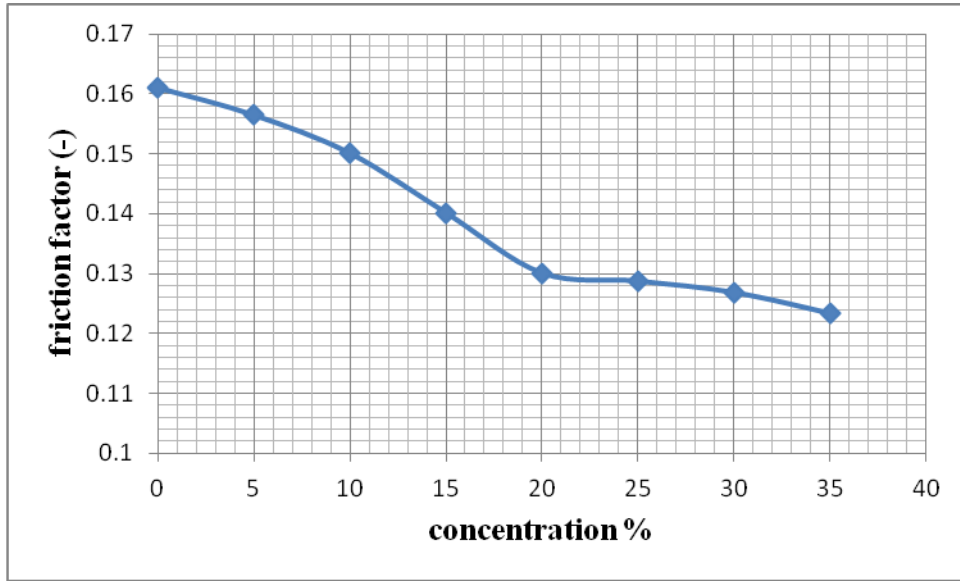


Figure 4: Impact of Ethanol addition on friction factor

Figure (5) shows the impact of ethanol addition on pressure drop. At a 20% ethanol concentration, the pressure drops drop from 4.92 kPa to 3.80928 kPa, a reduction of roughly 22.6%. Because a low friction factor results in a reduction in the pressure drop, the pressure drop is proportional to the friction factor. This is so that the energy of the liquid particles may be preserved and the Stream Energy can be kept in the form of pressure by reducing the friction between the molecules of heavy fuel oil and the pipe wall.

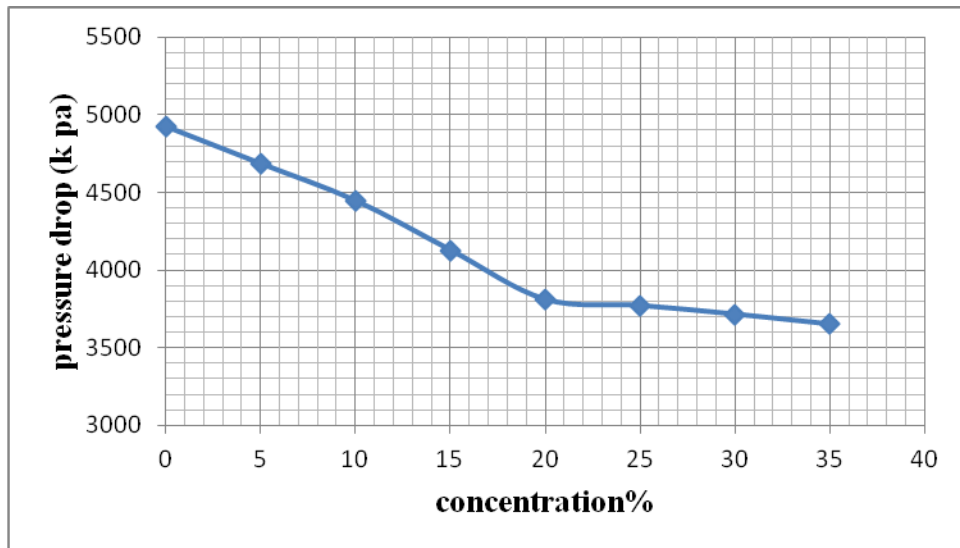


Figure 5: Influence of Ethanol addition on pressure drop

Figure (6) illustrates that adding ethanol with 20% concentration caused a reduction in power consumption by about 22.6%, from 12.46 kW to 9.650449 kW since the relationship between pressure decrease and power usage is linear.

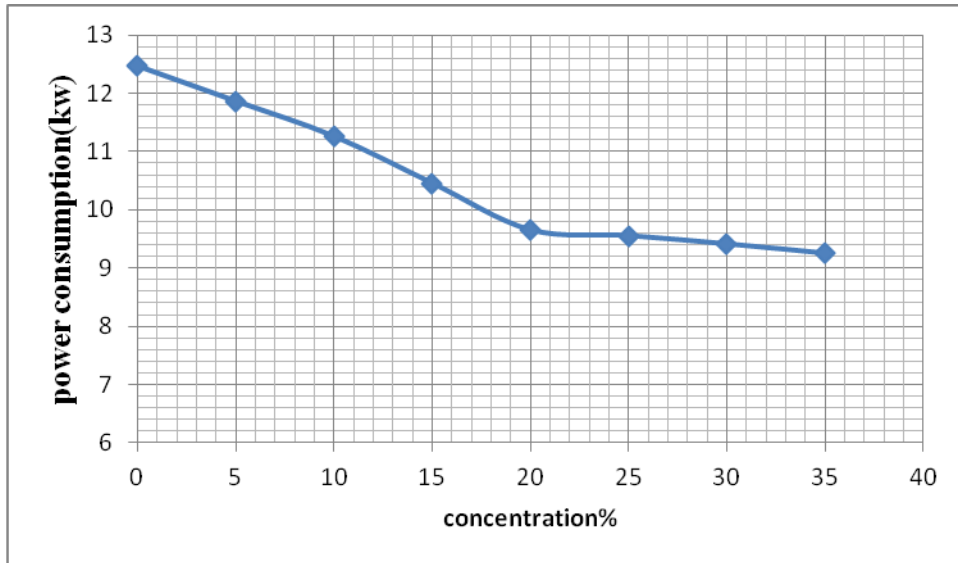


Figure 6: Effect of Ethanol addition on power consumption

4.2 Heavy fuel oil with kerosene

The addition of kerosene altered the heavy fuel oil's composition by dissolving asphaltene aggregates and transforming them into distinct particles. This may cause the viscosity of heavy oil to decrease. At a temperature of 20 C°, the viscosity of heavy oil decreases with a ratio of roughly 53.22% when 20% by volume of solvent is added. It has been shown that kerosene has the ability to significantly reduce the viscosity of heavy fuel oil. The effect of kerosene on the viscosity of HFO is seen in Figure (7).

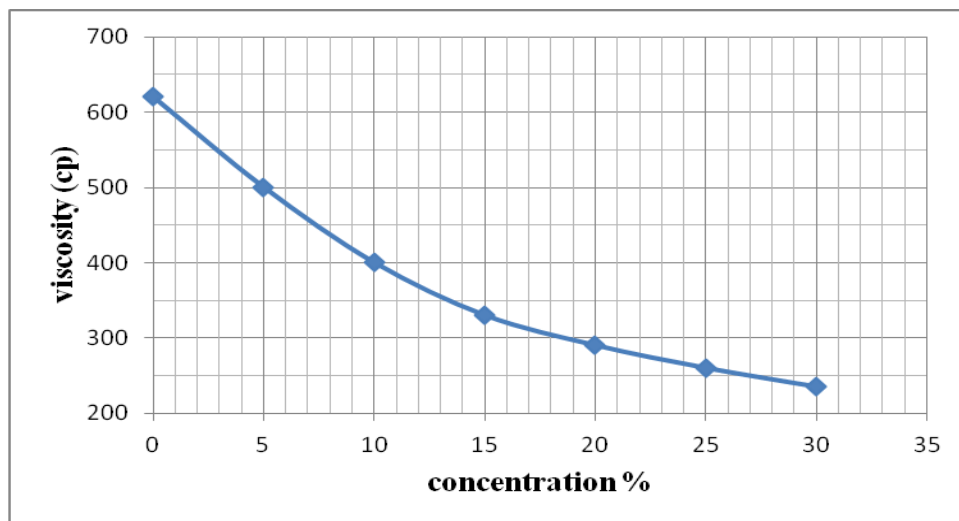


Figure 7: Effect of kerosene addition on viscosity

Figure (8) illustrates that the Reynolds number value increased from 397.387 with no addition to 492.125 when adding kerosene with a concentration of 20%. Thus, it is possible to increase the viscosity of heavy fuel oil inside the pipe by around 23.8% when employing the solvent.

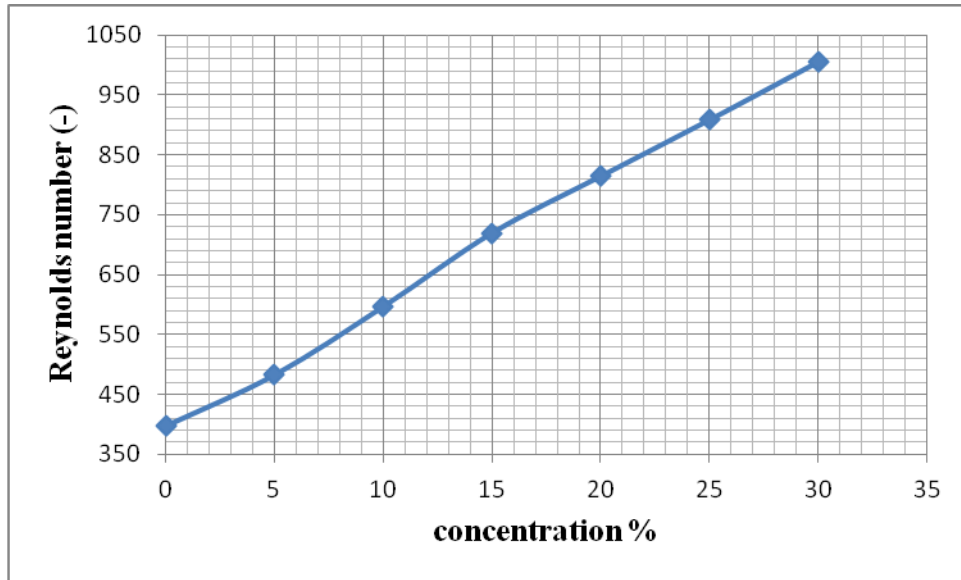


Figure 8: Effect of kerosene addition on Reynolds number

As a lubricant, kerosene increases the amount of slippage between heavy fuel oil molecules as well as between the oil molecules and the pipe wall, which is one example of how kerosene reduces friction. As a consequence, it was found that including 20% kerosene reduced friction by 51.2%. Figure (9) represent the Effect of kerosene addition on friction factor

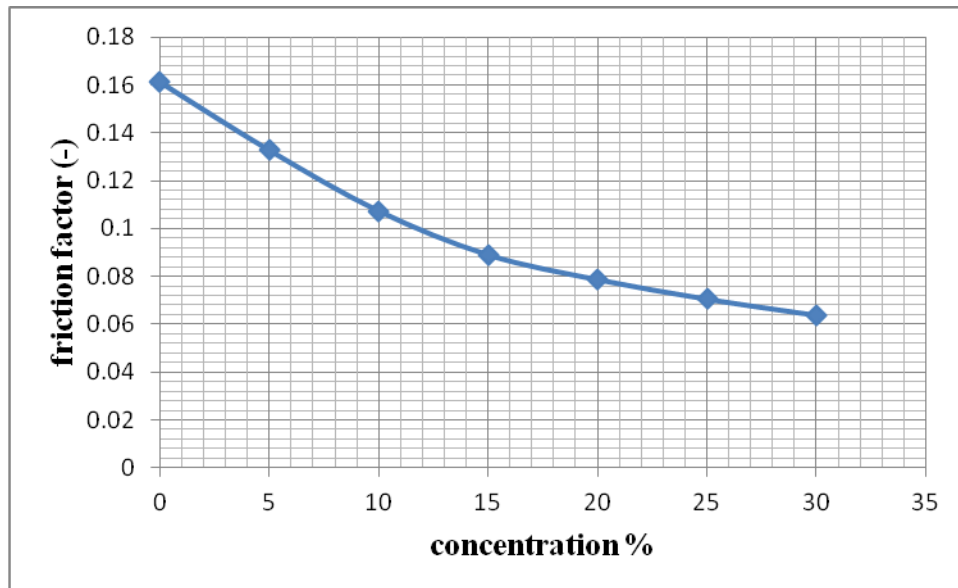


Figure 9: Effect of kerosene addition on friction factor

Figure (10) represents the impact of kerosene addition on pressure drop. At a 20% kerosene concentration, the pressure drops a reduction of roughly 47.128%. Because a low friction factor results in a reduction in the pressure drop, the pressure drop is proportional to the friction factor. This is so that the particles in the liquid's energy may be preserved and the Stream Energy can be kept in the form of pressure by reducing the friction between the molecules of heavy fuel oil and the pipe wall.

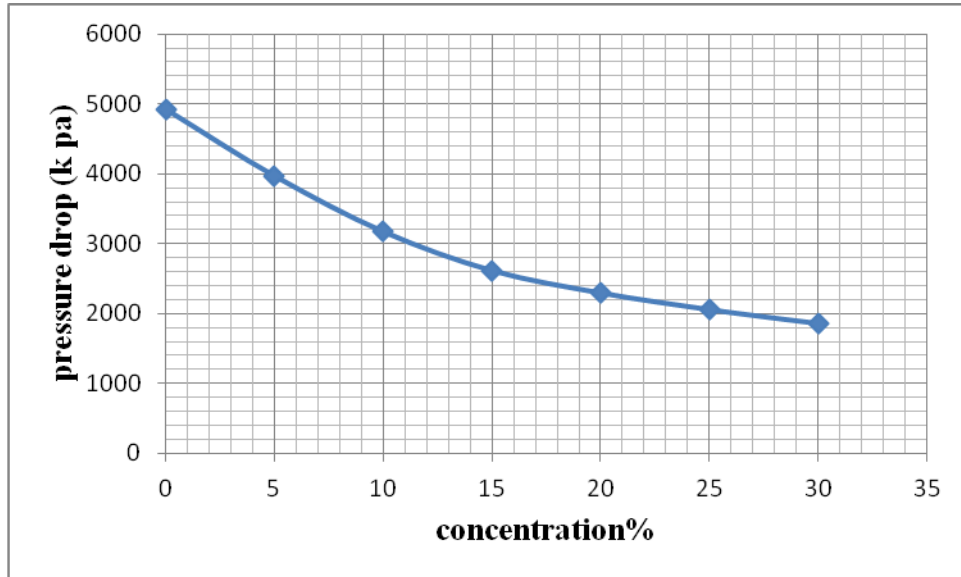


Figure 10: Effect of kerosene addition on pressure drop

Since the relationship between power usage and pressure decrease is linear, Figure (11) shows that adding kerosene with a 20% concentration resulted in a reduction in power consumption of around 53.229%, from 12.46 kW to 5.8304 kW.

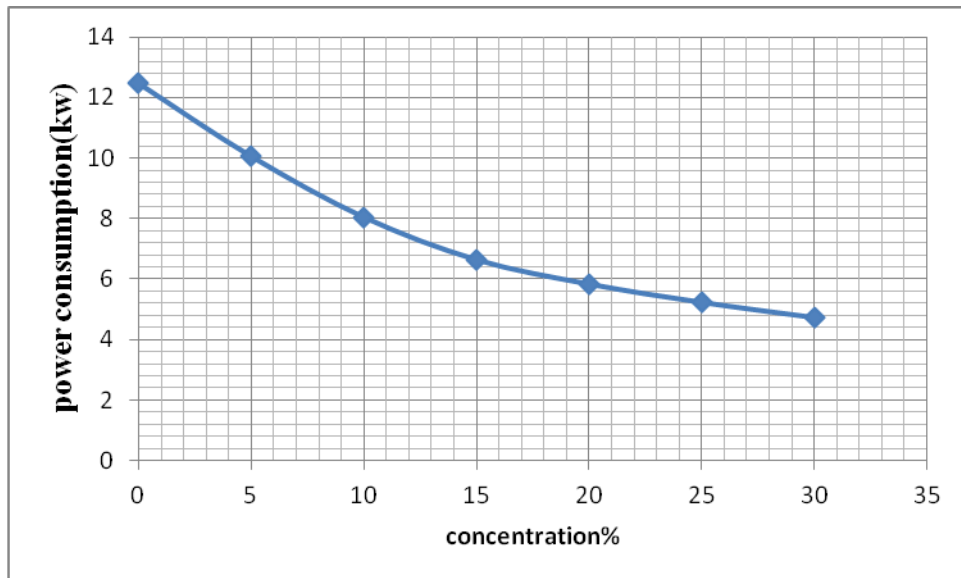


Figure 10: Effect of kerosene addition on power consumption

5. Conclusions:

Viscosity of heavy oil was reduced by diluting with several commercial solvents, ethanol and kerosene. The results of this work indicated that the dilution of HFO with kerosene and ethanol are economically feasible in Iraq and also contributes in environmental saving from injured gasses emissions.

The experimental results showed that 20 vol% of kerosene gives 53% viscosity reduction; in addition, the power consumption decrease by 53.22% while 20 vol.% of ethanol addition results in 26% reduction in HFO viscosity and power consumption drops by 22.6%. Results generally point to the advantages of dilution using solvents and/or petroleum fractions as a workable strategy for improved oil recovery and pipeline-based oil transportation. Furthermore, this research could be expanded in the future to investigate the impact of other solvents on the viscosity of heavy oil, especially in hard reservoir conditions.

6. Acknowledgment

The authors would like to thank the electromechanical department in the university of technology. Iraq for lab facilities.

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