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Enhancement of Vacuum Gas Oil Viscosity Using Ultrasound

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Abstract

Ultrasonic treatment is a suitable method for refinery processes that Acoustic cavitation is a technique that allows high levels of energy to be released into the liquid, which leads to changes in fluid properties such as a decrease in viscosity. Additionally, it's an effective way to improve the economic feasibility of physicochemical processing to enhance the quality of the product. In this work, vacuum gas oil with viscosity of 8.4 c.st, provided by Iraqi refineries, was treated by ultrasound radiation and studied the effect of several parameters on viscosity such as sonication time (5,10,15,20,30) min, power amplitude(10,20,30,40,50)watt, and frequency (20,30,40,50) kHr. It was found from the results that the viscosity decreased from (8.4) c.st to (5.82) c.st, which represents a percentage reduction of up to 30.7% compared to the value before treatment. This result was obtained after 30 min., also the 50% of ultrasound power is the appropriate to reduce the viscosity, where The experiment showed that 20 kHz of ultrasound frequency has a decreasing effect on the viscosity as the percentage reaches 30%.

Keywords: ultrasonic treatment, vacuum gas oil, petroleum, acoustic cavitation, ultrasound.

1. Introduction:

One of the most critical things in the petroleum industry is the improvement of the physical and chemical properties of crude oil or its fraction such as vacuum gas oil. As the need for energy, fuels, and industrial raw materials increases on a worldwide scale, crude oil remains the primary energy source available. The yearly growth rate of oil demand is roughly between 1% and 1.8% [1]. Renewable energy, however, and the research that surrounds it, are still in their infancy [2].The oil and petrochemical sectors also have a significant impact on the economy and the production of

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a variety of goods [3]. One of the most commonly utilized forms of fuel for transportation is gas oil. Gas oil is a complex combination of hydrocarbon compounds made up of around 30% aromatics and 70% aliphatic paraffins and naphthene compounds [4]. While organic oxygen molecules are very slightly present, organic sulfuric and nitrogenic compounds have also existed [5]. Gas oil has a boiling point between kerosene and vacuum gas oil, which is 250 ^{o}C to 370 ^{o}C [6].The type of feed crude oil determines the quality of vacuum gas oil [7]. According to API grades (American Petroleum Institute), there are several types of oil, each of which differs in terms of density, In accordance with API grades, crude oil can be divided into four categories: light (31.3-39°), medium (22.3-31.1°), heavy (10-22.3°), and extra-heavy (10°) [8]. Straight-flow gas oil is synonymous with gas oil that is obtained straight from the distillation of crude oil [9].

Upgrading consists of a set of techniques through which the hydrogenation of the molecules is achieved by the addition of hydrogen, which results in a lighter synthetic crude oil [10]. Classic crude upgrading methods applied in surface operations include dilution and heating, which generally involve a very high investment in equipment and complex infrastructure, resulting in an increase in capital and operating costs [11].There are also emerging technologies, which are based on principles such as: viscosity reduction, chemical changes, and friction reduction between the pipe and the fluid Some are relatively developed, while others are still in the study and application stages[12]. Some methods involve catalytic cracking using ionic liquids, as well as the use of nanoparticles to improve the properties of crude oil. The emerging technologies for crude oil upgrading are classified into four categories: i) hydrogen addition, ii) carbon rejection, iii) extraction, and iv) ultrasound [13].

One of the most developing technologies is ultrasound, which is used to create the acoustic cavitation phenomena [14].High energy may be released inside a liquid by a process called acoustic cavitation, which in turn causes catalytic chemical processes and alters the fluid's characteristics, such as reducing viscosity [15].The thermal separation of vacuum gas oil's bonds and the creation of hydrogen atoms that result from ultrasonic treatment are important for improving heavy molecules Cavitation is thought to be the cause of ultrasonic irradiation [16]. The ultrasonic power supply or generator converts 50/60 Hz electricity into high-frequency electrical energy, When this voltage is applied to the acoustic energy inside the converter, it is converted into little mechanical vibrations [17]. The probe amplifies the converter vibrations, which are then delivered into the liquid as compression and rarefaction containing ultrasonic waves. These

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pressure changes produce small bubbles or cavities, which violently expand and collapse, sending millions of shock waves into the air [18].

The aim of the research is to improve the quality of physical and chemical characteristics of vacuum gas oil achieved by ultrasound technology such as viscosity and density, and evaluate the optimum parameters such as power amplitude, time in minutes, and frequency in order to improve the properties of vacuum gas oil.

2. <u>Experimental Work</u>

2.1 Feedstock

The feedstock in this study was vacuum gas oil, obtained from Iraqi refineries. The properties of the vacuum gas oil are given in Table (1).

Table (1) Properties of vacuum gas oil [19]

properties	**Vacuum Gas oil**
Density (g/cm3)	0.8984
Viscosity at (40) ºC	8.4 c.st
Sulfur (wt.%)	4.1
Nitrogen (wt.%)	0.39
Aromatic content (%)	27.3
API, specific gravity at(60/60) °F	30.0
Pour point ºC	42.5
Boiling range ºC	299-538

2.2 Instruments

Instruments that have been used in this research are (ultrasound device, viscometer device). The ultrasound device is the first important apparatus employed in these experiments, as shown in Figure (1). It is a strong device for ultrasound wave processors, displaying programmable action and a numerical display of running parameters [20]. It also has a frequency of more than 20 kHz and a maximum amplitude of power ultrasound of (100-1200) watts. Table (2) shows the ultrasound specifications.

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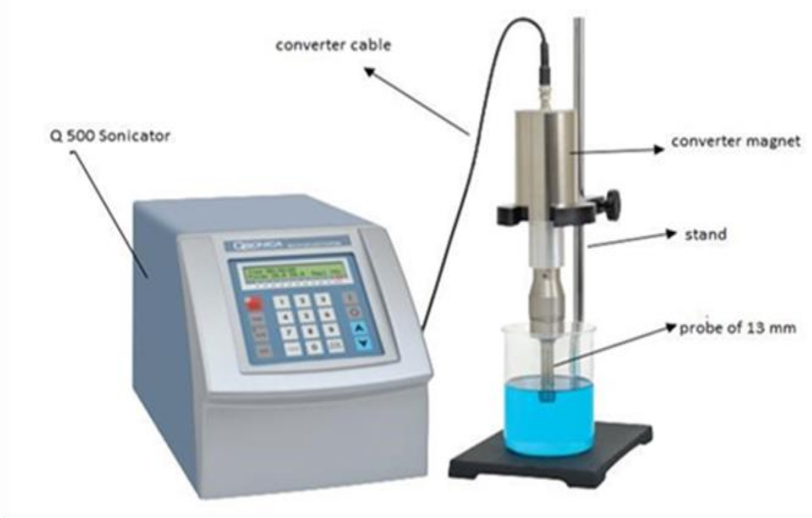

Fig. (1): Ultrasound device

Table (2) Ultrasound specifications [21]

1-power rating	100-1200 watts
2- frequency :	20-80 kHz
3- programmable timer :	10 hours
4- adjustable pulse on/off :	1 second to 1 minute

2.3 Treatment of gas oil

In this series of tests, an ultrasonic horn reactor was used to treat vacuum gas oil, a certain volume of vacuum gas oil (150 mL) was put in a 250 mL beaker and subjected for (5, 10, 15, 20, and 30) minutes to ultrasonic radiation, power range: 100 to 500 watts; frequency range: 20 to 50 kHz. The oil samples were exposed to ultrasonic radiation and then cooled to 25 °C, ambient temperature. Following the conclusion of each program, the vacuum gas oil's characteristics were evaluated. Table (3) showed the factors that used in experiment.

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Table (3) Factors of oil sample

Oil sample	Frequency kHr	Power %	Time (min)
1	20	10	5 10 15 20 30
2	20	20	5 10 15 20 30
3	20	30	5 10 15 20 30
4	20	40	10 15 20 30
5	20	50	10 15 20 30
6	20 30 40 50	50	30

3. Result and Discussion

3.1 Effects of ultrasound cavitation on the properties of vacuum gas oil

3.1.1 Effects of power amplitude

Figures (2) to (6) show the relationship between energy and viscosity of gas oil during different time periods. from the results, it is clear that the decrease in viscosity increases with an increase in power, as the best result was at 50% of that. The results obtained can be interpreted as a consequence of the mechanical churning and cavitation produced by the ultrasonic processing. The gas oil molecules experienced a variety of changes. The characteristics of the typical molecular structure were affected by microstructural changes [22]. Experiments indicate that the cavitation phenomena get more intense as ultrasonic power increases, resulting in a greater viscosity reduction impact for vacuum gas oil. A particular amount of ultrasonic power causes cavitation to become saturated, making the impact of ultrasonic waves on lowering gas oil viscosity more stable. The same results are obtained by [23].

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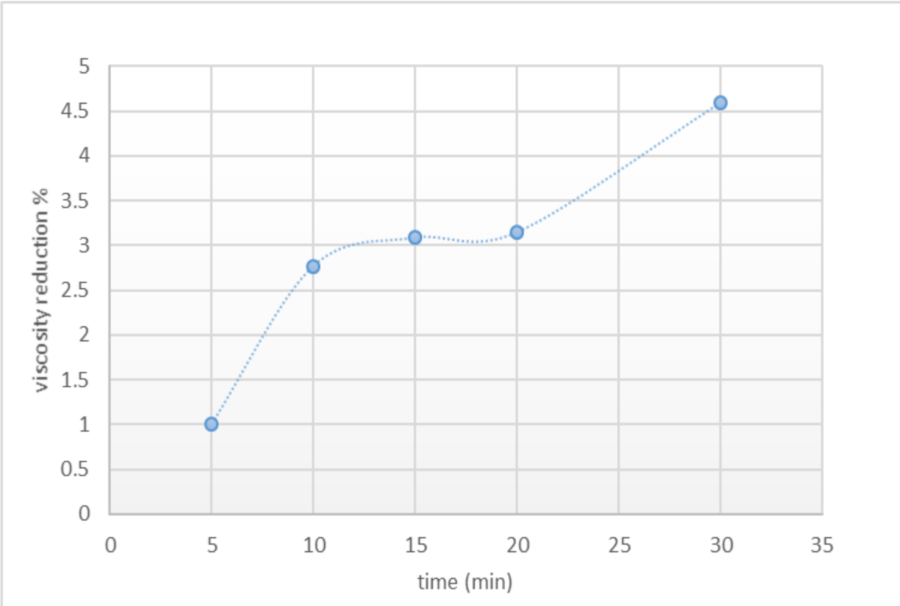

Fig. (2): Effect of the ultrasonic power on viscosity at (10% power).

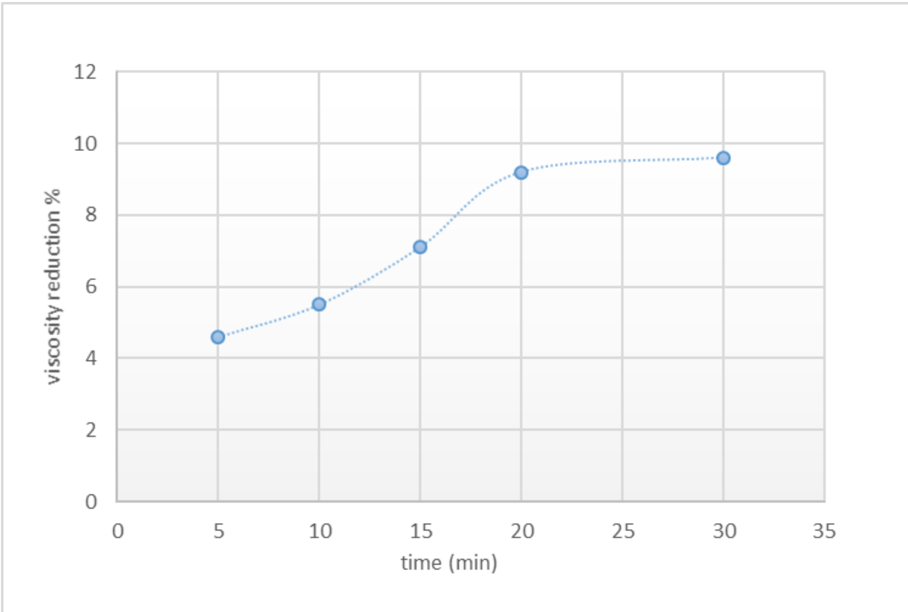

Fig. (3): Effect of the ultrasonic power on viscosity at (20% power).

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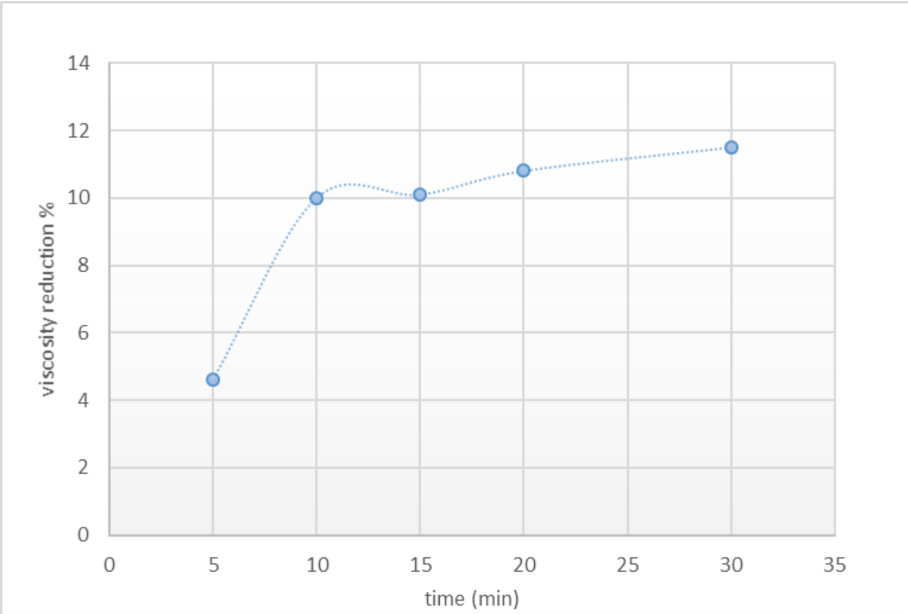

Fig. (4): Effect of the ultrasonic power on viscosity at (30% power).

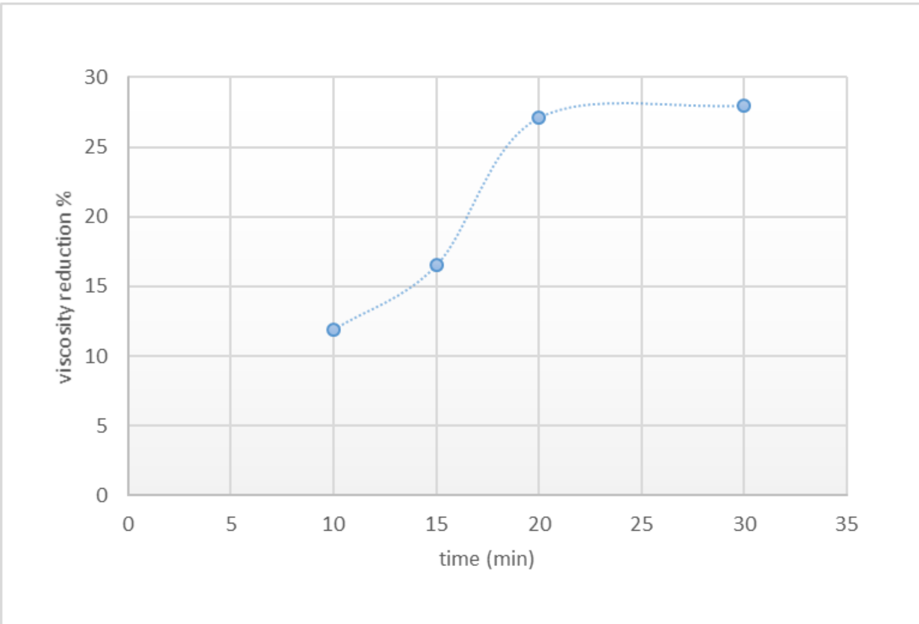

Fig. (5): Effect of the ultrasonic power on viscosity at (40% power).

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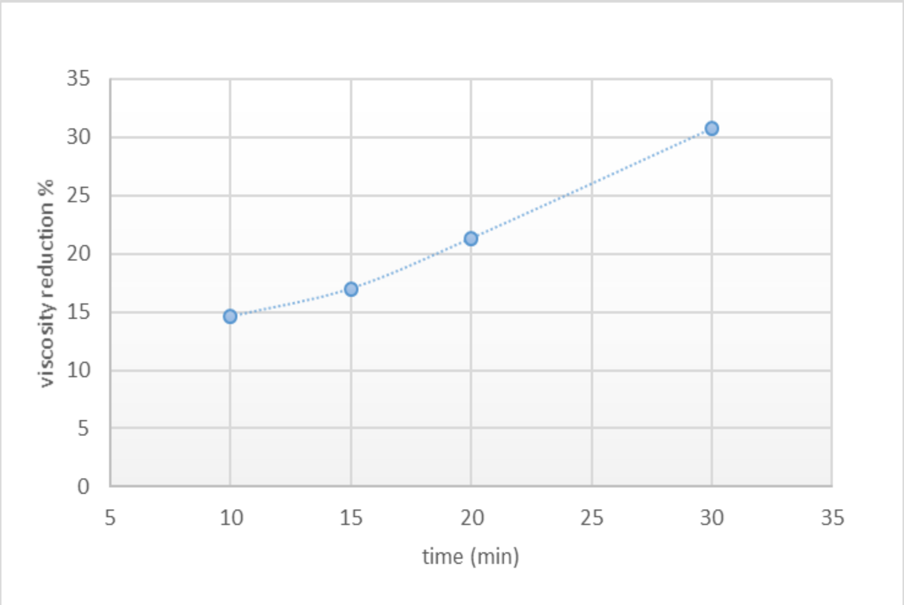

Fig. (6): The effect of the ultrasonic power on viscosity at (50% power).

3.1.2 Effects of frequency

Figure 7 shows the relationship between frequency and viscosity of gas oil. The results of the experiments proved that when frequency was increased, there was less effect on viscosity reduction due to the ultrasonic cavitation effect, which causes the fluid to produce a nuclear cavity during the sound wave expansion phase, so it is preferable to select a lower frequency. The best result was achieved at a frequency of 20 kHz and at a power of 50 %, which led to a reduction in viscosity by 30% after (30) min.

The rheology of the liquid will be impacted by the explosion that occurs when the hollow core is crushed by a sound wave. This explosion produces high temperatures and high pressures in an instant. The time required for the sound wave to expand and for the cavitation bubble to develop and collapse is decreased by increasing the ultrasonic frequency[24]. This prevents the growth and collapse of cavitation bubbles. when using ultrasound to reduce the viscosity of vacuum gas oil under certain other conditions, a lower frequency should be chosen.

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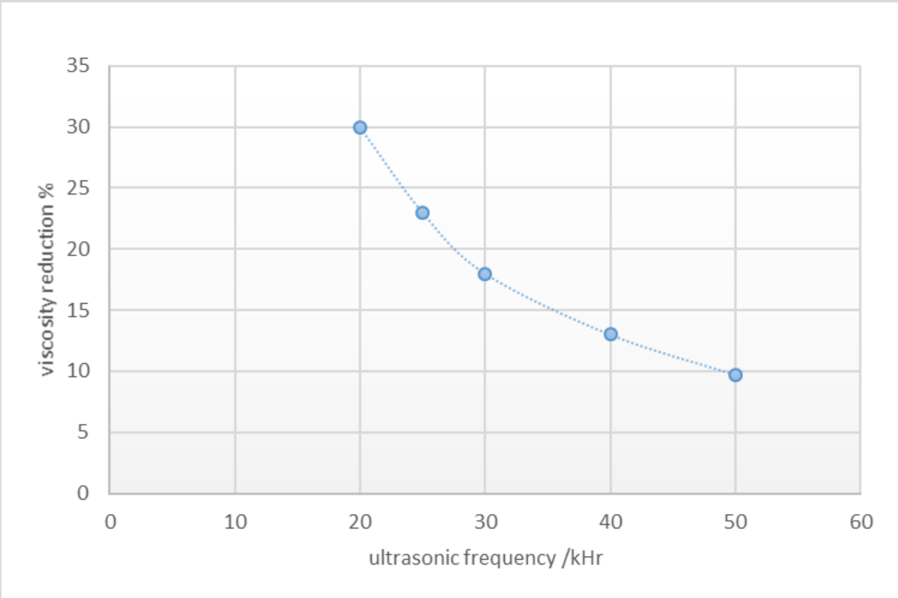

Fig. (7): The effect of ultrasonic frequency on viscosity

3.1.3 Effect of ultrasonic exposure Time

Figure 8 shows the effect of time on gas oil viscosity. The experiment was conducted to investigate the effect of ultrasonic radiation on the viscosity of vacuum gas oil. at intervals ranging at (5,10,15,20,25 and 30) min and at (50) % power, (20) kHr frequency. The experiment showed that 30 minutes of ultrasonic treatment reduced oil viscosity by 30.7%. With the increase of the duration, the viscosity of the oil decreased at a faster[25]. As a consequence of the experiment, it was found that ultrasonic treatment might cause the vacuum gas oil sample to become less viscous.

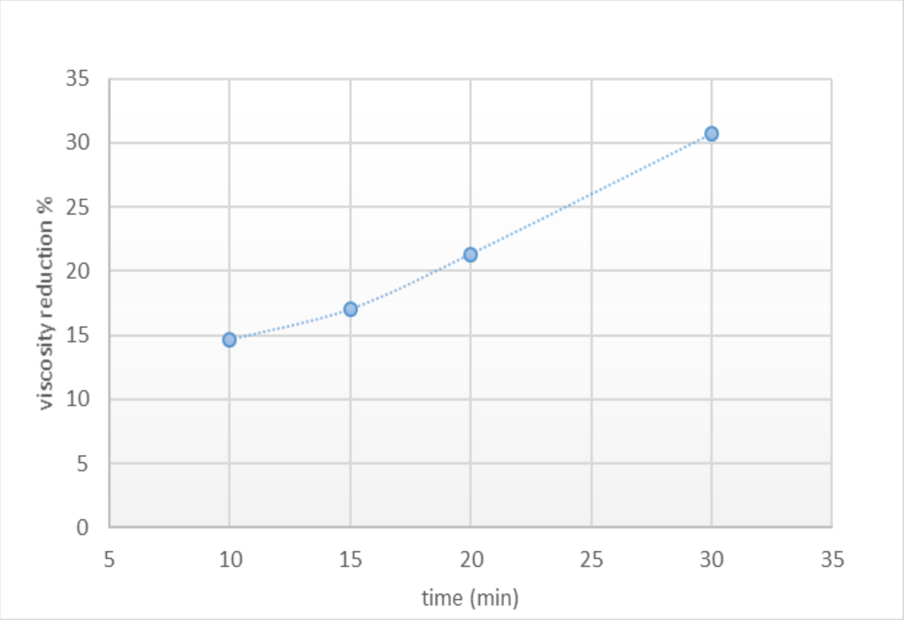

Fig. (8): The effect of ultrasonic exposure time on viscosity reduction, at (50) % power and (20) kHr frequency

As shown in Table (4), the viscosity of the vacuum gas oil was reduced by 30.7% because, with an increase in time and power, the viscosity of vacuum gas oil will decrease. This finding demonstrated how well viscosity may be decreased using ultrasound. Viscosity is a measure of an oil's internal resistance to flow and shear and is determined by adding the contributions of the dispersion medium and the dispersion phase[26]. It has to do with how the dispersion phase interacts with the dispersing media, the particle form and size, and interactions during that phase [27].

Table (4) Properties of vacuum gas oil before and after ultrasound radiation

Item	Before ultrasonic radiation	After ultrasonic radiation
Density (40^{o}C), g/cm^3	0.8984	0.8919
Viscosity(40^{o}C),mPa·s	8.4 c.st	5.82 c.st

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4. Conclusion

The following conclusions may be drawn from the results of a study:

1. Ultrasound is a developing technology that may be employed in oil production. It is critical to achieve a large drop in viscosity at this point in the oil chain. Ultrasound treatment may be used to enhance the qualities of Iraqi vacuum gas oil in order to minimize viscosity, but only if the final properties for the best model are established via trials.
2. The viscosity lowers with increasing power and duration, but spending too much time increases the cost of operation and shortens the life of the sonic device. Therefore, the ideal sonication time for vacuum gas oil is 30 min.
3. Low frequency and high power are predicted to be the future trends in ultrasonic industrial development. The lower the frequency, the lower the acoustic cavitation threshold and the higher the compression ratio of cavitation bubbles. The lower the frequency, the lower the acoustic energy attenuation coefficient and the greater the penetration distance. Furthermore, significant power is necessary to generate substantial sonic cavitation.
4. It is regarded as a helpful approach for oil refineries since it is a safe, affordable, economical, and successful method that can be used immediately without the need for equipment.
5. During the procedure, no related gases are released.

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