Available online at http://ijcpe.uobaghdad.edu.iq and www.iasj.net
Iraqi Journal of Chemical and Petroleum Engineering
Vol. 24 No.2 (June 2023) 107 – 112
EISSN: 2618-0707, PISSN: 1997-4884

The Effect of Variable Parameters on Carbon Residue of Iraqi Vacuum Gas Oil using Ultrasound Techniques

Fatima H. Abbas [a, *], Tariq M. Naife [a], and Hind Barghash [b]

a Chemical Engineering Department, College of Engineering, University of Baghdad, Baghdad, Iraq
b German University of Technology, Sultanate of Oman

Abstract

An ultrasonic treatment was applied to the vacuum gas oil at intervals of 5 to 30 minutes, at 70°C. In this work, the improvement of the important properties of Iraqi vacuum gas oil, such as carbon residue, was studied with several parameter conditions that affect vacuum efficiency, such as sonication time (5, 10, 15, 20, 25, and 30) min, power amplitude (10–50%). After ultrasonic treatment, the carbon residue of vacuum gas oil was evaluated using a Conradson carbon residue meter (ASTM D189). The experiment revealed that the oil's carbon residue had decreased by 16%. As a consequence of the experiment It was discovered that ultrasonic treatment might reduce the carbon residual and density of oil samples being studied. It also noticed that the carbon residue reduced with increased ultrasonic treatment duration and power. The mechanical mixing and cavitation brought about by ultrasonic processing led to a number of modifications in the gas oil molecules. The properties of a typical molecular structure were altered on a microscale.

Keywords: vacuum gas oil processing, ultrasonic cavitation, heavy oil, oil upgrading, petroleum, power amplitude.

Received on 06/08/2022, Received in Revised Form on 20/09/2022, Accepted on 21/09/2022, Published on 30/06/2023

https://doi.org/10.31699/IJCPE.2023.2.12

1- Introduction

The oil industry is currently facing huge challenges as a result of increased demand for gasoline and diesel fuel, as well as stronger environmental regulations and the commitment to achieve the related SDGs. Refiners are now compelled to treat leftover oil as traditional petroleum resources gradually diminish [1]. The usage of leftover oil, however, results in additional severe issues, such as catalyst deactivation caused by coke production. The structural properties of vacuum gas oil must be clarified in order to give the best processing conditions for their efficient conversion. The blend of different chemicals that make up gas oil is exceedingly complex [2].

Therefore, ultrasonic treatment is seen to be a successful method of transforming leftover oil to assist secondary processing in oil refineries [3]. Additionally, it uses less energy to amplify the effects of physicochemical processing Ultrasonic treatment results in the thermal scission of heavy oil bonds and the formation of hydrogen atoms, which are used to upgrade heavy molecules [4]. Furthermore, the relationship between carbon residue and volatile hydrocarbons, condensed aromatic hydrocarbons, non-hydrocarbons in oils, and notably asphaltenes and resins, reveals the proclivity for coke generation during residual oil processing. Carbon residue, an important control indicator for feedstock, can have an influence on product distribution in catalytic cracking: the greater the carbon residue, the higher the coke deposition and the lower the liquid yields[5].

However , ultrasonic treatment can reduce asphaltene and resin concentrations, lowering carbon residue [6]. This action has the potential to change the resin and asphaltene content, structure, and performance of oil processing, which are mostly composed of compounds with condensed rings and heterocyclic structures in resins and asphaltenes [7] . Resins and asphaltene include these chemicals. To some extent, ultrasonic treatment can increase the stability of the colloidal system of asphaltenes [8]. Ultrasonic therapy's effects on vacuum gas oil are being studied.

Ultrasound is a developing technology that can be employed in oil production. At this point in the oil chain, achieving a considerable reduction in viscosity is critical since it will minimize costs and operational challenges in pipeline transportation and refineries [9]. There are encouraging laboratory results, but no industrial application thus far, due in part to scaling issues and since all research is exploratory, none hints to the systematic development of the technology [10]. Among developing technologies, ultrasound is utilized to induce the acoustic cavitation phenomena. Acoustic cavitations allow for the release of high energy within a liquid, which causes catalytic chemical processes and changes in fluid characteristics [11].

Ultrasound is a mechanical wave with pressure oscillation, may flow through solid, liquid, and gaseous media. Power ultrasound in particular may cause serious sonic cavitation and transport large specific energy

*Corresponding Author: Name: Fatima H. Abbas, Email: fatma.abbas1607m@coeng.uobaghdad.edu.iq

density into the medium, leading to high temperatures and pressures as well as mechanical impacts (shock waves, micro-jets, and shear force) [12]. The improvement of cavitation bubbles is shown to be fundamental to these effects. When the medium is subjected to ultrasonic irradiation, a cycle of pressure expansion and compression occurs. When negative pressure overcomes the cohesive force between fluid particles, cavitation bubbles appear as medium nuclei. Three different ways for cavitation bubbles to form include: (1) a single bubble, (2) a chain of bubbles, and (3) small bubbles that separate from bigger bubbles [13].

When the acoustic intensity approaches the cavitation threshold, which has a certain value, a phenomenon known as acoustic cavitation can occur. As acoustic cavitation often happens at low frequencies, raising the frequency might result in a higher acoustic cavitation threshold [14]. Viscosity, interfacial tension, and vapor pressure are moderately active factors that have a significant impact on the cavitation threshold. The quantity of dissolved gas in the medium also has an impact on the cavitation threshold. The cavitation threshold is significantly lowered as a result of fluid microbubbles' assistance in cavitation bubble generation [15].

The carbon residues of petroleum and petroleum products indicate the sample's proclivity to develop carbonaceous deposits (thermal coke) under the effect of heat. The carbon residue is typically proportional to the crude's asphalt concentration and the amount of recoverable lubricating oil fraction. In most circumstances, the lower the carbon residual, the more valuable the oil. The Ramsbottom (RCR) or Conradson (CCR) ASTM test techniques represent this in terms of weight percent carbon residue (D-524 and D-189) [16].

The aim of the research is to improve the quality of vacuum gas oil achieved by ultrasound technology. Improvement in the physical and chemical characteristics of vacuum gas oil such as density and carbon residue by using ultrasound technology by evaluate the optimum parameters such as power, ultrasonic time, and temperature in order to improve the properties of vacuum gas oil.

2- Experimental work

2.1. Feedstock

Vacuum gas oil used in this study was obtained from Al-Dora refinery. Some important properties of the vacuum oil are shown in Table 1.

2.2. Experimental procedure by ultrasound device

In this series of studies, vacuum gas oil was treated with an ultrasonic horn reactor at 70 °C and directly subjected to ultrasonic waves for varied time intervals (5-30) minutes at a frequency of (20) kHz and a total given power input of (10-50) %. Following ultrasonic radiation, the oil samples were cooled to a temperature of 25 °C. The carbon residue of vacuum oil was tested using a the Conradson carbon residue (ASTM D189) after all programs were completed. And the equipment devices used are as follows:

A. Sonicator

As indicated in Fig. 1, the first major instrument used in these studies is a sonicator. It is a powerful ultrasonic wave processor with configurable action and a numerical display of operating parameters. The sonicator has a frequency of more than 20 kHz and a maximum amplitude of power ultrasound of (100–1200) watts; temperature range: 30~90 °C. Table 2 show that Sonicator specifications. Materials and Sonics, Inc. created and manufactured the gadget (VX 1200, Newton, United States).

Table 1. Properties of Vacuum Gas Oil

Properties	Gas Oil
Density (g/cm3)	0.896
Viscosity at (40) ºC	8.4 c.st
Sulfur (wt.%)	4.1
Carbon residue (wt.%)	12.5
Aromatic content (%)	42.0
API, specific gravity at (60/60 °F)	30.0
Pour point ºC	42.5
Boiling range ºC	299-538

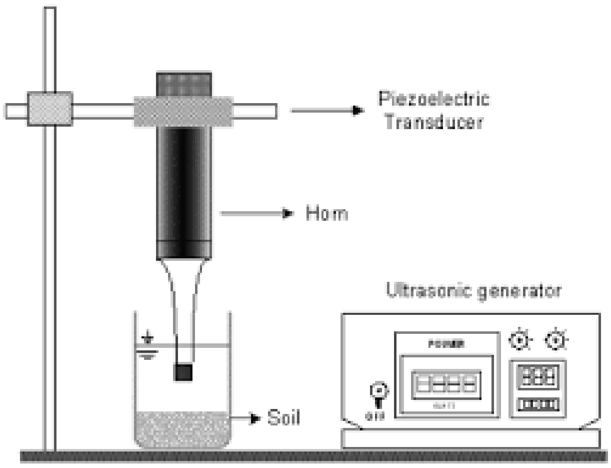

Fig. 1. Experimental Setup of the Ultrasound Reactor System

Table 2. Sonicator Specifications

Technical specifications	
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
5- voltage :	110v,50/60Hz

Adaptable off and On pulse times can be set up from 1 second to 60 seconds. Total program has a greatest setting up to 10 hours. Different types of probes are available to treat any application.

B. Magnetic stirrer

Hot plate magnetics stirrer with sensor for temperature degree measurements and of maximum 1100rpm, manufactured by PCE Americas Inc., USA.

3- Results and Discussions

3.1. The effect of ultrasonic radiation temperature on carbon residue content

The effect of ultrasonic radiation temperature on the amount of carbon residue in a vacuum gas oil sample was investigated by using 30% of ultrasonic power and a 20-minute treatment time. The carbon residue content in the vacuum residue decreased as the radiation temperature climbed from 30 °C to 70 °C. When the temperature was elevated to 70 °C, the carbon residue tended to level out. The results showed that a radiation temperature of 70 °C was adequate for ultrasonic radiation of vacuum gas oil. Increasing the temperature can enhance carbon residue while decreasing the cavitation threshold of vacuum gas oil. A certain temperature is required to obtain the highest cavitation effect. However, if the temperature is excessively high, the steam pressure rises, reducing the cavitation action. As a result, the optimum temperature is 70°C. Fig. 2 depicts the percentage variation of carbon residue concentration in vacuum residue with increasing ultrasonic radiation temperature at (30%) of power amplitude.

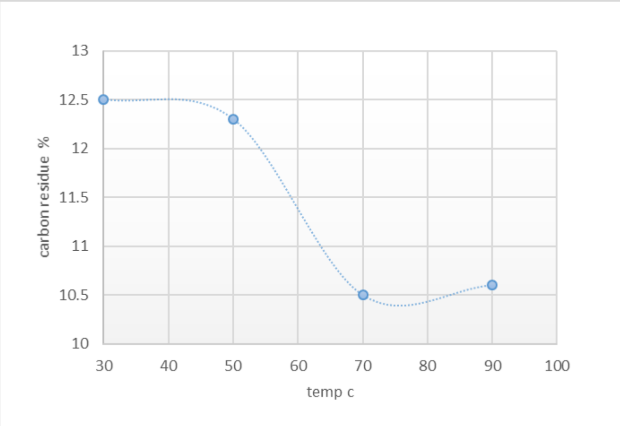

Fig. 2. Effect of Ultrasonic Radiation Temperature on Carbon Residue at 20 min and 30% Power

3.2. The effect of ultrasonic radiation time on carbon residue

Carbon residue is an important indicator of carbon deposits from petroleum processing, which is mostly obtained from chemicals found in resins, condensed ring asphalt, and heterogeneous ring structures. The experiment showed that, after ultrasonic processing and increasing time, the changes in resin and asphaltene content, as well as oil structure, will affect the carbon residue content and oil processing performance. As seen in Fig. 3 the carbon residue concentration decreased with increasing radiation time. The decrease occurred significantly at the beginning of ultrasound and became stable after 20 min. Under experimental conditions, the optimal time for carbon residue reduction was set at 20 min.

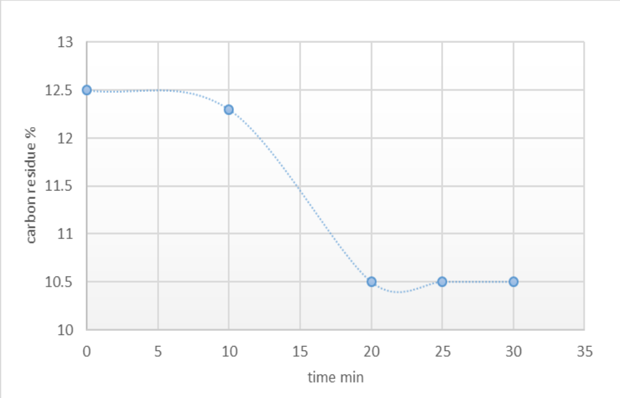

Fig. 3. Effect of Ultrasonic Radiation Time on Carbon Residue Content

3.3. The effect of ultrasonic radiation power on carbon residue content

The carbon residue reduction effect of ultrasonic waves on oil samples increases gradually and tends to be stable with the increase in ultrasonic power. This is because of the fact that the higher the ultrasonic power, the more energy is transferred to the sample, and the cavitation phenomenon is more intense, which makes the carbon residue reduction effect of vacuum oil more significant. When the ultrasonic power reaches a certain value, the cavitation phenomenon tends to be saturated, making the effect of the ultrasonic wave on reducing the carbon residue of vacuum gas oil stable.

Fig. 4 depicts the change in carbon residue content after increasing the ultrasonic radiation power to 30% for 20 minutes. The results indicated that as ultrasonic power increased, the amount of carbon residue in the sample decreased significantly. The best power for maximum carbon residue reduction under experimental conditions was determined to be 30% and remained stable after 30 minutes. Therefore, 20 minutes of radiation time and 30% of power were determined to be the optimal ultrasonic radiation processing parameters.

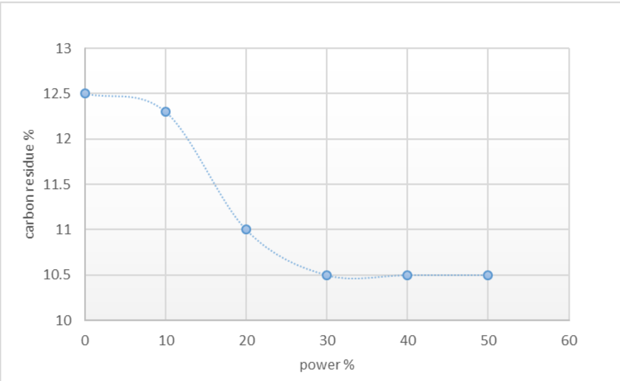

Fig. 4. Effect of Ultrasonic Radiation Power on Carbon Residue Content at 20 min

3.4. The Influence of ultrasonic on the Properties of vacuum gas oil

The influence of ultrasonography on vacuum oil properties The experiment was carried out across a range of time intervals (5–30 minutes) at 20 kHz and power (10-50) to assess the effects of ultrasonic radiation on the characteristics of vacuum gas oil such as (density, carbon residue). The result showed when increase in time and power the carbon residue value of the vacuum gas oil reduces by 16 %, from 12.5% to 10.5%. and the radiation temperature of 70 °C was adequate for ultrasonic radiation of vacuum gas oil and the density of the vacuum gas oil also decreased from 0.8984 to 0.8919 g/cm3. This finding demonstrated the effectiveness of ultrasound in reducing density and carbon residue levels. The properties of vacuum gas oil before and after ultrasound radiation is seen in Table 3.

Table 3. Properties of Vacuum Gas oil before and after Ultrasound Radiation

Item	Before the ultrasonic radiation	After the ultrasonic radiation
Density (40ºC). g/cm^3	0.8984	0.8919
Carbon residue, %	12.5	10.5

4- Conclusions

Ultrasound treatment can be used to improve the properties of Iraqi vacuum gas oil to reduce carbon residue as a crucial step in decarbonizing local oil industries to contribute in achieving SDG 13, knowing that it has been proven through tests that there is a drop in carbon residue percentage of 16%.

Through experiments, the results have proven that carbon residue decreases from 12.5 to 10.5 % with an increase in time, and the optimal time has been 20 minutes. Therefore, carbon residue also decreased with an increase in power, and the optimal power for greatest carbon residue reduction was estimated to be 50%. The process satisfies the carbon residue reduction of vacuum gas oil at ambient pressure without the use of a costly or toxic catalyst. It is considered a useful method for oil refineries as it's a safe, inexpensive, economical, and successful method that can be used directly without the use of equipment.

References

[1] S. Bezergianni, A. Dimitriadis, O. Kikhtyanin, and D. Kubička, “Refinery co-processing of renewable feeds,” Prog. Energy Combust. Sci., vol. 68, pp. 29–64, 2018. https://doi.org/10.1016/j.pecs.2018.04.002

[2] Á. Ibarra, E. Rodríguez, U. Sedran, J. M. Arandes, and J. Bilbao, “Synergy in the cracking of a blend of bio-oil and vacuum gasoil under fluid catalytic cracking conditions,” Ind. Eng. Chem. Res., vol. 55, no. 7, pp. 1872–1880, 2016. https://doi.org/10.1016/j.fuel.2022.124973

[3] B. Avvaru, N. Venkateswaran, P. Uppara, S. B. Iyengar, and S. S. Katti, “Current knowledge and potential applications of cavitation technologies for the petroleum industry,” Ultrason. Sonochem., vol. 42, pp. 493–507, 2018. https://doi.org/10.1016/j.ultsonch.2017.12.010

[4] E. Struhs et al., “Ultrasonic-assisted catalytic transfer hydrogenation for upgrading pyrolysis-oil,” Ultrason. Sonochem., vol. 73, p. 105502, 2021. https://doi.org/10.1016/j.ultsonch.2021.105502

[5] A. K. Coker, Petroleum Refining Design and Applications Handbook, Volume 1. John Wiley & Sons, 2018.

[6] A. N. Sawarkar, A. B. Pandit, S. D. Samant, and J. B. Joshi, “Use of ultrasound in petroleum residue upgradation,” Can. J. Chem. Eng., vol. 87, no. 3, pp. 329–342, 2009. https://doi.org/10.1016/j.ultsonch.2019.104690

[7] M. R. Yakubov, G. R. Abilova, S. G. Yakubova, and N. A. Mironov, “Composition and properties of heavy oil resins,” Pet. Chem., vol. 60, no. 6, pp. 637–647, 2020. http://doi.org/10.1134/S0965544120060109

[8] Mohammed, A.-H. A.-K., & Hussain, H. K. (2001). Deasphaltening and Hydrodesulfurization of Basrah Vacuum Residue. *Iraqi Journal of Chemical and Petroleum Engineering*, *2*(4), 12–18. https://doi.org/10.31699/IJCPE.2001.4.D.-R

[9] D.-R. Olaya-Escobar, L.-A. Quintana-Jiménez, E.-E. González-Jiménez; Erika-Sofia Olaya-Escobar, “Ultrasound Applied in the Reduction of Viscosity of Heavy Crude Oil,” Revista Facultad de Ingeniería, vol. 29 (54), e11528, 2020. https://doi.org/10.19053/01211129.v29.n54.2020.11528

[10] A. R. Artino Jr, J. S. La Rochelle, K. J. Dezee, and H. Gehlbach, “Developing questionnaires for educational research: AMEE Guide No. 87,” Med. Teach., vol. 36, no. 6, pp. 463–474, 2014. https://doi.org/10.3109/0142159X.2014.889814

[11] B. Savun-Hekimoğlu, “A review on sonochemistry and its environmental applications,” in Acoustics, 2020, vol. 2, no. 4, pp. 766–775. https://doi.org/10.3390/acoustics2040042

[12] X. Luo, H. Gong, Z. He, P. Zhang, and L. He, “Recent advances in applications of power ultrasound for petroleum industry,” Ultrason. Sonochem., vol. 70, p. 105337, 2021. https://doi.org/10.1016/j.ultsonch.2020.105337

[13] S. S. Rashwan, I. Dincer, and A. Mohany, “A review on the importance of operating conditions and process parameters in sonic hydrogen production,” Int. J. Hydrogen Energy, vol. 46, no. 56, pp. 28418–28434, 2021. https://doi.org/10.1016/j.ijhydene.2021.06.086

[14] S. Hong and G. Son, “Numerical modelling of acoustic cavitation threshold in water with non-condensable bubble nuclei,” Ultrason. Sonochem., vol. 83, p. 105932, 2022. https://doi.org/10.1016/j.ultsonch.2022.105932

[15] L. A. Yusuf, "Optimising acoustic cavitation for industrial application." University of Glasgow, 2022.
[16] C. Yang et al., "Characterization of naphthenic acids in crude oils and refined petroleum products," Fuel, vol. 255, p. 115849, 2019. https://doi.org/10.3390/catal12050495

تأثير العوامل المتغيرة على بقايا الكربون لزيت الغاز العراقي باستخدام تقنيات الموجات فوق الصوتية

فاطمه حامد عباس [١، *]، طارق محمد نايف [١]، و هند برغش [٢]

[١] قسم الهندسة الكيمياوية، كلية الهندسة، جامعة بغداد، بغداد، العراق
[٢] الجامعة الالمانية للتكنولوجيا، سلطنة عمان

الخلاصة

تم تطبيق معالجة بالموجات فوق الصوتية بنسبة ٥٠٪ على زيت الغاز المفرغ على فترات من ٥ إلى ٣٠ دقيقة، عند ٧٠ درجة مئوية. بعد علاج بالموجات فوق الصوتية لمدة ٣٠ دقيقة، كشفت التجربة أن بقايا الكربون في الزيت قد انخفضت بنسبة ١٦٪. نتيجة للتجربة تم اكتشاف أن المعالجة بالموجات فوق الصوتية قد تقلل عينة الزيت المتبقية من الكربون التي يتم دراستها، كما تقلل الكثافة. في هذا العمل، تمت دراسة تحسين الخصائص المهمة لزيت غاز الفراغ العراقي، مثل بقايا الكربون، بعدة عوامل متغيرة تؤثر على كفاءة الفراغ، مثل زمن الصوتنة (٥، ١٠، ١٥، ٢٠، ٢٥، ٣٠) دقيقة، سعة الطاقة (١٠-٥٠٪)، حيث وجدوا أن بقايا الكربون تقل مع زيادة مدة وقوة المعالجة بالموجات فوق الصوتية. أدى الخلط الميكانيكي والتجويف الناتج عن المعالجة بالموجات فوق الصوتية إلى عدد من التعديلات في جزيئات زيت الغاز. تم تغيير خصائص التركيب الجزيئي النموذجي على مقياس مجهري. بعد المعالجة بالموجات فوق الصوتية، تم تقييم بقايا الكربون من زيت الغاز الفراغي باستخدام مقياس بقايا الكربون(Conradson (ASTM D189 .

الكلمات الدالة: معالجة زيت الغاز الفراغي، التجويف بالموجات فوق الصوتية، الزيت الثقيل، تحسين الزيت، البترول، سعة الطاقة.