DOI: https://doi.org/10.61762/pajevol9iss2art002

PLATFORM - A Journal of Engineering

Received: 24 March 2025, Revised: 9 June 2025, Accepted: 20 June 2025, Published: 30 June 2025, Publisher: UTP Press, Creative Commons: CC BY 4.0

A STUDY ON THE USE OF NICHROME WIRE TO EASE THE FLOW OF HEAVY CRUDE OIL IN PIPELINES

Wafaa Rashid Al-Mahrooqi, Girma T. Chala*

Department of Mechanical Engineering (Well Engineering),
International College of Engineering and Management, Muscat, Oman

*E-mail: girma@icem.edu.om

ABSTRACT

Production of waxy crude oil poses significant challenges due to high wax contents, which negatively affects the production rate. Several techniques have been adopted to ensure the flow of heavy crude oil during production. However, many of the methods appear costly and pose challenges during installation. Therefore, this study aims to investigate using nichrome wire for heavy crude oil production. An experimental setup was developed to power the nichrome wire placed inside the production casing. It was observed that the temperature increased with the decrease in the diameter of the nichrome wire. Heavy crude oil's maximum temperature was 72.3°C for a diameter of 0.05 mm, while it was 63.2°C for light crude oil. Nichrome wire withstands a high temperature, reaching 1150°C, which would help reduce the viscosity of the crude oil.

Keywords: *Heavy crude oil, nichrome wire, heat, thermal method, viscosity, downhole condition, high viscosity oil*

INTRODUCTION

The major problem in waxy crude oil extraction lies in the high viscosity, which negatively affects the oil production rate and causes non-smooth flow during normal reservoir conditions. Several techniques have been adopted for heavy crude oil production: non-thermal and thermal recovery. There is a specific use of each method depending on the reservoirs [1]-[2]. Heavy oil production and transportation present several operational and economic challenges because of high density and viscosity [3].

Investigations into ways to lower the heavy crude oil viscosity have revealed that traditional methods are expensive, hazardous, and require much maintenance. They also have a lot of utility but are inefficient. Thermal cracking was the initial way of lowering viscosity, and using catalysts might help overcome some of its drawbacks, such as extremely high temperatures and instability [4]. However, the temperature remained high, and attempts to improve results and efficiency are continuing owing to these underlying issues. The use of scattered nano catalysts improved the effectiveness of these reactions so much that viscosity decreased by up to 99% in the presence of hydrogen and nano-distributed catalysts. Many nanocatalysts have been explored, such as carbon, iron, nickel, and Nano zeolite, which have provided significant results; nevertheless, these approaches have certain unique challenges, such as the synthesis of nanocatalysts with proper surface and collection after the reaction.

Heavy crude oil comprises nearly 70% of remaining oil reserves. Elshawaf et al. [5] investigated the effects of nanoparticles ranging from 0.01 to 0.5 wt%. The influence of reservoir temperature is explored in addition to viscosity. The temperatures employed in this study range from 40°C to 100°C. Their findings suggest that greater viscosity reduction is possible. As a result, the recovery factor for heavy oil has improved. Consequently, theoretical and experimental explanations for the viscosity decrease behaviour have been conducted. Thus, the study investigates the aquathermolysis reaction for such materials, which is the primary cause of heavy oil viscosity reduction behaviour.

Several low-cost chemicals are used to decrease the viscosity of heavy oil, improve transportation, and increase production from these reservoirs with minimal problems [6]. The study contains pure chemical additives such as heptane, toluene, naphtha, xylene and kerosene. The research showed that toluene decreased oil viscosity exceedingly, followed by xylene, kerosene, and naphtha [7]. On the other hand, heptane had a very low boiling point, leading to very fast evaporation. The advantage of these formulations is that they help the heavy oil reservoir to raise oil recovery and minimise lifting and transportation costs [8].

Paraffin wax deposition happens repeatedly when transporting waxy crude oil in pipelines [9]-[11]. Akinyemi et al. [12] investigated the effect of plant seed oil on Nigerian waxy crude oil deposition tendency. Three samples of waxy crude oil from three locations were collected, and viscosity and wax contents were determined using standard methods. The samples were determined under a dynamic flow in a cold situation using Jatropha and castor seed oil. The results showed that castor seed oil decreased the wax deposition tendencies of the crude oil samples by 40%.

On the other hand, Jatropha seed oil had excellent and positive impacts on the pour point of waxy crude oils in the condition of a cold finger under a dynamic flow [13]. A minimum of 79.1% has inhibited the paraffin. The test confirms that seed oils work positively under low temperatures with low concentrations of 0.10% additive to crude oil.

Ibrahim et al. [14] used nano silica and novel capacitors to reduce the viscosity of Iraqi crude oil. Locally produced nano silica at various concentrations was utilised to demonstrate its efficacy under perfect conditions in the presence of an electrical field that impacts crude oil viscosity. The results showed that growing the voltage, treatment time, and distance between electrodes significantly minimised viscosity. After 32 seconds of treatment, 188 V, and a distance of 6.11 cm between capacitor electrodes, the minimal viscosity was achieved. With a viscosity of 20.479 CST, these were perfect conditions. As a result of particle aggregation, the viscosity rose. Under ideal circumstances of 102°C, the constructed capacitor produced a decent reduction in viscosity and a good power saving of 37%. The best Nano silica concentration was 100 mg/L, which resulted in a minimum viscosity of 12.8 CST and a 60.6 per cent reduction in power consumption.

In a study by Medvedovski et al. [15], the performance of coating carbon steel in hard boronized with a process of two iron boride layers, Fe_2B and FeB, to protect from conditions, abrasion and erosion was investigated. The study tested the structure of the iron boride coating and bare carbon steel by applying high-velocity water-oil flows containing salts combined with silica sand. The iron boride coating resulted in a larger corrosion performance, while bare carbon steel had high chemical inertness, hardness, and good bonding with the substrate. The boronized steel casing and tubing, which protects the internal surface, can be effectively applied in critical operational conditions.

Oil spills by an ecologically friendly method are crucial for water clean-up by effectively recovering and collecting high-viscosity crude oil [16]. An ornamentation was presented over a compressible wood sponge as an adsorbent using a new hydrophobic layer material and a thermally reduced graphene-oxide covering. By the favoured photothermal transformation thermogenesis technology, in-situ solar assisted the temperature of crude oil to rise to 88°C in 100 seconds with sun irradiation for simple adsorption to lower the viscosity of crude oil. The produced adsorbent functioned wonderfully in terms of oil-spill separation. The temperature gradient and compression-stressed structure dots were investigated as primary factors of compressible recovery of crude oil and photothermal-induced adsorption. The adsorbent also proved the separation and adsorption capacities of model heavy and light oils [17].

Furthermore, the adsorbent may be employed for viable adsorption in semi-open seawater under light, indicating the possibility of realistic offshore oil spill clean-up. This work proposed a possible technique to solve the issue by using ecologically benign materials derived from natural wood to adsorb high-viscosity crude oil inherent in situ photothermal thermogenesis [18]. Extraction of high-viscosity oils necessitates a significant amount of energy. This increased greenhouse gas emissions, which had a more severe negative environmental impact than the output [19]. Though different studies have been reported on thermal methods for flow assurance of heavy crude oil, there have been limited studies on using nichrome wire to ease the flow of waxy crude oil in pipelines. Therefore, this study aimed to design and use nichrome wire for flow assurance of heavy crude oil in pipelines.

EXPERIMENTAL SETUP AND TECHNIQUES

The effectiveness of nichrome wire was tested in both light and heavy crude oils. A thermometer is used to measure temperature. The DC power supply converts alternating current (AC) into direct current (DC) from 1 V to 15 V. A pump was used to pump the waxy crude oil. A viscometer was used to measure the viscosity of the crude oil used. Nichrome wire is used as a resistance wire and heating component. Different diameters of nichrome wire, such as 0.5 mm, 0.2 mm, and 0.05 mm, were used. The nichrome wire length was 20 cm. A multimeter device was used to measure resistance, voltage, and current. Two types of crude oil were used for this study. Light crude oil viscosity at 100 rpm was 3 cP. It was 4 cP at 200 rpm with an 851 kg/m^3 density. Components of the crude oil are heteroatom compounds (S, N, O), hydrocarbons (C, H), metals and organic (Ni, V, Fe), inorganic (Na^+, Ca^{++}, Cl^-). The viscosities of heavy crude oil at Low 100 rpm is 3cp and High 200 rpm is 15cp with a density of 8.1 lb/gal (971.9 kg/m^3). Components of heavy crude oil include a high ratio of aromatics and naphthene to linear alkanes and high levels of NSOs (nitrogen, sulphur, oxygen, and heavy metals). The nichrome wire was connected to a DC power supply of 5 V, 10 V, and 15 V.

Experimental Procedures

Initially, nichrome wire of different diameters was used in the analysis: 1 mm, 0.5 mm, 0.2 mm, 0.07 mm, and 0.05 mm. To evaluate the nichrome wire's performance, it was first attached to a 5-cm length of the wire to a DC power source, from which varying voltages were applied to see how the temperature increased over time. The experiment aims to determine how the Nichrome wire behaves when used with various materials and whether or not the waxy material will stick to the wire. Additionally, by adding two distinct types of material, heavy and crude oil temperature increase and trend were observed in the selected substance after one minute and fifty seconds. The DC power supply is set to 15 volts, and the nichrome wire has a diameter of 0.05 mm. The experiments were conducted through the use of a power supply of 5 V, 10 V, or 15 V and a selected nichrome wire of 0.05 mm, 0.07 mm, 0.2 mm, 0.5 mm, or 1 mm diameters to determine the performance of nichrome wire for flow assurance of waxy crude oil. Figure 1 shows the schematic diagram of the experimental setup. Nichrome wire with a power supply and a pump for both heavy and light crude oil was adopted.

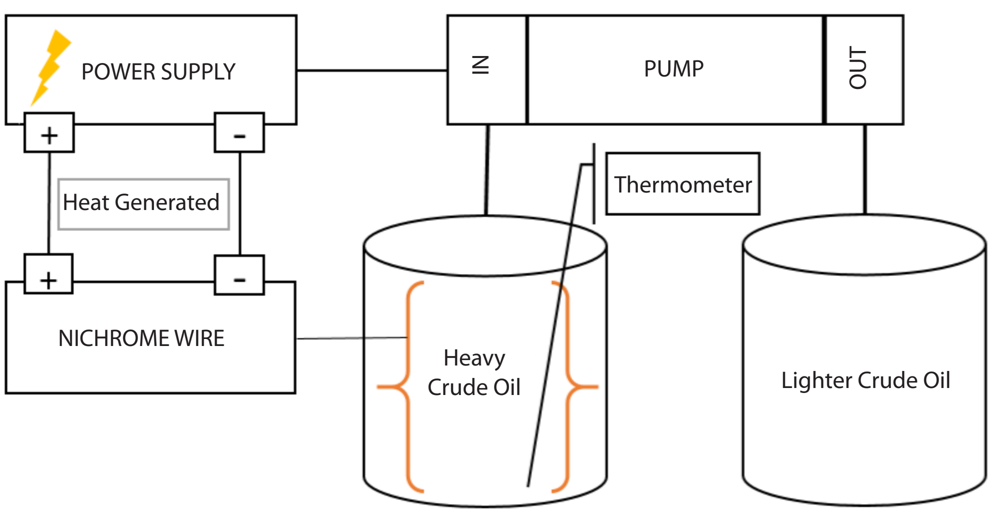

Figure 1 Experimental setup

RESULTS AND DISCUSSION

Effects of Different Diameters of Nichrome Wire on Light Crude Oil

Figure 2 shows temperature profiles in 110 s for different diameters of nichrome wire at 5 V. It was observed that using a 0.5 mm diameter, the starting temperature was 26.8°C, and the ending temperature was 28.7°C, the temperature increased by 1.9°C. When using a 0.2 mm diameter, the starting temperature was 26.8°C, and the ending temperature was 34.8°C, increasing by 8°C. Using a 0.05 mm diameter, the starting temperature was 26.8°C, and the ending was 37.1°C. The temperature increased by 10.3°C.

Figure 3 shows the change in temperature in 110 s for different diameters in the case of 10 V. It was observed that, using 0.5 mm, the starting temperature was 26.8°C, and the ending temperature was 31.2°C, a temperature increase of 4.4°C. For a 0.2 mm diameter, the starting temperature was 26.8°C, and the ending temperature was 45.6°C, experiencing a temperature rise of 18.8°C. When using 0.05 mm, the starting temperature was 26.8°C, and the ending temperature was 54.8°C, a higher temperature rise of 28°C.

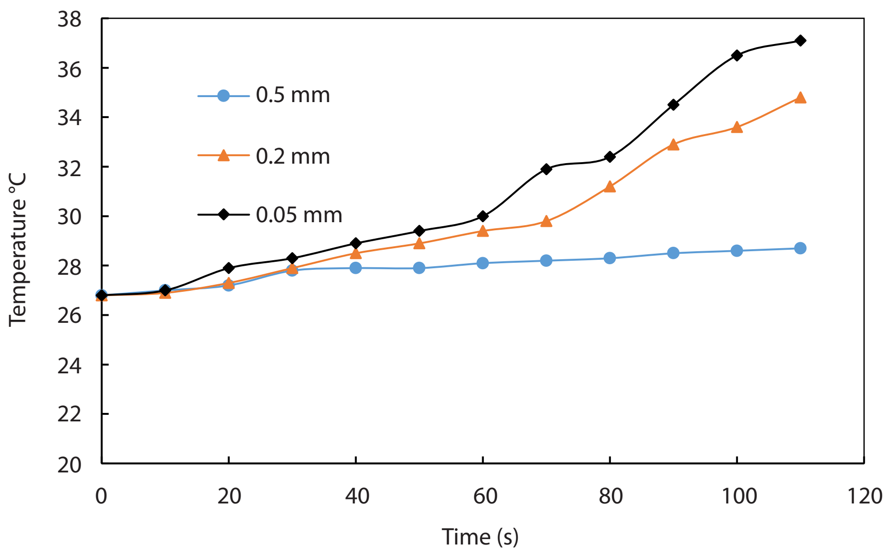

Figure 2 Temperature profiles in 110 s when using different diameters at 5 V

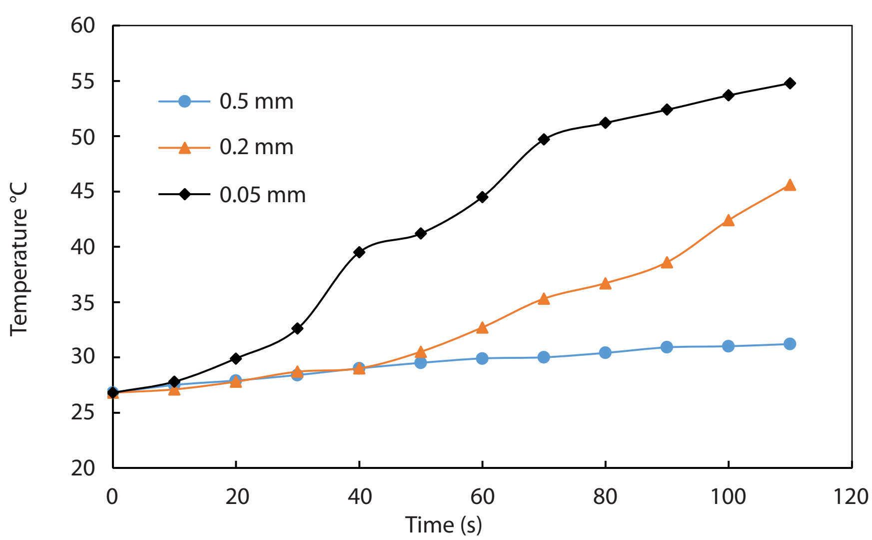

Figure 3 Temperature change in 110 s with different diameters in the case of 10 V

Figure 4 shows temperature profiles in 110 s for different diameters of nichrome wire at 15 V. It was observed that, when using 0.5 mm, the starting temperature was 26.8°C, and the ending temperature was 35.3°C, increasing by 8.5°C. When using 0.2 mm, the starting temperature was 26.8°C, and the ending temperature was 56.1°C, a temperature rise of 29.3°C. The starting temperature was 26.8°C, and the ending was 63.2°C for 0.05 mm, a temperature increase of 36.4°C.

Effects of Different Diameters of Nichrome Wire on Heavy Crude Oil

Figure 5 shows temperature variation in 110 s for different diameters of nichrome wire at 5 V. It was observed that, when using 0.5 mm diameter, the starting temperature was 26.8°C, and the ending temperature was 29.7°C, a temperature increase of 3.1°C. For a 0.2 mm diameter, the starting temperature was 26.8°C, and the ending temperature was 39.8°C, a temperature rise of 13°C. When using a 0.05 mm diameter, the starting temperature was 26.8°C, and the ending temperature was 42°C, a temperature rise of 15.2°C.

Figure 6 shows temperature variations in 110 s when applying different diameters of nichrome wire for heavy crude oil in the case of 10 V. It was observed that using a 0.5 mm diameter, the starting temperature was 26.8°C

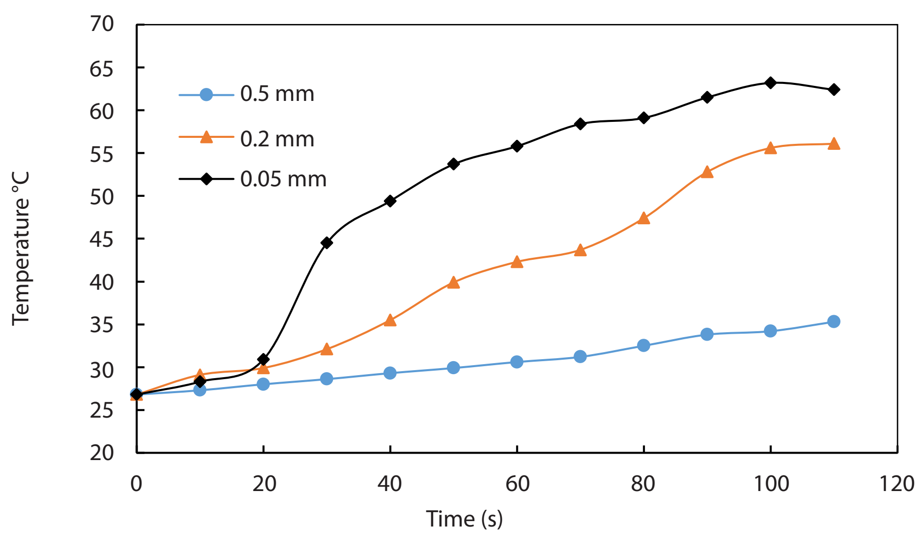

Figure 4 Temperature profiles in 110 s with different diameters for the case of 15 V

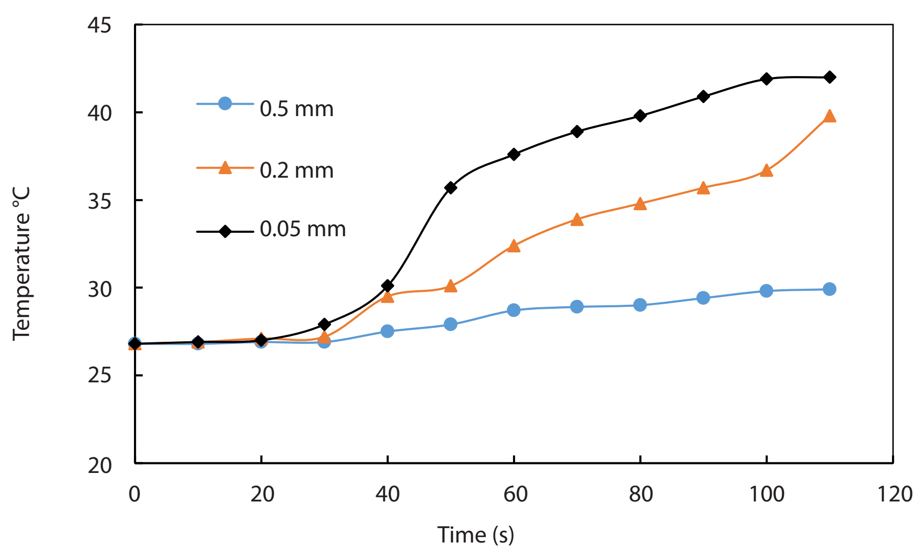

Figure 5 Temperature profiles of heavy crude oil in 110 s for different diameters at 5 V

and the ending temperature was 33.5°C, a temperature increase of 6.7°C. The temperature rise was higher for the smaller diameter of 0.2 mm, for which the starting temperature was 26.8°C, and the ending temperature was 20.2°C, a temperature increase of 39°C. For a 0.05 mm diameter, the starting temperature was 26.8°C, and the ending temperature was 65.8°C, a temperature increase of 39°C.

Figure 7 depicts a temperature variation in heavy crude oil in 110 s for different diameters of nichrome wire at 15 V. It was observed that by using a 0.5 mm diameter, the starting temperature was 26.8°C and the ending temperature was 38.6°C, showing a temperature increase by only 11.8°C. However, the temperature rise was higher for the 0.2 mm diameter, where the starting temperature was 26.8°C, and the ending temperature was 61.5°C with a temperature rise of 34.7°C. The increment in temperature was significant for the diameter of 0.05 mm, for which the starting temperature was 26.8°C and the ending temperature was 72.3°C, with a temperature rise of almost 45.5°C.

Comparison Between Light and Heavy Crude Oil When Using Nichrome Wire

Figure 8 shows the change in temperature in 110 s when applying 5 V for the case of 0.05 mm diameter. It was observed that the starting temperature was 26.8°C

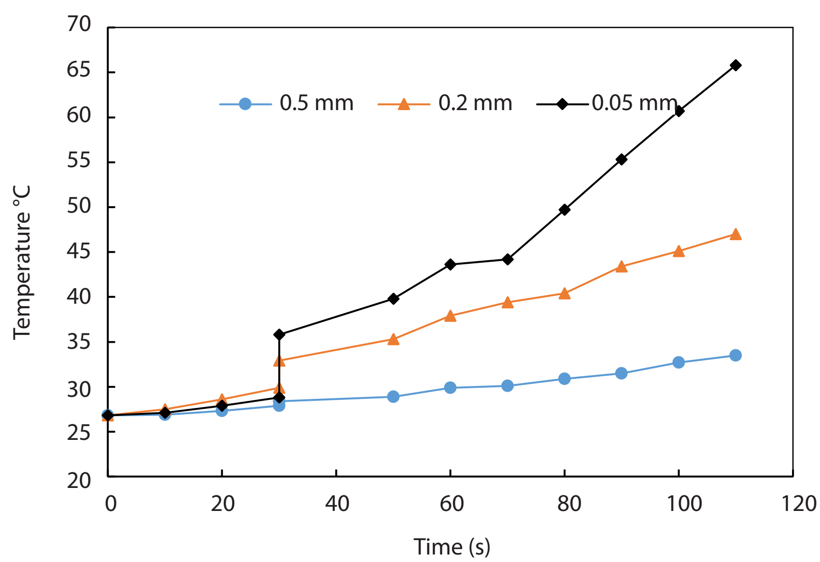

Figure 6 Temperature profiles of heavy crude oil for 10 V

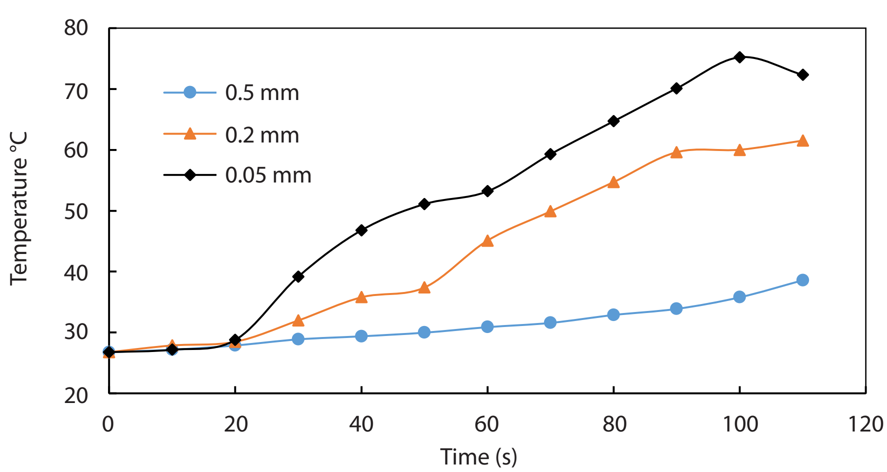

Figure 7 Temperate profiles of heavy crude oil in 110 s for different diameters of nichrome wire at 15 V

and the ending temperature was 42°C, a temperature increase of 15.2°C. On the other hand, for the light crude oil, it was observed that the starting temperature was 26.8°C and the ending temperature was 37.1°C. The temperature increased by 10.3°C. Several approaches exist for upgrading heavy crude oil to lighter oil.

On the other hand, current procedures typically need high temperatures and extended response times and cause significant environmental pollution [20]. In-situ steam-based technology is still dominant for heavy oil and bitumen extraction worldwide. Steam-driven heavy oil recovery systems, such as cyclic steam stimulation and steam-assisted gravity drainage, have various downsides, including steam flooding. The disadvantages include limited heavy oil or bitumen recovery, high greenhouse gas footprint, and difficulty stopping emergency operations [21].

Figure 9 shows temperature variations in 110 s when applying 10 V for a 0.05 mm diameter. It was observed that the starting temperature was 26.8°C and the ending temperature was 65.8°C, increasing by 39°C. Furthermore, in the case of crude oil, the starting

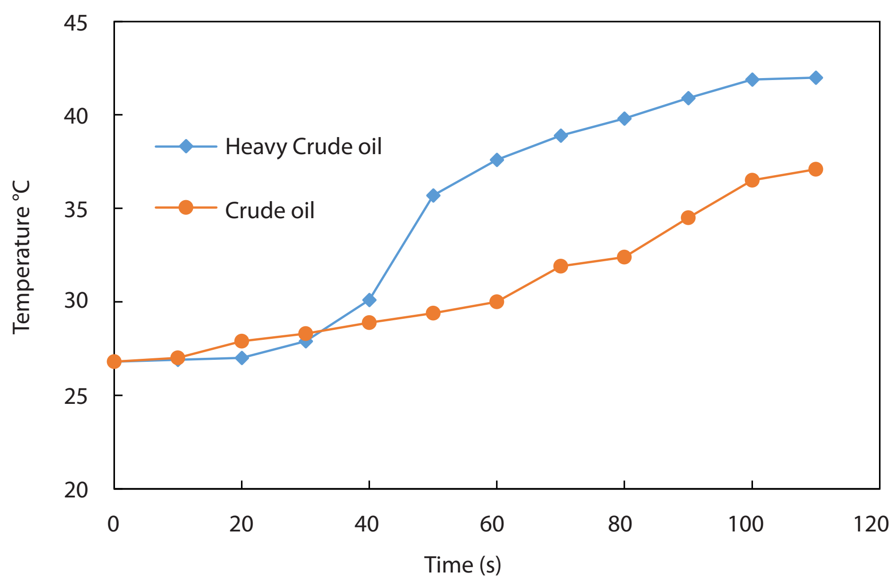

Figure 8 Temperature variation in 110 s at 5 V for light and heavy crude oil for the case of 0.05 mm diameter

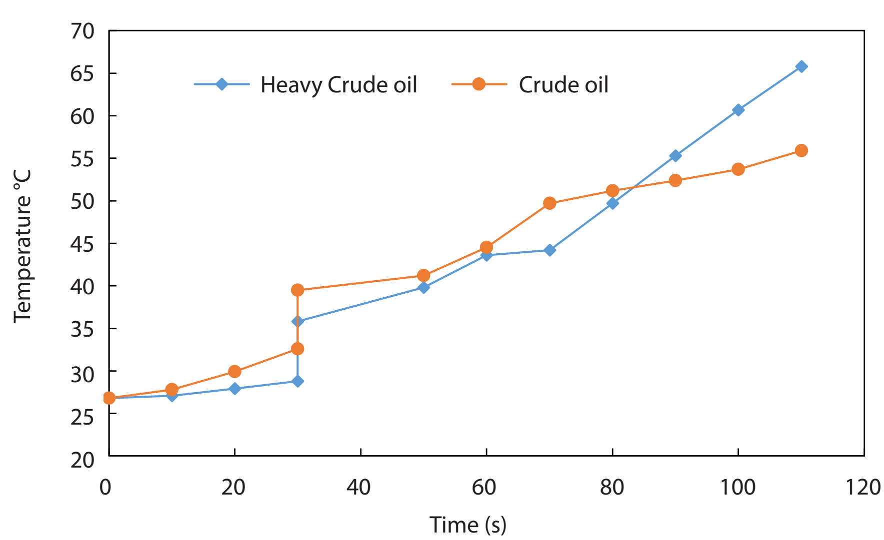

Figure 9 Temperature variation in 110 s when applying 10 V for light and heavy crude oil for the case of 0.05 mm diameter

temperature was 26.8°C, and the ending temperature was 54.8°C, a temperature increase of 28°C.

Figure 10 shows the change in temperature at 110 s when applying 15 V in the case of a 0.05 mm diameter. It was observed that the starting temperature was 26.8°C, the ending temperature was 72.3°C, and the temperature increased by 45.5°C. Moreover, in the case of crude oil, the starting temperature was 26.8°C, and the ending temperature was 63.2°C, with a temperature increase of 36.4°C.

Pumping Condition with Heat Generated from Nichrome Wire

Table 1 shows the pump conditions using different viscous fluids with a heat source from a nichrome wire. By applying a nichrome wire with a length of 20 cm and a voltage of 15, the start temperature of all the materials was 26.8°C. Firstly, in the case of water, by using 60 ml of water and applying a nichrome wire with 15 volts, the end temperature was 103.1°C. The amount of water was 1% less, with the time taken to pump 60 ml of water of 4 seconds. Secondly, when using 60 ml of cooking oil and applying a nichrome wire with 15 volts, the end temperature was 64.8°C. The amount of cooking oil was 4% less; the time taken to pump 60 ml of cooking oil was 5 seconds. Thirdly, in the case of crude oil, by using 60 ml of crude oil and applying a nichrome wire with 15 volts, the ended temperature was 58.6°C; the amount of crude oil was 15% less, and the time taken to pump 60 ml of crude oil was 5 seconds. Fourthly, in the case of using 60 ml of heavy crude oil and applying a nichrome wire with 15 volts, the end temperature was 64.9°C, the amount of heavy crude oil was 28% less, and the time taken to pump 60 ml of heavy crude oil was 15 seconds. This process is mainly referred to as the temperature rises, the viscosity of liquids and surface tension decrease, and the corresponding values rise on a vast scale [22].

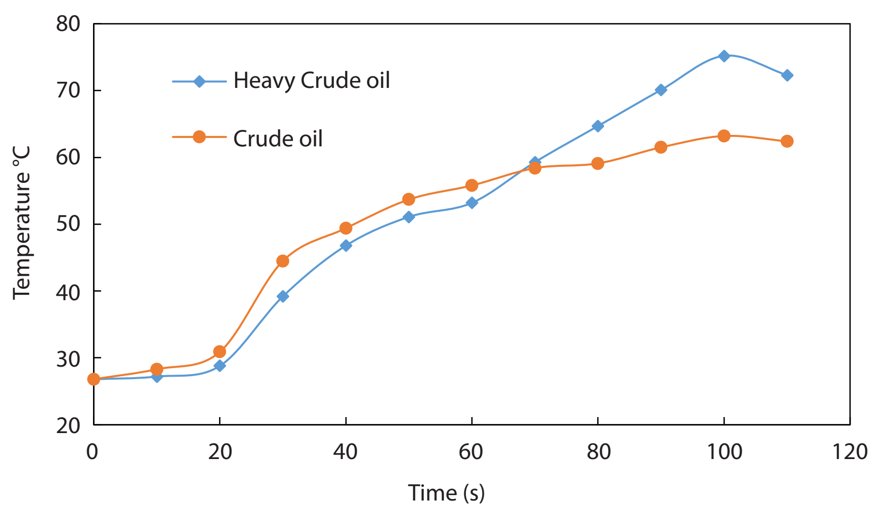

Figure 10 Temperature profiles in 110 s when applying 15 V for light and heavy crude oil in the case of 0.05 mm diameter

Table 1 Testing the pump with different viscosities by applying heat

Material	Amount		Pump voltage (volt)	Length of the wire (cm)	Voltage (volt)	Temperature (°C)	Time taken after applying heat (seconds)
	Start with (ml)	End with (% less)					
Water	60	1	12	20	15	103	4
Cooking oil	60	4	12	20	15	64.8	5
Crude oil	60	15	12	20	15	58.6	5
Heavy crude oil	60	28	12	20	15	64.9	15

CONCLUSION

The present study investigated using nichrome wire to ease the flow of heavy crude oil in pipelines. The production of waxy crude oil experiences wax precipitation, leading to a high viscosity and negatively affecting the production rate. Production issues due to flow blockage lead to increased costs, and resuming the flow might be impossible sometimes. Several technologies were developed for flow assurance and management of heavy crude oil. This study investigates the thermal method for heavy crude oil production problems using nichrome wire for high effectiveness, low price, and ease of application. Experiments were conducted on light and heavy crude oil to reduce viscosity and increase production. Applying nichrome wire increased the temperature with a decrease in viscosity. It was observed that the temperature increases with a reduction in the nichrome wire diameter. Additionally, it takes a longer time to generate heat when the diameter is bigger. In comparison between heavy crude oil and light crude oil for a diameter of 0.05 mm, the temperature increased by 45.5°C for heavy crude oil, whereas light crude oil temperature increased by 36.4°C.

ACKNOWLEDGEMENT

The authors would like to thanks the International College of Engineering and Management (ICEM) for the support provided.

REFERENCES

[1] I.C.V.M. Santos, P.F. Oliveira, and C.R.E. Mansur, "Factors that affect crude oil viscosity and techniques to reduce it: A review", *Brazilian Journal of Petroleum and Gas*, vol. 11, no. 2, 2017.

[2] E. Bell, Y. Lu, N. Daraboina, and C. Sarica, "Thermal Methods in Flow Assurance: A Review", *Journal of Natural Gas Science and Engineering*, p.103798, 2021.

[3] G. T. Chala, S. A. Sulaiman, A. Japper-Jaafar, and W.A.K.W. Abdullah, "Investigation of convective heat transfer coefficient and initial temperature of waxy crude oil on the formation of voids", *International Journal of Automotive and Mechanical Engineering*, vol. 13, no. 3, pp. 3754-3762, 2016.

[4] A. Sircar, K. Rayavarapu, N. Bist, K. Yadav, and S. Singh, "Applications of nanoparticles in enhanced oil recovery", *Petroleum Research*, 2021.

[5] M. Elshawaf, "Investigation of graphene oxide nanoparticles effect on heavy oil viscosity", In *SPE Annual Technical Conference and Exhibition*. OnePetro, 2018.

[6] G. T. Chala, S. A. Sulaiman, and A. Japper-Jaafar, "Flow start-up and transportation of waxy crude oil in pipelines-A review", *Journal of non-newtonian fluid mechanics*, vol. 251, pp. 69-87, 2018.

[7] S. Huang, M. Cao, and L. Cheng, "Experimental study on the mechanism of enhanced oil recovery by multi-thermal fluid in offshore heavy oil", *International Journal of Heat and Mass Transfer*, vol. 122, pp. 1074-1084, 2018.

[8] S. Fakher, A. Imqam, and E. Wanas, "Investigating the viscosity reduction of ultra-heavy crude oil using hydrocarbon soluble low molecular weight compounds to improve oil production and transportation", In *SPE International Heavy Oil Conference and Exhibition*. OnePetro, 2018.

[9] Y. Al Waleed, and G. T. Chala, "Flow assurance of waxy crude oil through thermal methods using nichrome wire and ultrasonic waves effects–Experimental investigation", *Geoenergy Science and Engineering*, vol. 243, p. 213277, 2024.

[10] S. A. Sulaiman, B. K. Biga, and G. T. Chala, "Injection of non-reacting gas into production pipelines to ease restart pumping of waxy crude oil", *Journal of Petroleum Science and Engineering*, vol. 152, pp. 549-554, 2017.

[11] G. T. Chala, and S. A. Sulaiman, "Voids size distribution in gelled waxy crude oil under dynamic and static cooling", *Petroleum Research*, vol. 9, no. 1, pp. 109-114, 2024.

[12] O. P. Akinyemi, J. D. Udonne, and K. F. Oyedeko, "Study of effects of the blend of plant seed oils on wax deposition tendencies of Nigerian waxy crude oil", *Journal of Petroleum Science and Engineering*, vol. 161, pp. 551-558, 2018.

[13] O. O. Akinsetea, S. M. Owoseni, and A. A. Sulaimon, "Experimental investigation of wax inhibition tendency of Jatropha oil in Niger Delta waxy crude-oil," *Petroleum Science and Technology*, 2023, doi:10.1080//10916466.2022.2149800.

[14] R. I. Ibrahim, M. K. Oudah, and A. F. Hassan, "Viscosity reduction for flowability enhancement in Iraqi crude oil pipelines using a novel capacitor and locally prepared nanosilica", *Journal of Petroleum Science and Engineering*, vol. 156, pp. 356-365, 2017.

[15] E. Medvedovski, G. L. Mendoza, and G. Vargas, "Influence of Boronizing on Steel Performance under Erosion-Abrasion-Corrosion Conditions Simulating Downhole Oil Production", *Corrosion and Materials Degradation*, vol. 2, no. 2, pp. 293-324, 2021.

[16] S. ben Hammouda, Z. Chen, C. An, and K. Lee, "Recent advances in developing cellulosic sorbent materials for oil spill cleanup: A state-of-the-art review," *Journal of Cleaner Production*, vol. 311, pp. 127630–127630, May 2021, doi:10.1016/j.jclepro.2021.127630.

[17] P. E. Ndimele, A. O. Saba, D. O. Ojo, C. C. Ndimele, M. A. Anetekhai, and E. S. Erondu, "Remediation of Crude Oil Spillage," *Elsevier eBooks*, pp. 369–384, Nov. 2017, doi:10.1016/b978-0-12-809399-3.00024-0.

[18] W. Chao, S. Wang, Y. Li, G. Cao, Y. Zhao, X. Sun, C. Wang, and S. H. Ho, "Natural sponge-like wood-derived aerogel for solar-assisted adsorption and recovery of high-viscous crude oil", *Chemical Engineering Journal*, vol. 400, p.125865, 2020

[19] G. Buslaev, V. Morenov, Y. Konyaev, and A. Kraslawski, "Reduction of carbon footprint of the production and field transport of high-viscosity oils in the Arctic region", *Chemical Engineering and Processing-Process Intensification*, vol. 159, p. 108189, 2021

[20] K. Li, B. Hou, L. Wang, and Y. Cui, "Application of carbon nanocatalysts in upgrading heavy crude oil assisted with microwave heating", *Nano letters*, vol. 14, no. 6, pp. 3002-3008, 2014.

[21] M. Ahmadi, and Z. Chen, "Challenges and future of chemical assisted heavy oil recovery processes", *Advances in colloid and interface science*, vol. 275, p.102081, 2020.

[22] H. Kajimoto, and L. A. Jones, "Wearable tactile display based on thermal expansion of nichrome wire", *IEEE Transactions on Haptics*, vol. 12, no. 3, pp.257-268, 2019.