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Analysis of the Effect of LEP-01 Pour Point Depressant on Crude Oil Viscosity Using Rotational Rheology

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Abstract

The transportation of crude oil through pipelines is significantly influenced by its viscosity, particularly at low temperatures where wax crystals begin to form and restrict fluid flow. The use of chemical additives, such as pour point depressants (PPDs), has become an effective approach to improving the flow characteristics of waxy crude oil. This study aimed to evaluate the effect of LEP-01 pour point depressant on the viscosity of crude oil using a rotational rheology method. Crude oil samples were treated with LEP-01 at concentrations of 1000, 2000, and 3000 ppm, while untreated crude oil was used as a blank sample. Before testing, all samples were heated, mixed to achieve homogeneity, and analyzed using a rotational rheometer under controlled cooling conditions. The experimental results showed that crude oil viscosity increased as the temperature decreased due to wax crystallization. The addition of LEP-01 effectively reduced the viscosity of crude oil compared with the blank sample, with the highest concentration (3000 ppm) providing the greatest viscosity reduction. This improvement is attributed to the ability of LEP-01 to modify wax crystal growth and inhibit crystal aggregation, thereby reducing flow resistance at low temperatures. Overall, the results demonstrate that LEP-01 has considerable potential as a flow improver for maintaining crude oil flowability during low-temperature transportation and handling.

Keywords: *Crude oil; Pour point depressant; LEP-01; Rotational rheology; Viscosity; Wax crystal.*

Introduction

Crude oil is one of the primary energy resources widely used to meet global energy demands. During production and transportation, crude oil is commonly transferred through pipelines, where its flow behavior is strongly influenced by viscosity (Onwumelu et al., 2022). At low temperatures, the viscosity of crude oil increases significantly due to the formation of wax crystals, which can restrict flow, reduce transportation efficiency, and increase operational costs. Therefore, controlling crude oil viscosity is essential to ensure a stable and efficient transportation process.

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One of the most effective methods for improving the flowability of waxy crude oil is the use of chemical additives known as pour point depressants (PPDs). These additives reduce the adverse effects of wax crystallization by modifying crystal growth and preventing excessive wax aggregation, thereby lowering flow resistance without changing the chemical composition of the crude oil. LEP-01 is a PPD that has been developed to improve the low-temperature flow properties of crude oil and enhance its transportability (Elarbe et al., 2021).

This study aims to investigate the effect of LEP-01 on crude oil viscosity using a rotational rheology method. The study evaluates the influence of different LEP-01 concentrations on the rheological behavior of crude oil under cooling conditions and assesses its effectiveness as a flow improver for petroleum transportation applications (Elganidi et al., 2021).

Materials and Methods

Crude oil was used as the test sample, while LEP-01 pour point depressant (PPD) served as the chemical additive. Four sample variations were prepared: untreated crude oil (blank) and crude oil containing LEP-01 at concentrations of 1000, 2000, and 3000 ppm. Before testing, the crude oil was heated to approximately 80 °C to dissolve existing wax crystals. The required amount of LEP-01 was then added to each sample, followed by homogenization using a magnetic stirrer for 30 minutes.

The rheological properties of the samples were measured using a rotational rheometer. Prior to measurement, an air check procedure was performed to ensure proper instrument operation. Each sample was subjected to a controlled cooling program from 80 °C to 15 °C at a cooling rate of 1 °C/min under a constant shear condition. Viscosity data were continuously recorded throughout the cooling process to evaluate the effect of temperature on crude oil flow behavior.

The viscosity profiles obtained from the blank and treated samples were compared to determine the effectiveness of LEP-01 in reducing crude oil viscosity. The influence of additive concentration was evaluated based on the viscosity changes observed during cooling, with particular attention given to the low-temperature region where wax crystallization becomes significant.

Instrumentation

Viscosity measurements were performed using an MCR 92 rotational rheometer equipped with a CP50 non-sandblasted spindle. The instrument was used to determine the viscosity response of crude oil samples under controlled shear and temperature conditions. A water bath was used to heat the samples to approximately 80°C during sample preparation and homogenization. Supporting equipment included beakers, graduated cylinders, test bottles, droppers, micropipettes, and an analytical balance. The rheometer was subjected to an air-check procedure before testing to ensure proper air-bearing performance, stable compressed-air supply, and reliable torque measurements.

Procedure

Crude oil samples were heated in a closed water bath at approximately 80°C for at least 4 h to dissolve pre-existing wax crystals. The samples were then divided into labelled test bottles as a blank and treatments containing LEP-01 at concentrations of 1000, 2000, and 3000 ppm. The additive was introduced using a micropipette, after which the samples were reheated and shaken until homogeneous. Before measurement, an air check was performed on the MCR 92 rotational rheometer to verify stable compressed-air supply, air-bearing performance, and baseline torque correction. Each sample was transferred into the rheometer cup and subjected to a pre-shear rate of approximately 10 s^{-1} at 80°C. Viscosity was subsequently measured during a controlled cooling program from 80°C to 10°C at 2°C min^{-1}. Viscosity data were recorded continuously as a function of temperature. All measurements were conducted in duplicate, and the viscosity-temperature profiles of the additive-treated samples were compared with that of the blank to evaluate the effect of LEP-01 on crude-oil flow behavior and viscosity reduction.

Results and Discussion

Effect of Temperature on Crude Oil Viscosity

the relationship between temperature and crude oil viscosity during the cooling process. The viscosity of all samples increased as the temperature decreased. At high temperatures, crude oil exhibited relatively low viscosity because the wax components remained completely dissolved in the liquid phase. However, as the temperature approached the Wax Appearance Temperature (WAT), wax crystals began to form and gradually increased the resistance to flow. Further cooling promoted the growth and aggregation of wax crystals, resulting in a significant increase in viscosity. The formation of a three-dimensional wax crystal network restricted the movement of liquid hydrocarbons, causing the crude oil to become more resistant to flow. These results indicate that temperature is one of the most important factors influencing the rheological behavior of waxy crude oil.

Effect of LEP-01 on Crude Oil Viscosity

The addition of LEP-01 significantly reduced the viscosity of crude oil compared with the untreated sample. As shown in Figure 1, all treated samples exhibited lower viscosity values throughout the cooling process, indicating that LEP-01 effectively improved the flow characteristics of crude oil under low-temperature conditions.

The viscosity reduction is attributed to the mechanism of LEP-01 as a pour point depressant. The additive interacts with paraffin wax molecules during crystalliza modifying crystal morphology and inhibiting excessive crystal growth and aggregation. Consequently, the formation of a continuous wax crystal network was suppressed, allowing the crude oil to maintain better flowability during cooling.

Effect of LEP-01 Concentration

Different concentrations of LEP-01 produced different levels of viscosity reduction. Increasing the concentration of the additive enhanced its ability to suppress wax crystal aggregation, resulting in progressively lower viscosity values. Among the tested samples, the addition of 3000 ppm LEP-01 produced the greatest viscosity reduction, demonstrating the highest effectiveness in improving crude oil flowability.

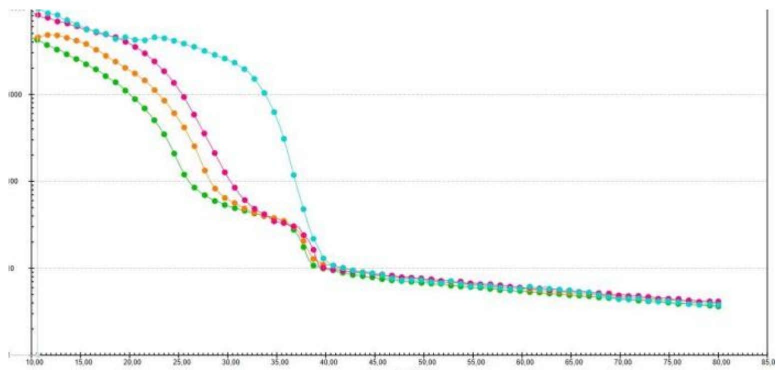

Figure 1. Effect of LEP-01 concentration on crude oil viscosity as a function of temperature.

These findings suggest that the performance of LEP-01 depends on additive concentration. A higher concentration provides more active molecules to interact with wax crystals, thereby reducing

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intermolecular interactions between crystals and minimizing flow resistance. Therefore, LEP-01 has considerable potential to be applied as a flow improver for crude oil transportation, particularly under low-temperature operating conditions.

Conclusion

The results of this study demonstrate that temperature has a significant effect on the viscosity of crude oil, with viscosity increasing as the temperature decreases due to wax crystal formation. The addition of LEP-01 pour point depressant effectively reduced crude oil viscosity by modifying wax crystal growth and minimizing crystal aggregation. Furthermore, increasing the concentration of LEP-01 enhanced its performance, with the 3000 ppm concentration showing the highest effectiveness in improving crude oil flowability. These findings indicate that LEP-01 is a promising flow improver for maintaining the transportability of crude oil under low-temperature conditions.

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