Experimental investigation of wax deposition in polyethylene pipe

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Introduction

The higher and higher demand of fossil fuel will increase the production and transportation of crude oil. The wax deposition arouses more attention in the fast-developing petroleum industry. Wax deposition occurs when the temperature of the waxy crude oil falls below the wax appearance temperature (WAT), where the wax component will precipitate out of the crude oil and deposit on the pipe wall.[1] The continuous wax deposition causes the deposit layer to grow thicker over time and may clog the transportation pipeline in the worst scenario.

Nowadays, the most common method to limit wax deposition is through the pigging operation, where an equipment named "pig" is inserted into the transportation pipeline and move forward with the flowing fluid and scrape the deposits off the inner pipe wall. However, the economical and safe operation of pigging needs the accuracy determination of the deposit thickness.[2]

Furthermore, in some cases, the corrosive agents in the oil and surroundings will reduce the thickness of the pipe wall from both inside and outside, leading to the perforation of the transportation pipelines.[3] As a result, high-density polyethylene (PE) pipelines have been widely used in some oilfields to prevent corrosion problems and transport the crude oil at the same time.

Therefore, it is necessary to investigate the wax deposition in the PE pipe, which can provide significant reference for the safe and economical pigging operation in the fields.

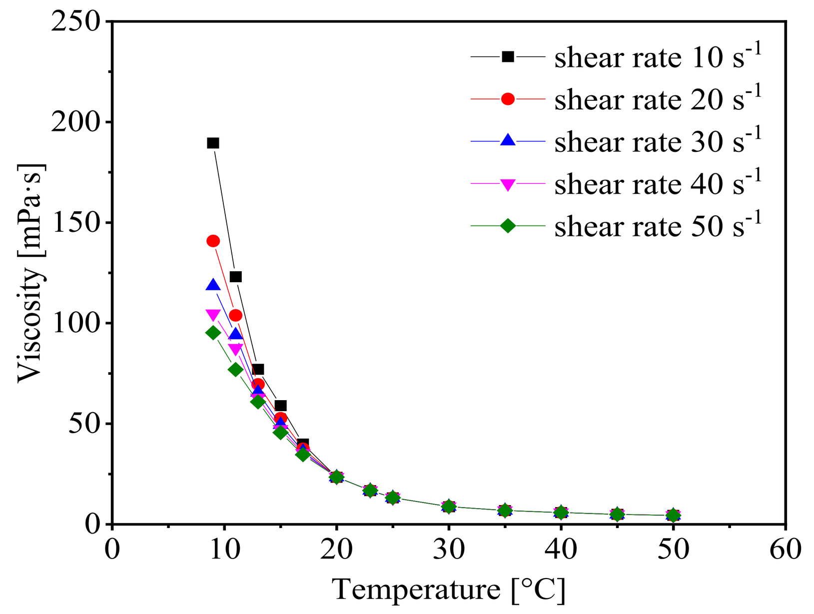
Materials

A waxy crude oil collected from the field.

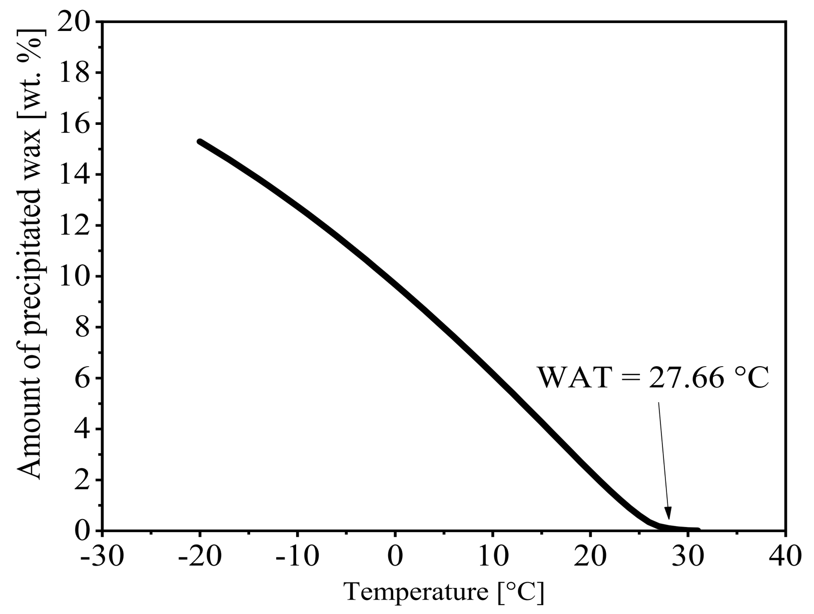
Physical properties of the crude oil

Density at 20 °C (kg/m^3)	Gel point (°C)	Wax appearance temperature (WAT) (°C)	Wax content (wt. %)
852.3	17	27.66	15.20

Viscosity-temperature relationship

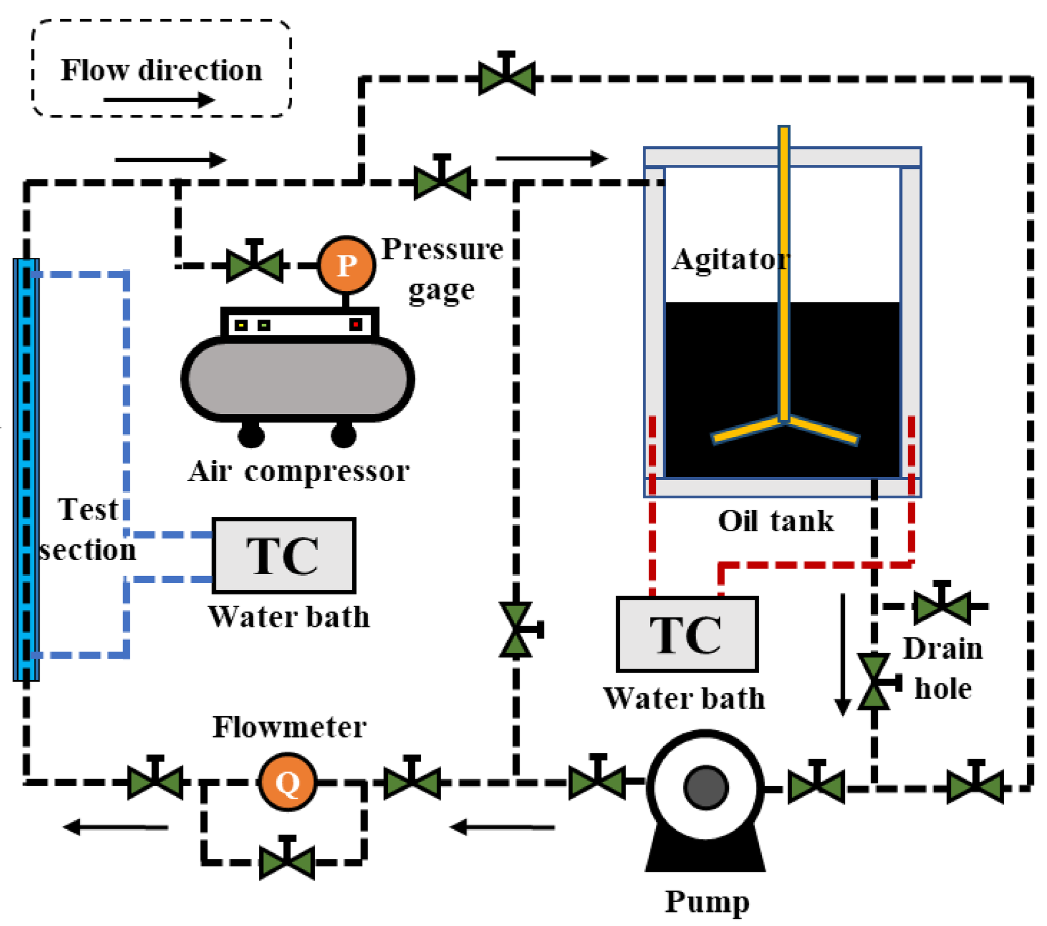


Wax precipitation curve



Apparatus

Flow-loop apparatus



The wax deposition experiments were performed using an in-house flow-loop apparatus, which consists of a test section, a pumping system, an oil tank, an air compressor, and a mass flow meter.

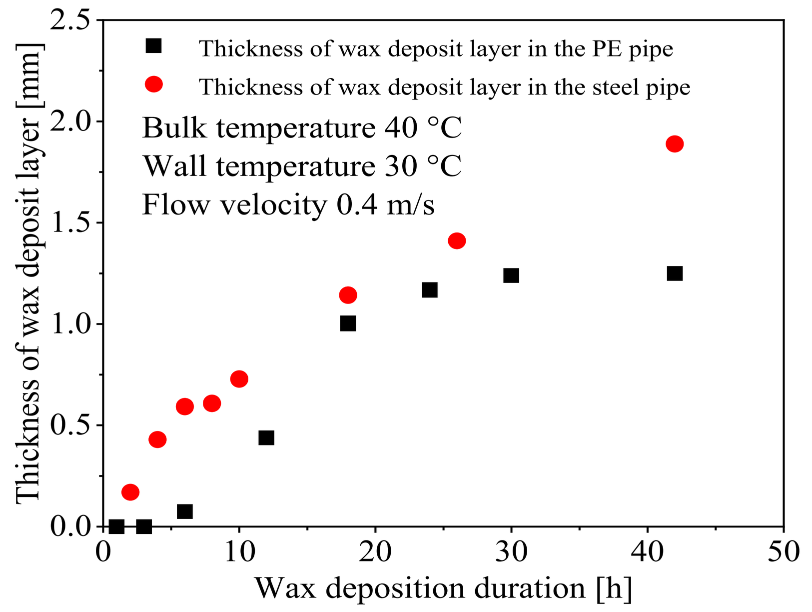
The temperature of all pipes, flow velocity, and wax deposition duration can be controlled accurately.

Two detachable test sections are coaxial double-pipe heat exchanger pipes with inner diameter of 16 mm and length of 1.5 m.

The hot waxy crude oil and coolant flow counter currently to generate wax deposits on the inner surface of the test section.

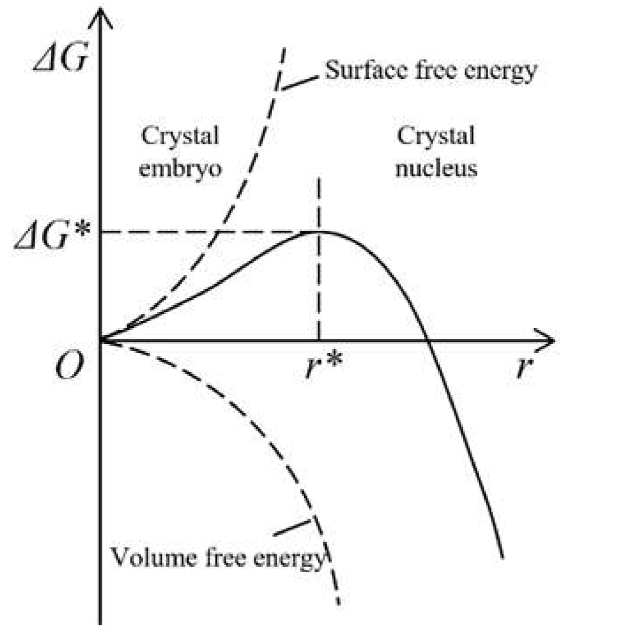
Results and Discussion

Thickness of wax deposit layer



The wax deposition in the PE pipe was delayed. No wax deposits were found in the first 4 h. The total growth rate of wax deposition in the PE pipe is lower.

Surface roughness



The surface roughness of the pipe wall is bigger than the critical crystallization radius of wax. The critical crystallization radius of wax is 10^{-9}. The surface roughness of pipe wall 10^{-6}.The surface roughness of pipe wall has no influence on the formation of wax deposit layer.

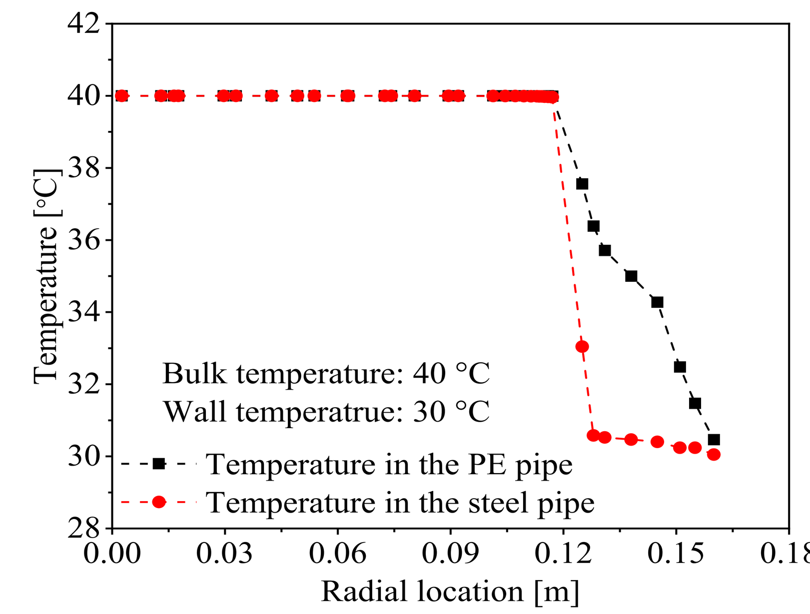
Surface energy

The adhesion work of the bulk on the pipe wall:

$$\gamma_{sl} = \gamma_s + \gamma_l - 2\sqrt{\gamma_s^d \gamma_l^d} - 2\sqrt{\gamma_s^p \gamma_l^p}$$

γ_s and γ_l are the surface tensions of pipe and oil, respectively. Crude oil is more prone to stick on the steel pipe wall.

Heat transfer



The difference in the thermal conductivity between the PE pipe and steel pipe can lead to different temperature distribution in the pipe. The thermal gradient in the PE pipe is lower, causing a lower growth rate of the wax deposition, which may also have influence on the formation of the wax deposit layer.

Conclusions

The formation of wax deposition in the PE pipe is delayed. The delayed formation was mainly related to the surface energy of the surface and the heat transfer process while the surface roughness has few influence on the wax deposition. These findings can help the pigging operation in the long -distance PE transportation pipelines in the field.

Acknowledgements

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