Experimental study on wax deposition using a test flow loop under laminar flow conditions for single oil phase flow

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With the exploration of the deepwater oil fields and the construction of the offshore pipelines, the problem of wax deposition has to be taken into consideration and significantly requires corresponding solutions for the transportation of waxy crude oil. Wax molecules in the waxy crude oil can precipitate out of the liquid oil to form solid wax particles which can deposit on the cold internal pipe wall when the waxy crude oil is transported in a cold ambient which is not only below the oil temperature but also below its Wax Appearance Temperature (WAT). It is obvious that offshore pipelines are subject to the wax deposition situation due to the low temperature of cold sub-sea environment. Owing to the occurrence of wax deposition, transfer pressure will increase and the transportation capacity of the pipeline will be reduced with the decreasing area open to flow. To make matters worse, it may lead to the pipe plugging which can cause enormous financial losses to the petroleum industry. Hence, so far wax deposition has become a focus studied by the global petroleum industry.

In this study, a test flow loop facility was designed and constructed to simulate the wax deposition occurring in pipelines. The influence factors affecting wax deposition in pipelines which include the oil temperature, the pipe wall temperature, temperature area, liquid velocity and shear dispersion mechanism were experimentally studied, respectively. All the experiments were performed under the laminar flow conditions.

Considering the practical situation where the ambient temperature may be below the gel point temperature of the waxy crude oil transported in pipelines, the pipe wall temperatures studied in the experiments were selected to be around the gel point temperature. Unlike the conventional phenomenon, the results show that under the constant oil temperature the thickness of wax deposits decreases with the decreasing pipe wall temperature which is around the gel point temperature of the waxy crude oil used in the experiments.

In the previous published literature sources, the selection of oil temperatures which were studied in experiments was not usually differentiated in terms of wax appearance temperature of the oil sample. However, in this study the selection of oil temperatures was differentiated in terms of wax appearance temperature (WAT). The results show that 1) when the oil temperatures which were below the WAT were selected for the experiments, the thickness of wax deposits increases with the increasing oil temperature under the constant pipe wall temperature conditions; 2) when the oil temperatures which were above the WAT were selected for the experiments, the thickness of wax deposits decreases as the oil temperature increases under the constant pipe wall temperature conditions.

There is no doubt that the temperature difference has a significant effect on wax deposition, however, it is likely that the different temperature areas under a fixed temperature difference conditions could lead to different wax deposition situation. The results show that 1) when the oil temperatures which were above the WAT were selected for the experiments, the higher oil temperature for a fixed temperature difference results in the smaller thickness of wax deposits; 2) when the oil temperatures which were below the WAT were selected for the experiments, the higher oil temperature for a fixed temperature difference leads to the larger thickness of wax deposits.

It is recognized that flow regime has a great impact on wax deposition. It is common that the higher oil velocity just in turbulent flow regime could cause less wax deposits due to the effect of shear stripping. In this study, all the experiments were performed under the laminar flow conditions. The results show that initially the thickness of wax deposits increases up to a certain maximum with the increasing oil velocity, and then decreases as the oil velocity continues increasing. Hence, the oil velocity rather than flow regime is found to be responsible for the shear stripping.

In addition, the shear dispersion included in wax deposition mechanisms was confirmed to be negligible during the period of wax deposition by conducting the experiments where the temperatures of oil and pipe wall were set to the same.