EFFECT OF ASPHALTENES ON THE HYDRAULIC DRAG IN PIPELINES WITH CRUDE OIL

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The feasibility has been established of using asphaltenes and tars for reducing the hydraulic drag in pipelines with a turbulent flow of crude oil.

The feasibility of reducing the hydraulic drag in petroleum pipelines by means of polymer additives is limited because of the difficulties in producing many synthetic polymers soluble in crude oil such as, for example, polyisobutylene and also because of their fast degradation in a shear field [1].

In the search for more suitable polymers soluble in crude oil, attempts have been made to use asphaltenes and tars, i.e., products contained in the residue of the cracking process or of direct distillation.

Asphaltenes constitute the heaviest fraction of all crude oil (molecular weight from 1000 to 10,000). They are heterogeneous organic compounds, very similar in chemical composition and structure to petroleum tars but have a much higher (2 to 3 times) molecular weight. Asphaltenes are amorphous solids which, depending on their concentration and on the chemical characteristics of the crude oil, exist in it in proper or colloidal solutions [2].

Preliminary exploratory studies were made concerning the drag reduction in a turbulent stream of Samotlorsk crude oil or Diesel fuel. As additives the authors used asphaltene with a molecular weight of 1320, tar with a molecular weight of 800, their synthetic mixtures in various ratios, and a mixture of heavy asphalt fractions. For comparison, Efremov polyisobutylene with a molecular weight of 10,000 was also used as additive.

The tests were performed in a semiclosed tubular apparatus $d = 0.6$ cm in diameter and $l = 220$ cm long or $d = 1.0$ cm in diameter and $l = 290$ cm long, following the standard procedure: the pressure drop was set to a definite level and the flow rate was measured by weighing.

The test results, evaluated in dimensionless $\log \lambda$, $\log (\mathrm{Re})$ coordinates are shown in Fig. 1a for the $d = 0.6$ cm tube and in Fig. 1b for the $d = 1.0$ cm tube.

In the tests with Tyumen crude oil (viscosity 16 P at 20°C) in the $d = 0.6$ cm tube the maximum reduction of hydraulic drag, by approximately 45%, was achieved with asphaltene additives at a weight concentration of 0.79% and the Reynolds number $\mathrm{Re} = 4{,}500$.

The reduction of drag was the same with a 1% as with a 0.79% addition of asphaltene, but much less (approximately 20% only) with a 0.25% addition of it.

Evidently, the optimum concentration for this given grade of crude oil lies within 0.75-1.0%.

According to the graphs in Fig. 1 (a, b), such amounts of asphaltenes do not reduce the hydraulic drag in Diesel fuel with a viscosity of about 3 P. This can, apparently, be explained by the insufficiently high molecular weight of asphaltenes, which renders their particles incapable of reducing the hydrodynamic drag — at least within the test range of the Reynolds number. Tyumen grade crude oil contains some

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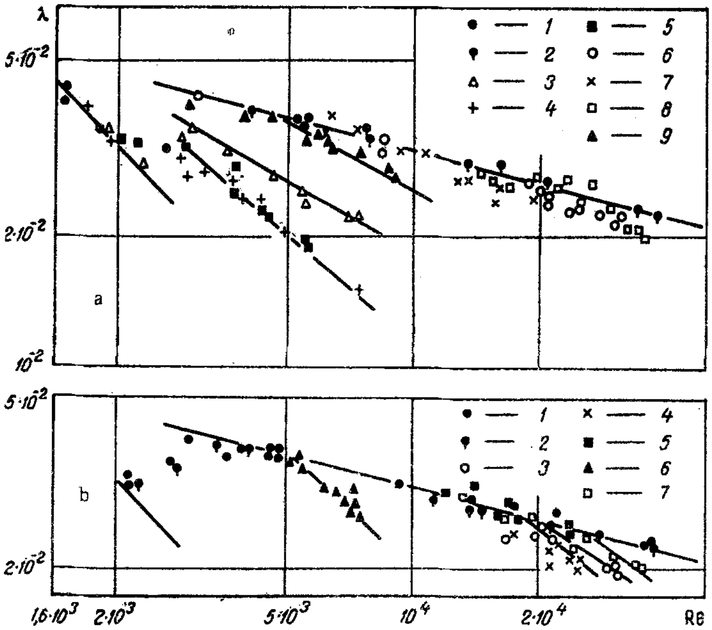

Fig. 1. Hydraulic drag coefficient λ as a function of the Reynolds number Re, for Tyumen crude oil and for Diesel fuel with asphaltene and tar additives in: (a) the d = 0.6 cm tube, 1) crude oil, 2) Diesel fuel, 3) crude oil with 0.3% asphaltene, 4) crude oil with 0.7% asphaltene, 5) crude oil with 1.0% asphaltene, 6) Diesel fuel with 0.3% asphaltene, 7) Diesel fuel with 0.7% asphaltene, 8) Diesel fuel with 0.6% asphaltene and 0.3% tar, 9) mixture of 50% Diesel fuel and 50% crude oil with 0.7% asphaltene; (b) the d = 1.0 cm tube, 1) crude oil, 2) Diesel fuel, 3) Diesel fuel with 0.3% asphaltene, 4) Diesel fuel with 0.7% asphaltene, 5) Diesel fuel with 1.0% asphaltene, 6) mixture of 50% Diesel fuel and 50% crude oil with 0.7% asphaltene, 7) Diesel fuel with 0.6% asphaltene and 0.3% tar.

amount of tars which, after combining with asphaltenes, raises their effective molecular weight. This hypothesis was tested by adding 0.3% tar to a 0.6% solution of asphaltene in Diesel fuel.

With such additions of asphaltenes and tars to Diesel fuel, the drag decreased by 10% at Re = 35,000 in the d = 1.0 cm tube and by 15% at Re = 10,000 in the d = 0.6 cm tube.

This hypothesis has also been confirmed by the results of tests with a 1:1 mixture of Diesel fuel and Tyumen crude oil, each containing 0.7% of dissolved asphaltene.

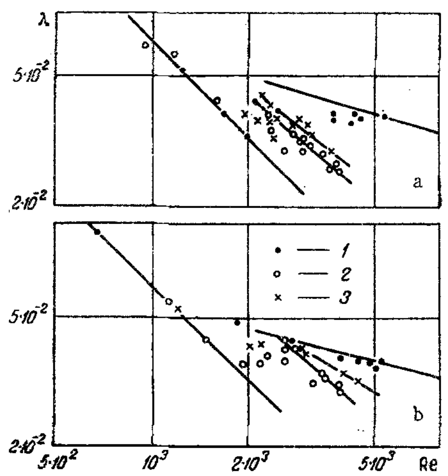

Fig. 2. Hydraulic drag coefficient λ as a function of the Reynolds number, for Tyumen crude oil with asphalt added in (a) the d = 0.6 cm tube and (b) the d = 1.0 cm tube: 1) crude oil, 2) crude oil with 0.8% asphalt, 3) crude oil with 1.2% asphalt.

In this case the drag was reduced by 20% (at Re = 9,000).

These tests with solvents of various viscosities have also revealed higher thresholds of the Reynolds number at lower viscosities of a solvent, a phenomenon which has also been noted in solutions of a polymer like polyisobutylene in kerosene and crude oil, for example [3].

All these results of tests with asphaltene and tar additives have led to the idea of using asphalt, which is a natural mixture of these substances.

The results of subsequent tests performed in the two tubes (d = 0.6 cm and d = 1.0 cm) are shown in Fig. 2 (a, b) respectively, for Tyumen crude oil with 0.8 and 1.2% asphalt. An addition of 0.8% asphalt at Re = 4,500 did, evidently, reduce the drag by 40% and by 35% in the 0.6 cm tube and in the 1.0 cm tube respectively.

The preliminary results of these studies, as well as the fact that asphaltenes are tars are subject to degradation, justify further research concerning their use in large-diameter pipes.

NOTATION

d is the tube diameter, cm;
l is the tube length, cm;
λ is the hydraulic drag coefficient in the axial direction;
Re is the Reynolds number.

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