RESEARCH

NEGATIVE VISCOSITY ANOMALY IN LIQUID PETROLEUM PRODUCTS AFTER HEAT TREATMENT


Heat treatment is a common method of improving the properties of heavy crude oils and petroleum products. Measurements showed for the first time that after heat treatment at 28-40°C, the rheological parameters of petroleum systems become much worse. The results obtained are important for improving shipping and storage technologies in conditions of periodic temperature drops. A theoretical explanation of these effects is given with consideration of the phase diagrams of petroleum systems and thermally induced changes in their colloidal structure.

The rheological properties are the most important properties of natural crude oils, heavy oil fuels, and residues. These properties determine the methods and duration of liquid-handling operations, shipping and pumping conditions, pressure loss during transport in pipelines, etc. One common method of modifying the rheological properties of heavy crude oils and petroleum products is heat treatment.

Monographs on transport of crude oils and petroleum products usually emphasize that heat treatment significantly improves their rheological properties [1]. Handbooks [2] also note the “positive” viscosity anomaly characteristic of all heavy oil fuels and residues: after heat treatment, the viscosity determined again at the same temperature is lower than the initial viscosity. These effects of heat treatment are assumed to be correlated with the presence of waxes in the treated liquids.

![Graph of dynamic viscosity η vs. shear rate](image)

Fig. 1. Dynamic viscosity η vs. shear rate for a solution of vacuum resid.
We relatively recently found a series of characteristics of different physicochemical processes in liquid petroleum systems caused by the presence of resin and asphaltenes components [3-6]. The temperature region of these characteristics is overlapped by the temperature range in which heat treatment is usually conducted, so that we decided to study the effect of the temperature on this viscosity anomaly and the rheological properties in detail.

A “negative” viscosity anomaly is among the most striking results obtained: after heat treatment at 28-40°C, the viscosity increases sharply and measured again at 5-26°C, the rheological properties of the investigated petroleum systems also worsen significantly.

The measurements were performed on a BROOKFIELD DV-11+ rotary viscometer equipped with a JULABO thermostat that maintains the temperature with an accuracy of ±0.1°C. The shaft rotation rate was 12-100 rpm, corresponding to a shear rate of 14.7-122 sec⁻¹. The dynamic viscosity $\eta$ (Pa·sec) was determined as the ratio of shear stress $\sigma$ (Pa) to shear rate $\dot{\gamma}$ (sec⁻¹). (The notation for the parameters corresponds to current terminology [7].)

All liquid petroleum systems investigated were stored for a long time at room temperature: 19-20°C, before the measurements. A new portion of liquid was used for each standard series of measurements. Before