

FORMATION OF STRUCTURES IN MEDIA CONTAINING OIL

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Abstract: A number of issues with crude oil production and transportation can arise from the presence of water dissolved in the oil as a water-in-oil emulsion. Issues related to transportation are demonstrated by the when water is present, the resulting fluids' viscosity increases. The effects of temperature, disperse phase droplet size, and disperse phase volume on the rheological characteristics of water-in-crude oil emulsions have been studied in order to better understand this undesired occurrence and to support demulsification research. The results obtained with various crude oils show that as the water content and water droplet size decrease, the viscosity of the water-in-light crude oil emulsions increases. The emulsions exhibit Newtonian behavior at low water contents but deviate from it as water content increases. The results show how the rheological characteristics and dehydration of these emulsions are impacted by the precipitation of specific native surface-active components in crude oil. Crude oil reservoirs are nearly invariably connected to gas and briny water. Therefore, it is highly possible that coproduction of water will also happen at some point during the production of crude oil. This often occurs as the reservoir gradually empties. The produced water may come from the reservoir's water-bearing portion or from water that has been injected for secondary or tertiary oil recovery. No matter what kind of water phase exists, as long as it is coproduced, shear and pressure drop at well-head chokes and valves will spread it out easily.

Key words: rheological models; settling; drag coefficient; effective viscosity; structure formation.

INTRODUCTION

A range of experimental data are taken into consideration and rheological models of viscous-plastic heavy oils are created. Numerous existing models can be made more universal by including new rheological models for viscous-plastic heavy oils. The criteria to produce disordered structures in the majority of the oil flow are documented to determine the range of rheological models for heavy oils [1, 2]. Based on the effective viscosity of the oil, pressure gradient, shear stress, and several other factors, a nonlinear equation for filtering in porous media is provided for heavy oils [3–6]. This equation has an analytical solution that is suggested and agrees with the results of the experiment. A nonlinear equation for filtering in porous medium for heavy oils is provided, which depends on many parameters such as the oil's effective viscosity, pressure gradient, and shear stress. This equation has an analytical solution that is suggested and agrees with the experimental results. Proposed are models for the drag coefficient and settling rate of particles in heavy oils. In order to improve the rheological characteristics of heavy oil during processing as a result of developing a recirculation scheme at an operational oil refining unit, applied rheology difficulties are taken into consideration [6–9].

The inclusion of naturally occurring surfactants from crude oil stabilizes the resulting water-in-oil emulsions by adsorbing at the oil-water interface and creating an interfacial skin around each water droplet. The physical barrier that prevents coalescence is what leads to the overall high stability of emulsions of water in crude oil [2, 7]. The addition of tiny, solid wax particles has been shown to enhance this skin when combined with specific crude oils. Water-in-crude-oil emulsions can cause a number of issues, such as: the cost of pumping or transporting the saline water by tanker or pipeline; corrosion of downstream overhead distillation columns and production equipment; the need for additional production equipment to provide export-quality crude oil; and poisoning of refinery catalysts. Therefore, it is evident that the removal of this emulsified water early in the production scheme

is justified for both operational and commercial reasons. However, in other situations, such as when producing crude oil from autonomous offshore platforms or satellite wells, it is not feasible to resolve emulsions before pipeline transmission. Then, the presence of emulsified water droplets in cooling crude oil causes a rise in viscosity, which is the immediate production issue rather than the removal of the water. The current work aims to tackle this topic by concentrating on how the addition of water in an emulsified form alters the rheological characteristics of crude oil. To suggest the appropriate placement of facilities for pumping the generated water-in-oil emulsion, the design engineer must have a thorough understanding of the rheological behavior of the emulsion. In fact, the outcomes might affect whether or not the oil needs to be dehydrated before being transported. We will thus demonstrate how several factors affect the rheological characteristics of water-in-crude oil emulsions, including temperature, disperse phase volume, and water droplet size. Next, we will create a theme that illustrates how the bulk rheology of the emulsions can be impacted by the presence or absence of fine particulates at the crude oil-water interface. There have been several presentations of preliminary evidence for this. The current research has been expanded to allow us to examine the potential effects of other oil-native chemical species, such as asphaltenes, on the rheological characteristics of emulsions made with various types of crude oil [7, 8]. Lastly, we will show how the resolution of water-in-crude oil emulsions corresponds with the observed rheological behavior. Our goal is to draw attention to the significance of emulsion rheology in relation to the extraction and transportation of crude oil, a subject that hasn't gotten much attention to this point.

1. VARIOUS BREAKDOWN PROCESSES IN EMULSIONS

A family of dispersion systems called emulsions is made up of two immiscible liquids [9–12]. In a liquid medium, the liquid droplets (the dispersion phase) are distributed (the continuous phase). Different classes can be identified: water with oil in it (O/W), both oil-in-oil (O/O) and water-in-oil (W/O) exist. An emulsion made of polar oil (propylene glycol, for example) dispersed in nonpolar oil (paraffinic oil) and vice versa can serve as an example of the latter kind. One needs an emulsifier, a third ingredient, to disperse two immiscible liquids. For the emulsion to form and remain stable over time, the emulsifier selection is essential [13, 14]. Emulsions can be categorized based on the system's structure or the type of emulsifier used. Fig. 1 gives an illustration of this.

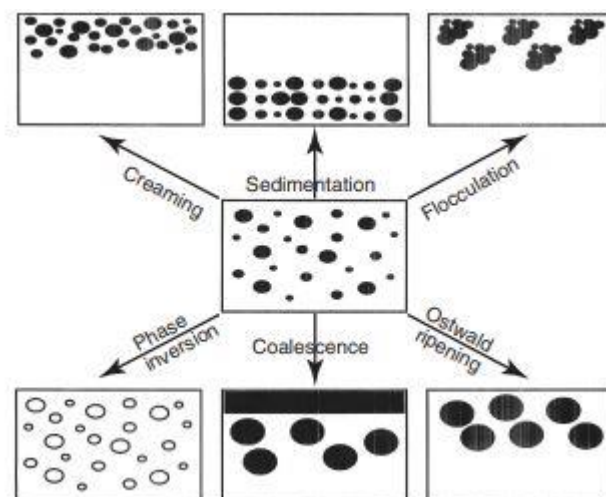


Fig. 1 Schematic representation of the various breakdown processes in emulsions

It is required to find solutions to a variety of occasionally contradictory issues in order to regulate the structural and mechanical features of oil dispersion systems in the processes of oil production, transportation, refining, and petroleum product consumption. A high concentration of dispersed particles (water droplets, gas bubbles, and solid particles), along with asphalt-resin and paraffin particles

dissolved in heavy oil, are considered the rheological properties of oil dispersed systems. These properties also include the ability of the particles to form different structures as a result of their physical interactions with one another. Particle size, shape, concentration, and characteristics all play a significant part in the creation of structures and the building of rheological models of non-Newtonian fluids. Many rheological models with distinct features that represent the flow of oils from diverse fields are provided in publications [3, 11]. The core of rheological study is, as is well known, the nature of the relationship between shear stress τ , shear strain $\dot{\gamma}$, and their changes in time $d\tau/dt$ and $d\dot{\gamma}/dt$ [13, 14]. Heavy processing products and high viscosity viscous plastic oils are categorized using rheological properties as a criterion. After the system under study limiting shear stress, τ_0 is overcome, a series of actions of breakage and restoration of links between scattered particles comprise the mechanism of plastic flow. The core of rheological study is, as is well known, the nature of the relationship between shear stress τ , shear strain γ , and their changes in time $d\tau = dt$ and $d\gamma = dt$ [3, 5, 8]. Heavy processing products and high viscosity viscous plastic oils are categorized using rheological properties as a criterion. After the system under study's limiting shear stress, τ_0 , is overcome, a series of actions of breakage and restoration of links between scattered particles comprise the mechanism of plastic flow. When the shear stress exceeds the elastic limit stress, $\tau \gg \tau_0$, the structure breaks down and the viscosity rapidly decreases. It is possible to assess the basic characteristics of the systems themselves using rheological models of oil dispersed systems. These models are primarily empirical or semiempirical in character since they lack a shared mechanism of flow and deformation. There are several empirical rheological models of structured dispersal systems, but yet, no qualitative or quantitative theories exist that relate the structure parameters to the rheological characteristics of the system. This might be the result of the flow, distortion, and creation of an unorganized structure in each unique instance. As a result, the findings demonstrate that several empirical or semiempirical equations can accurately represent the same experimental investigation while maintaining model fidelity.

2. EXPERIMENTAL PART

Particles that have intermolecular connections with one another produce coagulation structures. If there are liquid interlayers between the particles, the strength of the coagulation structure is strongly influenced by the thickness of these interlayers. The variable state of the 2 Topics on Oil and Gas environment and changes in the physical characteristics of the particles that is, a shift in the size and volume of asphaltene particles as a result of their interaction, collision, coagulation, and crushing at a specific concentration in a closed volume are the hallmarks of aggregate unstable oil systems. A shift in the structure brought about by the creation and disintegration of aggregates from asphaltene particles in the presence of resins explains the relationship between the structure and viscosity of petroleum dispersed systems as well as the characteristics of their non-Newtonian flow. High molecular weight paraffin crystals, resins, and asphaltene particles combined with oil-structured materials form a chain or, in the worst-case scenario, a continuous grid (framework) at very low laminar flow rates or without flow. Individual asphaltene nanoparticles coagulate or aggregate sequentially to create nanoaggregates and clusters of nanoaggregates, which ultimately forms a viscoelastic framework that gives heavy oils specific rheological characteristics. The study points out that two structural groups that differ in the kind of intermolecular interactions between particles in an oil-disperse medium are formed from the activation energies of real oil-dispersed systems. These groupings can be divided into two categories based on the amount of asphaltenes and resins they contain: immobile with a low asphaltene content and interactive with a high asphaltene content. The typical variations in activation energies for the two groups are displayed in Fig. 2.

The following presumptions can serve as the foundation for the rheological model of the flow of oil dispersed systems [14].

- As a result of diffusion in laminar and turbulent shear flow and sedimentation (gravitational coagulation), asphaltene particles in structured oil systems can collide, coagulate, and aggregate, forming nanoaggregates. These aggregates can be deposited on the surface, forming a relatively thick

layer of deposits on the walls of the porous oil reservoir. In addition, temperature-dependent pressure decreases during vigorous mixing or turbulent flow may cause precipitated asphaltene particles to dissolve or separate.

- Until they clash with asphaltene particles or other comparable aggregates, nanoaggregates travel as separate flow units.

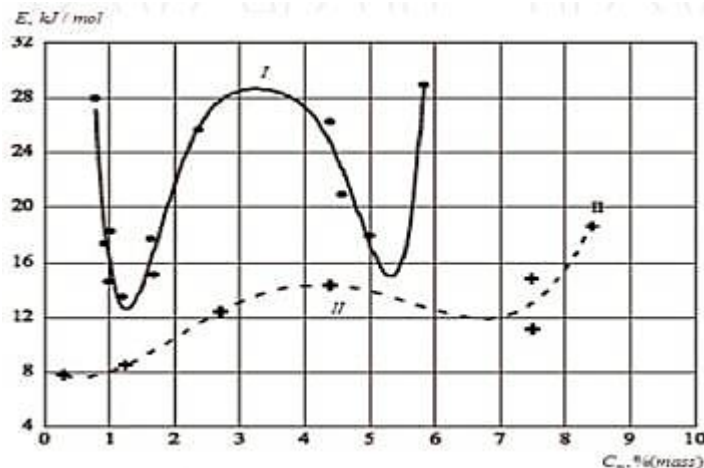


Fig. 2 For both the immobile group (*I*) and the interactive group (*II*), the activation energy is dependent on the asphaltene content [Ошибка! Источник ссылки не найден.].

Colliding nanoaggregates combine to form clusters, which in turn form a viscoelastic frame of a disordered structure with a loose coagulation structure and the maximum viscosity. The diameters of the channels (pores and pipes) that the flow passes through define the maximum size of the nanoaggregate structure. It is significant to remember that the variety of rheological models arises from the production of disordered structures in the oil volume.

Depending on the pressure gradient or flow rate, nanoaggregates can rotate in a gradient field and fracture due to tensile hydrodynamic forces.

The size of a single asphaltene particle to the largest possible cluster or disordered structure framework is the range of the linear dimensions of nanoaggregates.

Under the condition $\lim_{\tau \rightarrow \infty} (\tau_0/\tau) \rightarrow 0$, all aggregates are annihilated to individual particles in the limiting situation of infinite velocity, which causes the flow of a dispersed system to approach Newtonian.

3. RESULTS AND DISCUSSION

Asphaltenes dissolve readily in the presence of aromatic hydrocarbons, which inhibits the creation of structures such as clusters and viscoelastic frameworks. The solubility of asphaltenes is influenced by the existence of other compounds, like resins, in the oil.

Maxwell's viscoelastic fluid's rheological equation in considerable derivatives is expressed as follows:

$$\lambda \left(\frac{\partial \tau}{\partial t} + U \frac{\partial \tau}{\partial y} \right) + \tau = \eta_c \dot{\gamma}, \quad (1)$$

where λ is the relaxation time, $t = 0, \tau = \tau_0, \dot{\gamma} = 0$.

The Eq. (1), presented in the form

$$\lambda \left(\frac{\partial \tau}{\partial t} + U \frac{\partial \tau}{\partial y} \right) + \tau = 0. \quad (2)$$

The solution of Eq. (2) can be represented as

$$\tau = C_1 f(y - Ut) \exp\left(-\tau/\lambda\right). \quad (3)$$

We get an identity by substituting this answer into Eq. (2). Here, $\lambda = \eta_c/G$ is the Maxwell relaxation time, U is the strain front movement velocity $f(y - Ut)$ is a function that determines the strain front in the frame, y is the coordinate, G is shear modulus, $\dot{\gamma} = dy/dt$ is shear rate, γ is the shear gradient, τ_0 is the ultimate shear stress or yield strength. Moreover, if $\tau \leq \tau_0$, then $\dot{\gamma} = 0$. The complete solution of

Eq. (3) takes the form:

$$\tau = C_1 f(y - Ut) \exp\left(-t/\lambda\right) \tau_0 \quad (4)$$

or this equation can be written in logarithmic form:

$$\ln \tau = \ln \tau_0 - t/\lambda + \ln(C_1 f(y - Ut)), \tau_0 = \eta_c \dot{\gamma}. \quad (5)$$

It's clear that the value $t=\lambda$ in Eq. (5) describes the viscoelastic frame's deformation over time and that, when heavy oils flow, it depends on the pressure gradient or velocity, which, in an approximation, can be expressed as follows:

$$t/\lambda = t\dot{\gamma} / Wi \sim f[(\text{grad } P / (\text{grad } P)_0)^n],$$

where $Wi = \lambda \dot{\gamma}$ is the Weissenberg number.

CONCLUSION

For viscous-plastic heavy oils, new rheological models are put forth, allowing for the generalization of numerous previous models. It is observed that the circumstances for the production of disordered structures in the majority of the oil flow dictate the range of rheological models for heavy oils. A nonlinear equation for filtering in porous medium for heavy oils is provided, which depends on many parameters such as the oil's effective viscosity, pressure gradient, and shear stress. This equation has an analytical solution that is suggested and agrees with the experimental results. Proposed are models for the drag coefficient and settling rate of particles in heavy oils. Rheological application issues focused on enhancing heavy oil's rheological characteristics during processing.

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МЕТАДАННЫЕ / METADATA

Название: Формирование структур в средах, содержащих нефть.

Аннотация: Ряд проблем с добычей и транспортировкой сырой нефти может возникнуть из-за присутствия воды, растворенной в нефти в виде эмульсии «вода-в-масле». Проблемы, связанные с транспортировкой, демонстрируются тем, что при наличии воды вязкость полученных жидкостей увеличивается. Влияние температуры, размера капель дисперсной фазы и объема дисперсной фазы на реологические характеристики эмульсий вода-в-сырой нефти изучалось с целью лучшего понимания этого нежелательного явления и поддержки исследований по деэмульгированию. Результаты, полученные с различными видами сырой нефти, показывают, что по мере уменьшения содержания воды и размера капель воды вязкость эмульсий вода-в-легкой сырой нефти увеличивается. Эмульсии демонстрируют ньютоновское поведение при низком содержании воды, но отклоняются от него при увеличении содержания воды. Результаты показывают, как на реологические характеристики и дегидратацию этих эмульсий влияет осаждение определенных нативных поверхностно-активных компонентов в сырой нефти. Нефтяные резервуары почти всегда связаны с газом и соленой водой. Поэтому весьма вероятно, что в какой-то момент во время добычи сырой нефти также произойдет попутное производство воды. Это часто происходит по мере постепенного опустошения резервуара. Производимая вода может поступать из водоносной части резервуара или из воды, которая была закачана для вторичной или третичной добычи нефти. Независимо от того, какой тип водной фазы существует пока она попутно добывается, сдвиг и падение давления на штуцерах и клапанах устья скважины легко распространяют ее.

Key words: Rheological models; settling; drag coefficient; effective viscosity; structure formation.

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