Method of Automatic Measurement of Dynamic Viscosity of Oil Fluid

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***Abstract*—The article relates to the oil industry and can be used in oil fields for the automatic measurement of the rheological characteristics of reservoir fluid, particularly for high-viscosity oils.**

A method for the automatic measurement of the dynamic viscosity (DV) of oil fluid (OF) is proposed. In this method, pressure is measured at the outlet line of the tubing and at two points on the wellhead: one at the upper point of the tubing wellhead and the other below the first, at a distance corresponding to half the cylinder length of the pump used. The calculation of the DV of the OF takes into account the current data on the cross-sectional area of the tubing and rod and follows the proposed algorithm.

Keywords—oil field, dynamic viscosity, oil well flow rate, tubing, temperature, pressure

I. Introduction

Various methods are used for the automatic measurement of the dynamic viscosity of oil fluid. In particular, in [1], the dynamic viscosity (DV) of oil is determined as a function of its optical density using the following mathematical expression

$$\mu = 11{,}087\exp(1{,}4208\,OD)$$

where OD - optical density of oil; μ - DV of oil.

The disadvantage of this method is that, firstly, it is used to determine the DV- ti at the depth of wells and does not allow to determine the viscosity of produced oil in the wellhead tubing (tubing), and secondly, it is impossible to determine the DV of PF by this method.

The author of [2] conducted laboratory experiments to determine the dependence of the apparent viscosity of the emulsion depending on the percentage of water in the oil and the initial mixing temperature. The obtained results are presented in the form of a graph.

M.Y. Tarasov carried out studies of rheological characteristics of high- viscosity well products of the Vingapurskoye field. In particular, experiments were carried out to determine the effect of temperature and oil water cut on the DV of oil- water emulsion, using a rotational viscometer type REOTESG 21, according to standard methods. The obtained results are presented in the form of table and graph [3]

The general disadvantage of these works [2, 3] is that, firstly, the experiments were carried out in laboratory conditions, and secondly, taking a representative sample from the flow in field conditions and determining the water cut of oil are associated with large errors.

In [4], studies of physical and chemical parameters of Tatarstan formation oil were carried out to determine the DV of oil and gas mixture (OGS) depending on pressure (P) and temperature (T), as a result of which a mathematical expression was proposed taking into account 's formula

$$\mu_{\text{нг}}^{p,t} = \mu_{\text{нг}}^{\text{ст}}\frac{\exp\,[\sigma(\mathrm{p}-0{,}101)]}{exp[\tau(t-20)]}$$

where $\mu_{\text{нг}}^{p,t}$, $\mu_{\text{нг}}^{\text{ст}}$ are DV of NGS-i at pressure P and temperature T and at standard conditions; σ, τ are baric and thermal empirical coefficients.

The disadvantage of this method is that it is also a laboratory method and does not allow to determine the DV of the water-oil-gas mixture (WOGM) in the NF stream.

II. Problem Statement

To develop a method of automatic measurement of dynamic viscosity of oil fluid in order to improve the accuracy and efficiency of measurement.

III. Problem Solution

The above task is solved in the following way: pressure is measured at the tubing outlet line and at the wellhead at two points, one of which is located at the upper point of the tubing head, and the second one below it at a distance corresponding to 1\2 of the cylinder length of the pump used and using the current values of the cross-sectional area of the tubing and the rod, and the value of BF BF is automatically calculated according to the following algorithm

$$\mu_{\Phi} = \frac{F_0^2(\mathrm{P}_5-\mathrm{P}_1)}{l\,Q}\exp\left(\frac{t-20}{T_{\text{x}}}\right)$$

$$Q = 1440V_f\cdot n$$

$$V_f = \Delta\,h(F_T - F_{\text{ш}})$$

$$\Delta h = \frac{(P_3-P_2)}{\rho_{\Phi}g} = \frac{\Delta P_{\text{н}}}{\rho_{\Phi}g}$$

$$\rho_{\Phi} = \frac{(\mathrm{P}_3-\mathrm{P}_2)}{hg} = \frac{\Delta \mathrm{P}_6}{hg}$$

where μ - PF DV, MPas; $F0$ - cross-sectional area of the check valve installed on the tubing outlet line, м2; P5, P1 − - PF pressure on the outlet line and at the top point of the tubing, MPa; t - PF flow temperature, ;℃tk - characteristic values of temperature tx , ; ℃h - distance between pressure sensors (points) 1 and 2, m; Q -

pump delivery,м3 /day; n - number of swinging of the balancer of the machine swing, 1/min;Vf - volume of PF between pressure pointsP2 и P1 ; Δh - level of PF between points 3 and 2 at low position of the pump plunger, m;ΔPн, ΔPв - pressure differences between pressure pointsP2 и P1 at low and upper position of the pump plunger, MPa;g - acceleration of free fall, m\сек2; $\rho\varphi$ - density of PF, kg/м3

Fig.1 shows the circuit diagram of the device for automatic measurement of DV VNGS, which contains: 1- sensor located in the wellhead of the tubing (tubing); 2 - sensor located on the (tubing) below the sensor 1, at a distance of ½ the height of the cylinder used by the pump, and a difmanometer - 3; 4 - well discharge line; 5- pressure sensor on the well discharge line; 6 - difmanometer; 7 - liquid level sensor in the production (casing) string and the corresponding transducer - 8; 9 - calculation and indication unit; 10 - polished rod rod stem; 11 - production well string; 12 - tubing; 13 and 14 - temperature sensor and transducer.

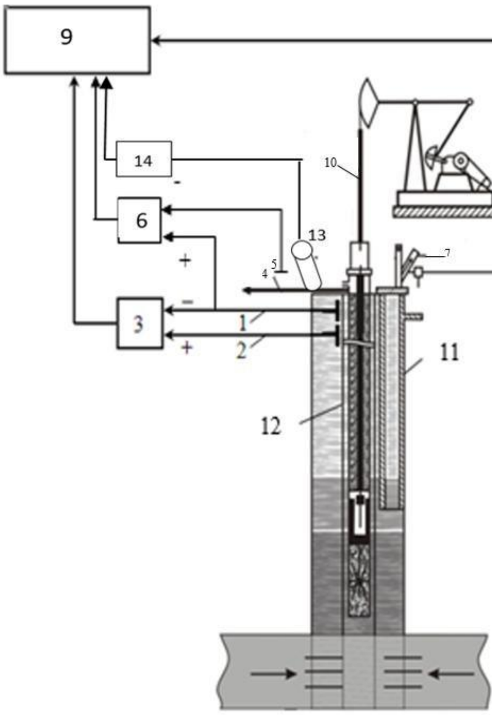

Fig. 1. Schematic diagram of the device for automatic measurement of dynamic viscosity of water-oil-gas mixture

The method is carried out as follows.

The differential pressure is measured between pressure sensors 1 and 2 installed at the wellhead at a distance of half the length l of the cylinder of the pump cylinder used at the given well: h = 1/2 l. Sensor 5 measures the pressure at the discharge line 4 of the well. The outputs of the pressure sensors are connected to the chambers of differential pressur 3 and 6, SAPPHIR type, the outputs of which are connected to the block 9 - calculation and indication. And the lower sensor 2 is connected to the positive chamber of the differential pressure gauge 4, and the upper sensor 1 is connected to the negative chamber of the differential pressure and the positive chamber of the differential pressure gauge 6. The outputs of the transducer 5 are connected to the negative chamber of the diffmanometer 6. The temperature is measured by sensor 13 and transducer 14.

Based on the signals from transducers 3, 6 and 14 in block 9, the values and DV of the VNGS are calculated.

An example of a particular implementation of the method:

$F_o = 1{,}77\text{см}^2;\ \text{P}_1 = 0{,}2\ \text{МПа};\ \text{P}_5 = 0{,}3\ \text{МПа};\ \text{P}_3 = 0{,}41\ \text{МПа};\ F_\text{Т} = 18{,}84\ \text{см}^2;\ F_\text{Ш} = 3{,}14\ \text{см}^2;\ t = 20°\text{C};\ n$=12

$$\rho_\text{ж} = \frac{\Delta P_\text{в}}{hg} = \frac{8820}{9{,}8 \cdot 1} = 900\ \text{кг/м}^3;$$

$$\Delta h = \frac{4410}{900 \cdot 9{,}8} = 0{,}5\ \text{м}$$

$$V_f=(1 + \Delta h)(\ F_\text{Т} - F_\text{Ш})=2355\ \text{см}^3$$

$$Q = V_f\,\frac{n}{60} = 471\,\frac{\text{см}^3}{\text{сек}}$$

$$\mu_{20} = \frac{{F_0}^2 \cdot \Delta P_1}{Ql} = \frac{(1{,}77)^2 \cdot 10^{-8} \cdot 10^5}{471 \cdot 10^{-6} \cdot 0{,}5} = 7{,}51\ \text{мПас}$$

$$\mu_{20} = \mu_{20}\exp\left(-\frac{30}{10}\right) = 6{,}02\ \text{мПас}$$

IV. Conclusion

In the article the method of automatic measurement of dynamic viscosity of oil fluid is developed, the pressure is measured at the tubing outlet line and at the wellhead at two points and using the current values of cross-sectional area of tubing and rod, the value of dynamic viscosity of oil fluid is automatically calculated.

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