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Measuring of Viscosity of the Liquid with the Tapering Device

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ABSTRACT: Comparison tests of vibrating-reed instruments are in-process reduced, influencing of attitude of the dipole of the viscometer on a bias of viscosity of a fluid are researched. Calculations measuring of viscosity by means of the confuser are reduced, is subject a wall constraint of the pipe line and presence of vials of free gas in a fluid at viscosity measuring. Approaches and a principle of measuring of viscosity of a fluid are tendered. The principle of operation of the elaborated continuous viscometer on the basis of the confuser is reduced. The straight-line flow method of measuring of viscosity of a fluid by means of the confuser and with a thermo compensation possibility is tendered.

KEYWORDS: a line mode, viscosity, narrowing device, viscometer, a method of dimensions and physical similarity.

I. INTRODUCTION

For today in many industries the problem of development of a measurement procedure and the multiple-purpose checker is actual, allowing to examine a rheological properties of multiphase medium with dependence determination between a stress tensor of a formation sample and tensor of strains in broad range of speeds of strains and temperatures, and also agency of an apparent density of firm and other admixtures on a rheological properties of a carrying phase.

Now on oil pipelines for measuring of viscosity of a cargo oil vibrational viscosity gauges which one in the complicated operating conditions (for example, sedimentation of admixtures on dipoles) can yield effects with a major lapse are used. [1,2,3]

In-process [4] study of agency of attitude of the dipole of the viscosity gauge on a measuring error of viscosity of a fluid has been conducted. Two working alternatives of attitude of the dipole in relation to an incident flow have been observed: attitude on a flow («0 °») and attitude perpendicularly to a flow («90 °»). The carried out accounts and experiments displayed that these two alternatives of attitude of the dipole are essentially discriminated by static pressure allocation in interior and exterior fields of its flow. These are condition leads to frequency change and Q-factor of the dipole, and, means, and to a measuring error of viscosity of a fluid.

Thus, at usage of the vibrational viscosity gauge even in ideal pure liquid (lack of unchecked precipitations on the dipole fork) there can be viscosity measuring errors which one magnitude is complicated for sizing up.

IIn this paper, the reduced working principle of the developed continuous viscosity gauge on the basis of the confuser is resulted. Tendered approaches and a principle of measuring of viscosity of a fluid are is short stated more low, and also effects of systematic experimental researches which one allow to state that simple, reliable and inexpensive straight-line flow method of measuring of viscosity of a viscous fluid leaking on the pipe line is developed are stated.

II. FLOW-THROUGH VISCOMETER

Generally it is possible to display [5] that dependence of a mass flow rate of a fluid through the tapering device (TD) depends on a differential head ΔP on the TD, geometry of the setting of the TD and properties of a fluid (gravity and viscosity). Traditional TDs use in such gamuts of charges of gauged medium when a friction loss is small in comparison with pressure losses on conversion of potential energy of a flow to a drop energy. In this case for the TD the multiple-purpose dependence from which one follows is gained that the differential head ΔP on the TD depends only on the charge V and gravities ρ a fluid flowing through the TD.

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At operation with naphtha and oil products generally to neglect a frictional force it is impossible, as their viscosity can be high enough, and charges are rather moderate. In this case, proceeding from principles of dimensional analysis and physical similitude of hydrodynamic processes [6], was very friend to characterise the concrete TD having certain geometry of the setting, the multiple-purpose dependence for any incompressible liquids:

$$K = f(R_e), \tag{1}$$

Or

$$K = \Delta P/(\rho U^2/2) \tag{2}$$

Here magnitude To represents the dimensionless ratio of pressure forces of a flow (ΔP - a differential head on the TD) to an inertial force (U - average rate in an inflow face of the TD in diameter d, ρ - liquid density) and the dimensionless argument Re - a traditional Reynolds number is called as TD coefficient of resistance, and.

$$R_e = U\frac{d}{\nu} \tag{3}$$

The dimensionless dependence (1) is individual for each TD as it includes the arguments presenting geometry of the TD. But this individual from the point of view of geometry of the TD dependence is multiple-purpose for any fluids (including for mixtures) in all accessible to practice a gamut of charges as it allows for flow kinematics (speed U) and properties of a fluid (gravity ρ and viscosity ν).

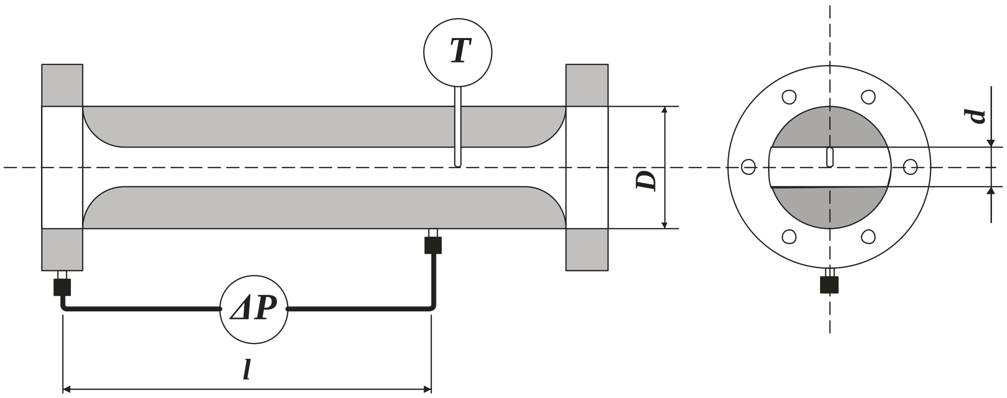

Figure 1. The confuser circuit design

For measuring of kinematic viscosity of a fluid ν it is possible to use inverse multiple-purpose dependence:

$$R_e = g(K), \tag{4}$$

$$U\frac{d}{\nu} = g(2\Delta P/\rho U^2) \tag{5}$$

In this case, if are known the characteristic diameter of the confuser d and liquid density ρ, are metered a differential head ΔP and the characteristic speed and, that, using experimentally the gained multiple-purpose curve (2) as calibrating, it is possible to define magnitude of kinematic viscosity ν. On figure 1 the TD circuit design is resulted.

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III. CALIBRATION OF VISCOMETER

The tapering device was a flat narrowing of d = 18 mm high in a section of a circular duct with a diameter of D = 50 mm, having a confuser and diffuser sections, smoothly matching the input and output sections of the narrowing device with a flat confuser. On a section of the TD in length of *l* = 250 mm (figure 1) by means of the differential pressure pickup the current differential head ΔP was metered. By means of a resistance platinum thermometer current meaning of flow temperature T was metered. Current meanings of the charge, an operating fluid and differential head flow temperature registered by expressly designed measuring system with frequency of the order of 10 measurings in a sec.

On figure 2 the calibration curve (5) is resulted.

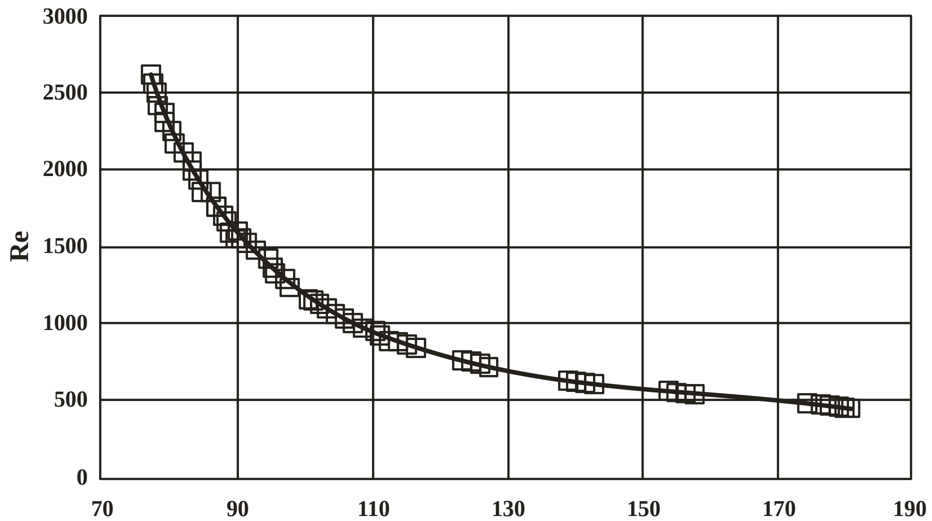

Figure 2. The TD Calibration curve

In a head loop of the down-pour bench circuit-breaker oil circulated. On a capillary viscometer with a pitch 1°C dependence of kinematic viscosity of this oil on temperature has been gained. The down-pour bench allowed to realise circulation of operating fluid with various controllable meanings of its charge and temperatures that allowed to know during each moment of conducting of experiment current meanings of average rate of a flow in an inflow face of the TD and fluid temperature, and, means, and current meaning of kinematic viscosity of operating fluid. The TD calibration curve has been built over the range variations of temperature of operating fluid from 21°C to 45°C that matched to variation of its kinematic viscosity from 7 cSt to 16 cSt. Average rate of a flow in the TD inflow face varied over the range from 0,16 m/s to 0,38 m/s. From figure 2 it is visible that all experimental data gained in the course of conducting of calibrating measuring are well extended by the dimensionless multiple-purpose dependence of an aspect (5). These are condition affirms all above-stated reasoning on a possibility of measuring of kinematic viscosity by means of the TD.

IV. MEASURING OF VISCOSITY OF LOW VISCOSITY FLUIDS BY THE AUTOMATED CAPILLARY VISCOMETER

The capillarimetric method of measuring of viscosity is one of the most exact and consequently gained the greatest extending. It is enough to tell that all the exemplary instrumentation for viscosity measuring is founded on the yielded method. At the heart of act of the gears grounded on the observed method of measuring, dependence of speed of the installed flow of a fluid flowing through a capillary on viscosity of a fluid, expressed by Poiseuille's law lies:

$$\mu = \frac{\pi d^4 \Delta P}{128\, l Q} \tag{6}$$

where μ - dynamic viscosity coefficient; $\Delta P -$ swing pressure, Q - a volume flow.

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At *l=const* and *Q=const*we gain,

$$\mu = K\Delta P\,, \tag{7}$$

where

$$K = \frac{\pi d^4}{128\, lQ}\,. \tag{8}$$

Thus, metering a differential head on a capillary, it is possible to judge magnitude of viscosity of an examined fluid. The assaying of some development displays that the gamut of measuring of capillary viscometers depends on diameter and length of a capillary and compounds from 0,001 ÷ 10 Pa*s. Intrinsic error of measuring of 1 %. Extending of these gears is promoted by a row of their virtues - such, as simplicity of a construction, ease of manufacture, persistence of relative error at persistence of the charge of controllable medium, a possibility of measuring of viscosity of hostile environments. To deficiencies it is possible to refer to: agency of the charge and temperature on metre readings, limitation on maximally both minimumly possible diameters and lengths of capillaries, and also on a Reynolds number.

In comparison with other types of measuring means of the continuous act (for example, the rotation and vibrational) capillary viscosity gauges are more simple in design, in them to implement thermocompensation system lighter.

Existing capillary measuring gears are intended for measuring of mean and high meanings of viscosity. At measuring of low meanings of viscosity in gamuts 0 ÷ 0,0025; 0 ÷ 0,01; 0,006 ÷ 0,025 Pa*s about an instrument error it is significant. So the problem of development of high-precision measuring gears for thin controllable medium is essential.

Above the reduced equation (1) is valid only at the laminar flow of an examined fluid through a capillary $\mathrm{Re} \le 2300$. For this parent the lower bound of measuring of viscosity of a feeler (capillary) of a capillary viscometer is defined on a Reynolds number:

$$\mathrm{Re} = \frac{\rho \omega d}{\mu} = \frac{4\rho Q}{\mu \pi d}\,. \tag{9}$$

Whence lower bound of measuring of viscosity

$$\mu_{\min} = \frac{\rho \omega d}{\mathrm{Re}_{cr}} = \frac{4 \cdot \rho \cdot Q}{\mathrm{Re}_{cr} \cdot \pi d} \tag{10}$$

From the equation (10) it is visible that for lowering of lower bound of measuring of viscosity it is necessary to diminish the charge of an examined fluid through a capillary. However on the equations (7) and (8) it is visible that charge decrease leads to decrease of a differential head which one leads to handicapping of measuring of a differential head the micro differential pressure gauge as the last have a dead zone (the limit of sensibility or a dead band). Thus the gamut of measuring of viscosity is defined by a capillary viscometer not only a feeler gamut, but also still a micro differential pressure gauge gamut. For overcoming of a limit of sensibility of the micro differential pressure gauge raise of a differential head by a flow confuser before a capillary is offered. Then the differential pressure is defined on the following equations

$$\Delta P_{total} = \Delta P_{fr} + \Delta P_{tap}\,, \tag{11}$$

where ΔP_{fr} - a differential pressureon friction, a ΔP_{tap} differential pressure on a confuser.

The differential head on a friction can be defined on the equation (6) or on the following equation of the Darcy - Vejsbah:

$$\Delta P_{fr} = \lambda \frac{l}{d} \cdot \frac{\rho \omega^2}{2}\,, \tag{12}$$

Where λ - a loss factor on a friction lengthwise, l - capillary length, d - diameter of a capillary.

Allowing that at a laminar flow a loss factor on a friction lengthwise

$$\lambda = \frac{64}{\mathrm{Re}} \tag{13}$$

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The equation (12) can be recorded in a following aspect:

$$\Delta P_{fr} = \mu \cdot \frac{32\omega l}{d^2} = \mu \cdot \frac{128Ql}{d^4}. \quad (14)$$

The differential head on a confuser can be defined on Bernoulli's theorem

$$\Delta P_{tap} = \frac{\rho}{2}\left(\omega_2^2 - \omega_1^2\right) = \frac{\rho}{2} Q^2 \left(\frac{1}{S_2^2} - \frac{1}{S_1^2}\right). \quad (15)$$

Common differential head

$$\Delta P_{total} = \mu \cdot \frac{128Ql}{d^4} + \frac{\rho}{2} Q^2 \left(\frac{1}{S_2^2} - \frac{1}{S_1^2}\right). \quad (16)$$

Allowing for persistence of length and diameter of a capillary, cross-sections before and after a confuser, and also persistence of the charge it is possible to inject following identifications::

$$K_1 = \frac{128Ql}{d^4}; \qquad K_2 = \frac{Q^2}{2}\left(\frac{1}{S_2^2} - \frac{1}{S_1^2}\right).$$

Then the equation (16) becomes:

$$\Delta P_{total} = K_1 \mu \cdot + K_2 \rho . \quad (17)$$

The metered viscosity of an examined fluid

$$\mu = \frac{\Delta P_{total} - \Delta P_{tap}}{K_1}. \quad (18)$$

The equations (16), (17) and (18) display that for such approach of lowering of meaning of lower bound of a gamut of measuring of viscosity gravity of an examined fluid should be predetermined or beforehand is metered.

The device working in a similar way, is resulted more low (figure 3).

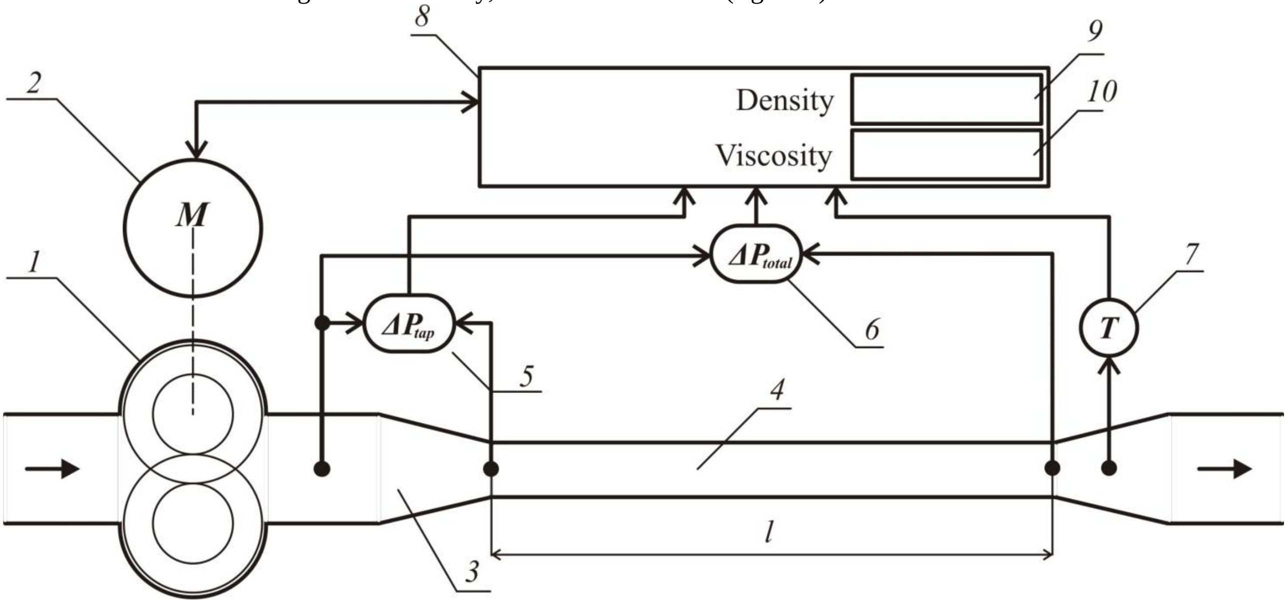

Figure3. Automaticcapillary viscosimeter of the continuous act

The device consists of a gear pump 1 which one is set in by means of the is frequency-operated servodrive 2, the confuser 3, a capillary in 4 length *l*, micro differential pressure gauges 5 and 6 which measure a differential pressure on a confuser and a total differential pressure. The measured data transmit to the control block of the viscometer (CBV) which controls the servo drive, and deduces the calculated values of viscosity and density on displays 9 and 10. Also,

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measuring of temperature by the thermometer 7 for thermo compensation is envisioned. The device works as follows: the gear pump is twirled with constant speed, a constant flow, giving an examined fluid to a capillary through the confuser which one has a gradient junction from the pump to a capillary. On the confuser there is a differential pressure which one is measured by the micro differential pressure gauge 5. The measured value is transmitted on CBV where density of investigated fluid computed with next equation

$$\rho = \frac{\Delta P_{tap}}{K_2}. \quad (14)$$

The common differential head is metered by the micro differential pressure gauge 6. The measured meaning is transmitted on CBV, where viscosity of an examined fluid on the equation is computed

$$\mu = \frac{\Delta P_{total} - \Delta P_{tap}}{K_1}. \quad (15)$$

At measuring of viscosity of mobile fluids rate of flow is slashed at the expense of servodrive driving down the pump rotational speed is slashed that ensures, in turn, the laminar flow of a fluid in a capillary as all these acts are controlled and controlled CBV.

V. CONCLUSION

As a result of the made comparative trials it is possible to draw a conclusion that measuring of viscosity by means of the confuser it is considerably less subject to agency as spacing intervals to walls of the pipe line (barrel) and presence of vials of free gas in a fluid, in difference from the vibrational transformer of viscosity with a feeler. To draw a conclusion about a possibility of application of the tendered viscosity gauge conducting of additional studies on real naphthas in the dynamic regimes analogous to regimes of an oil pumping through units of measuring of quality of naphtha on real installations is necessary.

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