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## MEASUREMENT OF THE VISCOSITY OF A LUBRICANT USED IN HYDRAULIC VIBRATION DAMPERS

by

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MEASUREMENT OF THE VISCOSITY OF A LUBRICANT USED IN HYDRAULIC VIBRATION DAMPERS

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Work [1] gives the theoretical foundation of hydrodynamic phenomena in a hydraulic vibration damper of the plate (disk) type. During calculations of the suppression of longitudinal vibrations of drilling tubes by a layer of lubricant included between the disks of the vibration damper, the basic attention is paid to the viscosity of the lubricant. A highly viscous fluid, with a viscosity of more than 5000-10,000 centipoise, can be obtained by using readily available nigrol with additions of kanifol' (colophony) in various weight ratios [2].

The calculation of a vibration damper is hampered if the value of the viscosity of the selected lubricant is unknown.

Measurement of the dynamic (effective)* viscosity by ordinary methods – e.g., with an Engler viscosimeter – becomes impossible because of the fact that the lubricant does not flow at temperatures below 50-100°C.

*A two-component lubricant is not a Newtonian fluid; therefore dynamic viscosity is more properly called effective viscosity.

At the Tyumen' Industrial Institute a viscosimeter has been constructed which is based on the idea of N. A. Slezkin [3] concerning the compression of a viscous fluid between two disks, of which one is fixed.

According to the hydrodynamic theory of lubrication, the compressive strength of a viscous film will be

$$P = -\frac{3}{2}\pi\mu\frac{a^4}{h^3}\frac{dh}{dt}, \tag{1}$$

where P is compressive strength in dynes; μ is the dynamic viscosity, poise ($dyn \cdot s/cm^2$); h is the thickness of the layer in cm; a is the radious of the disk in cm; t is the time of compression of the film, s; v = dh/dt is the rate of compression, cm/s.

If the mobile disk is loaded by force Q, the equation of motion of a system having mass m and acceleration ω is written as follows:

$$Q - P = m\omega = \frac{Q}{g}\cdot\frac{dv}{dt}. \tag{2}$$

By solving expressions (1) and (2) simultaneously, integrating under the initial conditions t = 0, v = 0, $h = h_0$ ($h_0$ is the initial thickness of the lubricant film), and ignoring small values of v, we will have

$$\mu = c\frac{t}{\frac{1}{h^2} - \frac{1}{h_0^2}}. \tag{3}$$

Here c is the instrument constant in $G/cm^4$; dimensionality Q is given in G; a, h, and $h_0$ are given in cm; and t is in seconds. If μ were expressed in cP, then $c = (4 \cdot 10^5 \cdot Q)/3\pi a^4$; if it is expressed in $(kgf \cdot s)/m^2$, then $c = 40Q/(3\pi \cdot a^4)$.

Equation (3) is the initial equation during designing of an instrument which must measure the time t of compression of a lubricant film during a change in its thickness from an initial value of $h_0$ to a final value h.

Figure 1 shows the diagram of an instrument based on the Wick [Translator's Note: exact spelling not determined] instrument. The lubricant is applied as a thin, even layer on the table of the device and is compressed by disk 2. The disk is first brought into contact with the surface of the lubricant.

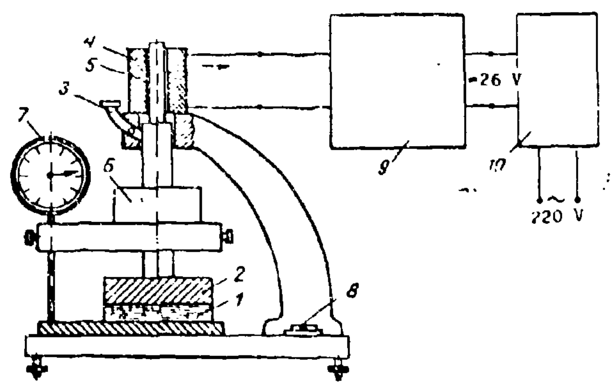


Fig. 1. Diagram of the instrument: 1 – lubricant; 2 – disk; 3 – brake; 4 – coil; 5 – magnet; 6 – load; 7 – arrow indicator; 8 – level; 9 – N-700 oscillograph; 10 – VNN-2 rectifier.

The measuring elements of the instruments are the arrow indicator 7 (measurement of h and $h_0$) and a time pickup with oscillograph 9 and rectifier 10 (measurement of t). The time pickup consists of permanent magnet 5, 12 mm in diameter, and coil 4. The internal diameter of the coil comprises 13 mm; the wire is PE-0.2, the length of the winding is 6 mm, and the number of turns is 80. Movement of the magnet in the coil excites an emf which is fed to the sweep of the magnetoelectric oscillograph. The time of excitation of the emf is recorded on photographic film (Fig. 2).

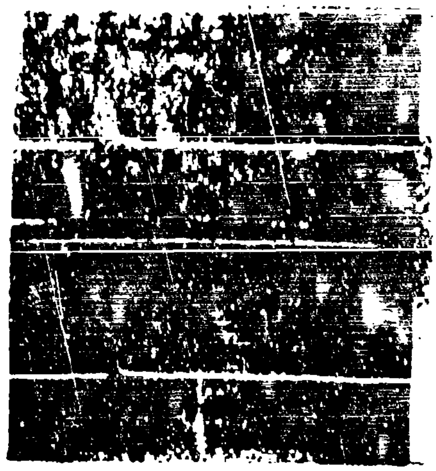

Fig. 2. Recording of the time of lubricant compression. The distance between time markers is 1/10 second.

When working with lubricants of different viscosities it is necessary to have a set of changeable disks of two different diameters. The more viscous the fluid, the smaller must be the diameter of the disk, whose radius can be calculated from equation (3) by giving tentative values of $\mu$ and $h_0$. With an excessively large disk diameter the time of compression is increased up to several seconds, which reduces the accuracy with which $t$ is measured (the curve of the emf as a function of $t$ becomes very shallow) and it increases the consumption of photographic film.

In our instrument the entire load Q was taken as 2560 G, with the weight of the mobile parts taken into account; the disk diameters were 6, 12, 20, and 50 mm. We measured the dynamic viscosity of nigrol, cup grease, and polyisobutylene, and also that of nigrol with additions of colophony, which increased the viscosity of the nigrol lubricant. Polyisobutylene was used to stabilize the viscosity of the lubricant during changes in temperature.

The results of measurement of viscosity (cP or $((kgf \cdot s)/m^2) \cdot 10^{-4}$) are given in the table.

| Temperature, °C | Cup grease | Polyisobutylene | Nigrol | Nigrol with colophony in the weight ratios: | | | |
|---|---|---|---|---|---|---|---|
| | | | | 3:1 | 2:1 | 1:1 | 1:2, 1:3 |
| 13 | — | — | 1100 | | | | — |
| 15 | | | | 9000 | | – | |
| 17 | | | | | 11160 | 16200 | — |
| 21 | 100 | 702 | 9[illegible]2 | 7260 | | | Solid mass |
| 40 | | | | 1914 | | 3000 | |

From the table it is clear that nigrol greases, especially in combination with colophony, possess the highest viscosity. Depending on the concentration of colophony the viscosity of the lubricant is increased by 10-16 times.

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3. Slezkin, N. A. Dinamika vyazkoy zhidkosti (Dynamics of a viscous fluid), Gostekhizdat, 1955.


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13. ABSTRACT

In selection of the vibration dampers for a long column of drill pipe, the most acceptable chem. compd. is considered as that with highest viscosity, V. Such a compd. is "nigrol" (I), a transmission lubricant mixed with "kanifol" (II), a resin. Mixts. in the ratios of 2 to 1 and 1 to 1 (I to II) by wt. at 17 degrees had V values of 116.6 and 162.0 poise, resp. The latter value decreased to 30.00 at 40 degrees. On the other hand, addn. of II to give I to II ratios of 1 to 2 and 1 to 3 solidified the mixt. The mixt. with a I to II ratio of 3 to 1 and V values of 90.0, 72.8, and 19.4 at 15, 21, and 40 degrees, resp. The V values, 4.0 and 7.92 had been detd. at 21 degrees for "solidole," a cup grease, and polyisobutylene, resp. The latter is used for viscosity stabilization in compds. subjected to temp. changes in drilling. (AP9038988)

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| Lubricant Vicosity | | | | | | |
| Hydrodynamic Theory | | | | | | |
| Hydraulic Vibration Damper | | | | | | |