LABORATORY 4

DETERMINATION OF THE KINEMATIC VISCOSITY AND VISCOSITY INDEX OF MOTOR OILS

Purpose of the laboratory work: To become familiar with the procedure for determining the kinematic viscosity and viscosity index of motor oils using a viscometer. With the help of the experiment, to evaluate the quality of petroleum products and determine their field of application.

Tools and equipment required for the laboratory work:

1. Graduated cylinders and test tubes
2. Thermostat
3. Viscometer

General information

Viscosity is the internal resistance that liquid molecules exert against one another under the action of an external force, and it is one of the most important properties of petroleum products. The formation of liquid friction between moving parts, their cooling, the provision of tight sealing, easy engine starting, and many other processes depend on viscosity.

Depending on the operating conditions of petroleum products, different viscosity standards have been established. For example, viscosity standards are specified at:

- 20°C for diesel fuels,
- 50°C for industrial oils,
- 100°C for motor oils and transmission oils.

The unit commonly used for kinematic viscosity is the stoke (St) or the centistoke (cSt), where:

$$1\text{St}=1\text{c}m^2/\text{s}$$

In diesel engines, the quality of fuel atomization in the combustion chamber depends on the kinematic viscosity of the fuel. If the viscosity of the fuel is too high, the fuel does not atomize properly, and as a result it does not burn completely. This causes smoke in the exhaust gases and an increase in fuel consumption. If the viscosity of the fuel is too low, the fuel does not lubricate the parts of the fuel pump properly, which leads to rapid wear of the plunger pairs of the pump. In addition, because the fuel flow does not enter the combustion chamber properly, the conditions for forming the mixture inside the cylinders also become worse.

The kinematic viscosity of summer diesel fuel should be 3.0–6.0 cSt, for winter diesel fuel it should be 1.8–5.0 cSt, and for Arctic diesel fuel it should be

1.5–4.0 cSt.The kinematic viscosity of motor oils is one of the main quality indicators that characterizes their ability to provide reliable liquid friction lubrication. The higher this indicator, the stronger the oil film on friction surfaces, the better the sealing of the piston rings in the cylinders, and the lower the oil consumption. Since the viscosity of oil increases as the temperature decreases, its value must be optimal both for long-term operation of a heated engine and for starting a cold engine at low temperatures.In diesel engines, under winter conditions, motor oils with a kinematic viscosity of 8–10 cSt at 100°C are used, while in summer oils with 10–12 cSt at 100°C are used. For injection engines, oils with a viscosity of 6–8 cSt in winter and 8–10 cSt in summer are applied.

Task: Examine the given oil sample**,** determine its viscosity and identify its type**,** compare the obtained results with GOST requirements, and indicate under what conditions the tested oil sample can be used.

Procedure for performing the work

1. Oil is poured into the lower enlarged part of the viscometer, then the viscometer is placed into a thermostat (Figure 1) and kept there for 15 minutes so that the sample reaches the required temperature. The experiment is carried out at three temperatures: 20°C, 40°C, and 100°C.
2. Using a vacuum, the oil is drawn from the lower part of the instrument into the first spherical bulb. The flow time of the liquid from mark (a) to mark (b) is measured with a stopwatch. To obtain a more accurate result, the measurement is repeated three times, and the average time is taken.

The kinematic viscosity is determined using the following formula:

$$V = \tau * c_t$$

τ - average flow time;
c_t - instrument constant; its value is specified in the instrument passport.



Figure 1. TV12LT Low Temperature viscosity bath
(low-temperature thermostat bath**)**

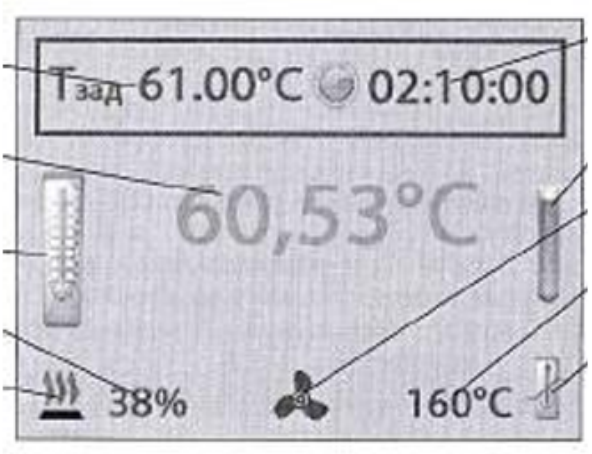
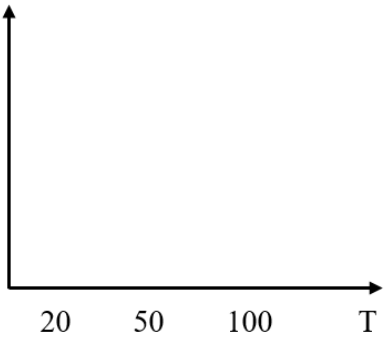


Figure 2. Display screen of the instrument used for determining the viscosity of oils

Usually, in order to determine the dependence of viscosity on temperature**,** viscosity is measured at three temperatures using Formula (3)**:** 20°C, 40°C, and 100°C**.** The obtained results are then entered into Table 1**.**

Oil temperature, °C	Average flow time, s	Viscometer constant, C□	Kinematic viscosity of oil, mm²/s
20			
40			
100			

The dependence of oil viscosity on temperature is shown graphically in the form of a curve based on the obtained results.



Determination of the viscosity index

For motor oils, not only the viscosity at 100°C is specified, but also the viscosity at 0°C and the viscosity index are taken into account. Because the operating temperature changes during service, it is required that the viscosity of the oil change as little as possible under the influence of temperature.As a characteristic of the temperature dependence of oil viscosity**,** the difference between the viscosities of the oil at 50°C and 100°C is used.

The viscosity index is a dimensionless quantity that shows the degree to which the viscosity of the tested oil changes with temperature in comparison with a reference oil**.** To determine the viscosity index, special tables and nomograms are used **(**Figure 3**),** and it can also be determined by the following formula:

$$Q.I = v_{50} / v_{100}$$

Here:

- v_{50} - viscosity of the oil at 50°C;
- v_{100} -viscosity of the oil at 100°C.

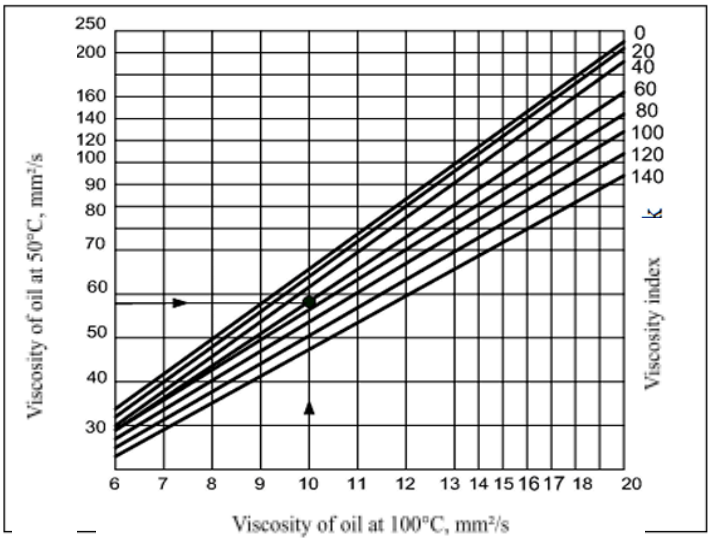
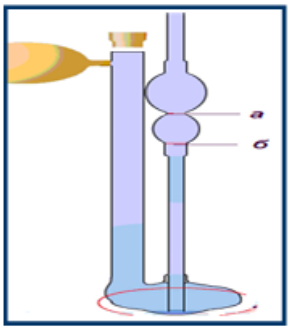


Figure 3. Nomogram for determining the viscosity index

3. **Determination of the viscosity of diesel fuel**

For diesel fuel**,** the viscosity is standardized at 20°C. For different grades of diesel fuel, the viscosity should be within the range of 1.8–6.0 cSt**.** In practice, it is advisable to use diesel fuel with medium viscosity **(**2.5–4.0 cSt at 20°C).

If the viscosity decreases too much or increases too much, the operation of the fuel supply equipment, the formation of the fuel-air mixture, and the combustion process are disturbed. The fuel does not burn completely, and fuel consumption increases. As a result of fuel settling on the piston bottom and the walls of the combustion chamber**,** the formation of carbon deposits increases, and the exhaust gases become darker.The viscosity is determined using a capillary viscometer.The viscometer is a U-shaped glass tube that has two enlarged spherical chambers on one side**.** Below the second chamber, a capillary tube is located. The diameter of the capillary tube is fixed and specified for the instrument.



Procedure for performing the work

1. Fuel is poured into the lower enlarged section of the instrument**,** then the instrument is placed into a thermostat and kept there for 15 minutes so that the sample reaches the required temperature.
2. The fuel is raised from the lower part of the instrument into the first spherical chamber by suction or with the help of a vacuum**.**
3. The time required for the fuel to flow from mark a to mark b is measured in seconds and determined with an accuracy of 0.1 s**.** To obtain a more accurate result, the measurement is repeated three times**,** and the average time is taken.
4. The kinematic viscosity is determined using the following formula:

$$V = \tau * c_t$$

τ - average flow time;

c_t - instrument constant; its value is specified in the instrument passport.

The obtained results are entered into the table, and a conclusion is written.

Diesel fuel grade	Average flow time, τ	Viscometer constant, c□	Viscosity of fuel at 20°C, ν^{20}, mm²/s
1			
2			

In the SI system, the unit of dynamic viscosity is the pascal-second **(**Pa·s**).** In practical work, the smaller unit mPa·s (10^{-3} Pa·s) is used. Dynamic viscosity is determined as the product of the kinematic viscosity ν and the density of the liquid ρ at the same temperature:

$$\mu = \nu\rho$$

Kinematic viscosity is the ratio of the dynamic viscosity to the density of the liquid at the same temperature:

$$\nu = \mu/\rho$$

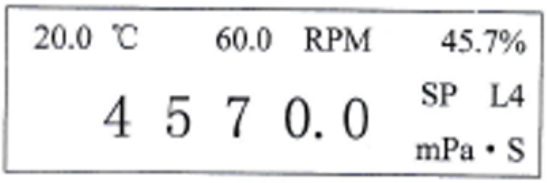
Dynamic viscosity is determined using the following instrument:



BDV-S & BDV Digital Rotational Viscometer

To evaluate dynamic viscosity resistance**,** BDV-S series and BDV-N series viscometers are used. These instruments are widely applied for measuring the viscosity of various materials. For example, they are used for paints, food products, cosmetics, liquids used in the chemical industry, capsule adhesives, and pharmaceuticals**.**The BDV-S series viscometer is considered a high-precision digital display viscometer**.** This instrument provides stable and accurate measurement performance**,** offers high display accuracy, and is convenient to

operate. The display shows the viscosity value directly**.**The main control panel and microprocessor board are designed using surface-mount technology (SMT)**.** The RS232 serial interface and the data acquisition software allow functions such as automatic operation**,** data storage**,** data comparison**,** and statistical analysis when connected to a computer.



Assessment question

1. Define the viscosity of liquids.
2. Give the definition of dynamic viscosity.
3. Explain the definition of kinematic viscosity.
4. What are the units of measurement for dynamic and kinematic viscosity?
5. Describe the sequence for performing the laboratory work.