Viscosity of liquid fuels – Höppler viscometer

The aim of this exercise is to determine viscosity of a liquid fuel as a function of temperature. By taking the measurement one also becomes acquainted with the Höppler method, which allows to determine dynamic (absolute) viscosities for Newtonian fluids.

The test stand

The experimental stand is composed of the Höppler viscometer and a thermostat. Determination of the viscosity is based on measurement of the time required for a ball to fall in a tube filled with the examined fluid (liquid or gas). The tube is transparent, is placed in a container and immersed in another fluid which is circulated through a thermostat. This fluid forms a bath for the immersed tube, which allows maintaining required temperature during the measurements. The viscometer allows measuring the viscosities in a very wide range. This is possible due to application of balls of various diameters and densities. Moreover, the angle of inclination of the tube (and the container) can be varied. The properties of the available balls are presented in Table 1. The ball for a given measurement should be selected in such a way that the real falling time is longer than the minimum time given in Table 1. The measurement should be taken at a given temperature of the examined fluid and at a given angle of inclination of the tube. Measuring the falling time for various inclination angles allows verifying correctness of the conducted experiments and accuracy of the measured viscosity.

Table 1. Properties of the balls available being part of the test bench equipment

Ball no.	Ball diameter, mm	Mass, g	Density, g/cm^3	Ball constant, mPa·cm^3/g		Min. falling time, s	Lower measurement limit, mPa·s	Upper measurement limit, mPa·s
				forward	backward			
1	15.811	4.594	2.2198	0.01311	0.01315	60	0.5	10
2	15.607	4.424	2.2226	0.10963	0.10979	30	2.5	130
3	15.552	15.993	8.1203	0.1573	0.1572	30	20	700
4	15.242	15.052	8.1184	0.624	0.625	30	200	7800
5	14.003	11.070	7.6999	6.844	6.845	30	1000	45000
6	11.006	5.318	7.6184	35.07	35.08	30	5500	

In Fig. 1 and 2 an image and schematic diagram of the test facility are presented, respectively. In Fig. 3 the schematic diagram of the viscometer is shown.

Fig. 1. The test stand

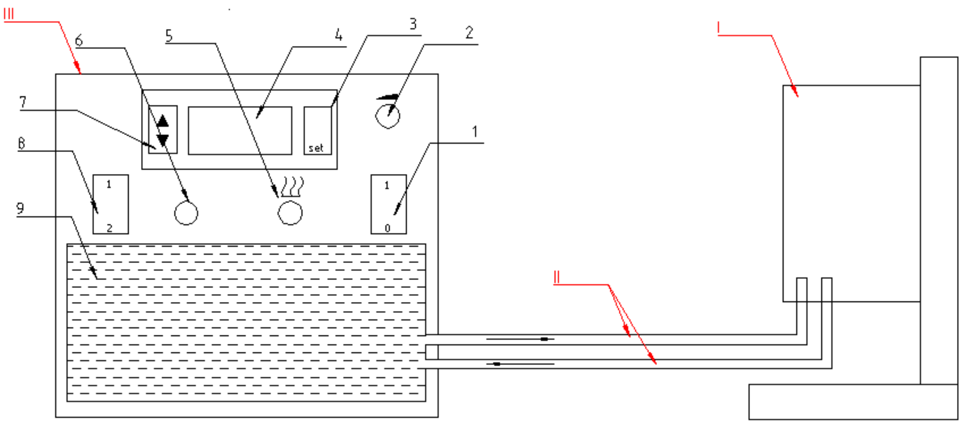

Fig. 2. Schematic diagram of the test facility: I- viscometer, II- conduits connecting the thermostat with the tube bath, III- thermostat; 1- power switch, 2- temperature regulator, 3- set button, 4- temperature display, 5- heating light, 6- alarm light, 7- temperature setting button, 8- pump switch, 9- thermostatic liquid

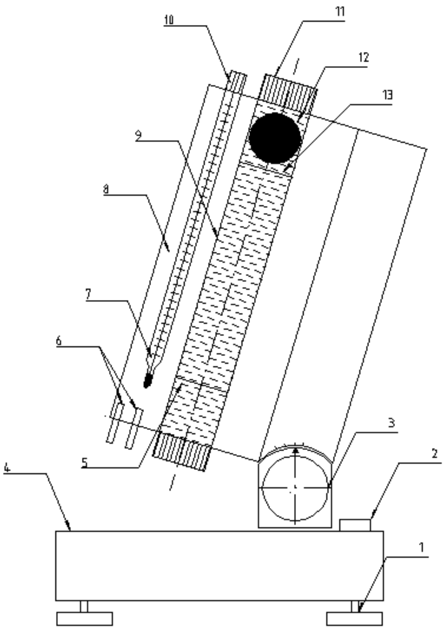

Fig. 3. Schematic diagram of the viscometer: 1- leveling screw, 2- bubble level, 3- clamp, 4- base, 5- bottom measurement ring, 6- thermostat connecting nipple, 7- thermometer, 8- water bath, 9- measurement tube filled with the examined fluid, 10- thermometer fitting nut, 11- measurement tube blanking nut, 12- ball, 13- top measurement ring

Methodology of the measurements

1) Make sure the thermostat is filled with water and connected to the mains,
2) Verify if the tube is filled with a liquid for which the viscosity is to be determined and make sure that an appropriate ball is placed inside,
3) Level the viscometer base using the leveling screw and the bubble level,
4) Ask the tutor to set the appropriate inclination angle of the tube,
5) The temperature display shows the current temperature of the thermostatic liquid (water). Set the required temperature by pressing the 'set' button and, at the same time, using the ▲▼ buttons to change the displayed value. Turn the thermostat pump on – the water will start circulating between the thermostat and the tube bath. After reaching the required temperature the heater will switch off,
6) When the circulating water reaches its temperature, verify its value using the additional thermometer installed in the bath. In order to equilibrate the temperature of the examined fluid (in the tube) allow the ball to fall down the tube twice before taking the proper measurements,
7) Take the measurements – measure the time the ball spends between the top and bottom measurement rings, which are drawn on the glass tube. If the ball is placed at the final bottom position rotate the viscometer by 180° in its horizontal axis. Its final appropriate position is fixed by a locking mechanism with a small ball. It is advised to press the stopwatch's start and stop buttons when the bottom end of the ball crosses the positions of the rings. The person measuring the time should look at the rings in the planes formed by the rings, so that they are visible as lines.

Note down the results in a measurement table, which can look like Table 2.

Table 2. Measurement results

Measured liquid	Ball no. used in measurement	Temperature in the viscometer	Inclination angle	Time of falling

Analysis of the results

The dynamic viscosity should be determined from the following equation:

$$\eta = (\rho_1 - \rho_2)KFt \qquad (1)$$

where:

η – dynamic viscosity coefficient, mPa·s

t – ball falling time, s

ρ_1 – density of the ball according to the certificate (given in Table 1), g/cm^3

ρ_2 – density of the measured fluid (determined from a plot provided during the class), g/cm^3

K – ball constant according to the certificate (given in Table 1), mPa·cm^3/g

F – inclination angle constant (given in Table 3)

Kinematic viscosity should be calculated according to

$$\nu = \frac{\eta}{\rho_2} \tag{2}$$

where:

ν – kinematic viscosity coefficient, mm^2/s

Table 3. Inclination angle constant

Angle	DIN (80°)	70°	60°	50°
Inclination angle constant, F	1	0.952	0.879	0.778

Create plots presenting the changes of dynamic and kinematic viscosity coefficients with temperature and draw conclusions.