AE 204 FLUID MECHANICS

VISCOMETER EXPERIMENT / EXP1

2023

OBJECTIVE

Rotary Viscometer Instrument (RVI) is used for determining the liquid viscose capacity and the absolute viscosity. RVI has been widely used to determine and measure the liquid viscosity in many applications such as grease, painting, plastic, pharmacy and adhesives. RVI is a machine that stirs a fluid. Depending on shape of spindle and fluid viscosity, particular force must be developed to stir the fluid at given speed.

THEORY

The shearing stress, τ, is increased by increasing pressure, P, recall that $\tau = P/A$, the rate of shearing strain is increased in direct proportion—that is,

$$\tau \propto \frac{du}{dy}$$

This result indicates that for common fluids such as water, oil, gasoline, and air the shearing stress and rate of shearing strain (velocity gradient) can be related with a relationship of the form

$$\tau = \mu \frac{du}{dy}$$

where the constant of proportionality is designated by the Greek symbol μ and is called the absolute viscosity, dynamic viscosity, or simply the viscosity of the fluid. Approximate viscosities of common materials at room temperature (20 °C) are given in the table below:

Material	Viscosity in Centipoise (or mPa.s)
Water	1 cps
Milk	3 cps
SAE 10 Motor Oil	85-140 cps
SAE 20 Motor Oil	140-420 cps
SAE 30 Motor Oil	420-650 cps
SAE 40 Motor Oil	650-900 cps
Honey	10,000 cps
Chocolate	25,000 cps
Ketchup	50,000 cps
Mustard	70,000 cps
Peanut Butter	250,000 cps

DESCRIPTION OF APPARATUS

The apparatus consists of precise synchronous electromotor, replaceable spindle that are screwed at a shaft, reading scale and clutch. There is also a speed changer for speed adjusting.

In order to meet the calibrated accuracy, speed of the spindle should be chosen so that we measure at least at the midpoint of the scale. When the clutch is depressed the measuring pin is pressed to scale, then one can stop the spindle and read the value. When the pin stops at the hidden part of scale plate, one should keep the clutch depressed and quickly start and stop the spindle so that we can read the value.

The fast acceleration of spindle makes a turbulent flow in a liquid, but after a short time it becomes laminar, thus, one can measure the viscosity.

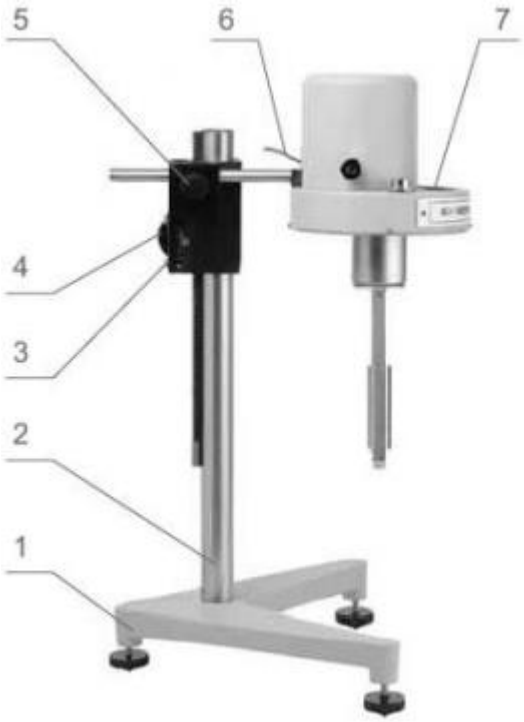


Figure 1 Side view

Figure 2 Front view

1. Support 2.Lifting bracket 3. Clamping bolt 4. Lifting screw

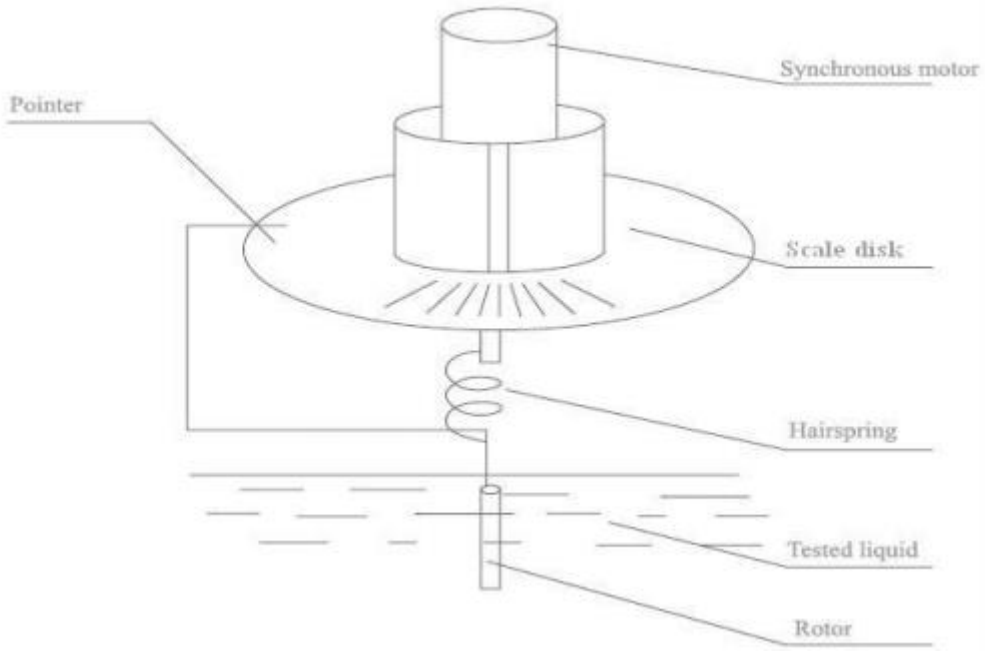
5.Handle fixed screw 6. Pointer joystick 7. Pointer 8. Variable speed knob

9. Level bubble 10. Dial 11.Protection bracket 12.Axle connecting connecting rod

13. Coefficient table 14. Power 15. Panel 16. rotor 17. Adjusting screw

How does it work?

1) Synchronous motor rotates with stable rate, connect scale disk, through hairspring and rotating shaft, drives rotors to rotate. The rotors will subject to a torque moment proportional to liquid viscosity because of the liquid viscose hysteresis. The torque moment will be measured by the sensors and processed into the viscosity and shown on the display.



2) Rate can be changed by using gear system and clutch, operated by rotary knob, four optional velocities.

3) According to different equipment, different rotors (Four rotors: NO.1-NO.4) will be attached, it can be select with the velocity according to the viscosity of the liquid.

4) The fixed control gear of pointer is used for accurate reading. When the rate is so fast (30 rpm, 60 rpm) that you cannot get the reading while it rotated, press pointer joystick, fix the pointer in order to get the reading.

5) The rotor bracket is used for the protection of rotors and the stability of the measurement, a more reliable measuring result can be made by using the protection bracket. The yellow protection cycle is used for the protection of instrument connecting rod.

6) It can be used as a portable instrument, assigned fixed bracket and elevating system. Generally, it should be fixed when determine small amount or the temperature is fixed in the laboratory.

PROCEDURE

1. Prepare the liquid to be measured and put it into a glass beaker or a right angle container with the diameter not smaller than 70 mm, height not smaller than 130mm, take care of the liquid temperature.

2. Mount the protection bracket on instrument, turning right for mounting, turning left for removing.

3. Screw the selected rotor into connecting rod, turning right for mounting, turning left for removing. Adjust the lifting screw and put the rotor into the liquid to be measured till the level mark on the rotor reach the liquid surface. Connect power supply, turn on the equipment, screw the speed knob, select velocity, relax pointer joystick, reading data can be displayed when the pointer becomes stable. You can get the reading data directly when you select 6 rpm or 12 rpm. When you select 30 rpm or 60 rpm, press the pointer joystick after pointer becoming stable, cut power supply, and then get the reading data.

4. When the reading data is too high or too low, the rotor or the rate can be changed, make sure the reading is between 30 and 90.

5. 0# Rotor and the testing annex of low viscosity liquid can be used following these steps below:
    a. Screw the 0# rotor into connecting bolt rod (turning left for mounting)
    b. Put fixed sleeve into the cylinder at the bottom of the instrument, and tight setscrew of sleeve.
    c. Assigning outer test tube with bottom， 20～25ml tested liquid should be injected into outer test tube then follow the steps below. Assigning test tube without bottom, follow the steps below directly.
    d. Set outer test tube into fixed sleeve and screw the test tube fixed screw tight. When screwing tight, the cone apex of test tube fixed screw should be screwed into the triangle groove at the top of outer test tube.
    e. Immerse outer test tube and rotor into liquid; make the red dot on the fixed sleeve as level line

6. Choice of range, coefficient, rotor and rate:
    a. Estimate approximately the viscose range, and then select the rotor and the velocity based on the range table given below:

Velocity / Range / Rotor	60	30	12	6
1	100	200	500	1000
2	500	1000	2500	5000
3	2000	4000	10000	20000
4	10000	20000	50000	100000

For example, the viscosity of liquid is about 3000 mPa·s the settings should be as following:
rotor 2 # with velocity of 6 rpm,
rotor 3 # with velocity of 30 rpm

    b. If the viscosity of liquid cannot be estimated, it should take a high value for real measurement, the rotor selection should be made from smaller to larger with their number from higher to lower. In general, high viscosity should use smaller rotor with slower velocity, lower viscosity use larger rotor with faster velocity.

c. Coefficient: the reading must be multiplied the specific coefficient in the coefficient table in order to get the absolute viscosity.

$\eta = k \cdot \alpha$

$\eta =$ absolute viscosity

$k =$ coefficient

$\alpha =$ reading (deflection angle)

Rpm / Rotor	60	30	12	6
1	1	2	5	10
2	5	10	25	50
3	20	40	100	200
4	100	200	500	1000

REFERENCES

1. http://www.vp-sci.com/viscosity-page, Access date: Feb 14th, 2022.
2. Munson, B.R. et al., Fundamentals of Fluid Mechanics, 7th Ed., 2013.
3. Operation Manual (pce-instruments.com), Access date: Feb 14th, 2022.

VISCOMETER EXPERIMENT / LAB 1 DATA SHEET DATE:

STUDENT NAME, SURNAME:

SIGNATURE:

Fluid Name (Write in brackets)	A (_____)	B (_____)	C (_____)
Rotor No (1, 2, 3, or 4)			
Rotor Speed (6, 12, 30 or 60) in rpm			
Dial Reading			
Coefficient			
Absolute viscosity, mPa.s (cp)			

Calculations:

1. Fill in the table above. Hint: Use procedure step 6.
2. Compare three fluids in terms of their viscosity. Comment on it.

LAB RULES:

•Each group should submit one report.

•Each group should write each parts by their own and get together with their group members to merge all of them.

•Reports are due to next week. They must be submitted to the corresponding assistant **till 17:00** on the next week.

•Students must sign the data sheet from the lab assistant at the end of each experiment and the signed sheet must be attached with the report. Reports without the signed data sheet will not be graded.

•Students are advised to read the detail of each experiment sheet before coming to the corresponding lab class.

LAB REPORT FORMAT (HANDWRITTEN EXCEPT COVER PAGE, TABLES AND PLOTS):

The lab report (no longer than 15 pages – all included –) should include the followings (unless otherwise specified):

1. Objective
2. Theory
3. Procedure
4. Results
5. Sample calculation
6. Necessary plots
7. Discussion on results, errors and graphs
8. Conclusion