Improvement of Michell Workshop Viscometer*

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The Michell viscometer is mainly composed of a cup and a ball. The viscosity is indicated by the time, during which the ball adheres to the cup against the gravity, after the space between them has been filled with oil sample and the ball has been pressed against the cup firmly. Although the mechanism of this viscometer is very simple and the viscosity can be measured using only several drops of the sample, it has not been used widely. The authors have improved this viscometer in several points and developed a constant temperature box for it. As a result, the reliability of the measurement has become higher and the operation of the viscometer easier. For example, we can know numerically the relation between the distance covered and the kinematic viscosity of automotive engine oil without any difficulties.

Key Words : Tribology, Lubrication, Measurement, Viscometer, Lubricating Oil, Internal-Combustion Engine

1. Introduction

There are so many kinds of viscometers that they can be classified in several types such as capillary, falling ball, rotatory, vibratory and other types according to the principles. The viscosity of the lubricating oils and other petroleum oils is measured by capillary method, that is, in accordance with 'TESTING METHOD OF KINEMATIC VISCOSITY' of the Japan Industrial Standards(1). Otherwise it is determined traditionally with Redwood or Seybolt viscometer.

In all of these methods we need 100 cc or at least 50 cc of sample oil and there are many advices given on handling and cleaning. We need in practice also a thermostatic room, because the viscosity is affected easily by temperature. Under such circumstances we have an impression that the measurement of viscosity is troublesome. On the other hand, a viscometer was developed by Michell several decades ago, in which

only some drops of sample oil were needed and its handling and cleaning were easy. This is, however, not wellknown today.

The reasons for its failure could be that the test results for one and the same kind of oil didn't coincide with each other depending on the manner of handling and that it was, therefore, not fully reliable also when it was considered a 'workshop viscometer' as he called it. The authors have improved the Michell viscometer such that it can be handled equally by everyone and developed a thermostatic box for this purpose. In other words, the authors gave a perfectness to Michell's 'workshop viscometer' in this study by consulting his own viscometer, and now it can be used with full reliability.

2. Michell's Viscometer

The main parts of Michell's viscometer consist of an iron cup and a steel ball as shown in Fig.1. The iron cup has 3

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Fig.1 Michell viscometer

projections on its inner surface as shown in Fig.2, so that a gap with a specified thickness is provided between the cup and the ball when they are coupled.

The measuring procedure is explained in Table 1. When the space between the cup and the ball is filled with a sample oil and they are then pulled apart with a specified force, the sample oil in the peripheral part streams to the center simultaneously with an enlargement of the gap between the surfaces. The removing speed is determined by this speed of oil stream, and the oil viscosity determines the time of adhesion between these two parts.

3. Improvement of the Viscometer

- (1) The position of the cup and the ball has been reversed by this improvement as shown in Fig.3. The inverting operation at the beginning of the measurement is now unnecessary, and the handle can be held on the holder stand before the test. Before this improvement the falling ball has to be received by velvet cloth or cotton wool so that it might not be scratched or might stain the surroundings because it is wet with oil. After improvement this is not necessary any longer, which makes the installation of a clock much easier, which is used for the adhesion time measuring.
- (2) The circular groove around the cup depression has been made wider as shown in

Fig.4, so that more sample oil can stay in it than before. The oil supply for the stream to the center can be maintained well by this enlargement of the groove. If the oil supply is not enough, the common wet area of both surfaces becomes smaller in shorter time, causing a reduction of the adhesion time. The reduction of the common wet area is hindered, on the other hand, by surface tension, which has a tendency to extend the adhesion time. The sample oil could flow out of the groove in inverting operation, by the way, if only the groove enlargement were made in the traditional manner.

- (3) The accuracy of the measurement cannot be high enough, when the adhesion time is either extremely short or extremely long. The adhesion time is determined only by the height of the projections, i.e. by the initial thickness of the gap between both surfaces in the traditional type, when the sample oil is specified. In the case of the improved type, however, the time is affected also by the cup weight. The authors have decided to apply always a constant height of the projections and to change the cup weight corresponding to the range of the viscosity measurement. In practice the authors employed 3 cups with different heights.
- (4) It seems that the cup depression of the traditional type is made by turning and rubbing against the model and the projections are provided by plating, which

Table 1 Measuring procedure of the traditional Michell viscometer

1. The cup is set with its depression upward and some drops of sample oil are given then to it.
2. The ball is set on the cup and pressed against it with appropriate force.
3. The whole viscometer is turned rapidly upside down and the handle is held in the manner shown in Fig.1.
4. The duration of adhesion between the ball and the cup is measured.

Fig.2 Geometry of the cup (1)

Fig.3 Improved Michell viscometer

Fig.4 Geometry of the cup (2)

causes irregularity of projection height because the height measurement involves some difficulties in this case. The authors have made another steel ball of such geometry, that three small flat surfaces are provided. This one is used as a press model. These flat surfaces make the supporting points in Fig.4 when the cup is made by press with this model.

(5) If the cup or the ball is magnetized, the adhesion time is affected by it in the traditional type. The authors used, therefore, brass for the cups. Brass was also easier to press than aluminum and copper.

(6) The wear of the projections might not be detected in the traditional type, also when it has advanced, making the measurement

impossible any longer. The authors plated the whole cup depression with a thin layer, so that we could see the end of life when the base metal of brass was exposed on the flat supporting surfaces of the plated layer.

Fig.6 Switch

Fig.5 Sketch of the thermostatic box

Fig.7 Results of temperature measurements at some points of the thermostatic box

4. Development of Thermostatic Box

The authors have constructed some kinds of thermostatic boxes exclusively for viscosity measurement use. The construction shown in Fig.5 is estimated to be the best one, in which the viscometer is the same as the one in Fig.3. The heater, the fan and the thermostat are installed for the purpose of maintaining a uniform temperature distribution and regulating the temperature level. The arm cover is useful for preventing in- and out-flow of air, when the hand is inserted into the box.

The own weight of the apparatus serves for the pressing of cup and ball against each other. The ball is raised by hand. The adhesion time is measured automatically by a clock with a switch under the cup as shown in Fig.6. Complete uniformity of the temperature inside the box can be obtained after at least 60 minutes as the experimental results in Fig.7 show. We must, therefore, hold the switch on for more than 60 minutes before we use this box.

5. Calibration of the Viscometer

Before the measurement the sample oil is to be supplied into the space between the cup and the ball. More than the minimum required amount of sample should be in the groove around the cup depression. Therefore, the authors have examined the minimum required amount for several values of viscosity using mixtures of automotive gear oil and spindle oil. Figure 8 shows results for two of them. Also for the other mixtures the authors have obtained similar results. From these data the minimum required amount has been determined to be 0.1 cc for each measurement with sufficient safety.

Figure 9 shows relations between cup weight and adhesion time and Fig.10 those between adhesion time and Redwood-second. Relations between kinematic viscosity and Redwood-second appear in the Japanese Industrial Standards(1) in detail.

Fig.8 Relations between sample oil volume and adhesion time

6. Application Example of the Viscometer

As one of the applications of this viscometer the authors have measured the viscosity change of an automotive engine oil depending on the driving distance covered. Figure 11 shows the results of this test. The measurement started after a distance of 600 km on a new car and the oil (SAE7.5W-30) was changed two times at 2080 km and 4136 km. Oil was sampled through a thin pipe inserted through the oil level gauge hole to reach the bottom of the sump.

7. Conclusions

The kinematic viscosity of automotive engine oil continues to reduced up to a driving distance of about 1400 km of a new car rather rapidly and then settles approximately constant. After the first oil

Fig.9 Relations between cup weight and adhesion time

Fig.10 Relations between adhesion time and Redwood-second

Fig.11 Kinematic viscosity of an automotive engine oil vs. driving distance covered

change the kinematic viscosity does not drop so much as that of a fresh oil. In obtaining these results with numerical verification the fact was contributive that this viscometer needed only a small amount of sample and that it offered high portability, easiness of operation and convenience for cleaning and maintenance.

Deterioration of lubricating oils being used in machines is detected by visual observation or inference in most cases as usually done with automobiles. This viscometer is inexpensive and easy to manufacture. But its results of measurement are sufficiently reliable for this purpose. The authors hope that it will find

widespread use in the future and the viscosity will be more often used for such estimations as illustrated above, examination of concentration of a liquid mixture composed of two ingredients and many other purposes.

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Reference

- (1) JIS K2283-1983, Japanese Industrial Standards Committee.