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Some Methods for Determining the Viscosity Index of Hydraulic Oil

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Abstract

Objectives: To determine the viscosity index of hydraulic oil by three methods. These methods are: the viscosity index determined by a mathematical relationship, using a calculation program and the graphic method. The study also intends to determine the viscosity-temperature coefficient for the hydraulic oil. **Methods:** To determine the kinematic viscosity of the hydraulic oil, we used a calculation formula that transforms the dynamic viscosity into kinetic viscosity knowing the density of the fluid. Thus, we determined the dynamic viscosity of the hydraulic oil with the Schott Ubbelohde viscometer at the temperatures of 40 and 100°C. To determine the dynamic viscosity of hydraulic oil at 40°C and 100°C, we used a water bath. The dynamic viscosity thus obtained was transformed into the kinematic viscosity of the oil by dividing it by density. **Findings:** The lowest viscosity index of the hydraulic oil determined using the computer program is 101. The viscosity index of the hydraulic oil determined with relation (1) is 58% higher than using the computer program. The viscosity index determined by the graphic method is 50% higher than the one determined by the computer program. The viscosity-temperature coefficient has a value of 0.8380. **Novelty:** Knowing the viscosity index of hydraulic oil is important for starting the engine at high temperatures and at low temperatures. At high temperatures, the oil chemically degrades and the molecules break down. The properties of hydraulic oils depend a lot on the way the hydraulic system works and the limits imposed on them in different conditions.

Keywords: Viscosity Index; Viscosity-Temperature Coefficient

1 Introduction

Little is said about hydraulic oil, although it is an important component of many machines and engines. Hydraulic oil is a basic element for productivity in various fields, from agriculture to industry and transport. Most hydraulic systems are designed for operations that require varying degrees of pressure, high speed and high temperatures. Hydraulic oil is often confused with other hydraulic fluids, which are similar, but are mainly used for the transmission, steering adjustment and braking of land and air vehicles. Hydraulic oil transmits energy within the hydraulic system and generates the power needed to perform tasks. The oil is pushed with the help of a pump to points where pressure is formed, which pushes pistons or other parts. Hydraulics is part of everyday life, it is hard to imagine that there is a machine working without hydraulic power, even if it is agricultural and, and construction equipment, conveyor belts, and equipment that operates in industries such as food, metallurgy, paper production and stationery, and even in aviation and the aerospace industry.

In machines such as those described above, hydraulic oil circulates through engines and cylinders, is controlled by valves and distributed through a variable number of tubes and hoses and reticulated through a filtration system back into the circuit. Oil is the most important aspect in the hydraulic system and the key element to ensure operation with optimized costs for your machine. Despite its critical nature, oil is seen as a common issue by most suppliers. In times when the cost of crude oil is rising, it is normal to look for the low-price option from suppliers. In any case, low-cost hydraulic oils made from poor quality raw materials or recycled materials will affect the performance of the hydraulic system and will add additional costs to your business.

The most important component parts of a hydraulic system are:

- Engines and pumps
- Hydraulic cylinders
- Valve
- Circuit elements: fluid tank, filtration system, pressure tank
- Sealing elements and gaskets

The hydraulic oil is designed to ensure the operation of each component and to ensure the optimum efficiency of the machine.

Pumps and motors are used in the hydraulic system to transfer energy and are subjected to a hydraulic stress of up to 700 bar. As a result, the hydraulic fluid is designed to protect moving components and also bearings against wear and corrosion and to reduce friction and to ensure the necessary energy. Preventing corrosion and reducing the effect of deposition of impurities brings a longer life to moving elements and less friction in the components of the hydraulic system, so less energy used and lowers costs.

The hydraulic cylinders transform the hydraulic pressure into translational motion, and subsequently into mechanical power. The hydraulic oil lubricates the piston and the bore, helps to eliminate the ”stick slip” phenomenon, minimizes wear and prevents corrosion. Low-cost oils can contain low values of anti-corrosion additives, leading to increased wear and the possibility of scratching the cylinder, reduce performance and require more energy. Incompatibility with the sealing elements can also lead to leaks, lack of lubrication and ultimately to the destruction of the system.

It is a characteristic introduced in 1935 by Dean and Devis, which allows the appreciation of the variation of oil viscosity at low (”cold”) or high (”hot”) temperatures, respectively at start-up or in normal operation.

The viscosity index has no dimensions. It is a simple coefficient that compares the viscosity at 100°F (37.8°C) according to Dean and Devis (at 40°C according to the new ISO classification) of two reference oils, one asphaltic and the other paraffinic, which have the same viscosity at 210 °F (at 100°C in ISO classification).

The two reference oils were thus chosen:

- an oil with a pronounced dependence of viscosity on temperature (for example, asphaltic oil from the Gulf[1,2] and to which VI = 0 is attributed, an oil with a less pronounced dependence on temperature and to which VI = 100 is attributed (Figure 1).

The diagram is determined for the kinematic viscosity, knowing its values at two reference temperatures T_1 and T_2. To determine the viscosity index of an oil, it is necessary to find two oils that have the same kinematic viscosity at the higher reference temperature, usually T_2 = 373K (or 210°F ≈100°C). All viscosities involved in estimating the viscosity index are determined following the ASTM D2270-2004 method (Standard Practice for Calculating Viscosity Index From Kinematic Viscosity at 40 and 100°C). This standard presents two procedures: A – for oils with a viscosity index up to 100 and B for viscosity indices greater than or equal to 100. The calculation of the viscosity index can also be done according to ISO 2909:2002 (Petroleum products - Calculation of viscosity index from kinematic viscosity).

The relation of the viscosity index of the given oil will be:

$$VI = \frac{v_1 - v}{v_1 - v_2}100 \tag{1}$$

In the last decades, the problem posed by this oil evaluation parameter is that oils 1 and 2 in the diagram in Figure 1 were chosen as extreme developments, at a given time. After this moment, oils with superior characteristics appeared, either by adding mineral ones or by developing synthetic oils, and according to relation (2) viscosity indices higher than 100 were calculated (the

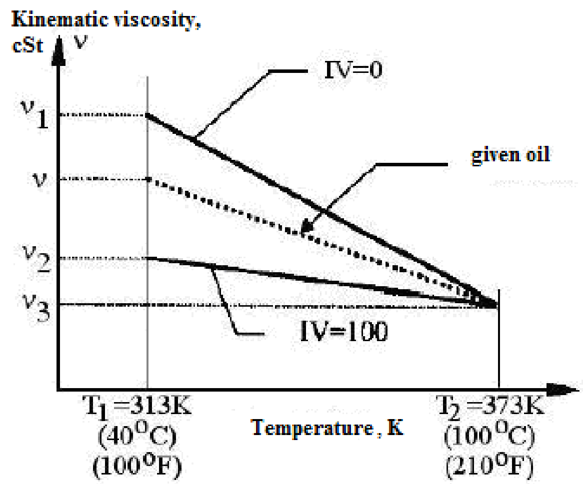

Fig 1. Viscosity index

value of 200 was exceeded). ASTM proposed for oils with a conventional viscosity index greater than 100, another relationship (procedure B of D2270) that better reflects a lower dependence of viscosity with temperature:

$$VI_E = 100 + \frac{10^N - 1}{0.000715} \tag{2}$$

where:

V_2 is the kinematic viscosity at 40°C, in cSt, of an oil with a viscosity index of 100 but which has the same kinematic viscosity at 100°C as the oil considered

V_3 is the kinematic viscosity of the given oil at 100°C [2], [3] .

V is the viscosity of the analyzed oil, at 40°C

$$N = \frac{\lg v_2 - \lg v}{\lg v_3} \tag{3}$$

For the calculation of the viscosity index, abbreviated VI, the tables and graphs given in the ISO 2909:2002 and ASTM D2270-2004 standards are used. Mineral oils are classified as follows according Table 1 to the VI value.

Table 1. VI of mineral oil

Group of oils	VI
Low viscosity index	under the 15
Average viscosity index	45 - 80
High viscosity index	80 - 110
Very high viscosity index	Over 110

In general, synthetic oils have a high or very high VI (viscosity index), while for mineral oils, in order to reach values of 100...120, it is necessary for the oils to be obtained through the hydrotreatment process, and above 120 - by adding polymers that improve the viscosity index. A very careful selection of these additives is required, as is the case for multi-functional automotive gear oils, for example, from SAE viscosity classes 75W/90, 80W/140, etc., taking into account the shear resistance of these additives. Oils with high VI allow easy starts at low temperatures and maximum safety at high temperatures in normal operation. The quick determination of the viscosity index is done with the help of abacuses, which offer sufficient precision, for which it is necessary to know only two viscosities of the studied oil at different temperatures (100°F and 210°F or 40°C and 100° C). Usual abacuses of this kind determine the VI value for the intervals: 0...100; 100...150 and 100...300 (extended VI). The same abacus can be used to determine the viscosity value at a certain temperature when the viscosity at one of the reference temperatures and the VI value are known [4,5].

The most convenient way to determine kinematic viscosity at temperatures other than those indicated or to determine viscosities at 40 and 100°C from viscosities at other temperatures is the graph, using ASTM D 341 diagrams[6]. The determination is reduced to finding the viscosity at those two standard temperatures from viscosity to one temperature and VI.

The calculation of the viscosity index was also carried out with a calculation program from the website https://www.kluebe r.com/[5] based on the ASTM 2270 standard.

The scale of viscosity indices established by SAE, according to ASTM 2270-93 elaborated for calculating viscosity indices of petroleum products such as lubricants and materials related to them[6–9], requires the knowledge of the kinematic viscosities of the oils at two temperatures[10].

The viscosity indices were also determined using the ASTM D 341 diagram, shown in Figures 1. The viscosity index of the hydraulic oil determined with equation (1) was 144. The kinematic viscosity of the hydraulic oil was 5.73 cSt at 100°C and 35.46 cSt at 40°C.

Another indication of the change in kinematics viscosity with temperature, which is less arbitrary than the viscosity index, is the viscosity-temperature coefficient, VTC, defined by the relationship[1–3,11,12]

$$VTC = (v_1 - v_2)/v_1 \tag{4}$$

where v_1 is the viscosity (cSt) at 40°C and v_2– viscosity at 100°C.

The objective of the present paper is the determination of viscosity index for hydraulic oil, viscosity-temperature coefficient and extended viscosity index.

2 Methodology

Viscosity index for hydraulic oil was determined using a set of Schott Ubbelohde-type viscometers selected according to the values of their constants, so that the margins of the uncertainty, inherent in the Hagebach-Couette correction, does not exceed the error allowed for the measurements. The measurements were carried out at 40± 0.1 and 100± 0.1°C, according to the recommandation of ASTM D2270[8,9].

3 Results and Discussion

Viscosity is a measure of an oil thickness and ability to flow at certain temperatures, while viscosity index is a lubricating oil quality indicator, an arbitrary measure for the change of its kinematic viscosity with temperature and provides an insight into the oil's ability to perform at high and low temperatures[1–3,10–12].

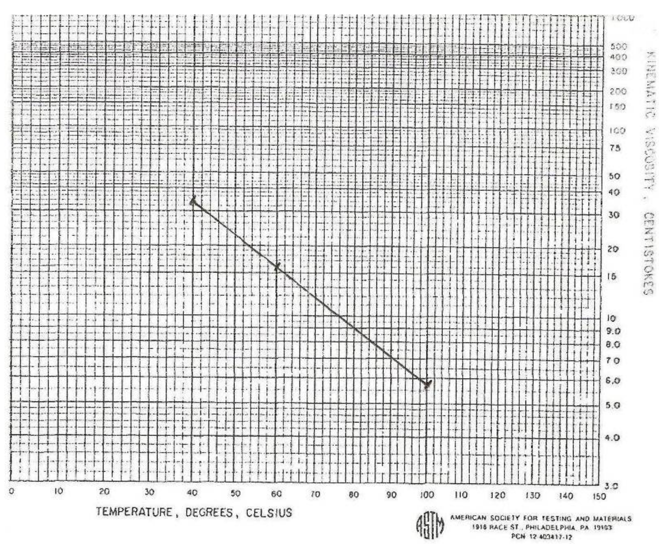

Fig 2. Viscosity index graph of hydraulic oil

The following conclusions can be drawn from table 1: the lowest viscosity index was determined using computer program 101. The viscosity index determined with relation (1) is 58% higher than using the computer program. The viscosity index determined by the graphic method is 50% higher than the one determined by the computer program. The viscosity-temperature coefficient has a value of 0.8380.

Table 2. Values of kinematic viscosities at 40 and 100^0C, viscosity index and viscosity-temperature coefficient for the hydraulic oil

Oil	Density (g/cm^3)	Kinematic (mm^2/s) 40^0C	viscosity 100^0C	Viscosity index relationship (1)	Viscosity index program VI	Viscosity index graph	Viscosity-temperature coefficient
Hydraulic	0.8900	35.46	5.73	176	101	205	0.8380

4 Conclusion

In this article, we determined the viscosity index of the hydraulic oil by three different methods, each of them obtaining different values. The conclusion that can be drawn is that the hydraulic oil has a high viscosity index and at high temperatures in the engine it chemically degrades.

The viscosity of hydraulic oil is dependent upon temperature. Viscosity decreases as temperature increases because the molecules vibrate more, and interact less.

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