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Kinematic Viscosity of Engine, Gear, Hydraulic and Special Purpose Oils at Temperatures of 25°C and 50°C

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Abstract. Oils are used in various lubrication systems, such as internal combustion engines, transmissions, hydraulic systems, and specialized industrial applications. The aim of this study is to show how the kinematic viscosity of oils for various applications changes with temperature. Sixteen different commercially available oils were evaluated, from the group of engine oils, transmission oils, hydraulic oils, shock absorbers, chain saw lubrication oils, air conditioning oils, hybrid vehicle internal combustion engines, and two-stroke engine fuel mixtures. Kinematic viscosity was measured for two temperatures, that is, 25 °C and 50 °C. For the purposes of the study, an Ostwald-Pinkiewicz capillary viscometer was used. According to the theory, the kinematic viscosity of all 16 oils tested decreased with increasing temperature. Knowledge of the viscosity behavior of oils in the group of engine oils, transmission oils, hydraulic oils, and specialized applications is of great importance, especially when considering the pumping resistance in gear pumps.

Keywords: chain saw lubrication oils, shock absorber oils, fuel mixture oils for two-stroke engines, SAE classification**.**

Introduction

The kinematic viscosity of oil is one of the key parameters that determine its lubricating properties and efficiency in various applications [1]. Oils are used in various lubrication systems, such as combustion engines, gears, hydraulic systems, or specialized applications in industry [2]. Each of these applications requires appropriate oil properties, which depend on, among others, viscosity, operating temperature, and environmental conditions. In technology, the concept of kinematic viscosity, also called kinetic viscosity or absolute viscosity, is very often used. In the CGS system, the unit of kinematic viscosity is Stokes [St]. In practice, a 100 times smaller, called centistokes [cSt]. The unit of kinematic viscosity in the SI system is square meters per second [m^2/s]. In practice, however, a unit 106 times smaller [mm^2/s] is used, which is the equivalent of centistokes (cSt) [3]. In industrial practice, the kinematic viscosity of oils is usually measured using a capillary viscometer, most often in accordance with the national standards PN-77/C04166 or international standards such as ISO 3104. This process consists in measuring the time in which a given volume of liquid flows through a capillary under the influence of gravity, which allows for precise determination of the flow properties of the liquid at different temperatures. Kinematic viscosity has been assessed many times in the world literature, although these data are still not consistent or made at different temperatures. In one of the works, the viscosity of 6 engine oils used on motorcycles was assessed with changing temperature in the range of – 5 °C to +115 °C, which are important for the performance of combustion engines [4]. The next paper presents the results of the measurements of kinematic viscosity obtained using three different fast measuring devices and a standardized method using the Ubbelohde capillary viscometer, where the most accurate results were obtained for the Stabinger viscometer [5]. The intensive development that is happening in the fuel and oil sector, both at the legislative and technological level, encourages scientists to carry out more ambitious research [6]. One can also encounter an analysis of the nature of the action of additives in the form of POLYTRONMTC in terms of its adaptation to high-speed and high-load conditions in the aspect of ball wear on a moving disc [7]. The results of the influence of the dynamic viscosity of the lubricant material on the parameters of the adhesive bond during the re-abrasion of Steel 45 [8] cannot be omitted. To examine resistance to degradation, the oils were also subjected to the oxidation process and the most resistant groups of oils were indicated [9]. For hydraulic oils, the dynamic viscosity was determined at temperatures of 40 °C and 100 °C [10], but hydraulic oils generally operate at temperatures not exceeding 50 °C, which is why we selected the temperature of 25 °C during start-up and 50 °C during standard pump operation during measurements. The aim of this article is to examine the kinematic viscosity of 16 oils from the group of oils: engine, gear, hydraulic and oils for special applications at temperatures of 25 °C and 50 °C. Special purpose oils include shock absorber oils, chainsaw lubrication oils, air conditioning oils, hybrid vehicle combustion engine oils, and two-stroke engine fuel mixture oils. The properties of the oils at these two temperatures will allow us to assess how the lubrication properties change at the operating temperature of standard gear pumps.

1. Materials and Methods

Kinematic viscosity was measured using an Ostwald-Pinkiewicz capillary viscometer in accordance with the Polish standard PN-77/C04166 [11] and the international standard ISO 3104 [12], in particular procedure A, which describes how to perform the measurement using hand-held glass viscometers. Kinematic viscosity ν is defined (1) as the ratio of the dynamic viscosity η of a liquid to its density ρ [12]:

$$\nu = \frac{\eta}{\rho} \tag{1}$$

The measurement of viscosity, using the flow of liquid through capillaries, is based on the Hagen-Poiseuille law [13] (2):

$$\eta = \frac{\pi r^4 \Delta p t}{8 l V} \tag{2}$$

where r – capillary radius in cm,

l – capillary length in cm,

t – flow time in s,

Δp – pressure difference causing liquid flow in Pa,

V – volume of liquid flowing in time t in cm^3.

Taking into account the flow through the capillary only under the action of its own weight, and the formula for the capillary constant k, we obtain and, dividing by the density of the liquid, we finally obtain the kinematic viscosity formula (3) [14]:

$$\nu = k \cdot t \tag{3}$$

where ν – kinematic viscosity

k – capillary constant,

t – flow time of a liquid of a given volume through the capillary.

The tests were carried out at two temperatures: 25 °C and 50 °C to assess the effect of temperature on the viscosity of the oils.

The test procedure was as follows:

1. The oils were heated successively to two temperatures, that is, 25 °C and 50 °C in a controlled chamber;

2. Kinematic viscosity ν was measured by determining the flow time of the oil under the influence of gravity [15, 16] through the Ostwald-Pinkiewicz capillary, used many times during similar tests [17]. Then, using the capillary constant k and the measured time t, the kinematic viscosity ν was calculated from the relationship(3);

3. Development of a database of kinematic viscosity results for the 16 different oils (3 repetitions were performed for each measurement test; then the mean and standard deviation were calculated, additionally indicating the confidence interval).

The principle of kinematic viscosity measurement using the Ostwald-Pinkiewicz capillary viscometer consists in measuring the liquid flow time of the tested from the measuring reservoir of the capillary with a volume precisely defined by measuring lines (upper and lower measuring line) [4]. Based on knowledge of the capillary constant k and the liquid flow time t, after substituting these values into formula (3), the liquid kinematic viscosity of the tested is calculated [14]. To present the tested samples, 16 oils were characterized in Figure 1.

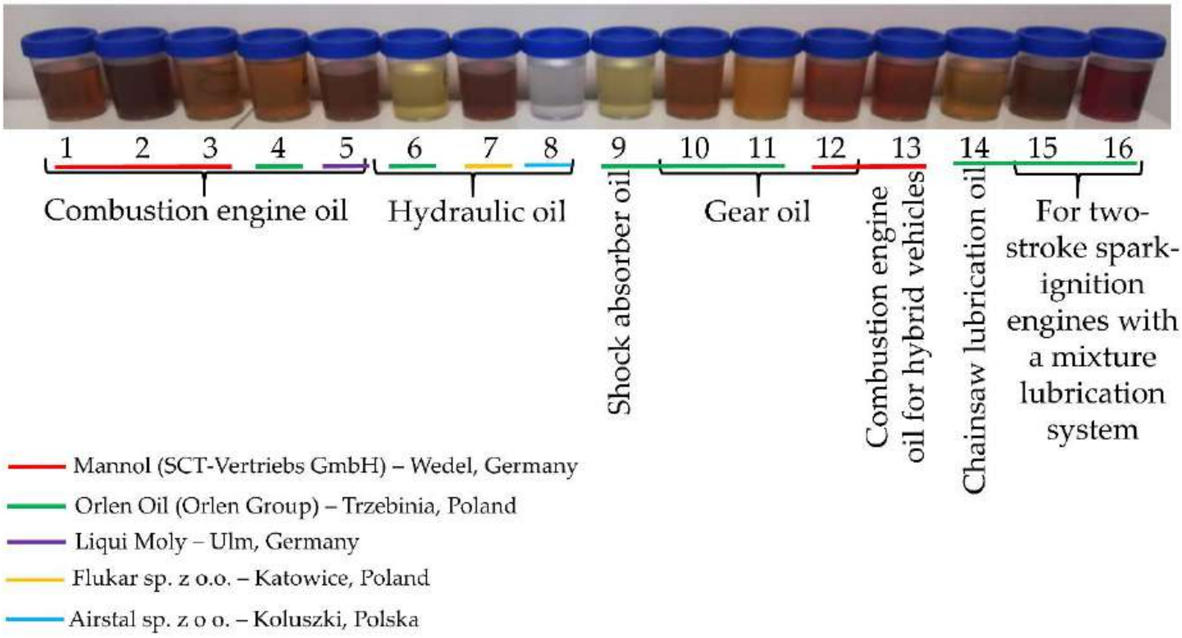

Fig. 1. Samples of tested oils: 1 - 5W/20 (Energy Ultra JP), 2 - 0W/30 (Legend Extra), 3 - 15W/40 (Universal), 4 - 20W/50 (Lubro), 5 - 10W/60 (Synthoil Race Tech GT1), 6 - L-HL 32 (Hydrol), 7 - HL 46 (Revline), 8 - PAO 68 (Hart), 9 - 15-WL 150 (Amortyzol), 10 - GL-4 80W/90 (Hipol), 11- GL-5 85W/90 (Hipol 15F), 12 - GL-5 LS 85W/140 (Hypoid LSD), 13 - 0W/16 (Hybrid SP), 14 - VG 68 (Pilarol), 15 - 0W/12 (Mixol S), 16 - 0W/20 (2T Semisythetic).

2. Results and discussion

According to the methodology indicated, the oil flow time t was determined and then the kinematic viscosity was calculated from the relationship (3). Table 1 presents the collected results of the kinematic viscosity ν tests at a temperature of 25 °C, while Table 2 presents the collected results of the kinematic viscosity ν tests at a temperature of 50 °C.

Table 1. Kinematic viscosity test results ν at 25°C

Oil ID	Time *t* [s]				Kinematic viscosity[mm²/s] $\nu=k\cdot t$				
	1	2	3	Capillary constant k	1	2	3	Mean	Standard deviation
5W/20	236	240	237	0,2736	64,57	65,66	64,84	65,03	0,47
0W/30	362	366	369	0,2718	98,39	99,48	100,29	99,39	0,78
15W/30	854	841	825	0,2736	233,65	230,10	225,72	229,82	3,24
20W/50	1016	1044	1036	0,2718	276,15	283,76	281,58	280,50	3,20
10W/60	1151	1192	1174	0,2736	314,91	326,13	321,21	320,75	4,59
L-HL-32	216	215	213	0,2736	59,10	58,82	58,28	58,73	0,34
HL46	324	320	325	0,2718	88,06	86,98	88,34	87,79	0,59
PAO68	456	422	423	0,2736	124,76	115,46	115,73	118,65	4,32
AMORTH_OL	80	80	81	0,2656	21,25	21,25	21,51	21,34	0,13
80W/90	985	992	980	0,2736	269,50	271,41	268,13	269,68	1,35
85W/90	1126	1105	1109	0,2656	299,07	293,49	294,55	295,70	2,42
85W/140	2879	2890	2833	0,2736	787,69	790,70	775,11	784,50	6,75
0W/16	228	230	232	0,2656	60,56	61,09	61,62	61,09	0,43
VG68	490	485	450	0,2656	130,14	128,82	119,52	126,16	4,73
0W/12	205	206	206	0,2656	54,45	54,71	54,71	54,63	0,13
2T	687	669	678	0,2656	182,47	177,69	180,08	180,08	1,95

Table 2. Kinematic viscosity test results ν at 50 °C

Oil ID	Time t [s]						Kinematic viscosity[mm²/s] $\nu=k\cdot t$		
	1	2	3	Capillary constant k	1	2	3	Mean	Standard deviation
5W/20	102	103	102	0,2736	27,91	28,18	27,91	28,00	0,13
0W/30	145	147	145	0,2718	39,41	39,95	39,41	39,59	0,26
15W/30	260	258	253	0,2736	71,14	70,59	69,22	70,32	0,81
20W/50	317	320	312	0,2718	86,16	86,98	84,80	85,98	0,90
10W/60	416	421	428	0,2736	113,82	115,19	117,10	115,37	1,35
L-HL-32	81	82	82	0,2718	22,02	22,29	22,29	22,20	0,13
HL46	105	104	104	0,2736	28,73	28,45	28,45	28,55	0,13
PAO68	162	160	161	0,2718	44,03	43,49	43,76	43,76	0,22
AMORTH_OL	40	40	39	0,2736	10,94	10,94	10,67	10,85	0,13
80W/90	297	304	306	0,2718	80,72	82,63	83,17	82,17	1,05
85W/90	298	296	297	0,2736	81,53	80,99	81,26	81,26	0,22
85W/140	620	622	646	0,2718	168,52	169,06	175,58	171,05	3,21
0W/16	96	92	92	0,2736	26,27	25,17	25,17	25,54	0,52
VG68	148	145	145	0,2718	40,23	39,41	39,41	39,68	0,38
0W/12	77	78	79	0,2736	21,07	21,34	21,61	21,34	0,22
2T	203	204	202	0,2718	55,18	55,45	54,90	55,18	0,22

In order to clearly present the measured values of the kinematic viscosity of oils, they are presented in Fig. 2, where a comparative graph for two temperatures (25 °C and 50 °C) is shown. Analysis of the test results shows that with increasing temperature, the kinematic viscosity ν of all 16 tested oils decreased according to the theory. It should also be noted that the error bars for the temperature of 50 °C are more than twice smaller than for the temperature of 25 °C.

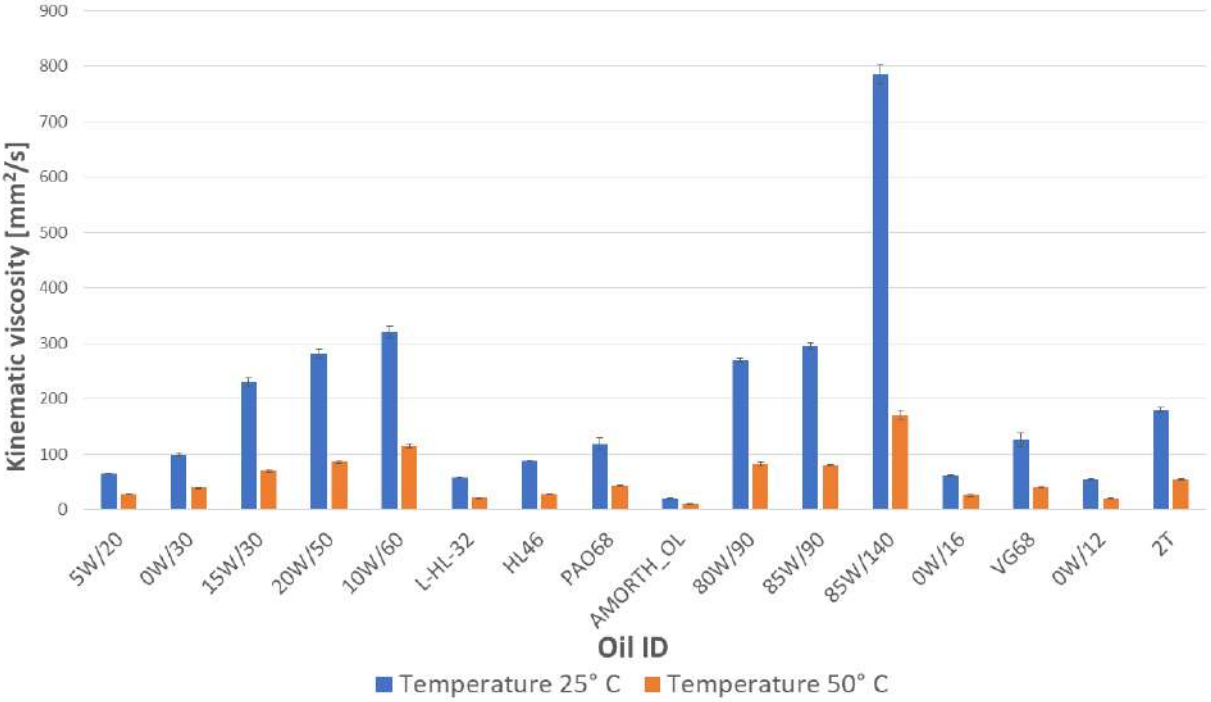

Fig.2. Dependence of kinematic viscosity of oil at two temperatures 25° C and 50° C

It should also be noted that the kinematic viscosity ν of the 85W/90 oil for the indicated temperatures drops more intensively than for the 80W/90 oil. For a temperature of 25 °C, the difference in kinematic viscosities ν

between the indicated oils is 26 mm2/s, while for a temperature of 50 °C, this difference decreases to 2 mm^2/s. On average, for all 16 oils tested, the kinematic viscosity ν drops by about 65%. The smallest decrease in kinematic viscosity ν was observed for the shock absorber oil (AMOTTH_OIL), which was 49%, while the largest decrease was observed for the gear oil (85W/140), which was 78%. It has been proven that operating temperature and the quality of the hydraulic oil quality affect the volumetric efficiency of the gear pump [18], therefore the presented results are essential for the users of these devices. It should be emphasized that the kinematic viscosities ν of the oils are determined at different temperatures. Usually according to the SAE classification [19] or according to the ISO classification [20, 21], which determines both cold and warm conditions. However, it is important to select temperatures that are as close as possible to the standard operation of the pump.

Conclusions

This study focuses primarily on indicating the decrease in kinematic viscosity ν of oils from the group of engine oils, transmission oils, hydraulic oils, shock absorbers, chain saw lubrication oils, air conditioning systems, hybrid vehicle combustion engines, and two-stroke engine fuel mixtures. Studies conducted at two temperatures will be helpful in making rational decisions regarding the selection of oil for pump operating conditions. The main conclusions of this study are as follows:

The kinematic viscosity ν of the 16 oils tested for temperatures of 25 °C and 50 °C drops significantly according to the theory. Moving from lower to higher temperatures, the kinematic viscosity ν of the oils tested dropped by an average of about 65%. The smallest decrease in kinematic viscosity ν was noted for shock absorber oil (AMOTTH_OIL) and the largest for 85W/140 transmission oil) was noted.

The kinematic viscosity ν of the oil is crucial for its lubricating properties and affects the efficiency of the mechanical systems in which it is used. Choosing the right oil, adapted to the temperature conditions in which it will operate, has a direct impact on the durability of the equipment, energy consumption, and efficiency of their work.

Knowledge of the kinematic viscosity ν behavior of oils from the group of engine, gear, hydraulic, and special-purpose oils is of great importance, especially when considering the pumping resistance in gear pumps, which we plan to study in the next stage of work.

In future studies, the analysis can also be extended to higher operating temperatures and other types of specialist oils to obtain a more complete picture of their behavior under variable thermal conditions.

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