“The Effect Of The Change In Oil Viscosity With Rising Temperature On The Service Life Of Engine’s Oils”

Research Question: “What Is The Effect Of The Change In Oil Viscosity Measured by DIN Cup 4 With Rising Temperature in the 23-93^{o}C Range On The Service Life Of Engine Oils?”

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Contents

1. Introduction

In the automotive industry, which is one of the factors that make human life easier, the service life of vehicles can be evaluated by the life of the engine, which is the main part of the vehicle. There are many factors that contribute to the longevity of the engine, such as the quality of the gasoline used in the vehicle, periodic maintenance, not using the vehicle at high speeds, and keeping the air filter clean. The operations performed during standard periodic maintenance include changing the oil filter, engine oil, air filter, pollen filter, fuel filter, tire, and battery maintenance; checking the spark plug; and the checking brake system, exhaust system, and suspension system. One of the basic points to be considered for periodic maintenance is the duration of the engine oil change, which is directly proportional to the performance of the engine oil during its use. One of the most important properties of engine oils is their viscosity value. The viscosity of engine oils is a property that directly affects the prevention of fuel waste, wear protection capacity, and engine efficiency, especially at different temperatures.

This research will examine how changes in viscosity of different engine oils occur within a certain temperature range and their effects on engine performance. In this study, it is studied how the oil's usage period, which affects the performance of engine oils, is affected by the change in viscosity of the oil with the increase in temperature.

The aim of the study is to clarify the responses of engine oils to temperature conditions and to determine the effects of these changes on the engine to achieve optimal lubrication conditions. Viscosity measurement is carried out with a DIN Cup 4. As a result of the research, it is aimed to better understand the main factors affecting the performance of engine oils and to contribute to the engine design and oil selection processes in this direction.

2. Background Information

2.1. Lubrication

Lubrication plays a major role in the engine functions, life, and performance of machinery. Reducing abrasion between two surfaces in contact occurs as lubrication, and it typically calls for the addition of a material called a lubricant. Lubricants, prevent metal to metal contact in engines, minimising wear and tear and spreading heat. Oil characteristics and types have a significant effect on engine performance, life, and functions. For engines and moving machinery, oil attributes need to remain stable. Succesful lubrication provides optimum benefits to prevent corrosion of metalic parts of engine. Lubrication fluids provide reduction the friction and provide good thermal conductivity. Thermal conductivity features of engine oils protect engines in vehicles and powered machines aganist negative effects of internal combustion. Lubrification of engine directly effect of maintenance period, vehicle fuel consumption. Thus, a successful and regular lubrication process is an important step in order to ensure long engine life. If oil loses its qualities, and the motor metals may corrode excessively mechanically and chemically.

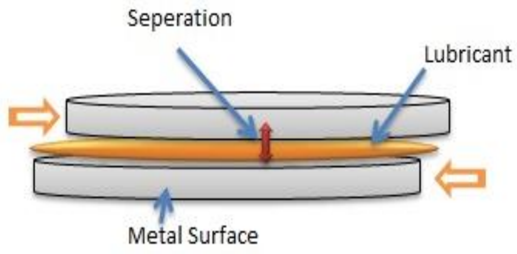


Figure 1. Lubrication of Metal Surfaces

A study found that engine oil can help determine when engines need an oil change, ensure optimum performance during scheduled maintenance, and extend engine life. (Kurre, Pandey, Khatri, Bhurat, Kumawat, Saxena &Kumar, 2021)

2.2. Viscosity

All fluids have an internal friction between molecules. Viscosity is resistance between fluids own particles to shear or motion in other word its internal friction. So viscosity is based on the internal friction of the fluid. At the molecular level, moving molecules in a liquid collide with each other and cause friction. Friction is the factor that determines the viscosity of a liquid. The magnitude of viscosity is found in various industries. For example, in the automotive industry, engine oil viscosity can affect engine performance. In addition, in the pharmaceutical industry, viscosity can affect drug injection and absorption. Measurement of Viscosity is an most useful method to determine of a fluid performance when fluids are used in lubrication. Viscosity use for different commercial applications such as paint, engine oil, pharmateutical and food products. There different measurement equipments to measure viscosity, Brookfield viscometer, Anton Paar dynamic rotational viscosimeter, *Ubbelohde* viscometer, viscosity cups (DIN, Zahn, Ford etc.).

Kinematic viscosity more useful than dynamic viscosity for production processes quality control. The dimension of kinematic viscosity are area divided by time; the units are metre squared per second. Expressed as centimetre squared per second.

The dimension of dynamic viscosity are force x time divided by area; the units are Newton second per square meter. Expressed as pascal second in SI units.

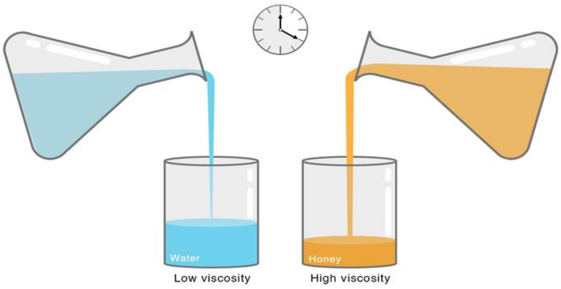


Figure 2. Viscosity of Liquids

There are various factors that affect viscosity in liquids. These are temperature, pressure, composition, and structural properties of the liquid. The viscosity of liquids generally decreases as temperature increases. This is because, as the temperature increases, the internal resistance of the liquid decreases and the mobility of the molecules increases. Under high pressure, viscosity increases as the liquid molecules find themselves in a tighter state. As the pressure increases, the friction force between the molecules increases, which makes the flow of the liquid more difficult. Since it is difficult for the chains to move in a liquid consisting of long-chain polymers, it has a higher viscosity. The chemical structure, molecular size and molecular arrangement of a liquid have an impact on viscosity.

2.3. Differences Between High And Low Viscosity

Viscosity is one of the basic properties defined as resistance to flow in liquids, viscosity.

The molecules of high viscosity liquids are tightly bonded to each other and therefore their fluidity is low. Therefore, these liquids are dense and thick. Examples of high viscosity liquids include caramel, honey, and mayonnaise. These liquids frequently demand more force and flow more slowly.

Low viscosity liquids, unlike high viscosity liquids, are thin, light and quite fluid. This is because the bonds between molecules are weaker. Liquids such as water, acetone and alcohol are examples of low viscosity liquids. These liquids frequently move more swiftly and with less effort.

The differences between high and low viscosity are very important in industrial processes. For example, high viscosity paints create thicker layers, have a longer adherence time to the surface, and are difficult to pump and spray. However, low viscosity paints create thinner layers, spread easily on the surface, and are more easily used in spray systems. As a result, everything from nozzle selection to pump type in the process is adjusted according to viscosity.

2.4. DIN Cup Flow Meter

Cup viscometers are easy-to-use gauges for measurement of the viscosity of liquids. They are used to measure the flow time of a fluid commonly used for paint, varnishes, and oils. This method is used for general viscosity control in the laboratory. However, due to the light weight and ease of use of the cups, measurements can also be made very easily outside the laboratory. The cup is supported in a stand and is filled with the liquid to be measured. And then, the time taken for liquid to drain through an orifice in the bottom of the cup is measured. Viscosity cups are designed to measure viscosity values of Newtonian and near-Newtonian liquids.

Newtonian liquid, liquid in which the viscosity is independent of the shear stress or shear rate. If the ratio of shear stress to shear rate is not constant, the liquid is non-Newtonian.

Near-Newtonian liquid, liquid in which the variation of viscosity with shear rate is small and the effect on viscosity of mechanical disturbances such as stirring is negligible.

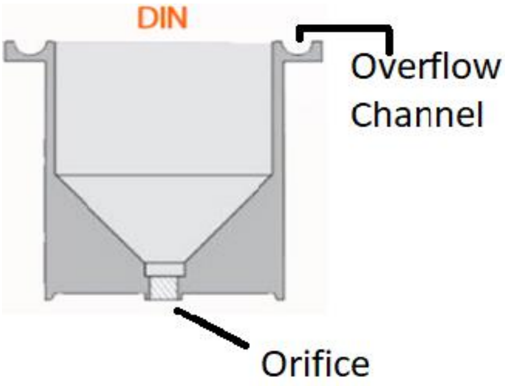


Figure3. DIN Flow Cup

DIN Cup 4 is a measured kinematic viscosity of a fluid. And it is expressed in seconds(s) flow time, which can be converted to Centistokes(cSt). A wide range of cups with different orifices is avaible for measurements between 5cSt and 5100cSt. DIN 4 Viscosity flow cup has 100 ml. Volume and 4 mm. Flow hole diameter and meets the DIN 53211 standard requirements.

2.5. Operating Conditions Which Can Cause Changes In The Physical Properties Of A Fluid

Pressure and temperature changes have significant influences on viscosity. The temperature can be one of the most important parameters that change the rheological properties of a fluid. Rheology is defined as the study of the flow of matter. Intermolecular attraction decrease with increases in temperature so temperature most effective parameter on viscosity.

The reason of increasing the temperature is increasing the average thermal energy of its molecule. The fluids viscosity decreases with an increase of temperature.

Viscosity that given information about the physical condition of the oil is directly linked to temperature, friction and wear. Therefore, the change in viscosity of oil is an important reference in determining oil change intervals. In 2016 study, viscosity analyzes were performed by using Mobil Super 3000 Formula FE 5W30 fully synthetic engine oil in the same brand vehicles (Ford Connect 1.8 TDCI) with different engine ages (130.000-265.000 km range). Initially, samples were taken at 10.000 kilometers from vehicles. Then they have been taken approximately every 1.000 kilometers, the changing in viscosity of the engine oil that determined by operating times depending on the engine ages (Halis, S., 2016)

In another study, malfunctions were predicted by examining the work machines used in Soma ELİ. Oil samples were filtered to appropriate standards and possible malfunctions were determined by checking the limit values of the particle quantity (PQ) obtained. The filtrates were examined using a microscope and the observed particles were compared with the wear atlas. The role of particles in wear was investigated by establishing the wear particle analysis method. Thus, it was determined that the operating life of the engines increased and a better plant performance was achieved. (Cebeci, T., 2022)

And Rawashdeh, Fayyad & Awad's study, testing engine oil specifications and properties and their effects on engine maintenance and performance were investigated. Degree of stability from the properties of oils it is very important. Because excessive mechanical and chemical corrosion of the motor metals may happen if oil or lubricants lose their qualities. The required values for viscosity are ideals that give stable results no matter what. Whatever happens temperature changes in any operating condition where power losses are minimal and fuel consumption is minimal It has been seen to optimize fuel economy. (Rawashdeh, Fayyad & Awad, 2020)

When oil is heated its viscosity is reduced, this reduces its load carrying capacity. Viscosity changes based on load and temperature. When temperature increases, the lubricant becomes thinner and the viscosity becomes lower. Oil becomes more fluid and may not adequately lubricate metal surfaces when it becomes too hot. Wear and tear may result from this. Inversely as the temperature decreases, the lubricant thickens and viscosity increases, making it more difficult to pour or pump. Oil with higher viscosity can cause wear and make it harder to start the engine in cold weather.

In addition, engine oil combines with oxidation products and contaminants inside the engine over time, reducing the performance of the oil and changing its viscosity.

3. Research Question

What Is The Effect Of The Change In Oil Viscosity Measured by DIN Cup 4 With Rising Temperature in the 23-93^{o}C Range On The Service Life Of Engine Oils?

4. Methodology

4.1. Hypothesis

The viscosity of the oils decreases as the temperature increases, at different rates in used and non-used engine oils. As engine oils are used, they heat up and reach higher temperatures and therefore lower viscosity values. This shortens the effective lubrication time of the oil and may adversely affect engine performance. The aim of this hypothesis is investigate how temperature changes affect the viscosity of engine oil and how time of oil spending affects this change.

4.2. Variables

4.2.1. Dependent Variables

Viscosity of engine oil: DIN Cup 4 measuring values are given in seconds (s), and kinematic viscosity values calculated from DIN Cup 4 measurement results in centistokes (cSt).

4.2.2. Independent Variables

Measured temperatures: different temperature levels were used to measure viscosity changes of oils.

Usage status of engine oils: non-used and used (used for 15,000 km) engine oils were compared.

4.2.3. Controlled Variables

Control Variable	Method of Control	Why controlled
Engine oil type	Used Shell Helix Ultra 5W-30 synthetic engine oil	To ensure consistency in viscosity measurements
Viscosity Measurement Method	Used DIN Cup 4 viscometer	To make the measurement method standardize
Experimental Environment	Conducted in a standard environment	To eliminate external factors affecting the results
Equipment Used	Same equipment used for all measurements	To minimize variability from multiple instruments

Table1. Controlled Variables and Methods

4.3. Materials and Methods

This essay focuses on the investigation of viscosity changes in two different engine oils (used & non-used) according to temperature changes. How was the effect of used and non-used engine oils viscosity changes via temperature changes? Two different engine oils were used. Both of them were synthetic Shell Helix Ultra 5W-30 engine oils. The first sample was new, and the second sample was 15,000 km used.

Two different engine oils have been compared at different temperatures. Five measurement values were obtained at different temperatures (40^{o}C, 50^{o}C, 60^{o}C, 70^{o}C, 80^{o}C, 90^{o}C.)

The method used in this study was the measurement of viscosity via a DIN Cup 4 viscometer for used and non-used Shell Helix Ultra 5W-30 motor oil at different temperatures.

Used material is given below.

- DIN Cup 4 viscometer (Time deviation 1.14%)
- Beaker
- Stand
- Glass plate
- Metal water jacket
- Shell Helix Ultra 5W-30 (non-used)
- Shell Helix Ultra 5W-30 (15000 km. used)
- Thermometer (-50^{o}C/+300^{o}C)$\pm$0.1^{o}C

Picture 1. DIN Flow Cup 4 Portable DIN 53211

4.4. Safety and Risk Assessment

Risks	Possible Dangers	Taken Precauntions
High temperatures	Risk of burns due to hot engine oil	Precautions have been taken paying attention to hot surfaces.
Contact with chemicals	Engine oil may come into contact with the skin and cause irritation or allergic reactions.	Gloves were used and in case of contact, the affected area was cleaned with soap and water.
Incorrect measurement or margin of error	Obtaining incorrect data as a result of incorrect viscosity measurements.	Accuracy was checked by repeating the measurements more than once.
Oil spillage and slippery floor	Risk of slipping and falling as a result of engine oil spillage.	The work area was kept tidy and spills were cleaned immediately.
Use of incorrect equipment.	Incorrect use of measuring devices resulting in incorrect data or damage to equipment.	The devices were used correctly and calibration checks were performed before each measurement.
Evaporation and air bubbles	Evaporation of the oil due to temperature change or incorrect measurement due to air bubbles.	The sample was carefully prepared before the measurement to prevent the formation of air bubbles.

Table 2. Risks, Possible Dangers and Precautions Taken

4.4.1. Ethical Assesment

The ethical principles observed in this study were evaluated as accuracy and objectivity, scientific and academic honesty, source use and citation rules, environmental ethics, safety and human health and transparency.

Accuracy and objectivity: The data used in the study were collected accurately and analyzed impartially.

Scientific and academic honesty: Data from other studies were not used, only the data obtained as a result of the experiment was reported and analyzed.

Source use and citation rules: All sources and literature studies used in the study are cited correctly.

Environmental ethics: Chemical substances such as engine oil were disposed of using appropriate methods that would not harm the environment.

Safety and human health: Necessary precautions were taken and safety rules were followed when working with chemicals during the experiment process.

Transparency: The methods and data used are clearly stated.

4.4.2. Envorinmental Assessment

If used engine oil is released directly into nature, it may cause water and soil pollution. Used engine oil was delivered to waste oil collection centers and recycled. Excessive water use in cooling and cleaning processes can lead to depletion of water resources. In this study, only the required amount of water was used to avoid wastage. Since evaporation of engine oil at high temperatures will negatively affect air quality, the experiments were carried out in a well-ventilated laboratory environment.

4.5. Procedure

1. First, the cup was placed on the stand, and the glass plate was used to adjust the cup so that it was in a flat position.
2. The cup temperature and sample temperature were stabilized by adjusting them to the same level. 3.
3. Sample temperature was checked before filling.
4. The cup hole was covered with a finger to close the orifice.
5. The engine oil was slowly poured into the cup, avoiding the formation of air bubbles.
6. The test environmental temperature was stabilized by using a double-walled metal jacket.
7. To prevent excess sample, the glass plate was slid over the edge of the cup and care was taken to avoid air bubbles forming between the glass plate and the oil during this process.
8. The glass plate was removed.
9. The finger covering the orifice was removed and the stopwatch was started.
10. The sample flow through the orifice is monitored and the time measurement is stopped when the sample flow is not flowing evenly.
11. Both engine oils were heated to 23 to 93^{o}C and measured viscosity via DIN Cup 4.
12. At the end of the measurement, the data was recorded.

5. Data

5.1. Qualitative Data

In this study, the viscosity change of used and non-used fully synthetic motor oils at different temperatures was examined. The DIN cup 4 viscometer was used in the measurements. Non-used Shell Helix Ultra 5W-30 engine oil was observed to be light amber in colour, clear, and clean. However, Shell Helix Ultra 5W-30 engine oil, which was used for 15 000 km, appeared darkened and opaque. The reason why used oil looks cloudy is the combustion residues and dirt accumulated in it. At the same time, the reason why the oil used appears to be a colour close to black is that it contains carbon and metal particles.

5.2. Quantitative Data

The results obtained from the experiments are given in the tables below.

Temperature (°C)±0.1°C	Non-used Fully Synthetic Motor Oil Viscosity (DIN 4 Seconds)±0.01
23.6	32.84
23.6	32.95
23.6	33.24
23.6	32.80
23.6	31.70
23.6	33.27
43.0	23.71
43.0	20.98
43.0	19.38
49.5	17.19
49.5	16.39
49.5	16.91
68.0	15.57
68.0	15.64
68.0	14.84
80.0	15.40
80.0	14.41
80.0	14.50
89.5	14.24
89.5	13.63
89.5	13.50
92.2	14.81
92.2	14.09
92.2	13.49

Table 3. Non-used fully synthetic motor oil viscosity

Temperature (°C) ± 0.1°C	Used Fully Synthetic Motor Oil Viscosity (DIN 4 Seconds) ± 0.01
23.6	32.04
23.6	32.01
23.6	31.47
23.6	31.94
23.6	32.69
23.6	32.34
45.1	16.74
45.1	16.80
45.1	15.96
57.5	15.87
57.5	15.51
57.5	15.59
69.2	14.31
69.2	13.79
69.2	14.09
77.9	13.71
77.9	13.86
77.9	13.45
87.2	14.02
87.2	13.54
87.2	13.27
92.2	13.57
92.2	13.22
92.2	13.54

Table 4. Used fully synthetic motor oil viscosity

5.3. Data Analysis

The measured DIN Seconds can be converted to kinematic viscosity value (cST, mm/s^2) by two different methods.

The second method is using formula according DIN 53211;

Where: v= Kinematic Viscosity, Centistokes (cSt) (mm^2/s)

t= efflux time in Seconds

$v=4.57t-452/t$ (DIN 4mm)

Units: Kinematic Viscosity : 1 cSt=10^{-2} St= 10^{-6} m^2/s= $1mm^2/s$

Dynamic Viscosity : 1 mPa.s=10-3 Pa.s=1 cP=10-2 P

Dynamic Viscosity= Kinematic Viscosity x Density (at the same temperature)

First method is using conversion chart;

For example;

t= 32,84s

Kinematic Viscosity=v=4.57(32,84)-452/32,84

v=136.32cSt

Viscosity Cup Type

Time (seconds)	DIN	BS					ISO				FORD / ASTM				ZAHN					SHELL					
	4	2	3	4	5	6	3	4	5	6	1	2	3	4	1	2	3	4	5	1	2	3	4	5	6
15	38	6.4		19	40	234			35	66			19	40		4	88	148	322			20	48	91	235
16	45	6.8	3	24	48	262			39	75			22	44		7	99	163	345			21	52	98	251
17	51	7.3	5	28	56	290			43	84			24	48		11	111	178	368			23	55	104	267
18	57	7.7	7	32	64	317			47	93			26	52		14	123	192	391	1.1	7.5	24	59	111	284
19	63	8.1	9	35	72	343			51	101		1	29	56		18	135	207	414	1.4	8.1	26	62	117	300
20	69	8.6	11	39	79	369			55	110		3	31	60		21	146	222	437	1.6	8.6	27	66	124	316
21	74	9.0	13	43	86	395			58	118		4	33	64		25	158	237	460	1.8	9.2	29	69	130	332
22	80	9.4	15	47	93	420			62	126		6	36	67		28	170	252	483	2.0	9.8	30	72	137	348
23	85	9.8	17	50	100	445	1		66	134		7	38	71		32	181	266	506	2.3	10.4	32	76	143	365
24	91	10.3	18	54	107	470	2		70	142		9	40	75		35	193	281	529	2.5	10.9	33	79	150	381
25	96	10.7	20	57	114	494	3		73	150		10	43	79		39	205	296	552	2.7	11.5	35	83	156	397
26	101	11.1	22	60	120	519	4		77	157		12	45	83		42	216	311	575	2.9	12.1	36	86	163	413
27	107	11.5	23	64	127	543	4.5		80	165		13	47	87		46	228	326	598	3.2	12.7	38	90	169	429
28	112	12.0	25	67	133	567	5		84	173		14	49	91		49	240	340	621	3.4	13.2	39	93	176	446
29	117	12.4	26	70	140	591	6		88	180		16	52	94		53	252	355	644	3.6	13.8	41	97	182	462
30	122	12.8	28	73	146	614	6.6		91	188		17	54	98	1	56	263	370	667	3.8	14.4	42	100	189	478
31	127	13.3	30	77	153	638	7.3		95	196		19	56	102	2	60	275	385	690	4.1	15.0	44	104	195	494
32	132	13.7	31	80	159	662	7.9		98	203		20	59	106	3	63	287	400	713	4.3	15.6	45	107	202	510
33	137	14.1	33	83	165	685	8.6		102	210		22	61	110	4	67	298	414	736	4.5	16.1	47	110	208	527
34	142	14.5	34	86	171	709	9.2		105	218		23	63	114	6	70	310	429	759	4.7	16.7	48	114	215	543
35	147	15.0	35	89	177	732	9.8		109	225		24	66	117	7	74	322	444	782	5.0	17.3	50	117	221	559
36	152	15.4	37	92	184	755	10.4		112	233		26	68	121	8	77	333	459	805	5.2	17.9	51	121	228	575
37	157	15.8	38	96	190	778	11.0		115	240		27	70	125	9	81	345	474	828	5.4	18.4	53	124	234	591
38	162	16.3	40	99	196	801	11.6		119	247	1.5	29	73	129	10	84	357	488	851	5.6	19.0	54	128	241	608
39	167	16.7	41	102	202	825	12.1		122	254	2.0	30	75	133	11	88	369	503	874	5.9	19.6	56	131	247	624
40	172	17.1	43	105	208	848	12.7		126	262	2.5	32	77	137	12	91	380	518	897	6.1	20.2	57	135	254	640
41	176	17.5	44	108	214	871	13.3		129	269	3.0	33	80	141	13	95	392	533	920	6.3	20.7	59	138	260	656
42	181	18.0	45	111	220	893	13.8		133	276	3.5	35	82	144	14	98	404	548	943	6.6	21.3	60	141	267	672
43	186	18.4	47	114	226	916	14.4		136	283	4.0	36	84	148	15	102	415	562	966	6.8	21.9	62	145	273	689
44	191	18.8	48	117	232	939	14.9		139	291	4.5	37	86	152	17	105	427	577	989	7.0	22.5	63	148	280	705
45	196	19.2	50	120	238	962	15.5		143	298	5.0	39	89	156	18	109	439	592	1012	7.2	23.0	65	152	286	721
46	200	19.7	51	123	244	985	16.0		146	305	5.5	40	91	160	19	112	450	607	1035	7.5	23.6	66	155	293	737
47	205	20.1	52	126	250	1008	16.6		149	312	6.0	42	93	164	20	116	462	622	1058	7.7	24.2	68	159	299	753
48	210	20.5	54	129	255	1030	17.1		153	319	6.5	43	96	168	21	119	474	636	1081	7.9	24.8	69	162	306	770
49	215	21.0	55	132	261	1053	17.6		156	326	7.0	45	98	171	22	123	486	651	1104	8.1	25.3	71	166	312	786
50	219	21.4	56	135	267	1076	18.2		160	334	7.5	46	100	175	23	126	497	666	1127	8.4	25.9	72	169	319	802
51	224	21.8	58	138	273	1099	18.7		163	341	8.0	48	103	179	24	130	509	681	1150	8.6	26.5	74	173	325	818
52	229	22.2	59	141	279	1121	19.2		166	348	8.3	49	105	183	25	133	521	696	1173	8.8	27.1	76	176	332	834
53	234	22.7	60	144	285	1144	19.7		170	355	8.8	50	107	187	26	137	532	710	1196	9.0	27.6	77	179	338	851
54	238	23.1	62	147	291	1166	20.2		173	362	9.0	52	110	191	28	140	544	725	1219	9.3	28.2	79	183	345	867
55	243	23.5	63	150	297	1189	20.7		176	369	9.8	53	112	194	29	144	556	740	1242	9.5	28.8	80	186	351	883
56	248	24.0	64	153	302	1212	21.2		180	376	10.3	55	114	198	30	147	567	755	1265	9.7	29.4	82	190	358	899
57	253	24.4	66	156	308	1234	21.7		183	383	10.8	56	116	202	31	151	579	770	1288	9.9	30.0	83	193	364	915
58	257	24.8	67	159	314	1257	22.2		186	390	11.3	58	119	206	32	154	591	784	1311	10.2	30.5	85	197	371	932
59	262	25.2	68	162	320	1279	22.7		190	397	11.8	59	121	210	33	158	603	799	1334	10.4	31.1	86	200	377	948
60	267	25.7	70	165	326	1302	23.2		193	405	12.3	60	123	214	34	161	614	814	1357	10.6	31.7	88	204	384	964
65	290	27.8	76	179	354	1414	26		210	440	15	68	135	233	40	179	673	888	1472	11.8	34.6	95	221	416	1045
70	313	29.9	83	194	383	1526	28		226	475	17	75	147	252	45	196	731	962	1587	12.9	37.4	103	238	449	1126
75	337	32.1	89	208	412	1638	31	3	243	510	20	82	158	271	51	214	790	1036	1702	14.0	40.3	110	255	481	1207
80	360	34.2	96	223	441	1750	33	16	260	545	22	89	170	291	56	231	848	1110	1817	15.1	43.2	118	273	514	1288
85	383	36.4	102	237	469	1861	35	28	276	580	25	96	181	310	61.6	249	907	1184	1932	16.3	46.1	125	290	546	1369
90	406	38.5	108	252	498	1973	38	40	293	615	27	104	193	329	67	266	965	1258	2047	17.4	49.0	133	307	579	1450
100	452	42.8	121	280	554	2195	42	62	326	684	32	118	216	368	78	301	1082	1406	2277	19.7	54.7	148	342	644	1612
110	499	47.0	134	309	611	2418	47	83	359	754	37	132	239	406	89	336	1199	1554	2507	21.9	60.5	163	376	709	1774
120	545	51.3	146	338	668	2640	51	102	392	823	42	147	262	445	100	371	1316	1702	2737	24.2	66.2	178	411	774	1936
130	591	55.6	159	366	724	2862	56	120	425	893	47	161	285	483	111	406	1433	1850	2967	26.4	72.0	193	445	839	2098
140	637	59.9	171	395	781	3084	61	138	458	962	51	176	308	522	122	441	1550	1998	3197	28.7	77.8	208	480	904	2260
150	682	64.2	184	424	837	3305	65	156	491	1031	56	190	331	560	133	476	1667	2146	3427	31.0	83.5	223	514	969	2422

All measurements are in Centistokes (cSt). Centipoise (cP) = cSt x product density

Reference: https://www.elcometer.com/pub/media/contentmanager/content/viscosity_cups.pdf

Table 5. Viscosity conversion table

In our expermient, kinematic viscosity values given in the tables were calculated using the formula, and the data in terms of cSt for both samples are given in the tables below.

Temperature (°C) ± 0.1°C	Non-used Fully Synthetic Motor Oil Viscosity (DIN 4 Seconds)± 0.01	Non-used Fully Synthetic Motor Oil Viscosity (cSt) ± 0.1
23.6	32.84	136.3
23.6	32.95	136.9
23.6	33.24	138.3
23.6	32.80	136.1
23.6	31.70	130.6
23.6	33.27	138.5
43.0	23.71	89.3
43.0	20.98	74.3
43.0	19.38	65.2
49.5	17.19	52.3
49.5	16.39	47.3
49.5	16.91	50.5
68.0	15.57	42.1
68.0	15.64	42.6
68.0	14.84	37.4
80.0	15.40	41.0
80.0	14.41	34.5
80.0	14.50	35.1
89.5	14.24	33.3
89.5	13.63	29.1
89.5	13.50	28.2
92.2	14.81	37.2
92.2	14.09	32.3
92.2	13.49	28.1

Table 6. Viscosity values in cSt for the non-used fully synthesis motor oil

Temperature (°C) $\pm$0.1°C	Used Fully Synthetic Motor Oil Viscosity (DIN 4 Seconds) $\pm$0.01	Used Fully Synthetic Motor Oil Viscosity (cSt) $\pm$0.1
23.6	32.04	132.3
23.6	32.01	132.2
23.6	31.47	129.5
23.6	31.94	131.8
23.6	32.69	135.6
23.6	32.34	133.8
45.1	16.74	49.5
45.1	16.80	49.9
45.1	15.96	44.6
57.5	15.87	44.0
57.5	15.51	41.7
57.5	15.59	42.3
69.2	14.31	33.8
69.2	13.79	30.2
69.2	14.09	32.3
77.9	13.71	29.7
77.9	13.86	30.7
77.9	13.45	27.9
87.2	14.02	31.8
87.2	13.54	28.5
87.2	13.27	26.6
92.2	13.57	28.7
92.2	13.22	26.2
92.2	13.54	28.5

Table 7. Viscosity values in cSt for the used fully synthesis motor oil

When the obtained data were plotted according to temperature and the kinematic viscosity was formulated according to the trend line with the help of excel, the following formulas were obtained for the oils.

Standard deviation=σ=$\sqrt{\frac{\sum(x^{i}-\mu)^2}{N-1}}$

- x^i = Individual measured values
- μ = Average of measurements
- N= Number of measurements

For example;

Temperature (°C) ±0.1°C	Non-used Fully Synthetic Motor Oil Viscosity (DIN 4 Seconds)±0.01	Non-used Fully Synthetic Motor (cSt) ±0.01
23.6	32.84	136.3
23.6	32.95	136.9
23.6	33.24	138.3
23.6	32.80	136.1
23.6	31.70	130.6
23.6	33.27	138.5

Table 8. Viscosity values in cSt for the non-used fully synthesis motor oil at 23.6°C

$\mu=\frac{32.84+32.95+33.24+32.8+31.7+33.27}{6}$

μ=32.8

$(x^{32.84}-\mu)$ =$(32.84-32.8)^2$=0.0016

$(x^{32.95}-\mu)$ =$(32.95-32.8)^2$=0.0225

$(x^{33.24}-\mu)$ =$(33.24-32.8)^2$=0.1936

$(x^{32.8}t-\mu)$ =$(32.8-32.8)^2$=0

$(x^{31.7}-\mu)$ =$(31.7-32.8)^2$=1.21

$(x^{33.27}-\mu)$ =$(33.27-32.8)^2$=0.2209

σ=$\sqrt{\frac{\sum(x^{i}-\mu)^2}{N-1}}$

σ=$\sqrt{\frac{\sum(0.016+0.0225+0.1936+0+1.21+0.2209)}{6-1}}$

σ=$\sqrt{0.3297}$

σ=0.574

The tolerance of the DIN Cup 4 viscometer=±0.01 s

Thermometer error= ±0.1°C

Human observation/time measurement error=±0.1 s

Systematic uncertainty=u_B

$u_B=\sqrt{0.01^2 + 0.1^2}$

u_B=0.101s

Uncertainty of the mean= $U_A=\frac{\sigma}{\sqrt{N}}$

$U_A=\frac{0.574}{\sqrt{6}}$=0.23s

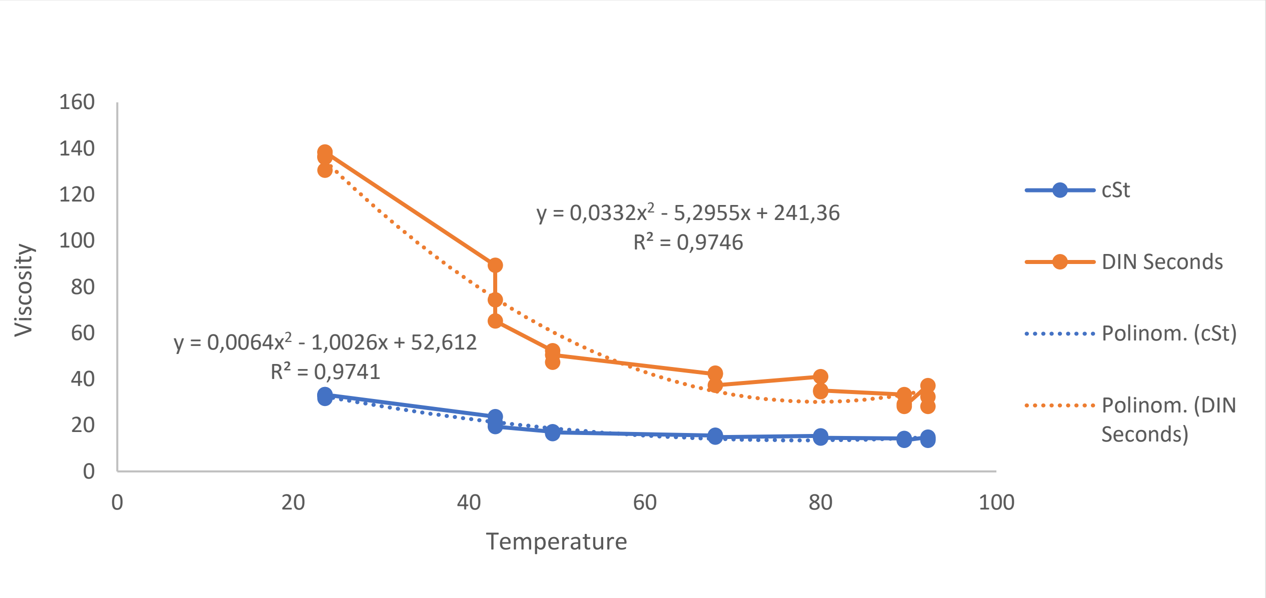
Total uncertainty calculation=$U=\sqrt{U_A{}^2 + U_B{}^2}$

$U=\sqrt{(0.23)^2 + (0.101)^2}$

$U=\sqrt{0.0631}$

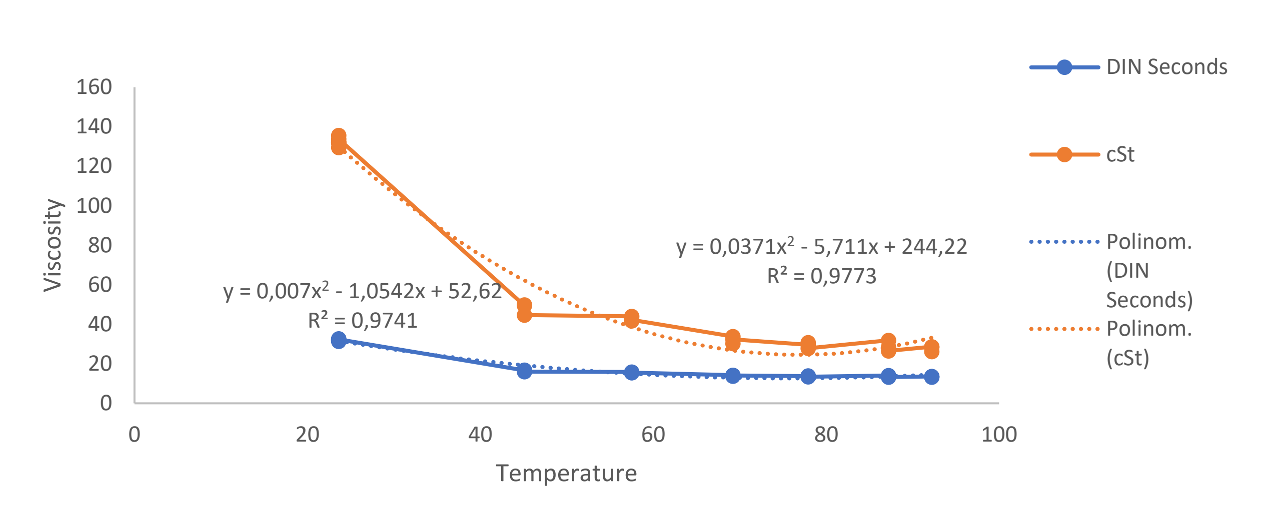
U=0.25s

Total uncertainty indicates that the measured viscosity time has a margin of error of ±0.25 seconds.



Graph 1. Non-used fully synthesis motor oil viscosity (DIN Cup4)

In Graph 1, trend lines are shown, which are created with the data obtained in seconds from the measurements made using DIN cup 4 of unused fully synthetic engine oil and by making conversion calculations in centistokes. It is seen that the equations of the resulting trend lines have a second-degree polynomial function. It is observed that the values of R^2 = 0.9746 and R^2 = 0.9741 are quite high, that is, the model explains approximately 97.46% and 97.41% of the change in the dependent variable, viscosity.

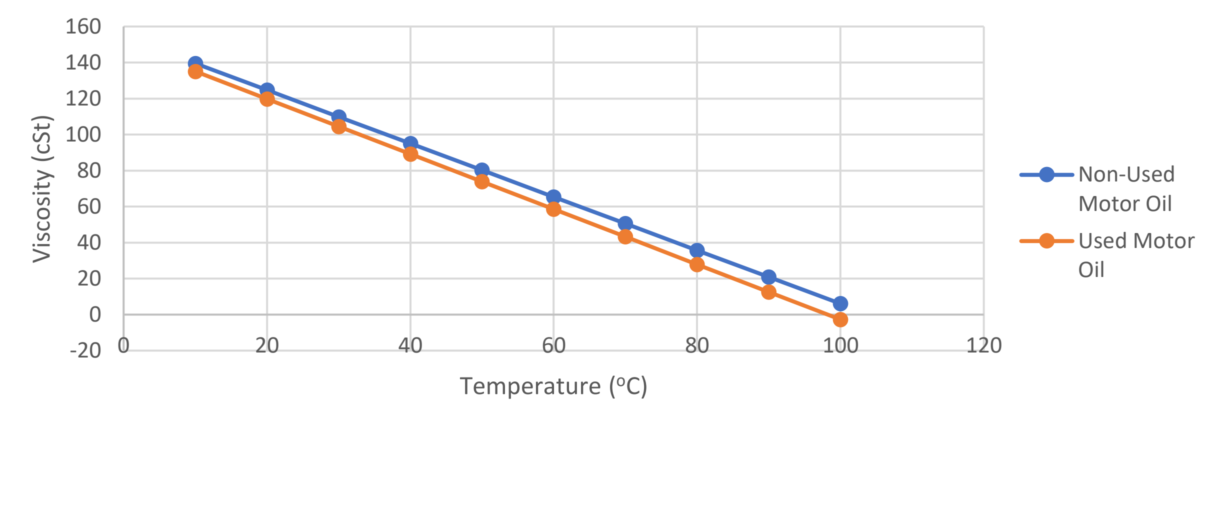


Graph 2. Used fully synthesis motor oil viscosity for 15000km (DIN Cup 4)

Similarly, when Graph 2 is evaluated, it is seen that the trend lines created with the data obtained in seconds from the measurements made using DIN cup 4 of unused synthetic engine oil for 15000 km and by making cycle calculations in centistokes and the equations of the resulting trend lines also have a second-degree polynomial function. It was observed that the values of $R^2 = 0.9773$ and $R^2 = 0.9741$ were again quite high, explaining approximately 97.73% and 97.41% of the change in viscosity, which is the model dependent variable.

Temperature (°C) ± 0.1°C	Non-used Fully Synthetic Motor Oil Viscosity (cSt) ± 0.01	Used Fully Synthetic Motor Oil Viscosity (cSt) ± 0.01
	y = -1.4826x + 154.35	y = -1.5311x + 150.41
10	139.524	135.099
20	124.698	119.788
30	109.872	104.477
40	95.046	89.166
50	80.220	73.855
60	65.394	58.544
70	50.568	43.233
80	35.742	27.922
90	20.916	12.611
100	6.09	-2.7

Table 9. The viscosity values of cSt type are in the range of 10-90°C.



Graph 3. Viscosity changes of samples in cSt range between 10-90°C

Finally, it was observed how viscosity changes occur in the temperature range of 10-90°C. From this graph, it is seen that the viscosity of sample engine oils decreases linearly as the temperature increases.

6. Conclusion

According to ASTM D445 standard information, suitable viscosity values for unused fully synthetic engine oils are specified as 66.34cSt at 40°C and 11.77cSt at 100°C. When the data obtained in the study are examined, it is seen that the temperature values between 23.6°C and 92.2°C are between the suitable viscosity values. Thus, it was observed that the measurements were consistent and out of range at 100°C. It was also observed that the increase in temperature causes the viscosity of the engine oil to decrease, which directly affects the performance and service life of the oil. The data has shown that both new and used full synthetic motor oils experience a consistent decrease in viscosity with increasing temperature. It was also observed that this decrease was slightly higher in used oils. This observation indicates that long-term use of engine oil causes deterioration and makes it more susceptible to temperature-related viscosity loss.

Examples of increases or decreases in viscosity include oxidation, polymerization, carbon buildup (soot), contaminants, antifreeze, water ingress, and/or the addition of the wrong type of oil. A decrease in the viscosity of engine oil as temperature increases indicates that the level of oxidation in the oil is increasing and it is time to change the oil. Decreases in viscosity can indicate fuel dilution, thermal cracking, extended oil drain periods, and again, the addition of the wrong type of oil.

These results are supported by the science of lubrication and fluid dynamics. The oil's ability to preserve a protective layer between components of the engine is reduced as viscosity decreases, increasing friction and possibly causing damage. Additionally, the data complies with industry standards, which advise routine oil changes to guarantee the longevity and best engine performance. The results aid in improving lubrication techniques, which in turn optimise maintenance plans and boost engine performance.

This study aims to understand how the viscosity of engine oils responds to temperature changes. Compared to previous studies, the change in the viscosity of engine oils depending on temperature and the effect of the usage condition were examined, while others generally focused on the viscosity changes of oils, the effect of additives and the comparison of different types of oils. At the same time, temperature (°C) and the usage condition of the engine oil (used vs. new) were studied, while in others, factors such as temperature, pressure, oxidation time and additives were generally examined. Looking at the studies in terms of dependent variables, in this study the viscosity of the engine oil (DIN Cup 4 and kinematic viscosity - cSt) was examined, while in most studies additional parameters such as thermal stability, oxidation resistance and lubricity performance of the oil were examined in addition to viscosity measurement. Another difference is the viscosity measurement method. In this study, DIN Cup 4 was used, and in other studies, Brookfield viscometer and Anton Paar dynamic rotational viscometers were commonly used. The result is consistent with previous scientific research in understanding how engine oils respond to temperature changes. This study's distinctive feature is its direct comparison of new and used oils, which is crucial for figuring out when to change engine oil.

7. Evaluation

A standard measurement method such as the DIN Cup 4 viscometer used in the study was preferred. This ensured that the experimental data was consistent and reliable. Comparing the viscosity changes of both new and 15,000 km used engine oils is a powerful method to evaluate the effect of usage time. A measurement range of 23°C to 93°C is adequate to comprehend how engine oil behaves in relation to temperature. Providing both directly measured times and viscosity values calculated with formulas enabled the results to be analyzed in more detail. The work advances lubrication science in academic research as well as oil selection in the motor vehicle sector by showing how engine oils respond to temperature variations. The study analyses when engine oils should be changed from a more scientific standpoint, which could aid in optimising vehicle maintenance plans. Temperature changes might be directly calculated due to trend lines and viscosity change formulas made with Excel. In the future, this might open the door for the creation of prediction models for various kinds of oil.

In this study, only Shell Helix Ultra 5W-30 engine oil was used as engine oil, and it may be useful to test oils of different brands and viscosity classes for a more comprehensive analysis. Likewise, only DINCup 4 was used as the measurement method, and analysis using different types of viscometers can increase the reliability of the results. The data was obtained in a laboratory environment and does not include interactions such as actual pressure inside the engine, fuel vapor mixture, oxidation and contamination. The results need to be verified by testing in real engine conditions. By examining the reasons why the engine oil used in the study has deteriorated (oxidation, contamination, loss of additives, etc.) and the changes in the oil content through detailed chemical analysis (such as FTIR spectroscopy), the results can be made stronger. Comparing oils used in various engine types, such as petrol and diesel engine oil, could yield a more thorough analysis.

In this study, he successfully analyzed how engine oil viscosity changes with temperature. However, testing different engine oils, testing in a wider temperature range, using alternative viscosity measurement methods, testing in real engine environments and adding various chemical analyzes may lead to the method being improved and becoming a more comprehensive guide for industrial applications.

The fact that the calculated standard deviation value (0.574) is greater than the uncertainty value (0.25) indicates that there may be high random and systematic errors in the measurements. Thus, it should be evaluated whether there are weaknesses in the methodology and whether the controlled variables are kept sufficiently constant. Verifications can be carried out with more measurements and different measurement devices to reduce uncertainty.

Effects such as high temperature fluctuations in the real engine environment, degradation of additives and contact of oil with combustion by-products were not taken into account, and at the same time, verification was not made with various methods (Brookfield or Anton Paar viscometer) and was limited to the laboratory environment and the DIN Cup 4 measurement method.

Using different measurement techniques, measuring with changes in the working environment, testing different engine oils such as synthetic, semi-synthetic and mineral oils, examining the chemical content of the oil with various test methods, and measuring viscosity at different mileage intervals by changing the usage rate of the oil will expand the scope of this study.

All things considered, the study contributes to our understanding of how temperature changes impact engine oil viscosity.

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