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THE SPECIFIC HEAT CAPACITIES AND RATE OF COOLING OF SOME GRADES OF ENGINE OIL SAMPLES

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Abstract: This study examined specific heat capacities and rates of cooling of different SAE20W-50 multi-viscosity engine oil samples (Amasco oil, A-Z oil, Express oil, Oando oil, Jezco oil, Total Classic and Total Quartz) using method of mixture and Newton's law of cooling, respectively. Results showed that, Oando oil had the highest value of the cooling rate, K followed by A-Z and Total Classic oils while other oil samples had closely related values of K. This implied that Oando, A-Z and Total Classic oils have the best cooling abilities. Also, A-Z oil had the highest value of specific heat capacity while Oando oil had the lowest value indicating that A-Z oil is the best absorber of heat. From the analysis of specific heat capacities and rates of cooling of the samples, it is suggested that A-Z, Oando and Total Classic oil will enhance the performance of the engine by reducing wearing and tearing and prevent hard starting.

Keywords: Specific heat capacity, cooling rate, SAE20W-50, engine oil

Introduction

It is experimentally observed that when two or more substance of different chemical, atomic and structural composition are heated with the same amount of heat energy, for a specific period, there is a significant difference in the rise in temperature of the heated samples. In addition, if the samples are allowed to cool, their rates of cooling will differ. Therefore, different materials have different heat capacities. When the heat capacities of different samples are compared, the word 'specific Heat capacity'' is used. Nelkcon and Packer (1987), defined specific Heat capacity (SHC) as that amount of heat energy required to raise the temperature of a unite mass of that substance by one Kelvin (1K). Thermodynamic concept such as heat capacity, SHC, rate of cooling of materials and thermal conductivity are extremely important when designing internal combustion engines and machinery. It is important to know how heat will be distributed throughout the engine system, since poor heat management can lead to decreased in its efficiency. Therefore, specific heat capacity and rate of cooling of the materials used in constructing an engine system entails the amount of heat energy the system can withstand at higher temperatures and how fast it will be lost or converted into other forms of energy, when the system stops working.

Engine oils are used to cool internal combustion engine (ICE) and overcome the effect of friction. They are derived from Petroleum-synthesized compounds. Engine oils are derived from crude oil or petroleum by the process of fractional distillation (George *et al.*, 2010; Evans *et al*., 2013; Ugochukwu *et al*., 2016). They are denser petroleum products which are used as lubricants in engines and machineries. Lubrication is needed for correct operation of mechanical systems: pistons, pumps, cams, bearings turbines (Okeola, 2011). Without lubrication the pressure between the surfaces in close proximity would generate enough heat for rapid surface damage which in coarse condition may literally weld the surfaces together, causing seizure. Besides lubrication, engine oils also serve as coolant (they carry heat away from the moving parts of the engine); they also clean and inhibits corrosion and improve sealing of parts of an engine. The cooling in an engine system also depends on the SHC of the fluid (lubricants) and its viscosity.

Cooling is the process of loosing heat by a hot body to its surrounding or another body of lower temperature. According to the law of heat exchange when a hot body is mixed or in contact with a cold body in an isolated container, the hot body loose heat while the cool body gain heat. Cooling leads to fall in temperature. The rate at which liquid cools depends on their masses, temperature, ambient air and surface area of liquid exposed. Substances with high specific heat capacities do not lose their internal energy completely even at freeze point.

Collins (2007) suggested that the properties of engine oil vary according to their individual needs of the engines. Good engine oils are characterized by their high viscous property. The viscosity must be high enough to maintain a lubricating film between the moving parts and steady enough to enhance the flow of oil round the engine parts. The viscosity of motor oil is graded in terms of the SAE (Society of Automotive Engineers) index number. For example, SAE 10 motor oil is less viscous than SAE 30 motor oil. Viscosity depends on temperature of the engine while in operation. At a very low temperature SAE 30 motor oil will be too thick to be used as a lubricant, while at a very high temperature, SAE10 will be too light to be used as a lubricant (George *et al.*, 2010). It is therefore recommended to use SAE multi-grade engine oils such as SAE 20W-50 (Woydt, 2007). Multi-grade oils such as SAE10W 40 has the property of a 10 weight oil when cold and 40 weight oil when hot.

Nigeria has large petroleum deposits with production capacity of about 2.3 million barrels per day. As a result, many oil companies have found Nigeria as a fertile ground for engine oil manufacturing. Trade names of some engine oils multi viscosity companies in the country includes: Total, Oando, Amasco, Jezco, A-Z, Ambro, mobil, Tomimas, etc. It is then important to determine the heat capacities and cooling rates of engine oils sold in the market. This also aids in comparing and contrasting which of the selected oils have higher or low specific heat capacity and cooling rate. By so doing, this will give technical advice to the manufacturers to improve on the qualities of their products and recommend to the oil users, the sample that is most suitable for use.

Materials and Methods

Seven different samples of SAE 20W-50 engine oil were collected from different standard engine oil dealers in Jalingo, the Taraba State capital North Eastern Nigeria. The samples (Amasco oil, A-Z oil, Express oil, Oando oil, Jezco oil, Total Classic and Total Quartz) taken to the laboratory for the determination of their specific heat capacities and cooling rates. The apparatus used for the experiment are: Copper calorimeter, mass balance, thermometer, Bunsen burner, stirrer, tripod stand, stop watch, solid block of copper material, thread and lagging material were used for the experiments.

Determination of specific heat capacity of the samples

The specific heat capacities of the samples of SAE20-50 samples were determined using the method of mixtures. A copper block was weighed and its mass recorded as m_1 and placed by means of a thread tied to it into a beaker of water and heated until the water began to evaporate. A dried copper calorimeter and it accessories were weighed and recorded as m_2. It was then filled halfway with oil sample, weighed and recorded as m_3. The initial temperature of the oil sample was read and recorded as θ_1. The heated solid copper block, whose temperature was recorded as θ_2 is then quickly transferred to the calorimeter and its content and the mixture was stirred gently and continuously for even distribution of temperature until a steady temperature θ_3 was reached. The experiment was repeated for other samples and in each case m_1, m_2, m_3, θ_1, θ_2 and θ_3 were recorded with necessary precautions taken to minimize experimental errors. The specific heat capacity of the various oil samples were then evaluated from the law of heat exchange which states that:

Heat lost by copper block = Heat gained by engine oil and the calorimeter.

$$m_1C_2(\theta_2 - \theta_3) = m_2C_2(\theta_3 - \theta_1) + (m_3 - m_2)C_3(\theta_3 - \theta_1) \quad (1)$$

$$C_3 = \frac{m_1C_2(\theta_2-\theta_3) - m_2C_2(\theta_3-\theta_1)}{(m_3-m_2)(\theta_3-\theta_1)} \quad (2)$$

Where: C_1 = C_2= specific heat capacity of copper and C_3 = specific heat capacity of oil.

Cooling rate of oil samples

For cooling rates, the samples were heated to a temperature of about 80°C and then allowed to cool. The falling temperature of the oil was recorded after every two minutes interval as it drops until it eventually reached 50°C. The same procedure was repeated for other oil samples. In addition, three selected oil samples were heated up to a temperature of about 250°C, and the falling temperature was taken after an interval of five minutes for a period of one hour. Theoretically, the time rate of decrease of temperature is proportional to the difference in initial temperature before cooling and the surrounding. That is

$$\frac{d\theta}{dt} \propto (\theta - \theta_R) \quad (3)$$

$$\frac{d\theta}{dt} = -K(\theta - \theta_R) \quad (4)$$

Where: K is a positive constant known as cooling constant, the negative sign indicates that the temperature is decreasing. Using method of separation of variables and integrating we obtained:

$$\theta = \theta_o e^{-Kt} \quad (5)$$

Where: $\theta_o = \theta - \theta_R$. θ_R is the ambient temperature and θ is the falling temperature. A graph of temperature θ, against time t, gives an exponential decay curve with gradient, which is equivalent to the rate of cooling K, and is a determining factor of the time it takes a multi-grade oil to adjust between their high and lower temperature ranges (George *et al*., 2010). This is based on Newton's law of cooling.

Results and Discussion

The specific heat capacities of the different samples are presented in Table 1 and Fig.1. The values were obtained by substituting the values of m_1, m_2, m_3, C_1, C_2, θ_3, θ_3 and θ_3 into equation 2. The results showed that A-Z oil has the highest specific heat capacity followed by Total Classic and Amasco oils while Oando oil has the least value. Oils with high specific heat capacity are preferred because it can absorb a large amount of heat energy from the engine but its temperature does not rise too much (Ugochukwu *et al*., 2016).

Table 1: Specific heat capacities of oil samples

SAE20W-50 Sample	Specific heat capacity ($Jkg^{-1}K^{-1}$)	Rate of cooling (°C/min)
Amasco Oil	2096.60	1.26
A-Z Oil	2344.30	1.40
Express Star Oil	1391.90	1.21
Oando Oil	1156.80	1.59
Jezco Oil	1566.67	1.25
Total Classic Oil	2125.00	1.34
Total Quartz Oil	1958.80	1.24

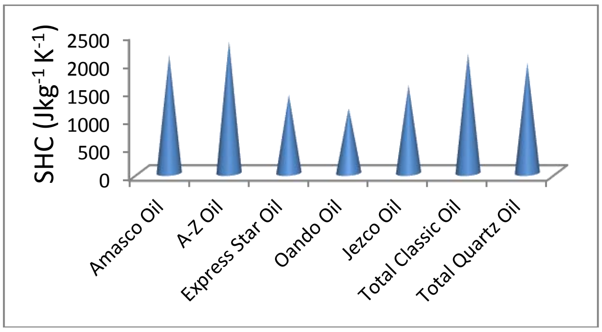

Fig. 1: Comparison of specific heat capacities of the coded samples

The implication here is that the A-Z oil having the highest SHC will contain more heat than other samples at the same temperature. This high heat content will cause a greater percentage of the internal energy to be retained, enabling the engine to start faster, since heat lost by engine is usually stored as internal energy in the lubricating systems.

The rate of cooling of the different oil samples are presented in Table 2 and their respective cooling curves in Fig. 2. The value of K, which is the rate of cooling for the various oil Samples, is obtained from the slope of the cooling curves (Fig. 2). The cooling rate here is considered among lower engine that generates heat in the temperature range $30 \geq \theta < 100^oC$. The lower temperature being the ambient environmental temperature and the upper temperature stands for the maximum temperature when the engine is heated up (George *et al*., 2010). The intercept on each graph indicates the maximum temperature before the sample starts cooling.

In this study Oando oil has the highest value of K (1.59 °C/min) followed by A-Z oil (1.40 °C/min) and Total Classic oil (1.34 °C/min) (Table 1). Other samples had closely related values that ranged from 1.21-1.26 °C/min. According to Schlosberg *et al*. (2001), substances with high cooling rates are good coolants and lubricants. This implied that Oando oil is most appropriate coolant followed by A-Z oil.

It is important to note that the product of Total (Total Classic and Total Quartz) had different specific heat capacity and cooling rates. This is purely due to the manufacturers preferences. Specifically, Total classic is mono-grade engine oil with SAE 40 index number and is suitable for use at higher ambient temperature (100°C). This implied that it might not be suitable for marine engines, which is in agreement with the findings of Evans *et al*. (2013). It must be noted that different lubricating oils are used in various engines because the fuels used differ chemically from one another and hence resulting products of combustion differ (Okeola, 2011).

Table 2: Variation of temperature fall with time

Time (Min)	Falling Temperature of Coded Oil Sample (^0C)						
	Amasco	**A-Z oil**	**Express Star**	**Oando**	**Jezco**	**Total Classic**	**Total Quartz**
0	80	80	80	80	80	80	80
2	75	75	75	74	70	76	76
4	72	71	72	70	72	72	72
6	68	67	69	66	69	68	69
8	64	64	67	63	65	65	66
10	62	61	64	59	62	63	63
12	59	58	61	57	60	60	60
14	57	55	58	55	57	58	57
16	55	52	57	53	56	56	56
18	53	51	55	50	54	54	54
20	51	50	53	-	52	51	53
22	50	50	52	-	50	50	51
24	50	-	50	-	-	-	50

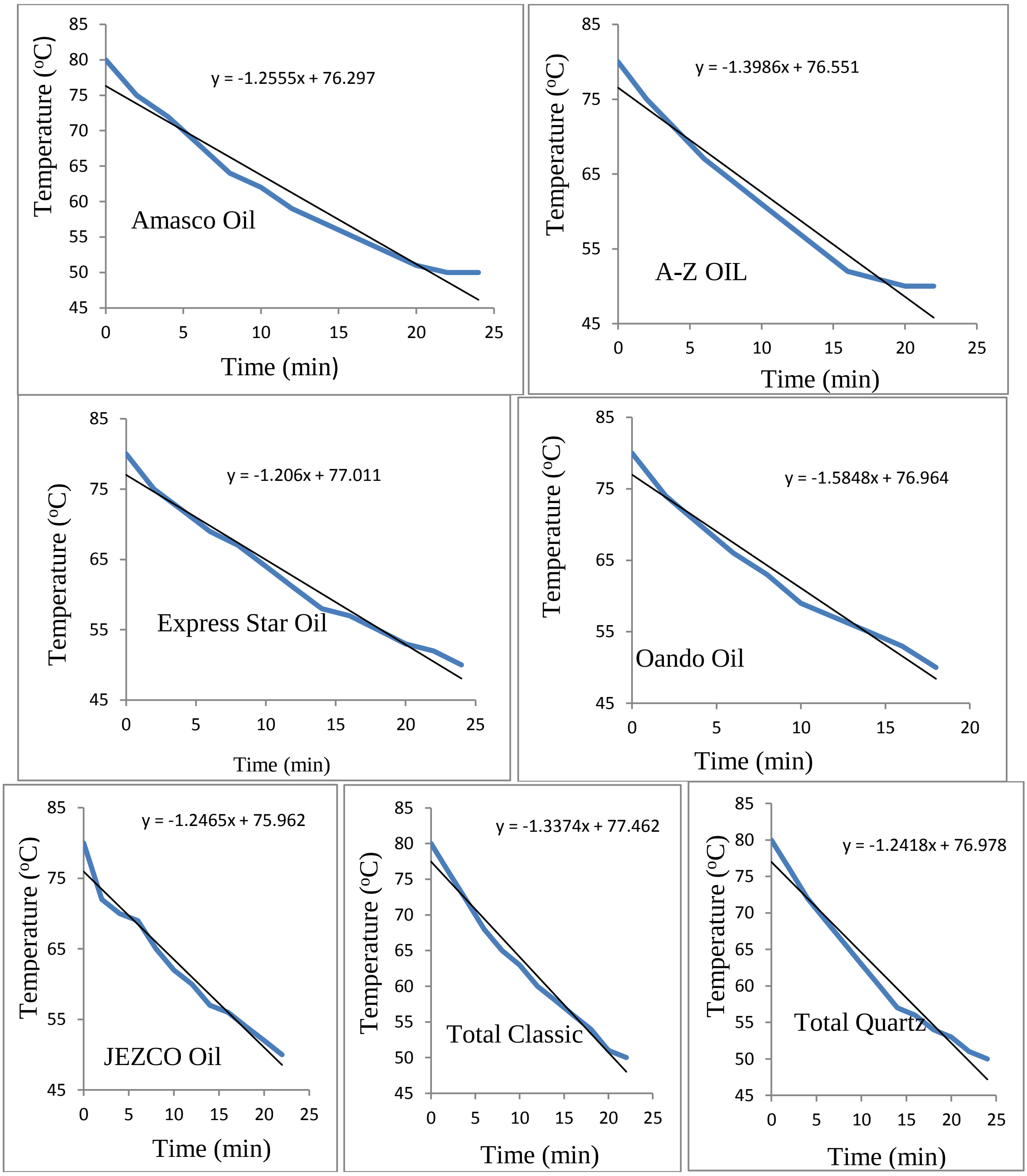

Fig 2: The rate of fall of temperature for the different oil samples

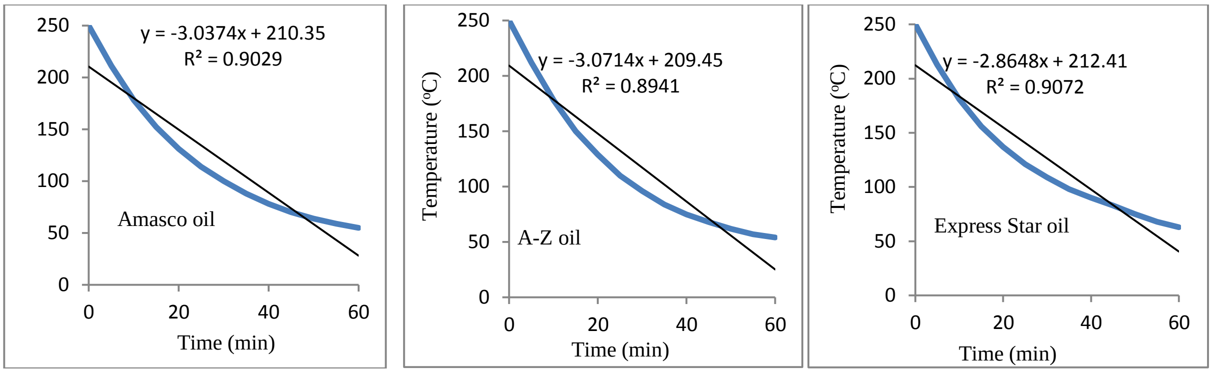

Fig 3: The rate of fall of temperature for the different oil samples heated to 250ºC

The rate of cooling of three selected samples heated to 250ºC is presented in Table 3 and the corresponding cooling curves in Fig. 3. It appears increase in temperature increases the cooling rate of lubricating oils. It is observed that Amasco oil increased from (1.26 - 3.04) ºC/min, A-Z from (1.40 - 3.07) ºC/min and Express Star from (1.21 - 2.87) ºC/min.

Table 3: Variation of temperature fall with time for selected samples heated to 250ºC

Time (Min)	Falling Temperature of Oil Samples (ºC)		
	Amasco	**A-Z oil**	**Express Star**
0	250	250	250
5	211	212	213
10	178	178	181
15	152	150	156
20	131	129	137
25	114	110	121
30	100	96	109
35	88	84	98
40	78	75	90
45	70	68	83
50	64	62	75
55	59	57	68
60	55	54	63

Conclusion

Lubricants are used for the purpose of reducing friction, heat, wear and tear between mechanical parts in contact with each other. The performance of lubricating oils depends on cooling rate, specific heat capacities and viscosity. Engine oils with higher specific heat capacities and cooling rates readily becomes less viscous and lubricates better. These properties minimize wearing, tearing, difficulty in starting and increases longevity of the engine. The result obtained revealed that A-Z oil has the highest SHC followed by Total classic and Amasco. In terms of the rate of cooling, Oando had the highest rate of cooling followed by A-Z and total classic. This implied that A-Z, Oando and Total classic oils are the most appropriate to maintain the life of an engine, since oils with higher specific heat capacities and cooling rates are most suitable for engines. Specific heat capacity and cooling rate are good parameters for the selection of appropriate engine oil that can enhance the lifespan of engines.

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