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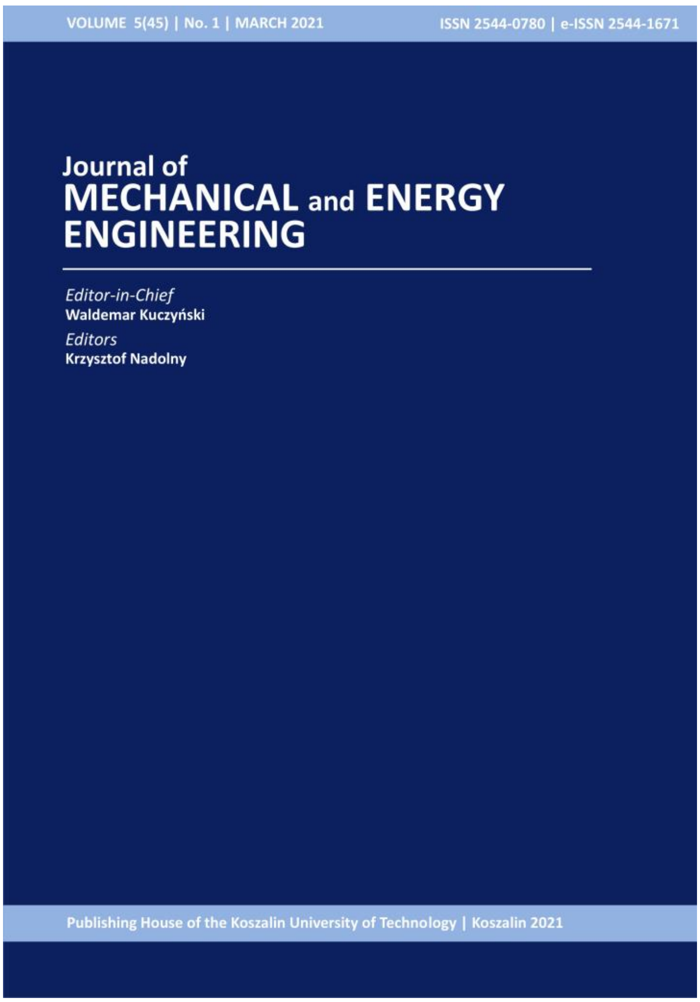

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EXPERIMENT TO DETERMINE THE SPECIFIC HEAT OF OILS

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Abstract: Cutting fluids are used during metal cutting process to minimize the heat that is developed between tool, work piece and the chip. A good cutting fluid should absorb maximum heat from the machining zone. Heat absorption capacity of any cutting fluid used is measured by specific heat. Higher the specific heat better will the heat absorption capacity. This paper discusses a simple experimental procedure that is used to measure the specific heat of Neem oil, Honge (Karanja), Sunflower oil and Petroleum based oil (Hydro 68). This experiment is a function of temperature with respect to time. The rise in temperature with respect to time will determine the heat absorption capacity of fluids or oils or liquids. This method is validated by measuring the Specific heat of distilled water, the standard specific heat value of distilled water is 4.4 J/g/°C and measured value from the experiment is 4.5 J/g/°C. The results obtained are similar to the results observed by using other methods like TGA and DSC instruments. From the experiment the Specific Heat of Neem measured is 4.1032 J/g/°C which is high compared to Honge oil with the value of 2.3630 J/g/°C and Sunflower oil with 2.4311 J/g/°C, but less compared to hydro68 with value measured as 7.4850 J/g/°C.

Keywords: specific heat, neem, honge, sunflower, hydro 68

1. INTRODUCTION

In Industries, the cutting fluids are used in machining operations to minimize the heat that is developed between tool, work piece and the chip, so heat absorption capacity is measured by Specific Heat. Specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. There are different methods to determine Specific Heat oils or liquids. In the present work, an experiment is conducted to determine specific heat of Bio-Oils; Neem oil, Honge oil and sunflower oil by means of function of temperature with respect to time. To validate the experiment, specific heat of water is determined and compared the result with the specific heat of water as it having well-known value. Many researchers have used different methods for measuring specific heat of oils.

O. O Fasina and Z. Colley [1] has determined specific heat of 12 vegetable oils (sunflower is one of them) experimentally as a function of temperature (35°C to 180°C) using DSC (Model Q 100, TA Instruments, New Castle, DE) and concluded that the change in temperature affects the viscosity and specific heat of vegetable oils. The specific heat increases linearly with increase in temperature (35-180°C) by 17%. A.O. Kuye [2] has determined specific heat of neem seeds using inverse method and concluded that inverse heat conduction problem is reliable method to determine thermophysical properties of solids. Leonard franklin long [3] has conducted experiment to study the specific heats and fats of oils using thermometer and heating coil to measure the increase in temperature with time and concluded that the results obtained for specific heat were fairly accurate to the third decimal place. Vinay Atgur [4] has worked on thermal conductivity and specific heat with the help of TGA and DSC Instruments. The specific heat was determined in the range of 35°C to 120°C for sunflower oil and it varied from 2.244 to 2.491 KJ/Kg K. J.C.O. Santos [5] proposed a method to determine thermal properties of edible oils using DSC and Micro Oven [MO] for specific heat capacities and it was observed that the specific heat of each edible oils increases with saturation of fatty acids. Shaik Moulali [6] considered two non-edible oils i.e. pongamia Honge Oil Methyle Ester (HOME) and Rubber seed oil Methyle Ester

(ROME) to determine thermal conductivity, Specific heat and thermal degradation as a function of temperature using Guarded Plate, DSC and Thermo Gravitic Analyzer (TGA) respectively. The result of specific heat varies for HOME from 2.345 to 2.64 kJ/Kg. A.Dauda [7] has investigated specific heat capacity of Neem nut kernels and moisture content on the physical properties. Copper calorimeter placed inside the flask by the method of mixture to determine specific heat and concluded that Specific heat increases with increase in moisture content and temperature in the range of 5.82 to 49.7% and 303-341.4 k respectively and lies between 1547-6102.8 J/kg.

This paper discusses simple method of measuring specific heat of oils considered.

2. MATERIALS AND METHODS

In this experiment, the small quantity of water is heated by supplying known power input to raise the temperature of water. The rise in temperature over period of time is noted down and difference in temperature and time are substituted in the formula to measure specific heat of water. The heat transfer to or from the surroundings will lead to experimental error. The error is minimized by taking measurements on equal amount of time before and after the ambient temperature is reached.

2.1. Elements used for Experiment

1. Digital postal scale.

The digital postal scale is used to measure the quantity of fluid which is used to conduct the experiment. It is as shown in The Figure 1.

Fig. 1. Digital postal scale

2. Glass beaker.

The required amount of fluid is collected in the beaker that will hold at least 250 ml or gram. So a glass beaker is used to have transparency effect. The glass beaker used is as shown in Figure 2.

Fig. 2. Glass Beaker

3. Variable DC Power Supply

A digital variable power supply is used to raise the temperature of fluid keeping constant voltage and current supply. In this experiment, aplabs variable power supply of capacity 0-16 V DC voltage and 0-2 A current is used. The apparatus is as shown in Figure 3.

Fig. 3. Variable DC Power Supply

4. Digital thermometer with probe

To measure the raise in temperature for every two minutes, a digital thermometer with probe is used so that accurate temperatures can be noted down. The Figure 4 shows digital thermometer used.

Fig. 4. Digital Thermometer with probe

5. The 10 ohm or 7.5 ohm, 5W resistor (or something close)

Resistors are connected to Digital Variable Power Supply using wires and the resistor of 10 ohm is immersed in fluid. The resistor will increase the temperature of the fluid. The resistor of 10 ohm with 5Watt is as shown in Figure 5.

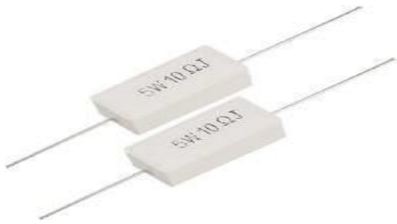

Fig. 5. Resistor with 10 ohms 5 watt

6. Short length of wire

The short length wires with probes are used to connect resistors to the Variable power supply. The wires are as shown in Figure 6.

Fig. 6. Short length wires

7. Digital Stop Watch

A digital clock is used to observe the time in seconds which is as shown in Figure 7. For every 120 seconds, the rise in temperature from before ambient temperature to after ambient temperature is noted to calculate difference in temperature and time.

Fig. 7. Digital Stop Watch

2.2. Experimental set up

The experimental set up is simple and requires less time. The detailed set up of experiment is explained as below.

1. Some quantity of cold water (distilled water)/oil is prepared to reduce temperature by refrigerating water/oil for an hour or so. Because the experiment data should include temperature on either side of the ambient temperature.
2. The glass beaker is kept on digital scale and zero the scale.
3. The 250 g. of the cold water or cold oil is poured into the beaker using digital scale and the mass M of water or oil that actually added is recorded.
4. A short length of the insulation from the wire is striped to connect the resistor in series with the variable power supply by twisting the bare wires around the resistor leads.
5. The resistor is dipped into the cold water beaker so that the resistor is submerged.
6. The ambient temperature T_a is recorded and then the temperature probe is dipped into the water or oil as well.

The schematic representation and experimental set up are as shown in Figure 8, 9 and 10 respectively. Once the setup is ready, the experiment is carried out for distilled water for validation of the procedure. The result obtained is validated with standard value of specific heat of water. Then for each oil experiment is conducted and obtained results are validated with the results observed from the literature. The detailed procedure is explained next section.

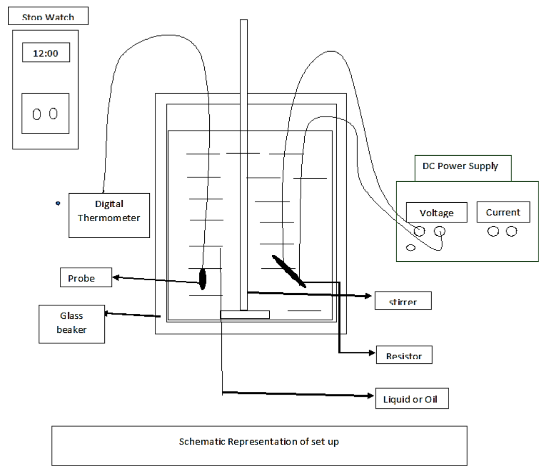

Fig. 8. Schematic representation of experimental set up

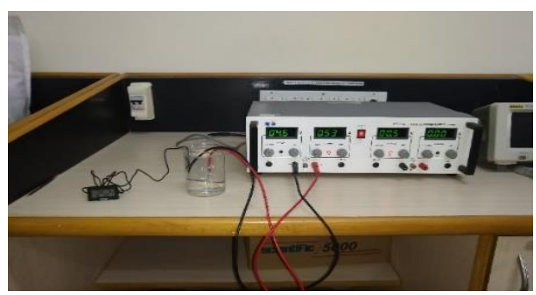

Fig. 9. Experimental setup with distilled water

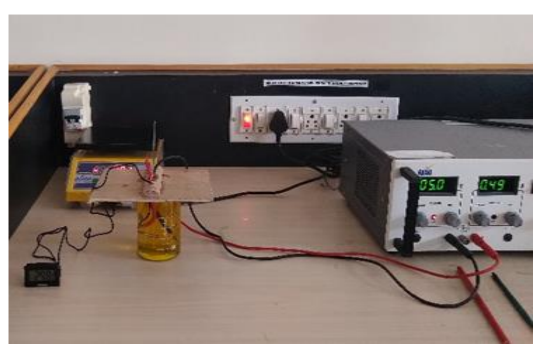

Fig. 10. Experimental set up with Oil

3. EXPERIMENTAL PROCEDURE

The detailed procedure to determine specific heat of oils is as follows.

1. The power supply is turned on and the voltage is adjusted to around 10 volts (or the value of the resistor that is being used). The voltage V and the current I are recorded.
2. Then the water temperature is recorded (oil temperature) for every 2 minutes until the temperature is about 5°C above the ambient temperature. This set up based on ohm's law, which states that voltage, current and resistor are related by formula $V=I\times R$ (where V is in Volts, I is in amps and R is in ohms). Here V and I are measured and $R=V/I$ calculated and this value is compared with the known value of the resistor used and both the value should be nearly same.
3. The data i.e. mass M, ambient temperature Ta, voltage V and current I is recorded and also the temperature variation for every 2 minutes from t=0 to temperature above 5°C from ambient temperature. The error due to heat transfer to or from the surroundings, is minimized by considering the data from 12 minutes before till 12 minutes after this ambient temperature T_a or closure to that T_a.

4. RESULTS AND DISCUSSIONS

The results are obtained by using the formula:

$$\frac{c=V\times I\times(t_2-t_1)/M}{(T_2-T_{1})}, \quad (1)$$

where: c – specific heat, V- voltage in Volts, I- current in A, M - mass of the oil in grams, (t_2-t_1) - total time in s, (T_2-T_1) - change in Temperature in °C.

The error due to the heat transfer to or from the surroundings is minimized by taking measurements on equal amount of time before the ambient temperature $T1$ and after the ambient temperature T_2 is reached. The time t_1 is recorded for temperature T_1 and t_2 is recorded for temperature T_2. Difference of (T_2-T_1) is ΔT and difference of (t_2-t_1) is Δt.

4.1. Calculation:

Total time is calculated by:

$$t=(t_2-t_1),\ s. \quad (2)$$

Temperature change is calculated by:

$$T=(T_2-T_1),\ ℃. \quad (3)$$

Electrical power in Watts is equal to $V\times I$. Also, 1 watt is equivalent to 1 J/s (joules per second), therefore:

$$Power, P=V\times I,\ \frac{J}{s}. \quad (4)$$

$$Energy\ E=P\times(t_2-t_1)=V\times I(t_2-t_1),\ J \quad (5)$$

$$c=\frac{E}{M}/(t_2-t_{1)},\ \frac{J}{g}/℃. \quad (6)$$

$$c=V\times I\times\frac{(t_2-t_1)/M}{(T_2-T_1)}=V\times I\times\frac{\Delta t}{M}/\Delta T. \quad (7)$$

Because:

$$E=Mc\Delta. \quad (8)$$

So, by substituting the measured values gives specific heat of water or oils or liquids.

4.2. Results

The temperature increases with increase in time as power supply rises the temperature of fluids. Increase in temperature with respect to time during the conduction of experiment are tabulated in Table 1. The temperatures T_1 and T_2 Before and after ambient temperature respectively are represented in bold numbers.

Tab. 1. Rise in temperature with respect to time

OIL	NEEM	HONGE	SUNFLO-WER	PETRO-LEUM OIL
Time t, sec	Temperature T, °C	Temperature T, °C	Temperature T, °C	Temperature T, °C
0	22.9	19.0	22.3	23.7
120	23.1	22.2	23.0	23.8
240	23.2	22.0	23.6	23.8
360	23.4	25.0	24.6	23.9
480	23.4	27.0	24.9	24.3
600	23.5	28.0	25.2	25.1
720	23.7	30.0	25.9	25.3
840	24.0	31.0	26.3	26.5
960	24.3	32.0	26.8	27.2
1080	24.6	34.0	27.3	27.9
1200	24.8	34.0	27.8	29.4
1320	25.6	36.0	28.5	30.5
1440	26.6	36.0	28.7	31.0
1560	27.1	38.0	29.1	31.8
1680	27.6	39.0	29.4	32.6
1800	27.9	40.0	28.8	-
1920	28.3	-	-	-
2040	28.9	-	-	-

The specific heat is determined by substituting values in the Formula 1 and results are tabulated in Table 2. As this set up is based on ohm's law, even though the values of voltage, current and power supply are different for each experiment, they satisfies formula $R=V/I$ i.e. the value of Resistor R used for experiment is equal to calculated Value of R.

The observations and calculations of the experiment are explained in detail and mentioned in the Table 2.

The Figure 11 shows the results of specific heat of neem, honge, sunflower and petroleum-based oils. From the measured values it is be observed that neem oil is having better specific heat compared to honge oil and sunflower oil but less than petroleum based oil. The petroleum oil is mixed with water to form soluble oil, so there may be reduction in the value of specific heat measured in the present experiment.

Tab. 2. Determination of Specific Heat of the oils

	Distilled water	Neem oil	Honge (Karanja) oil	Sunflower oil	Petroleum oil
Ambient temperature T, °C	24.0	23.9	27.0	26.9	26.6
Mass M, g			250		
Voltage, V	4.6	5.4	8.0	5.0	10.0
Current I, A	0.53	0.53	1.00	0.49	1.04
Power Supply, W	8.6	8.6	8.6	10.0	10.0
Observations: Time, s	$t_1 = 3960$ $t_2 = 5400$	$t_1 = 120$ $t_2 = 1560$	$t_1 = 0$ $t_2 = 960$	$t_1 = 120$ $t_2 = 1560$	$t_1 = 120$ $t_2 = 1560$
Observations: Temperature, °C	$T_1 = 22.1$ $T_2 = 25.2$	$T_1 = 23.2$ $T_2 = 26.6$	$T_1 = 19.0$ $T_2 = 32.0$	$T_1 = 23.8$ $T_2 = 31.8$	$T_1 = 23.8$ $T_2 = 31.8$
Calculations	$\Delta t = (t_2\text{-}t_1)$ = 5400-3960 = 1440 s $\Delta T = (T_2\text{-}T_1)$ = 25,2-22,1 = 3,1°C Specific Heat, $c = E/M/\Delta T$ $= V \times I \times \Delta t/M/\Delta T$ = 4.6×0.53×1440/ 250/3.1	$\Delta t = (t_2\text{-}t_1)$ = 1560-120 = 1440 s $\Delta T = (T_2\text{-}T_1)$ = 27.1-23.1 = 4.0°C Specific Heat, $c = E/M/\Delta T$ $= V \times I \times \Delta t/M/\Delta T$ = 5.4×0.53×1440/ 250/4.0	$\Delta t = (t_2\text{-}t_1)$ = 1560-120 = 1440 s $\Delta T = (T_2\text{-}T_1)$ = 27.1-23.1 = 4.0°C Specific Heat, $c = E/M/\Delta T$ $= V \times I \times \Delta t/M/\Delta T$ = 8×1×960/250/13	$\Delta t = (t_2\text{-}t_1)$ = 1560-120 = 1440 s $\Delta T = (T_2\text{-}T_1)$ = 31.8-23.8 = 8.0°C Specific Heat, $c = E/M/\Delta T$ $= V \times I \times \Delta t/M/\Delta T$ = 10×1.04×1440/ 250.1/8	$\Delta t = (t_2\text{-}t_1)$ = 1560-120 = 1440 s $\Delta T = (T_2\text{-}T_1)$ = 31.8-23.8 = 8.0°C Specific Heat, $c = E/M/\Delta T$ $= V \times I \times \Delta t/M/\Delta T$ = 10×1.04×1440/ 250.1/8
Results	c = 4.500 J/g/°C	c = 4.1032 J/g/°C	c = 2.3630 J/g/°C	c = 2.4311 J/g/°C	c = 7.4850 J/g/°C

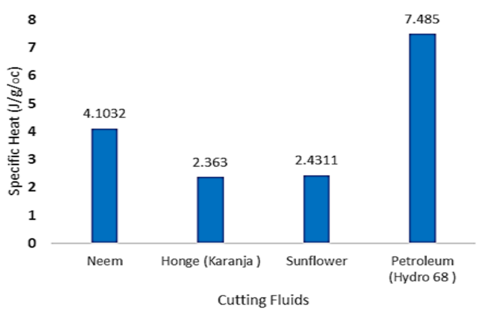

Fig. 11. Specific heat of oils measured with variation of temperature with time

4.3. Discussions

The specific heat is measured to determine heat absorption capacity of Cutting fluids. High specific heat indicates better cooling properties of cutting fluid. It is determined by different methods like using TGA and DSC Instruments. These instruments require huge investment. This experimental method is simple in construction and needs minimum quantity of oil. The other elements like resistor, digital thermometer and variable DC power supply are also available with low cost. So total cost of experimental setup is less. The results obtained using this experiment is same as compared with results obtained for using TGA and DSC instruments (which are considered from literature).

The result of Specific heat obtained for distilled water is 4.5 J/g/°C where as standard value is 4.4 J/g/°C. There is very neglegible difference in the measured value and standard value i.e 0.1 J/g/°C and hence this method is considered to determine Specific heat of other oils or liquids.

The results of neem oil, honge oil, sunflower oil and petroleum oil are compared. It is seen that; neem oil is having better specific heat of 4.1032 J/g/°C than other two oils but less than petroleum oil 7.485 J/g/°C. Even though petroleum oil is having high specific heat, it is hazardous to the environment. But the oils used for experiment are bio-oils and even though the specific heat is less compared to petroleum oil, bio-oils possesses good lubricating property.

5. CONCLUSIONS

1. The experimental procedure used to measure Specific heat of oil is simple and can be set up easily at low cost.
2. The experiment gives fairly good results and this method is validated using distilled water. The errors due to heat transfer from and to surrounding is minimized by considering difference of temperature before and after ambient temperature.
3. From the experiments conducted it is observed that:

- standard specific heat of distilled water is 4.4 J/g/°C and measured value from the experiment is 4.5 J/g/°C,
- the measured Specific Heat of Neem is 4.1032 J/g/°C which is high compared to Honge oil with the value of 2.3630 J/g/°C and Sunflower oil with 2.4311 J/g/°C, but less compared to hydro68 with value as 7.4850 J/g/°C.

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Biographical notes

Viraja Deshpande is a Research Scholar at K.S.School of Engineering and Management. She has worked as assistant professor in AMC Engineering College and has total of 4 years of teaching and research experience. Currently she is working on the area of cutting fluids. She is life member of Institute of Engineers (India).

P. N. Jyothi is presently working as a Professor in Mechanical Engineering Department at K.S.School of Engineering and Management and has total experience of 19 years in the field of Teaching and Research. She has published several papers in various International/ National Journals. She is a life member of Indian Society for Technical Education (ISTE) and Institution of Engineers (India). Her research is on understanding the melt flow behavior of ZA alloys processed through centrifugal casting and evaluating the performance of vegetable oils as cutting fluids during drilling and turning operation of mild steel.