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THE EFFECT OF TEMPERATURE VARIATION AND VARIOUS METAL MATERIALS ON CONDUCTION HEAT TRANSFER RATE

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ABSTRAK

Konduktifitas thermal merupakan nilai kemampuan material dalam menghantarkan panas. Perpindahan panas terjadi karena adanya perbedaan suhu yang terdapat pada suatu benda. Perpindahan panas dapat berlangsung melalui tiga cara yaitu konduksi, radiasi dan konveksi. Tujuan dari penelitian ini untuk mengetahui besar laju perpindahan panas konduksi terhadap 3 material silinder pejal yaitu alumunium, besi, dan kuningan. dengan memvariasi temperatur 50 °C, 55 °C, 60 °C, 65 °C, 70 °C, 75 °C, dan 80 °C. Prinsip kerja pada percobaan kali ini yaitu dengan menyiapkan 3 variasi silinder pejal, kemudian diletakkan pada trainer thermal konduksi dengan mengatur besar temperatur pengujian pada display thermocontrol (T1) secara bertahap dan didapatkan hasil pengujian yang ditunjukkan digital thermometer (T2). Dari hasil pengujian maka telah dapat ditemukan hasil laju perpindahan panas, untuk material logam yang yang paling besar laju perpindahan panas adalah aluminium dengan nilai laju kalor 479,7 Watt pada suhu 80 °C, nilai laju perpindahan panas yang paling besar kedua yaitu aluminium dengan nilai laju kalor 299,7 Watt pada suhu 80°C sedangkan untuk material laju yang paling kecil didapatkan pada material besi dengan nilai 214 Watt pada suhu 80°C. Rata-rata laju perpindahan panas alumunium sebesar 325,5 Watt, untuk rata-rata laju perpindahan panas besi sebesar 147,1 Watt, dan rata-rata laju perpindahan panas kuningan sebesar 218,5 Watt.

Kata kunci: konduktifitas, mesin trainer konduksi, perpindahan panas

ABSTRACT

Thermal conductivity is the value of a material's ability to conduct heat. Heat transfer occurs due to the difference in temperature found in an object. Heat transfer can take place in three ways, namely conduction, radiation and convection. The purpose of this study was to determine the conduction heat transfer rate for 3 solid cylindrical materials, namely aluminum, iron, and brass. by varying the temperature 50 ℃, 55 ℃, 60 ℃, 65 ℃, 70 ℃, 75 ℃ and 80 ℃. The working principle in this experiment is to prepare 3 variations of solid cylinders, then place them on a thermal conduction trainer by adjusting the temperature of the test on the thermocontrol display (T1) in stages and the test results are obtained as shown by a digital thermometer (T2). From the test results, the results of the heat transfer rate have been found, for the metal material that has the greatest heat transfer rate is aluminum with a heat rate value of 479.7 Watt at 80 ℃, the second largest heat transfer rate value is aluminum with a heat transfer rate of heat is 299.7 Watt at 80℃ while for the material the smallest rate is found in iron *material with a value of 214 Watt at 80°C. The average heat transfer rate for aluminum is 325.5 Watt, for an average heat transfer rate for iron is 147.1 Watt, and the average heat transfer rate of brass is 218.5 Watt.*

Keywords: *conductivity, conduction trainer machine, heat transfer*

1. INTRODUCTION

Heat transfer is the transfer of energy that occurs from a material with a high temperature to a material with a low temperature so that in the end it reaches a heat balance in the material [1]. Heat transfer is a scientific term that describes the transfer of energy due to a temperature difference between two materials. Temperature is a measure of the degree of hotness or coldness of an object. The instrument used to measure temperature is called a thermometer. Temperature indicates the degree of heat in objects. Simply put, the higher the temperature of an object, the hotter it is [2]. When two systems with different temperatures are connected, energy transfer occurs between them. The process by which energy transfer takes place is heat transfer. The process of heat transfer will flow from areas with lower temperatures to areas with higher temperatures. This statement is known as the second law of thermodynamics [3].

The transfer of energy that occurs only due to temperature differences is called heat flow or heat transfer, while the energy that is transferred is called heat. Energy transfer occurs from a high-temperature system to a low-temperature system [4]. Heat transfer will occur if there is a temperature difference between the two parts of the object. Heat will move from high temperature to low temperature.Materials always have different characteristics, such as different heat-conducting properties, some are radiation, convection, and conduction, the properties of each material cannot be observed directly by the eye. Therefore an experiment was carried out to observe the character and properties of each material. In industry, some instruments are used to provide quantitative information. The quality of intrust production is influenced by the instrumentation used. Temperature is the most important physical quantity, so a very reliable instrument is needed to measure temperature. Every engineering material can conduct heat.

This ability to conduct heat is called thermal conductivity. Thermal conductivity is the ability of a material to transmit heat from one place to another. Heat transfer can occur in solid materials, one example is metal. For example, iron (Fe), brass (CuZn), aluminum (A1), and stainless. Each of these metals has a different level of conductivity. The rate of heat transfer that occurs in metals when heated has different levels because the conductivity value of each metal is different. The higher the conductivity value of the metal, the higher the heat transfer rate [5][6]. According to previous studies, thermal conductivity is the rate of heat transfer through the thickness of a unit material per unit area per temperature gradient, the highest thermal conductivity value indicates that the material is a conductor, while low thermal conductivity indicates the material is an insulator. In previous studies, the thermal conductivity value of brass was 49% of the reference value. The conductivity value of copper is 346 W/mK, brass is 120 W/mK, iron is 80 W/mK [7][8][9].

Thermal conductivity itself is one of the basic properties of materials, namely the rate of heat transfer through a unit thickness of material per unit area per temperature gradient. Thermal conductivity can also indicate how fast heat flows in a particular material [10]. Heat is a form of energy that can be transferred from one point to another due to a temperature difference. Heat flow occurs from a point with a high temperature to a point with a lower temperature [11]. In heat transfer by conduction, the material from the metal does not move. What happens during heat transfer by conduction is that metal molecules that are placed above a high temperature collide with nearby molecules and give up some of their energy. This occurs continuously propagating along the material so that the temperature of the metal. other parts have changed. The heat conductivity of each material has a different value and in general solid materials are higher than liquids [12]. If the solid is a metal, then the transfer of heat energy is assisted by free electrons moving throughout the metal while receiving and transmitting heat when colliding with metal atoms in the material. The heat transfer process occurs through metal media whose conductivity is measured. Heat-related material characteristics greatly determine the amount of heat generated [13]. Therefore, the different types of materials determine the amount of heat produced.

The thermal conductivity of a material can describe the properties of the material. Materials with high thermal conductivity have great heat conductivity [14]. If the conductivity value of the material is small, then the material is not a good conductor of heat but is a good insulating material. In general, metallic materials have greater thermal conductivity than non-metals. Materials with high thermal conductivity are referred to as conductors (conductors), while materials with low thermal conductivity are referred to as insulators [15]. A material is a good conductor if it has a high thermal conductivity, while a material with low thermal conductivity is a poor charge. Materials with high thermal conductivity are called guides, while materials with low thermal conductivity are called shielding. Thermal conductivity, in general, changes with temperature, but this change is small enough to be neglected in many engineering problems [16]. The k values for various materials are shown in Table 1.

Table 1. Table of thermal conductivity values [15].

Materials	*k* (W/m.K)	Materials	*k* (W/mK)
Metals		**Lain-lain**	
Aluminium	205.0	Brick	0.6
Brass	109.0	Isolated Brick	0.15
Copper	385.0	Concrete	0.8
Lead	34.7	Cork	0.04
Silver	406.0	Glass	0.8
Steel	50.2	Rock	0.04
Mercury	8.3	Styrofoam	0.01
Iron	7.3		
Gas			
Air	0.024		
Argon	0.016		
Helium	0.14		
Hydrogen	0.14		
Oxygen	0.023		

This study aims to find out how the conduction heat transfer rate is by varying the temperature of 50 ℃, 55 ℃, 60 ℃, 65 ℃, 70℃, 75℃, and 80℃.which occurs in 3 types of metal namely aluminum, iron, and brass. Each metal has a different thermal conductivity, so each heated metal has a different heat transfer rate to reach the desired boiling point and the length of time required during the test. on cylindrical specimens made of Iron (Fe), Aluminum (Al), and Brass (Cu-Zn).

2. METHODOLOGY

This study uses an experimental research approach. Namely by testing the conduction heat transfer rate and final temperature on 3 heated specimens with variations in the initial heating temperature of 50 ℃, 55 ℃, 60 ℃, 65 ℃, 70℃, 75℃, and 80℃on cylindrical specimens Iron (Fe), Aluminum (Al) and Brass (Cu-Zn). Measurement of the conduction heat transfer rate using a conduction trainer machine. The heat transfer conduction trainer machine is a media learning tool used to demonstrate the process of heat propagation on an object by conduction [13]. The role of the trainer machine is to distribute heat where the initial temperature can be set (constant) by the trainer. Then at the other end of the object, a thermocontrol is installed to detect the temperature in that part. The following are the components of the trainer machine which are presented in Figure 1, and the electrical testing circuit in Figure 2.

Conduction Trainer Machine Components	
1. Power socket	8. AC relays
2. MCB	9. Display Thermocontrol
3. Fuse	10.Power supplies
4. Voltmeters	11. Glow plugs
5. Ammeter	12. Solid cylinder
6. Connection box	13 Thermocouples

Figure 1. Conduction heat transfer trainer drawing

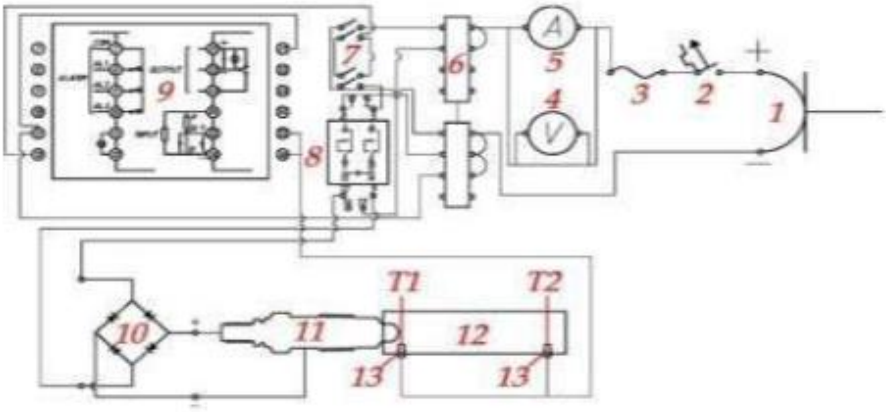

Figure 2. Conduction heat transfer system trainer circuit

The materials used as test specimens consist of aluminum, iron, and brass.

Figure 3. Test specimens

The steps taken in this conduction experiment consist of several steps, namely:

1. Preparatory Steps
   a) Prepare the tools and materials needed in the testing process.
   b) Place the heat transfer trainer in a flat condition.
   c) Install the test material (media) on the stand provided.
   d) Connect the power supply to the power source.
   e) Turn on the MCB and display the thermocontrol switch (T1) in the "ON" position.
   f) Ensuring that the digital thermometer (T2) testing measuring instrument is in a calibrated condition.
2. Work Steps
   a) Prepare the trainer according to the preparation steps.
   b) Set the temperature of the test according to the criteria on the thermocontrol display (T1) in stages. The temperature to be set is from 50°C, 55°C, 60°C, 65°C, 70°C, 75°C, and 80°C.
   c) Turn on the glow plug switch in the “ON” position.
   d) Record the test results, namely, how much the temperature is shown by the digital thermometer (T2).
   e) Repeat the testing phase 3 times. Namely on Brass, Iron, and Aluminum specimens.
3. Final Step
   a) Gradually the glow plug switches, thermocontrol display switches, digital thermometers and MCB are positioned in the “OFF” condition.
   b) Disconnect the electricity at the source of the electric current.
   c) When finished, return the heat transfer trainer, tools, and materials that have been used to their original places.
   d) Clean workplace

The heat conduction equation can be applied to analyze heat transfer by conduction, for example, to determine the heat distribution that occurs in metal materials. The results in the research analyzed were the heat rate (Q) and temperature at the tip of the specimen. Heat propagation that occurs in the cylinder is by conduction, therefore the formula used to calculate the heat that occurs is :

$$Q = - k\ A\ dT/dx \tag{1}$$

Information: Q = Heat transfer (W), k = Thermal conductivity (W/mK) A = Surface area (m^2), dT = Temperature difference (ºK) dx = Surface thickness (m). From the measurements that have been made and the latest data are used to calculate the conduction heat transfer rate.

3. RESULTS AND DISCUSSION

The data that has been obtained in the test thermal conduction trainerMetal materials can be arranged in tabular form. Then based on the results obtained can be used to determine the value of the conduction heat transfer rate (Q) based on Equation 1.

Table 2. Data on conduction test results in solid aluminum cylinders

Solid cylinder	Temperature variation (ºC)	k (W/mºC)	A (m^2)	T_1 (℃)	T_2 (℃)	ΔT(℃)	L (m)	Q (watt)
Alumunium	50	205	0.013	50	36.8	13.2	0,2	175.9
	55			55	38	17		226.5
	60			60	40	20		266.5
	65			65	40.8	24.2		322.5
	70			70	41.5	28.5		379.8
	75			75	42.9	32.1		427.7
	80			80	44	36		479.7
Average heat transfer rate								325.5

Based on the test data shown in Table 2 from the test specimen material, namely aluminum which has a material thermal conductivity value of 205 W/mºC, and final temperature variation data, then the value of the heat transfer rate by conduction can be calculated. From the seven initial temperature variations that have been determined, the average value of conduction heat transfer (Q) is 325.5 Watt.

Table 3. Conduction test result data on solid iron cylinders

Solid cylinder	Temperature variation (ºC)	k (W/mºC)	A (m^2)	T_1 (℃)	T_2 (℃)	ΔT(℃)	L (m)	Q (watt)
Alumunium	50	73	0.013	50	33.6	16.4	0,2	175.9
	55			55	33.7	21.3		226.5
	60			60	33.7	26.3		266.5
	65			65	33.8	31.2		322.5
	70			70	34	36		379.8
	75			75	34.3	40.7		427.7
	80			80	34.9	45.1		479.7
Average heat transfer rate								147.1

Based on the test data shown in Table 3 from the test specimen material, namely iron, which has a material thermal conductivity value of 73 W/mºC and final temperature variation data, an average conduction heat transfer rate value of 147.1 Watt is obtained.

Table 4. Data on conduction test results in solid brass cylinders

Solid cylinder	Temperature variation (ºC)	k (W/mºC)	A (m^2)	T_1 (℃)	T_2 (℃)	ΔT(℃)	L (m)	Q (watt)
Brass	125.4	109	0.013	50	32.3	17.7	0,2	125.4
	192.7			55	32.5	27.2		192.7
	251.5			60	32.8	35.5		251.5
	159.4			65	33.5	22.5		159.4
	223.2			70	34.5	31.5		223.2
	277.7			75	35.8	39.2		277.7
	299.7			80	37.7	42.3		299.7
Average heat transfer rate								218.5

Based on the test data shown in table 5 from the test specimen material, namely iron, which has a material thermal conductivity value of 109 W/mºC and final temperature variation data, an average conduction heat transfer rate value of 218.5 Watt is obtained.

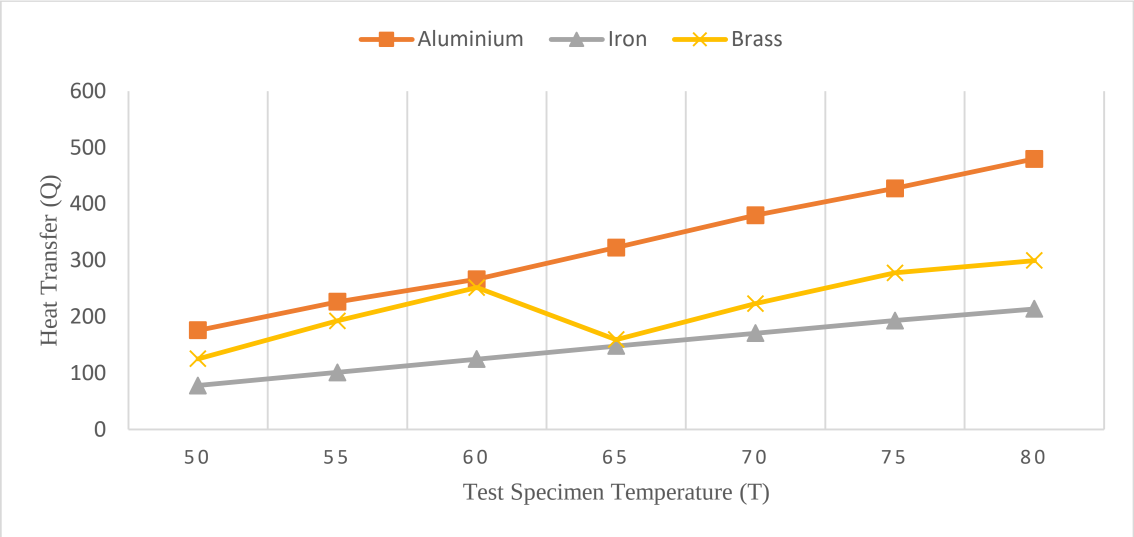

Figure 4. Graph of conduction heat transfer rate comparison data

The results of the conduction heat transfer rates of the three metal materials depicted in Figure 4 show that aluminum and iron experience a significant increase gradually with increasing temperature. Then the yield on the brass specimen has an insignificant increase, whereas, at temperatures above 60 ºC, the heat transfer value tends to decrease compared to the initial temperature. The average calorific value of the three materials is aluminum having a high heating value, followed by aluminum and iron, the thermal conductivity of the materials in these three conductor materials greatly influences the heat produced. The high thermal conductivity of the material indicates that the material can conduct heat well.

If we draw correlations from the figures in the graphs in Tables 2, 3, and 4, in a row the material that has the highest thermal conductivity value is aluminum at 205 W/mºC, then the second is brass at 109 W/mºC, and the last is iron at 73 W/mºC. This is in line with the results shown in Graph 4, which shows that aluminum produces the highest calorific value when compared to brass and iron. A higher thermal conductivity value will improve the heat-fixing performance of the workpiece [17], besides that materials with high thermal conductivity also have good heat resistance. Based on the test results of the three materials above for heat transfer that have been obtained, we can determine which material is more appropriate to use according to individual needs. More in-depth research regarding the phenomenon of heat transfer from several types of materials is presented in the article [18][19][20][21].

4. CONCLUSIONS

The conclusion of the research shows that the heat transfer results obtained by aluminum have the greatest average compared to the heat produced by brass and iron. The heat difference that occurs in each specimen is influenced by several variables such as the thermal conductivity of the material, the final temperature of each material, and also several variables that cannot be controlled such as the effectiveness of the heating element. The average calorific value of aluminum is 325.5 Watt, while brass and iron produce an average heating value of 218.5 Watt and 147.1 Watt respectively. Based on the data that has been obtained, it can be seen that aluminum has good heat conductivity and heat resistance when compared to brass and iron.

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