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Experimental Determination of Thermal Conductivities of Cast Iron and Copper using Linear Heat Conduction Principle

Peter U. Nwachukwu

Department of Mechanical Engineering,
Caritas University Amorji Nike Enugu
Email: ebubedikeugwu@gmail.com

ABSTRACT

This research work deals with the determination of thermal conductivities of aluminum, cast iron and copper using linear heat conduction principle. The experiment was carried out within a distance of holes 15mm for copper and 12mm for aluminum and cast iron drilled on the plastic rod enable the sample material fit in perfectly between the heat region and the cold region. From the analysis, the results show that the thermal conductivity of copper, aluminum and cast iron is 289.023W/m. K,133.983W/make and 55.046W/make respectively. Comparing the results obtained with previous experiment, the thermal conductivity values obtained from the sample fall within the general range for materials.

Keywords: thermal conductivity, linear heat conduction.

INTRODUCTON

From 1807 to 1811, Joseph Fourier (1) conducted experiment and devised mathematical techniques that yielded he first estimate of a material's thermal conductivity. His methodology has influenced all subsequent work. The quantitative study of heat became feasible in the early 18th century when Daniel Fahrenheit (2) invented a mercury thermometer capable of reproducible measurement. even earlier, however at the turn of century, Guillaume Amounts (3) had intuitively surmised that heat flowed in solids in the direction of decreasing temperature and that temperature varied in some predictable manner with distance. amotions (4) himself though the variation was linear in 1761, joseph black introduced the concepts of the latent heat and the spaedifice heat both of which pertain to heat storage rather than heat movement. With the invention of the calorimeter in the 1780s by Antione Lavoisier (7) and Pierre Simon LaPlace the latent heat of the melting ice proved to be standard for qualifying heat. the nature of what had been quantified, though, would elude comprehension throughout the 19th century.

In the 1776 Johann Heinrich lambert (9) took a major step forward in understanding heat movement in solids by considering a long metal rod heated at one end., with heat allowed to radiate to the atmosphere. His motivation in performing that experiment was to correct amotions (10) suggestion to linear temperature profile. the experiment and its interpretation were posthumously published in1779. lambert found that the temperature profile along the rod temperature decreases logarithmically. Lambert (11) exhibited remarkable insight in framing steady-state heat conditions in terms of energy balance when he remarked that the heat flows gradually to the more distant parts, but at the same time travels from each travel from each from part of air so that when the fire has burnt and been maintained long enough at the same strength, every part of the bar finally acquires a definite degree of heat because it constantly acquires as much heat from parts of the fires as it transmits to the more distant parts and the air.

Also insightful was lambert (12) recognition of the importance of geometry in governing temperature profi observed that there is an uncertainty because amotions does not say what is rod looks like lamberts conceptual framework played an important role in later formulation of the heat equation j joseph Fourier (13).

At about the timer of lamberts experiment, Benjamin franklin (14) conceived a scheme toevaluate relative heat - conducting abilities of different metals by coating them with wax, heating them and observing the distance to which wax would melt in different cases. During a visit toFrance in 1780, franklin gave his experimental concept and the materials he had collected toIngenuousjean (1730-99), a Dutch biologist and chemist, whom he encouraged to conduct the experiments at his leisure.

INGEN-House coated a number of wires with wax, all had same length and diameter, but each was of a Different material. The wires were tightened in parallel between blocks of wood. Ingen-House then dipped one end of each wire in hot oil, taking care to dip all the wires at the same time and over the same length. He observed that the wax coat melted along all the wires, but the speed of the melt propagation varied among the materials, he presumed that it varied directly with the speed with which heat ran through the various metals. in all, he conducted twelve experiments using seven metals. Although intent -house observed some variation he found the following order of deceasing house, tin, iron, steel and lead.

The next major contribution was that of count Rumford (born BenjaminThompson1753-1814). The existing principal compilations and reviews were used as a starting point for these compilations. the resulting list of references was updated by searching current literature, abstracting services, and computerized data banks, as well as the reference lists of the most recent publications. The initial emphasis was directed towards temperature below 300k later the scope was extended to include temperature up to near the melting point of each metal. the high temperature compilations were directed towards obtaining the most significant publications rather than a complete listing. since the principal interest is the dependence of thermal conductivities on temperature for

Aluminum, copper and cast iron not all of the literature data for a given base metal is reference here. for example, numerous publications on the measurement on specimens with more 1% total impurity concentrations were excluded. each of the selected sources was coded for content, and the data were extracted for computer analysis. when the literature data were presented in graphical form the graphs were entangled and read as accurately as possible. the resulting data were then smoothened to reproduce the original curves. each set of data for a given measured specimen was characterized with values of residual resistivity, chemical impurity concentrations and thermal mechanical history. other details regarding the experimental procedure, purpose of the work, and analysis of data are also coded in the annotated bibliography for the convenient of the reader.

THERMAL CONDUCTIVITY

Thermal conductivity refers the ability of a given material to conduct /transfer heat .in this research work, it is required to evaluate the thermal conductivity of copper, aluminum, and cast iron, experimentally and get the temperature distribution for constant and variable area metal bars. the transfer of heat is normally from a high temperature object to lower temperature object. heat transfer changes the internal energy of both systems involved according to the first law of thermodynamics. conductions are the heat transfer by the means of molecular agitation within a material without any motion of the material as the whole. if one end of a metal rod is at higher temperature, then energy will transfer down the road towards the colder end because the higher speed particles will collide with the slower one with a net transfer of energy to the slower ones.

An empirical relationship between the conduction rate in a material and the temperature gradient in the direction of energy flow, first formulated by Fourier in 1822 who concluded that ''the heat flux resulting from thermal conduction is proportional to the magnitude of the temperature gradient and opposite to it in sign''.

Fourier's law thus provides the definition of thermal conductivity and forms the basis of many methods of determining its value.Fourier 's law, as the basic rate equation of the conduction process when combined with the principle of conservation of energy, also forms the basis for the analysis of most conduction problems.

ELECTRO –CONDUCTIVE MATERIALS

Electrical resistivity (also known as resistivity, specificresistance, or volume resistivity) is a measure of how strongly of how strongly a material opposes the flow of electric current. A low resistivity indicates a material that readily allows the movements of electric charge. it is commonly represented by the Greek letter p (rho) its SI unit is the ohm meter ohms'. electrical conductivity or specific conductance is the reciprocal quantity, and measures a material's ability to conduct an electric current. it is commonly represented by the Greek letter, and its SI unit is siemens per meter(s. m -l).

RESISTIVITY OF VARIOUS MATERIALS

The conductivity of a solution of water is highly dependent on its concentration of dissolved salts, and other chemical species that ionize in the solution. electrical conductivity of water samples is used as an indicator of how salt – free, ion – free, or impurity -free the sample is, the purer the water, the lower the conductivity (the higher the resistivity). conductivity measurement in water is often reported as specific conductance, relative to the conductivity of pure water a 25 degree Celsius. the effective temperature coefficient varies with temperature and purity level of the material. the 20-degree c value is only an approximation when used at other temperatures

For example, the coefficient becomes lower at the higher temperatures for copper, and the value 0.00427 is commonly specified at 0 degree Celsius.there extremely low resistivity (high conductivity) of silver is characteristic of metals. George Gamow (15) tidily summed up the nature of the metals' dealing with electrons in his science – popularizing book, one two three …infinity:"the metallic substances differ from all other materials by the fact that the outer shells other shells of their atoms are bound rather loosely, and often let one of their electrons go free.thus, the interior of a metal is filled up with a large number of unattached electrons that travel aimlessly around like a crowd of displaced persons.

When a metal is subjected to electric force applied on its opposite ends, these free electrons rush in the direction of the force, thus forming what we call an electric current ". table 2.1 show the resistivity, conductivity and temperature coefficient of various materials at 20 degree C (68-degreeF) electrically resistivity of CS A1 was higher than the bulk A1 sample measured, anisotropic. These characteristics can be attributed to intrinsic defects within A1 spalts (e.g., high dislocation density) and oxidized interfaces between splats.anisotropy, on initial approximation. could be attributed to the quasi – lamellar microstructure containing more interfaces per unit length through the thickness of the coating versus in- plane.nevertheless, examining the data from choi (2007) on the thickness dependence of resistivity (as specimen thickness approaches splat size thus effectively confines electrons to a single interrupted conductive path). this concept was fully explored in Sharma (2006); the imperfect interfaces between splats (interface normal perpendicular to subtractnormal) have a non – trivial effect on anisotropy. it could further be argued that these interfaces are less well bonded than those above and below particles, but this assertion must be certified with direct measurements.

THERMAL RESISTANCE O CONDUCTION

An important concept for evaluating the heat transfer is the thermal resistance. there is an analogy between the heat diffusion and its electrical charge. as the electrical resistance is associated with the conduction of electricity, the thermal resistance can be associated with the heat conduction. the ohm 's law of electricity defines the resistance as.

Re=V1-V2/I

Where; Re = the resistance

V1-V2 is difference of electrical potential. and

I is the electrical current.

Rt = T1-T2/Q

Where T2-T1 is the temperature difference,

Q is the rate of heat transfer from the equation, the thermal resistance is deduced from the calculation.

Rt conduction = X/KA

CONDUCTION IN A SIMPLE BAR

Theoretical Fundamental of Fouriers's Law

The basic law that governs the heat condition is perfectly illustrated when it is considered the simple and ideal case shown below. Considering a sheet with a surface (A) and thickness (X) I maintained one of its faces at a temperature T1 and the other to the other to a temperature T2 being Q the velocity of power flow, and the border effect. the experiment has demonstrated that the flow velocity is directly proportional to the area (A) and to the temperature differences (T2-T1) but inversely proportional to the thickness (X) this proportionality becomes an equality for the definition of proportionality 'k' Q=K.A (T1-T2) /X

The proportionality constant 'k' is called "thermal conductivity" and depends on the material in which the sheet has been manufactured. its properties depend on material and not on geometric configuration. /As well an illustrative example, the values that this constant can end up taking a diverse function of the material. in gas as the freon -R12 we have a thermal conductivity of 417W/m degree C in as discreet environment, the previous equation of the Fourier'slaw, which is given by Fan=-KT/N

Where,Fan is the heat steam in the n direction t/n I the thermal gradient.

MATERIALS AND METHOLOGY

Materials and Equipments

The materials and equipments used include:

i. Linear heat conduction module
ii. Refrigerant section
iii. A control valve
iv. Heating material
v. Temperature sensor
vi. Interface

EXPERIMENTAL METHODS

There are a number of methods to measure thermal conductivity: steady – state methods and transient or non-steady state methods, but I worked on the linear heat transfer module method in determining the thermal conductivity of aluminum, cast iron and copper. each of these methods is suitable for a limited range of materials, depending on the thermal properties and the medium temperature. three classes of methods exist to measure the thermal conductivity of a sample: steady – state, time

– domain, and frequency – domain methods, the temperature distribution for the cylindrical bar made a linear relation between the temperature.

PROCEDURE FOR DETERMINING THERMAL CONDUCTIVITY USING LINEAR HEAT CONDUCTION MODULE

I verified that the power cable (that belongs to the heating element) was connected to the interface and the metal material (copper, aluminum or cast iron9 is connected the hot and cold region. There were about 4 temperature sensor) connected to hot region and temperature sensor 5,6, &7 was connected to the experimental material (cast iron, copper and aluminum) also connected 4 thermocouples (temperature sensor 8,9,10, and 11) to the refrigerant section. I regulated water flow to allow water circulate through the cooling system. After I was sure that every connection was properly done, I switched on the computer and also turned on the interface, I regulated the flow to allow water circulate through the cooling system. after I was sure that every connection was properly done. I switched on the computer and turned on the interface, I regulated the heat flow rate, I set a period when reading was to be taken, I saved the data and waited Patiently for the system to compute the table.after all data had been collected, I stopped, quit and searched for the result at EDIBON file, I copied the data and pasted on excel. I then printed out the experimental data.

RESULTS AND DISSCUSSION

EXPERIMENTAL DATA OF THE RESEARCH WORK

Experimental data of the aluminumrod cast iron rod and copper rod are presented in table 4.1. the temperature difference as well as the thermal conductivities of aluminum, copper and cast iron can be determined from the tables below. table one: experimental data for copper

ST-1	ST-2	ST-3	ST-4	ST-5	ST-6	ST-7	ST-8	ST-9	ST-10	ST-11	SC-2	SW-1
44.514	38.065	36.804	33.546	31.728	30.672	29.102	28.998	28.546	28.845	28.546	4.721	22.016
42.865	36.865	35.236	33.856	31.605	30.527	29.165	29.095	27.976	28.933	27.976	4.722	22.007
39.89	37.555	35.764	33.821	31.651	30.557	29.228	29.186	27.954	28.017	27.954	4.746	22.043
40.259	37.807	35.308	33.642	31.654	30.546	29.294	29.017	27.865	28.124	27.865	4.737	22.039
40.154	37.704	35.256	33.562	32.088	31.03	29.38	28.823	28.55	28.823	27.55	4.698	22.026

From the table, I observed that the temperature (ST-11) was lower. this temperature drop resulted because temperature sensor 1,2,3 and 4 are connected to the hot region (heat section) and temperature sensor 8,9,10, and 11 are connected to the colling section (refrigerant section) therefore, more heat is conducted at the hot region and lesser heat as the flow approaches the refrigerant section.

Table 2: experimental data for aluminum

ST-1	ST-2	ST-3	ST-4	ST-5	ST-6	ST-7	ST-8	ST-9	ST-10	ST-11	SC-2	SW-1
50.543	50.345	50.152	49.824	49.712	47.567	43.443	43.367	43.128	43.871	42.524	4.709	121.424
50.346	50.157	49.908	49.785	49.537	48.675	43.299	43.135	42.828	42.702	42.538	4.732	122.975
50.556	50.362	50.102	49.841	49.457	47.254	43.254	43.204	42.972	42.782	42.383	4.731	122.904
50.471	50.321	49.956	49.725	49.511	47.229	43.031	42.865	42.711	42.532	42.321	4.706	123.174
50.557	65.876	65.724	59.457	50.328	49.647	43.056	42.801	42.585	42.356	42.165	4.732	122.264

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FINDINGS AND RESULTS

Table 3: produced table for copper

TIME	Q%(W)	T5	T7	T	K(K/Mk)
270	22.007	31.728	30.627	1.056	295.026
300	22.016	31.605	30.527	1.078	288.887
330	22.043	31.654	30.557	1.094	285.127

360	22.039	32.088	30.546	1.108	281.474
390	22.026	32.088	31.030	1.058	294.602

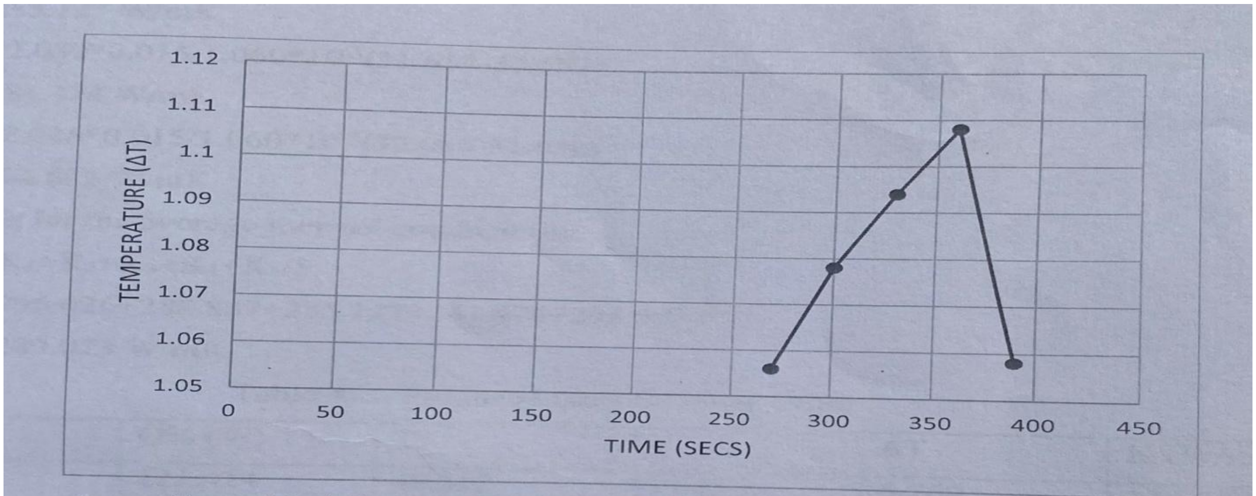

Figure 4.0: A Graph of Temperature (°C) Against Time (sec) for Copper

TIME	Q% (W)	T5	T7	T	K(Wmk)
50	121.424	49.712	43.443	6269	136.964
75	122.975	49.531	43.299	6.232	139.537
100	122.904	49.457	43.254	6.203	140.108
125	123.174	49.511	43.031	6.480	134.414
150	122.264	50.328	43.056	7.272	118.890

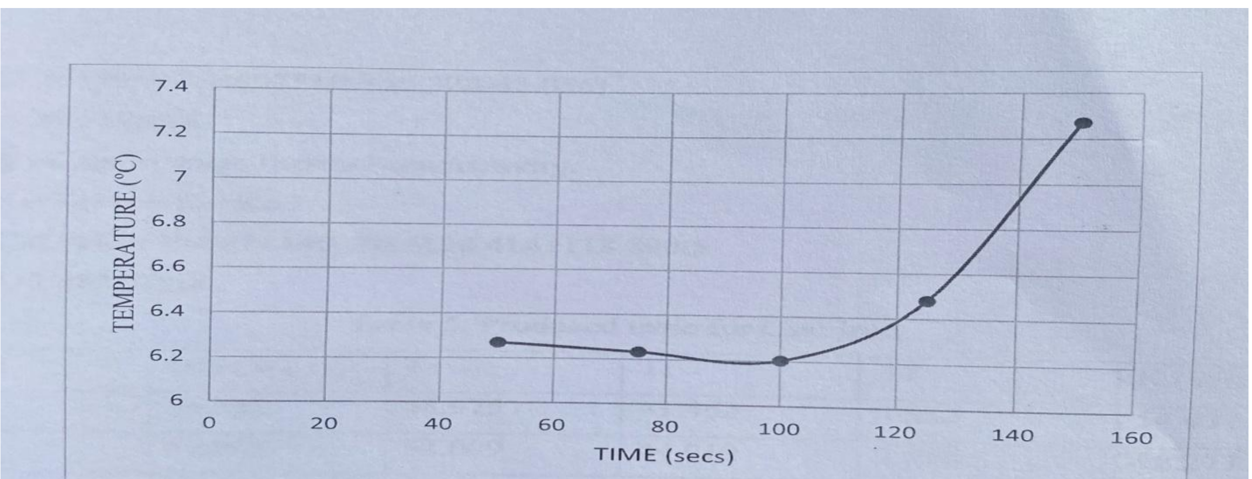

Figure 4.1 A Graph of Temperature (°C) Against Time (sec) for Aluminium

TIME	Q%(W)	T5	T7	T	K (Wmk)

105	58.362	48.975	41.462	7.513	54.931
120	59.069	52.009	44.091	7.990	52.277
135	75.834	52.768	43.264	9.504	56.423
150	86.096	54.312	43.244	11.068	55.006
165	89.764	54.448	43.232	11.216	56.593

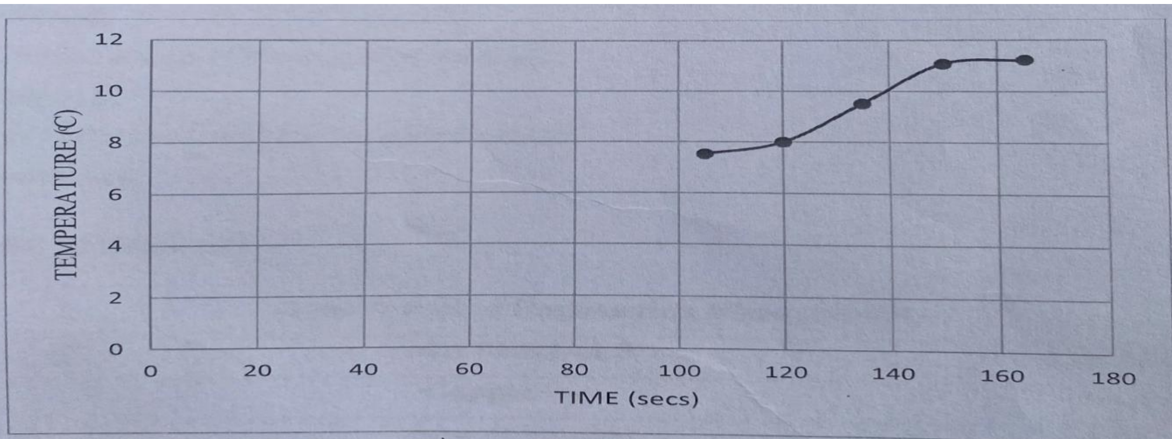

Figure 4.2 A Graph of Temperature (°C) Against Time (sec) for Cast Iron

CONCLUSION AND RECCOMENDATION

The results in general, revealed that copper possesses good thermal properties than aluminum and cast iron. after the researched work, it was observed that aluminum conducts more heat than cast iron. cast iron did not posses' good thermal properties. the thermal conductivities values for the sample's metals were found to conform to the general range of conductivity for aluminum, copper and cast-ironbars. this would assist engineers in the choice of construction materials to adopt for effective use. Also, thermal conductivity is regarded as the most important characteristic of a thermal insulator since it affects directly the resistance to transmission of heat that a material offers. the lower thermal conductivity value, the lower the overall heat transfers. comparing the results with other thermal insulators as reported by other researchers who have carried out a similar experiment. therefore, it was observed that the maximum amount of heat that flows through a copper bar is too high for cast iron bar to withstand.

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