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Research Paper

THERMAL CONDUCTIVITY DETERMINATION BY LAGGED PIPE APPARATUS

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Thermal conductivity is basically the property of a material that allows the flow of heat through the material. It is also known as the coefficient of conductivity, because it is given as a number that can be used in equations. The thermal conductivity of any particular material, it indicates how well it allows heat to flow, is therefore also a good indicator of how well the material insulates, or blocks the flow of heat. Objectives of this paper are to determine the thermal conductivity of the given insulating material by using lagged pipe apparatus (Asbestos and Sawdust) and to plot the temperature distribution across the lagging material. Lagging of pipes is required to prevent leakages of heat. The Apparatus is designed to study the lagging phenomenon. The apparatus consists of three concentric pipes, at the axis of which a heating element is positioned. Two types of lagging materials are filled up, one between innermost and middle pipe and other between middle and outermost pipe. Temperature across the lagging material, i.e., temperature of pipe walls for radial outward heat flow are measured by the thermocouples. The heater can be supplied with different heat inputs with the help of dimmer stat so that characteristics of lagged pipe can be studied at different heat flow rates.

Keywords: Heat transfer, Thermal insulation, Thermal conductivity, Asbestos and saw dust, Lagged pipe

INTRODUCTION

Akhan Tleouvaea (2005) developed a new combine guarded hot plate and heat flow meter method. It provides absolute values of thermal conductivity of various important materials such as ceramics, glasses, plastics, asbestos etc.In this method a thin flat heater of known area is placed between two flat-parallel specimens of the same material and of different thicknesses. The stack is clamped between two isothermal plates each having a heat flow meter and a temperature sensor. After applying a constant electric power to the heater the heat fluxes through each of the two specimens and consequently the two heat flow meters signals then it reach some final thermal

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equilibrium values. Each of the equilibrium heat fluxes is inversely proportional to the respective total thermal resistance-sum of each specimen's thermal resistance and two surface contact resistances which are assumed to be the same for the two specimens. The absolute thermal conductivity of the specimens then can be calculated using the measured electric power of the center of the heater, temperatures of the heater and of the plates, thicknesses of the two specimens, and the two heat-flow meters signals.

Marteen van Glender (1998) introduced factor that affects the heat flow paths such as porosity and shape, size and arrangement of void spaces, homogeneity, fibers and their orientation. The majority of the research on thermal conductivity of materials has been conducted in the low temperature range. Few researchers have measured thermal properties at temperatures above 100 °C. Baghe-Khandan and Okos (1981) measured the thermal conductivity through the temperature range 30-120 °C. Choi and Okos (1983) measured the thermal conductivity concentrate. The measurements were performed over the range from 20 to 150 °C. The line heat source probe is most commonly used for measurement of thermal conductivity, both at low and at high temperatures. Sweat and Haugh (1974) developed a miniature line heat source probe for the measurement of thermal conductivity of small cylindrical samples. Choi and Okos (1983) and Casada and Walton (1989), used an additional temperature sensor with known distance to the probe for direct determination of thermal diffusivity. A method that can simultaneously measure thermal conductivity and diffusivity is the thermistor probe method. The method was developed by researchers in the biomedical fieldfor measuring thermal conductivity and diffusivity of human tissue (Chato, 1968; Balasubramaniam, 1974; and Valvano, 1981). thermal conductivity of liquid products was measured over the temperature range 25 to 125 °C (Kravets, 1988). The thermistor based method utilizes a small thermistor probe whose active region approximates a sphere. Because of the small diameter of this region, beads with diameters of 2.54 mm and smaller are commonly used, it is applicable to small samples. Kravets (1988) concluded that samples could be as small as 5 mm in diameter.

Robert Virta (2002) explained in details the thermal properties of asbestos and also discussed about the uses of asbestos as an insulating materialAsbestos fibers historically have been used in a broad variety of industrial applications. Because of recent restrictions, many of these applications have now been abandoned and others are pursued under strictly regulated conditions. The main characteristic properties of asbestos fibers that can be exploited in industrial applications are their thermal, electrical, and sound insulation; inflammability; matrix reinforcement (cement, plastic, and resins); adsorption capacity (filtration, liquid sterilization); wear and friction properties (friction materials); and chemical inertia (except in acids). These properties led to several main classes of industrial products or applications: fire protection and heat or sound insulation, fabrication of papers and felts for flooring and roofing products, pipeline wrapping, electrical insulation, thermal and electrical insulation, friction products in brake or clutch pads, asbestos-cement products, reinforcement of plastics, fabrication of packing's and gaskets, friction materials for brake linings and pads, reinforcing agents, vinyl or asphalt tiles, and asphalt road surfacing. Of these, asbestos-cement products, roof coatings, brake pads and shoes, and clutches are the major markets for asbestos. The microscopic and macroscopic properties of asbestos fibers stem from their intrinsic, and sometimes unique, crystalline features. As with all silicate minerals, the basic building blocks of asbestos fibers are the silicate tetrahedra which may occur as double chains $(Si_4O_{11})^{-6}$, as in the amphiboles, or in sheets $(Si_4O_{10})^{-4}$, as in chrysotile. In the case of chrysotile, an octahedral brucite layer having the formula $(Mg_6O_4 (OH)_8)^{-4}$ is intercalated between each silicate tetrahedra sheet. Asbestos fibers used in most industrial applications consist of aggregates of smaller units (fibrils). This is most evident with chrysotile that exhibits an inherent, well-defined unit fiber.

Yu Kumzerov (2002) discussed about possibility of using asbestos in studies of thermal conductivity of thin filament of metal and semiconductors incorporated into channel of crystalline crysotile asbestos tube measured in the range of 5-300 K.

Jezowski (2004) discussed thermal conductivity specific heat crystallinechrysotile asbestos made up of hollow tabular fibrils of composition $Mg_3Si_2O_5(OH)_4$ having measured in range of 5-300 K, 3-65 K, 77 K.

Kumar (2003) focused on basic of heat exchange equipment and energy related problems.

Yunis Cengel (2011) discussed about the thermal conductivity of material which is helpful to understand insulation constrains.

METHODOLOGY AND EXPERIMENTATION

Geometry

Selection of Cartridge Heater

Heating Element Type: Nichrome wire (Cartridge type)

Material: Brass

Maximum Wattage Capacity: 400 watt

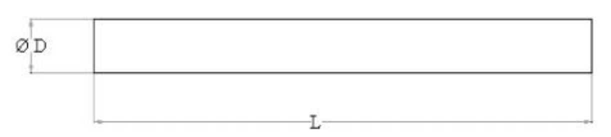
G.I Pipe Geometry-Size Selection

Pipes are available in standard diameters from 3 to 150 mm and in lengths from 500 to 6000 mm.

Inner Pipe

Standard diameter (ØD) = 57 mm, Standard length (L) = 500 mm, Material = G.I

Figure 1: Pipe Geometry of Inner Pipe



Middle Pipe

Standard diameter (ØD) = 85.5 mm, Standard length (L) = 500 mm, Material = G.I

Outer Pipe

Standard diameter (ØD) = 109.5 mm, Standard length (L) = 500 mm, Material = G.I

Figure 2: Pipe Geometry of Middle Pipe

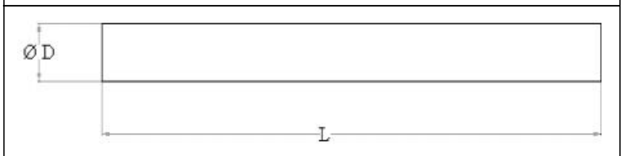
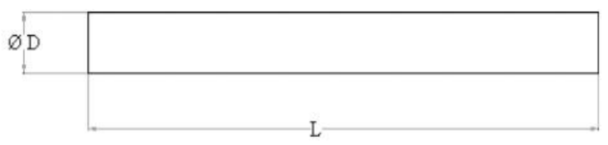


Figure 3: Pipe Geometry of Outer Pipe



Temperature Sensors

Thermocouple of Ø4 mm as a temperature sensing element.

Display is 10 channel temperature indicator.

MATERIAL SELECTION

We have used asbestos and sawdust as insulating material.

Selection of Electrical Equipments

Dimmerstat, voltmeter and Ammeter are selected according to the power rating $Q = V*I$

Figure 4: Experimental Setup Oftesting and Analysis of Lagged Pipe

Testing and Analysis of Lagged Pipe Apparatus

Description

The apparatus consists of three concentric pipes mounted on suitable stand. The inside pipe consists of a heater, which is wound with nichrome wire on the insulation. Between first two cylinders the insulating material with which lagging is to be done is filled compactly. Between second and third cylinder another material used for lagging is filled. The thermocouple is used attached to surface of cylinders to measure the temperatures. The input to the heater is varied through a dimmerstat and measured on voltmeter and ammeter. The experiments can be conducted at various values of input and calculations can be made accordingly. Similarly the experiments can be made for single or double lagging by removing appropriate pipes.

Apparatus Required

Ammeter, Voltmeter, Thermocouple, Temperature indicator

Specification

1. Inner pipe diameter d1 = 57 mm
2. Middle pipe diameter d2 = 85.5 mm
3. Outer pipe diameter d3 = 109.5 mm
4. Length of pipe L = 500 mm = 0.5 m
5. Heater: nichrome wire heater (cartridge type) placed centrally having suitable capacity 400 watts.

Formulae

$$Q = \frac{K * 2\text{®}L(\Delta T)}{\ln(r2/r1)}$$

Q = Power input (watt)

r = Radius of pipe (m)

L = length of pipe (m)

K = Thermal conductivity of material (W/m^2K).ΔT = Temperature Difference (K).

Precautions

1. Keep dimmerstat to zero position before start.
2. Increase voltage gradually.
3. Keep the assembly undisturbed while testing.
4. While removing or changing the lagging material, do not disturb the thermocouples.
5. Do not increase voltage above 140 volts (i.e., dimmer stat ranges between 60-120 watts).
6. Operate selector switch of temperature indicator gently.

Procedure

1. Connect the three pin plug to the 230 v, 50 Hz, 15 amps main supply and switch on the unit.
2. Turn the regulator knob clockwise, set the heat input by fixing the voltmeter and ammeter readings and note down the heat input *Q* in the table.
3. Allow the unit to attain the steady state condition.
4. When the steady state condition is reached note down the temperature indicated by the temperature indicators.
5. In the temperature indicator, the temperatures *T*1, *T*2, *T*3 represents the temperature of the heater, *T*4, *T*5, *T*6 represents the temperature of the asbestos and *T*7, *T*8, *T*9 represents the temperature of the sawdust lagging by using the multipoint digital temperature indicator.
6. These values are noted in the table.
7. Calculate *K*1 (Thermal conductivity of asbestos) and *K*2 (Thermal conductivity of asbestos), by using the given formula and note the value in the table.
8. Repeat the experiment from step 2 to step 6 by varying the heat input to the system.

Sample Calculation

$$Ti = \frac{T1+T2+T3}{3} = \frac{81+83+81}{3} = 81.67$$

$$Tm = \frac{T4+T5+T6}{3} = \frac{55+56+56}{3} = 55.67$$

$$To = \frac{T7+T8+T9}{3} = \frac{50+50+50}{3} = 50.00$$

$$Q = V * I = 84 * 0.6 = 50.4$$

$$Q = \frac{K1 * 2\text{®}L(\Delta T)}{\ln(r2/r1)}$$

$$K1 = \frac{Q * \ln(r2/r1)}{2\text{®}L(Ti - Tm)} = \frac{50.4 * \ln(0.04275/0.0285)}{2\text{®} * 0.5\,(81.67 - 55.67)}$$

= 0.25 W/m °C

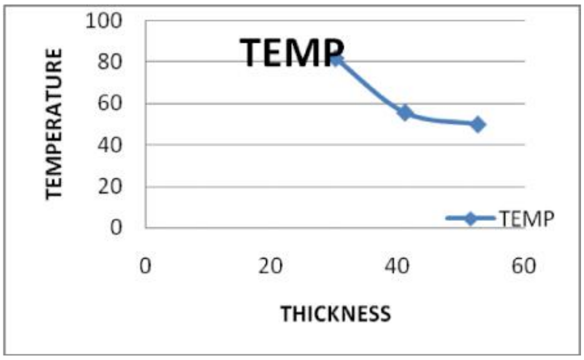
$$K2 = \frac{Q * \ln(r3/r2)}{2\text{®}L(Tm - To)} = \frac{50.4 * \ln(0.05475/0.04275)}{2\text{®} * 0.5\,(55.67 - 50)}$$

= 0.70 W/m °C

RESULTS AND DISCUSSION

Form Figure 5 we can say that as thickness of insulation increases temperature at

Figure 5: Temperature v/s Thickness



corresponding layer decreases hence temperature difference also decreases which results in reduction in heat transfer rate.

For asbestos as temperature increases thermal conductivity also increases but raise in thermal conductivity isconsiderably small hence we can say that up to certain temperature thermal conductivity of asbestos remains constant.

From the Figure 7 we can see that for small temperature rise there is considerable raise in thermal conductivity.

Figure 6: Thermal Conductivity v/s Temperature (Asbestos)

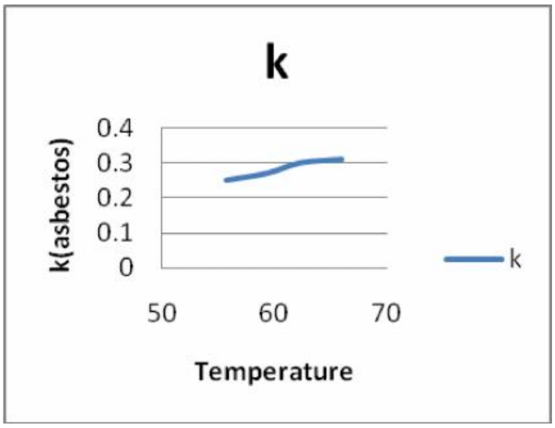
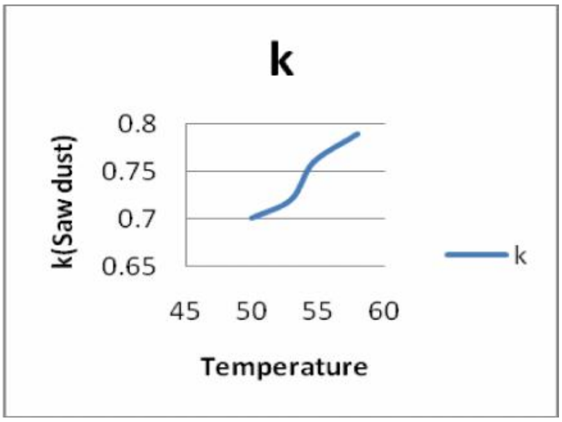


Figure 7: Thermal Conductivity v/s Temperature (Saw Dust)



CONCLUSION

1. As the thickness of insulation increases, the thermal resistance increases, thereby affecting heat transfer, due to which the temperature of the insulation reduces.
2. The amplitude of vibrations of molecules and lattice vibrations along with electron motion is more in saw dust as compared to asbestos, henceincrease in thermal conductivity of sawdust is more than asbestos.

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APPENDIX

Nomenclature
Q = Power input (*watt*).
r = Radius of pipe (m).
L = length of pipe (m).
K = Thermal conductivity of material (W/m^2K).
ΔT = Temperature difference (K).