Investigations on Thermal Insulation Characteristics for A Cylindrical Pipe

[1]Puspendra Upadhyay, [2]Sunil Yadav

Indira College of Engineering and Management [1,2]
puspendrau@gmail.com[1], sunilicem@gmail.com[2]

Abstract— Critical radius is property of a material and ambient convective heat transfer coefficient. However, if it is desirable to decrease heat gain or heat loss, the critical radius only serves as a necessary condition, but it is not sufficient. To address design issues of such thermal systems, the crossover radius is utilize. In this experimental study factor such as heat input, thermal conductivity of base material and insulating material is taken into consideration to find relationship between them Optimum insulation thickness for ceramics, asbestos and fiberglass for base material of copper and aluminum for heat input of 50W, 75W, 100W, 125W and 150W lies between 6mm to 9mm.

Index Terms-insulation, crossover radius, critical radius, heat transfer.

I. INTRODUCTION

In present days the focus on energy saving and efficiency has increased globally. Energy consumptions from space cooling/heating can be reduced by using insulation materials. Even in good-insulated system energy consumption can be reduced further by insulating heating and cooling pipe. It is noted that the effective thermal insulation of piping system plays an important role in the energy consumption for transmission and distribution of heating/cooling and in reduction of heat loss from various sources of heat loss, selection of insulating material is depends on the thermal property of material. Low thermal conductivity and price increases economic efficiency of insulating material.

The critical radius of insulation is an interesting parameter of heat transfer in insulated system. Insulating system like a cylinder or sphere greater than the critical radius has the expected effect of retarding heat loss. In case the insulation radius of system (i.e. cylinder or spherical system) is smaller than the critical radius of insulation, adding insulation will actually increase heat loss.

In order to define critical radius and crossover radius convection and conduction plays a major role [1,2]. Biot number can be used to define relation between convection, conduction and insulation thickness [1]. Sunan et al.used Finite Differential Equation method to drive relationship between transient heat system and steady state [4]. M.R Kulkarni derived the relationship between heat transfer ratio and insulation thickness ratio in terms of biot number. [3].

This experiment deals with study of effect on heat transfer of different insulation at different thickness at different heat input.

II. EXPERIMENT SETUP AND FORMULATIONS

Experimental setup is design and fabricated in such that same input parameters can be maintain for desired insulation. It consist of frame, thermocouple, temperature indicator, voltmeter, ammeter, copper pipe, resistive heater, main switch, electric conductor wire, insulating material.

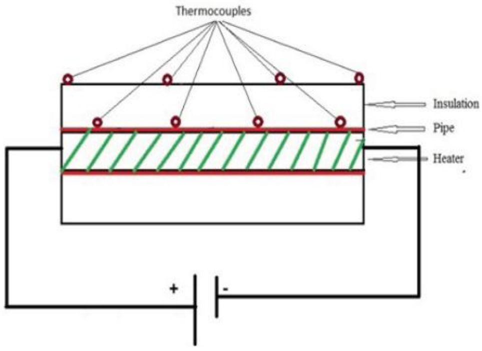

Figure 1: Schematic Diagram of Experimental Setup

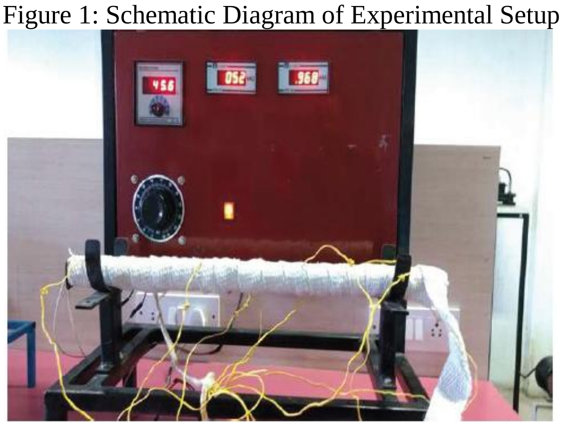

Figure 2: Experimental Setup

Heat transfer through insulation is given by

$$Q_{Ins} = \frac{temperature\ drop\ across\ insulation}{thermal\ insulation\ resistance}$$

For natural convection convective heat transfer coefficient is a function of velocity of air, which can be obtain by relation:

$$h_c = 10.45 - v + (10v)^{0.5} \quad \text{.....................} \quad (I)$$

Total thermal resistance is combine effect of convective and conductive thermal resistance can be calculated as:

$$R_{Total} = R_{Conv} + R_{Cond} \quad \text{.....................} \quad (II)$$

Heat ratio is defined as heat transfer through insulation to heat transfer without insulation.

Thickness ratio is defined as particular insulation radius to maximum insulation radius.

Table 1: Sample Effective Thermal conductivity for Al pipe in W/mK

Insulation Thickness t (mm)	Ceramic tape	Asbestos tape	Fiberglass
Base material	237	237	237
3	0.165	0.236	0.0687
6	0.144	0.182	0.0601
9	0.137	0.1725	0.0572
12	0.134	0.168	0.0557
15	0.131	0.165	0.0548

Table 2: Sample observation Heat transfer of bare pipe for cu and Al at different heat inputs

Heat input (W)	Q_bare(Cu) W	Q_bare(Al) W
50W	11.7023	11.5032
75W	18.30	16.952
100W	23.08	22.731
125W	28.95	25.316
150W	31.374	28.925

Table 3: Sample Q_ins At different thicknesses and heat input for pipe material Al and insulating material asbestos

Heat input (W)	Q_{bar} (Al) W	Heat transfer (Q_{ins}) W				
		3mm	6mm	9mm	12mm	15mm
50W	11.5	9.232	15.39	10.53	17	19.18
75W	16.9	14.85	23.86	18.95	23	35.5
100W	22.7	28.35	34.23	25.35	29.	36.3
125W	25.3	32.36	41.32	28.35	36.	40.01
150W	28.9	29.3	39.28	36.25	40.8	49.28

III. RESULT AND DISCUSSION

Plots between heat ratio and thickness is plot at a heat input of 50W for base material of cooper and aluminum at 50W for ceramics, asbestos and fiberglass. Fig.3 it is observed that

a-b: convective resistance of insulation decrease which leads to increase in heat ratio

b-d: conductive resistance of insulation increases exponentially

d-e: due to higher temperature difference across insulating material heat ratio increases and heat transfer through radiation may also play role between d to e due to high temperature difference between insulation surface and surrounding.

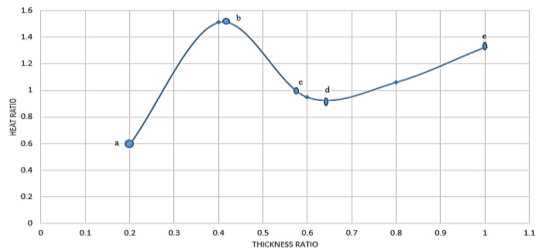

Figure 3: variation of heat ratio with thickness ratio through asbestos with coper at 50W as a heat input

Plot between heat transfer ratio and thickness of insulation of ceramics, asbestos and fiberglass at a constant input is plotted is obtain which shows Variation of heat transfer ratio with thickness ratio of different insulation at a particular heat input. 50W is heat input and base material is same then it is observed that for same heat input heat transfer ratio of asbestos, ceramics and fiberglass varies from 1.5 to 1.59, 0.59 to 1.3 and 0.3 to 0.5 respectively

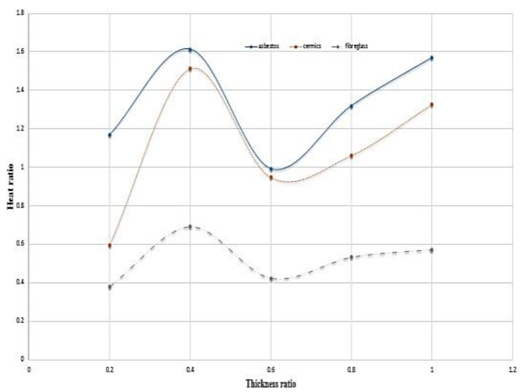

Figure 4: variation of heat ratio with thickness ratio through asbestos, ceramics and fiberglass with coper at

50W as a heat input

It observed that heat ratio of fiberglass is very low as compared to asbestos and ceramics because effective thermal conductivity of fiberglass is very low. At same time critical radius can be obtain but crossover radius cannot be determined at low effective thermal conductive of insulation.

Heat transfer rate varies thickness is calculated at different heat inputs. Fig.5 it is observed that for asbestos as input increases heat transfer through insulation increases,

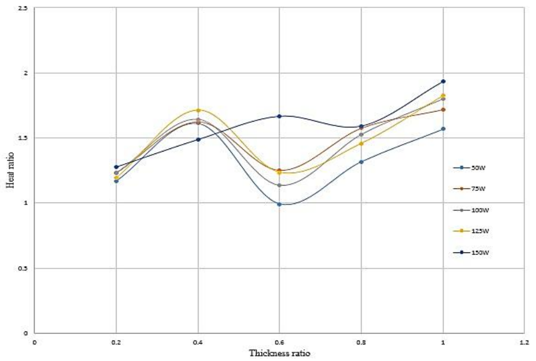

Figure 5: variation of heat ratio with thickness ratio through asbestos at 50W, 75W, 100W, 125W and 150W

for higher input heat transfer increases with linear rate it may happen because of higher surface temperature of insulation and radiation might be become significant at higher heat inputs. Heat input have no significant effect on critical radius of insulation it seems that critical radius of insulation is independent of heat input.

IV. CONCLUSION

From experimental study of thermal insulation characteristics for cylindrical pipe of cooper and aluminum with insulating material as asbestos, ceramics and fiberglass with thickness of 3mm, 6mm, 9mm, 12mm and 15mm with heat input as 50W, 75W, 100W, 125W and 150W is studied. Following things can be concluded by experimental study:

a) Critical radius is independent of heat input, it depends only on thermal conductivity of insulating material and convective heat transfer coefficient.

b) Optimum thickness ratio of insulation is 0.4 to 0.6 for asbestos, ceramics and fiberglass.

c) Effect of base material on critical radius is not significant but crossover radius vary with base material.

d) Crossover radius increases as effective thermal conductivity of insulation increase.

e) Crossover radius is high from high effective thermal conductivity.

h) At low heat input 50W and effective thermal conductivity between 0.13W/mK to 0.14W/mK relation between effective thermal conductivity and crossover radius is second order polynomial.

REFERENCES

[1] M. R. Kulkarni “Critical radius for radial heat conduction:A necessary criterion but not always sufficient,” pp. 967-979, 30 Aug 2003.

[2] Dinesh kumar Sahu, Prakash kumar sen, Gopal sahu “A Review on Thermal Insulation and Its Optimum Thickness to Reduce Heat Loss,” IJIRST. Vol.2 issue.06 pp. ISSN (online): 2349-6010, November 2015

[3] N.B.Totala, Anant A.Paralkar,Nikhil R.Kakade, Kunal R.Kawthekar “Analysis for critical radius of insulation for a cylinder,” vol.3, issue.9 pp. 32-38, November 2013.

[4] Sunan Huang, Jaronie Mohd Jani, Martin Leary, Aleksandar Subic “The critical and crossover radii on transient heating,” pp. 325-334, 2013.

[5] M. S. a. R. M. K. Abdul Razak.R.Kaladgi, "A Study on Critical Radius and Crossover Radius of Insulation for Various Heat Transfer Problems," Columbia International Publishing American Journal of Heat and Mass, vol. 3, pp. 149-156, 2014.

[6] J. B. Wachtman “Mechanical and Thermal Properties of Ceramics: Proceedings”, Issue 303, pp. 79, 1969.