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Investigation of Thermal Insulation on Ice Coolers

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Abstract: *The effective analysis of this study involves the investigation of suitable density and thickness of the materials for the best performance of low temperature thermal insulation in ice coolers. The requirement of energy conservation in ice coolers and to decrease the spoilage of food is essential nowadays. This investigative study is over the ice coolers performing with coconut fibre and polystyrene as insulation materials with different possible thermal conductivities and also about a better a choice of using polyurethane as insulator in ice coolers. In which, the optimised density and thickness of the polyurethane is analysed and the thermal conductivity is found experimentally by Lee's Disk Apparatus from all the three materials namely coconut fibre, polystyrene and polyurethane. It is found that polyurethane of density 95kg/m^3 is the best with least thermal conductivity of 0.0195 W/m K. The experimental data is compared with the numerical analysis by which the best density and thickness for the insulating material is found in order to minimize the loss of heat energy in the ice coolers and to increase the melting time of the ice in it.*

Keywords: *ice coolers, polystyrene, polyurethane, thermal conductivity and melting time*

I. Introduction

The need of energy conservation has become a major issue, where a lot of work is required to do. In case of thermal losses, thermal insulating materials play an important role in preventing heat losses in many of the applications. Various Insulation materials are present in markets which have shown excellent insulating ability are discussed and researchers had also worked out on different alternative insulation materials like bagasse, coconut husks, corn by-products, cotton wool, sheep wool etc. point of interest is the development of the "alternative" insulation materials, so it becomes essential to review literature on worked out insulation materials in the past.

Energy Conservation is "buzz" words of our times. There are many forms of energy conservation concerned with the methods of conserving energy by means of thermal insulation. To change the temperature of an object, energy is required in the form of heat generation to increase temperature, or heat extraction to reduce temperature. Once the heat generation or heat extraction is terminated a reverse flow of heat occurs to revert the temperature back to atmospheric temperature. To maintain a given temperature considerable continuous energy is required. Insulation process will reduce this energy loss. Heat may be transferred in three mechanisms: conduction, convection and radiation.

Heat transfers through insulation material occur by means of conduction, while heat loss to or heat gain from atmosphere occurs by means of convection and radiation. Heat passes through solid materials by means of conduction and the rate at which this occurs depends on the thermal conductivity (expressed in W/m K) of the material in question and the temperature drive.

In general the greater the density of a material, the greater the thermal conductivity, for example, metals has a high density and a high thermal conductivity. Materials, which have a low thermal conductivity, are those, which have a high proportion of small voids containing air or gas. These voids are not big enough to transmit heat by convection or radiation, and therefore reduce the flow of heat. Thermal insulation materials fall into the latter category. Thermal insulation materials[1] may be natural substances or man-made.

II. Sample Collection And Preparation

Different samples were collected like coconut fibre[2], polystyrene[3] and polyurethane. The collected samples were to be made into five samples each into different densities as 50 kg / m^3, 65 kg / m^3, 80 kg / m^3, and 95 kg / m^3.

Samples were cut into the diameter of 10cm then with different masses was kept in the mould and then covered with a metal plate. The sample was then compacted slowly and gently using a hydraulic manual press. These samples were compacted until a set pressure was attained. When the set pressure was attained, it was maintained for about 5 minutes to allow the pressure to stabilize.

The press was then released and the disk blocks were then removed. As required by the Lee's Disk apparatus, the disk samples of diameter 10cm and thickness of about 2mm were made, and obtained after compacting the powdered samples at different pressures.


Fig.1 Coconut Fibre Sample


Fig.2 Polystyrene


Fig.3 Polyurethane

III. Lee's Disk Method

Thermal conductivity, k, is the property of a material that indicates its ability to conduct heat. Conduction will take place if there exists a temperature gradient in a solid (or stationary fluid) medium. Energy is transferred from more energetic to less energetic molecules when neighboring molecules collide. Conductive heat flow occurs in direction of the decreasing temperature because higher temperature is associated with higher molecular energy. Fourier's Law expresses [4] conductive heat transfer as

$$H = k\,A\,\frac{(T_2 - T_1)}{x} \quad \ldots\ldots\ldots\ldots\ldots\ldots..\ (1)$$

Where H is the steady state rate of heat transfer, k is the thermal conductivity of the sample, A is the cross sectional area and (T 2 – T1) is the temperature difference across the sample thickness 'x', assuming that the heat loss from the sides of the sample is negligible.

Table 1: Thermal Conductivities using Lee's Disk Method

MATERIALS	DENSITY	dT/dt	T1	T2	CONDUCTIVITY
	Kg/m^3	^{0}C/Sec	°C	°C	W/m. k
COCONUT	50	0.015	90	52	0.04455
	65	0.0095	90	63	0.03971
	80	0.0092	90	62.5	0.03749
	95	0.0091	90	62	0.03667
POLYSTYRENE	50	0.0072	90	63	0.03009
	65	0.0069	90	61	0.02685
	80	0.0067	90	60.5	0.02577
	95	0.0065	90	60	0.02445
POLYURETHANE	50	0.0061	90	61	0.02373
	65	0.0057	90	59	0.02075
	80	0.0056	90	59.5	0.02012
	95	0.0055	90	58	0.01939

IV. Numerical Analysis Of Thermal Conductivity

The finite element method (FEM)[5] rapidly grew as the most useful numerical analysis tool for engineers and applied mathematicians because of it natural benefits over prior approaches. The main advantages are that it can be applied to arbitrary shapes in any number of dimensions. The shape can be made of any number of materials. The material properties can be non-homogeneous (depend on location) and/or anisotropic (depend on direction). The way that the shape is supported (also called fixtures or restraints) can be quite general, as can the applied sources (forces, pressures, heat flux, etc.).

4.1 Numerical Results By Varying Densities

The numerical data was obtained for the inside temperature maintained within the ice cooler. With all the samples made with different densities the analysis were made and the specimen with the least inside temperature is considered for the ice cooler [6].

Table 2: Thermal Conductivities by Numerical Method

MATERIALS	DENSITY	THERMAL CONDUCTIVITY	OUTSIDE TEMPERATURE	INSIDE TEMPERATURE
	Kg/m^3	W/m k	^{0}C	^{0}C
COCONUT	50	0.04455	28	8
	65	0.03971	28	5
	80	0.03749	28	4.5
	95	0.03667	28	3.75
POLYSTYRENE	50	0.03009	28	6.2

	65	0.02685	28	5.5
	80	0.02577	28	4.3
	95	0.02445	28	3.5
POLYURETHANE	50	0.02373	28	6
	65	0.02075	28	5.2
	80	0.02012	28	3.9
	95	0.01939	28	3.1

4.2 Numerical Results By Varying Thickness

The numerical data was obtained for the inside temperature maintained within the ice cooler. With all the samples made with different thicknesses[7] like 38mm, 51mm, and 64mm, the analysis were made and the specimen with the least inside temperature is considered for the ice cooler.

Table 3: Thermal Conductivities using Lee's Disk Method for Coconut Fibre

MATERIALS	DENSITY	THERMAL CONDUCTIVITY	OUTSIDE TEMPERATURE	INSIDE TEMPERATURE
	Kg/m^3	W/m k	^{0}C	^{0}C
COCONUT FIBRE	50	0.02373	28	4
	65	0.02075	28	3.25
	80	0.02012	28	2.9
	95	0.01939	28	2.5

Table 4: Thermal Conductivities using Lee's Disk Method for polystyrene

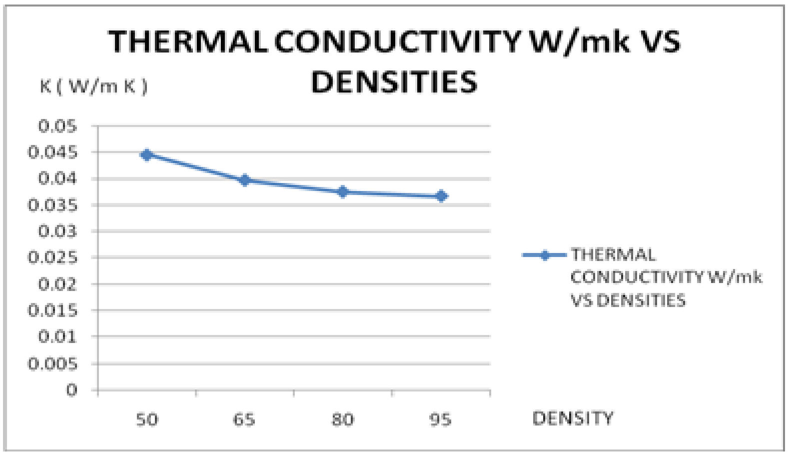
MATERIALS	DENSITY	THERMAL CONDUCTIVITY	OUTSIDE TEMPERATURE	INSIDE TEMPERATURE
	Kg/m^3	W/mk	^{0}C	^{0}C
POLYSTYRENE	50	0.02373	28	3.8
	65	0.02075	28	3.2
	80	0.02012	28	2.8
	95	0.01939	28	2.4

Table 5: Thermal Conductivities using Lee's Disk Method for polyurethane

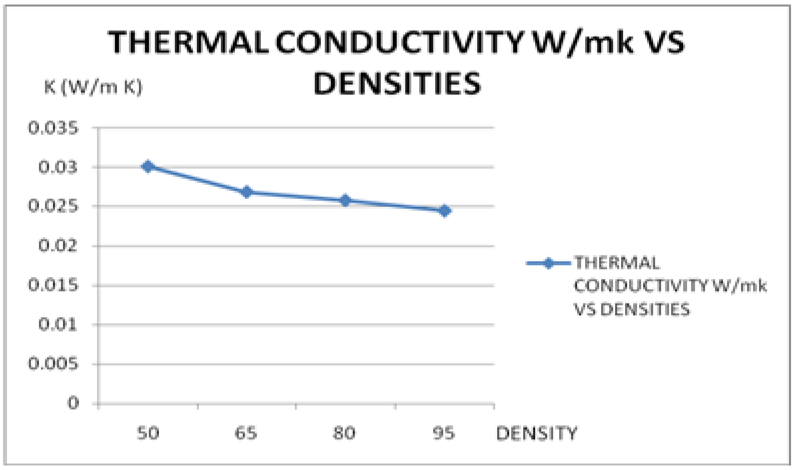
MATERIALS	DENSITY	THERMAL CONDUCTIVITY	OUTSIDE TEMPERATURE	INSIDE TEMPERATURE
	Kg/m^3	W/mk	^{0}C	^{0}C
POLYURETHANE	50	0.02373	28	3.5
	65	0.02075	28	3.1
	80	0.02012	28	2.7
	95	0.01939	28	2.2

V. Results And Discussion

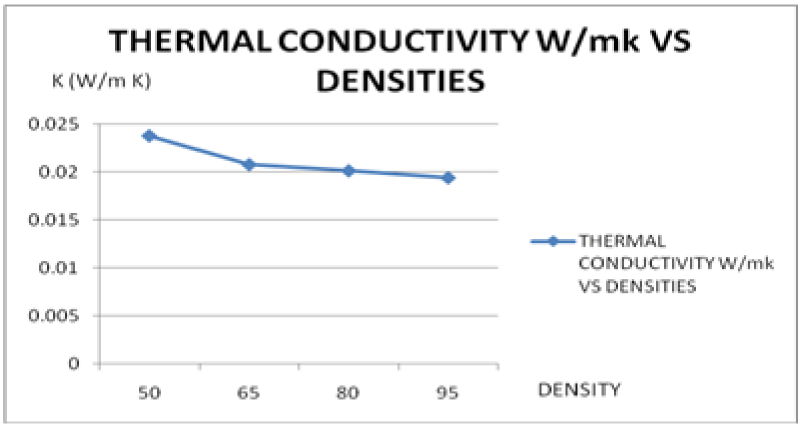
From the data obtained from different specimens the thermal conductivity[8] for the densities 50 kg/m^3, 65kg/m^3 80kg/m^{3}and 95kg/m^3 it has been found that density 95 kg/m^3 is having the least thermal conductivity of Polyurethane material. The experimental values using the Lee's Disk Apparatus [9] the following graph is being plotted between densities and their thermal conductivities. This plot is done for all the samples made.



Graph 1: Thermal Conductivity Vs Densities of Coconut Fibre



Graph 2: Thermal Conductivity Vs Densities of polystyrene



Graph 3: Thermal Conductivity Vs Densities of polyurethane

VI. Conclusion

The experimental values are found from the test samples and hence that polyurethane material is having the least thermal conductivity and under the analysis in simulation software it reveals that lowest temperature is found in the inside of the sample such that the heat transfer is also very less[10].

Thus such a material is iterated using the variable thickness, such that for thickness of about 64mm the heat transfers is much lesser.

In this, the optimized density and thickness of the polyurethane was analyzed and the thermal conductivity is found experimentally by Lee's Dick apparatus from all the three materials namely coconut fibre, polystyrene and polyurethane. It is found that polyurethane of density 95kg/m^3 and thickness 64mm of is the best with least thermal conductivity of 0.0195 W/m K.

The experimental data is compared with the numerical analysis by which the best density and thickness for the insulating material is found in order to minimize the loss of heat energy in the ice coolers and to increase the melting time of the ice in it. The laboratory built ice cooler with approximate volume and shape of commercial ice coolers, and the melting rate of ice shall be conducted as the future work with the optimised polyurethane.

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