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Numerical Study and Determination of Thermal Conductivity of Paper –Fenugreek Composite

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ABSTRACT— The use of thermal insulators is one of the most important aspects in thermal energy storage systems as well as air conditioning systems. This dissertation presents investigation of thermal property of selected composite material available in India which can be used for thermal insulation. Thermal property of two different materials was already measured independently. By make use of these two materials, a composite material is prepared which is named as Paperpulp-Fenugreek composite. The property which is under investigation is the thermal conductivity. The effective thermal conductivities of fiber and particle reinforced composite material are calculated by numerical method using finite element analysis software. Different filler concentration, arrangements and geometries are examined. The results are compared with the results obtained from theoretical models. The samples of composite were prepared by mixing of paper pulp and fenugreek pulp. The mixture is then dried for 72hrs in the form of sheets having certain thickness as per required. The Quick thermal conductivity meter, in which the Guarded Hot Plate method was used in the measurement of thermal conductivity at room temperature (approximately 28°C). Theoretical analysis, simulation analysis and experimental analysis is also studied.

Key Words: Guarded Hot Plate, Paper-Fenugreek Composite, and Thermal conductivity.

I. INTRODUCTION

Thermal insulators are those materials, which are homogeneous or heterogeneous combinations of materials which restrict the flow of heat energy. Installation of thermal insulation can significantly reduce the thermal energy (heat) loss from thermal heat storage system surfaces as well as air conditioning systems. The energy lost for an insulating material depends on the thermal properties and thicknesses of the insulation. It is necessary to use thermal insulators such as in thermal energy storage systems and air conditioning systems to maintain low temperatures inside by preventing heat losses from the surroundings [1]. There are varieties of insulating materials which are available in different forms like pipe and foam, loose fill, rigid boards etc.

Selection of Proper insulating material to be used is based on the thermal properties which include the specific heat capacity, thermal conductivity and thermal diffusivity. The thermal insulation is provided by embedding insulation materials at least on the roof areas and on the storage system vertical walls. Poor thermal insulation of the heat storage systems leads to high heat losses [2].

1.1 STATEMENT OF THE PROBLEM

Rock wool and fibre glass are presently used as thermal insulation materials for the prevention of heat loss in to or out of system. This is mainly due to having their low thermal conductivity values leading to good thermal insulation. However, these thermal insulators are expensive and also risky to human health as a result of exposure during handling especially those in fibrous form. The people who are working with the manufacturing of fibre glass, studies on them found that 60% more fibre glass particles compared to the normal people. There is a need for finding alternative thermal insulating materials which is cheap, easily available and does not affect a risk to human health and also cheaply and readily available

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[3]. So an alternative material has to be chosen for proper insulation to resist the energy transfer. The material should be low cost in preparation and renewable resource, easy to handle. The material used is Paperpulp- Fenugreek composite. The composition of different materials changes the thermal properties and considered as per required conditions.

1.2 OVERLOOK OF COMPOSITE MATERIALS

A composite material can be defined as a microscopic combination of two or more different materials, having an identifying interface between them. However, composites are usually used for their structural properties, the definition can be limited to include only those materials that contain reinforcement (like fibers or particles) supported by a binder (i.e. matrix) material [4].

1.2.1 PRESENT:

From early Originating agricultural societies after centuries almost forgotten, a true improvement in the condition, strength of something started of using light weight structural composite for various technical solutions during the beginning of the 21st century. After being slowly used for the electrical devices, also using composites to improve the structural behavior of spacecraft and military aircraft became popular in the last two decades of the previous century. First at any costs, with improved materials development, with increasing costs, nowadays cost reduction during manufacturing and operation are the main technology drivers. The use of composites are latest development, is to protect man against fire impact and a susceptible to a more environmental friendly design, reduce the risky in health, leading to the introduction of natural fibers in the composite technology.

1.2.2 FUTURE:

In future, composites will be manufactured even more according to the required results of the design process resulting in the optimum construction according to parameters such as shape, durability, costs, mass, strength, stiffness etc. Newly developed design tools must be able to instantaneously show customers, the influence parameters of a design change on each one.

1.3 THERMAL CONDUCTIVITY

1.3.1 DEFINITION OF THERMAL CONDUCTIVITY

Thermal conductivity is defined as "the quantity of heat transmitted through a unit thickness of a material - in a direction normal to a surface of unit area - due to a unit temperature gradient under steady state condi*tions"* [5].

According to the second law of thermodynamic, heat always flows in the direction of higher concentration to lower concentration. Transport of heat energy through a body of mass in the result of temperature gradient is termed as “thermal conductivity”.

In a steady state, temperature at any point in the material is constant with time & thermal conductivity is the parameter which controls heat transfer by conduction. We know that the rate of heat flow is given by Fourier's law.

The relationship between transported heat per unit of time (**dQ/dt** or heat flow Q) and the temperature gradient ($\Delta T/\Delta x$) through Area A (the area through which the heat is flowing perpendicularly at a steady rate) is described by the thermal conductivity equation. Fourier’s Law is used to express conductivity heat transfer as shown below.

$$\mathbf{Q = -kA \frac{T_2 - T_1}{L}}$$

Q = heat transfer (W, J/s)

A = heat transfer area (m^2)

k= thermal conductivity of the material (W/m K or W/m ^oC)

dT =(T_2-T_1)= temperature difference across the material (K or ^oC,)

L = material thickness (m).

1.3.2 MEASUREMENT OF THERMAL CONDUCTIVITY:

There are a number of ways to measure thermal conductivity. Each of these is suitable for a limited range of materials, depending on the thermal properties and the medium.

1.4 SELECTION OF MATERIAL FOR SAMPLE PREPARATION:

1.4.1 FENUGREEK

Fenugreek is dried ripe fruit (Trigonella foenum-graceum L) is an annual herb of leguminosea family, is being used as spice with its seeds and as vegetable with its leaves. In the ancient world, its history is prominent in cooking and medicinal herb. Fenugreek is known as Greek hay. The seeds are somewhat bitter in taste and have a strong aroma. Fenugreek major production is from Southern Europe, the Mediterranean region and Western Asia. It is still grown for fodder in parts of Northern Africa and Europe. It is cultivated from Western Europe to China. The seeds are very hard, and difficult to grind.

It is used as an herb (leaves) and as a spice (seed). Seeds look like small, smooth, hard, oblong and yellowish brown in colour. Substances like proteins, sugars, starch, mucilage, mineral matter, fixed oil, volatile oil, vitamins and enzymes are contained. For diabetic patients it holds medicinal properties and there is a prominent hypoglycemic effect especially (Blumenthal et al. 2000). Fresh tender leaves and shoots of fenugreek are rich in iron, calcium, protein and vitamins A and C, eaten as vegetables [7].

1.4.1.1 SEED PHYSICAL PROPERTIES RANGE FROM:

- The average length = 4.01 to 4.19mm
- Width = 2.35 to 2.61mm
- Thickness = 1.49 to 1.74mm
- Geometric mean diameter = 2.40 to 2.66mm
- unit mass = 0.0157 to 0.0164g

1.4.1.2 THERMAL PROPERTIES RANGE FROM:

- Thermal conductivity = 0.140-0.186 W/m^2 K
- thermal diffusivity = 8.13 × 10^{-6} - 11.38 × 10^{-6} m^2/s
- Specific heat = 295.9 to 5794.4 J/kgK

1.4.2 PAPER

Paper is a thin material produced by pressing moist fibers together; typically cellulose pulp obtained from wood, rags or covered with grass and made them dry into flexible sheets.

Paper is a flexible material with many functions. While the most commonly used for writing and printing upon. It is also widely used as a packaging material, in many electrical products, in industries and construction processes, and also as an ingredient in food particularly in Asian cultures.

The modern pulp and paper industry is global, with production leads by China and then United States is after [8].

1.4.2.1 Thermal properties:

- Thermal Conductivity = 0.05 W/m^2 K
- Thermal Diffusivity = 0.22× $10^{-6}$$m^2$/s
- Specific Heat = 1.36 kJ/kgK
- Burning Point = 233^0C

1.4.2.2 Physical properties:

- Density = 610 – 690 kg/m^3
- Typical Thickness = 60-80 µm

II. LITERATURE REVIEW

Different methods are tried for conservation of energy. Thermal insulators play a vital role in the prevention of heat losses. So for the future thermal insulators made of naturally available materials are studied.

Researchers worked out on different alternative insulation materials like bagasse, coconut husks, corn by-products, cotton wool, sheep wool, which are presented.

In this, there are various insulating materials are available in market. Various sources like Organic, Inorganic, agricultural industries, combined materials and new technology materials are discussed. Different Methods of obtaining physical, mechanical and thermal properties for insulating material are observed. Its usefulness as thermal insulator is seen and found materials have excellent insulating ability [9].

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Insulating materials available in various forms like loose fill, rigid boards, pipe and foam which are available in the market. Proper selection of the insulating material to be used is based on the thermal properties which include the thermal conductivity, specific heat capacity and thermal diffusivity. The thermal insulation is provided by embedding insulation materials at least on the roof areas and the vertical walls of the storage systems [10].

Rock wool and fiberglass are currently used as thermal insulation materials for the storage systems. This is mainly due to their low thermal conductivity. However, these are risky to human health and also expensive as a result of exposure during handling especially those in fibrous form. The disadvantage is fibrous dust is released during processing mineral dust or the fibrous dust from the mineral wool insulation can cause eye irritation [11].

There is a need for finding alternative thermal insulating materials which are cheap, readily available and do not effect a risk to human health and also cheaply and readily available [12].

Summary of literature review:

These literature reviews helped me to know how the insulating material plays a prominent role in energy storage or dissipation. So a better insulating material can be prepared using organic materials like paper - fenugreek composite material.

This was observed by the theoretical calculation of thermal conductivity K at different combinations of paper and fenugreek at definite ratio. In this composite material, the paper is used as a matrix and fenugreek is used as re-enforcement. A transient heat transfer finite element (FE) model was developed to predict the ceiling heat gain or loss and estimate the savings of radiant barrier application in cooling and heating loads [13].

From this a better ratio of volume was chosen using theoretical calculation of this particulate reinforced is shown below.

III. THEORETICAL CALCULATION OF THERMAL CONDUCTIVITY

Since there are various models for theoretical calculation, only required model is considered. The cases to consider are the series, parallel and geometric mean models, for which the conductivity of composite is given by:

A new theoretical approach to find the effective thermal conductivity of heterogeneous materials is chosen for different arrangement as shown below equation 3.1.1 a, b.

Series $k_e = \frac{k_m k_f}{\varnothing k_f + (1-\varnothing).k_m}$ …3.1.1(a)

Parallel $k_e = \varnothing k_f + (1-\varnothing).k_m$ .....3.1.1(b)

Since the required materials are arranging in parallel contact as seen in the methodology, a parallel theoretical approach is considered for calculating the properties of sample i.e. paper-fenugreek composite. Where $\mathbf{k_f}$ and $\mathbf{V_f}$ or Φ is the thermal conductivity and fractional volume of reinforcement and $\mathbf{k_m}$ **or** $\mathbf{k_p}$ and $\mathbf{V_p}$ or (1- Φ) is the thermal conductivity and fractional volume of matrix.

$k = k_f V_f + k_p V_p$ ……………Eq 3.1.1(b)

k_f = thermal conductivity of fenugreek= 0.14W/mK

k_p = thermal conductivity of paper= 0.05 W/mK

V_f = fractional volume of fenugreek.

V_p = fractional volume of paper

3.1.2 CALCULATION

1. $V_f = \frac{1}{1+5} \times 100 = 16.66\%$ $V_f : V_P = 1:5$

$V_P = 100 - 16.66 = 83.34\%$

Then $k = k_f V_f + k_p V_P$

$= (0.14\times16.66 + 0.05\times 83.34) / 100$

$= 0.065$ W/mK

2. at 1:7.5 k= 0.06W/mK
3. at 1:10 k= 0.054W/mK

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4. at 2:5 k= 0.075W/mK
5. at 2:7.5 k= 0.069W/mK

3.1.3. Similarly the properties of paper fenugreek composite are calculated:

3.1.3.1. Maximum Temperature

a. Paper - 233°C
b. Fenugreek - 184°C

$T = T_f V_f + T_p V_P$

$=(233\times16.66+184\times83.34) / 100$

$= 185°C$

Paper-Fenugreek

1. at 1:5 - 185°C
2. at 1:7.5 - 227°C
3. **at 1:10 - 229°C**
4. at 2:5 - 218°C
5. at 2:7.5 - 223°C

3.1.3.2 Thermal diffusivity (α): m^2/s

a. Paper - 1.22×10^{-6}
b. Fenugreek- 9.75×10^{-6}

Paper- Fenugreek

1. at 1:5 - 6.54×10^{-6} m^2/s
2. at 1:7.5 - 8.62×10^{-6} m^2/s
3. **at 1:10 - 8.88×10^{-6}** m^2/s
4. at 2:5 - 6.99×10^{-6} m^2/s
5. at 2:7.5 - 7.72×10^{-6} m^2/s

3.1.3.3 Specific heat (c): kJ/kgK

a. C_f = Specific Heat of Fenugreek = 3.045kJ/kgK
b. C_p = Specific Heat of Paper = 1.34 kJ/kgK

For Paper- Fenugreek

1. at 1:5 - 1.62 kJ/kgK
2. at 1:7.5 - 1.54 kJ/kgK
3. **at 1:10 - 1.52 kJ/kgK**
4. at 2:5 - 1.82 kJ/kgK
5. at 2:7.5 - 1.69 kJ/kgK

3.2 SELECTED ASPECT RATIO COMPOSITE

The values obtained in theoretical calculations paper-fenugreek composite, the better aspect ratio is 1:10. The values obtained at 1:10 ratio is shown below.

Thermal diffusivity - 8.88×10^{-6} m^2/s
Specific heat - 1.52 kJ/kgK
Thermal conductivity - 0.05 W/mK

At this ratio the values obtained are better for the composite preparation. Further experimental investigation is conducted on the chosen composite at 1:10 aspect ratio of paper-fenugreek composite.

IV. METHODOLOGY SAMPLE PREPARATION

4.1 PREPATION OF FENUGREEK SEED IN TO PULP:

The seeds are easily available in the market and widely grown in India, as already discussed in introduction chapter. First the fenugreek seeds are of 100 grams are taken and soaked with water about 3days minimum. Then after, soaked fenugreek is grinded in to fine pulp. Precaution is to be taken while grinding, by covering your nose with small cloth. Because a small unordered smell is liberated. But it doesn't affect or create any health problem. The preparation is shown in below fig.

Fig.4.1.1 preparation of fenugreek pulp

4.2 PREPATION OF PAPER IN TO PULP

In the similar manner, 1000 grams of newspapers are taken soaked with water for one day. In the following day the paper is made in to fine particles by tearing. Then again it is dried for one 2 hours in the hot sunny. The dried matter is again soaked with water for 2 more days. After two days, the soaked paper is grinded into pulp using mixture grinder. The preparation is shown below.

Fig.4.1.2 preparation of paper pulp

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4.3 BLENDING OF FENUGREEK PULP AND PAPER PULP

After obtaining both pulps separately, blending has to be done so that they are mixed in proper proportion. Again the grinding machine is turned on .the fenugreek pulp is dropped completely. After that, paper pulp is dropped slowly in small proportions at regular intervals of time. The proportion of both the pulps is blended together for about 30 min. The blended mixture is collected in a container and arranged the pulp in a disk shaped pattern as per the required dimensions.

Fig.4.2.The above figure shows the disc pattern of sample with an outer diameter of 150mm and thickness of 10mm with a hole of 13mm diameter for fixing of bolt.

After that the mixture is dried for 48 hours in atmospheric temperature to make it to solid disc form as per required dimension.

4.4. CONSTRUCTION DETAILS OF EQUIPMENT:

For the table set up we require plywood sheets of length 2 meters, 0.5 meters width and 12mm thickness are cut in rectangular shape by using hacksaw blade, then we drill the 13mm diameter hole on the plywood sheet at the center and, an iron frame of rectangular type made of iron bars of square type attached to a plywood sheet and drill the 5mm diameter holes by using radial drilling machine and fix plywood sheet to the iron frame by using screws and nuts.

Take another plywood sheet of same dimensions for fixing of ammeter, voltmeter, temperature indicator, a switch for on & off and a channel selector. Mark the same dimensions of above components on to the plywood sheet and cut the plywood sheet along the dimensions by using the hammer, chisel, and rough files and fix this plywood sheet to the table by using two iron frames.

Take two rectangular shape mild steel plates of 7 cm length and 3cm of length and joined by welding process in L- shape after that 8mm drills is held on the L-shape frame of both sides by using radial drilling machine. These frames are attached to the backside of the plywood sheet and under the iron frame table joined by using screws and nuts, the construction of table set up is done and finally the paint is coated on table.

Fix the ammeter, voltmeter, temperature indicator, switch and channel selector to the side plywood sheet by using screws and nuts. The horizontal plywood sheet kept as base and a bolt is fixed. A nut of 13mm diameter and 6 inch in length is tight by the first bolt. From that we leave 5cm gap for the nut. Tight the second bolt and after that place the disc shape plates through the nut in the order of plywood disc, testing material of paper and fenugreek disc, aluminium disc, and above that heater is placed. Same material is repeated on the top side of heater. Thermocouples of J-type are connected to all materials in grooves of material by using M seal.

Fig.4.4.1Temperature Indicator Fig.4.4.2 Control Switch.

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Fig.4.4.3 Voltmeter Fig.4.4.4 Voltmeter

Thermocouple: 8 Numbers J-type thermocouples connected to measure temperature at various points between heater, aluminium disc, paper fenugreek composite disc and plywood disc as shown below.

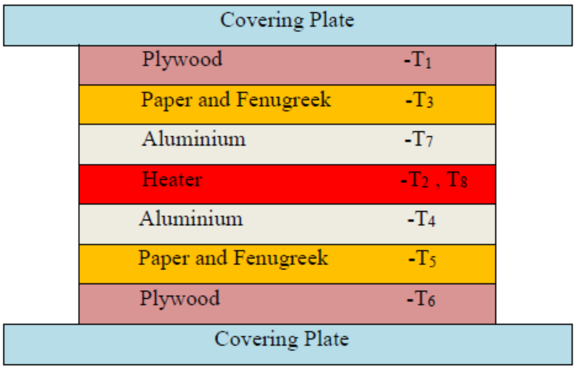

Fig.4.4.5 (a) & (b). Experimental setup with thermocouples

4.5 DIMENSIONS OF SPECIMENS:

The below dimensions which are tabulated below are required to find the thermal conductivity of paper fenugreek composite.

Table 4.5:

Material	Thickness (mm)	Diameter (mm)	Hole Diameter(mm)
Aluminium	10	145	13
Plywood	10	150	13
Paper and Fenugreek	10	150	13

V. PROCEDURE AND OBSERVATIONS

5.1 PROCEDURE:

As described in the previous chapter, the complete details of experimental device design and its construction. In this chapter, investigation of thermal conductivity is done on the device known as guarded hot plate method. Observe the temperatures of each indicator which are thermally coupled. Before starting the experiment care should be taken that all the connections are properly connecter or not.

1. Switch on the power supply to the whole equipment.
2. On the control switch which is connected to the heater, so that the electric current is supplied to the heater.
3. Observe that the temperature channel is at the initial position at T_1 temperature indicator. A thermo couple is also placed around to take the values of ambient temperature.
4. Using Dimmer start, the input voltage is given slowly by rotating the knob in clockwise direction to the heater. The voltage given is recorded by observing from the voltmeter.
5. Current reading is also recorded by observing the Ammeter.
6. Wait for steady state, so that the heat will be uniformly distributed throughout the system.
7. Once the steady state is attained, note down the values of current, voltage and temperature at various points.

Once the steady state is attained, note down the values of current, voltage and temperature at various points.

5.1.1 Formulae:

$$Q = V \times I = \frac{\Delta T}{\frac{1}{2} \times \left(\frac{L_1}{A_1 k_1} + \frac{L_2}{A_2 k_2} + \frac{L_3}{A_3 k_3}\right)}$$

Q = Power (Watts)

V = Voltage (Volts)

I = Current (Amperes)

ΔT = Temperature difference (° C)

L_1 = Thickness of Aluminium (m)

L_2 = Thickness of Paper and Fenugreek (m)

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L_3 = Thickness of Plywood (m)
K_1 = Thermal Conductivity of Aluminium (W/m °K)
K_2= Thermal Conductivity of Paper and Fenugreek (W/m °K)
K_3 = Thermal Conductivity of Plywood (W/m °K)
A_1 = Area of Aluminium (m^2)
A_2 = Area of Paper and Fenugreek (m^2)
A_3 = Area of Plywood (m^2)

5.2 CALICULATIONS:

D1 = 0.145 m A1 = $(\Pi / 4)\, D_1^2 = 0.0165\ m^2$
D2 = 0.150 m A2 = $(\Pi / 4)\, D_2^2 = 0.0176\ m^2$
D3 = 0.150 m A3 = $(\Pi / 4)\, D_3^2 = 0.0176\ m^2$
Voltage V= 80 Volts
Current I = 0.5 Amperes
Power input Q = V×I = 80 × 0.5 = 40 Watts

5.3 Readings at power input of 40 W.

Table 1:

S.No.	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	T_7 (°C)	T_8 (°C)
1.	58	91	79	82	67	55	72	89
2.	59	110	81	89	67	55	92	104
3.	61	126	90	100	72	57	103	114
4.	64	142	98	112	74	60	103	125
5.	67	153	105	120	81	62	103	138
6.	71	164	111	130	86	65	126	145
7.	75	168	115	136	92	69	126	151
8.	79	175	123	149	93	71	126	159
9.	79	176	128	151	100	73	127	160
10.	86	188	136	157	103	74	127	162
11	87	189	139	167	107	77	128	169
12	87	189	139	167	107	77	128	169

$$\Delta T = \frac{169+189}{2} - \frac{87+77}{2} = 97^0K$$

$$40 = \frac{2 \times 97}{\frac{0.01}{205 \times 0.0165} + \frac{0.01}{k_2 \times 0.0165} + \frac{0.01}{0.13 \times 0.0165}}$$

5.4 Readings at power input of 50 W.

Table 2:

S.No.	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	T_7 (°C)	T_8 (°C)
1.	43	110	63	84	55	40	81	93
2.	50	125	79	91	68	45	98	107
3.	55	136	88	96	79	47	110	116
4.	61	150	99	110	92	54	116	124
5.	67	171	117	124	102	57	145	156
6.	73	201	143	140	120	66	173	178
7.	80	209	150	151	128	72	178	185
8.	85	221	162	156	139	76	189	206
9.	90	225	168	160	146	79	190	207
10	91	227	169	163	147	81	191	208
11	92	228	170	164	148	83	191	209
12	92	228	170	164	148	83	191	209

$$\Delta T = \frac{228+209}{2} - \frac{87+83}{2} = 133.5^0K$$

k_2 = 0.0518 W/m°K

5.5 RESULTS:

1. It was observed that the thermal conductivity of paper and fenugreek composite at power at 40 W is 0.0375 W/m °K
2. It was observed that the thermal conductivity of paper and fenugreek composite at power at 50 W is 0.0518 W/m °K

VI. ANALYSIS

6.1PROCEDURES FOR PAPER-FENUGREEK SAMPLE ANALYZING USING ANSYS WORKBENCH:

Go To Start Programmes. Select the Ansys Workbench 14.5. The Below Dialog Box Will Appear I.E.S

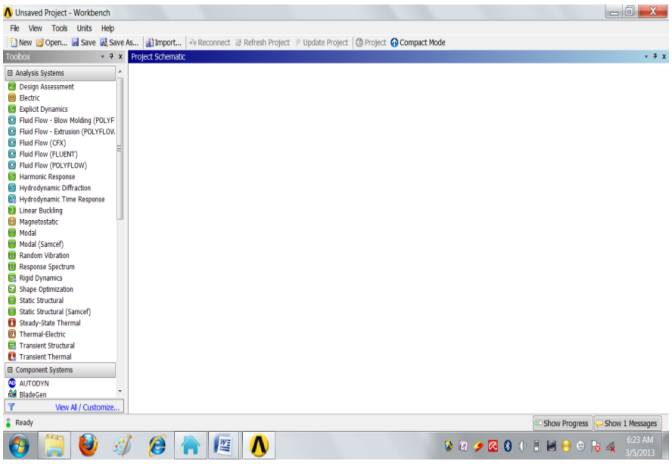


Fig a. Importing of Part Body

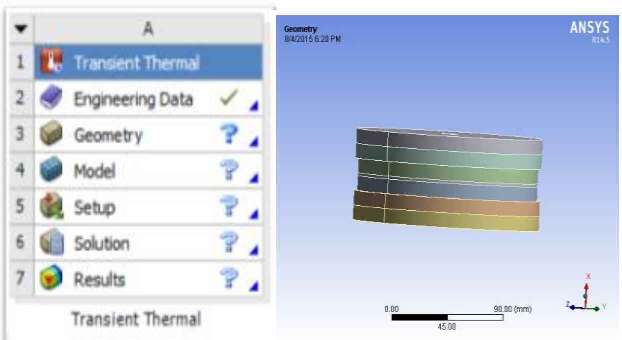


Fig b. Assigning Engineering Data

After importing the part in ANSYS 14.5 using geometry option, engineering data is assigned to each material as shown below.

Mesh and right click generate mesh

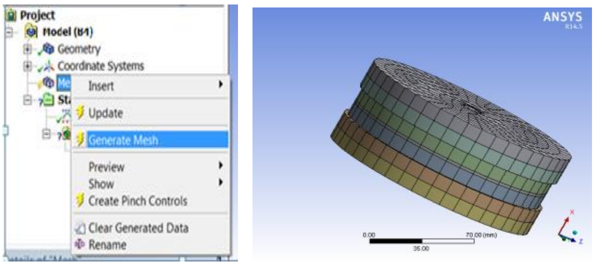
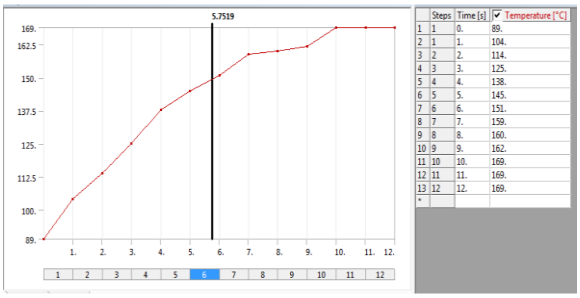


Fig c. Meshing

6.2 INPUT TABLE



	Steps	Time [s]	Temperature [°C]
1	1	0.	89.
2	1	1.	104.
3	2	2.	114.
4	3	3.	125.
5	4	4.	138.
6	5	5.	145.
7	6	6.	151.
8	7	7.	159.
9	8	8.	160.
10	9	9.	162.
11	10	10.	169.
12	11	11.	169.
13	12	12.	169.

Fig d. Input Data

6.3 SOLUTIONS AT 40W:

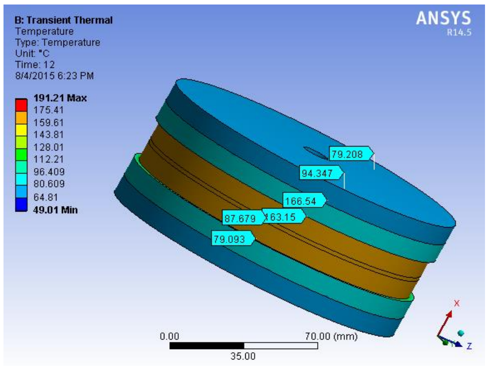


Fig e. Overall Temperature

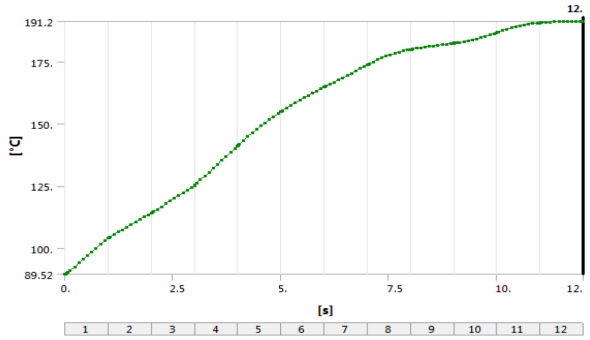


Fig f. Overall Temperatute vs Time graph

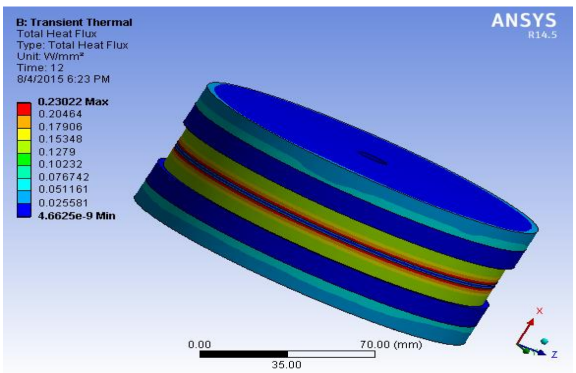


Fig g. Heat Flux

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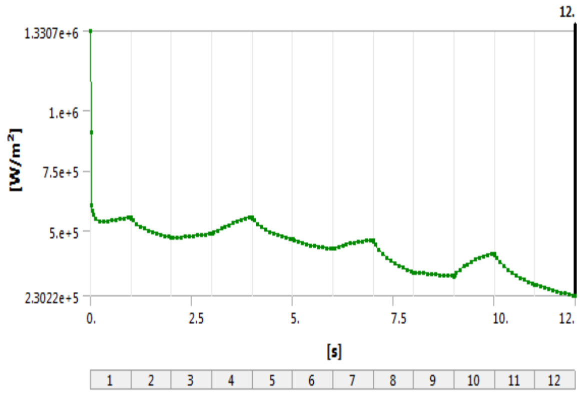

Fig h. Graph of Heat flux vs Time

6.4 SOLUTIONS OF GLASSWOOL

Similarly with the same input, analysis is carried with same inputs of 40W.

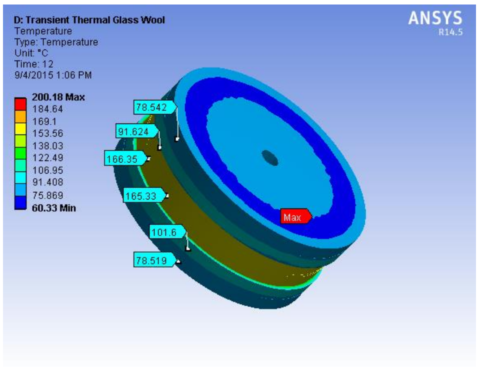

Fig i. Overall Temperatures of Glasswool

6.5 SOLUTIONS OF ASBESTOS

Similarly with the same input, analysis is carried with same inputs of 40W.

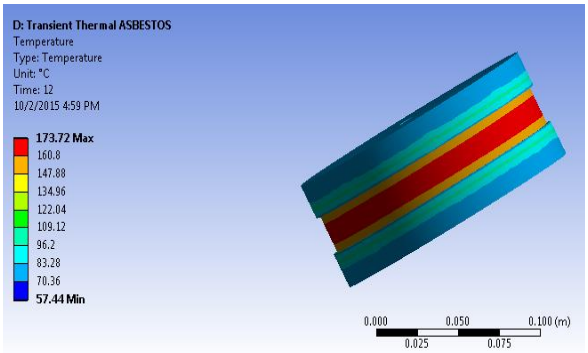

Fig j. Overall Temperatures of Asbestos

VII.RESULTS AND DISCUSSIONS

This chapter discusses the various results obtained for thermal conductivity (k) and maximum temperature with which the sample (Paper-Fenugreek) can withstand.

7.1 THEORETICAL VALUES:

The thermal conductivity is calculated theoretically in the introduction chapter as shown in the below tabular form.

Table 3:

S. No	Ratio V_f : V_p	k W/mK	α m^2/s	C_p kJ/kgK
1	1:5	0.065	6.54×10^{-6}	1.62
2	1:7.5	0.064	8.62×10^{-6}	1.54
3	**1:10**	**0.054**	**8.88×10^{-6}**	**1.52**
4	2:5	0.075	6.99×10^{-6}	1.82
5	2:7.5	0.069	7.72×10^{-6}	1.69

7.2 EXPERIMENTAL VALUES:

From this theoretical analysis, 1:10 ratio is considered and sample is prepared to conduct experimental investigation. The thermal conductivity obtained for different inputs, at 40W of heat supply k = 0.0375W/mK. At 50W input k = 0.0518W/mK.

7.3 ANALYSIS VALUES:

Then after, numerical analysis is done on the same sample using ANSYS 14.5.

7.3.1 COMPARISON:

Comparing the variation of Temperatures vs Time is shown below in the form of graph for Paper-Fenugreek, Glasswool and Asbestos.

Overall Temperature Graph

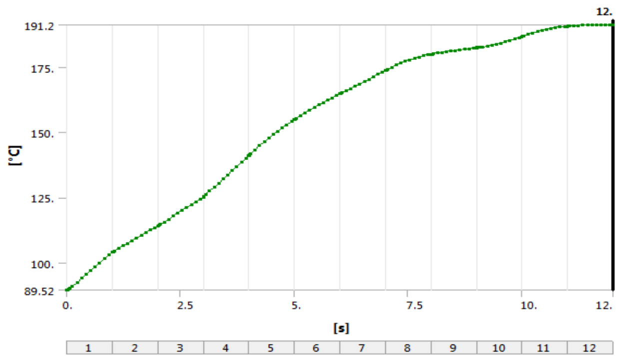

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Fig 7.3.2 (a) Paper-Fenugreek

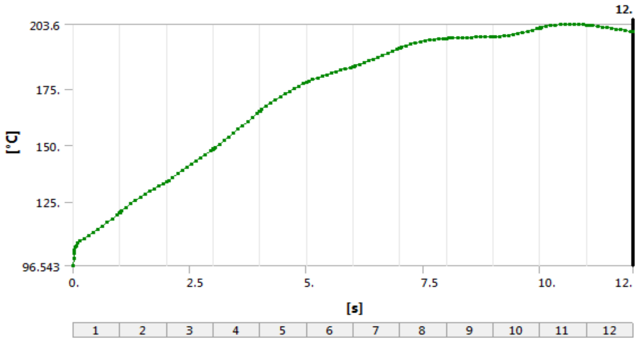

Fig 7.3.2(b) Glasswool

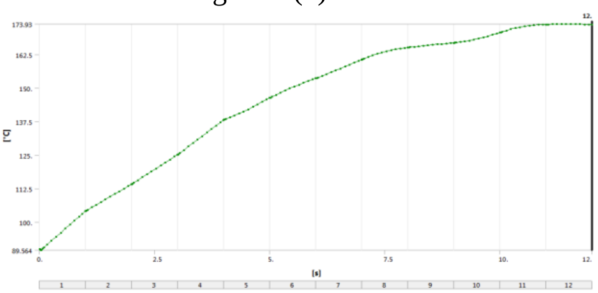

Fig 7.3.2(c) Asbestos

7.3.2 Comparison of total Heat Flux:

The below three graphs a, b, c shows Heat Flux varying with time are compared.

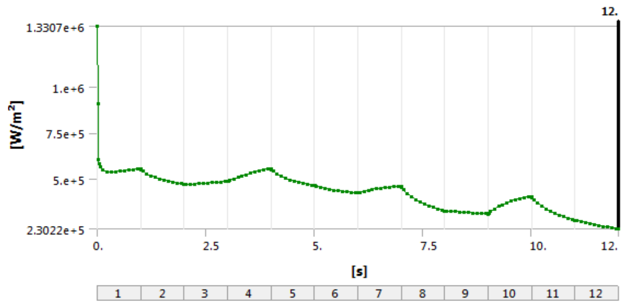

Fig 7.3.2 (a) Paper-Fenugreek

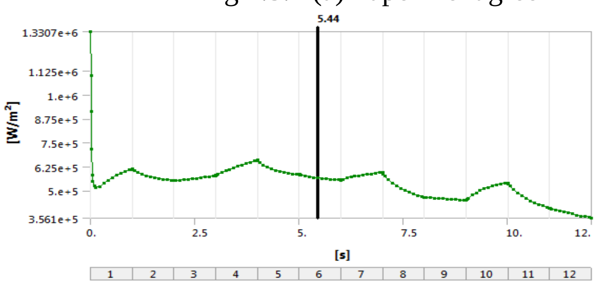

Fig 7.3.2(b) Glasswool

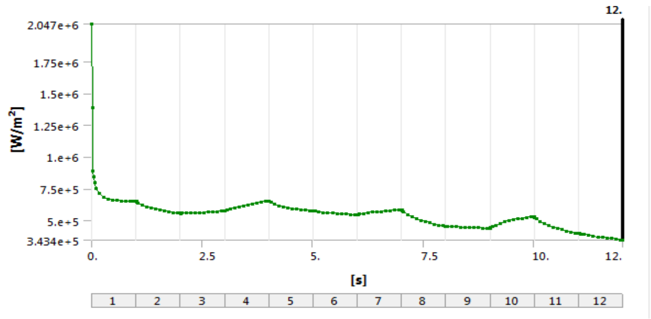

Fig 7.3.2(c) Asbestos

7.4 COMPARISON OF VALUES

The maximum and minimum values of different parameters is shown below

7.4.1 Table-1: Results of sample (paper-fenugreek).

Results				
Type	Overall Temperature (°C)	Total Heat Flux (W/m²)	PAPER-FENUGREEK	Wood
			Temperature °C	
Minimum	49.01	4.6625e-003	47.346 °C	75.721
Maximum	191.21	2.3022e+005	140.07 °C	79.975
Minimum Occurs On	Body.4	Part Body	Body.4	Body.5
Maximum Occurs On	Body.4	Body.3	Body.4	Body.5

7.4.2 Table-2: Results of Glasswool.

Results				
Type	Overall Temperature	Total Heat Flux W/m²	GLASSWOOL	Wood
			Temperature (°C)	
Minimum	60.33 °C	2.0899e-002	68.632 °C	75.27
Maximum	200.18 °C	3.561e+005	178.58 °C	79.607
Minimum Occurs	Body.4	Part Body	Body.4	Body.5
Maximum Occurs	Body.4	Body.3	Body.4	Body.5

7.4.3 Table-3: Results of Asbestos.

Results				
Type	Overall	Total	ASBEST	Wood

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	Temperature	Heat Flux (W/m²)	OS	
			Temperature	
Minimum	57.44 °C	7.4232e-003	57.44 °C	69.88 °C
Maximum	173.72 °C	3.4342e+005	173.72 °C	75.337 °C
Minimum Occurs On	Body.4	Part Body	Body.4	Body.5
Maximum Occurs On	Body.4	Body.3	Body.4	Body.5

VII. CONCLUSION

The results shown low thermal conductivity and hence the rate of heat transfer in the samples is low. Its thermal conductivities ranged from 0.0375 to 0.0518$Wm^{-1}K^{-1}$.

- The preparation of this sample is also easy, not much time taken. The cost is also minimum because it is prepared using waste newspaper and fenugreek seeds.
- Experimental value of Thermal conductivity obtained is optimum compared to the theoretical value.
- By the comparison the sample paper fenugreek is better insulation properties compared to Asbestos and Glasswool for low temperature application up to 200^0C.

In this study a numerical approach (ANSYS) was used to determine the maximum temperature that the sample can withstand. And those values are compared with the theoretically and experimentally.

VIII. RECOMMENDATION FOR FUTURE WORK

1. The variation of thermal conductivity with particle/fibre size and with compaction pressure has been clearly observed. Thermal conductivity increases with increases with increasing compaction pressure and decreasing particle size due to a decrease in porosity.
2. Also a study to be taken as the application of the recommended material (Paper-Fenugreek) as a thermal insulation material to evaluate environmental and health impacts need be carried out using life cycle analysis.
3. The property thermal conductivity of sample can be improved by the addition of ingredients for better application.

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