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Investigation of Thermal Conductivity of Sawdust andConstructing an Environmental Friendly Insulating Container

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ABSTRACT

In this study, thermal conductivity of sawdust under different compression conditions was determined. Lee's disk method was used to determine the thermal conductivity values.. Since sawdust was available in different sizes, the size of the sawdust particles was also taken into consideration in making disks from sawdust. To avoid the crumbling of sawdust, a binder (wood working glue) was used to make these disks. When mixing the binder and sawdust, the volume ratio of sawdust and binder used was kept constant for all the disks. According to the results of this experiment, it was observed that the thermal conductivity of sawdust increased with the compression ratio and sawdust which contained smaller particles showed a higher thermal conductivity. It was clearly seen that the sawdust has higher thermal conductivity thanrigid-foam. Sawdust which contained particles in between 0.5 mm and 1 mm in size with a compression ratio of 1.9 showed a thermal conductivity of 0.069 $Wm^{-1}K^{-1}$.Since the thermal conductivity ofrigid-foam is 0.033 $Wm^{-1}K^{-1}$, sawdust is not a good thermal insulating material asrigid-foam.The other disadvantage is that it absorbs water. Buta special type of box made out of sawdust has the potential of replacing conventionalrigid-foam containers.

1.0 INTRODUCTION

Heat insulation is very important in thermal applications. In thermal applications, insulators are used to keep objects in a constant temperature. So, this process totally depends on the insulating properties of the insulator used. Therefore, if good insulators are used, that is helpful to save the energy. Nowadays, the widely used insulating material is polystyrene foam (rigid-foam). Mainly, it has a very low thermal conductivity of 0.033$Wm^{-1}K^{-1}$[1]. But, availability ofrigid-foam in very low density and at a low cost is also a main reason for the popularity ofrigid-foam as an insulator. Whenrigid-foam is concerned, it is an artificial material. There are disadvantages inrigid-foam. Lots of pollutants are added to the environment even in the production of polystyrene. Another horrible thing about polystyrene is that it takes hundreds of years to break down naturally. Not only that, it could release chemicals which are dangerous to humans health. But, in the food industry, styrene foam is very commonly used as an insulating material. Therefore, looking for a natural insulating material which has an acceptable thermal conductivity for insulation is very important for the environment and humans' health.

2.0 SAWDUST

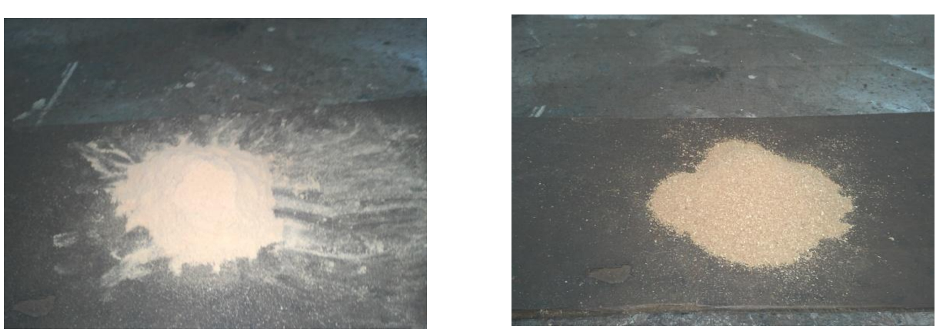
Sawdust is produced in the wood industry by cutting, drilling and sanding wood with a saw or any other tool. The sizes of the sawdust particles depend on the dimensions of the saw or the tool used. Therefore, when a sawdust sample produced from one particular saw or tool is taken, that sample always has a particular distribution of particle sizes[2]. Therefore, sawdust can be categorized according to the particle size. Since, different types of wood are used in wood industry, sawdust also can be categorized according to the type of wood. When sawdust is concerned, it is cheaply available in Sri Lanka. Although, sawdust could be used as a fuel and it is used to make particle boards, most of the time it is treated as awastein wood industry. Because sawdust is produced in huge amounts,sawdust is always put in to the category of garbage.

Sawdust is used in some thermal applications as an insulator by people. For example, sawdust is used to keep ice cubes in constant temperature, when they are transported. But, if sawdust can be used as an insulator in wide range of thermal applications in today's world, that will helpus to replacerigid-foam as it is not good for the environment and the humans' health. In the example mentioned above, sawdust can be used as it is. But sawdust is friable. So, it is a limitation to use sawdust as an insulator. Containers can be rigidly made in any shapeusingrigid-foam. Therefore, rigidness is important in making an insulating vessel with sawdust. For this, a binder should be used. When a binder is chosen for this, there are two facts to be considered. First thing is that the binder should not affect the thermal conductivity of sawdust. The other thing is that the binder should be a natural one. If not, it will not be able to replace rigid-foam.

3.0 METHODOLOGY

3.1 Categorizing sawdust

Since the size of the sawdust particles was concerned in this study, the collected sawdust was categorized into two samples using two sieves (0.5 mm and 1 mm).



(a) (b)

Fig. 1(a) Sawdust particle size < 0.5 mm(b) 0.5mm<sawdust particle size < 1 mm

3.2 Determining thermal conductivity

Lee's disk method was used to determine the thermal conductivity of sawdust. For this, sawdust has to be in the form of disks. Therefore, sawdust disks with different compression ratios were made from the above two sawdust samples. For this, a hydraulic compressor with a special mould was used.

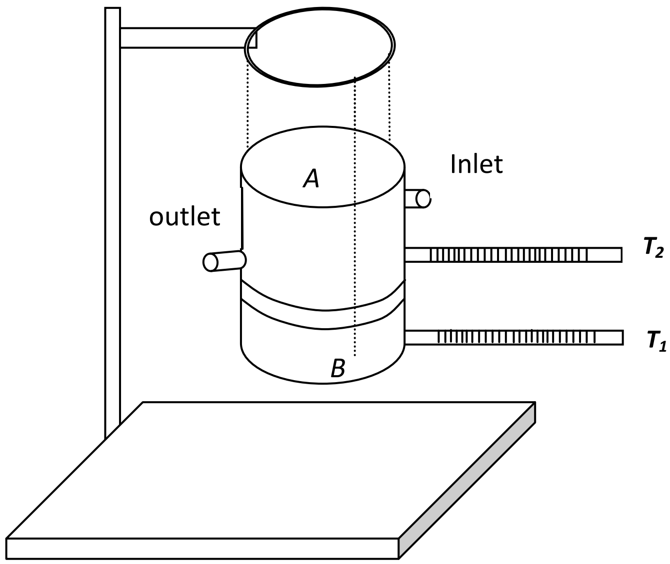


Fig.2: Lee'sDisk Apparatus

The sample is placed in between steam chest *A* and metal disk *B*. Then, steam is supplied to the steam chest through the inlet. Complete system was freely suspended in the atmosphere. When the steam is passing through the chest, heat flows through the sample to the metal disk *B*. Then, the heat is emitted from the surface of the metal disk. Once, the rate of heat conducted through the sample to the metal disk B is equal to the rate of heat emitted from the surface of the metal disk *B*, the temperatures T_1 and T_2 become steady. At this time, it is said that the system has reached steady state.

If *M* is the mass of the metal disk *B* and its specific heat capacity is *C*, then the rate of heat emitted from the metal disk is given by,

$$\frac{dQ}{dt} = MC \times \frac{dT}{dt} \quad \text{.........(1)}$$

Here, $\frac{dT}{dt}$ is the rate of change of temperature of the metal disk *B* at T_1.

At the steady state, the rate of heat conducted through the sample is given by,

$$\frac{dQ}{dt} = \frac{k\pi r^2 (T_2 - T_1)}{d} \quad \text{.........(2)}$$

Here, k is the thermal conductivity of the sample, r is the radius of the disk and d is the thickness of the disk.

By equating the equations (1) and (2),

$$\frac{k\pi r^2 (T_2 - T_1)}{d} = MC \times \frac{dT}{dt}$$

$$k = [MCd / \pi r^2 (T_2 - T_1)] \times \frac{dT}{dt} \quad \text{.......} (3)$$

But, when the system reaches the steady state, the heat does not emit from top face of the metal disk B. Therefore, the actual rate of heat emitted from the metal is given by,

$$\frac{dQ}{dt} = \frac{k\pi r^2 (T_2 - T_1)}{d} \times f \quad \text{.......} (4)$$

where, $f = \dfrac{(r+2h)}{2(r+h)}$ ....(5)

Here, h is the thickness of the metal disk B

Therefore, $k = [MCd / \pi r^2 (T_2 - T_1)] \times \dfrac{dT}{dt} \times f$ .... (6)

For obtaining dT/dt at T_1 (at steady state temperature), the metal disk was heated about 10 °C above $T_1$and it was allowed to cool (without the sample). The temperatures were recorded in every 30 seconds.

4.0 RESULTS AND DISCUSSION

Table 1: Thermal Conductivity of Sawdust which Contains particle less than 0.5 mm in size.

Disk	Compression Ratio	Thermal Conductivity ($Wm^{-1}K^{-1}$)
1	1.821±0.006	0.081±0.001
2	2.376±0.006	0.089±0.001
3	2.815±0.006	0.092±0.001
4	3.135±0.004	0.097±0.001
5	3.5191±0.0003	0.100±0.001
6	4.1667±0.0003	0.104±0.001

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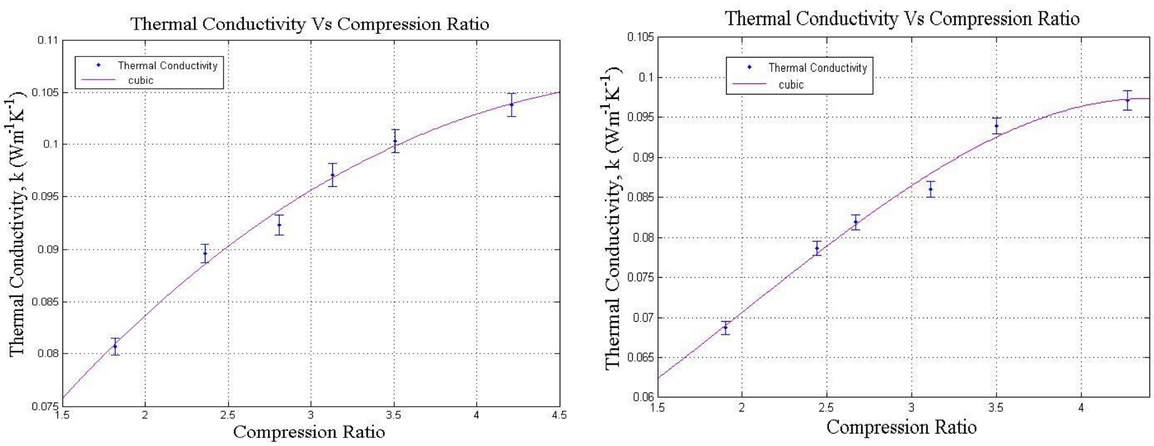
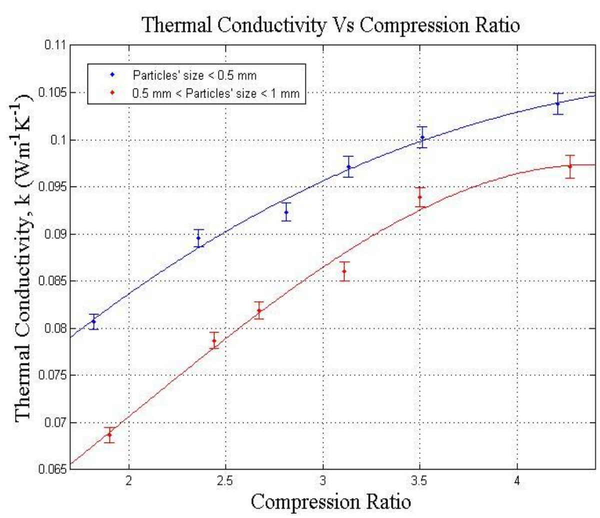
Table2: Thermal Conductivity of Sawdust with particles in between 0.5 mm and 1 mm in size.

Disk	Compression Ratio	Thermal Conductivity ($Wm^{-1}K^{-1}$)
1	1.903± 0.004	0.0690 ± 0.001
2	2.435±0.004	0.079 ± 0.001
3	2.662±0.003	0.082 ± 0.001
4	3.109±0.004	0.086 ± 0.001
5	3.498±0.004	0.094 ± 0.001
6	4.276±0.005	0.097 ± 0.001



(a)(b)

Fig. 3:
(a) Thermal Conductivity of Sawdust which Contains particle less than 0.5 mm in size.
(b) Thermal Conductivity of Sawdust with particles in between 0.5 mm and 1 mm in size.



Fig, 4: Comparison of Thermal Conductivity of two sawdust samples

It can be seen that the thermal conductivity of sawdust increases with the compression ratio (Fig. 3) and the sawdust sample which contained smaller particles showed a higher thermal conductivity (Fig.4). If it is required to obtain a lower thermal conductivity from sawdust, sawdust particles should not be too small and sawdust should have a lower compression ratio. But, the lower the compression ratio is the lower the strength of sawdust walls. When constructing a container from sawdust, attention has to be paid to the strength of that container. Therefore, sawdust with these compression ratiosdoes not help to replacerigid-foam which has a lower thermal conductivity as $0.033 Wm^{-1}K^{-1}$[1].

4.1 Constructing an insulating container from sawdust

As sawdust shows a higher thermal conductivity thanrigid-foam, sawdust cannot be directly used to replacerigid-foam. But an insulating wall canbe made from sawdust using the fact that the air has a very low thermal conductivity as $0.024\ Wm^{-1}K^{-1}$[1].

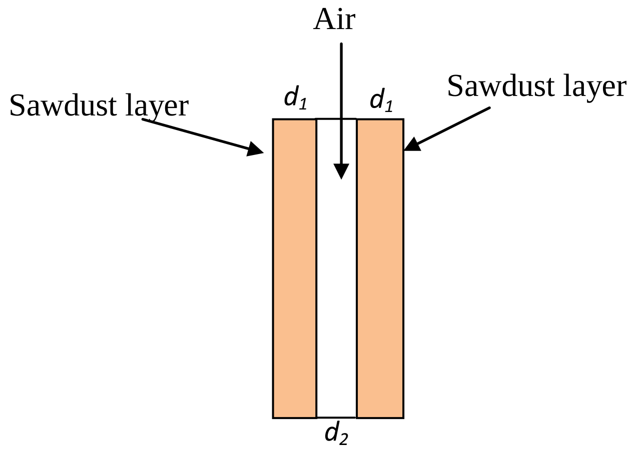


Fig.5: Double layered sawdust wall

Let K_s=Thermal conductivity of sawdust, K_a=Thermal conductivity of air.

Then, it can be shown that the effective thermal conductivity of the wall,

$$K_e = \left(\frac{K_s K_a (2d_1 + d_2)}{(2d_1 K_a + d_2 K_s)} \right) \qquad (7)$$

When the thickness of the air layer (d_2) is greater than zero, the effective thermal conductivity (K_e) is always smaller than the thermal conductivity of sawdust (K_s).

An insulating container was made using above technique. For this, sawdust with particles in between 0.5 mm and 1 mm and a compression ratio of 2 was used. Then, the sawdust layers had an approximate thermal conductivity of $0.07 Wm^{-1}K^{-1}$. The thicknesses of the sawdust layers and the air layer (d_1 and d_2) were chosen to be 6 mm. Therefore, the effective thermalconductivity of a wall of the container (according to the equation (7)) was 0.0427 $Wm^{-1}K^{-1}$. The container was made in the shape of box with height of 15 cm, width of 15 cm and length of 19 cm. But, practically this box cannot be used to store cold objects,because sawdust absorbs water. To overcome this, a very thin aluminum foil was used to cover the inner surface of the box. This aluminum foil also helps to reduce the heat transmitted into the box by radiation.

4.2 Testing the insulating box and its results

Even though, the walls of the insulating box made had a low thermal conductivity, it was tested to find weather it works as a good insulating container. For this, the box was filled with ice cubes of 770 g and it was kept in a temperature of 26°C. After ten hours, the ice cubes were taken out. Then it was observed that some amount of ice cubes had converted into water.After removing the water, the mass of the ice cubes was measured. It was 465 g. Therefore, it can be said that 60% of the ice cubes were as ice. Only 40% of the ice cubes had converted into water

Fig. 6: Insulating Box

4.3 Further improvements

An insulating box can be made from sawdust to store ice cube for a longer period of time than now by increasing the air layer of the box. Because, then, the rate of heat transmitted into the box decreases. In making the insulating box, it was considered only the transmittance of heat by only conduction. But, air can transmit heat by convection. The air can go through even through the sawdust layers. Therefore, it might be a disadvantage. To overcome this, a sealer can be used to cover the two inner surfaces of the walls of the insulating box. Then it will be a help to trap the air well in the inner layer. When the air is well trapped in between two walls, it will help to minimize the heat transfer by convection.

5.0 CONCLUSIONS

Thermal conductivity of sawdust increases with their compression ratio.But, the rate of increase of thermal conductivity decreases with the compression ratio (Fig. 3).Thermal conductivity of sawdust has a relationship with its particle sizes.Sawdust which contains smaller particles has a higher thermal conductivity.Sawdust is not good for insulating as rigid-foam. Since sawdust absorbs water, it is also a practical problem to use sawdust as an insulator.But boxes unsheathed by aluminum foils with air cavities inside could be used effectively instead ofrigid-foam containers.

REFERENCES

1. D R Lide, *Hand book of Chemistry and Physics*.84th edition.(CRC Press, (2003-2004)
2. T Vítez, P Travnicek, *Particle size distribution of sawdust and wood shavings mixtures*, Re .Agr. Eng.56(4),(2010), 154–158