SISAL FIBER (*Agave sisalana*) AS THERMAL INSULATOR OF MANIFOLD

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Abstract. *Natural fibers are frequently used as insulanting material, principally in composites, with excellent thermal insulation properties. In the present work, we have investigated the thermal behaviour of a sisal fiber blanket and its thermal properties. The results shown the viability of the use of this material as a thermal insulating for industrial applications, due to its low thermal conductivity.*

Keywords*: thermal insulation, natural fiber, Agave sisalana*

1. Introduction

The motivation in pipe insulation is often to reduce the total cost, that is, the cost of the insulation, its installation and maintenance as well as the cost of the energy lost (Sahin and Kalyon, 2004).

The cost increasing in the synthetic fibers and their consequences to the environment have forced scientists and engineers to search for alternatives for the synthesis of new products, which must to have mainly a low cost-effective and environmentally friendly material. In this context, the inclusion of natural fiber over synthetic fiber in polymers matrix has gained momentum during last decade (Mangal *et al*, 2002).

Low cost cellulose based nonwoven composites, with excellent thermal insulation properties, fabricated from kenaf, jute, flax and waste cotton, were studied by Yachmenev, Parikh and Calamari (2002) for automotive applications.

Mendes and Marinho (2002) analyzed the micro-structural, thermal and physical properties of coconut fiber and latex for use in composites as a thermal insulator applied to hot (180ºC) and cold systems (0ºC).

Evseeva and Tanaeva (2004) studied the influence of the impregnation degree of two inorganic agglutinants, in the thermal properties of a fibrous natural material for thermal insulation.

The objective of the present work is to analyze some thermal properties and the thermal behavior of sisal fiber blanket. The use of sisal fiber, besides providing significant decrease in the costs of thermal insulation when compared with conventional materials, has a commercial appeal and it is an environmentally friendly material. Those factors can contribute to join value to the product and to diversify the industrial application of the sisal fiber and, consequently, improve the social condition of the peasants of poor regions of 3rd word countries.

2. Experimental

To viability of this research, there were considered the conditions of laboratories of governmental universities of the 3rd word countries; thus, the instrumentation used during the experiments were that commonly used to educational activities (except the thermal sensor calibration apparatus).

2.1. Materials

The samples of blankets of sisal fibers (Fig.1) were supplied by TECSAL/BA, with density 1200-1400 g/m^2 and 0,01m of thickness.

Figure 1. Blanket of sisal fibers

2.2. Instrumentation

The experimental determination of the thermophysical properties of the blankets of sisal was made using a Thermal Conductivity Meter (model Quickline-30 – ABX-99), as shown in Fig. 2.

Figure 2. Thermal Conductivity Meter (model Quickline-30 – ABX-99)

The experiments were carried out at the temperature of 40 ºC, in agreement with the specifications of the equipment's manual. The samples had dimensions of 0,20m x 0,15m x 0,01m.

The mean values of the thermal conductivity "k" and the volumetric specific heat "c_p" of the sisal blanket were determinate considering the average of three independent measurements.

The overall accuracy of the measurements of "k" and "c_p" was respectively 5% of the reading + 0,001W/mK and 15% of reading + $1x10^3$J/m^{3}K, and the reproducibility of the results was 3% of reading + 0,001 W/mK and 3% of reading + $1x10^3$ J/m^{3}K.

2.3. Experimental apparatus

The experimental apparatus was constituted of a tube of stainless steel with diameter of 0,05m and 0,20m of length (Fig. 3) with an electric resistance inside (41 Ω), which was connected to a voltage regulator (30V ± 3V) and a multimeter.

Temperature sensors were fixed at the surface of the tube and to a temperature data acquisition system, that was connected to a microcomputer.

To analyze the thermal stability of the tube, T–type thermocouples were used for the temperature measurements; after the calibration, the thermocouples were fixed with epoxy resin in 7 different points along the surface of the tube, as can be seen in the Fig. 4.

Each one of the three experiments was carried out during approximately 6 hours, in a laboratory with controlled ambient temperature (30 ºC ± 2ºC).

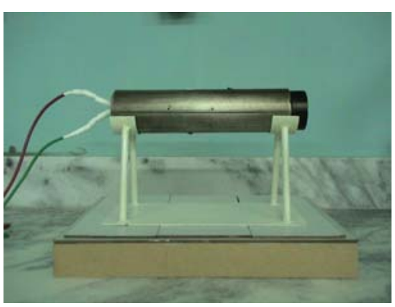

Figure 3. Tube of stainless steel

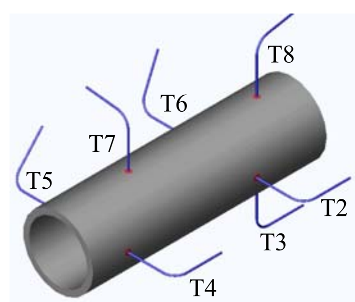

Fig. 4. Distribution of thermocouples

To simulate the thermal behavior of the sisal as a thermal insulating material of manifolds, the blanket was fixed at the tube surface, as can be seen in Fig. 5.

The distribution of the thermocouples (Fig. 6) is in agreement with the following description: T4 and T7 were glued in the surface of the tube with epoxy resin; T3 and T5 were fixed in the interface between the tube and the blanket; T2 and T6 were put in a cavity with 0,005m of depth inside the blanket; and T8 was put in the surface of the blanket.

The complete experimental apparatus is shown in Fig. 7. In this configuration, each experiment were carried out during approximately 8 hours, in a laboratory with ambient temperature of 25±3 ºC.

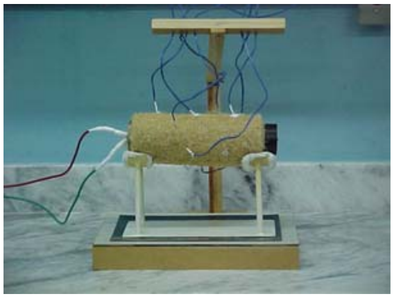

Figure 5. Fixation of the blanket

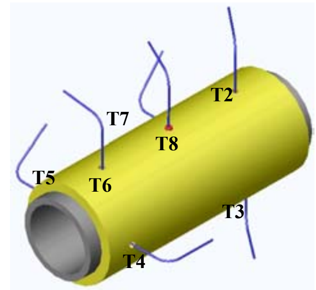

Figure 6. Distribution of the thermocouples

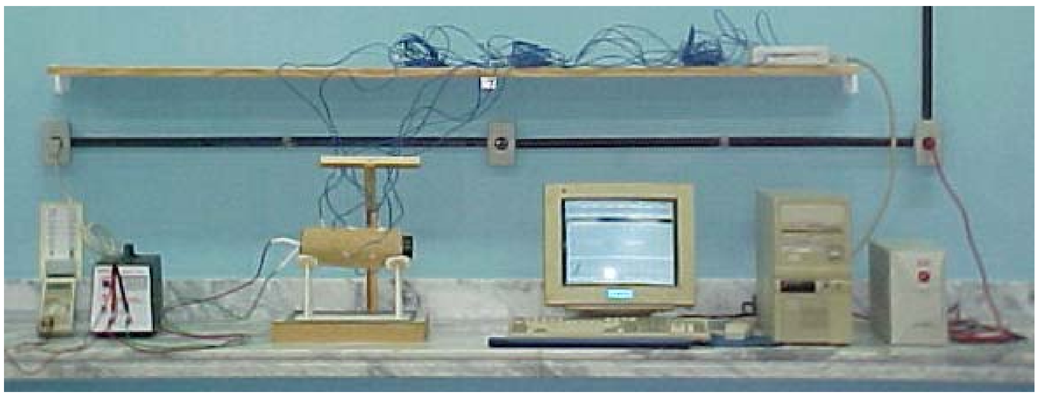

Figure 7. Experimental apparatus

3. Results and discussion

3.1. Thermal properties

One of the most important properties of the thermal insulators materials is the thermal conductivity (“k”). Kaganer (1966) observed that, among the fibrous materials, the value of the “k” of thermal insulating materials is affected mainly by the density and the type of the fiber, the size and location of the pores, and the type and the pressure of the gas confined inside the pores. Besides of these parameters, the factors that can modify the results of the experimental thermal conductivity determination are: thermal contact, fluctuations of temperature, non homogeneity, anisotropy and content of humidity of the material. The averages of the thermal properties of sisal blanket are presented in Tab. 1.

Table 1. Thermal properties of sisal blanket

Thermal properties	
k (W/mK)	0,067
c_p (J/m³K)	217×10^3
α (m²/h)	0,0011

The measured values of “k” was not very different from those of commercial thermal insulators materials, as glass wool (0,039 W/mK) and rock wool (0,036 W/mK), for instance (Incropera and Dewitt, 1992).

The volumetric specific heat (“c_p”) is an intrinsic characteristic of materials. The “c_p” of thermal insulating materials usually presents higher values comparing with the “c_p” of other materials; this is because it needs more energy to range over its temperature.

The thermal diffusivity (“α”) is a property of the material that denotes the reason between the capacity of heat transfer of the material and its capacity of storage of the thermal energy.

Thermal insulating materials present low values of “α” when compared with other kinds of materials. Analyzing the value of “α” presented in Tab. 1, we can observe that the sisal presents a value not very different from those of commercial thermal insulators, as glass wool (0,0011 m²/h) and rock wool (0,0009 m²/h), Kreith (1998).

3.2. Thermal stability of the tube

Three experiments were carried out for analyzing the thermal stability of the tube; one of them is shown in Fig. 8. The average temperature difference between the points T2 and T4 was around 15 ºC; between T5 and T6 was around 2,2 ºC; for the points T7 and T8 it was around 17 ºC; between the points T3 and T8 was around 10 ºC; and between T7 and T8 was around 6,4 ºC. Those differences may be considered acceptable, once there were consequence of the convective currents inside the tube.

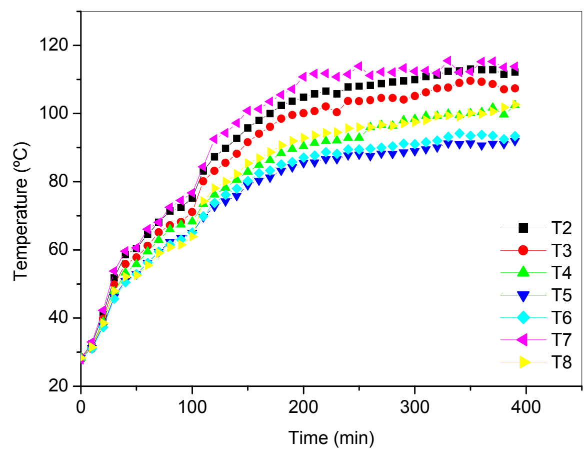

Figure 8. Thermal stability of the tube test

3.2. Thermal behavior of the sisal blanket

Once analyzed the thermal stability of the tube, it was initiated the experiments to evaluate the thermal behavior of the sisal blanket applied to thermal insulation of the tube. The results of the experiments are shown in Fig.9.

The maximum tube surface temperature was around 160°C, and it was detected by the thermocouple T7. Keeping the room temperature at 25±3ºC, in all of the three experiments, the temperature detected by the thermocouple T8 was around 60 ºC, as it can be seen in Fig. 9.

The differences between the temperatures of the surface of the blanket (T8) and the other temperatures (T2 to T7) are shown in Tab.2.

Table 2. Gradient of temperatures T2 to T7 and the temperature of the surface of the blanket (T8)

Experiment	T2-T8 (ºC)	T3-T8 (ºC)	T4-T8 (ºC)	T5-T8 (ºC)	T6-T8 (ºC)	T7-T8 (ºC)
1	11,85	33,41	69,18	49,82	09,54	88,39
2	07,00	32,32	68,41	48,70	04,90	89,50
3	07,00	26,46	56,90	42,70	03,50	79,90
average	**08,61**	**30,73**	**64,83**	**47,07**	**05,98**	**85,93**

It was verified that the sisal was not very resistant to applications beyond 160 ºC, as can be seen in Fig. 10; we can notice that the blanket changed its color from natural to dark brown, which is attributable to the carbonization of the fibers, as a consequence of the heating of the tube, indicated the beginning of the burning. It happened just in the contact area of the blanket with the surface of the tube.

In spite of that, for the temperature gradients between the surface of the tube and the blanket, significant values were observed:

- between T7 (surface of the tube) and T8 (surface of the blanket) it was approximately 85 ºC;
- between T4 and T8 (just 0,01m of thickness of blanket) it was around 64 ºC;
- between T2 and T8 it was approximately 8ºC;
- between T6 and T8 (0,005m of thickness of blanket) it was approximately 6ºC.

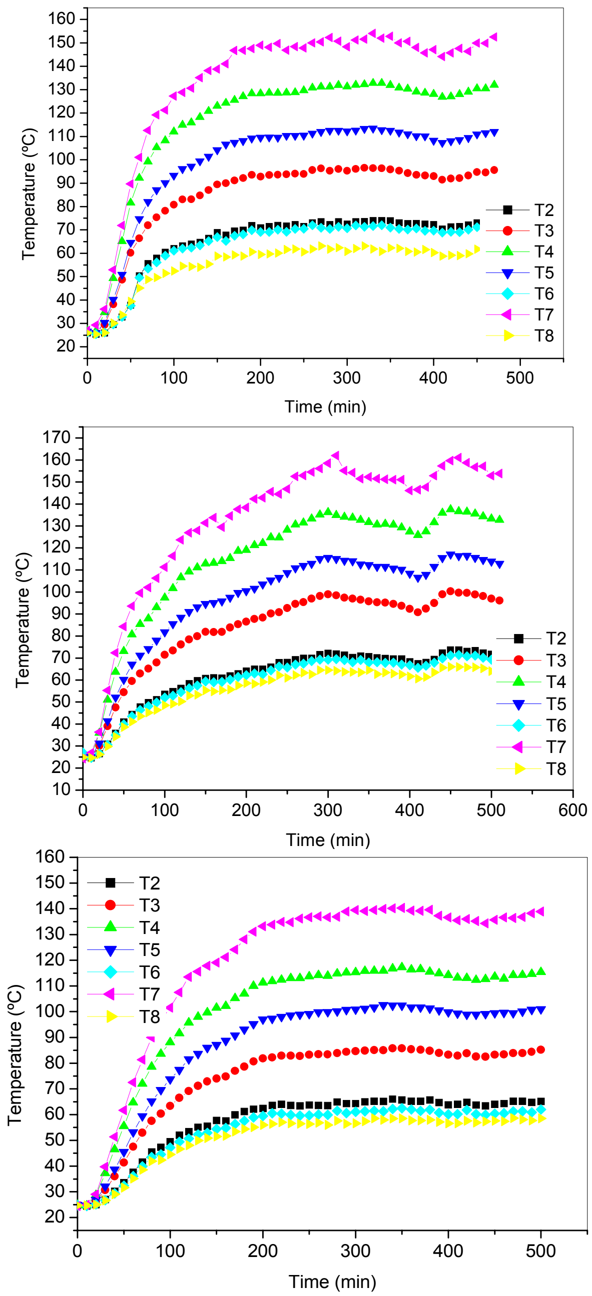

Figure 9. Thermal behavior of sisal blanket tests

Figure 10. Blanket after the experiments

4. Conclusions

The thermophysical properties ("k", "c_p" and "α") of the sisal blanket determinate during the experiments were not very different from those of commercial thermal insulation materials.

Regarding the geometry of the blankets (plain plate form), due its flexibility, it can be adapted to the geometry of curved surfaces, as in the case of manifolds.

In utilization of this material, one must take in account that its structure changes with heating to temperatures above 160 ºC. However, there are many situations in industry, as well as in domestic application, where the temperature does not reach more than 150°C. Thus, the use of sisal blanket, besides providing significant decrease in the costs of thermal insulation when compared with the commercial materials, configures a viable alternative that can contribute to join value to the product and to diversify the industrial application of the sisal fiber, improving the social situation of peasants of the 3rd world countries.

5. Acknowledgements

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6. References

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