COMPARATIVE STUDY OF MATERIAL WITH BETTER PERFORMANCE IN TERMS OF THERMAL ABSORPTION INSIDE AN AIRCRAFT

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Keywords: *PET wool, Glass wool, Aircraft, Thermal absorption*

Abstract

This project proposes a comparative study of material with better performance in terms of thermal absorption inside an aircraft. The material to be compared are PET wool and glass wool.

1 Introduction

With the significant growth of commercial aviation producing aircraft with differentiated levels of comfort, it has become an important marketing and sales tool. With the purpose of guaranteeing favorable thermal comfort, respecting the environment and the norms applied to aircraft, this project proposes a comparative study of material with better performance in terms of thermal absorption inside an aircraft. The material to be compared are PET (Polyethylene terephthalate) wool and glass wool, where the second, respectively, is already used in the coating of aircraft. However, PET wool is more cost-effective than glass in the face of ecological, economic and thermal absorption aspects. All this validation was possible with CATIA, SolidWorks and Novus FieldLogger.

KORPELA & HOUSTON, students of heat transference area, analyzed and proved, in a study in 1982 that was consisted to measure the heat transference through a glass wool between two plates and by means he proved that the glass wool has a higher quality insulation performance [2].

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2 Objectives

2.1 General objective

Heat is the form of energy that can be transferred from one system to another as a result of the temperature difference. This energy transference is processed from the environment of higher temperature to the environment of lower temperature and ceases when the two sides get to equilibrium. Heat can be transferred in three different ways: conduction, convection and radiation. Knowing this concept, it is desired to experimentally verify the thermal conduction of PET wool and glass wool. To start the study, a specimen made of aeronautical aluminum, PET wool, glass wool and a source of heat was submitted to tests.

2.2 Specific objective

Verify the thermal conduction of PET wool and glass wool using the results to compare the efficiency of each one and obtain the conclusion of which is the best wool to be used inside an aircraft considering the conditions similar to those used in the laboratory.

3 Bibliographic Revision

The thermal energy balance in a system by the law of conservation of energy is given by the equation (1):

$$E_{ent} + E_g - E_{sai} = E_{acu} \quad (1)$$

That,

- E_{ent}: energy entering the system;
- E_g: energy generated by the system;
- E_{sai}: energy that leaves the system;
- E_{acu}: energy acumulated in system.

For a system that does not generate energy E_g=0 and in a steady system E_{acu}=0.

Therefore, the energy balance is defined in equation (2)

$$E_{ent} = E_{sai} \quad (2)$$

the calorimetry equation is expressed in (3) [3]

$$q = \dot{m}c_p\Delta T \quad (3)$$

Where q is the heat transferred, $\dot{m}$ is the mass flow, c_p is the specific heat and ΔT is the inlet and outlet temperatures of the fluid.

Conduction is the transfer of energy from the higher energy particles to the lower energy particles in solid, liquid or gaseous system. In solids the transfer takes place because of the combination of the vibrations of the molecules and the energy is carried by the free electrons. The rate of conduction of heat by a system depends on the geometry, the thickness, the type of material and the temperature difference in which the medium is subjected.

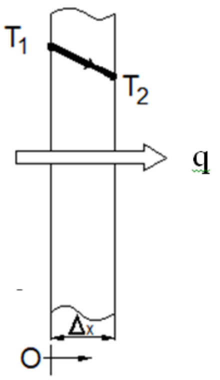


Fig. 1. Direction of the Heat Transference in a flat wall. (Own authorship)

Considering heat transfer at steady system through a flat wall of thickness Δx = L and area A, the temperature difference across the wall is $\Delta T = T_2 - T_1$. Experiments show that the rate of heat transfer Q through the wall doubles when the temperature difference ΔT or the normal area A towards the heat transfer is doubled. If the thickness L of the wall is reduced by half, the transfer Q is doubled. Then it is concluded that the rate of heat transfer through a flat layer is proportional to the temperature difference across the layer and the area A; and inversely proportional to the thickness of the layer according to equation (4) [3]:

$$q = k \cdot A \cdot \frac{T_2 - T_1}{\Delta x} = -k \cdot A \cdot \frac{dT}{dx} \quad (4)$$

Where,

- *K: thermal conductivity constant;*
- A: area of the material;
- T_n: temperature;
- $\frac{dT}{dx}$: temperature gradient.

Furthermore, the temperature in the flat wall can be given by the equation (5):

$$T = T_0 + \frac{dT}{dx}\Delta x \quad (5)$$

4 Laboratory measurements

To carry out the experiment, a specimen was designed with the characteristics similar to the aircraft fuselage. After that, the measurement inside the cockpit of a Hawker 800 aircraft was performed to give greater credibility to the results.

4.1 Materials and equipment used for laboratory measurement

- Aeronautical aluminum sheets (0,04');

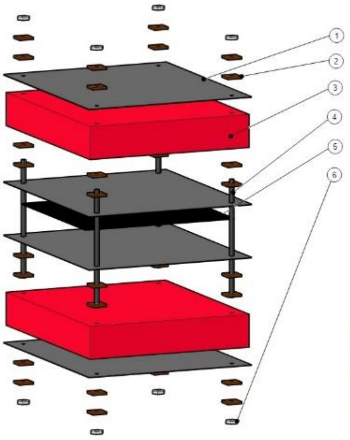
- PET wool and glass wool;

- Box for thermal insulation (styrofoam and cork);

- Heat Source, Heated Bed, 24 Volt;
- Voltage source, Minipa mpl 1303M;
- White silicone, Loctite;
- Eight K-type thermocouples;
- One 8-channel Novus data collector;

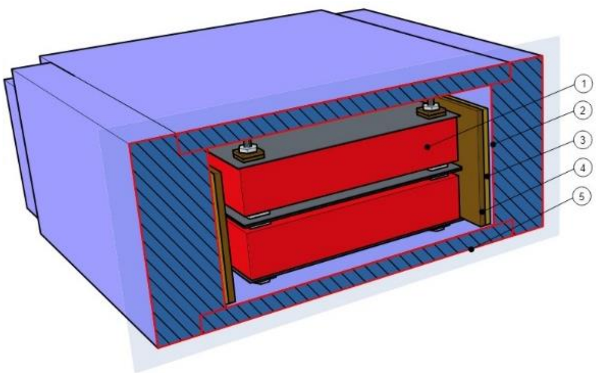
-Notebook with software FieldLogger v1.2.1.

To fasten the cold and hot plates, four screw joints and nuts were used between the plates and the glass wool as can be seen in Fig. 1 and Fig. 2.



Description	BOM ID	Qty	Color
Aluminum plate	1	4	
Cork	2	32	
Heating plate	5	1	
Insulation wool	3	2	
Nut	6	8	
Screw joint	4	4	

Fig. 1. Specimen Assembly (Representative Model). (Own authorship)



Description	BOM ID	Qty
Cork sheet	4	3
Plywood board	3	3
Specimen	1	1
Styrofoam cover	5	2
Styrofoam wall	2	4

Fig. 2. Design of the Laboratory Experiment Set Using CATIA Software. (Own authorship)

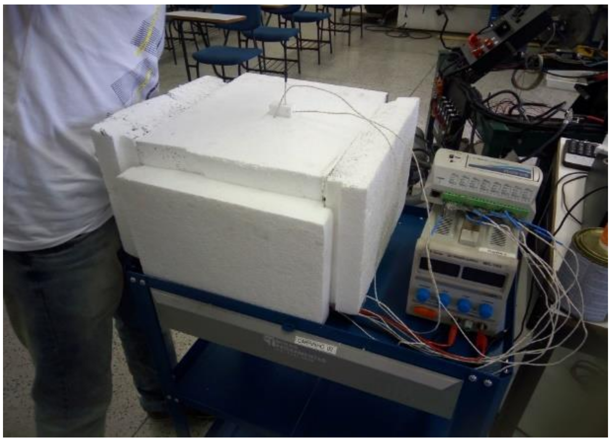


Fig. 3. Specimen Assembly. (Own authorship)

4.2 Procedure of the laboratory measurement

Initially, the heat source was installed in the center of the specimen, between aeronautical aluminum plates, so that the heat transmitted by it is dissipated unidirectionally up and down. In this way, the wool was placed based in a format similar to the aircraft fuselage using the aeronautical aluminum plates. The thermocouples were positioned to measure this heat flow. As shown on Fig. 4. one thermocouple was positioned in the heat source, two below the first aluminum plate (top plate), two after the test wool, and two other thermocouples after the last aeronautical aluminum plate (bottom plate), being spaced about 75 *mm* horizontally and about 100 *mm* vertically (based on the thickness of the wool and sheets).

Fig. 4. Location of the Thermocouples on the Specimen. (Own authorship)

After assembly and instrumentation described in the previous items, the data collection was started. It took about an hour and a half for the system to reach its steady state. This phenomenon was followed by observing the graph on the desktop screen. After entering the steady state, it took about 20 to 30 minutes to complete the experiment, ensuring that data was collected in this regime.

5 Results obtained in laboratory

Differential behavior was observed between different types of wools; Black PET wool, Grey PET wool, White PET wool, and Glass wool. It was possible to verify the existing temperature differences after establishing a permanent regime in the respective tests. To facilitate visualization of the thermocouples, they were numbered in ascending order preceded by the letter "T" as shown on Fig. 5 and the Table 1.

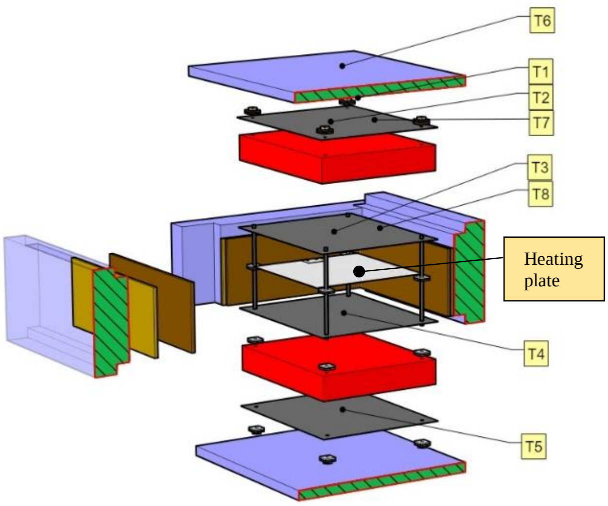
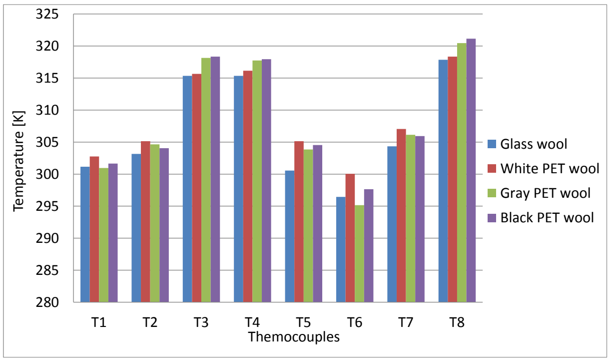


Fig. 5. Location of the Thermocouples. (Own authorship)

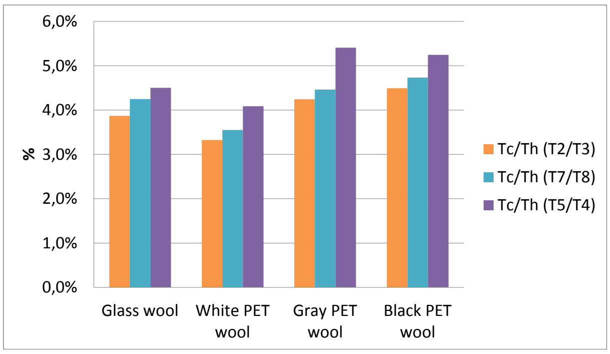
	Location of the Thermocouples
T1	Internal temperature of the specimen
T2	Cold Top Plate
T3	Hot Top Plate
T4	Bottom Hot Plate
T5	Bottom Cold Plate
T6	External temperature of the specimen
T7	Sideline of the Cold Top Plate
T8	Sideline of the Hot Top Plate

Table 1. Thermocouple Position



Graph 1. Steady State Temperatures

It was necessary to make a ratio with the temperatures to compare the heat insulation of each wool, as shown in the graph below. The ratio informs about the how much heat was absorbed, knowing the heat source temperature.



Graph 2. Comparison of temperature variation

6 Test on the aircraft

6.1 Materials and equipment used in aircraft tests

- One Hawker 800 aircraft;
- One 8-channel *Novus* data collector;
- Eight K-type thermocouples;
- Thermocouple fixing tape;
- Notebook with software *FieldLogger v1.2.1* installed.

6.2 Instrumentation

The airplane cabin was instrumented to perform the experiment in a way that the thermocouples were in the following locations:

one of the center of the roof of the cabin, another one to the right pilot side of the pilots instruments panel, another one to the left copilot side of the pilots instruments panel, one on the center of the pilots instruments panel, another thermocouple suspended on the left side of the pilot seat, and a thermocouple suspended on the right side of the copilot seat, another one of the left side of the pilot seat and one of the right side of the copilot seat.

Fig. 6. Location of the Thermocouples inside the Hawker 800 aircraft. (Own authorship)

In order to collect the thermocouple data and convert the voltage data to temperature, the *Novus* data acquisition system according to Figure 7 was used, connected to a Desktop via USB connection.

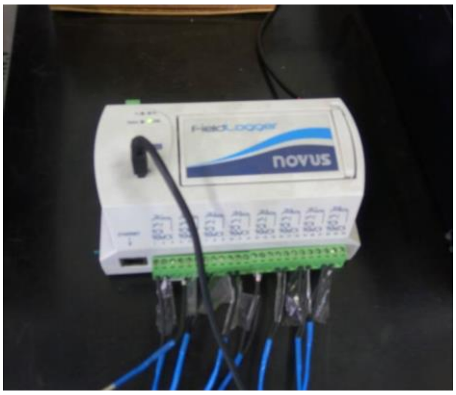
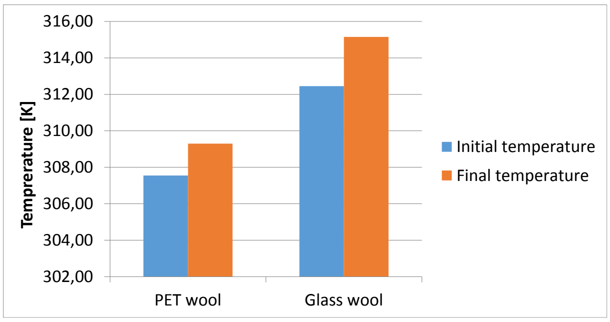


Fig.7. *Novus* Data Acquisition System. (Own authorship)

It was set to a collection frequency, enabling it every 10 seconds for 50 minutes.

7 Results of tests performed on the aircraft

After instrumentation and realization of the two tests in the aircraft, it was possible obtained information about the tests and by means plotted a bar graph to analyze the temperature variations as a function of time between Black PET wool and the glass wool, however, in the exact value of this variation, according to Graph 3.



Graph 3. Initial and final temperatures of the 50 min interval measured in each test (Black PET wool and glass wool)

8 Results analysis

In the laboratory test the temperature in the cold zones (thermocouples 2, 5 and 7) for grey PET wool and black PET wool were higher by approximately 2K when compared to glass wool, as shown on Graph.1. However, what justifies black PET wool as a more appropriate material for application (thermal insulation in the aircraft) is that its absorbed in relation to glass wool extra 2% of the heat and the black PET wool presented itself as a material that absorbs the temperature homogeneously.

In the field test (using the aircraft) it was observed that for black PET wool the temperature bars of the thermocouples tended to enter steady state after 90 minutes, which did not happen for glass wool (it took longer). However, the temperature variations of the wools were very close, the difference between the temperature variation of black PET wool was less than 1% than glass wool.

9 Conclusion

After the experiment was completed, it was noted that due to the complexity of the study of the thermal conductivity of a material and the enormous sensitivity to change of any of the variables included in the study region and its vicinity, the present study is given as satisfactory. The result showed a small dispersion between the conventional value of the thermal conductivity of the material and the actual value found by doing the experiment within the conditions of the laboratory.

In addition, the overall objective of this work was to find the best material among the comparators that presented the best performance in terms of thermal absorption and in aircraft to obtain an alternative material that in this case would be the black PET Wool to be used in the coating of an aircraft as a thermal insulation instead of glass Wool.

The experimental tests performed met the expectations generating satisfactory results, allowing the production of analyzes on the results of temperatures found for both glass wool and black PET Wool in laboratory and aircraft, thus the black PET Wool absorbs more heat and is an excellent thermal insulation compared to glass Wool.

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