THE CHALLENGE OF NATURAL FIBRES FOR THE THERMAL AND ACOUSTIC INSULATION OF AIRCRAFT

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ABSTRACT

The cabin of a civil aviation aircraft needs adequate sound and thermal insulation to guarantee passenger's comfort. Among this scenario, the purpose of the following paper is to mark a path that leads to the use of natural fibers to ensure compliance with the requirements together with a mitigated environmental impact.

The characteristic parameters to be examined for proper insulation are first described, including insulation and sound absorption characteristics, thermal insulation and the necessary flame resistance condition as well as their measurement methods and performances of actual technologies (i.e. glass fiber blankets). Hemp and kenaf fibers are than introduced, together with their manufacturing technologies. Natural fiber's blanket are successively introduced together with relative characterization in terms of acoustic, thermal and fire resistance properties. With specific reference to acoustic properties, also different stratification configuration have been tested and relative insulation and absorption properties compared.

The study shows that natural fibers can provide acoustic responses that approach some solutions almost directly in some cases and with a minimum increment of thickness and density in others. Also from the thermal and flame resistance point of view, the response of the natural fiber is favorable if treated with fireproof spray or immersion treatments with nitrate or potassium alum.

Keywords: Natural fibers, thermo-acoustic materials, insulation, aircraft

1. INTRODUCTION

The internal environment of an aircraft requires adequate insulation to ensure the comfort of passengers and flight crew. Fuselage skin temperatures can range from -60°F in flight to 160°F when parked in direct sunlight, threatening the cabin interior temperature. In addition, the aircraft engine, especially the movement of the compressor and turbine blades, especially in supersonic, the rotor of helicopters and the aerodynamics of flight as the air flow around the surfaces is compressed and expanded, generate a significant amount of noise, causing discomfort to passengers and crew if proper insulation is neglected.

To moderate the internal temperature of the aircraft and to provide sound insulation, many aircraft use blankets. Such blankets are typically placed in the cavity between the fuselage skin panels and the interior panels of the aircraft. It is also desirable that such insulating blankets incorporate fire-resistant materials to protect the passengers of an aircraft in the event of a fire such as that caused by ground fuel or a post-accident fire.

Well-known thermal and acoustic insulation systems typically include thermal and acoustic insulation blankets contained within a coating or bag. FAA burnthrough regulations primarily affect the contents of insulation system bags, and flame resistance regulations primarily affect the film coatings used to manufacture bags. Film coatings are typically used as a layer or cover, for example, layered composed of layers of thermal and acoustic insulation material, or as a bag that partially or totally contains one or more layers of thermal and acoustic insulation material.

The main objective of the present work deals with the direct comparison of technical performances of standard configuration with natural fiber's based ones to preliminary identify potentiality and drawback of more environmental friendly solutions to be applied at this specific application.

2. REFERENCE TECHNOLOGIES

Glass fibers, fabrics, foams and other materials are currently used for sound control. The overall effectiveness of the system is determined by the density, thickness of the material and design of the system.

Lightweight and flexible microlite blankets represent the most diffused solution due to effective thermal and acoustic performance for a variety of aerospace applications where space and weight are key considerations. Formed by biosoluble glass fibers in borosilicate 502 bonded with resin, they are particularly suitable for insulating fuselage wall cavities of commercial and corporate aircraft and are available in a variety of density and thickness combinations.

Other systems include the use of open-cell melamine foams that provide excellent thermal and sound insulation for airplanes and aerospace vehicles. These composites reduce condensation and increase the thermal efficiency of environmental control systems (ECS).

These specific foams and composites have a natural resistance to sedimentation, such as fiberglass, which allows them to be used inside frames and on transoms with little or no loss of thickness; a critical factor in acoustic and thermal performance.

Foam composites are applied directly to the outside of cladding panels for further noise attenuation and reduction of vibration or resonance of a panel.

Frequent is also the use of solid silicone rubbers. This material demonstrates a high loss of sound transmission across a wide frequency range. Stringent flammability, smoke density and toxicity (FST) requirements are also met. It is used in aircraft sound insulation, noise reduction liner for interior panels, aircraft floor noise barrier and railway interior noise blocking applications. It meets the new FAR25.856 radiant panel flammability test.

2.1 SOUND ABSORPTION AND SOUND INSULATION CHARACTERISTICS OF AERONAUTICAL BLANKETS

As a part of previous activities there was the opportunity to test materials of current use and in particular five typical configurations of materials were found.

Material ID	Material Type	Material Name	Sample Dimensions [Diameter] [mm]	Sample Nominal Thickness [mm]
SA1	Fiberglass	Microlite AA Premium NR 1.2 pcf 3/8"	100	9.52
SA2	Fiberglass	Microlite AA Premium NR 0.5 pcf 1"	100	25.40
SA3	Melamine Foam	Skandia SK-13200 0.63 pcf 2" (Aerocell)	100	50.80
SA4	Melamine Foam	BASOTEC UL	100	15.00
SA5	Fiberglass	Microlite AA Standard 0.6 pcf 2"	100	50.80

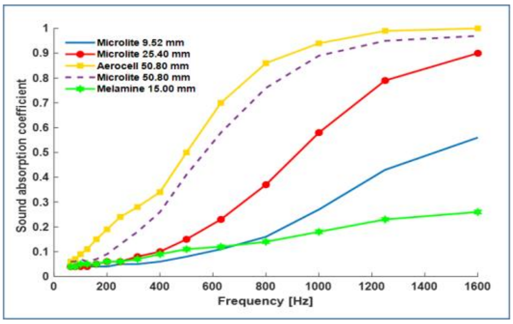

Figure1 : Tested configuration and relative sound absorption diagrams

Taking into account the different thermoacoustic stress found in the different parts of the aircraft (just think of the greater stress of the propeller plane) and therefore the need for an adapted insulation that complies with respect for weight and production costs and that does not damage the performance of the aircraft, combined solutions of the various materials are often used.

In particular, within the previous project we were given the opportunity to characterize 5 materials, one of which is homogeneous and others heterogeneous that include:

•Sound Barrier Roger Bisco HT-200: silicone elastomers specifically designed to reduce sound transmission within indoor spaces and prevent the spread of fire and smoke;

•Microlite;

•Aerocell SK-13200: AeroCell is a very light open-cell melamine foam that has exceptional sound absorption properties. AeroCell has excellent thermal properties and does not contain fiber.

•Basotect UL: is a flexible open-cell foam based on melamine resin, a thermosetting polymer. It has a high sound absorption capacity and good thermal insulation properties. Basotect melamine foam has inherently excellent fire, smoke and toxicity (FST) properties that meet rigorous aerospace fire standards

Insulation Package Id.	Configuration
#1	Sound Barrier Roger Bisco HT-200 (0,635mm 1,220kg/m2) + Microlite (9,525mm 0.183Kg/m2) + Microlite (50,8mm 0,488kg/m2)
#2	Sound Barrier Roger Bisco HT-200 (0,635mm 1,220kg/m2) + Microlite (9,525mm 0.183Kg/m2)
#3	Sound Barrier Roger Bisco HT-200 (0,635mm 1,220kg/m2) + Aerocell SK-13200 (50,8mm 0,513kg/m2) + Sound BarrierRogerBisco HT-200(0,635mm 1,220kg/m2)
#4	Aerocell SK-13200 (50,8mm 0,513kg/m2)
#5	Microlite 28,575 0.183Kg/m2 + Basotec UL 15 mm 0,089kg/m2

Figure2 : Tested configuration and relative samples

Examples of relative STL diagrams are reported in the next picture, highlighting the properties of each specific configuration. It appear evident the very interesting performances of some configuration.

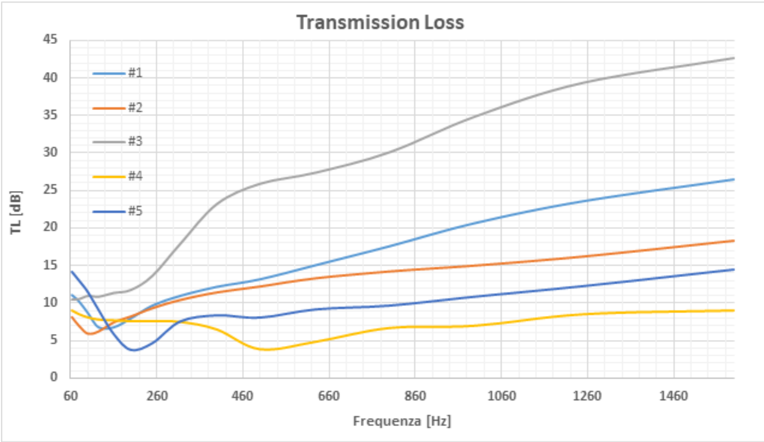

Figure 3 : Tested configuration and relative sound insulation diagrams

Although fiberglass is one of the major solutions adopted for insulation, it has an environmental impact and an impact on health of considerable importance.

Glass production is an energy-intensive activity. To be melted, the glass must reach high temperatures. Energy consumption is therefore a key indicator for the sector both in terms of absolute consumption, energy efficiency and use of energy from renewable sources. The increase in energy consumption is due to increased production. On the other hand, the percentage of renewable energy used increased (from 15% in 2016 to 26% in 2018). CO2 emissions are almost stable (mainly from the melting process at high temperatures).

Even foams have a very bad environmental impact being very polluting. The foam, in fact, contains chlorofluorocarbons, which contribute to ozone depletion and global warming. Some types of foam insulation, such as phenolic insulation, are no longer produced due to damage to the atmosphere.

Commercially available insulation materials that contain glass fibers, glass wool and other inorganic fibers typically cause irritation of the eyes, skin, mouth and nose. In addition to these factors there is a health risk associated with glass fibers when broken fragments are dispersed into the air. Glass fibers, given their fragile nature, have a propensity to fracture and create dust. These fine fibers, if inhaled, pose a serious risk to human health because they are able to enter the lungs leading to a chronic condition known as silicosis. For example, a fiberglass commonly used in aircraft insulation has an average diameter of 4.7 microns. Since fibers smaller than 3 microns in diameter are within the breathable range, a significant portion of them are breathed in.

As for polyurethane, research has revealed that the isocyanates contained in polyurethane materials are potentially harmful compounds for the lungs: in the long run exposure to these substances can cause lung irritation and asthma. Incineration of polyurethane and contact with the resulting fumes can also cause skin irritation and some forms of migraines.

In light of these awareness, although fiberglass represents the production standard for the costs that characterize it, for the ease of production and for the performance, there is a constant search for more eco-compatible solutions.

3. HEMP AND KENAF FIBERS

Cultivated first by the Mongols, then by the Tartars and the Japanese, hemp is a plant with a mysterious and ancient history. The importance of hemp as a textile fiber has always been very high, so much that this plant was called green gold: from 1631 until the early '800 in America it was, in fact, also considered as a currency to pay taxes.

To obtain hemp fibers, which can be used for production and as additives, the fibers must be separated in a process known as "scutching." During the scutching process the hemp straw is mechanically processed to break down the hemp plant, for example using a hammer mill. In this mechanical process hemp is slammed against a screen, smaller beaten fibers and dust falls through that screen. Modern high-speed kinematic decomposition machines are able to separate hemp into three streams: crude fibers, hurd and green microfiber. The cellulose content in hemp is about 70-77%.

Once short fibers (3-4 cm length) have been prepared, two methods are generally used to produce semi-rigid panels (in our case rigid ones are of little interest because they fall into other technologies); they are essentially mechanical processing. The first is a classic weaving process called needling, used above all for very thin fabrics therefore light layers and lately in disuse because it requires the use of obsolete and risky machines and the second is carding.

With the second processing method, called “carding” the mass of fibers is mixed and divided into a layer of uniform distribution, from which flakes elementary fibers are obtained. The fiber, from a roll reaches a conveyor cylinder, to then reach, through the introducer cylinder, the drum and finally the unloading cylinder, from which it is detached in the form of a veil.

These veils are compacted from time to time with a percentage of about 9% of polyester fiber or in any case a low-melting fiber (polylactic acid, corn starch, depending on the economic need) that has dimensions uniform to those of the natural fiber and that tends to be distributed randomly. The advantage lies in the fact that, once passed in the oven, it melts and tends to bind and then compact the fibers.

Figure 4 : Hemp straw, fibers and panel

Hemp insulation is a composite material but very environmentally friendly. Instead of being made up of 51% plant fibers and 49% plastics and chemicals, hemp insulation contains up to 92% hemp and about 8% polyester fibers.

4. HEMP BLANKET CHARACTERIZATION

In the context of this work, the greatest effort has been made to qualify the acoustic aspects both in terms of absorption and insulation. For the rest, thermal insulation requirements and necessary flammability tests will be dealt with the aid of parallel conducted studies.

4.1 ACOUSTIC CHARACTERIZATION

Acoustic characteristics such as absorption and insulation were evaluated by the use of Kundt tube on samples of 10cm in diameter with variable density and thickness. For simplicity of exposure and representation a specific mark for each specimen has been adopted.

Figure 5 : Kundt Tube

Both sound absorption and Sound Transmission Loss properties have been evaluated for homogeneous materials as well as for sandwich configuration for a more direct comparison with actual blanket configuration.

For reason of synthesis just some results are reported below where direct comparison is presented for similar configuration (similar in terms of weight for square meter).

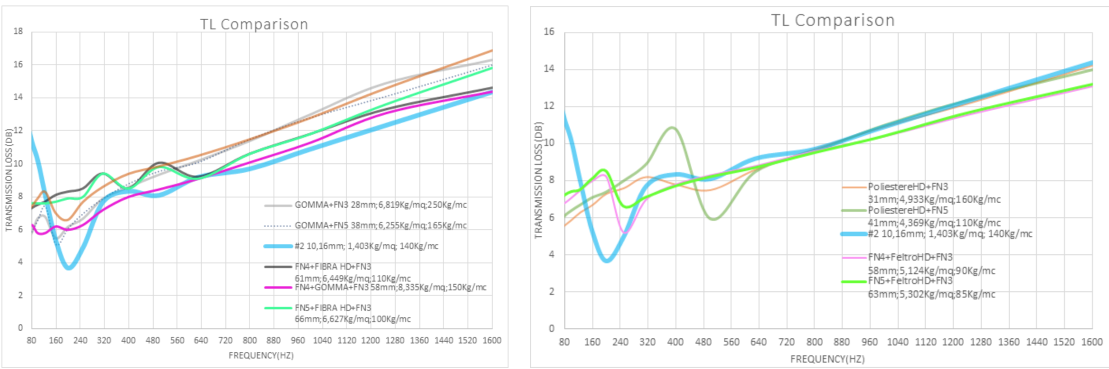

Figure 6 : Sound Transmisison Loss properties of some sandwich configuration

4.2 THERMAL PROPERTIES CHARACTERIZATION

It has therefore been demonstrated by means of parallel studies that as density and thickness vary, the λ of natural fibers varies between 0.032 and 0.034 W/mK. These values are completely aligned with those referred to classical materials.

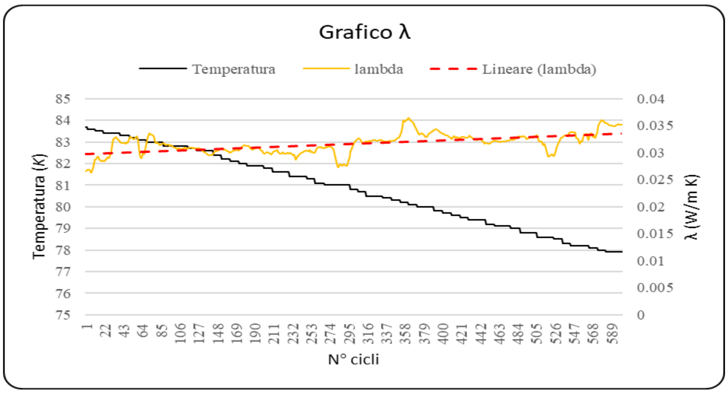

Figure 7 : Thermal properties test raw data

4.3 FLAME RESISTANCE PROPERTIES CHARACTERIZATION

The U.S. Federal Aviation Administration (FAA) has enacted regulations requiring thermal and sound insulation cover systems in commercial aircraft to provide better burn through protection and flame resistance in certain areas of airplanes. In addition, the FAA provided guidance for a test method to determine the burn through resistance of thermal and acoustic insulation materials installed in the lower half of the fuselage in transport-class aircraft.

FAR 25.855 sets out flame requirements that a material cannot exceed for use in an aircraft. For example, materials in the internal compartments occupied by the crew or passengers:

•It must be self-extinguishing if tested vertically.

•Have an average combustion length that does not exceed 6 inches (15.24 cm).

•Have a flame time after flame removal that does not exceed 15 seconds.

•Have drips from the test sample that do not continue to burn for more than an average of 3 seconds after the fall.

As a synthesis of performed activities, it has been verified that while the glass fiber is highly resistant to flame, the natural fiber, which in its pure state is an highly flammable material, assumes behavior in compliance with FAA regulations if properly treated with potassium alum and nitrate.

Following pictures, well explain this concept.

Figure 8 : Flammability test of Untreated Hemp fibers

Figure 9 : Flammability test of Treated Hemp fibers (left) – Glass fibers (right)

5. CONCLUSION

The present work aimed at the evaluation of the acoustic performance of natural fibers with high environmental compatibility.

Single and stratified natural fiber samples were examined, requiring, to expand the range of research and comparison with specimens of current technology, a rubber and others obtained from fibers of eco-sustainable origin and size compatible with natural ones, such as HD felt and HD polyester.

On various tests carried out, competitive combinations have been found with some solutions of current use almost with the same thickness or almost the same density.

The answers regarding thermal conductivity and flammability under appropriate fireproof treatment were fulfilled.

The studies conducted in the following work together with those carried out by parallel activities, open the way to the real evaluation of the possibility of using natural fibers in the aeronautical field. Further evaluation will be taken into account in forthcoming experimentation for the assessment of most appropriate configuration and manufacturing technologies.

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