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# Thermal Insulation analysis of an Aramid honeycomb Sandwich Structure Filled with Silica Aerogel

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***Abstract:*-- Aerogel is a synthetic porous ultra-light material which is a solid with extremely low thermal conductivity, approximately 15 mW/m-K. Their low relative density (typically less than 5%) reduces conduction through the solid and their small pore size, typically less than one hundred nanometers, on the order of the mean free path of air, reduces conduction through air as well as convection and radiation. On the other hand, Aramid fibers are a class of heat-resistant and strong synthetic fibers. Aramid honeycombs excel as ultra-lightweight material for structure reinforcement when good thermal and fire retardant are desired especially in case of building insulation. They are predominately used as a core in sandwiched structures to meet design requirements for highly stressed components. Aluminium honeycomb possess highest strength to weight ratio but due to its corrosive nature it cannot be installed in marine application and building insulation. Here we report on the hexagonal honeycomb structure of aramid fiber filled its core with silica aerogel to make it mechanical, corrosive as well as thermal resistant for building insulation or like other applications. The report work has already done on the mechanical behavior of it here we will analyze its thermal behavior experimentally.**

**Index Terms:- Aramid Honeycomb, Silica Aerogel, Building Insulation, Thermal Check, Corrosive Resistance.**

## I. INTRODUCTION

### *1.1 Sandwich Panel*

A sandwich panel is any structure made of three layers: a low-density core and a thin skin-layer bonded to each side. Sandwich panels are used in applications where a combination of high structural rigidity and low weight is required. Sandwich structure as shown in fig.1 is currently being used in the construction of high performance aircraft and missiles and are also being used for construction of building insulation.

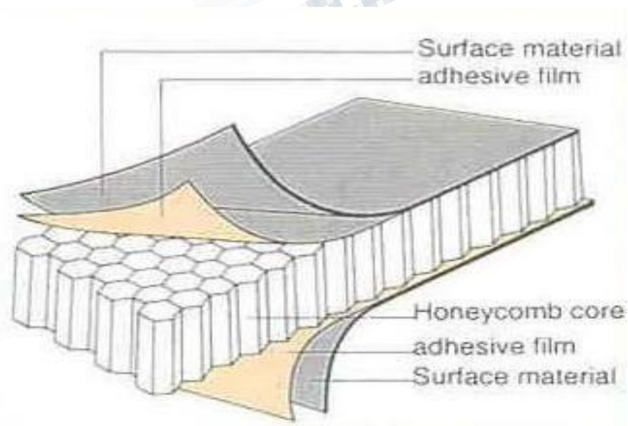


***Fig-1.1: Sandwich Panel showing three layers***

### *1.2 Aramid Honeycomb*

In structural sandwiches, face sheets are mostly identical in material and thickness and they primarily resist the in plane and bending loads. The explored view of the honeycomb core sandwich structure is shown in fig.2. The adhesion of face sheets and core is another important criterion for the load transfer and for the functioning of the sandwich structure as a whole. Aramid honeycombs possess the highest strength / weight ratio, unmatched by most of the other structural materials.

***Fig-1.2: Explored view of aramid honeycomb structure***

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### *1.3 Honeycomb Core:*

The purpose of the core is to increase the flexural stiffness of the panel. The honey comb core as shown in fig.3, in general the core has low density in order to add as little as possible to the total weigh of the sandwich construction. The core must be stiff enough in shear and perpendicular to the faces to ensure that face sheets are constant distant apart to present their detachment.

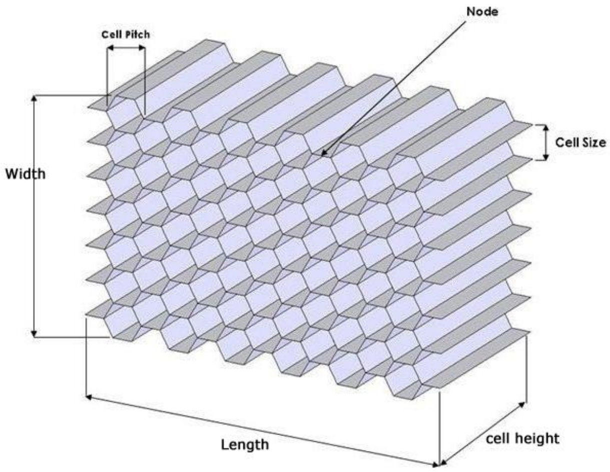


***Fig-1.3: Honeycomb Core***

### *1.4 Silica Aerogel:*

Aerogel Insulation Blanket is made by special techniques, in which nanosilica aerogel is adopted as leading material. It is a flexible composite blanket designed for high-temperature applications (up to 600C/1150F), with thermal performance two to eight times greater than other high-temperature insulating materials. It is available in multiple thicknesses up to 10 millimeters, and can be used as thermal insulation in buildings and industrial insulation. It is particularly well-suited for applications that require a thin product that can be easily cut, rolled and shaped on the job site. Because it offers high insulation performance even when compressed.

**Fig- 4: Silica Aerogel**

**Application Areas:**

The use of honeycomb sandwich structures has excellent stiffness to weight ratios that leads to weight reduction. It can be used in building insulation and marine applications where non corrosion insulation is primary objective. Further applications are Flooring, Antennas, Military shelters, Fuel tanks, Helicopter rotor blades, Navy bulkhead joiner panels.

## 2. OBJECTIVE:

I. Experimental validation of Aramid Honeycomb Sandwich Panel by taking optimum thickness of 15mm.
II. To compare it with aluminium honeycomb structure filled with silica aerogel and also the bare one aluminium honeycomb structure.
III. Setting up the upper temperature limit.

## 3. LITERATURE REVIEW:

K.Kantha Rao et al [1] This paper focus the heat transfer analysis and in exploring the ways to reduce the heat transfer effect. ANSYS analyses have been done for both square cell sandwich panel and hexagonal honeycomb panel for comparison. Experiments are done on using Al alloy honeycomb sandwich panels and the validations of experimental work using ANSYS analysis have been performed. ANSYS modeling analysis have been done for both, the square and hexagonal honeycomb sandwich panels of the Al alloy. The geometrical (shape) analysis of different candidate honeycomb cells that have the same effective density but different cell geometrical shapes. Heat transfer, analysis are performed on a aluminum alloy thermal protection system (TPS) for future vehicles. Effect of honeycomb cell geometry on the heat-insulating performance, are fin out. Infra-red experiment was conducted to investigate the response of several areas of the shield during the flight. The Aluminum alloy specimen researches its temperature limits in 90 seconds. For aerospace use, it is desirable to use the material which can attain its temperature limit after the elapse of more time. The heat-insulating performance of a honeycomb TPS is insensitive to the shape of the honeycomb cell under the same effective core density, but improves with the core depth.

Chen, K., et al [2] Here in this paper the mechanical and thermal analysis is performed on the aerogel filled sandwich panels where aluminium was the base sandwich material. They also used truss structure instead of hexagonal structure to make it more mechanically stable for building insulation.

Matthias Rößler [3] This paper mainly focused on the composites of aerogel with honeycomb structures. In this thesis three different nano-porous silica aerogels filled in the pores of aramid honeycomb structures of different dimensions are investigated. The composites have a prospective use as insulation material. They were prepared by employing a two-step acid–base sol–gel process utilizing the silicon alkoxides methyltrimethoxysilane (MTMS) or tetraethylorthosilicate (TEOS) as precursors and supercritically dried in CO2. In order to drastically improve the mechanical properties of silica aerogel monoliths, different aerogel formulae were synthesized in aramid honeycomb structures of different height and cell size. From here I decided to choose MTMS based aerogel for my research work.

Mangesh M. Kakade et al [4] In this paper Heat-transfer analysis has been performed on sandwich thermal protection system (TPS) for future vehicles. The structures are fabricated from thin walled metal sheets. These fabricated structures are part of the air frame outer cover provides thermal protection to the interior parts mounted inside the vehicle. The temp protection system materials used for sandwich structures should have high strength even at elevated temperatures. It is easier to simulate the 1500 C temperature on the Aluminum sandwich structures and find out the temperature gradient across the sandwich depth. Experiment was done on hexagonal structure honeycomb cell, the ANSYS analyses have been done for both square cell panel and hexagonal honeycomb panel for comparison. Experiments we conducted on Aluminum alloy honeycomb sandwich panels and the validations of experimental work using ANSYS analysis have been performed. The ANSYS modeling done for both, the square and hexagonal honeycomb sandwich panels of the Aluminum alloy. This paper focus the heat transfer analysis and in exploring the ways to reduce the heat transfer effect with the methods mentioned above, which would be effectively used for flight vehicle applications. And from here I decided to choose 15mm optimum thickness for my research work.

## 4. MATERIAL PROPERTIES:

The honeycomb structure was modeled with Aramid material and their cores were filled with silica aerogel.

***Table -4.1:***

The model no. of used honeycomb aramid is Hax-NHC-01 of Nomex type and the properties are shown in table no 4.1.

| S.N | Properties | Aramid honeycomb |
|---|---|---|
| 1. | Utilized Chemical | *Methyl-tri-methoxy-silane* (MTMS) |
| 2. | Cell Size *(fig.3 for nomenclature)* | 12.7 mm |
| 3. | Density | 1.38 g/cm$^3$ |
| 4. | Elastic Modulus | 75.8 MPa |
| 5. | Ultimate Tensile Strength | 1448 MPa |
| 6. | Cell length *(fig.3 for nomenclature)* | 318 mm |
| 7. | Cell Width *(fig.3 for nomenclature)* | 298 mm |
| 8. | Cell height *(fig.3 for nomenclature)* | 10 mm |
| 9. | Upper Plate thickness | 2.5 mm |
| 10. | Lower Plate Thickness | 2.5 mm |

***Table -4.2:***

The model No of used Silica Aerogel is YQMM-450 and the properties under this material are as follows in table no 4.2.

| S.N | Properties | Silica Aerogel |
|---|---|---|
| 1. | Thermal Conductivity | 0.018 W/m.K |
| 2. | Density | 200 Kg/m$^3$ |
| 3. | Compression Performance | @10% at 60KPa, @20% at 120KPa |
| 4. | Material | $SiO_2$ |

## 5. EXPERIMENTAL SETUP:

Matthias Rößler proposes Synthesis and characterization of aramid-honeycomb reinforced silica aerogel composite materials. In our experiment we used the the porous form of silica aerogel for filling the honeycomb cells.

First we laid the aramid sheet of 2.5mm over the floor and put aramid honeycomb of defined size of 10mm over it. After that filled it with silica aerogel and put another aramid sheet (called face sheet) of 2.5mm to cover it completely. The experiment is done by putting it on the vertical side so that it is easier to measure temp. For availing the temperature we went through different types of heater available with the vendor and choose the band type as it is most effective for

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our design. For measuring the temp thermocouple is set on both the sides.

The setup is divided into two parts that is heating system on which band type heater is installed (Called Part A) with thermocouple arrangements and on the other side (Called Part B) only thermocouple is installed.

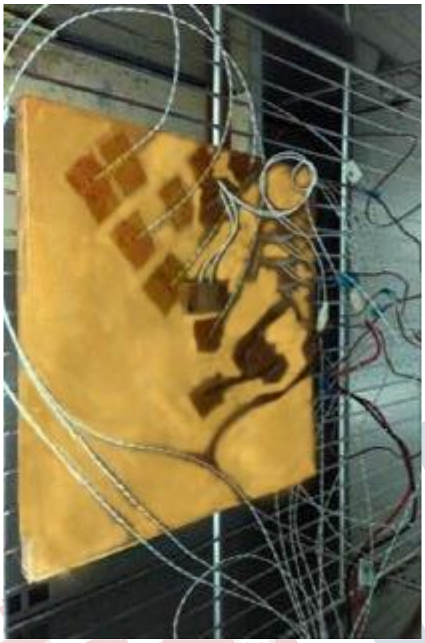

*Fig. - 5: Experiment setup*

## 6. METHODOLOGY:

The following assumptions were made for experiments.
1) The surrounding temp of setup is constant.
2) The material is isotropic.
3) Inertia effects of thermocouple is not considered.
4) Change in conduction due to surface of material is neglected.
5) The effect of internal radiation turned out to be much smaller than that of conduction for the present core geometry, hence radiation can be negligible.
6) The thermal properties of the materials used do not change with the temperature

Tests were conducted on 318 mm × 298 mm aerogel-filled honeycomb of 15 mm thickness. By increasing the alternating current value of band type heater we can set the temp limits. As temp increased from room temp of 25.8 °C we noted down temp of both sides and time duration by stop watch. After 15 sec the top side temp (On which side heater is installed) is 52.7 °C while the lower side is measured to 25.5 °C or we can say there is difference of 27.2 °C. The maximum temperature on the top surface around the localized heat source was about 150 ºC the temperature on the bottom surface was about 30.3 ºC. It can also be seen that the area of the panel away from the heated zone is not affected by the heat source, indicating that the heat is largely restricted to the heated zone. In the course of the above experiments it was found that the aramid honeycomb sandwich panels started to oxidize when the temperature reached 182 ºC. The last test was stopped at 350 ºC. This limit was considered the upper bound for the designed material system as the silica aerogel had its flash point stated by the manufacturer at 395 ºC.

In order to quantify the contribution of the aerogel towards providing heat insulation, the same tests were carried out on a panel without aerogel. It can be seen that for a maximum temperature of 124.9 ºC on the top heated surface, the bottom surface temperature was 63.1 ºC. The results clearly indicate the effectiveness of aerogels as thermal barriers. For the heat transfer studies, the bottom surface temperature was taken as the reference temperature for thermal barrier applications. Once the bottom temperature for the panel without aerogel went above the bottom temperature for the panel with aerogel, the tests were stopped. At this point, the top surface temperature of the panel without aerogel was lower than the temperature for the panel with aerogel. This implies that if the test was allowed to continue, the bottom temperature for the panel without aerogel would shoot up beyond the desired limit. It may be seen that thermocouples B1 and B2 on the bottom face-sheet of the air filled sandwich panel show higher temperature readings than the corresponding points on the top surface. This could possibly be due to circulation and convectional heat transfer of air within the core. As the air inside the core gets heated up, it starts to move inside the cell allowing more pronounced convection within the air cavity causing rise in the bottom surface temperatures. This effect was nullified when the core was filled with the aerogel.

## 7. RESULT AND CONCLUSION:

The following readings and chart of the experiment in terms of time and temp:-

Table 7.1 time vs. temp are taken by using aramid hexagonal honeycomb filled its core with silica aerogel.

| S.N. | Time (in sec) | Plate A temp | Plate B temp | Temp difference |
|---|---|---|---|---|
| 1 | 1 | 27.512 | 27.510 | 0.002 |
| 2 | 5 | 29.156 | 28.564 | 0.592 |
| 3 | 9 | 32.644 | 29.102 | 3.542 |

| | | | | |
|---|---|---|---|---|
| 4 | 12 | 39.121 | 29.864 | 9.257 |
| 5 | 15 | 55.397 | 31.026 | 24.371 |
| 6 | 18 | 72.417 | 33.579 | 38.838 |
| 7 | 24 | 119.482 | 39.457 | 80.025 |
| 8 | 28 | 151.981 | 51.238 | 100.743 |
| 9 | 35 | 182.323 | 67.569 | 114.754 |
| 10 | 42 | 242.545 | 87.248 | 155.297 |
| 11 | 46 | 284.235 | 109.987 | 174.248 |
| 12 | 52 | 351.876 | 148.457 | 203.419 |

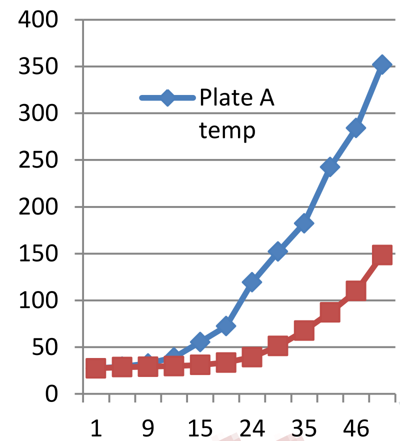


Chart: 7.1 Aramid hexagonal honeycomb filled its core with silica aerogel

Table 7.2 The following readings of time vs. temp are taken by using aramid hexagonal honeycomb without silica aerogel.

| S.N. | Time (in sec) | Plate A temp | Plate B temp | Temp difference |
|---|---|---|---|---|
| 1 | 1 | 27.622 | 27.611 | 0.011 |
| 2 | 5 | 29.354 | 28.998 | 0.356 |
| 3 | 9 | 33.445 | 31.042 | 2.403 |
| 4 | 12 | 40.831 | 35.621 | 5.210 |
| 5 | 15 | 56.545 | 39.454 | 17.091 |
| 6 | 18 | 74.121 | 49.442 | 24.679 |
| 7 | 24 | 121.785 | 60.564 | 61.221 |
| 8 | 28 | 155.128 | 70.156 | 84.972 |
| 9 | 35 | 186.023 | 86.028 | 99.995 |
| 10 | 42 | 249.272 | 100.121 | 149.151 |
| 11 | 46 | 290.451 | 138.154 | 152.297 |
| 12 | 50 | 349.982 | 182.653 | 167.329 |

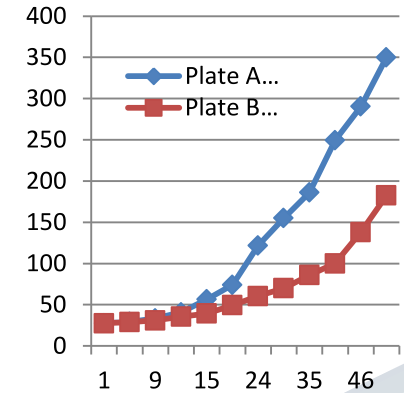


Chart:7.2 Aramid hexagonal honeycomb filled without silica aerogel

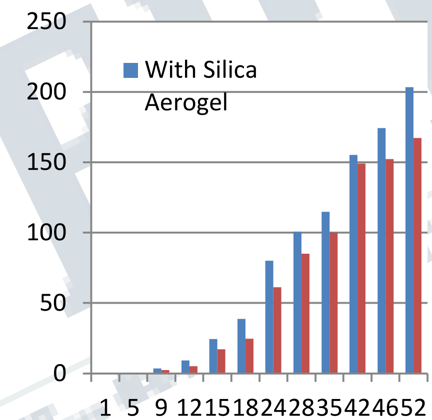


Chart 7.3 Time vs temp difference comparison graph of aramid honeycomb filled with silica aerogel and bared one aramid honeycomb.

From above graph we can conclude that the aramid honeycomb filled with silica aerogel have a higher temp difference that is the heat will take longer time to pass from one side to another side. And after comparing aramid honeycomb filled with silica aerogel with bared one aluminum honeycomb and also with silica aerogel filled aluminum honeycomb we can further added that aramid honeycomb are the best among these building insulations irrespective of the fact that aramid honeycomb of same volume are quiet heavier than aluminum honeycomb.
Further I can add that the higher temp limit is far beyond than maximum possible environment temp in case of building insulations. If such insulations are applied in other applications it can tolerate the upper temperature up to 180C.

And the most importantly is to make corrosion resistance insulations so in marine applications up to the higher depth it can be used.

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