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Thermal Analysis of Honeycomb Sandwich Panel

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Abstract

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 airframe outer cover provide 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.

Keywords: Hexagonal core cell, Square core cell, aluminium panel, Adhesive, FEA

1. Introduction:

Honeycomb Structures

In honeycomb structural sandwiches cell, face sheets are mostly identical in material and thickness, structures cell are called symmetric sandwich structures. However, in some special cases face sheets thickness or material may be vary because of different loading conditions or working environment. In general the sandwich structures are symmetric; the variety of sandwich constructions basically depend on the configuration and size of the core. The honeycomb core consists of very thin foils in the form of hexagonal cells perpendicular to the facings. (K. Kantha Rao, et al, 2014) Honeycomb sandwich structure as shown in fig.1 are currently being used in the construction of high performance aircraft and missiles and are also being proposed for construction of future high speed vehicles. The sandwich structure can be classified in to four types, foam or solid core, web core, corrugated or truss core and honeycomb core.

Fig 2 shows the face sheets and core is another important criterion for the load transfer and for the functioning of the sandwich structure as a whole.



Fig - 1 Honeycomb Core

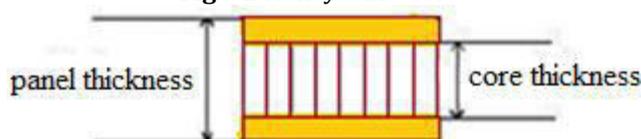


Fig - 2 Honeycomb Sandwich Structure

The function of the core is to increase the flexural stiffness of the panel. The honeycomb core as shown in fig.3, in general the core has low density in order to add as little as possible to the total weight of the sandwich construction. The core must be strong enough in shear and perpendicular to the faces to ensure that face sheets are constant distance apart to prevent their detachment.

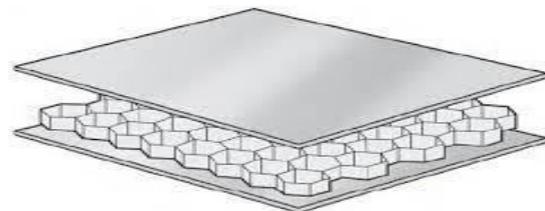


Fig - 3 Honeycomb Sandwich Panel

Heat transfer analysis plays a vital role in the design of many engineering applications. Heat transfer analysis can be find out the temperature distribution and related thermal quantities in the system or component .In general, the heat transfer in honeycomb sandwich panels is a result of (1) conduction of heat transfer in the cell walls, (2) radiation interchange within the cell walls, and (3) convection of heat through the air contained back side of the panel. However, this paper is concerned with sandwich panels in which the primary modes of heat transfer is consider due to conduction in the cell walls and radiation exchange within the cell. For most honeycomb sandwich cores used in the fabrication of sandwich panels, it can be shown that the heat exchange by convection and conduction within the air contained in the cell is negligible compared to

conduction in the cell walls and radiation within the cell.

2. Literature Review:

The Honeycomb core sandwich structures are widely used in aerospace applications due to their high specific strength and specific stiffness, good thermal insulation and vibration absorption capabilities, etc. A typical sandwich panel consists of three layers: two thin and stiff face sheets and a lightweight core (J Jhao, et al). A stainless steel material is chosen to a face sheet and copper as a core material. The main characteristic of these Honeycombs is a very high porosity; typically 75-95% of the volume consists of void spaces. There are static three-point bending tests were carried out in order to investigate load and deflection variations. The theoretical load and deflections value in copper honeycomb sandwich panel is used and compared with experimental and simulation results. Based on the experimental results it is found that the gradient of deflection curve is high for lower core height and stress is low for higher value of core height. These results can be used as input when designing sandwich panels (A. Gopichand, et al, 2013). ANSYS analyses have been done for both square cell sandwich panel and hexagonal honeycomb panel with different thickness for comparison. Experiments are done by using Al alloy honeycomb sandwich panels and the validations of experimental work using ANSYS analysis have been performed (K. Kantha Rao, et al, 2014) In experimental analysis one side of the panel is subjected to a heat flux on the surface. Two types of surface heating were considered: (A) hexagonal honeycomb sandwich panels, and (B) square honeycomb sandwich panel, which approximates the actual surface temperature distribution associated with the existence of edge heat sinks. The finite-element method is used to find out the thermal stress distributions in the face sheets and core of the sandwich honeycomb panel, (K. Jayathirtha Rao, et al 2012) This study explores the heat transfer characteristic of a complex heat flow path that exists in these panels, achieved through Finite Element modelling and experimental investigation. (Dr. FereshtehSanaei)

3. Nomenclature:

Sr. No.	Nomenclature	Description
1	TPS	Thermal Protection System
2	ΔT	Change in Temperature
3	L	Length
4	D	Diameter
5	T	Thickness
6	FEA	Finite Element Analysis

4. Material Properties:

For Aluminum honeycomb panel (upper & lower parts) material is Al-2024 and core material is Al-3003. These properties are summarized in Table-1.

Table- 1 Honeycomb Panel Material Properties

S.No	Properties	Al-2024	Al-3003
1	Thermal Conductivity W/(mo C),	121	162
2	Heat Transfer Coefficient (W/m2-K)	25	25
3	Poisson ratio	0.33	0.33
4	Density (Kg/m3)	2780	2730
5	Specific Heat J/(kg K)	875	893
6	Thermal Expansion (m/ m- °C)	22.9×10-6	23.1×10

5. Honeycomb Cell Geometry:

Below figure shows two types of honeycomb cell geometry to be analysis. The thickness of honeycomb cell for the first two types is t_c . The first type is a right hexagonal cell with identical side lengths of b_1 . The second type is a square cell with side lengths of b_2 , which is modified from the right hexagonal cell by reducing the bonding interface length to a minimum of $\sqrt{2} t_c$. The size, $d(i)$ ($i=1,2$) of each type of honeycomb cell is defined as the maximum diagonal of the cell cross section. The honeycomb size cell are types 1, 2, are adjusted to have the same effective density (that is, $\rho_1 = \rho_2$). Honeycomb structures are composed of plates or sheets that form the edges of unit cells. (K. Kantha Rao, et al, 2014). These can be arranged to create, square and hexagonal as shown in fig.4.

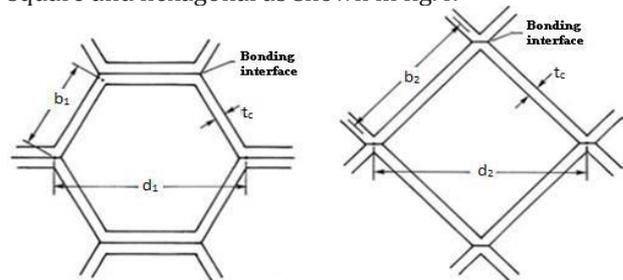


Fig - 4 (A) Hexagonal Honeycomb Cell (B) Square Honeycomb Cell

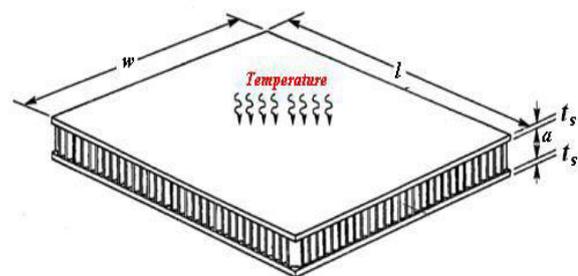


Fig - 5 Honeycomb sandwich (TPS) subjected to overheating entire upper surface.

Abovefig 5 showsHoneycomb sandwich thermal protection system (TPS) subjected to heating over entire upper surface. Honeycomb-core sandwich thermal protection system isentirely subjected to transient surface temperature, over its entire outer surface. The thermal protection system panel is rectangular with a side length -l & width-w, and is constructed with two identical face sheets with a

thickness of t_s and honeycomb core with a depth of. The performances of heat-insulation of honeycomb thermal protection system depends on the thickness of the face sheets, depth of the honeycomb core, thickness of the honeycomb cell walls, and size and shape of the honeycomb cells. (K. Kantha Rao, et al, 2014)

5.1 Geometry of Hexagonal Honeycomb Cellof thickness 15mm, 20mm, 25mm

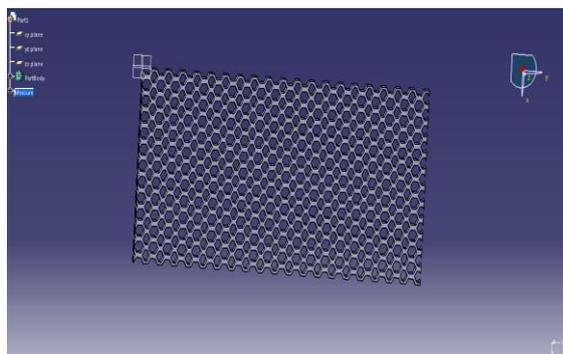


Fig - 6 Honeycomb_Hexagonal Core Structure

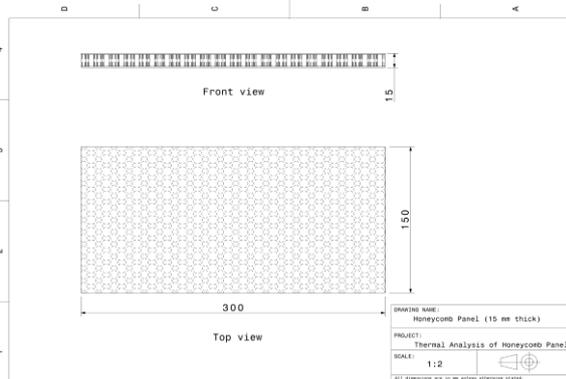


Fig- 7 HoneycombHexagonal Structure T-15 mm

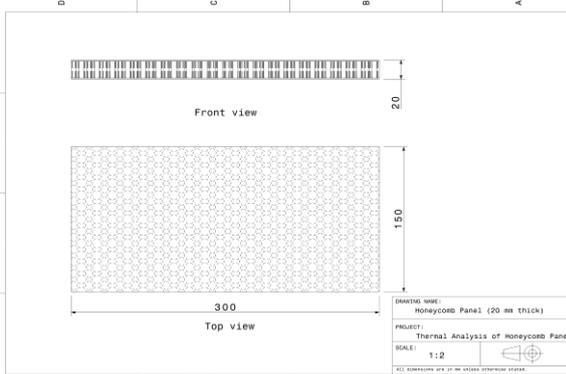


Fig – 8 HoneycombHexagonal Structure T-20 mm

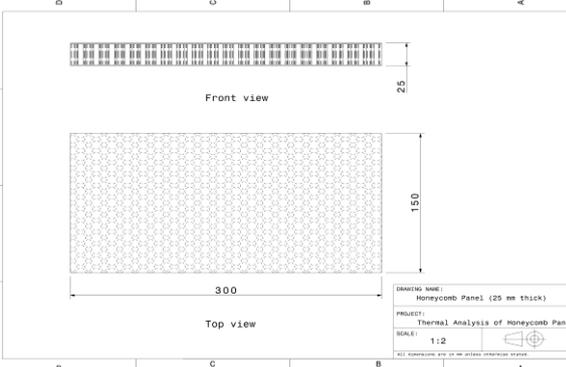


Fig – 9 HoneycombHexagonal Structure T-25 mm

6. Finite Element Analysis:

Heat transfer is a science that studies the energy transfer between two bodies due to temperature difference. Conductive heat transfer analysis on honeycomb sandwich panels and the tiny volume inside each honeycomb cell, convection heat transfer of the interior air mass were negligible. Now in this section studies the effect of honeycomb cell geometry on the heat shielding performance of the TPS panel. Before starting analysis to mesh the model so that the effectively find the change in temperature at each and every point. As it is difficult to regenerate all cells, Heat transfer analysis only on one cell by symmetry and calculate heat transfer in all cells. Performing heat transfer analysis under transient state condition.

6.1 Analysis of Honeycomb Sandwich Structure

Heat transfer analysis plays a very important role in the design of many engineering applications. Heat transfer analysis find out the temperature distribution and related thermal quantities in the system or component. In general, the heat transfer in honeycomb sandwich panel cell is a result of

- (1) Conduction of heat transfer in the cell walls,
- (2) Radiation interchange within the cell, and
- (3) Convection of heat transfer through the air contained back side of the panel.

However, this paper concerned with sandwich panels in which the primary modes of heat transfer are due to conduction in the cell walls and radiation exchange within the honeycomb cell. For number of honeycomb cores used in the fabrication of sandwich panels, it can be shown that the heat exchange by convection and conduction within the air contained in the cell is smaller compared to conduction in the cell walls and radiation within the cell.

6.2 Heat Transfer Analysis:

Heat transfer analysis is a science that studies the energy transfer between two bodies due to temperature difference. For honey comb sandwich panels conductive heat transfer analysis and the tiny volume inside each honeycomb cell, convection heat transfer of the interior air mass were neglected. This section studies the effect of honeycomb cell geometry on the heat- insulating performance of the Thermal Protection System panel. Before analysis starting to mesh model we can effectively find out the change in temperature at each and every point. We perform heat transfer analysis under transient state condition. (K. Jayathirtha Rao, et al, 2012)

6.3 Transient Thermal Analysis:

Transient Thermal Analysis find out temperatures and other thermal quantities that vary over time. Engineers commonly use temperatures that a transient thermal analysis calculates as input to structural analysis evaluations. A transient thermal analysis follows the same procedures as a steady -state thermal analysis.

The main difference is that most applied loads in a transient thermal analysis are functions of time. To specify time-dependent loads, use both the function tool to define an equation or function describing the curve and then apply the function as a boundary conditions or divide the load –versus –time load into load steps. Aluminum Hexagonal Honeycomb Sandwich Structure.(K. Jayathirtha Rao, et al,2012)

6.4 Assumptions Made During FEA:

1. First, honeycomb cells have the same effective density, but different geometrical shapes are considered (i.e. hexagon & square shapes).
2. Second, the internal radiation effect much smaller than that of conduction for the present TPS core geometry, hence radiation can be negligible.
3. Third, the thermal properties of the materials used do not change with the temperature.
4. Fourth, there is no convection heat transfer inside the panel, as the experiment will take place inside a steady environment. Convection heat transfer is considered for backside of the panel.

6.5 Finite Element Analysis of SquareHoneycomb Sandwich Structure:

Boundary conditions-

Fig shows a square honeycomb sandwich subjected to transient surface temperature of 90⁰ C, over 30 seconds on its entire top surface for varying thickness of 15mm, 20mm, 25mm. same loadings are applied to hexagonal honeycomb sandwich of 15mm, 20mm, 25mm too.

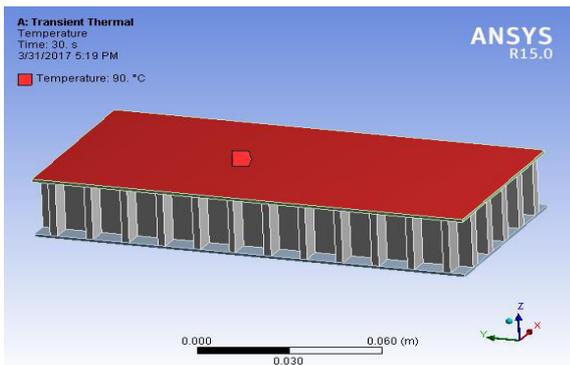


Fig - 10 Square Honeycomb Sandwich of 15 mm Thickness

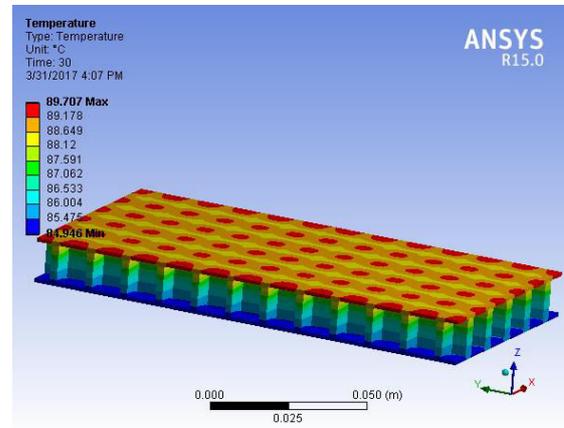


Fig - 11 Temperature distribution plots for 15 mm Thickness

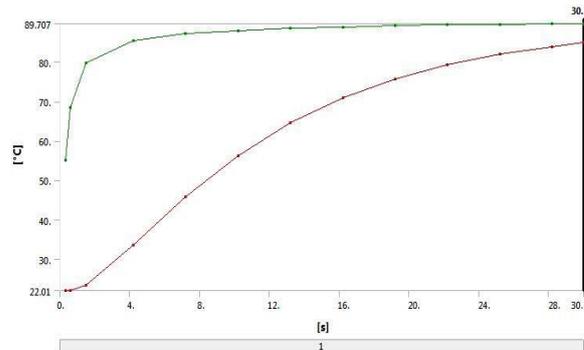


Fig - 12 Temperature (°C) V/S Time (s) graph

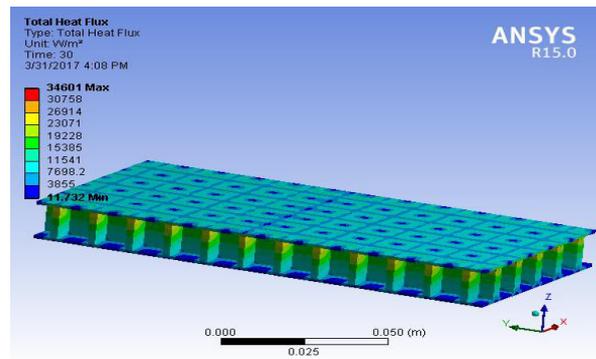


Fig - 13 Heat Flux Plot for 15 mm Thickness

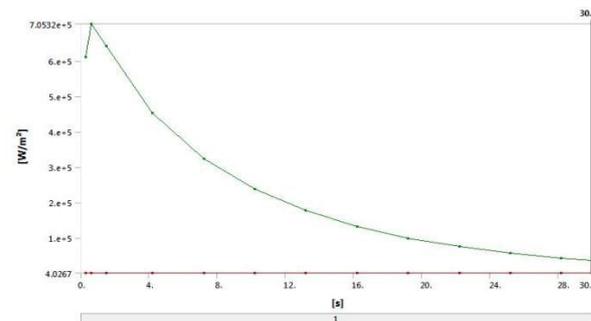


Fig - 14 Heat flux (W/mm²) V/S time (s) graph

6.6 Square Honeycomb Sandwich of 20 mm Thickness

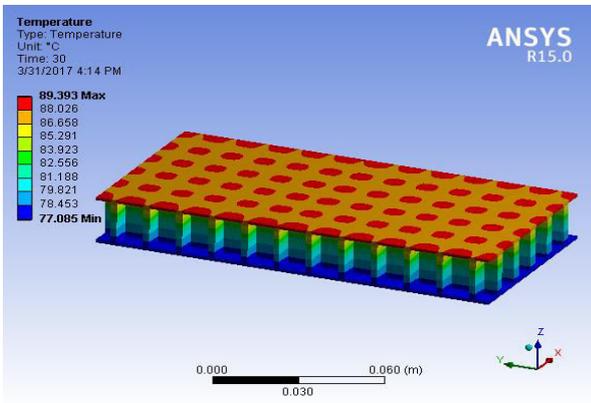


Fig - 15 Temperature distribution plots for 20 mm Thickness

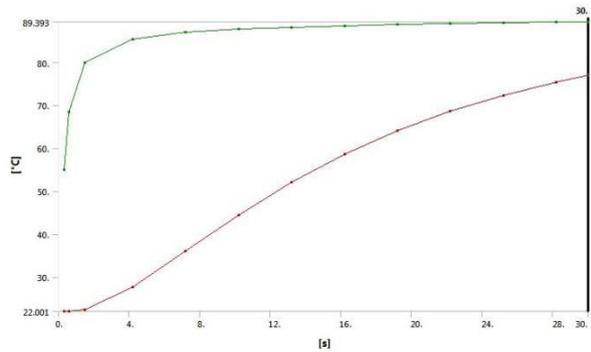


Fig - 16 Temperature (°C) V/S Time (s) graph

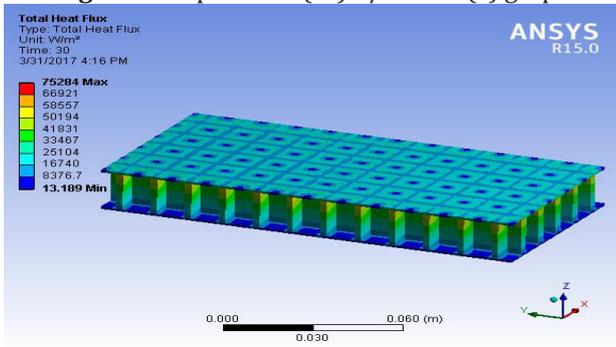


Fig- 17 Heat Flux Plot for 20mm Thickness

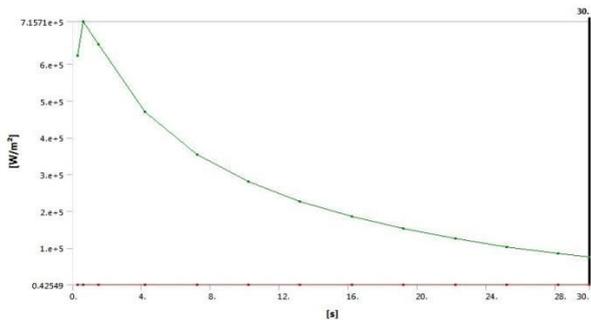


Fig - 18 Heat flux (W/mm²) V/S time (s) graph

6.7 Square Honeycomb Sandwich of 25 mm Thickness

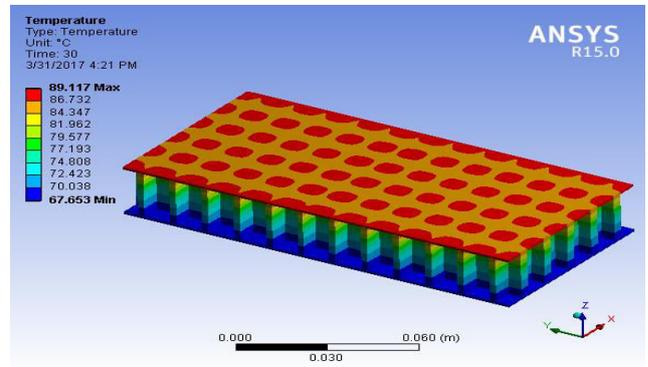


Fig - 19 Temperature distribution plots for 25 mm Thickness

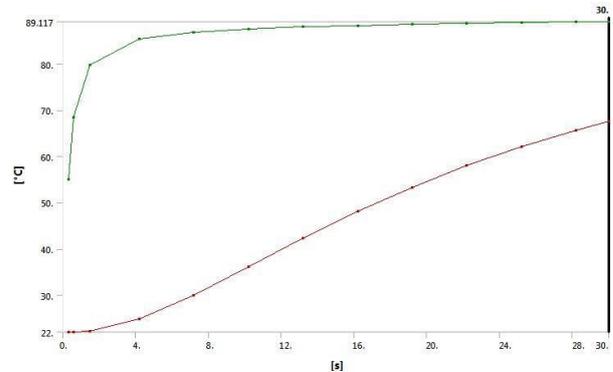


Fig - 20 Temperature (°C) V/S Time (s) graph

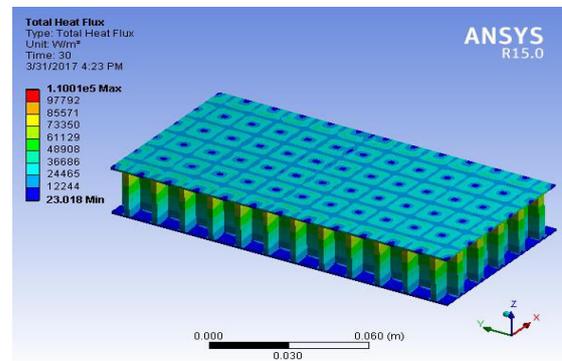


Fig - 21 Heat Flux Plot for 25 mm Thickness

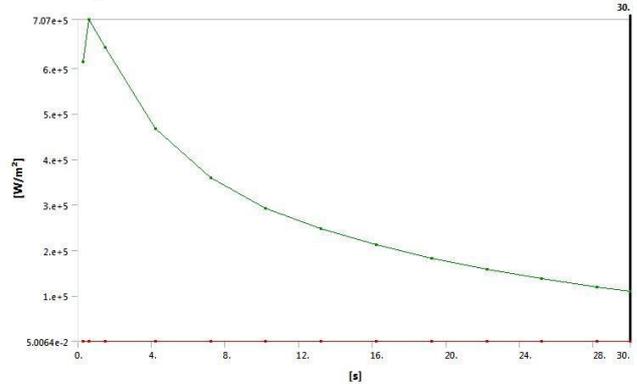


Fig - 22 Heat flux (W/mm²) V/S time (s) graph

6.8 Finite Element Analysis of Hexagonal Honeycomb Sandwich Structure:

Boundary conditions-

Fig shows a hexagonal honeycomb sandwich subjected to transient surface temperature of 90⁰ C, over 30 seconds on its entire top surface for varying thickness of 15mm, 20mm, 25mm. same as applied in case of square honeycomb sandwich.

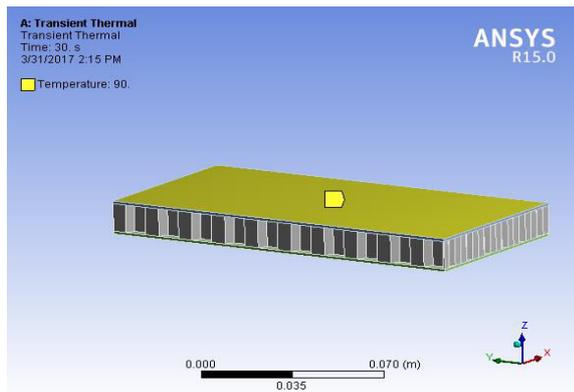


Fig -23 HexagonalHoneycomb Sandwich of 15 mm Thickness

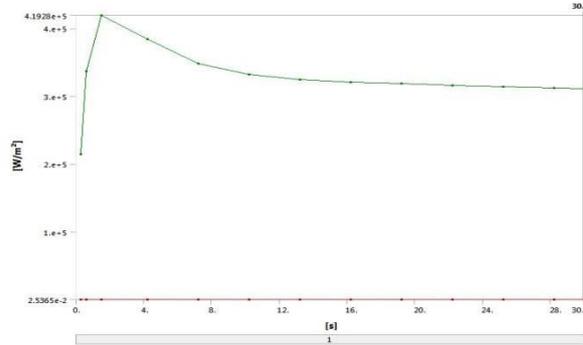


Fig - 27Heat flux (W/mm²) V/S time (s) graph

6.9 Hexagonal Honeycomb Sandwich of 20 mm Thickness

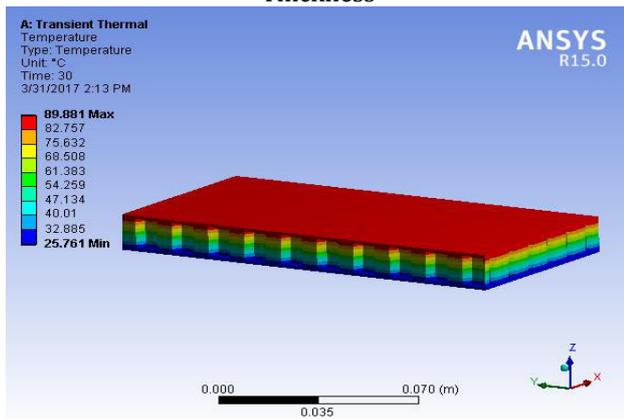


Fig -24 Temperature distribution plots for 15 mm Thickness

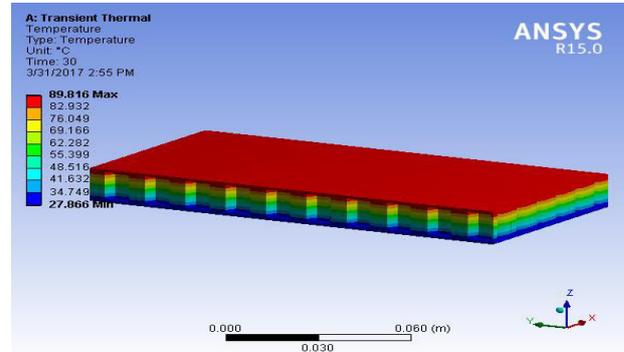


Fig -28 Temperature distribution plots for 20 mm Thickness

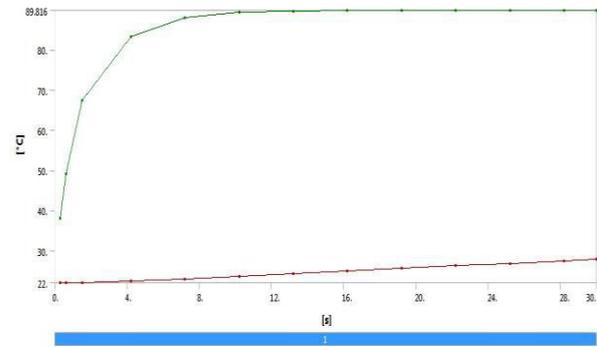


Fig -29 Temperature (°C) V/S Time (s) graph

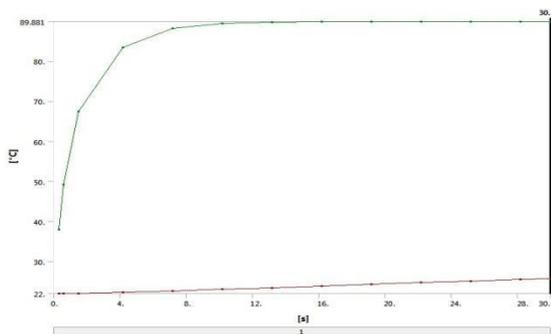


Fig - 25 Temperature (°C) V/S Time (s) graph

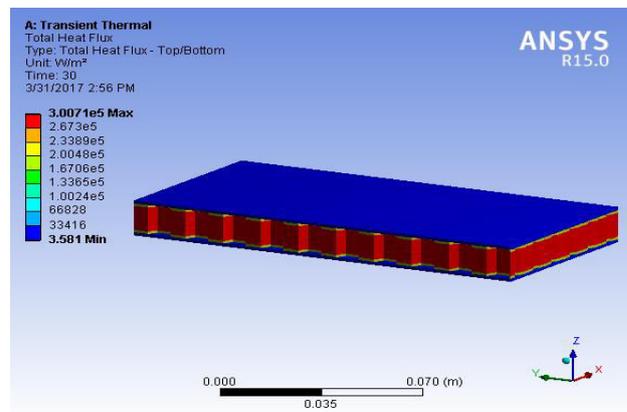


Fig -30 Heat Flux Plot for 20 mm Thickness

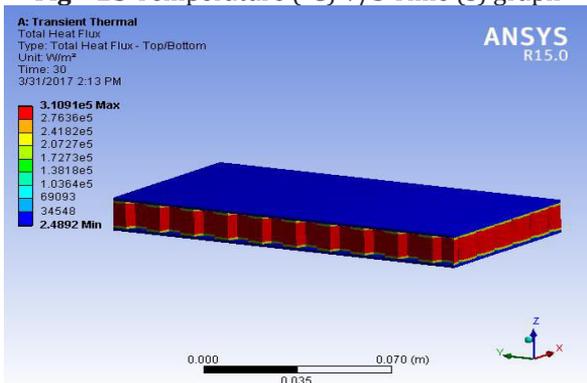


Fig - 26Heat Flux Plot for 15 mm thickness

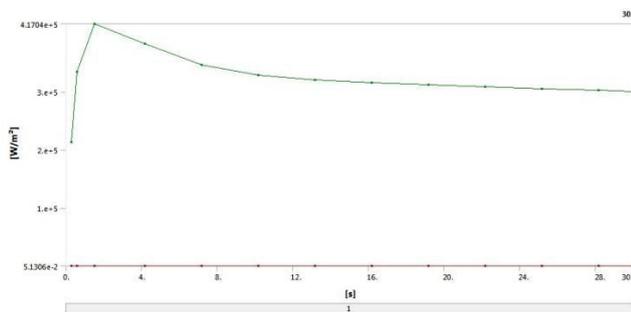


Fig - 31 Heat flux (W/mm^2) V/S time (s) graph
6.10 Hexagonal Honeycomb Sandwich of 25 mm Thickness

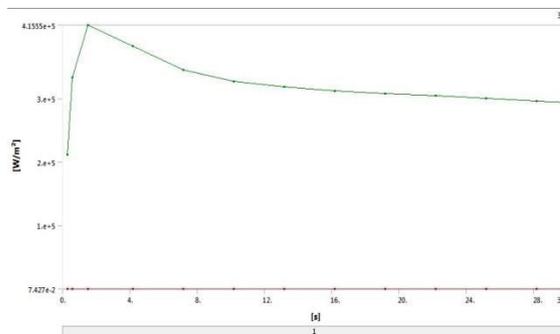


Fig -35 Heat flux (W/mm^2) V/S time (s) graph
7. Results and Discussion:

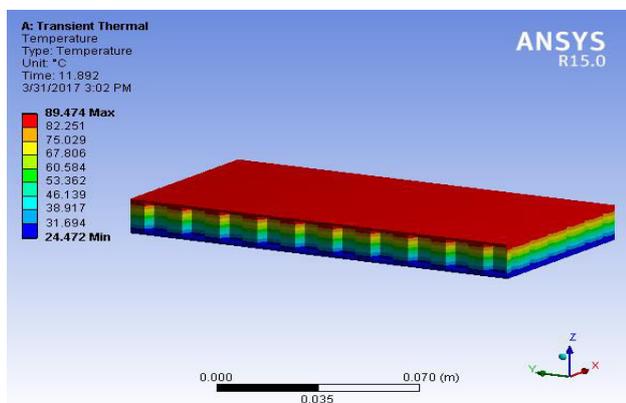


Fig -32 Temperature distribution plots for 25 mm Thickness

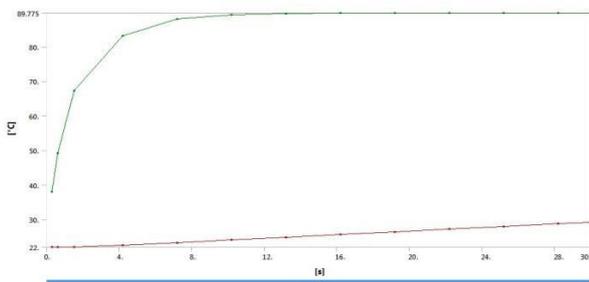


Fig -33 Temperature ($^{\circ}C$) V/S Time (s) graph

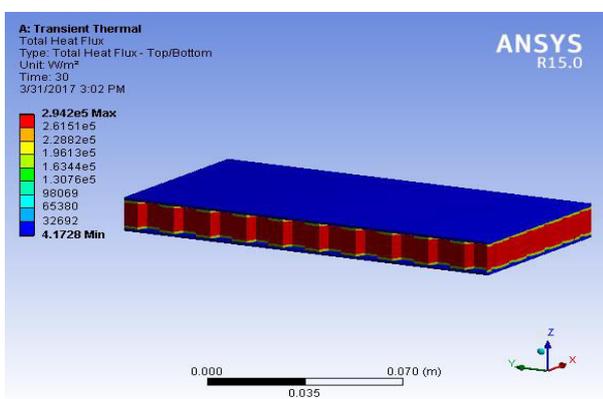


Fig - 34 Heat Flux Plot for 25 mm Thickness

Comparing Square section structure with varying thickness i.e. 15mm,20mm, 25mm to hexagonal section with varying thickness i.e. 15mm,20mm,25mm above graph shows that 15 mm thickness with hexagonal section give best result for temperature distribution. The heat insulating performance of honeycomb shape of the honeycomb cell under the same core density, but improves the core depth. Aluminium hexagonal honeycomb structure for heat insulating is better than square honeycomb structure.

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