THERMAL AND MECHANICAL ANALYSIS OF SQUARE HONEYCOMB PLATE FILLED WITH AIR

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***Abstract*:** Heat conduction is mainly due to molecular momentum transfer due to which solids conduct more heat than liquids and gases. Solids with high porous nature cannot conduct more heat because of air gaps present in the high porous solid. In this paper a square honeycomb sandwiched plate was studied numerically to evaluate its thermal and mechanical properties with the help of ansys software. Square honey comb structure has more section modulus. In general structures with high section modulus are subjected to high load applications because they reduce the weight of final component with slight change in maximum equivalent stress (von-mises stress). The square honey comb sandwiched plate is analysed numerically and the results are compared with the solid plate of same projection area of cross section and made of same material. From the results of mechanical analysis, it shows that the square honeycomb sandwiched plate producing more deformation than the solid plate at same applied load and boundary conditions but results from thermal analysis shows that there is a decrease in 18% of heat transfer through the square honey comb plate.

Keywords: **Porosity, Section Modulus, Square honeycomb sandwiched plate, Maximum Equivalent stress (von-mises stress), Heat conduction.**

1. INTRODUCTION:

According to theory of bending, the following equation is applicable for the structures subjected to bending moment:

$$\frac{M}{I} = \frac{F}{Y} = \frac{E}{R}$$

Here M is bending moment acting on structure
I is the moment of inertia of cross section of the structure
F is bending stress developed in the structure
Y is the distance of fiber from neutral fiber
E is young's modulus of the structure
R is the radius of bending deformation

From the above equation

$$F = \frac{MY}{I}$$

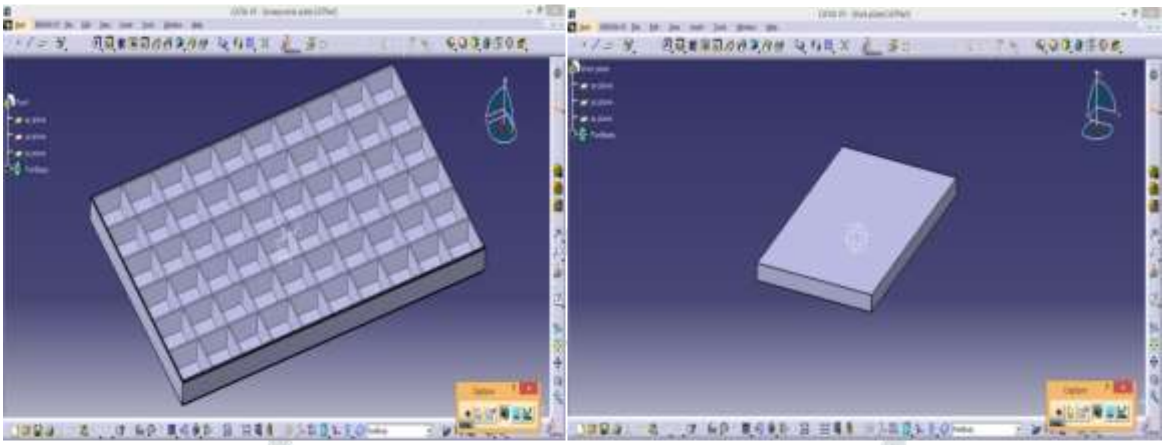
$$=> F = \frac{M}{Z}$$

Here Z is called as section modulus and it is directly proportional to moment of inertia of the cross section.

Square honeycomb plate is basically having more section modulus and it can be employed for developing thermal resistive surfaces[1] because it having less solid mass when compared with the solid plate of same thickness and projection area of cross-section. Author Guo cai in his paper he developed a multifunctional composite square honeycomb sandwich structure (MCHSS) which provides both high thermal conductivity and adequate mechanical property for a thermal management system and his studies concluded that MCHSS is used as a promising structure in high end heat dissipation applications [2]. Periodic lattice materials are considered as the most optimistic multipurpose structural materials in this present scenario, and excelled by Ashby, Evans, Fleck, Gibson, Hutchinson and Wadley, due to their exceptional mechanical properties (specific strength & stiffness) and their potential in multipurpose applications [3-7]. It was concluded that composite square honeycomb sandwich panels [8] have significantly more shear and compressive strength than the other types of sandwich panels for constant mass basis. Along with the above said properties square honeycomb plate is also having more bending strength.Bending stress developed in the structure due to bending moment depends on moment of inertia of the cross section of structure. More moment of inertia mean its bending strength is more as a result it can withstand more bending loads. In this project a square honey comb structure was proposed to increase the bending strength and the bending strength of proposed structure was evaluated by using ANSYS software. Thermal properties are also evaluated by using ansys software.

2. MODELING OF THE SQUARE HONEYCOMB SANDWICHED PLATE:

CATIA V5 software is used to develop the 3D models and the following models are developed in this software.



1(a) 1(b)

Figure.1: (a) Square honeycomb plate (b) Solid plate

Both models are having same thickness and same projection area of cross section and both are made of structural steel.

3. NUMERICAL ANALYSIS

Following are the common steps involved in any numerical analysis

3.1 Pre-processing
3.2 Processing
3.3 Post-processing

3.1 Pre Processing

Pre processing step is initial phase of analysis in which the following steps are performed

3.1.1 Developing Geometry

In this step the required geometry is developed in any one the 3D modeling software like CATIA, Solid edge, Fusion 360 etc as per the required specifications. After developing the 3D model it is imported into the ANSYS work bench. Simple geometry can also be developed in ANSYS workbench with the help of modeling commands.

3.1.2 Apply material

After importing the geometry into work bench material is added to the geometry by using apply material command from system library. New material needs to be defined properly before applying it to the geometry.

3.1.3 Define Boundary Conditions and loads

Boundary conditions are the constraints that are subjected to the problem. Boundary conditions depend on the type analysis. In case of thermal problems boundary conditions are three different types they are boundary condition of first kind, boundary condition of second kind and boundary condition of third kind. First kind of boundary conditions is like surface temperature, initial temperature, and final temperature of surface. Second kind of boundary conditions are specified by Heat flux through surface and third kind of boundary conditions are specified by thermal convection heat transfer.

3.1.4 Meshing

Meshing is the process of dividing the model into small components by using meshing elements. Meshing elements are divided into two types they are 2D elements and 3D elements. Fine meshing is very important to get more accurate results. Meshing software packages are also available for fine meshing. But fine meshing requires more computational time and more complex.

3.2 Generate Solution

In this step, solution is generated according to the selected mathematical model by satisfying the constraints and boundary conditions with applied loads. Accuracy of the solution mainly depends on meshing of model. If number of elements in meshing is more then the solution reaches the exact solution and also computational time also increased. For complex models it is impossible to solve by using normal computers, in this case super computers are required to solve the problems.

3.3 Post processing

After generating solution it is reviewed whether it meets the constraints or not. In case of any deviations found, then the model is subjected to some changes and the process is repeated to get accurate results. After applying loads the model behavior is simulated according to the generated solution by using different tools like deformation, von-mises stress, displacement, temperature distribution, total heat flux etc.

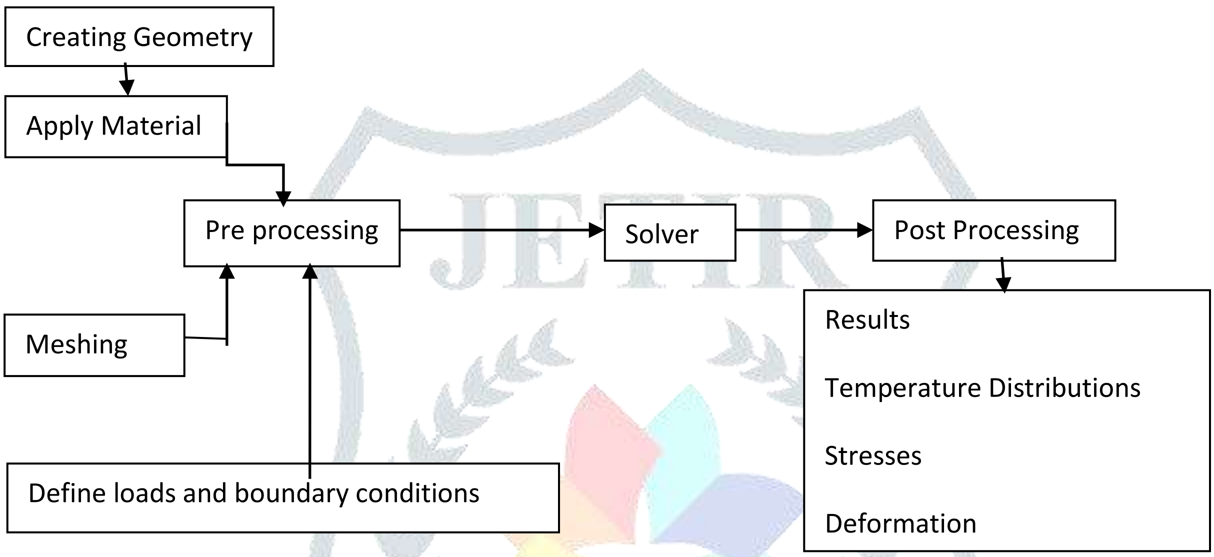


Figure 2. ANSYS Analysis flow chart

4. RESULTS

Square honeycomb structure is analyzed numerically to evaluate its thermal and mechanical properties with the help of ansys software and the results were compared with solid plate results. The following are results from numerical analysis of both plates.

4.1 Strength based Analysis of the Plate:

The two plates are analysed in static structural module to evaluate their mechanical strength and behaviour with same boundary conditions and load. Both the plates are subjected to a load of 88 kN at same specified location.88 kN load is the maximum load that can withstand by the square honey comb plate.

- Boundary conditions

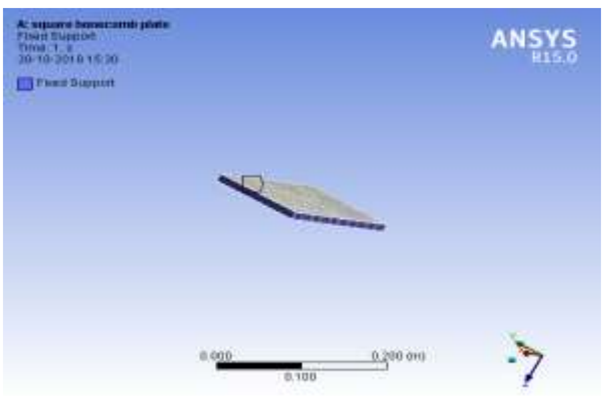


Figure 3(a) Boundary Conditions

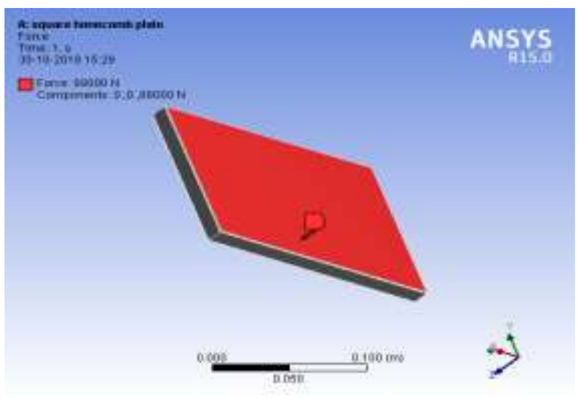


Figure 3(b) applied Load

- Von-mises stresses developed in the square honeycomb plate and solid plate

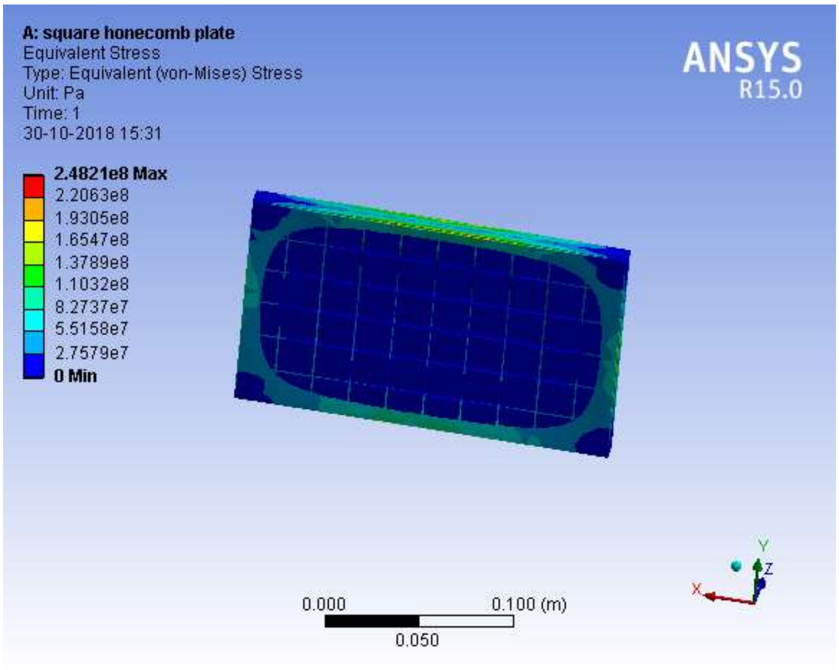


Figure 4.Von-mises stress developed in square honey comb plate

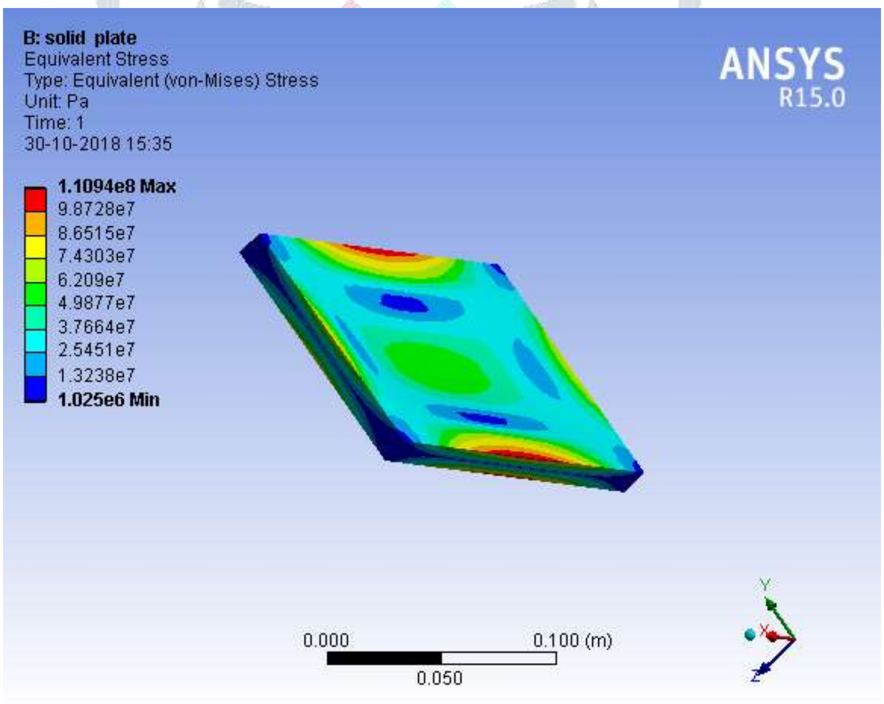


Figure 5.Von-mises stress developed in solid plate

- Deformation of the plates

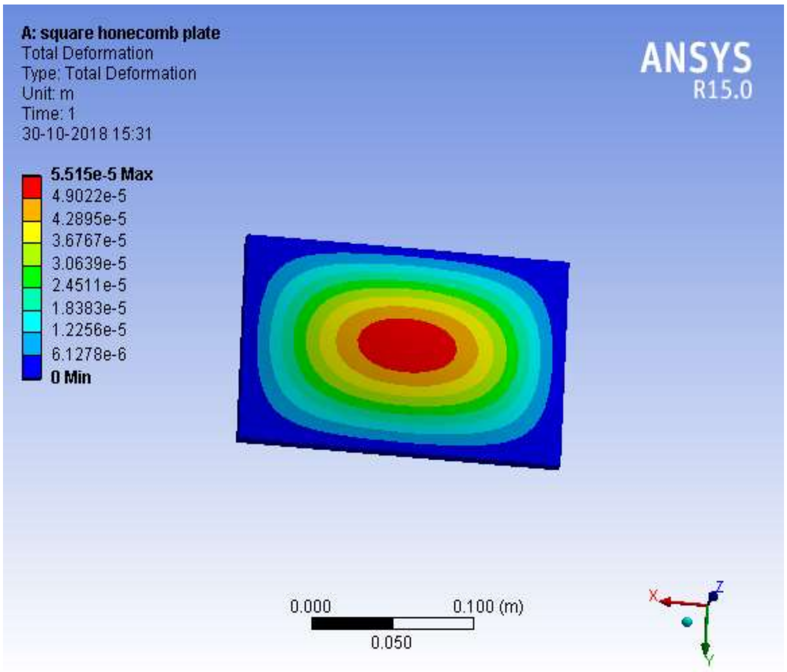


Figure 6. Deformation in square honey comb plate

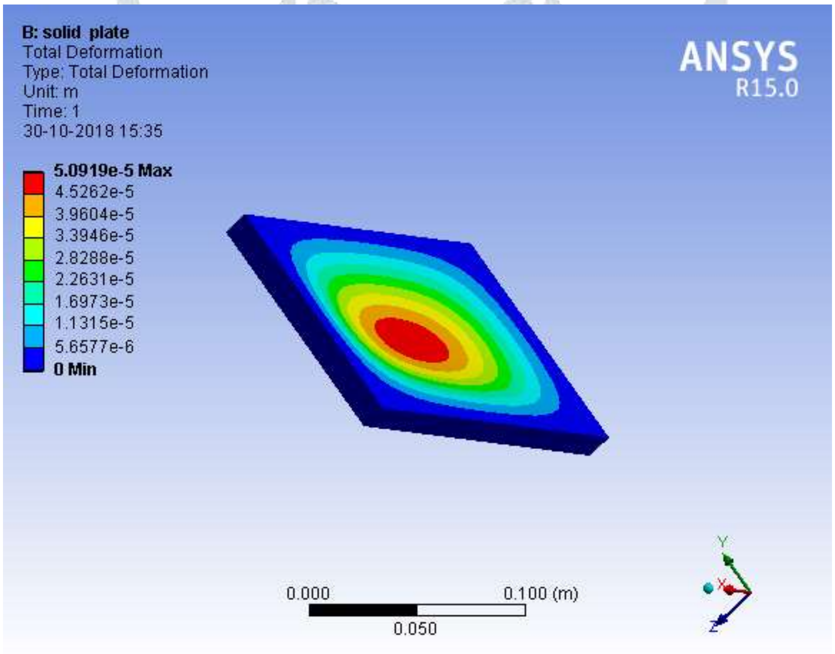


Figure7. Deformation in solid plate

4.2 Thermal Analysis of the Plate:

Both the plates are subjected to thermal analysis in steady state thermal analysis module with the same load and boundary conditions. Following are the results from thermal analysis.

- Boundary Conditions

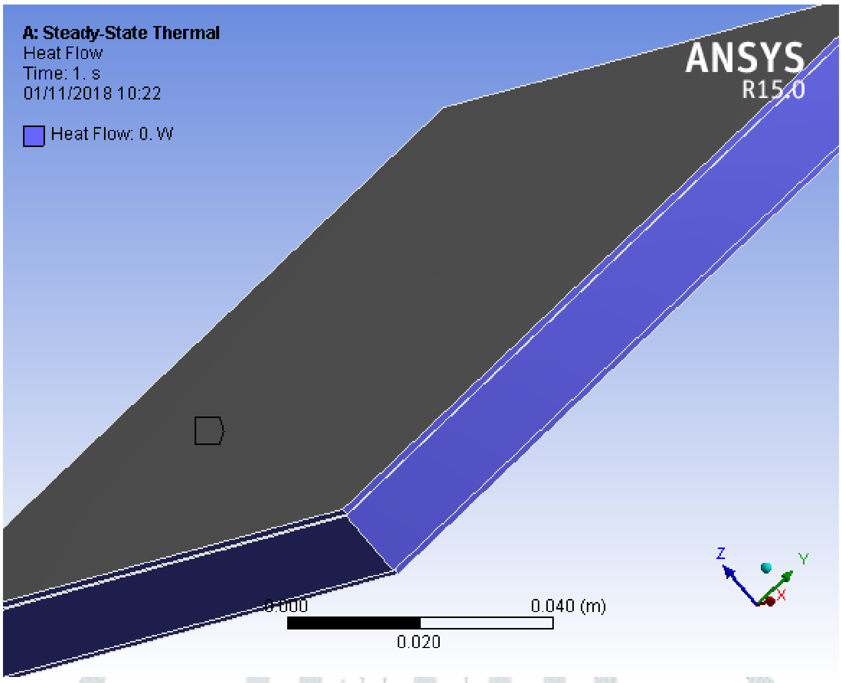


Figure 8. Boundary conditions in thermal analysis

- Applied load

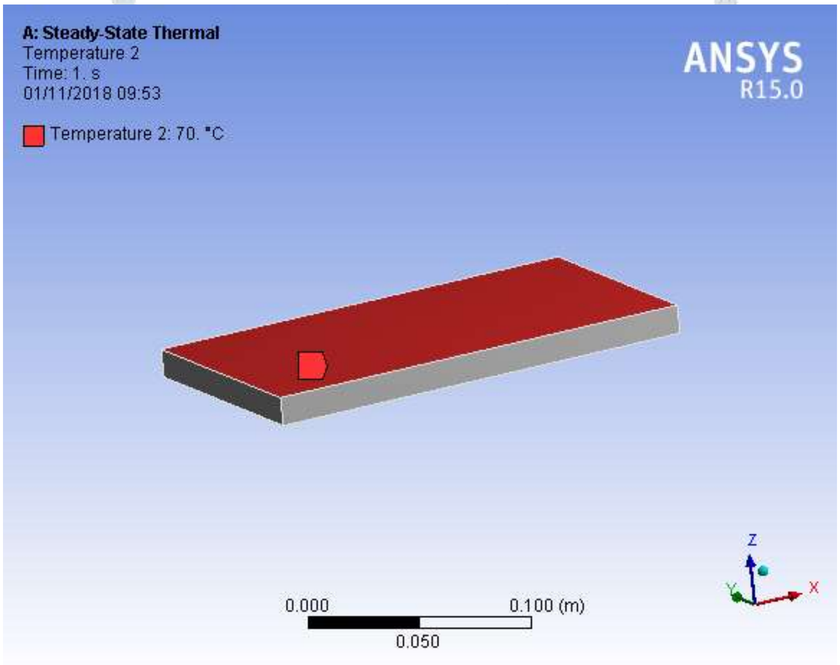


Figure 9. Applied Load in terms of temperature

- Temperature distribution in the plates

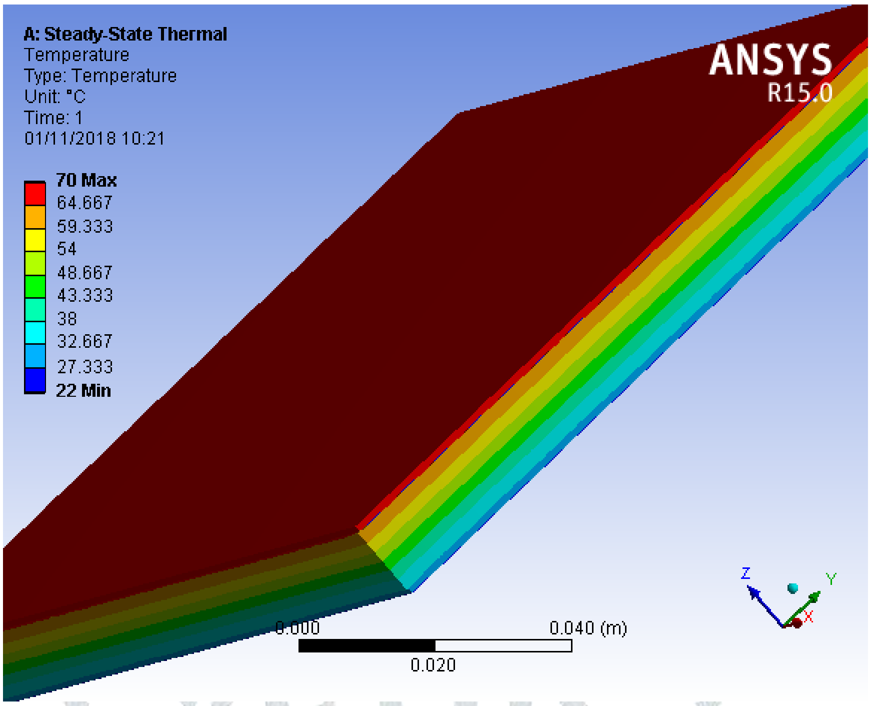


Figure 10. Temperature distribution in square honey comb plate

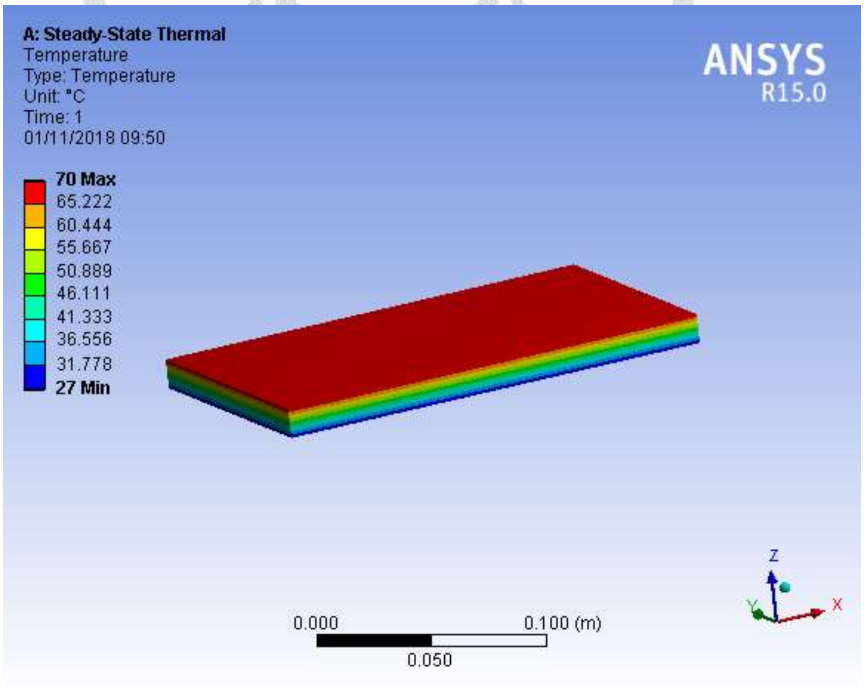


Figure11. Temperature distribution in solid plate

5. CONCLUSIONS

- From the above results it was found that 18% of the heat transfer is reduced by the square honeycomb plate when compared with solid plate of same thickness and cross sectional area. This is because that the square honey comb plate is having cubical voids filled with air. Due to this air voids heat conduction through the plate is reducing.
- Along with the reduction in heat transfer there is a reduction in weight is also observed. This is because that the most of solid portion of plate is replaced with air voids.
- For the same thickness and cross sectional area of plate there is an 8% increase in maximum deformation and 23% increase in von-mises stresses was observed in square honey comb plate at a load of 88kN. This increase in stress indicates that solid

plate can withstand more loads than square honey comb plate for same thickness and same cross sectional area. Due to this reason square honey comb plates are employed for low and medium load thermal insulation applications.

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