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A COMPREHENSIVE ANALYSIS OF PCB COOLING HEAT SINKS USING ANSYS - COMPARATIVE TRANSIENT THERMAL STUDY

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Abstract - Heat is frequently produced inside the electronic equipment's because the electricity-conducting components are not always 100% efficient. As most electrical components cannot resist the excess heat produced, the heat must be dispersed. Practically, applications involving forced or natural convection use heat sinks. Fins are thin surfaces that extend from the heat sink base and are typically present on heat sinks. By expanding the accessible surface area for heat transmission, these fins efficiently improve the heat transfer between its surface and the surrounding air. These fins receive heat from the electrical gadgets by conduction, and the surrounding air absorbs this heat energy through convection. An aluminum heat sink and a copper plate make up the heat sink assembly.

In the current work, a thermal heat sink that uses forced convectional cooling is used to cool electronic equipment. The copper plate surface receives 1000 W of thermal power in the suggested paradigm. This heat sink is forced to receive cold air, which dissipates heat. The main goal of this research was to estimate the average temperature of a copper plate in steady state and to describe the transient heat transfer phenomenon. Design modification on currently using heat sink is done. Later on, FEM analysis is done for steady state and transient heat transfer on modified designed heat sink.

Based on the simulation findings, it can be shown that the increased surface area of the interrupted rectangular pin fin caused a 5.32% increase in the temperature drop. The zone of maximal heat flow was constrained close to the connection of the fins to the base plates, however the maximum heat flux occurs in interrupted rectangular pin fins. This occurrence is understandable because heat sink construction typically includes soldering fins. The heat sink is designed with these fins oriented to give a surface area that permits air to circulate through them. They are essential to the cooling process because of this.

Keywords: Heat sink, forced convection, FEM analysis, Ansys, & Transient Thermal

1 FACTORS AND CONSIDERATIONS IN HEAT SINK DESIGN

1.1 Thermal Resistance

Thermal resistance can simply be defined as the combined thermal resistance the generated heat faces as it moves through a temperature gradient. This includes thermal resistance within the heat sink assembly, any friction, and thermal energy wastes because of resistance between the coolant and heat exchanger surface.

Thermal resistance can be calculated using the thermal resistance value. It is extremely helpful in finding out the most effective thermal resistance for components and ICs.

1.2 Types of Materials

Heat sink design is largely affected by the material of choice. Popular materials for heat sinks include aluminum alloys like AA 6063-T6 and copper tungsten or copper-molybdenum. Copper heat sinks offer excellent thermal conductivity and corrosion resistance but are heavier and more expensive than aluminum. Moreover, Chemical Vapor Diamonds (CVDs), lab-grown diamonds are used owing to their thermal conductivity coming from vibrations within their lattice structure.

Other heat-generating devices affected by thermal resistance include lithium-ion batteries used in cars and transferring heat away from these batteries is crucial, otherwise, thermal runaway can lead to a chain reaction destroying the battery. A carbon fiber heat sink with higher conductivity offers a thermal management solution to the car industry.

1.3 Heat Sink Fins

Fins are the component of a heat sink that allows heat transfer away from the heat sink toward ambient temperature. The shape and location can largely affect how the heat sink transfers energy while the size and a sheer number of these fins determine its efficiency.

1.4 Additional Factors that Impact Heat Sink Performance

Maybe the temperatures aren't as low as desired for the component, even if the heat sink computer design calculations were accurately performed. There are other ways of bringing the temperature down that work in conjunction with the heat sink.

1.5 Thermal Heat Sink Compound Conditions

The goal is to not only have a well-rated thermal heat sink compound, but also want to ensure it is only as thick as it needs to be to fill the gap between the component and heat sink. If the gap is too thick, it may slow heat transfer.

1.6 Natural and Forced Convection

Since a heat sink works by dispersing heat to the surrounding air, the process can be improved by moving that free air into forced convection air parallel to the heat sink fins by the use of a heatsink fan. Using forced air convection significantly increases the rate of heat transfer. This forced convection will lower the effective thermal resistance of the heat sink, while ensuring that the ambient air remains at a lower temperature. On that same note, if the heat sink is packaged in a very small package with restricted air flow, natural convection is hampered and may reduce the effectiveness of the heat sink.

1.7 Main Takeaways

- The most efficient heat sink design from a geometrical standpoint is one that contains fins or pins to increase the surface area for heat transfer.
- Copper is one of the best materials to choose for heat sinks as it has a high thermal conductivity. But aluminum is most commonly used due to it's lower cost and relatively high thermal conductivity.
- A heat sink design can be improved by adding fans or pins, choosing an alternative material, or adding in forced cooling via convection.
- A heat sink works by absorbing thermal energy in the surrounding environment from electrical component inefficiency via the conduction method of heat transfer.
- A powered fan works to allow a higher flow rate of air over a surface, thereby increasing the rate of heat transfer over the surface, drawing more heat energy away from the surface.

2 REVIEWED ARTICLES

1. Nuraini Binti Sukhor et. al. systematically modeled and investigated computational heat transfer characteristics of Al_2O_3-Cu/water hybrid nanofluid in micro heat sink. Volume concentration in the range of 0.1%-0.5% was used for the working fluid. Hexagonal micro-pin fin heat sink with staggered arrangement was simulated in ANSYS Fluent. Reliable experimental result from literature was used to validate the accuracy of the results. The most obvious finding to emerge from this study is that the Nusselt number increases with increase in Reynolds number and this observation is consistently the same at different concentrations and pin spacing. Lower transverse pitch was observed to dominate the enhancement of Nusselt number. There was a 10% increase in heat transfer coefficient at 0.5% nanofluid concentration when compared to 0.1%. This phenomenon is highly influenced by the transition of the Re into turbulent situation which eventually enhances the heat transfer characteristics. Also, lower transverse pitch promotes swirling flow situation. At 0.5% hybrid nanofluid concentration, it was observed that the Nusselt number increased from 14.00 at transverse pitch of 3.81 mm to 17.00 at a transverse pitch of 1.81 mm and this corresponds to 16.05% enhancement of Nusselt number. The pressure drop penalty of the working fluid is a result of increase in viscous effect of the hybrid nanofluid, especially at high concentration.
2. Vivek Kumar & Dr. V. N. Bartariacarries out numerical physical insight into the flow and heat transfer characteristics. The governing equations are solved by

adopting a control volume-based finite-difference method with a power-law scheme on an orthogonal non-uniform staggered grid. The coupling of the velocity and the pressure terms of momentum equations are solved by the computational fluid dynamics. The Elliptical Pin Fin Heat Sink is composed of a plate fin heat sink and some circular pins between plate fins. The purpose of this study was to examine the effects of the configurations of the pin-fins design. The results show that the Elliptical Pin Fin Heat Sink has better unnaturally performance than the plate fin heat sink. Computations of the Elliptical Pin Fin Heat Sink and provides.

3. Tu-Chieh Hung et. al. constructed three-dimensional models of micro channel heat sinks (MCHSs) with different geometric configurations(such as single-layered- (SL), double-layered- (DL) or tapered-(T)-channels) by an optimization procedure. This procedure integrates a direct problem solver with a simplified conjugate gradient method as the optimizer. The overall thermal resistance of an MCHS is the objective function to be minimized with respect to geometric parameters, such as the number of channels, channel width ratio, channel aspect ratio and tapered ratios, as the search variables. The optimal thermal resistance is found to decrease in the following order: the initial guess parallel channel (IGP channel), SL-, DL- and T-channel designs. In addition, the T-channel design has the minimum temperature difference and the most uniform temperature distribution, followed by the DL-, SL- and IGP-channel designs. Moreover, the optimal thermal resistance reduces with the pumping power for the various channel configuration designs, and the lowest thermal resistance corresponds to the T-channel design. The larger the pumping power, the larger the decrement in thermal resistance. Therefore, the optimal T-channel is the best MCHS design when considering thermal resistance and temperature distribution uniformity.

3 ADOPTED METHODOLOGY

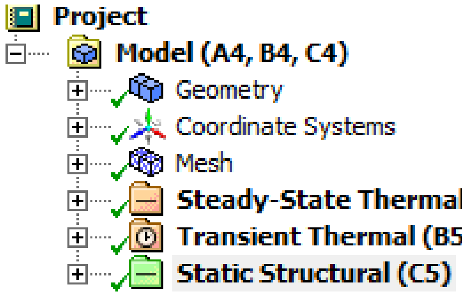
1. 3D modeling with Solid works 2013
2. Refinement of the model such as elimination of bad geometry, simplification of unnecessary parts and improvement of contact regions
3. ANSYS workbench18.1 Initial setup. This information will allow the model to work properly during simulation and will define the behavior of the parts during the analysis.
4. FEM inputs. Boundary Condition as per the work environment.
5. Steady state and transient thermal Simulation.

Transient thermal analysis shows temperature and other thermal parameters that vary over time; which are taken the input as in evaluating the steady-state thermal structural analyses. The induced loads in a transient analysis are functions of time that can separate the load versus time curve into load step.

Figure 3.1 Methodology

4 RESULT AND DISCUSSION

Two different configuration are taken to be care and compare for the better design option. In I case six rectangular fins were considered taken for analysis, II case was consider 40 rectangular pin fins. Both of these cases were consider for the analysis under Steady state and transient thermal real working conditions and result will be compared and therefore the best alternative was suggested. Directional and total deformation were also be analysed for both of these case under the thermal stress.



Project
- Model (A4, B4, C4)
  - Geometry
  - Coordinate Systems
  - Mesh
  - Steady-State Thermal (A5)
  - Transient Thermal (B5)
  - Static Structural (C5)

Figure 0.1 Outline

4.1 Steady –State Thermal Analysis

4.1.1 Temperature Distribution

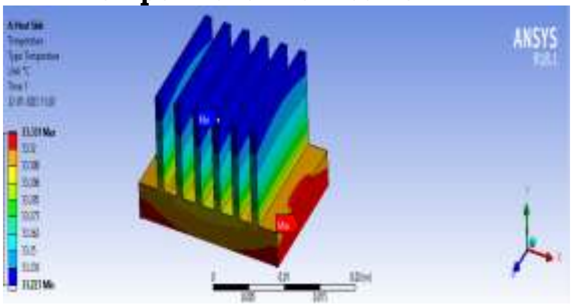


Figure 0.2 Steady State Temperature Distribution: Case 1

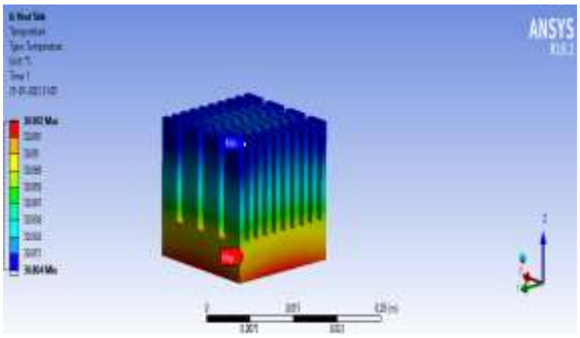


Figure 0.3 Steady State Temperature Distribution: Case 2

By means of simulation, temperature distribution is represented for both cases. InFigure 4.2 & 4.3 clearly shown that the max temperature in case 1 is 33.331^0 C and that is in case 2 is 30.902^0 C, similarly minimum temperature in case 1 is 33.227^0 C and for case 2 it is 30.804^0 C. It can be visualize that the maximum temperature is at near the base where the load is directly connected to the load and het is transferring through conduction. And convection took place in fins and temperature is gradually decreasing with altitude and shows the minimum temperature at top.

4.1.2 Total Heat Flux

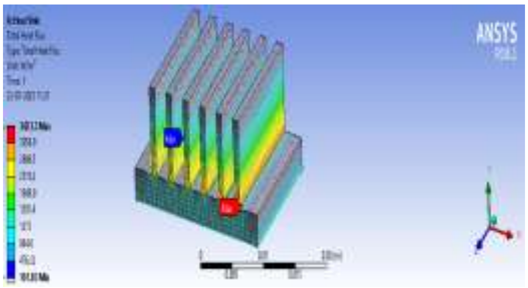


Figure 0.4 Steady State Total Heat Flux: Case 1

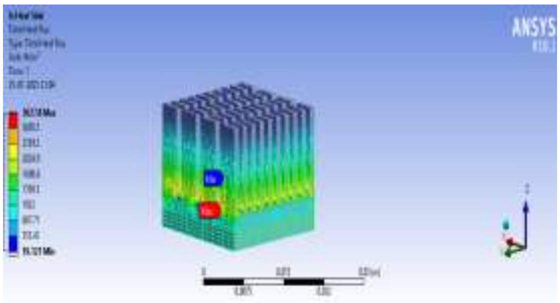


Figure 0.5 Steady State Total Heat Flux: Case 2

The fin tips are exposed to atmosphere and the figure 4.3 and 4.4 are showing the vector representation of heat flow from the base plate to atmosphere in both the cases. In steady state maximum and minimum heat flux were 3423.3 W/m^2 and 107.83 W/m^2 respectively in case 1. Whereas in case 2 maximum and minimum heat flux were 3027.8 W/m^2 and 19.121 W/m^2 respectively. Result shows that the maximum heat flux occurs at the fin interface and the zone of minimum heat flux is near about the tip of fin. The range of heat dissipation was 107.83 to 342.3 W/m^{2}in case 1 and that was 19.121 to 3027.8 W/m^2. So it is clearly depicted by the results that Case 2 is more effective than case 1. So case 2 is more preferable configuration.

4.1.3 Directional Heat Flux

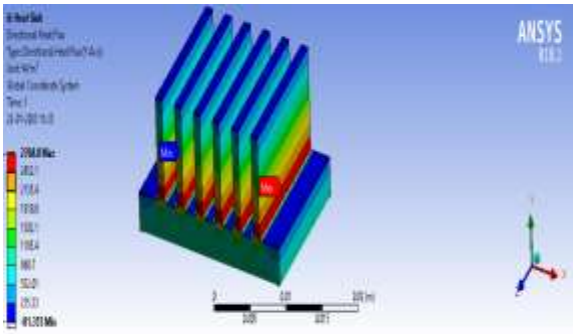


Figure 0.6 Steady State Directional Heat Flux: Case 1

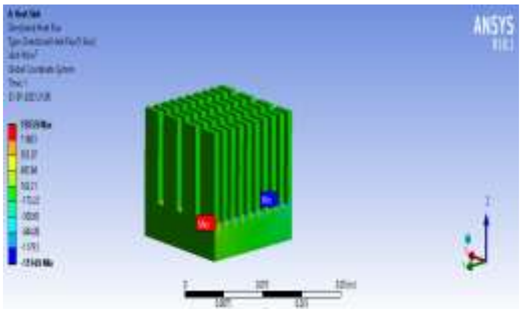


Figure 0.7 Steady State Directional Heat Flux: Case 2

Directional heat flux was varying from -81.355 W/m^2 to 2768.8 W/m^2 for case 1 and -1514.9 W/m^2 to 1503.9W/m2.The Directional heat flux conducted by the material increases with increase in amount of material but decreases with increase in fin thickness and it is high in rectangular geometry when compared with Interrupted rectangular pin fin conducts more directional heat than rectangular fin. In the negative direction opposite to the positive direction same effects are applicable.

4.2 Transient Thermal Analysis

4.2.1 Temperature Distribution

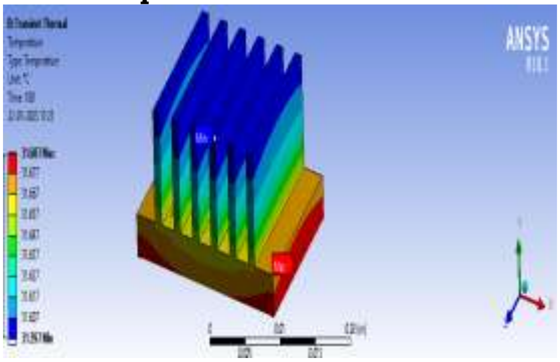


Figure 0.8 Transient Temperature Distribution: Case 1

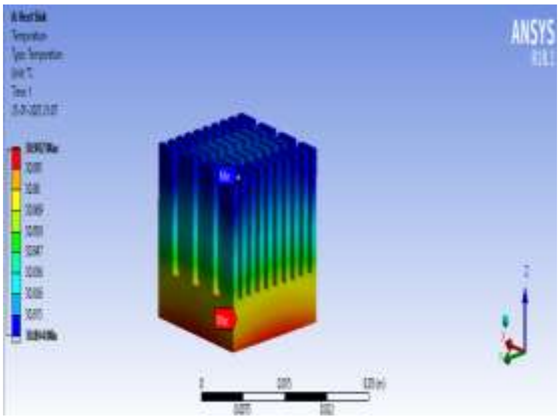


Figure 0.9 Transient Temperature Distribution: Case 2

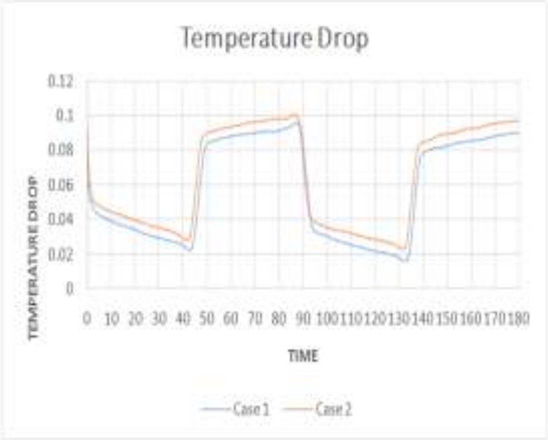


Figure 0.10 Temperature Drop

As represented in the above figure that the value of maximum temperature obtained is different for both heat sink profiles. It shows that 30.902^0 C was the maximum temperature in case 2 which is lesser than the minimum temperature i.e. 31.597^0 C for case 1.

In Case 2 when interrupted rectangular pin fin were to be considered the Maximum temperature drop was 0.099^0 C and the minimum temperature drop was 0.025^0 C, Whereas in Case 1when rectangular fins were to be considered the maximum temperature drop was 0.094^0 C and the minimum temperature drop was 0.018^0 C. and figure 4.10 shows the higher temperature drop with respect to time (180 sec) for case 2.The above phenomenon occurs because the total effective surface area were increased due to number of fins instead of a single fin. So it can be concluded that the heat dissipation in case 2 is better than in case 1.

4.2.2 Total Heat Flux

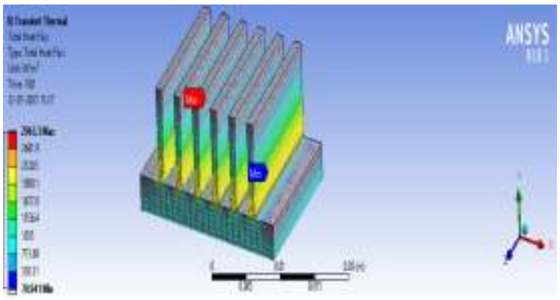


Figure 0.11 Transient Total Heat Flux: Case 1

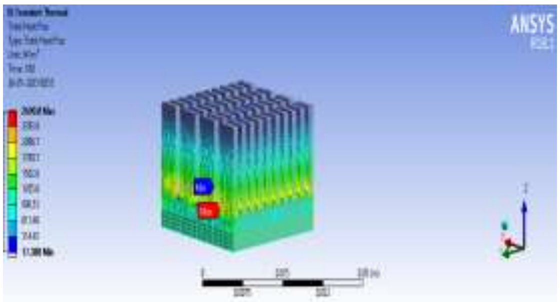


Figure 0.12 Transient Total Heat Flux: Case 2

The figure 4.10 and 4.11 are showing the vector representation of heat flow from the base plate to atmosphere in both the cases. Under transient thermal condition maximum and minimum heat flux were 2963.3 W/m^2 and 70.941 W/m^2 respectively in case 1. Whereas in case 2 maximum and minimum heat flux were 2690.8 W/m^2 and 17.388 W/m^2 respectively. Result shows that the maximum heat flux occurs at the fin interface and the zone of minimum heat flux is near about the tip of fin. The range of heat dissipation was 70.941 W/m^{2}to 2963.3 W/m^{2}in case 1 and that was 17.388to 2690.8W/m^2. So it is clearly depicted by the results that Case 2 is more effective than case 1. So case 2 is more preferable configuration.

4.2.3 Directional Heat Flux

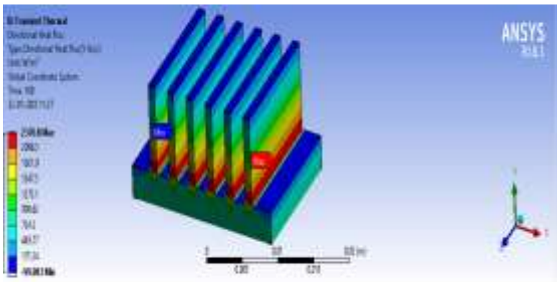


Figure 0.13 Transient Directional Heat Flux: Case 1

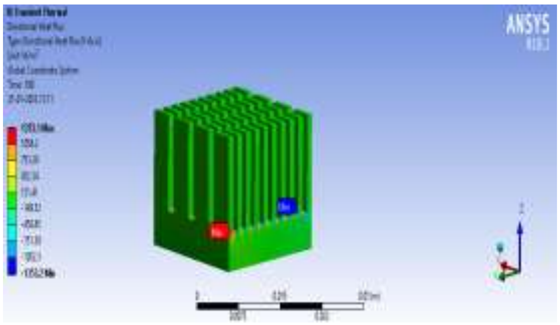


Figure 0.14 Transient Directional Heat Flux: Case 2

Directional heat flux was varying from -99.083 W/m^2 to 2370.8 W/m^2 for case 1 and -1353.2 W/m^2 to 1355.1W/m2.The Directional heat flux conducted is high, when compared with Interrupted rectangular pin fin conducts more directional heat than rectangular fin. In the negative direction opposite to the positive direction same effects are applicable.

4.3 Static Structural Analysis

4.3.1 Total Deformation

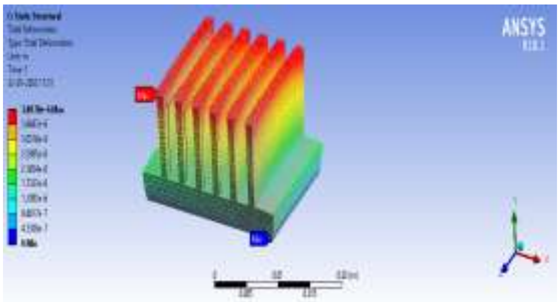


Figure 0.15 Static Structural Total Deformation: Case 1

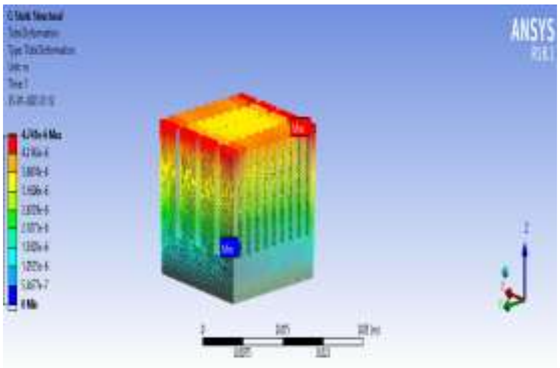


Figure 0.16 Static Structural Total Deformation: Case 2

The above figures are representing that for case 1 maximum total deformation is 3.8978 x10^{-6}m at fin tip which is free for expansion and minimum total deformation is 0 m because base plate is fixed and in case 2 for interrupted rectangular pin fin maximum total deformation is 4.741x10^{-6}m at fin tip which is free for expansion and minimum total deformation is 0 m. so it need proper clearance space of at least 0.5 mm each side for proper functioning.

4.3.2 Directional Deformation

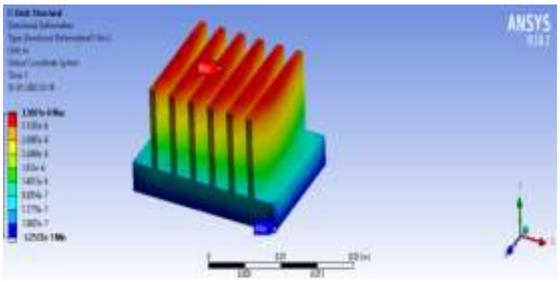


Figure 0.17 Static Structural Directional Deformation: Case 1

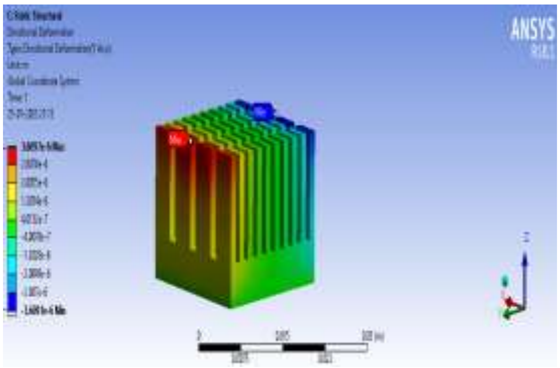


Figure 0.18 Static Structural Directional Deformation: Case 2

The above figure4.16 & 4.17 are representing that for case 1 maximum directional deformation is 3.5601 x10^{-6}m and minimum directional deformation is -3.2572x10^{-6}m along y axis and in case 2 for interrupted rectangular pin fin maximum directional deformation is 3.6097x10^{-6}m and minimum directional deformation is -3.609x10^{-6} m.

4.3.3 Equivalent Stress

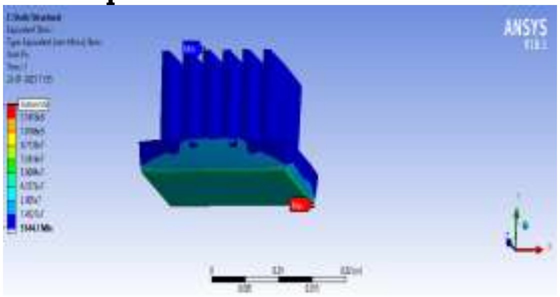


Figure 0.19 Static Structural Equivalent Stress: Case 1

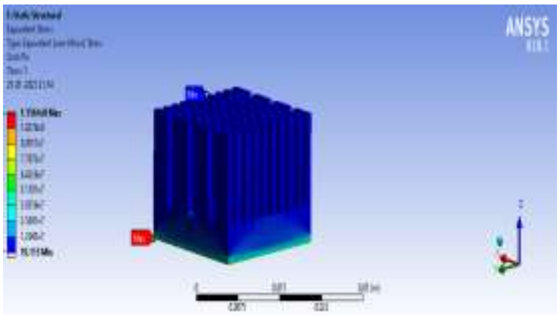


Figure 0.20 Static Structural Equivalent Stress: Case 2

Results show that the equivalent stress is near about zero because only thermal load is applicable and model is free for expansion as base is fixed and the other end is free in both the cases.

5 CONCLUSION

An alternative model of heat fins has been designed to increase heat dissipation. In ANSYS both the Configuration is analysed and the results of steady state and transient thermal analysis are taken for comparison. From the observations the following conclusions are made:

1. CPU cooling performances of a computer chassis with rectangular and interrupted rectangular pin fin heat sinks were investigated using transient thermal analysis and the results were compared. In case of Interrupted rectangular pin fin 5.32% more temperature drop was observed which is due to the increment in surface area.
2. The maximum heat flux is occurring in interrupted rectangular pin fin but the zone of maximum heat flux was limited near the connection of fins to the base plates. This phenomenon can be understood as the Heat sink design normally features fins soldered during heat sink construction. These fins orientation is to provide a surface area that allows air to pass through the heat sink. Therefore, they are critical in the cooling process. Therefore, heat sink fin efficiency depends on the shape of the fins and you must consider it to ensure effective convection of heat from the electronic device and, in turn, guarantee the cooling of the device and the heat sink.

3. Result shows that the maximum heat flux occurs at the fin interface and the zone of minimum heat flux is near about the tip of fin. The range of heat dissipation was 70.941 W/m^2 to 2963.3 W/m^2 in case 1 and that was 17.388 to 2690.8 W/m^2. So it is clearly depicted by the results that Case 2 is more effective than case 1. So case 2 is more preferable configuration.
4. The Directional heat flux conducted is high, when compared with Interrupted rectangular pin fin conducts more directional heat than rectangular fin. In the negative direction opposite to the positive direction same effects are applicable.
5. In case 2 for interrupted rectangular pin fin maximum total deformation is $4.741x10^{-6}$m at fin tip which is free for expansion and minimum total deformation is 0 m. so it need proper clearance space of at least 0.5 mm each side for proper functioning.

5.1 Future Scope

In presented work two configuration of heat sink were investigated with air convection with forced air. In future heat dissipation could be increase by using different cooling liquids i.e. PCM, or nano fluids can be used instead of air.

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