Design and Finite Element Analysis of Cold Plate Used in Electronic Power Cooling

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Abstract: Liquid cooling is the techniques used in industries to remove heat from mechanical devices with the help of cold plates in heat exchangers. These cold plates are rapidly used in navy and electronic applications. Normally electronic applications having VLSI systems. Due to transmission of applied current and voltage sometimes the temperature of the circuit plate goes increasing. This temperature limits the electronic operation. Usually the temperature increases up to 90⁰C, thus it is necessary to control such temperature, in order to maintain speed of electronic devices.

The approach is presented here to maintain the temperature lower with respect to circuit plate in electronic applications. The cold plates are formed of copper with grooving at two different orientations one is horizontal and other is diagonal. A CFD analysis is carried out to find the outlet temperature of cooling water flowing through groove.

Keywords: Liquid Cooling, Cold Plates, VLSI, Temperature, Electronic Applications, etc.

I. INTRODUCTION

In heavy electronic equipments in enterprises, high temperatures are achieved in working conditions. The safe temperature confine for the electronic hardware's is 90⁰C. This bring up in temperature will take an antagonistic impact on the equipments and sometimes fails to operate well. This is because of the electronic equipment’s life time will be diminished. So the hardware keep up safe temperature condition which is underneath 90⁰C. The liquid cooling is more effective to this problem, since convective heat transfer takes place in system.

The convective heat exchange takes place by cold plate. The cold plate is simply a plate having grooves at different orientations. The plate is formed by copper and aluminum material and is mounted at surface below the electronic device. The coolant (water) flows from the grooves at specific flow rate. The cooling is done by exchanging heat from lower surface of circuit to the coolant, rising the temperature of coolant.

The cold plates have certain types depends on size, shape, orientation, and application. Following are the three main classifications of the cold plates:

1) Formed Tube Cooling Plate (FTCP)
2) Deep Drilled Cooling Plate (DDCP)
3) Machined channel Cooling Plate (MCCP)

FTCP guarantee least warm resistance between the electronic device and liquid plate by flowing the coolant tube in direct contact with the gadget base plate. In this plan, copper plate is for the most part utilized, in spite of the fact that aluminum is some of the time utilized in low power applications.

A DDCP exchange more heat flux and power scattering increments, the contact resistance of the plate and the tube divider turned out to be unsatisfactorily high. In this plate, the drills are penetrated in the plane of subsequent plate.

The MCCP give better results compared with other types. The plate is made by machining the groove on the surface of the plate and cover for the passage to flow coolant. It improves thermal performance of the plate.

The present investigation based in formed tube cold plate. The material for the plates is copper and coolant is flowing water at 25⁰C. The outlet temperature of water is measured theoretically. The theoretical results are compare with CFD for validation. The plate surface is at 80⁰C. The various properties of system are taken from Table 1. The various types of cold plates are shown in figure 1-3.
II. PROPOSED METHOD

The two cold plates are modeled in CATIA V5R19 version. The size of the plates is 145 mm length and 145 mm width. The groove is made by CNC machining. The one plate having groove along vertical direction while other plate having diagonal orientation of groove. The first plate is modeled as model 1 and other plate is modeled as model 2 as shown in figure 4-5.
Now, making theoretical calculations from table 1, following assumptions are required to make analytical calculations.

1. The heat is convected from hot surface only.
2. The heat transfer by conduction of plate is neglected.
3. The heat transferred to cold water only.

The Heat Balance for the plate is given by,

\[ hA(T_s - T_{\infty}) = mC_p(T_{wo} - T_{wi}) \]

Where,
\[ h = \text{Heat Transfer Coeff. in } W/m^2K \]
\[ T_s = \text{Surface temp. of plate.} \]
\[ T_{\infty} = \text{final Temp. of plate.} \]

\[ m = \text{Mass flow rate of water = 0.05 Kg/sec.} \]
\[ C_p = \text{Sp. Heat of Water in KJ/KgK} \]
\[ T_{wi} \text{ and } T_{wo} = \text{inlet and outlet temp. of water.} \]

In the above equation, area, surface temp. of plates, mass flow rate and water inlet temp. are known. So it is necessary to find out heat transfer coefficient required for convection.

The heat transfer coefficient can be obtained by, considering following properties:
Density of water = 995.8 Kg/m³
Kinematic Viscosity = 0.00864 m²/s
Sp. Heat = 4.18 KJ/KgK
Thermal Conductivity = 0.614
\[ T_s = 80^\circ C \]
\[ T_{\infty} = 25^\circ C \]
\[ m = \text{Mass flow rate of water = 0.05 Kg/sec.} \]
\[ T_{wi} = 25^\circ C \]
\[ D_h = \text{Hydraulic dia. (m) = 4A/P} \]
Where, \( \rho \), \( V \), \( D \) and \( P \) are density, velocity, diameter and perimeter.
\[ Pr = 7.02, \quad Re = \rho V D / \mu \]
\[ Nu = \frac{hD}{\mu} \]

From above equations, the heat transfer coefficient is,
\[ h = 150 W/m^2K \]

Now, applying heat balance to the system to find out outlet temp of water.

### III. FINITE ELEMENT ANALYSIS

Transient heat transfer decide temperatures and other heat amounts that change after some time. The variety of temperature circulation after some time is of enthusiasm for some applications, for example, with cooling of electronic bundles or an extinguishing examination for heat treatment. Likewise of intrigue are the temperature conveyance brings about warm burdens that can bring about disappointment. In such cases the temperatures from a transient warm investigation are utilized as contributions to a basic examination for warm anxiety assessments. Transient warm investigations can be performed utilizing the ANSYS or Samcef solver.

Many heat exchange applications, for example, warm treatment issues, electronic bundle plan, spouts, motor squares, weight vessels, liquid structure association issues, thus on include transient heat investigations.
A transient thermal analysis can be either linear or nonlinear. Temperature dependent material properties (thermal conductivity, specific heat or density), or temperature dependent convection coefficients or radiation effects can result in nonlinear analyses that require an iterative procedure to achieve accurate solutions. The thermal properties of most materials do vary with temperature, so the analysis usually is nonlinear.

Typically, a steady-state thermal analysis include several steps:
- Create Analysis System
- Define Engineering Data
- Attach Geometry
- Define Part Behavior
- Define Connections
- Apply Mesh Controls/Preview Mesh
- Establish Analysis Settings
- Define Initial Conditions
- Apply Loads and Supports
- Solve
- Review Results

Open ANSYS Workbench. From the Toolbox, drag the Transient Thermal or the Transient Thermal (Sascecf) template to the Project Schematic. There are several material in the Engineering Data Sources that we can use directly. By clicking the Engineering Data Sources, then Thermal Material, then clicking the plus near Copper. Import the geometry in IGES format. There are no specific considerations for steady-state thermal analysis itself. However if the temperatures from this analysis are to be used in a subsequent structural analysis the mesh must be identical. Therefore in this case you may want to make sure the mesh is fine enough for structural analysis.

For a steady-state thermal analyses you typically do not need to change these settings. The basic controls are:

**Step Controls** allow you to control the rate of loading which could be important in a steady-state thermal analysis if the material properties vary rapidly with temperature. When such nonlinearities are present it may be necessary to apply the loads in small increments and perform solutions at these intermediate loads to achieve convergence. You may wish to use multiple steps if you a) want to analyze several different loading scenarios within the same analysis or b) if you want to change the analysis settings such as the time step size or the solution output frequency over specific time ranges.

**Output Controls** allow you to specify the time points at which results should be available for postprocessing. In a nonlinear analysis it may be necessary to perform many solutions at intermediate load values. However i) you may not be interested in all the intermediate results and ii) writing all the results can make the results file size unwieldy. In this case you can restrict the amount of output by requesting results only at certain time points.

**Nonlinear Controls** allow you to modify convergence criteria and other specialized solution controls. Typically you will not need to change the default values for this control. **Nonlinear Controls** are exposed for the ANSYS solver only.

**Analysis Data Management** settings enable you to save specific solution files from the steady-state thermal analysis for use in other analyses.

The ANSYS in transient thermal analysis has carried out. For this, a plate of size 145*145 mm is selected and groove of 4*4 mm is created as shown in model 1 and model 2 from figure 4-5. The fluid domain is created between plate and groove. A convection is given to the surface of groove. The boundary conditions are the surface temp. is 80°C and the cooling water inlet temp. is 25°C. The outputs are defined by the outlet temp. of cooling water if the plate is cooled by 10°C. The temp. Counters and flow lines are specified for comparison of results. The figures below shows the results for the two models of cold plates.
IV. CONCLUSION

The physical characteristics shown in the results are different in each model. From the above results the heat removal rate is more in Model 2. When comparing the weights of these cold plates, Model 1 cold plate has less in weight, than Model 2 cold plate. By considering these results the behavior showed by the Model 2 cold plate is within the safe temperature limit. This is due to carry the more amount of heat according to design of Model 2 cold plate and finally this is the best method of cold plate to maintain the industrial equipment in a safe desired conditions. This concludes that, the optimized method i.e. Model 2 cold plate can be adopted for industrial purposes.

References


