Heat Transfer Numerical Simulation And Optimization Of A Heat Sinks

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Abstract: In order to maintain operating temperature of the integrated circuits in electronic components there is a continuous need for effective cooling by proper heat dissipation method there by keeping operating conditions within safe level. To achieve this continuous research has been carried out for various heat sinks with different orientations and geometries. In the present work heat transfer coefficient of fin with different orientation and geometries is compared for increasing the heat transfer by reducing the pressure gradient, thermal resistance and laminar air velocities. these consists of pin fins that can be of different cross sections like circular, elliptical and square of inline and staggered array type.

1. Introduction

The modes of heat transfer from a heat sink fin are due to conduction, convection and radiation. Heat is dissipated by conduction from the electronic components by means of interface at the junction and in to the fin, from which heat is expelled out through convection and radiation. A detailed review on the past work carried out on the thermal performance of a fin pin shows that fewer work has been done on pin fin with different orientation like cross cut pin and parallel plate pin and compared with the existing fin pin of elliptical cross section.

Many situations arise where solutions are required for low to moderate. Reynolds numbers, between the diffusive and laminar boundary layer regimes. Such solutions are of particular interest to thermal engineers involved with cylinders or pin-fin heat sinks. In light of these facts, it is necessary to develop analytical models for the fluid flow and heat transfer from single cylinders (circular and elliptical) and pin-fin heat sinks for a range of Reynolds numbers, pin aspect ratio, base plate thickness, longitudinal and transverse spacing's.

Solution due to the non-linear governing differential equations and complex geometry, it is the challenge in solving this problem analytically that provides the motivation for this work. fin heat sinks consist of a array and base of integral attached pins. They can be classified in many ways, e.g.(i) low or high density and (ii) in-line or staggered Fig. 1.2.the effective cooling of the integrated circuit is by the forced convection because the heat sink pressure drop is removes heat easily by the heat sinks.
2. Objective

The heat transfer from single and multiple cylinders is conducted which is a critical step for developing fluid friction and heat transfer models for arrays of pin fins heat sinks.

The objectives of the present work are:

- Calculation of pressure drop, theoretically for the following cases:
  
  Case (i) Plate pin fin
  Case (ii) Circular pin fin
  Case (iii) Elliptical pin fin
  Case (iv) Square pin fin

- Also CFD Flow and heat transfer analysis of array of Aligned above Pins
- CFD Flow and heat transfer analysis of array of Staggered above Pins
- Comparing the theoretical results with the CFD results.
- For the theoretical and CFD analysis plate, Circular, Elliptical, square, pin fin heat sink is considered, which has the geometric models as shown in Fig 1 to 2 the heat sinks has dimension shown in the Table 3.1 and the material is taken as Aluminum.

3. Total Heat Sink Pressure Drop

A heat sink model and fan based on the some assumptions.

1. Consider heat sink is ducted with no flow bypass.
2. Uniform properties of the materials
3. Heat does not crosses the boundary
The system resistance is considered as pressure drop across the heat sink. In a heat sink its thermal performance is mainly affected by system resistance.

Convective heat transfer is reduced between pin fin and surrounding air due to minimal flow if air in the heat sink due to high system resistance. The performance curve of a blower gives actual volumetric flow rate in the heat sink to the total pressure drop when resistance across heat sink is known.

The following equations is commonly used for finding the pressure drop theoretical calculations. Apparent Pressure drop calculation for plate pin fin heat sinks is given by the formula.

$$\Delta P = \left( \frac{f_{app} N(2HL + bL)}{HW} + K_C + K_e \right)$$

$$\Delta P = \left( K_C + 4. f_{app} \frac{L}{D_h} + K_e \right) \rho \frac{V^2}{2}$$

Channel pressure drop formula is given by the equation

$$\Delta P = 4 \left( f_{app} X^+ + K_C + K_e \right) \left( \frac{1}{2} \rho V_{ch}^2 \right)$$

*Fig 2: Heat sink mesh and boundary conditions.*
By considering the laminar flow (Reynolds number below the 2400) the velocity is 1 m/s to 5 m/s and temperature is 29°C. The logarithmic density is high applied at the entry and exit of the model to getting accurate pressure drop in the heat sink with greater accuracy.

4. Results and discussions
The representation of the pressure contours in fig 6.1 shows the higher pressure around plate fin heat sink at the entry. A detailed view of the heat sink allows observing that higher pressure lie on the surface that most exposed incoming air the maximum pressure attained is 5.04 Pa for symmetry 2.54 Pa. the contours of temperature with higher temperature around the heat sink. A detailed view of the heat sink base observing that the higher temperature i.e 352.4 K. The model is created for the symmetric analysis to calculate the pressure drop for the numerical method. The above graph indicates the pressure v/s velocity of analytical, experiment and numerical comparison of the pressure drop with varying the velocity at the sink. Comparing three methods theoretical gives accurate pressure drop without considering the losses and practical and numerical gives almost equal pressure drop by observing the above graph.
Fig 4: Comparison pressure drop results for inline pin and staggered fin geometries

Fig 5: Comparison Drag results for pin fin geometries

The drag coefficient for plate, circular, elliptical, square, geometries is shown in the Fig 6.27 and the optimum drag coefficient 0.74 for elliptical pin fin heat sink and the maximum drag coefficient 2 for square pin fin heat sink. Compare to other geometries the Elliptical geometry is good for heat transfer application of electronic cooling application.
Fig 6: Comparison velocity results for pin fin geometries

The Velocity for different cases are compared for both arrangement the maximum velocity is 5.02 m/sec of square staggered arrangement and minimum velocity is 2.57 m/sec of elliptical inline arrangement.

5. Conclusions

Comprehensive analytical and numerical investigations of heat transfer surfaces with pins-fins have one of the most effective passive elements for the enhancement of heat transfer was performed. It was demonstrated that pin fins belong to the group of fins that simultaneously increase both the heat transfer surface area and the heat transfer coefficient.

- Analytical and CFD calculation is performed for circular pin fin sinks (inline and staggered) circular pin fin sinks results of drag coefficient of 1.42 and 1.67, pressure drop for inline and staggered 5.55 Pa and 8.66 Pa respectively, temperature for in line and staggered 350.52 K and 341.92 K respectively. For point of view of pressure drop heat transfer will be little more than the plate pin fin heat sink.
- Analytical and CFD calculation is performed for elliptical pin fin sinks (inline and staggered) elliptical pin fin sinks results of drag coefficient of 0.74 and 0.8 pressure drop for inline and staggered 3.02 Pa and 4.66 Pa respectively, temperature for in line and staggered 355.52 K and 342.19 K respectively. For the point of view of heat transfer compared to other geometry the pressure drop is very low compared plate pin fin and circular pin fin.
- Analytical and CFD calculation is performed for square pin fin sinks (inline and staggered) square pin fin sinks results of drag coefficient of 1.97 and 2, pressure drop for inline and staggered 7.38 Pa and 13.36 Pa respectively, temperature for in line and staggered 344.44 K and 341.83 K respectively. For the heat transfer point of view in this case the pressure drop will more than the other three cases.
- Analytical and CFD calculation is performed for p heat sinks with plate type, plate pin fin heat sink results of drag coefficient of 0.87, pressure drop 5.04 Pa, temperature 352.4 K. In this case as the fin height is increases pressure drop is less and number of fins increases the pressure drop is also less.
Comparing the all above geometry, heat transfer, drag coefficient, pressure drop, temperature is very poor in square geometry when compare to all other geometries. For the staggered elliptical pin fin arrangement performed better than Cylindrical, Plate, Square, pin fin heat sinks. Elliptical fin heat sinks good for electronic cooling purpose.

5. References

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