Design and Computational Analysis of Inline Array Heat Sink Models

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Abstract— *The multiple challenges in the avionics industry, which needs the thermal management system for its electronic components. To enhance the performance, reliability and safety of its systems an innovative technology required to reduce the temperature developed at the source. Inline Extended surfaces as heat sinks with different array systems under design considerations to enhance the performance an electronic component as if the internal temperature of the component arises from its application the module may fail to work efficiently which persistently challenge the engineers towards the heat dissipation process. The perforated heat sink designs are reviewed with conventional designs with the available innovations.*

Index Terms— *Fin geometries, Heatsinks, Computational Fluid Dynamics, heat transfer, thermal management, fin array, extended surfaces, conduction, convection,Fin Arrays*

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1 INTRODUCTION

Transforming of thermal energy from a heated body to a colder body with the help of an object or fluid, transfer of thermal energy is also known as heat transfer. Exchange of heat occurs till body and the surroundings reach the same temperature. According to the second law of thermodynamics, Where there is a temperature difference between objects in heat transfer between them can never be stopped. The study of heat transfer deals with the rate at which such energy is transferred. Heat is thus the energy in transit between systems which occurs by virtue of their temperature difference when they communicate. Obviously, conditions of temperature disparity and communication must be fulfilled simultaneously for heat interaction between systems to occur. The finite temperature difference existing between the systems makes the process of heat exchange irreversible, i.e. flow of heat cannot be reversed.

In the heat transfer study, the surface that extends from an object is known as a fin. This is used to increase the rate of heat dissipation from or to the environment by increasing the rate of convection. The total of convection, conduction, or radiation of an object decides the amount of heat it dissipates. It increases with the difference in temperature between the environment and the object, also increasing the convection coefficient of heat transfer, or increasing the surface area. But, an increase in the area also causes increased resistance to the heat flow. Hence, the coefficient of heat transfer based on the total area (the base and fin surface area) comes out to be less than that of the base without fins, at the same temperature difference. If there is an increase in the area of surface proportionately more than the decrease in the heat transfer coefficient, the total heat dissipation rate increases.

2.1 Design

The heat exchanger domain consists of three connected channels: Entrance section, pin-fin section and exit section. The pin-fin section consists nine rows and seven columns of in-line fig1, fig2, fig3, fig4 with its axis perpendicular to the flow. Two different pin shapes are considered: cylindrical, drop-shaped with Perforations and without Perforations.

These different pin shapes are arranged on a base plate 57.656 X 36.04 X 2 mm^3 with a distance of S_L = 7.207mm and S_T = 3.604mm. In inline arrangement there are 63 pin fins and staggered 32 pin fins. Mean radius of different fins is taken as 1.15mm and length of the fin as 23mm.

2.2 Computational analysis

By using CATIA software the fin models are designed and the data were passed to the ANSYS-FLUENT software for various analyses. No special boundary conditions were applied to pins. Since each pin has a fluid contact on all sides of the solid region. An enclosure is created around it with a proportionate ratio of hydraulic diameter. When a grid containing this type of wall zone is imported into FLUENT, a "shadow" zone will automatically be created so that each side of the wall is a distinct wall zone. The governing equations solved by Fluent are the Navier-Stokes equations combined with the continuity equation, the thermal equation and the standard k-€ turbulence model with standard wall function was set for each model. Once the analyses are completed, the resulting data can be easily evaluated by the Fluent postprocessor.

2.3 Numerical analysis

The appropriate equation for the convective heat transfer between a surface and an adjacent fluid is prescribed by Newton's law of cooling:

$$Q = h\,A\,(Ts - T_f)$$

The convective heat transfer coefficient *(h)* can be defined as *the rate of heat transfer between a solid surface and a fluid per unit surface area per unit time difference.*

$$h = q/\Delta t$$

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Reynold's number = $\rho * v * L/\mu$

Nusselt number = $N_u = \bar{h}D_h/k$

2.4 Fin Efficiency

Fin efficiency is defined as the actual heat transferred by the fin, divided by the heat transfer where the fin is to be isothermal. The performance of the fins can be determined in three different ways. They are

1. Effectiveness: The ratio of the heat transfer rate through the fin to the heat transfer rate of the object if it had no fin. The formula for this is

$$\eta_f = \frac{\dot{Q}_f}{hA_f\theta_b}.$$

2. Fin Efficiency: The Fin Efficiency must be always less than unity and its formula is

$$\eta_f = \frac{\dot{Q}_f}{hA_f\theta_b}.$$

3. Overall Surface Efficiency: The Overall surface Efficiency determines the performance of heat sinks

$$\eta_o = \frac{\dot{Q}_t}{hA_t\theta_b},$$

Where:

h = convection heat transfer coefficient, W/m^2-K

A_s = heat transfer surface area, m^2

T_s = temperature of the surface, ^{o}C

T_f = temperature of the fluid sufficiently from the surface, ^{o}C

q: amount of heat transferred (heat flux), W/m^2

h: heat transfer coefficient, $W/(m^2 \bullet K)$

ΔT: difference in temperature between the solid surface and surrounding fluid area, K.

v is the max velocity of the object relative to the fluid (m/s)

L is a characteristic linear dimension,

D hydraulic diameter when dealing with river systems) (m)

μ is the dynamic viscosity of the fluid (kg/(m·s))

ϑ (nu) is the kinematic viscosity ($\vartheta = \mu/\rho$) (m^2/s)

ρ is the density of the fluid (kg/m^3).

K is the thermal conductivity of the material

L_f is the fin height (m)

T_f is the fin thickness (m)

W_f is the width of the fin

T_b is the thickness of the base

T_f is the thickness of the fin

A_b is the area of the base

3 SECTIONS

The present work deals with heat transfer through natural convection. The circulation of the fluid medium is caused by buoyancy effects i.e., by the difference in densities of the cold and the heated particles due to the heat energy, the hotter particles become less denser than the colder particles so they move upwards providing the natural convection process.the high conductive heat sink is arranged over a heat source to decrease ejection of heat from the source usually the heat sink is preffered more larger than the heat source or the electrical component that dissipates heat energy. The design section of the perforated fins is as shown in the below figures.

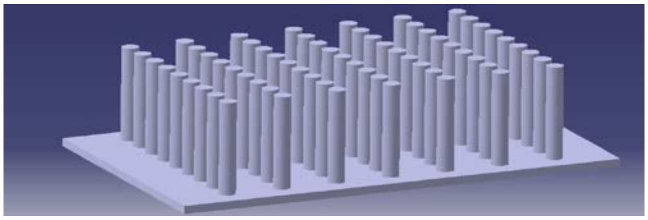


Fig 1: Circular pin fin arrangements (Inline)

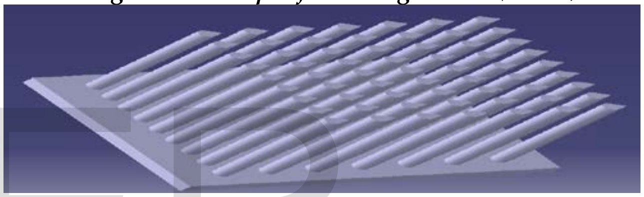


Fig 2: Drop shape pin fin arrangements (Inline)

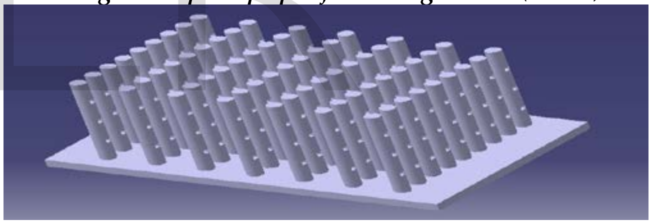


Fig. 3: Circular pin fin arrangements (perforated Inline)

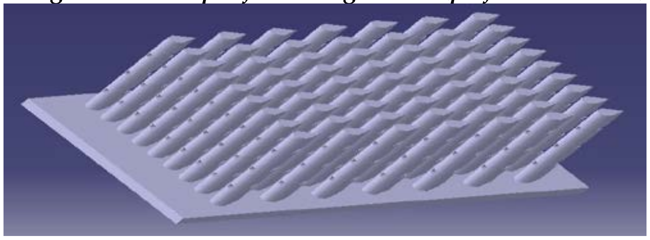


Fig.4: Drop shape pin fin arrangements (perforated Inline)

The above figure represents the basic design version of the heat sink with and without perforated fins. The thermal performance is founs by the analysis softwares

4 RESULTS AND DISCUSSION

From the above analysis the theoretical and computational calculations [Fig.5, Fig.6, Fig.7, and Fig.8] shows that more heat transfer rate is observed in circular perforated pin fins compared among the models. The contours of heat transfer show that transfer rate is maximum for perforated circular fins, presence of perforations increase the surface area which results in high heat transfer rate.

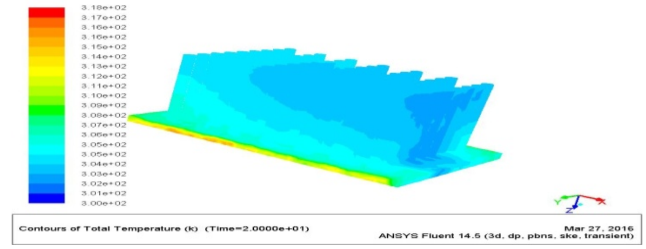


Fig.5: Temperature contours, circular pin fin arrangements (Inline)

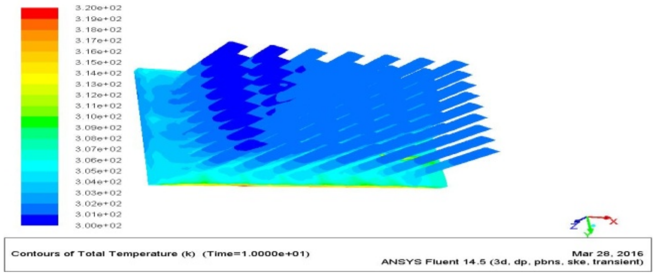


Fig.6: Temperature contours, drop shape pin fin arrangements (Inline)

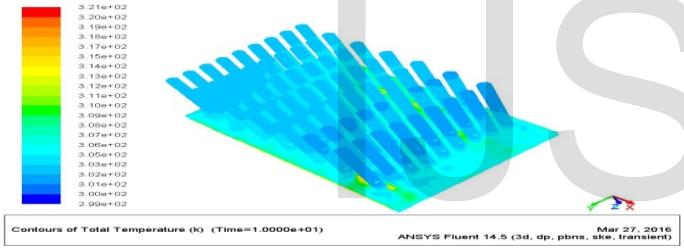


Fig .7: Temperature contours, circular pin fin arrangements (perforated Inline)

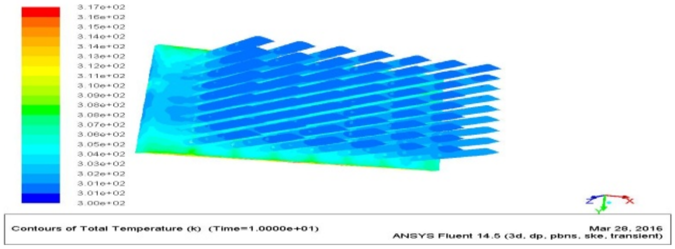
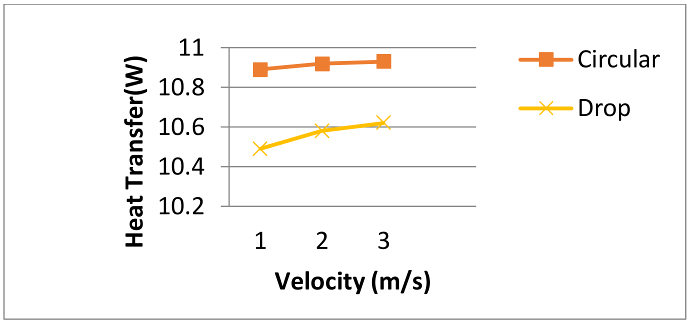
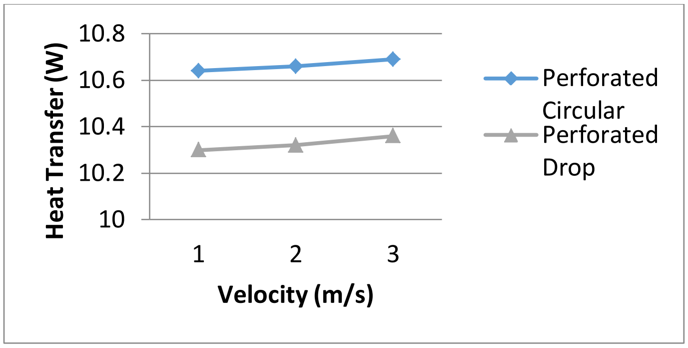


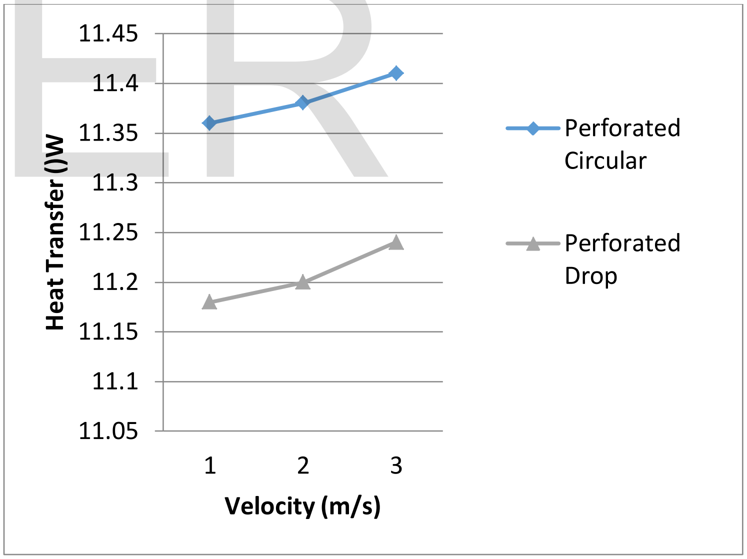
Fig.8: Temperature contours, drop shape pin fin arrangements (perforated Inline)



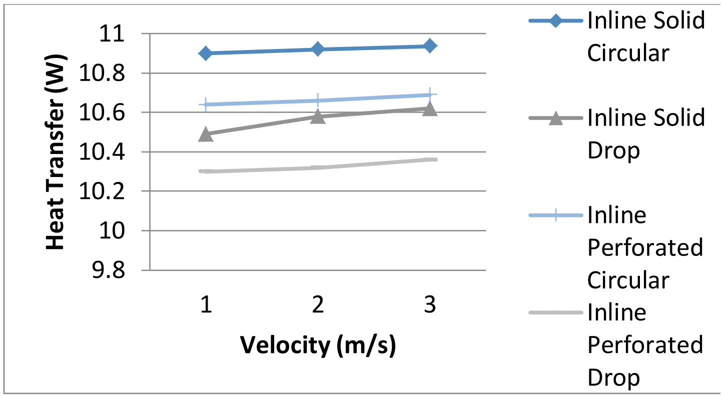
Graph 1: Variation of Heat Transfer with Velocity of Different Solid Pin Fins in Inline Arrangement



Graph 2: Variation of Heat Transfer with Velocity of Different Perforated Pin Fins in Inline Arrangement



Graph 3: Variation of Heat Transfer with Velocity of Different Perforated Pin Fins in Staggered Arrangement



Graph 4: Variation of Heat Transfer with Velocity of Different with and without Perforated Pin Fins in inline arrangements

5 CONCLUSION

Thermal analysis on Circular and the drop is carried out with and without perforated Pin fins Graph1, Graph2, Graph3, and Graph4. Heat transfer rate is increased by decreasing the Reynolds number by comparing the inline interfin distance ratio the friction factor is varying.

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