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Thermal Analysis of Optimized Porous Fin on Various Profiles: A Review

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Abstract - A heat sink is designed to increase the surface area in contact with the cooling medium surrounding it, such as the air. Approach air velocity, choice of material, fin (or other Protrusion) design and surface treatment are some of the factors which affect the thermal performance of a heat sink. Heat sink attachment methods and thermal interface materials also affect the eventual die temperature of the integrated circuit. Thermal adhesive or thermal grease fills the air gap between the heat sink and device to improve its thermal performance. Theoretical, experimental and numerical methods can be used to determine a heat sink's thermal performance. Thermo-hydraulic Performance of Solar air collector. Number of roughness elements has been investigated on heat transfer & friction characteristics of solar air collectors. The Power Heat Sink is designed to solve the heat problems of high performance computer systems. With a weight per volume less than half that of a traditional solution, and with its smaller base surface area, the Power Heat Sink is a powerful thermal solution to the problems faced by designers of high performance computer systems. Correlations developed by various researchers with the help of experimental results for heat transfer & friction factor for solar air collector by taking different roughness geometries are given & these correlations are useful to predict the Thermo-hydraulic performance of solar air collector having roughened ducts.

***Keywords* - Pin fin heat sink, Electronics cooling simulation, Fin Profiles, Thermal Resistance**

I. INTRODUCTION

A computer's CPU may perform millions of calculations every second [1]. As the processor continues to work at a rapid pace, it begins to generate heat. If this heat is not kept in check, the processor could overheat and eventually destroy itself. Fortunately, CPUs include a heat sink, which dissipates the heat from the processor, preventing it from overheating. The heat sink is made out of metal, such as aluminum, zinc or copper alloy, and is attached to the processor with a thermal material that draws the heat from away the processor towards the heat sink. Heat sinks can range in size from barely covering the processor to several times the size of the processor if the CPU requires it Most heat sinks also have "fins," which are thin slices of metal that are connected to the base of the heat sink. These additional pieces of metal further dissipate the heat by spreading it over a much larger area. A fan is often used to cool the air surrounding the heat sink, which prevents the heat sink from getting too hot. In electronic systems, a heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. In computers, heat sinks are used to cool central processing units or graphics processors. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes (LEDs), where the heat dissipation ability of the basic device is insufficient to moderate its temperature. A heat sink is designed to maximize its surface area in contact with the cooling medium surrounding it, such as the air. Air velocity, choice of material, protrusion design and surface treatment are factors that affect the performance of a heat sink. Heat sink attachment methods and thermal interface materials also affect the die temperature of the integrated circuit. Thermal adhesive or thermal grease improve the heat sink's performance by filling air gaps between the heat sink and the device.

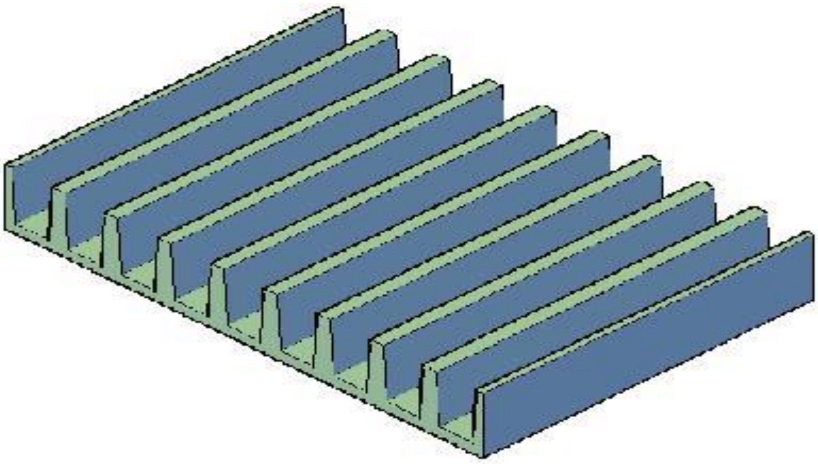


Fig- Pin Fin Heat Sink

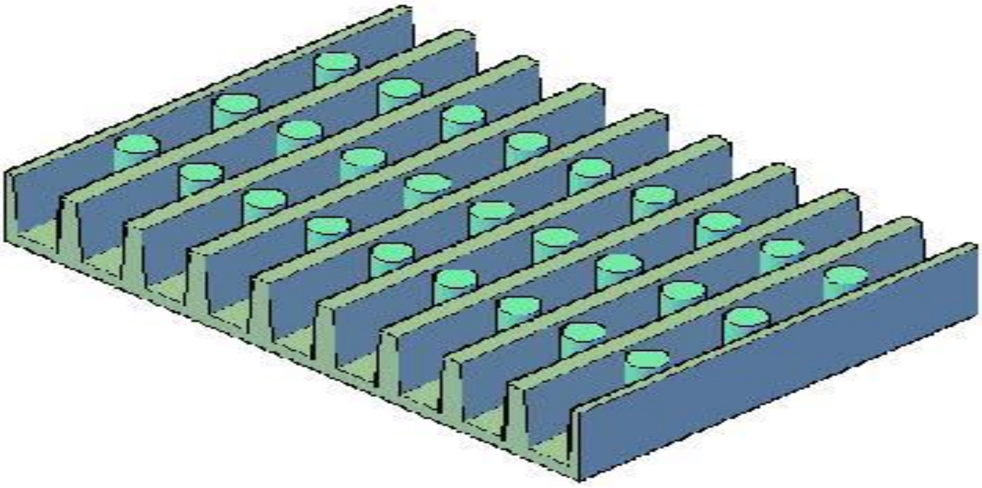


Fig-Cylindrical Pin with Trapezoidal Fin

Passive Heat Sinks

- Used in natural convection applications or in applications where heat
- Dissipation is not dependent on designated supply of air flows

Semi-Active Heat Sinks

- Leverage off of existing fans in the system
- Usually a passive heat sink set in front of a fan to produce impingement or vertical flow.

Active Heat Sinks

- Fans are designated for its own use
- Reliability is dependent on moving parts

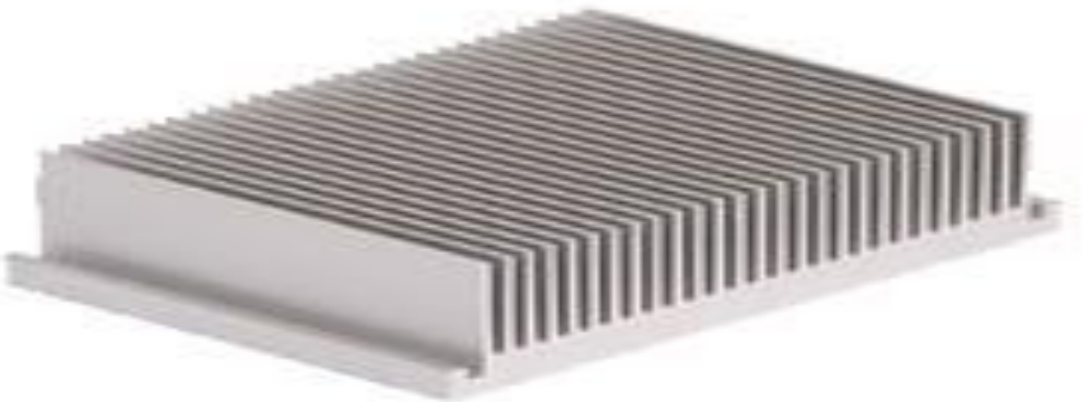


Fig - Passive Heat Sink

Fig - Active Heat Sink

Fig - Folded Fins

I Heat Transfer Principle

A heat sink transfers thermal energy from a higher temperature device to a lower temperature fluid medium [2]. The fluid medium is frequently air, but can also be water, refrigerants or oil. If the fluid medium is water, the heat sink is frequently called a cold plate like a radiator. In thermodynamics a heat sink is a heat reservoir that can absorb an arbitrary amount of heat without significantly changing temperature. Practical heat sinks for electronic devices must have a temperature higher than the surroundings to transfer heat by convection, radiation, and conduction. To understand the principle of a heat sink, consider Fourier's law of heat conduction. Fourier's law of heat conduction, simplified to a one-dimensional form in the x-direction, shows that when there is a temperature gradient in a body, heat will be transferred from the higher temperature region to the lower temperature region. The rate at which heat is transferred by conduction, is proportional to the product of the temperature gradient and the cross-sectional area through which heat is transferred.

Heat Sink Geometries:

(1) Rectangular fins have better performance than square fins, whose back edges have poor air flow past them.

(2) Rectangular fins also have better performance than round fins; however, pressure drop is also higher for rectangular fins.

(3) Round fins are good if you don’t know which direction your airflow will be from or if airflow may not be straight through the heat sink (its Omni-directional).

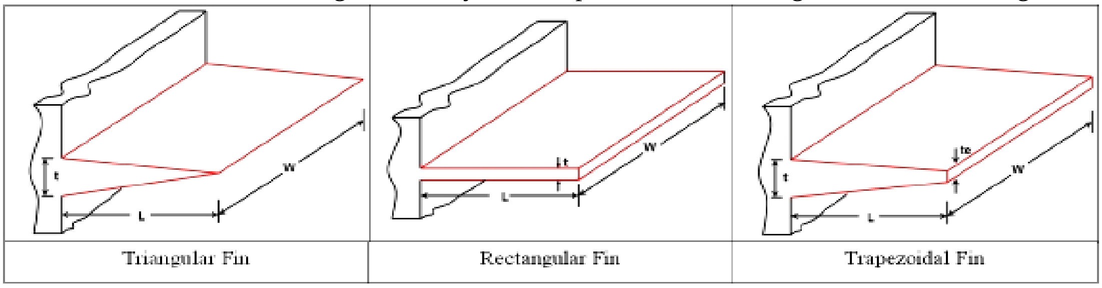
(4) For natural convection/radiation, solid black anodized fins mounted in a vertical direction tend to work best

Heat Sink Material

The most common heat sink materials are aluminium alloys. Aluminium alloy 1050A has one of the higher thermal conductivity values at 229 W/m•K but is mechanically soft. Aluminium alloys 6061 and 6063 are commonly used, [2] with thermal conductivity values of 166 and 201 W/m•K, respectively. The values depend on the temper of the alloy. Copper has excellent heat sink properties in terms of its thermal conductivity, corrosion resistance, biofouling resistance, and antimicrobial resistance. Copper has around twice the thermal conductivity of aluminium and faster, more efficient heat absorption. Its main applications are in industrial facilities, power plants, solar thermal water systems, HVAC systems, gas water heaters, forced air heating and cooling systems, geothermal heating and cooling, and electronic systems.

Heat Transfer from Extended Surfaces (Fins)

The heat conducted through solids, walls or boundaries has to be continuously dissipated to the surroundings or environment to maintain the system in a steady state condition. In many engineering application large quantities of heat have to be dissipated from small areas. Heat transfer by convection between a surface and the fluid surroundings it can be increased by attaching to the surface thin strips of metals called fins. The fins increase the effective area of the surface there by increasing the heat transfer by convection. The fins are also referred to as ‘extended surface’. The fins may be of uniform or cross-section. They have many different practical applications, viz. Economizers for steam power plants; Radiators of automobiles; Air-cooled engine cylinder heads; Cooling coils and condenser coils in refrigerators and air conditioners; cooling of electronic components; small capacity compressors ; electric motors, transformer; high-efficiency boiler superheated conducting heat down their length to a cool disc.



II. analysis performed in various profile of heat sink

Numerical and Experimental Investigation

Yue-Tzu Yang and Huan Sen Peng [3] The plate-circular pin-fin heat sink and provides 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 SIMPLEC algorithm. The plate-circular pin-fin heat sink is composed of a plate fin heat sink and some circular pins between plate fins. The purpose of this study is to examine the effects of the configurations of the pin-fins design. The results show that the plate-circular pinfin heat sink has better synthetically performance than the plate fin heat sink. Yue-Tzu Yang and Huan Sen Peng "Investigation of planted pin fins for heat transfer enhancement in plate fin heat sink"

Anil Kumar Rao et al[4] The design of Elliptical Pin fin heat sink (EPFHS) having minor axis is 1.5mm, 2.0mm and 2.5mm. In this study, the simulations of EPFHS at various wind velocity i.e., 6.5, 9.5 & 12.5 m/s and the configurations of pin-fins design are proposed. The results show that increasing wind velocity could reduce the thermal resistance and increase the pressure drop simultaneously. The thermal resistance of the EPFHS is lower than that of the plate-circular pin-fin heat sink (PCPFHS) at the same wind velocity and the pressure drop of the EPFHS is much higher than that of the PCPFHS.

Selma Ben Saad et al [6] Compact heat exchanger with two-phase inlet conditions and vertical upflow in order to study the flow behavior. The test section consists of an offset strip fin heat exchanger with a rectangular cross-section (dimensions:1 m × 1 m × 7.13 mm). The distributor was designed to optimize two-phase flow distribution. In a preliminary step, pressure drop of single phase flow in offset strip fins is needed to assess the quality of the distribution in the single phase case. For low Reynolds numbers, numerical results show good agreement with experimental measurements. In a second step, the two-phase flow distribution at the outlet was characterized using air and water as working fluids and for different operating conditions. the measurement of gas and liquid flow rates in different zones evenly distributed at the outlet. high air flow rates led to a more homogenous distribution.

W. Leonard, P. Teertstra, et al.[2002] In this report Experimental testing has been performed on two plate fin heat sinks in order to examine flow bypass phenomenon. The present study examines pressure drop and thermal resistance as well as flow velocities within the heat sinks. Tests are performed for bypass channel/fin height ratios of 0.25, 0.5, 0.75 and 1 with approach velocities from 2 to 8 m/s. By examining flow behavior within the heat sinks and the bypass channel, a model for predicting flow bypass is presented that incorporates only the significant pressure drop mechanisms that affect the flow path. This model allows for a simple prediction of flow bypass for plate fin heat sinks based solely on geometry. For all of the heat sinks tested the agreement between model and experimental data is ±8%.

Vijaisri Nagarajan et al [7] A fin configuration for high temperature ceramic plate-fin heat exchanger (PFHE) was developed using the three-dimensional computational fluid dynamics (CFD) FLUENT code. Numerical analysis was carried out for different types of fins and their results were compared with the selected design. The working fluids used in the model were sulfur trioxide, sulfur dioxide, oxygen and water vapor. The rip saw fin design (case 9) with thickness of 0.05 mm gives the maximum heat transfer performance with less pressure drop and friction factor. The results of the rip saw fin design were found in good agreement with the analytical results of a rectangular fin. Further effects of Reynolds number on pressure drop and Nusselt number were studied.

Li-Zhi Zhang [9] Plate-fin and tube heat exchangers are extensively used in air conditioning and the petro-chemical industries Duct selected is surrounded by two neighboring columns of tubes at half the fin pitch. The unsteady behavior of fluid flow and heat transfer in the exchanger duct in transitional flow regime is studied. A large eddy simulation (LES) technique is used to perform a detailed investigation of the temporal oscillations of streamwise, spanwise and normal velocity components in the exchanger duct and their effects on conjugate heat transfer between fins and fluid. Temperature fields, pressure drops, and fin efficiencies are calculated. The focus of the study is on the instability and transitional behavior of fluid flow in the exchanger

Yu Xiaoling, Feng Quanke,Liu Qipeng [2003]The Study of this paper a new type of composite heat sink, in whose each tunnel two rows of circular pins are staggered at proper positions between two plate fins, is suggested to improve electric and electronic device cooling. The heat transfer and flow performance is investigated experimentally. The experimental results show that, under the same conditions of heat dissipation and wind velocity, the thermal resistance of the composite heat sink is 10%~20% lower than that of the current plate-fin heat sink. When wind velocity is 2 m/s, the flow resistance is about 10% higher than that of the plate-fin heat sink, but much lower than that of the staggered pin fin heat sink. While the wind velocity and the temperature of heat sink base remain the same, the heat dissipation per square centimeter of the composite heat sink is almost the same as that of staggered pin fin heat sink, and 10%~17% higher than that of the plate-fin heat sink.

Poh-Seng Lee, Suresh V. Garimella *, Dong Liu 2004 An experimental investigation was conducted to explore the validity of classical correlations based on conventional sized channels for predicting the thermal behavior in single-phase flow through rectangular micro channels. The micro channels considered ranged in width from 194 lm to 534 lm, with the channel depth being nominally five times the width in each case. Each test piece was made of copper and contained ten micro channels in parallel. The experiments were conducted with deionized water, with the Reynolds number ranging from approximately 300 to 3500.

Numerical predictions obtained based on a classical, continuum approach were found to be in good agreement with the experimental data (showing an average deviation of 5%), suggesting that a conventional analysis approach can be employed in predicting heat transfer behavior in micro channels of the dimensions considered in this study. However, the entrance and boundary conditions imposed in the experiment need to be carefully matched in the predictive approaches

G.Hetsroni, A.Mosyak et al.[2005] This paper considers experimental and theoretical investigations on single-phase heat transfer in micro-channels. It is the second part of general exploration ‘‘Flow and heat transfer in micro-channels’’. The first part discussed several aspects of flow in micro-channels, as pressure drop, transition from laminar to turbulent flow.In this paper, the problem of heat transfer is considered in the frame of a continuum model, corresponding to small Knudsen number. The data of heat transfer in circular, triangular, rectangular, and trapezoidal micro-channels with hydraulic diameters ranging from 60 µm to 2000 µm are analyzed. The effects of geometry, axial heat flux due to thermal conduction through the working fluid and channel walls, as well as the energy dissipation are discussed. We focus on comparing experimental data, obtained by number of investigators, to conventional theory on heat transfer. The analysis was performed on possible sources of unexpected effects reported in some experimental investigations.

Xiaoling Yu , Jianmei Feng [2005] ,These Paper Based on plate fin heat sinks (PFHSs), a new type of plate-pin fin heat sink (PPFHS) is constructed, which is composed of a PFHS and some columnar pins staggered between plate fins. Numerical simulations and some experiments were performed to compare thermal performances of these two types of heat sinks. The simulation results showed that thermal resistance of a PPFHS was about 30% lower than that of a PFHS used to construct the PPFHS under the condition of equal wind velocity. Another obvious advantage of PPFHSs is that users can change an existing unsuitable PFHS into a required PPFHS by themselves to achieve better air-cooling results. This paper proposed a special solution for improving heat transfer performance of a PFHS by planting some columnar into flow passages of the PFHS to disturb airflows passing through the heat sink. So a PPFHS was constructed. Numerical simulation and experimental results show that the thermal resistance of a PPFHS is 30% lower than that of a PFHS used to construct the PPFHS with the same blowing velocity, and the profit factor of the former is about 20% higher than that of the latter with the same pumping power.
M.R. Salimpour et.al [2009] Three heat exchangers with different coil pitches were selected as test section for both parallel-flow and counter-flow configurations. All the required parameters like inlet and outlet temperatures of tube-side and shell-side fluids, flow rate of fluids, etc. were measured using appropriate instruments. Totally, 75 test runs were performed from which the tube-side and shell-side heat transfer coefficients were calculated. Empirical correlations were proposed for shell-side and tube-side. An experimental investigation was carried out to study heat transfer coefficients of the shell and helically coiled tube heat exchangers. Heat exchangers with three different coil pitches were tested for counter-flow configuration. It was revealed that the empirical correlation for constant temperature boundary condition is quite in agreement with the present data in low Dean number region. From the results of the present study, it was found out that the shell side heat transfer coefficients of the coils with larger pitches are higher than those for smaller pitches.

N. Sahiti, A. Lemouedda et al [2006] In his studies pin fin arrays are frequently used for cooling of high thermal loaded electronic components. Whereas the pin fin accomplishment regarding heat transfer is always higher than that of other fin configurations, the high pressure drop accompanying pins seriously reduces their overall performance. In order to check how the form of pin cross-section influences the pressure drop and heat transfer capabilities, six forms of pin cross-section were numerically investigated. Two geometric comparison criteria were applied so that the conclusions derived from numerical computations were valid for various possible geometric parameters and working conditions. Both staggered and inline pin arrangements were investigated as these are common in practical applications. The heat transfer and pressure drop characteristics are presented in terms of appropriate dimensionless variables. The final judgment of the performance of the pin fin cross-section was performed based on the heat exchanger performance plot. Such a plot allows the assessment of the pin performance including their heat transfer and the pressure drop.

Ethan M.Parson et.al [2010]. They successfully simulate the response to arbitrary loadings because their macroscopic predictions derive from the deformation of a unit cell which faithfully represents the mesostructure and modes of deformation of the fabric. The elements predict not only macroscopic deformation but also the yarn-level quantities necessary for anticipating failure and designing composite forming processes, for example. Because they model the fabric as a continuum, not discrete yarns, the elements are computationally inexpensive and therefore capable of simulating real-sized, complex structures, including multi-ply systems. Within the elements, we use the novel approach of defining nodal degrees of freedom with physically correct mass to represent the change in crimp amplitude of the yarns. Solving for the crimp amplitudes in this manner automatically includes the inertia of un-crimping and is much more efficient than the energy minimization procedure or numerical methods used in other woven fabric simulations of this type.

Parinya Pongsoet.al [2011]. The experimental results reveal that the fin pitch casts insignificant effect on the heat transfer characteristics (Colburn j factor). However, a detectable rise of the friction factor is seen when the fin pitch is increased to fp = 6.2 mm. On the other hand, the effect of fin material on the airside performance is negligible. A total of 6 samples were tested with associated fin materials of copper or aluminum, respectively. The associated fin thickness and outside diameter is 0.4 mm and 34.8 mm, respectively. The number of tube rows is two and fin pitches are 3.2, 4.2 and 6.2 mm, respectively. It is found that the proposed simple average effectiveness equation from the pure counter and parallel circuitry arrangement can well represent the effectiveness-NTU relationship for the current z-shape arrangement.

III.CFD Governing Equations Solve by Fluent

This section is a summary of the governing equations used in CFD to mathematically solve for fluid flow and heat transfer, based on the principles of conservation of mass, momentum, and energy. These equations solve by the fluent software. The conservation laws of physics form the basis for fluid flow governing equation

Law of Conservation of Mass

$$\frac{\partial(\rho u_i)}{\partial x_i} = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3.1)$$

Momentum Equation:

$$\frac{\partial}{\partial x_i}(\rho u_i u_j) = \frac{\partial}{\partial x_i}\left(\mu \frac{\partial u_i}{\partial x_i}\right) - \frac{\partial p}{\partial x_j} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (3.2)$$

Energy

$$\frac{\partial}{\partial x_i}(\rho u_i T) = \frac{\partial}{\partial x_i}\left(\frac{k}{C_p}\frac{\partial u_i}{\partial x_i}\right) \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

The fluid behavior can be characterized in terms of the fluid properties velocity vector u (with components u, v, and w in the x, y, and z directions), pressure p, density ρ, viscosity μ, heat conductivity k, and temperature T. The changes in these fluid properties can occur over space and time But for simplification we use changes occurs only in space. Using Fluent, these changes are calculated for the fluid, following the conservation laws of physics listed above. The changes are due to fluid flowing across the boundaries of the fluid element and can also be due to sources within the element producing changes in fluid properties

Solution Techniques

After create geometry and meshing, incorporate boundary conditions as per model and then export this file as an .msh file. Now the problem is ready to solve by using fluent software. The solution algorithm SIMPLE (semi-implicit method for pressure-linked equations) is used to solve for the velocity field in all three directions and the pressure

IV CONCLUSION

The present study proposes the inverse method and the commercial software of FLUENT in conjunction with the experimental temperature data to determine the average heat transfer coefficient h, heat transfer coefficient based on the fin base temperature and fin efficiency for various fin spacing's. These were simplified by assuming periodically developed two-dimensional flow and isothermal heat transfer surfaces. In general, it is found that rounded geometries outperform similar sharp-edged fin shapes. In all cases, staggered geometries perform better than inline. At lower values of pressure drop and pumping power, elliptical fins work best. At higher values, round pin fins offer highest performance. The small number of previous studies of these fin geometries, usually comparing only two at a single operating point, has demonstrated some of the conclusions reached here. These conclusions are qualitatively known, but the current study quantifies these effects and compares various geometries with equal values of fin/base area ratio and lengthwise span wise pitch ratio.

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