

EXPERIMENTAL STUDIES ON EFFECTIVENESS AND EFFICIENCY OF RADIATING PIN FINS AND ITS GEOMETRY: A REVIEW

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Abstract: Heat transfer through radiating pin fins is determining factor on performance of heat dissipation in space or low air pressure applications of hot bodies. The recent research papers shows the need and importance of a detailed review of the literature to identify the potential areas and possibilities of further research on the efficiency and effectiveness studies of pin fins. The vital performance factor considered as area of contact to the atmosphere and the material characteristics with respect to effectiveness of the Radiating Pin fins. These most important parameters in systems operating in vacuum and space, since cooling effectiveness and temperature stabilization is considered to be the most important next to low weight, zero maintenance, and reliability requirements.

1. Introduction

Maintenance of isothermal structures is important task for space orbiting systems and equipments under adverse solar heating. The orbiting objects fixed and body of the aircraft is always facing intense solar radiation, while the other is exposed to deep space and equally colder face. Most systems designed with adequate fin type arrangement to transport the heat from that side to the cold side in order to equalize the temperature of the structure. Many heat pipe based techniques being used to dissipate heat generated by electronic components in satellites. Early experiments of heat pipes for aerospace applications were conducted by many researchers and given considerable ray of results to do further research. Hence this review paper is aimed to find the different research opportunities in material and geometrical parameters of fins for space crafts and airborne vehicles.

2. Literature Review Presentation

Ganesh Murali.J et.al., (2006) has studied the effect of modification of surface geometry for a radiating pin fins with a test set up of vacuum of 680 mm Hg to reduce the contribution of convective heat transfer for a given base temperature and suggested an optimum

depth of groove for heat loss to be maximum to the optimum depth of cut the grooved fin and recorded a loss of 1.34 times greater heat per unit mass compared to flat radiating pin fin.

Ganesh Murali.J et.al., (2006) investigated the effect of modification of surface geometry for a radiating pin fin, which revealed an optimum angle groove in pin fin with its thread per inch as parameter for the same wall thickness and cone angle of tapered fins gets a loss of 1.2 to 1.52 times greater heat per unit mass of normal pin fin.

Ganesh Murali.J et.al., (2007) performed tests on emanating pin blade with strings and scores on its outside surface and exhibited an ideal string for every inch (TPI), point of strings and profundity of notches for which the warmth misfortune per unit mass is a most extreme which expanded the loses because of radiation as 1.2 to 1.34 times more prominent warmth per unit mass contrasted with the uncovered stick balance.

Masoud Asadi and Ramin Haghighi Khoshkho (2013) contrasted air-with air and air-to-fluid warmth exchanger and proposed to improve warm move coefficient noticeable all around side by expanded balance surfaces, wherein temperature appropriation is to a great degree influenced by convection and radiation and overlooked radiation in figuring heat exchange rate and temperature dissemination. However radiation is critical in spots of vacuum then the framework would encounter common convection. A few applications like micro-turbine, where the temperature of hot fluid is about 950 K also in some spacecraft appliances. They also presented a solution for temperature distribution for uniform cross sectional area surfaces with pin fins in the terms of entropy generation. The effects of considering radiation on the heat transfer dimensionless numbers are analyzed. The results dictate that the speed of transferring heat by radiation and convection increases with respect to geometrical changes, which improves area of exposure and point effect of radiation full length of the fin.

Shukla.K.N. (2015) found the range of working fluids in heat pipes from Helium and Nitrogen. He

analyzed for a cryogenic temperature of 2 K - 4 K. Also analyzed the liquid metals like Mercury (523 - 923 K), Sodium (873 - 1473 K) and even Indium (2000 - 3000 K) for extremely high temperatures. The temperature of the Working fluid used in a heat pipes are to be chosen according to the normal operating conditions. The vast majority of heat pipes for space craft and electronics cooling use Ammonia (213 - 373 K), Alcoholal (Methanol (283 - 403 K) or Ethanol (273 - 403 K)) or Water (298 - 573 K) as the working fluid.

Chyu et al. led an examination to assess the warmth exchange execution of stunned and in-line pin- blade clusters in a cooling channel. The warmth exchange rate was improved by no less than a factor of two by presenting one of the pin- blade clusters in the smooth channel, and the amazed pin- balance exhibits demonstrated higher warmth exchange execution.

Dhumne Amul B. et.al., (2013) talked about exploratory examination of a warmth exchange upgrade and round and hollow cross segment region punctured stick blades in a rectangular channel. Strong tube shaped stick blades prompts warm exchange expanding the barrel shaped stick balances and increment the effectiveness differs rely on the material and there freedom proportion and enter balance.

U S Gawai, et al. (2013) have contemplated warm exchange and erosion trademark warm exchange rate expanding utilizing dimple in light of the guideline of the cleaning cooling of move liquid making place inside the dimple and wonders of increasing.

Baskaya Senol, et.al. (2000) examined common convection warm exchange from the flat ventured strung stick balance exhibits the geometrical parameters additionally researched and the impact happen by balance separating, length of balance, tallness of stick and the temperature distinction amongst blades and encompassing, by the even balance clusters the warmth is exchange.

Incropera, et al. (2007) studied the investigations of longitudinal fins with cylindrical profile which were used to enhance the applications like heat sinks, space radiators, etc., based on the heat transfer rate. Normally the weight of triangular and trapezoidal fin profiles is lighter in weight and also having some disadvantages like higher production costs and also safety issue because of having the sharp tips. He conducted the experimental work on threaded fin heat transfer. Most literatures have proposed the case of increasing fin height; it was shown that an increase in the heat transfer coefficient can be achieved without an increase in pressure drop when compared at equal mean fin height. Diagnostic models created and furthermore decided the warmth exchange from different kinds stick blade warm sinks like in-line and stunned writes which can be utilized as a part of the utilizations of electronic bundling. The warmth exchange coefficient of the warmth sink and the normal temperature of the liquid

which is streaming inside the warmth sink are gotten from a vitality adjust over a control volume. Normal consequence of the investigations demonstrates the expansion of 30% of the warm conductivity by scattering 0.1% copper particles in water. They exhibited critical change of warmth exchange rates by scattering copper, alumina-and silver colloid suspensions in water.

Mohammad Mashud, et.al (2013) had investigated a strong round and hollow blade and barrel shaped balances with roundabout depressions and strings on their outside surface with load vacuum of 680 mm Hg. The trial result for the round and hollow blade having the profundity of 3.5mm roundabout notches on its outskirts demonstrates the most extreme warmth misfortune. The misfortune in the furrowed tube shaped blade will be 1.2256 times more prominent warmth per unit zone around when contrasted with the strung barrel shaped balance, and furthermore it is 0.1678 times more noteworthy warmth per unit territory.

Nagarani.N., et al. published the comparison of numerical and experimental study for elliptical and circular fins. It is found that more distribution of isotherms and elevated rate of temperature distribution along the major axis of elliptical fin than those of circular fin in the result. The experimental result stated that the surface temperature of elliptical fin decreased with increase in fin length along major axis.

Shivdas S Kharche et al, it is explained that the when a notch is provided on the surface of fin with a rectangular shape the fin supports for much heat transfer and also compared the heat transfer rate of fins by changing the material from Aluminium to copper and then found that copper shows much heat transfer value than aluminium.

Pratapa Reddy.Y. et al., made an experimental analysis on a pin fins made of different materials (aluminium, copper) and composite bars (brass and aluminium, copper and aluminium) and proved that the composite bars made of copper and aluminium shows higher efficiency than the solid pin fin and from these the values of base temperatures are considered as input source for simulation analysis on different materials.

Bahadur (2005) researched the Orthotropic warm conductivity impact on barrel shaped stick balance warm exchange. Diagnostic conditions for temperature dissemination and warmth exchange rate from a barrel shaped stick blade with orthotropic warm conductivity, experienced in the utilization of thermally improved polymer composites, are inferred and approved utilizing nitty gritty limited component comes about.

Rao et al. have investigated heat transfer from a horizontal fin array by natural convection and radiation. The problem of natural convection heat transfer from a horizontal fin array is theoretically formulated by treating the adjacent internal fins as two-fin enclosures. A balance equation is formed for the mass, momentum and energy for the fluid in the two-fin enclosure. The

result is solved with the heat conduction equations in both the fins. Numerical results for the various values of fin heights, emissivities, number of fins in a fixed base, fin base temperature, fin spacing, etc., are obtained and studied the effectiveness for the same.

Sahiti.N. et al conducted experiments in the Performance comparison of pin fin in-duct flow arrays with various pin cross-sections. In this investigation they had checked how the form of pin cross section influences the pressure drop and heat transfer capabilities; six forms of pin cross-section were numerically investigated. By employing the conjugate heat transfer boundary conditions, numerical simulations close to realistic working conditions were performed. Similar 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. Finally the performance of the pin fin cross-section was judged by the performance based on the heat exchanger performance plot. This kind of plot allows the assessment of the pin performance along with respective heat transfer and the pressure drop.

Chiang K.T investigated the application of response surface methodology in the parametric optimization of a pin-fin type heat sink. A compelling system for the Response Surface Methodology (RSM) has been effectively created by this examination and found the ideal esteems for outlining parameters of a stick balance write warm sink (PFHS) considering the mass and space restriction to accomplish the high warm execution/cooling effectiveness. Different outline parameters, for example, tallness and breadth of stick blade and width of pitch between balances are investigated by this test. The outcomes distinguish the huge impact components to limit warm protection and weight drop.

Abdullah H. et al describes about the enhancement of natural convection heat transfer from a Fin by triangular perforation of bases parallel end turned its tip. In this investigation the triangular perforation made in rectangular pin investigated with variable thickness of pin and this equals high compound with solid fin.

P. K. Nag and M. Ali Nawsher Moral (2007) studied experimentally the effect of pin fins on heat transfer in circulating fluidized beds. It was watched that, in spite of the fact that the warmth exchange coefficient diminishes with the utilization of blades, the aggregate warmth exchange builds inferable from the expansion in surface zone which the balances give. The aftereffects of warmth exchange for unfinned surface were contrasted and those of different scientists and observed to be in great understanding.

Qingling Li et al analyzed the heat transferred characteristics of a tube with elliptic pin grains in cross flow at air. In this experiments they concluded that using the naphthalene sublimation recharge heat/mass

coefficients of pin fin and on tube. Surface of a tube with elliptic pin fins can be measured. More over the nusselt number and heat transfer coefficient values to be calculated. A mean heat transfer rate has calculated and the overall mean heat transfer methods of elliptic pin found tube are ethical than smooth tube has concluded.

Abdullah H.M. found out the one dimensional heat transfer solution of the performed fin gives a acceptable result of the bio & number in lateral directions less than 0.1 and the generic modification made by perforation impresses the performance at the fin. He also concludes the efficient of thermal conduction resistance of the fin due to perforation can be decreased as its thermal conductivity is increased.

Chen, (2007) directed tests to Estimate the warmth exchange coefficient on the blade of annular-finned tube warm exchangers in common convection for different balance spacings. The finite difference method is used in conjunction with the least-squares scheme to find out the experimental temperature data which is used to predict the average heat transfer coefficient along with fin efficiency on the fin of annular-finned tube heat exchangers in natural convection for various fin spacings. The radiation and convection heat transfer coefficients are simultaneously taken into consideration in this study. The outcomes demonstrate that the esteem increments with expanding the balance dividing S , and the balance productivity diminishes with expanding the balance separating. They tentatively explored the blade temperature which leaves from the perfect isothermal circumstance and further abatements quickly far from the round fixate in view of the expansion in balance dividing. After a careful report in writing review, the undertaking have an exploratory setup made for assessing heat exchange rate and temperatures at various hubs which are to be observed and for viable count.

Jubran et al. (1996) analyzed the effects of inter fin spacing, shroud clearance, along with missing pin for the heat transfer from the cylindrical pin fins those were arranged in staggered and in-line arrays by means of experimental investigations. Razelos et al. (1996) investigated convecting trapezoidal pin fins with internal heat generation. The effect of the fin's profile and thermal conductivity upon the optimum dimensions is discussed. An example serves to demonstrate the usefulness of the method. Georgiou (1998) analyzed the thermal performance for convective pin fins, having a trapezoidal profile and internal heat generation density is presented. An additional optimum solution is given for spines located in limited spaces, and is necessary to specify the height. The effect of the fin's profile and thermal conductivity upon the optimum dimensions is discussed.

Fisher and Torrance (1998) presented the solution for a pin-fin heat sink. The optimization is used to show

that the minimum thermal resistance from a pin fin heat sink is about two times larger than that of an idealized model based on inviscid flow. Jamal and Khashashneh (1998) investigated triangular pin fin array experimentally at constant heat flux and correlations were developed.

Md.Abdul Raheem Junaid. et.al., (2014) Warmth dissemination methods are the prime worry to expel the waste warmth created by Electronic Devices, to keep them inside allowable working temperature limits. In warm dispersal strategies, it joins the warmth sinks, fans for air cooling, and fluid cooling and so on., Heat created by electronic gadgets and hardware must be disseminated to enhance unwavering quality and avert untimely disappointment. Over warming may cause disappointment in the instances of Integrated circuits, for example, CPUs, chipset, realistic cards, and hard plate drives are powerless to brief glitch or perpetual disappointment if overheated. Thus in warm building, electronic gadgets remain a test for cooling viably and productively. This paper demonstrates an Optimal Heat Sink utilized for productive cooling of electronic gadgets. The decision of an ideal warmth sink relies upon various geometric parameters, for example, blade stature, balance length, balance thickness, number of balances, base plate thickness, space between balances, balance shape or profile, material and so forth. Consequently for an ideal warmth sink plan, an underlying investigation on the liquid stream alongside warm exchange qualities of a standard stick balance, spread stick balance and Hybrid stick balance warm sinks have been helped through CFD demonstrating and reproductions. It is seen from the outcomes that ideal cooling is accomplished by spread and cross breed stick balance warm sinks. These warmth sink outlines enhance the productivity of electronic circuits by 20 to 40% cooler than standard stick balance warm sinks.

Devendra J. Waghulde et.al., (2017) Finite element analysis and experimental investigation on the thermal behavior of cylinder with different fins of varying fin thickness, geometry and material is carried out. Based on the finite element analysis and experimental investigation of different fins, following conclusions are drawn. The study shows that the temperature distribution is maximum for the cylinder with rectangular fin of 3.5 mm fin thickness for aluminium alloy 2014 and minimum for triangular fin of 2.5 mm thickness for aluminium alloy 2024. It also shows that the total heat flux is maximum for the cylinder with rectangular fin of 2.5 mm fin thickness for aluminium alloy 2014 and minimum for triangular fin of 3.5 mm fin thickness for aluminium alloy 2024 and directional heat flux is maximum for the cylinder with rectangular fin of 2.5 mm fin thickness for aluminium alloy 2014. Minimum for triangular fin of 3.5 mm fin thickness for aluminium alloy 2024. It can be seen that the temperature at the tip of fin increases

with increasing fin thickness for both rectangular and triangular fins.

Vijayakumar P et.al.,(2017) Fins are analyzed with different fin profiles, fin materials, variable fin profile and with minimal cooling conditions for an air cooled diesel engine of 5 H P. From the investigation, it is observed that Trapezoidal profile or Stepped rectangular profile adoption will result in material saving and increases in performance. By using aluminum alloy as an alternative fin material for cast iron, performance of fins is increased about 7% with reduction in fin length is experienced, which in turn results in engine compactness and reduction in fin weight. By using variable fin profile, 13.191 % savings in material is achieved. "Variable length fins" offers lesser resistance to air flow compared to the "equal length fins". The 13th and 14th fin lengths are determined by using fin profile tip contour equation without analyzing the problem in two dimensional manners with an accuracy of 99.99933 %. Thermal efficiency of the engine will be improved and the rise in exhaust gas temperature can be used to activate the energy recovery devices with the adoption of minimal cooling technique by removing the bottom two fins. Thus, Cost reduction and weight reduction is achieved with increase fin performance and increase in power to weight ratio.

Prem Prakash Pandit and Chauhan P S (2015) Governing equation has been solved and converted into algebraic form by using finite difference scheme. A numerical technique has been developed to solve the above physical problem. Different shapes of fin have been studied by changing the length of the fin. Aluminium has been used as a fin material. Convective boundary conditions on the walls of the fin have been considered which represents the actual physical scenario. A mathematical formulation has been developed in the present study which can be used to study the effect of fin length and fin material for any real fin problem. Using the above formulation one can also study the temperature contour inside the fin for any fin length and fin material. MATLAB will be used to code the algebraic governing equation.

3. Analysis on the Literature Findings

This review presents overview of aerospace applications of heat pipes possible conventional thermal solutions for spacecraft are challenging tasks by adverse environmental radiation. Heat pipes are one such technology for high temperature applications have already been discussed extensively. Looped heat pipes with capillary pumped loops are used in evaporators and condensers for high powered communication satellites. The micro and micro loop heat pipes are now used extensively by small satellites as they are easy to use and cost effective. The results were encouraging to find that different geometrical conditions, which would

result in best heat transfer in constrained conditions. Some of the recent research findings are pointing to the optimum shape and materials for the same. The related experiments need to be conducted using popular material combinations.

Some of the latest research papers addressed the use of nanostructures and nanofluids as agents improve the heat transfer rates of the heat pipe. Most reports in recent past also shows improved heat transfer performance, oil-less operation, compact size, reduced weight, and low power consumption, all of which are especially important for space, air, and even naval operations, many such studies reference to the road map of NASA for the development of high temperature heat pipes with nanofluids to improve on performance during heavy heat flux encountered during ascent and reentry of the space vehicle. The fluid with ultra fine suspended nanoparticles will be the advanced fluid for satellite applications of the heat pipes, but after all these studies the geometric features of the heat pipe of pin fin and material of the fin are the other important factors which determines the heat transfer rate though many other factors also needs consideration.

4. Conclusion

The major research possibilities in this specific application area are a bit challenging and tricky since the space or vacuum requirements and conditions for testing with respect to realities of the satellites and spacecrafts. To conclude the opportunities are to find an optimum shape which exposes maximum area of contact for the heat transfer, where the material should have the capacity to perform better in heat transfer and also should have good structural properties like strength and toughness. Most recent researches in composites, nanomaterials, smart and phase change materials are also needs to be looked upon for the alternatives in high temperature heat transfer problems and issues.

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