International Journal of Academic Research and Development
ISSN: 2455-4197
Impact Factor: RJIF 5.22
www.academicsjournal.com
Volume 3; Special Issue 2; March 2018; Page No. 127-131

Experimental analysis of heat transfer performance of wavy fin heat sink with different orientation

Nitin Pulate[1*], Ravindra Navthar[2], Shrikant Kathwate[3]
[1] Research Scholar, GH Raisoni College of Engineering, Savitribai Phule Pune University, Ahemednagar, Maharashtra, India
[2] Dean of Mechanical Department, P.D.V.V.P. College of Engineering, Savitribai Phule Pune University, Ahemednagar, Maharashtra, India
[3] M.E. Co-ordinator, GH Raisoni College of Engineering, Savitribai Phule Pune University, Ahemednagar, Maharashtra, India

Abstract

Heat dissipation is a drastic issue to tackle due to continued integration, miniaturization, compacting and lightning of equipment. Heat dissipaters are not only chosen for their thermal performance; but also for other design parameters that includes weight, cost and reliability, depending on application. A heat sink is a device that is used to cool many various types of electronic devices by absorbing and dissipating the heat device produces through direct contact. Heat sink works the basis of transferring heat from a high temperature source to a lower temperature source, where the lower temperature source has much greater heat capacity. The primary of this study is to experimentally obtain the performance of a wavy fin heat sink by conducting free convection test.

Keywords: wavy fins, electronic cooling and natural convection

1. Introduction

Many engineering systems during their operation generate heat. If this generated heat is not dissipated rapidly to its surrounding atmosphere, this may cause rise in temperature of the system components. This by-product cause serious overheating problems in system and leads to system failure, so the generated heat within the system must be rejected to its surrounding to maintain the system at recommended temperature for its efficient working. The techniques used in the cooling of high power density electronic devices vary widely, depending on the application and the required cooling capacity. The heat generated by the electronic components has to pass through a complex network of thermal resistances to the environment.

In the current electronics industry, heat sinks are used extensively to provide cooling for electronics components. The process of making a heat sink is often by extrusion, cold forging, pressed fin, or bonded fins. Even though extruded and cold forged heat sinks require easier manufacturing processes compared to the other two, they have a limited fin aspect ratio due to the manufacturing processes. Whereas the pressed fins or bonded fins techniques offers a higher aspect ratio. Pressed fin is a process where fins are fitted into tapered tip grooves on the base. The fins are pressed by machine to establish contact surface with the base. The disadvantage of this method is that air gaps can exist in the joint which causes higher thermal resistance. However, this problem can be resolved by adding bonding materials, such as adhesive, into the gap. Both pressed fin methods also require grooves to be made on the base before the bonding process. This method is suitable only for thicker fins. However, the waveform fin does not require a grooved base and has no restriction on the fin thickness. This makes waveform fins a highly suitable candidate for future electronics in heat rejection. Methods of attaching the waveform fin to the base include brazing, adhesive bonding and solder bonding.

The enhancement of heat transfer is an important subject of thermal engineering. The heat transfer from surface may, in general, be enhanced by increasing the heat transfer coefficient between a surface and its surrounding, or by increasing heat transfer area of the surface, or by both. Extended surfaces that are well known as fins are commonly used to enhance heat transfer in many industries. Heat transfer rate is increased by using natural, forced or mixed convection. But now a day's application of natural convection to the cooling of electrical and electronic equipment has received considerable attention over the years. Natural convection doesn't require either a fan or a blower, is free of maintenance, has zero power consumption, is low cost, the noise level is reduced and the cleanliness of the system is improved. These features of natural convection cooling play an important role in the electrical and electronic cooling industry; therefore, natural convection plays an important role in the design and the performance of the system. Improvements in the design of natural convective cooling systems are required to deal with the increased performance of electrical and electronic systems.

A heat sink is a device that is used to cool many various types of electronic devices by absorbing and dissipating the heat the device produces through direct contact. Heat sinks are an extremely useful component that can be used to drastically lower the maximum temperature of electronic devices, as well as increase their overall thermal efficiency and performance. A heat sink works on the basis of transferring heat from a high temperature source to a lower temperature source, where the lower temperature source has a much greater heat capacity. Furthermore, it is desired to have a transfer in thermal energy from the high temperature electronic device into the heat sink (low temperature source). The hope is to produce a system which reaches thermal equilibrium rapidly, by using the most efficient heat sink possible. Most heat sinks are metal devices which contain a base in the shape of a flat surface. On top of this flat base, a large number of thin, fin like protrusions extend out of the flat surface of the device. These fins produce a high surface area, which reduces the thermal resistance and enhances the cooling for the primary electronic device. Rectangular fin or plate fin geometries and their thermal effectiveness are investigated extensively in various literatures; most of the studies are done for limited range of pin fin configurations. Moreover, even though there are many experimental studies on performance of fin configurations, the amount of numerical studies is lacking. In this study, the heat transfer performances of pin fin configurations will be investigated by the help of commercial CFD software.

The performance criterion of heat sinks is the thermal resistance, which is expressed as the temperature difference between the electronic components and atmosphere per watts of heat load. It is expressed with units K/W. Today's electronic chips dissipate approximately 70W maximum heat whereas this number will be multiples in the near future. The temperature differences from the heat sink surface to the ambient ranges from 10 ºC to 35 ºC according to the heat removal capability of the installed heat sink. Heat sinks may be categorized into five main groups according to the cooling mechanism employed

1. Passive heat sinks which are used generally in natural convection systems
2. Semi-active heat sinks which leverage off existing fans in the system
3. Active heat sinks employing designated fans for forced convection system
4. Liquid cooled cold plates employing tubes in block design or milled passages in brazed assemblies for the use of pumped water, oil or other liquids
5. Phase change recirculating systems including two-phase systems that employ a set of boiler and condenser in a passive, self-driven mechanism.

Radiation and convection heat transfers are two modes of heat transfer that takes place while dissipating to surrounding from fins. Since the fins are made of duralumin and aluminum alloys, which have low emissivity values, low radiation heat transfer values to be consider. Therefore, heat transfer by convection is the dominant heat transfer mode while dissipating heat from fins to atmosphere.

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 heat spreader on the device.

Natural convection cooling describes a situation where there is no forced air flow from a fan, blower, or any other source. Under natural convection cooling, the temperature of the air within the heat sink's fins increases due to heat from the heat source. The higher temperature air is less dense than the surrounding air and rises out of the heat sink. This movement will generate a small amount of airflow within the heat sink fins, cooling the heat sink. Due to the relatively low airflow generated by natural convection cooling, the fin pattern will need to be very sparse to provide optimal performance. A dense fin pattern will generate too much restriction to airflow, preventing the warm air from rising out of the heat sink efficiently. Heat sink attachment or orientation plays a significant role under natural convection.

When a heatsink is heated, the buoyancy force causes the surrounding fluid to start moving and, as a result, thermal boundary layers start to develop at the bottom edges of the opposing surfaces of the neighboring fins; the boundary layers eventually merge if the fins are sufficiently long. If we use pin fin structure instead of other fins like longitudinal fin, it will ideally reset the thermal boundary layer growth, maintaining a thermally developing flow regime, which, in turn, leads to a higher natural heat transfer coefficient.

2. Literature Review

C.C. Wang *et al.* [1–2]. Finned surfaces are widely used to enhance heat transfer in such applications as heat exchangers and heat sinks. In particular, the wavy plate fin is one of the most attractive fin types owing to its large surface area and simplicity of manufacture. Numerous experimental and numerical studies have been performed on wavy plate fin-and-tube heat exchangers and wavy plate fin heat sinks.

Y.B. Tao *et al.* [3-4]. Most of these studies have focused on evaluating the thermal performance of each device. A few fundamental studies dealing with the fluid flow and heat transfer characteristics for forced convection between wavy plate fins have been reported.

Rush *et al.* [5]. experimentally studied the water flow passing through sinusoidal wavy passages and concluded that the parameter space in wavy-channel flows is extensive and needs to be explored more thoroughly before an optimum geometry for specific conditions can be determined. It may be desirable to undertake thermal performance testing of wavy channel heat exchangers in full scale experiments such experiments are needed to account for the geometrical complications, manufacturing commonly encountered in application.

Zhang *et al.* [6]. investigated the effect of waviness and spacing of wavy plate fins on the pressure drop and thermal performance using numerical simulations. Their results show that the Poiseuille number, fRe, monotonically increases as the surface area increases and that severe wall waviness deteriorates the thermal performance. However, to the authors 'knowledge, no correlations or analytic solutions have been presented for the Poiseuille number or the Nusselt number of the wavy plate fin. In addition, their results are applicable only to fin design using air as the working fluid. It means that the effect of the Prandtl number on the thermal performance of the wavy plate fin was not investigated.

Zhou *et al.* [7]. attempted to design a microchannel heat sink with wavy channels by using CFD simulations. Since there was no correlations or analytic solutions for the wavy channels, they had no other choice but to perform numerous cases of simulations or experiments and then pick the best one among them. To optimize the thermal performance of the wavy plate fin, it is necessary to evaluate the effects of numerous parameters: fin spacing, amplitude and wavelength of waviness, Reynolds number, and Peclet number. Extensive numerical calculations and/or experimental works could be required to estimate the quantitative effects of each parameter. On the other hand, if analytic solutions were available to predict the exact values of the Poiseuille and Nusselt numbers depending on the various parameters, it would be much easier and simpler to optimize the thermal performance as well as to identify critical parameters.

Y. Song *et al*. [8–11]. Instead of restarting the boundary layer and inducing vortices to cause mixing in slit and louver fins, the flow is mixed in the wavy fins duct through shear-layer instabilities and the generation of secondary flow. The effect of fin pitch, number of tube rows, fin thickness, wavelength ratio, amplitude and air velocity for heat transfer and friction characteristics of wavy fins were studied by a lot of researchers.

Aliabadi *et al*. [12]. did a lot of work for wavy fin-and-flat tube heat exchangers. At first, they experimentally investigated the influence of sinusoidal wavy-surface plate-fin geometries, such as wave length (l = 10, 20 and 40 mm) and wave amplitude (a = 0.5, 1.0 and 2.0 mm), on laminar and transition airflows.

3. Objective & Scope

1. To construct a test chamber to allow experimental data to be obtained under different conditions.
2. To investigate the flow pattern inside the chamber.
3. To increase the thermal performance of wavy fins also increase the heat transfer ability.
4. To avail the platform for educational purpose, non-educational purpose and research purpose at local level to measure heat transfer rate for different material.

The scope of the current project is limited to determine the effect of fin geometry on convective heat transfer rate.

4. Methodology

4.1 Overview

In this study, a systematic approach is adopted to study the natural convection heat transfer from the interrupted square, horizontally-installed fins. In order to study the heat transfer rate using Wavy fins by replacing the rectangular pin fins with the virtue of increasing the overall heat transfer rate the natural convection methodology is consider by making use of ANSYS software. The focus of this study is on developing compact easy-to-use thermal models that can predict the natural convective heat transfer. The wavy fin array problem is numerically studied, using ANSYS software, and a relationship for the optimum fin array interruption length is developed to obtain the maximum natural convective heat transfer.

4.2 Natural convection over surfaces

Natural convection heat transfer on a surface depends on the geometry of the surface as well as its orientation. It also depends on the variation of temperature on the surface and the thermo physical properties of the fluid involved. Some analytical solutions exist for natural convection, but such solutions lack generality since they are obtained for simple geometries under some simplifying assumptions.

5. Equipment Used

5.1 Frame

Frame is made up of cast iron. It is made to support the whole setup of the apparatus on which all equipment’s i.e. ammeter, voltmeter, multipoint temperature indicator, closed enclosure, concrete block, heater & fins are mounted.

5.2 Clamping Device

Clamping device is made up of cast iron material it is used to give support to the concrete block, heater plate and sink clamping device is use to give better fitting of the testing set up, and also balance the set up. It gives better conduction heat transfer process as it provides better contact between the aerated concrete block, heater plate and sink.

5.3 Aerated Concrete Block

It is made for the mounting of the heater plate and fins. It is made from mixture of sand stone and mixture of water. Clamping arrangement is made to attach heatsink on heater plate.

5.4 Heater Plate

Heater plate is made of nichrome wire which is sandwiched in Mica sheets. It is used for heating the aluminum pin fin heat sink.

Heater specifications:
Capacity – 180W, 50 Hz
Material - Mica sheet

5.5 Thermocouples

It is used to measure the temperature of base of fin at different locations which are selected as per the scale.

There are six numbers of thermocouples are as follows:
Base temperature: T_1, T_2, T_3, T_4, T_5
Ambient temperature: T_6.

These six K type thermocouples are connected to multi point temperature indicator to measure the fin temperature at different locations. Average of all five thermocouple readings is taken as base temperature.

5.6 Voltmeter

Voltmeter is an instrument used for measuring the electrical potential difference between two points in an electric circuit.

A voltmeter finds it’s important whenever voltage is to be measured.

5.7 Ammeter

Among its many uses, electricity heats and lights our homes, makes our cars start up when we turn the key, and powers all our electronic devices. Sometimes we need to measure the electricity flowing through these devices. One of the instruments that can do this is the ammeter, which measures electric current. It gets its name from the standard unit of measurement for electric current, the ampere O ften you will see the word ampere shortened to amp.

An ammeter is a measuring instrument used to measure the electric current in a circuit. Electric current are measured in amperes hence the name instrument used to measure smaller current, in the milliampere or microampere range, are designated as milliammeters or microammeter. digital ammeter design use a shunt resistor to produce a caliberated voltage proportional to the current flowing. This voltage is then measured by digital voltmeter, through analog to digital converter the digital display is caliberated to display the current through the shunt.

5.8 Dimmer Stat

It is useful for setting the voltage input for set-up. By using this we change the input such as 20W, 40W, 60W, 80W and 100W.

5.9 Multi point temperature indicator

It has temperature sensor at 12 points. These points are connected to the thermocouples and these thermocouples are sensing the temperature of fin base. Multi point temperature indicator is an instrument which senses the temperature from source and give output to the display by the expanse of electrical supply, it has 12 channel to connect 12 thermocouples.

6. Experimental Setup

In this study, a systematic approach is adopted to study the natural convection heat transfer of Wavy fin with different orientations. The focus of this study is on developing compact easy-to-use thermal models that can predict the natural convective heat transfer of Wavy fin, rectangular walls to the ambient. The fin array problem will be studied, using ANSYS software and a relationship for the optimum pin fin array will be developed to obtain the maximum natural convective heat transfer. The new experimental test bed has to be designed and built to verify the developed models and the proposed correlations. Experimental studies with various testing samples at different scales will be performed.

6.1 Experimental Equipment and Instrumentation

The front surfaces of the frames are covered with metal plates, which have rectangular holes at the center, so that fin arrays are placed into the cases through these holes. The experimental set-up primarily consists of an aerated concrete case and supporting frame on which the concrete is mounted, and various instruments for measuring the ambient temperature, base-plate temperature and the power input for the heater plate rated for 300W and 220V, AC.

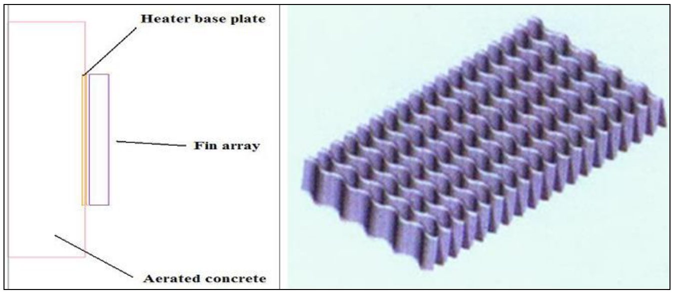

Fig 1: Side view of modeled set-up

7. Test procedure and data collection

During the experiments, the input power supplied to the heater and surface temperatures will be measured at various locations at the back of the base-plate. Electrical power can be applied using the AC power supply. The voltage and the current will be measured with voltmeter and ammeter to determine the power input to the heater. Thermocouples will be installed in various locations on the surface of the enclosures. All thermocouples are taped down to the inside surface of the enclosure, to prevent disturbing the buoyancy-driven air flow in front of the fins. An additional thermocouple can be used to measure the ambient room temperature during the experiments. Temperature measurements will be performed at four points in order to monitor the temperature variation on the tested heatsinks. The average of these four readings will be taken as the base plate temperature. For each heatsinks, the experimental procedure will be repeated for different power inputs. The base-plate temperature, the ambient temperature, and the power input to the heater considering that the power factor equals 1, will be recorded at steady-state.

The steady state is considered after 60 minutes elapsed from the start of the experiment and the rate of temperature variations with respect to time for all the thermocouples were less than 1^0/hour.

8. Summary

At the end of dissertation, the experimental studies of effect of geometrical parameters on thermal performance of wavy fin heat sink in natural convection for upward and sideward facing orientation with different angle of inclination will be completed. Experimental investigation of steady state natural convection heat transfer wavy fin arrays will be carried out. Effect of fin height, fin length, aspect ratio and fin spacing with different heat inputs over natural convection heat transfer is to be found out by considering suitable fin spacing values.

9. References

1. Wang CC, Fu WL, Chang CT. Heat transfer and friction characteristics of typical wavy fin-and-tube heat exchangers, Exp. Thermal Fluid Sci. 1997; 14:147-186.
2. Xie G, Liu J, Liu Y, Sunden B, Zhang W. Comparative study of thermal performance of longitudinal and transversal-wavy microchannel heat sinks for electronic cooling, J. Electron. Packag. 2013; 135:021008-21011.
3. Tao YB, He YL, Huang J, Wu ZG, Tao WQ. Numerical study of local heat transfer coefficient and fin efficiency of wavy fin-and-tube heat exchangers, Int. J. Therm. Sci. 2007; 46:768-778.
4. Jang JY, Chen LK. Numerical analysis of heat transfer and fluid flow in a three-dimensional wavy-fin and tube heat exchanger, Int. J. Heat Mass Transf. 1997; 40: 3981-3990.
5. Rush TA, Newell TA, Jacobi AM. An experimental study of flow and heat transfer in sinusoidal wavy passages, Int. J Heat Mass Transf. 1999; 42:1541-1553.
6. Zhang J, Kundu J, Manglik M. Effect of fin waviness and spacing on the lateral vortex structure and laminar heat transfer in wavy-plate-fin cores, Int. J. Heat Mass Transf. 2004; 47:1719-1730.
7. Zhou J, Hatami M, Song D, Jing D. Design of micro channel heat sink with wavy channel and its time-efficient

optimization with combined RSM and FVM methods, Int. J Heat Mass Transf. 2016; 103:715-724.

8. Song Y, Asadi M, Xie G, Rocha LAO. Constructal wavy-fin channels of a compact heat exchanger with heat transfer rate maximization and pressure losses minimization, Appl. Therm. Eng. 2015; 75:24-32.
9. Zhan F, Tang J, Ding G, Zhuang G. Experimental investigation on particle deposition characteristics of wavy fin-and-tube heat exchangers, Appl. Therm. Eng. 2016; 99:1039-1047.
10. Wongwises S, Chokeman Y. Effect of fin pitch and number of tube rows on the air side performance of herringbone wavy fin and tube heat exchangers, Energy Convers. Manage. 2005; 46(2005):2216–2231.
11. Ma X, Ding G, Zhang Y, Wang K. Effect of hydrophilic coating on air side heat transfer and friction characteristics of wavy fin and tube heat exchangers, Energy Convers. Manage. 2007; 48:2525-2532.
12. Aliabadi MK, Sahamiyan M, Hesampour M, Sartipzadeh O. Experimental study on cooling performance of sinusoidal-wavy minichannel heat sink, Appl. Therm. Eng. 2016; 92:50-61.