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Performnce Analysis on Array of Circular Fins through Forced Convection

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Abstract

Intensification of heat transfer from aerospace and automobile vehicles, gas cooled nuclear reactors, cooling of electronic components are desired. The cooling of electronic components continues to be an active branch of heat transfer investigation. Due to wide applications and miniaturization of electronic components an efficient cooling technique is needed, normally this is achieved by extended surfaces (FINS). The present investigation is aimed at studying the forced convection thermal characteristics of circular pin fin, the effect of pin fin spacing in both stream wise and span wise directions and the rate of heat dissipation from the heat exchanger fort different air flow rate are examined while maintaining low viscous losses is investigated. For this investigation a wind tunnel having the size of 0.2 X 0.25 X 1 meter, base plate 0.25 X 0.20 meter and pin fin having the height of 0.2 meter and 0.006-meter diameter are built and used. During the trial number of geometric and flow parameters have been varied and its performance were studied. From the experimental result it is observed that the heat transfer rate is higher in lower inter fin distance, heat transfer coefficient increases with increasing mass flow rate in both stream wise and span wise direction. Construction and calibration of wind tunnel, Pin fin assembly, and measuring devices are also discussed in this paper.

Keywords: heat transfer; heat exchangers; pin-fins; thermal systems; fluid flow

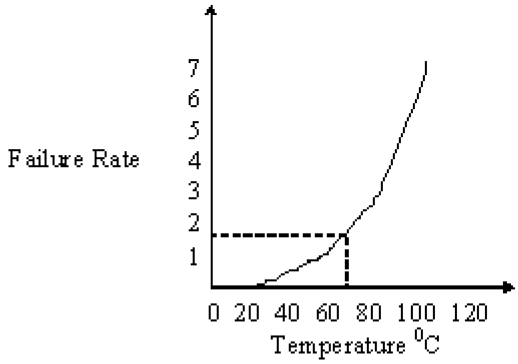
Introduction

The development of microprocessor in the early 1970's by the Intel Corporation marked yet another beginning in the electronic industry. The accompanying rapid development of large-capacity memory chips in this decade made it possible to introduce capable personal computers for use at work or at home for an affordable price. Electronic has made its way into practically everything from watches to household appliances to automobiles. Today it is difficult to imagine a new product that does not involve any electronic parts.

Electronic components depends on the passage of electric current to perform their duties, and they become potential site for excessive heating, since current flow through a resistance is always accompanied by heat generation in the amount of I^2R, where I is the electric current and R is the resistance. When the transistor was introduced, it was touted in the newspaper as device that “produces no heat”. This certainly was a fair statement, considering the huge amount of heat generated by vaccum tubes. Obviously, the little heat generated in its predecessor. But when thousands or even millions of such components are packed in a small volume, the heat generated increases to a high level that its removal becomes a formidable task and a major concern for the safety and reliability of the electronic devices. The heat flux encountered in electronic devices ranges from less than 1 W/cm^2 to more than 100 W/cm^2.

Heat is generated in a resistive element as long as current continues to flow through it. This creates a heat built-up and as a subsequent temperature rise at and around the component. The temperature of the component will continue rising until the component is destroyed unless heat is transferred away from it. The temperature of the component will remain constant when the rate of removal from its equal the rate of heat generation.

Individual electronic components have no moving parts, and thus nothing to wear out with time. Therefore, they are inherently reliable, and it seems as if they can operate safely for many years. Indeed, this would be the case if the components operated at temperatures. Possible causes of failure are temperature, vibration, humidity, dust, among other things. The failure rate of components increases almost exponentially with the operating temperatures. Also, the high thermal stresses in the solder joints mounted on circuit boards resulting from temperature variations. A rule of thumb is that the failure rate of electronic components is halved for each 10°C reduction in their junction temperature.



From the figure it is well known that, for more reliability the electronic devices should be designed with better cooling system with temperature below 70°C. The cooler the electronic device operates, the more reliable it is.

COOLING OF ELECTRONIC COMPONENTS:

The first step in the selection and design of cooling system is the determination of the dissipation, which constitutes the cooling load. The easiest way to determine the power dissipation of electronic component is to measure voltage applied V and the current I at the entrance of electronic device under the full load conditions and to substitute them into the relation

$$We = VI = I^2R$$

Where We is the electric power consumption of the electronic device, which constitutes the energy input to the device. The first law of thermodynamics requires that in steady operation the energy input to a system be equal to the energy output from the system. Considering that only change form of energy leaving electronic device is heat generated as the current flowing through resistive elements i.e. Q= We

The cooling technique depends on the environment in which the electronic component is to operate. For the cooling of low power density such as TV or VCR in a room, simple ventilation holes on the case may be used. A fan may be adequate for the safe operation of a home computer. The thermal environment in marine applications is relatively stable, since the ultimate heat sink is the atmospheric air, whose temperature varies from -50°C at Polar Regions to+50°C in desert Eli mates.

Electronic devices are rarely exposed to uncontrolled environmental conditions directly, because of the wide variations in the environmental variables. For an electronic device a 10°C increase above 65°C approximately halves its mean time to failure. To overcome this problem, thermal systems with efficient heat sinks (e.g., Pin-finned heat exchangers) are essential. Also optimization of the heat exchanger design is desirable.

Experimental setup

Pin-fin assembly:

The array consist of circular sectioned pin-fin

Diameter - 6mm

Height - 200mm

S_X - 25mm

S_Y - 25mm

Base plate - 250 x 200mm

The number of fins is varied in accordance with the spacing. For the smallest pin-fin spacing the maximum number of pin-fin are 95 whereas the largest spacing, the array consist of only 57 pin-fins. The pin-fin can be easily removed and replaced with studs made from the same material as the assembly base; when fully screwed in, their heads are flush with the upper surface of the horizontal base plate. Thus, the air flows never flow over a hole in the base plate. The rectangular base as well as the pin-fin was manufactured from pure aluminum alloy.

Proprieties of aluminum are as follows:

Symbol =Al

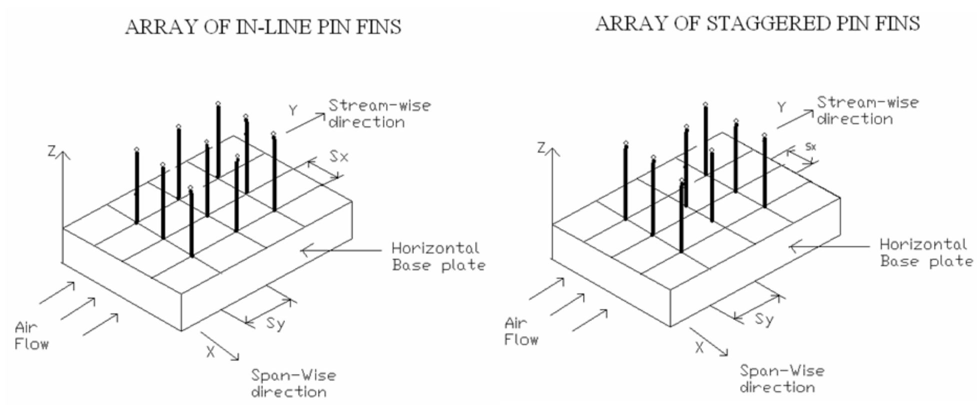
Atomic weight= 26.97

Melting point =658.7°C

Density =2800 kg/m^3
Sp heat of air Cp= 0.938kJ/kg k
Thermal conductivity K= 228 W/mK.

The material Al has good electrical conductivity and high resistance to corrosion and non-toxicity. For each test, the pin-fin heights were kept constant with zero clearance between the tips of the pin-fin and the shroud (i.e. they were in full contact with the shroud).

Pin fin spacing in stream wise direction in mm	Pin fin spacing in span wise direction in mm	Ratio of stream and span wise with respect to width and Length	
		Sx/W_b	Sy/L
25	25	0.1	0.0625
25	25	0.125	0.05



Heating system

The base of the exchanger is heated almost uniformly by two electrical resistor strips, each rated at 500W, and this is the main heater. The base assembly is firmly bolted together to the bottom of the rectangular base. The presence of thin layer of highly thermal conductivity heat – sink putty ensured that good thermal contact exists between the main heater and the rectangular base, as well as between the fin roots and the rectangular base. The lower horizontal surface and sides of the main heater block were insulated thermally with glass wool and asbestos sheet.

The properties of asbestos and glass wool are

Properties	Asbestos	Glass Wool
Temperature	20°C	20°C
Density Kg/m^3	577	24
Specific Heat C_p KJ/KgK	1.05	0.70
Thermal Conductivity K	0.157	0.038

The whole system of the heat exchanger base, heater with associated thermal insulator, is located in and protected by a well fitting open-topped box. The horizontal edges of this box and the top surface of the laterally placed thermal insulated during each experiment, where flush with the upper surface of the multi-component rectangular base, which the fins protected upward. The power supplied to the main heater could be adjusted by altering the variac setting and it is measured by a inline electronic wattmeter.

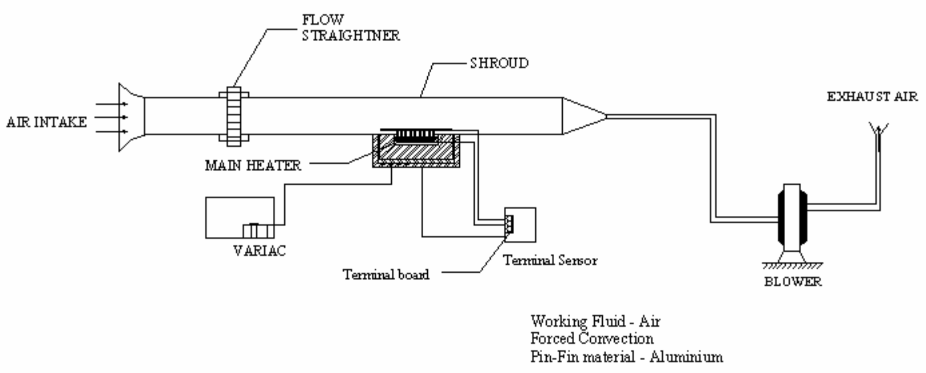
Temperature measurement

The temperature measurement plays a major role; the temperatures at the base of the fin array were indicated by an approximated distributed two set of iron constantan thermo junctions embedded with in the rectangular base. All thermocouple junctions were bonded in position with a thin layer of epoxy resin so as to ensure good thermal contact. The average values obtained from these appropriately located thermo junctions are regarded as the mean overall base temperature.

This is maintained constant each experiment at 45°C .The inlet and outlet stream temperatures in the wind-tunnel duct were measured using four copper constant thermocouples.

One is located immediately before the entrance of the pin-fin assembly. Another three was located downstream of the array. All the thermocouples as well as those indicating the ambient temperature were connected, to temperature sensor to indicate temperature until steady state conditions were attained.

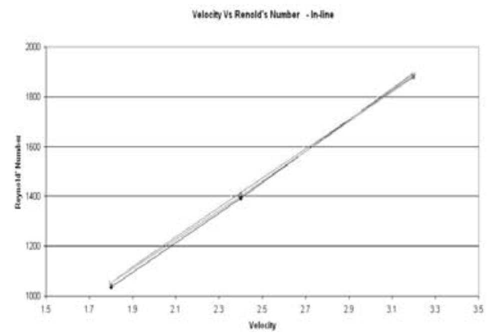
Wind tunnel

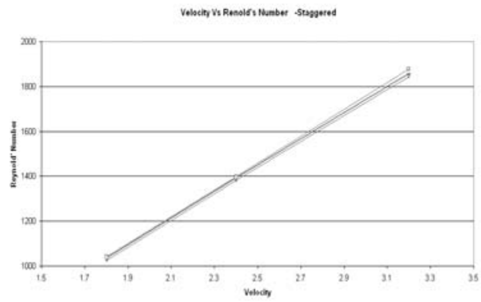


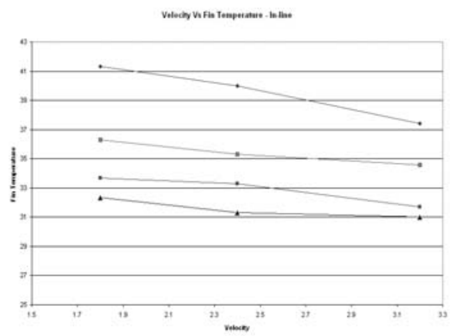
EXPERIMENTAL SETUP

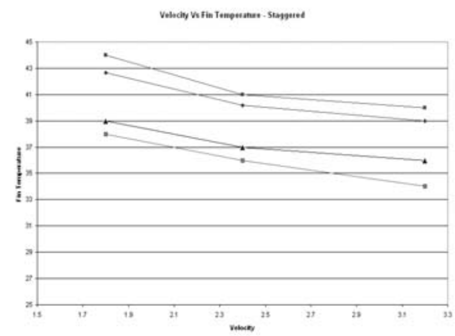
The main body of the rectangular cross-sectioned wind-tunnel duct was manufactured from wood and it is of 4.5m long with a constant internal width of 200mm. different duct heights were obtained by means of an adjustable roof. (or shroud) Approximately halfway along the length of the wind tunnel duct is the test section. The roof and side wall of the test section were made up of 7mm thick plywood. A small opening is placed at the middle of the test section so enabling the fin array (and the air, via smoke –flow visualization around it) to be observed.

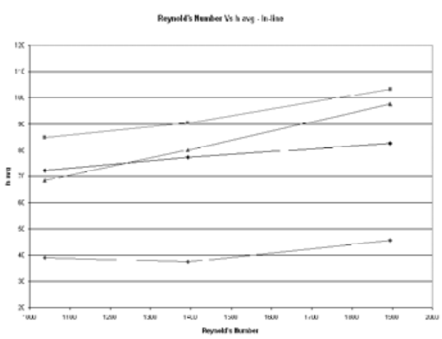
A bell mouth is fitted at the entrance of the win tunnel duct; followed by a resin impregnated, low porosity, cardboard honey comb flow straighter. The exhaust air from the pin fin assembly is passed through an insulated chamber when mixing was accomplished by two resin impregnated card board honey combs, one being of relatively low porosity and the other of higher porosity. The letter is situated at the upstream of the former. The two honey combs were mounted perpendicular to the undisturbed flow stream. At the exhaust end of the duct, a gradual area contraction section is attached. It is connected via a plastic pipe, to a blower and preceded by a throttle control valve. The wind tunnel is operated in the suction mode i.e., the fan sucked atmospheric air through the fin assembly and the test section via the bell-mouthed entrance section, with the fan motor assembly on the exhaust side of the system. This avoided the air stream being heated by the motor prior to its passage through the exchanger assembly, this would thereby, have reduced the cooling period capability of the air.

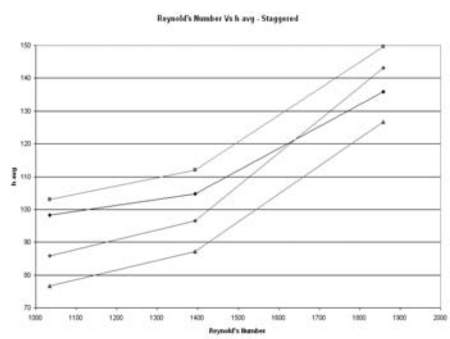


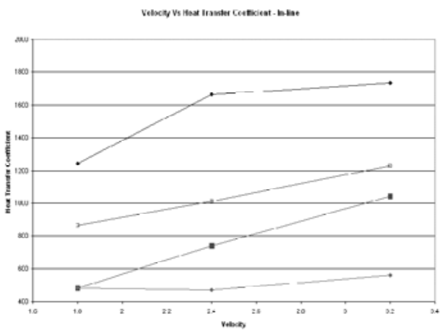


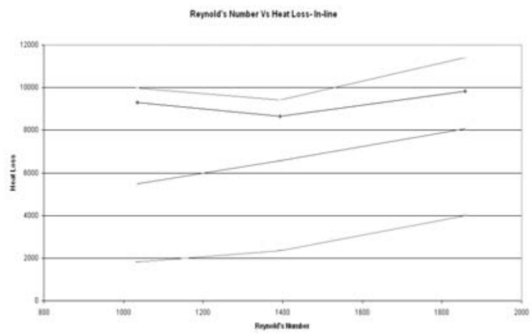


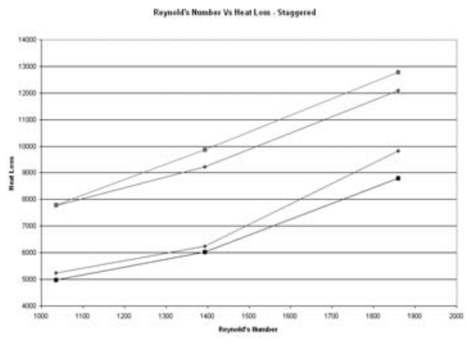












Conclusion:

The enhancement of the heat transfer from a flat surface in a rectangular channel by the attachment of staggered and in-line circular cross-section pin fin

The conclusions are summarized as

1. The average heat transfer coefficient increases with increase in Reynolds number
2. The fin temperature decreases with increase in velocity
3. Heat transfer coefficient increases with increases in velocity any Reynolds number
4. The rate of heat loss increases with increase in Reynolds number
5. The rate of heat transfer is higher in staggered arrangement

The present investigation may be extended in future by considering the following parameters

1. Square, Diamond, Rectangular pin-fin
2. Clearance ratio
3. Various mass flow rate / Reynolds number
4. Number of pin-fin in stream wise and wise
5. It can also be numerically analyzed ANYSYS

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