Experimental Analysis of Circular Perforated Fin Arrays by Forced Convection using wind tunnel

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Abstract: *The enhancement of heat transfer is an important subject of thermal engineering. The removal of excessive heat from system components is essential to avoid the damaging effects of burning or overheating. 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. Various types of fins like rectangular plate fins, square pin-fins and circular pin-fins are commonly used for both natural and forced convection heat transfers. The trapezoidal micro fins array with circular perforation is selected to study among different types of fins. In different industries fins haves many application. Task is to design the fin for enhancement the heat transfer and also for drag force calculation. The fin is designed using Taguchi Method.*

The input parameters are velocity of air and heat input. The experiment is performed on the wind tunnel under forced convection and the output parameters are efficiency of fin, effectiveness, lift force, drag force etc. only the review of my project is shown in this paper.

Keywords: Heat Transfer Enhancement, Micro Fin Arrays, Perforated Fins, Forced Convection, Fin Performance

1 Introduction

Extended Surface (Fin) is used in a large number of applications to increase the heat transfer from surfaces. Typically, the fin material has a high thermal conductivity. The fin is exposed to a flowing fluid, which cools or heats with it. The high thermal conductivity allowing increased heat being conducted from the wall through the fin. Fins are used to enhance convective heat transfer in a wide range of engineering applications, and offer practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly applied for heat management in electrical appliances such as computer power supplies or substation transformers. Other applications include IC engine cooling; such as Fins in a car radiator. Perforation in the fines enhances heat dissipation rates. Also, the heart transfer of perforated fin enhances with increase in the fin thickness. Thermal Performances of the solid fins and drilled fins compared under same condition. Perforated or drilled fins can be used for many practical applications. It is necessary to determine the economic benefits for the heat transfer enchantment. Perforated fins are very useful in situations which require higher heat transfer rates than what can be achieved by the use of regular solid fins.

1.1 Objectives of the study:

- To determine the value of heat transfer coefficient under forced convection for the fin arrays.
- To find overall efficiency and effectiveness of fins array with perforation and without perforation.
- To see the effect of heat input and air velocity on the overall efficiency and effectiveness of fins.
- To see the effect of heat input and air velocity on the lift force and drag force acting on fin array.

2. Literature review: P Teertstra et al. presented an analytical model that calculates the average heat transfer rate for forced convection of air cooled plate fin heat sinks for use in design and selection of heat sinks for electronics applications. The average Nusselt number can be considered as of a function of the heat sink geometry and fluid velocity. The subsequent model is valid for the full range of Reynolds no 0.1<Re<100[1]. Zhipeng Duan et al. studied impingement cooling of plate fin heat sinks. It is observed that percentage uncertainty in the measured thermal resistance was a maximum of 2.6% in the validation experiments. A simple thermal resistance model based on developing laminar flow in rectangular channels was developed for the impingement plate fin heat sink system[2]. Yevov Peles et al. (2007) investigated the heat transfer and pressure drop phenomenon over a array of micro pin fins. They derived a basic expression for the total thermal resistance and the same is validated experimentally. It is concluded that forced convection over shrouded micro fins heat sinks is a very effective heat transfer mode [3]. Yang et al. (2010) studied the forced convective heat transfer in three-dimensional permeable pin fin channels numerically. It found that heat transfer performances on porous pin fin channels are much better than those in traditional solid pin fin channels. It is observed that the effect of pore density is major. As PPI increases, the pressure drops and heat fluxes in porous pin fin channels increase while the overall heat transfer efficiencies reduce and the maximum overall heat transfer efficiencies are obtained at PPI-20 for both air and water cases. It is found that the effects of pin fin form are also remarkable. It is observed that the overall heat transfer efficiencies in the long elliptic porous pin fin channels are the maximum [4]. Seth A. Lawson et al. (2011) studied the effects of pin spacing on heat transfer and pressure loss through pin fin arrays for a range of Reynolds number between 5000 to 30000. It concluded that span wise pin spacing had a greater effect than stream wise spacing on array pressure loss while stream wise spacing had a large effect than span wise spacing on array heat transfer [5]. Magarajan U.et.al (2012) studied heat release of an internal combustion engine cylinder cooling fins with six numbers of fins having pitch of 10mm and 20mm are calculated numerically using commercially available CFD and ANSYS Fluent. The heat release from the cylinder which is calculated numerically is validated with the experimental results. It is concluded that CFD results are mostly as same as that of the experimental results, it is possible to modify the fin geometry and predict those results. Changes like tapered fins, providing slits and holes in fins geometry can be made and the optimization of fins can be done with the help of CFD results [6].

3. Methodology (Analytical Calculation)

3.1 Trapezoidal micro fin array is designed by Taguchi Method.

Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on "ORTHOGONAL ARRAY" experiments which gives much reduced "variance" for the experiment with "optimum settings" of control parameters.

3.2 Material selection

Generally, there are two types of materials used for fins aluminum and copper. The thermal conductivity of aluminum is 200 W/mK and that of copper is 385 W/mK. The melting and boiling point of copper are 10840 and 25950 and that of aluminum are 6580 and 20570.

3.3 Manufacturing of specimen

Aluminium plates which are available in standard sizes are first cut by jig-saw cutting machine in required sizes after these plates are transferred to next station i.e. shaping. Shaping process involves machining of work specimen on universal milling machine. It is used to obtain required dimensions of specimen, after machining in universal milling machine is transferred to drilling machine. Six holes of micro 3 mm diameter were drilled in the work specimen. Drilling if followed by the chamfering process. Grinding process is use to obtain tapper shaped fins which are difficult to machine on milling machine of brazing in some application. Aluminium rod is used to weld plates.

3.4 Experimental methodology

Test will be conducted in a subsonic wind tunnel with three different test specimen made of aluminium base plate having extended fins of trapezoidal shapes. Specimen will be heated by an electric heater of 200 watts' capacity having flat surface. The temperature will be measured by 8 thermocouples at different locations on the surface of the fin specimen. Along with the measured velocity is passes to obtain forced convection of heat transfer. readings of temperature measured by thermocouples input convection of heat transfer. Readings of temperature measured by the thermocouples input voltage and current will be measured by reading on control panel. The air velocity will be measured with the help of anemometer. Input and output parameters are selected.

Sr.no	Types of Specimen	Dimensions(mm)	No. of perforations per fin	Perforation pitch (mm)
1	Solid rectangular	40x60x3	Nil	Nil
2	Trapezoidal with circular perforation	40x60x3	9	5
3	Trapezoidal with circular perforation	40x60x3	9	7

Table no3.1: Dimensions of test specimen

Experimental setup

Results

Sr no	Test specimen	Control factors		Overall efficiency
		Velocity of air	Heat input	
1	Rectangular solid fin array	6	180	0.852
2	Trapezoidal perforated fin array with 5 mm diameter	2	150	0.901
3	Trapezoidal perforated fin array with 7 mm diameter	6	120	0.888

Sr no	Test specimen	Control factors		effectiveness
		Velocity of air	Heat input	
1	Rectangular solid fin array	6	120	3.808
2	Trapezoidal perforated fin array with 5 mm diameter	2	120	4.168
3	Trapezoidal perforated fin array with 7 mm diameter	2	120	4.018

4. Conclusion:

According to experimental results the overall efficiency for all three specimens were calculated. It is found that maximum overall efficiency is obtained for trapezoidal perforated fin array at velocity of 2 m/sec and at a heat input of 150 Watt. Hence it is observed that adding perforation to the fins helps to increase the overall efficiency. And also perforation in the fins enhances heat transfer rate. Optimum effectiveness is obtained for trapezoidal perforated fin array at velocity of 2 m/sec with heat input of 120 Watt. Optimum lift force is obtained for rectangular solid fin array of 2 m/sec velocity of air and at all level of heat input. It is also concluded that only the heat input does not affect the lift force. It is observed that the lift force for rectangular solid fin array is minimum at velocity of air 2 m/sec and is increases with increase in velocity of air. Optimum drag force is obtained for rectangular solid fin array of 2 m/sec velocity of air and at all level of heat input. It is also concluded that only the heat input does not affect the drag force. It is observed that the drag force for rectangular solid fin array is minimum at velocity of air 2 m/sec and is increases with increase in velocity of air. The average efficiency of the trapezoidal fin has increased in forced convection. The average effectiveness of a trapezoidal fin has increased in forced convection. Finally it is concluded that from my project the trapezoidal micro fin array with 5 mm perforations diameter will give the best performance for heat transfer than rectangular under forced convection.

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