ISSN: 0974-5823 Vol. 7 No. 5 May, 2022

International Journal of Mechanical Engineering

Performance Enhancement of Different Fin Geometry with Aluminum, Brass and Steel as Fin Materials

Praveen Kumar Kujur[1], Uday Khakha[1], Bhavyavesh Sahu[2], Kranti Kumar Dhruw[2], Gulab Verma[2], Shyam Singh Kanwar[1]

[1]Department of Mechanical Engineering, Government Engineering College Bilaspur (CG) India

[2]Department of Mechanical Engineering, Government Engineering College Raipur (CG) India

Abstract: Heat rejection has been a big problem in engineering practices around the world, such as internal combustion engines, cooling in nuclear plants, mobile devices, and thermal heaters. This research paper uses the performance of a pin fin as an extended surface from a region where heat dissipation is a major concern. Fins are used to increase the rate of heat transfer and, as a result, reduce the likelihood of system failure. Conduction, convection, and radiation all help to dissipate heat. Experiments on materials for fins, such as aluminum, brass, and steel, have been conducted. The impact of design parameters such as fin length, diameter, and material on efficiency for a pin fin has been investigated in both natural and forced convection environments. According to the results of the experiment, aluminum pin fins dissipate the most heat, followed by brass and steel.

Keywords: Protruded Fins, Heat dissipation, Natural and Forced convection

I. INTRODUCTION

Extended surfaces or fins are used to improve heat transfer rates from a surface to the surrounding fluid while increase g the value of the surface heat transfer coefficient or the temperature difference between the surface and the fluid is not possible. Fins are available in a variety of shapes and sizes. The temperature differential between the surrounding fluid and the fins decreases as the fins extend from the primary heat transfer surface. The circular pin-fins protruded vertically upward from a heat source. The optimal spacing to diameter ratios corresponding to the maximum rate of heat dissipation from the array has been calculated for each perfect combination of defined pin-fins and air-flow rate. The effect of modifying the pin-thermal fin's conductivity and shape has been investigated [1]. Experiments are carried out with air that has been magnetized by a magnetic gradient field. Experiments are carried out on two distinct geometry fin shapes. The effects of magnetic body field, mass flow rate, and applied heat flux on convection heat transfer phenomenon was investigated using experimental test sets fitted with the required measuring instruments [2]. Using a conjugate heat transfer model, the advantages of using pin heat sinks with single, rectangular slotted are computed. As the size of the rectangular perforation increases, the heat transfer rate increases monotonically while the pressure drop decreases monotonically [3]. An array of solid and perforated fins mounted on a flat plate is investigated using CFD for 3-dimensional fluid flow and convective heat transfer. The Navier Stokes equations are used to model incompressible air as the working fluid, and a RNG-based k-e turbulent model is used to estimate turbulent flow parameters. Solving Fourier's conduction equation [4] yields the temperature field within the fins. The heat sink's numerical analysis with an un-uniform fin height and confined impingement cooling. The governing equations are discretized using a non-uniform staggered grid control-volume-based FDM [5]. Using the time-dependent single-blow process, the pressure drop and heat transfer of a square pin-fin array in a rectangular duct were investigated experimentally. The results of this experiment show that aluminum pin fins dissipate the most heat, followed by brass and steel, in that order [6]. The results of an experimental and numerical study of natural convection in a radial heat sink with a horizontal circular base and rectangular fins [7] are presented in this paper. Under constant heat flux conditions, experimental and numerical results of the heat transfer characteristics of the in line and staggered taper pin fin heat sinks are provided. An experimental modal is set up to analyze the problem [8].

II. OBJECTIVES

The main goal of this experiment is to identify and compare forced convection and natural convection heat transfer through pin fins made of various metals, as well as to investigate pin fin thermal efficiency. The main aim of this research work to carried out the most effective fin material from a series of selected fins of different materials and shape of geometries.

III. METHODS AND PROCEDURES

The primary goal of this experiment is to improve heat transfer rates by extending the base plate's surface area. Conduction, convection, and radiation are the heat transfer modes by fins. In today's world, pin-fins come in a variety of shapes and materials, depending on their intended use. Finned tubes of double-pipe, shell and tube, and compact heat exchangers are examples of fins that are commonly found in industry, especially in the heat exchanger industry. Fins are also used in heat exchangers for thermal storage. The experimental setup consists of a rectangular duct with a pin fin of various materials that are used one by one at the same time. A blower is connected to the suction end of the duct. An electrical heater heats one end of the fin to provide heat. Five thermocouples are located along the length of the fin, and a thermocouple is also installed to test the temperature of the duct fluid. When top cover over the fin is opened and heating started, performance of fin with natural convection can be evaluated and with top cover closed and blower started, fin can be tested in forced convection shown in Figure 1. Heat is conducted along the length of fin and also lost to surroundings. From first law of thermodynamics to a control volume along the length of fin at a station which is at length ‘x’ from the base.

$$\frac{d^2T}{dx^2} - \frac{hP}{k_f A} = 0 \tag{1}$$

$$\phi = C_1 e^{mx} + C_2 e^{-mx} \tag{2}$$

Where, $m = \sqrt{\frac{hP}{k_f A}}$ with the first boundary conditions of $\theta = \theta_1$ at $x = 0$, $\theta_1 = T1 - T_f$ and here with the condition, tip is to be insulated hence second boundary condition is to be $\frac{d\theta}{dx} = 0$ at x=L, results in obtaining equation (2) in the form

$$\frac{T2 - T6}{T1 - T6} = \frac{\cosh[m(L-x)]}{\cosh[m * L]} \tag{3}$$

This is the equation for temperature distribution along the length of the fin. Temperatures T1 and Tf will be known for the given situation and the value of ‘h’ depend upon mode of convection i.e. natural or forced.

IV. Experimental Setup

Fig. 1 shows a schematic diagram of the experimental system for the pressure loss and heat transfer measurements for the channels with pin and rectangular fins are used for analysis. Pin fin are made up of brass and mild steel mean while the rectangular fin made up of aluminum for present analysis. This experimental setup consists of a variable-speed blower; a settling chamber, a nozzle flow meter, set of thermocouples and a rectangular test section. For measuring temperature across the fin thermocouple placed within the test pin fin for. The air is drawn into the wind channel by the blower, and the air mass flow rate is measured by the flow meter. The test fin has a length of 150 mm, which is made of 12 mm diameter and profile of rectangular fin is 12×10 mm .

Fig.1 Experimental Setup

Table 1

Specification of Experimental Setup

S. No.	Parameters	Values
1.	Length of the fin (L)	150 mm
2.	Diameter of the fin (d_f)	12 mm
3.	Profile of rectangular fin(A)	12×10 mm
4.	Thermal conductivity of fin material (brass)	110 W/m K
5.	Thermal conductivity of fin material (Aluminum)	232.0 W/m K
6.	Thermal conductivity of fin material (mild steel)	46.0 W/m K
7.	Diameter of the orifice (d_o)	27 mm
8.	Duct Size	1150 mm ×150 mm × 100 mm
9.	Breadth of the duct (B)	100 mm
10.	Coefficient of discharge of the orifice (C_d)	0.64
11.	Density of monomeric fluid (Mercury)	$^{13.6}$ x 1000 kg/m^3

V. RESULT AND DISCUSSION

Table 2

The following equations used for calculation of fin parameters

S. No.	Parameters	Equations for Calculation	
1.	Reynolds Numbers (Re)	$\mathrm{Re} = \frac{v_m \times d_{fin}}{v_a}$	(4)
2.	Nusselt Number (Nu) Forced convention	$Nu = 0.615 \times \mathrm{Re}^{0.466}$	(5)
3.	Coefficient of heat transfer (h)	$h = Nu \times k_{air} / d_{fin}$	(6)
4.	Fin parameter (m)	$m = \sqrt{\frac{h \times p}{k \times A}}$	(7)
5.	Fin efficiency	$\eta = \frac{\tanh ml}{ml}$	(8)
6.	Mean Temperature T_m	$\frac{T1 + T2 + T3 + T4 + T5}{5}$	(9)
7.	ΔT	$T_m - T_f$	(10)
8.	$T_{m\ f}$	$\frac{T_m + T_f}{2}$	(11)
9.	Volume flow rate of Air, (Q)	$\frac{C_d A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g[\rho_w / \rho_a - 1]}$	(12)
10.	Fin effectiveness q_{eff}	$\frac{q_{fin}}{q_{withoutfin}} = \frac{(T_s - T_f)\tanh mL\sqrt{hPka}}{hA(T_s - T_f)} =$	(13)
11.	Rate of heat transfer through fin	$q_{fin} = \sqrt{hPka}\tanh mL(T_s - T_f)$	(14)
12.	Rate of heat transfer without fin	$q = hA(T_s - T_6)$	(15)

Table 3

Temperature variation along the fin length for two heater inputs to fin base

S. No.	Heater Input (VI)	Steady state fin Temperature in ^{0}C					Ambient Air Temp. (T_f)=T6	Manometer Reading Δ H cm of Water
		T1 x=3cm	T2 x=6cm	T3 x=9cm	T4 x=12cm	T5 x=15cm		
1.	7	72	66	53	54	47	34	1.8
2.	16	92	86	72	58	57	35	1.8

Volume flow rate of Air, (Q) = 3.221 $\times 10^{-3}$ m/sec

Velocity of flowing Air, V= Q/a = 0.262 m/sec.

For First Reading and from relation (3), $\frac{T2-34}{72-34} = \frac{\cosh[m(0.150-0.03)]}{\cosh[m*0.150]}$

$$T2 = 62.37\ ^0C$$

Thus the other temperature are, T3 = 56.12 ^{0}C, T4 = 54.18 ^{0}C, T5= 53.32 ^{0}C

For second reading, using relation (3), T2 =77.61 ^{0}C, T3 = 73.12 ^{0}C, T4 = 64.21 ^{0}C, T5 = 60.61 ^{0}C

Table 4

Comparison between different fin materials

S. No.	Fin Material	Reynolds Numbers (Re)	Nusselt Number (Nu)	Coefficient of heat transfer (h)	Fin parameter (m)	Fin efficiency
1.	Brass	189.96	7.09	15.48	6.85	75.22%
2.	Aluminum	2374.62	23.01	25.221	5.41	82.62%
3.	Mild steel	189.96	7.09	15.48	10.58	57.95 %

Table 5

Rate of heat transfer through fins for different materials of construction

S. No.	Fin Material	Rate of heat transfer with fin (q_{fin}) (in W)	Rate of heat transfer without fin (q_{fin}) (in W)
1.	Brass	0.84	0.031
2.	Aluminum	1.606	0.061
3.	Mild steel	0.64	0.018

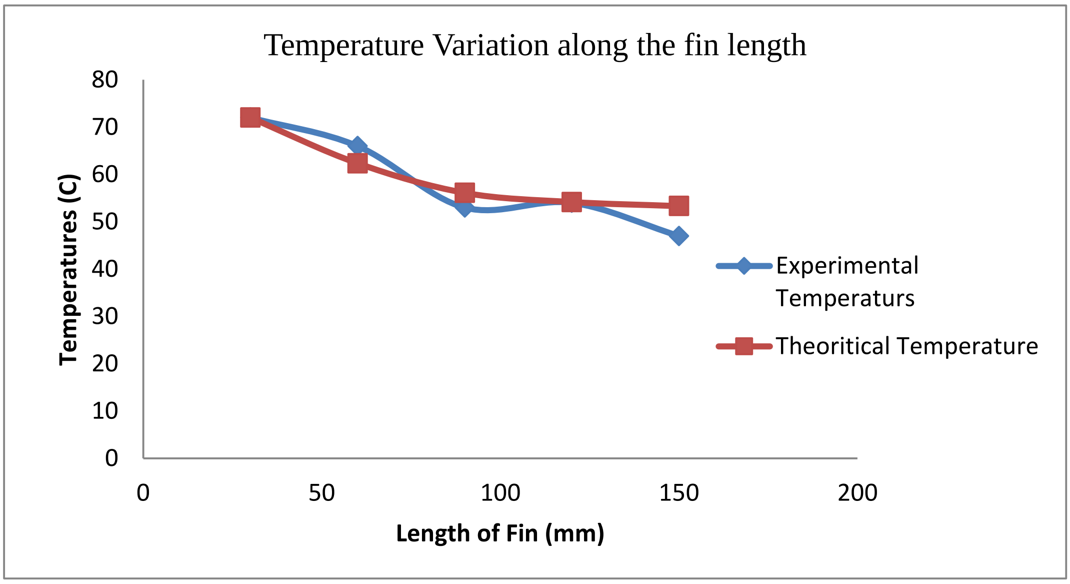

Fig. 2 Temperature Distribution along the fin length with 7 W heaters input

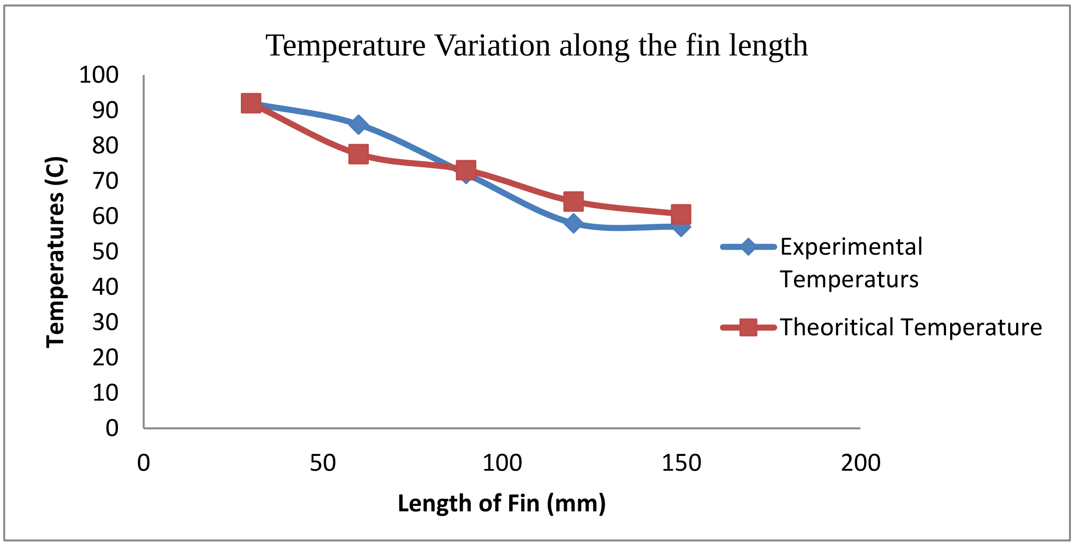

Fig. 3 Temperature Distribution along the fin length with 16 W heaters input

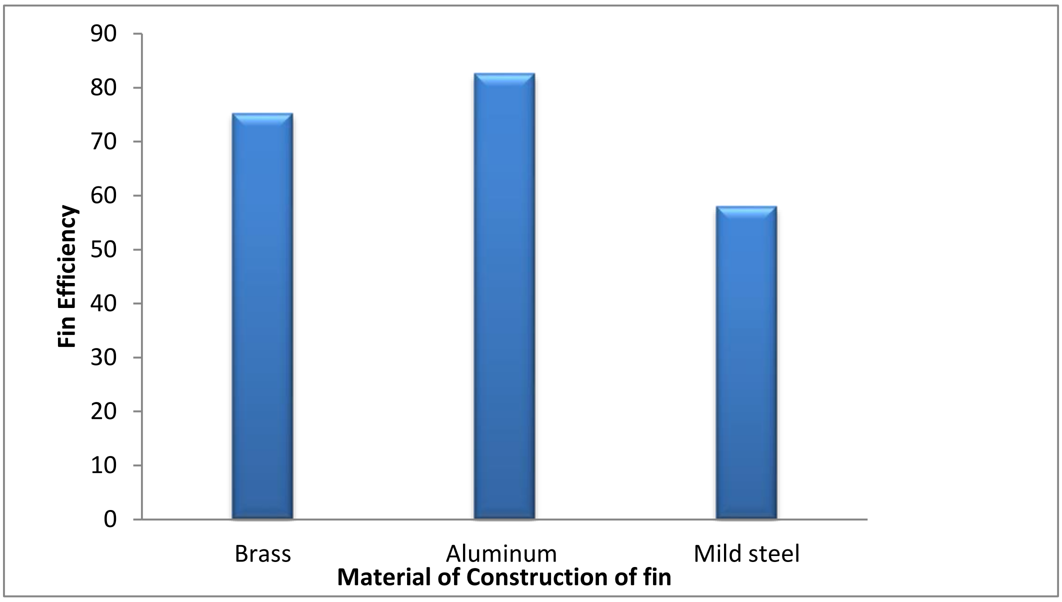

Fig.4 Efficiency of fin for different material of construction

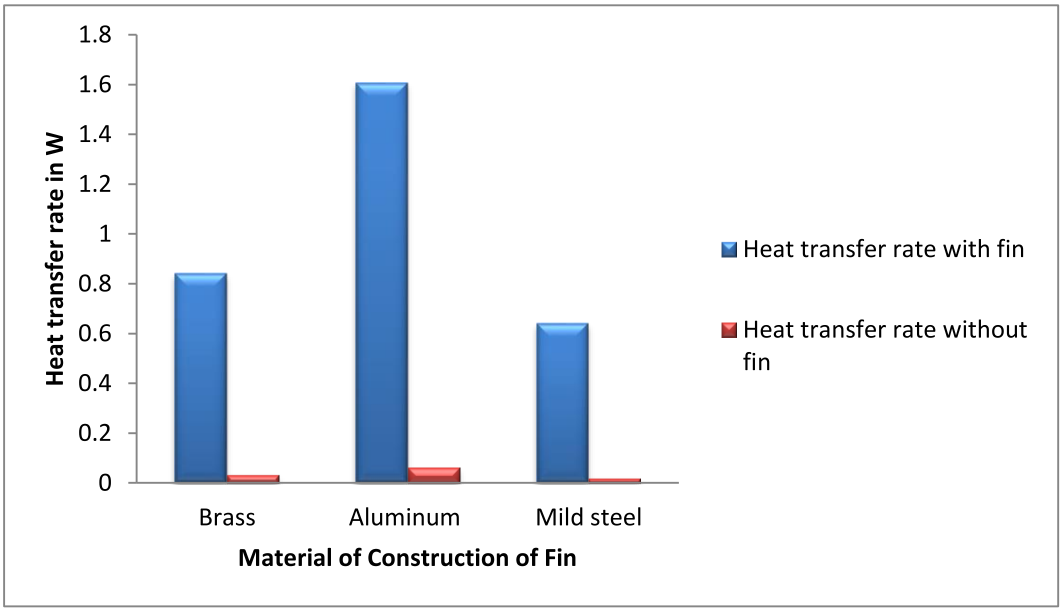

Fig. 5 Heat transfer rate through fin and without fin

From fig. 2 and fig. 3 shown that temperature obtain by thermocouple from fin surface at different locations at 7 W and 16 W heater input are good agreement with the theoretical temperature result as well. From fig. 4 shows that efficiency that using aluminium as fin material in highest from other two materials. From fig. 5 shows that the heat transfer rates from by fin surfaces are high for aluminium also it is clear that by using fins rate of heat transfer increases drastically.

1. **Conclusion**

The impact of different fin materials on fin efficiency and heat transfer across extended fin surfaces is investigated in this paper. In comparison to brass and mild steel, the experiment results show that aluminium has the highest heat transfer rate and reliability.

References

[1] Akintunde K, Probert SD (1995). Thermal performance of a pin-fin assembly, International Journal of Heat and Fluid Flow. 16 (1):50-55. https://doi.org/10.1016/0142-727X(94)00005-W

[2] Mousa MG (2013). Thermal performance of pin–fin heat sink subject in magnetic field inside rectangular channels, Experimental Thermal and Fluid Science. 44: 138-146. https://doi.org/10.18186/thermal.889174

[3] Al-Damook A, Kapura N, Summers JL, Thompson HM (2016). Computational design and optimisation of pin fin heat sinks with rectangular perforations, Applied Thermal Engineering. 105: 691-703. https://doi.org/10.1016/j.applthermaleng.2016.03.070

[4] Shaeri mr, Yaghoubi M (2009). Numerical analysis of turbulent convection heat transfer from an array of perforated fins, International Journal of Heat and Fluid Flow. 30: 218–228. https://doi.org/10.1016/j.ijheatfluidflow.2008.12.011

[5] Yang YT, Peng H (2008). Numerical study of pin-fin heat sink with un-uniform fin height design, International Journal of Heat and Mass Transfer. 51: 4788–4796. https://doi.org/10.1016/j.ijheatmasstransfer.2008.02.017

[6] Jeng TM, Tzeng SC (2007). Pressure drop and heat transfer of square pin-fin arrays in-line and staggered arrangements, International Journal of Heat and Mass Transfer. 50: 2364–2375. https://doi.org/10.1016/j.ijheatmasstransfer.2006.10.028

[7] Yu SH, Lee KS, Yook S (2010). Natural convection around a radial heat sink, International Journal of Heat and Mass Transfer. 53: 2935–2938. https://doi.org/10.1016/j.ijheatmasstransfer.2010.02.032

[8] Naphon P, Sookkasem A (2007). Investigation on heat transfer characteristics of tapered cylinder pin fin heat sinks, Energy Conversion and Management. 48 :2671–2679. https://doi.org/10.1016/j.enconman.2007.04.020

[9] Saurabh D, Gosavi GD (2014). Enhancement of Natural Convection Heat Transfer from Perforated Fin, International Journal of Engineering Research. 3: 531-535. http://dx.doi.org/10.15282/ijame.4.2011.5.0035

[10] Saadat H, Tavakol MM , Yaghoubi M (2014). Experimental Study on Heat Transfer from a Perforated Fin Array with Cross Perforations, The 2nd Iranian Conference on Heat and Mass Transfer-ICHMT, 19-20. https://doi.org/10.1016/j.ijheatfluidflow.2008.12.011

[11] Ahmed M, Jabbar A, Khalifa N (2014). Convection Heat Transfer from a Heat Sink with Fins of Different Configuration, International Journal of Innovation and Applied Studies. 9:1043-1047. Open access

[12] Umesh V, Pise AT (2015). An Experimental Investigation of Natural Convection Heat Transfer Enhancement from Perforated Rectangular Fins Array at Different Inclinations, Experimental Thermal and Fluid Science, 68:145-154. https://doi.org/10.1016/j.expthermflusci.2015.04.008