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HEAT TRANSFER ANALYSIS OF PIN FIN HEAT SINK (PFHS) WITH AND WITHOUT SPLITTER

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Abstract

Present work is based on the numerical analysis of pin fin heat sink using splitters. Splitters were provided on fins and the optimum angle is determined using CFD analysis. The splitter with fins arrangement for heat sink are the extended surfaces that are extending from an object to enhance the rate of overall heat transfer within the exposed surfaces by accelerating the rate of convection. Under the present investigation, attempts have been made to maximize the heat removal through heat sink by varying the angle of splitter in a ‘pin fin heat sink with splitter’ and using staggered orientation of fins. The results of numerical investigation prove that maximum heat transfer coefficient is observed at 35° splitter angle. The maximum heat transfer was found out for the configuration of splitters inclined at 35 degree angle with the direction of inlet air with heat transfer coefficient value of 318 W/m2 K using air velocity as 8 m/s.

Keywords: Pin fin heat sink, Heat transfer, Splitter, Inline fins, Staggered fins, orientation of fins, convection

1. Introduction

Fluid flow and heat transfer analysis of Pin fin heat sink (PFHS) with splitter staggered orientation at varying angles and subsequent experimental validation of optimum configuration. To design a pin fin heat sink with optimum angle of splitter which gives maximum heat flow and reasonable pressure drop thereby increasing the efficiency of heat emission from the equipment in which heat sink is being brought into use. The air cooled heat sinks were famous in the initial period of heat transfer enhancement

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researches. With the inventions and enhancement in rate of use of electronic equipments, and the wild use of the various applications, the need for more and more heat dissipation is increased. With this the use of water became popular as another dielectric fluid. The dielectric fluid used is still in the single phase mode. Also, the requirement of all recent electronic gadgets needs the amplification of heat flux to 100 W/cm2. It has increased the need to develop different cooling technologies like two-phase cooling.

R Sajedi, et al.[1] carried analysis to improve the hydro-thermal nature of the PFHS adding splitter placed on back of pin. Hence two common PFHS with their circular and square shape were analyzed. It results to decrease in pressure drop and thermal resistance of heat sink.Also it concludes that use of splitter in circular PFHS is more effective than square PFHS.

S E Razavi et al.[2] carried numerical process to finalize and optimize PPFHSs. A thin plate placed back to the cylindrical pin and hydro-thermal nature was studied calculating pressure drop and thermal resistance coefficients. The dimensionless parameter was calculated by combining pressure drop influence and thermal resistance. Because of placing the splitters behind the pin, pressure drop is get reduced and hence it would be concluded as an efficient alternative for heat sinks. The splitter plate gives great performance at large heat fluxes with large free stream velocities.

Hsin-Hsuan Wu [3] derived the practical model predicting the heat transfer performance of the plate-fin heat sink. It concludes that within acceptable range of accuracy, predicted model is useful to obtain a set of parameters for designing a plate-fin heat sink with required performance.

Xiaoling Yu [4] proposed a perfect solution for improving heat disiipation performance of a PFHS by planting some columnar into flow passages of the PFHS to disturb airflows passing through the heat sink. Hence a PPFHS was constructed **Octavio Leonet al. [5]** The four various models were analyzed to get the ratio between the heat removed and the energy spent for the fluid -coolant flow going through the cooling fins. If the Re, obtained on the basis on the spacing between the cooling fins is more or equal than 800, the reduction of the fluid-flow resistance can be obtained by the use of aero-dynamic profiles for the cooling fins without affecting heat dissipation. Hence the ratio between the heat dissipation and the energy spent for the fluid-coolant flow going through the cooling fins is more for an aero-dynamically optimized layout than in a standard one.

Mi-Ae Moon et al. [6] proposed a fan profile pinfin and the heat dissipation and friction loss in a rectangular channel with the pinfin were analyzed and compared with those of the circular pinfin using 3-dimensional RANS analysis. Making comparison with circular pinfin, the fan profile pinfin showed an improved Nusselt number for Re less than 100,000.

Jin Zhao et al. [7] studied numerically the cooling capacity of micro square pinfin heat sinks with geometry.

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In present work the heat transfer analysis of pin fins is done by locating splitter behind the fins. The numerical analysis is done to fine the best angle to be given to the splitter to have optimum heat transfer. . The preset study is based on developing the fins with splitter to increase the heat transfer rate for electronic cooling application. Experimental study is carried out and results of heat transfer coefficient are plotted.

2. NUMERICAL SIMULATION

The preset study is based on developing the fins with splitter to increase the heat transfer rate for electronic cooling application. Numerical study is carried out and results of heat transfer coefficient are plotted with respect to the splitter angle varying from 0 to 45°. The fluid used is mainly air or can be a coolant, liquid or gas. The heat is carried away from the component, and maintains the surface temperature and component temperature within optimum limit. The central processing units and graphics processor units of computers are cooled using such types of heat sinks. Under the present investigation, attempts have been made to maximize the heat removal through heat sink by varying the angle of splitter in a 'pin fin heat sink with splitter' and using staggered orientation of fins.

It involve, study on various configuration of pin fin (Inline and Staggered), creation of CAD models of staggered arrangement with varying angle of splitter using SOLIDWORKS and CFD Analysis (ANSYS FLUENT) to obtain Heat Transfer Coefficient. Comparison of Heat Transfer Coefficients obtained from various angles of splitter.

3. DESIGN OF PFHS WITH SPLITTER

3.1 Design Parameters

Base plate length	Base plate breadth	Length of splitter
51	55	1D, 2D and 3D
Transverse Spacing	Pin Number	Base Plate Thickness
10	18	2
Longitudinal Spacing	Pin Height	Pin Diameter
12	10	2

3.2 Orientation of Fins

Fins have been taken in staggered configuration and not in inline orientation in keeping with the literature reviewed in 2 wherein staggered configuration is found to be more efficient than inline. Fins have been taken in staggered configuration and not in inline

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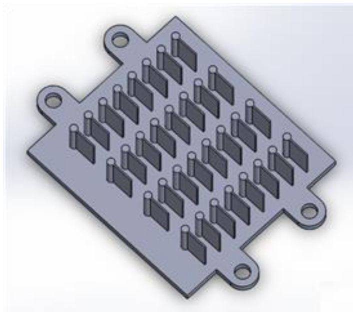
orientation in keeping with the literature reviewed in 2 wherein staggered configuration is found to be more efficient than inline. Vertical milling is used to prepare staggered fin combination. Fig. 8 shows the scaled model of staggered fins. The scaled model is prepared after studying the numerical model.



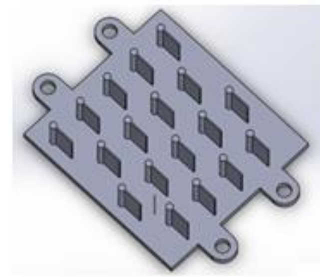


Figure 1. Inline configuration **Figure 2. Staggered configuration**

4. EXPERIMENTAL SETUP

Experimental investigation has been done on a 150 x 150 x 60 mm block of Aluminium using heating plate and various equipments as mentioned earlier in section. The main objective of this work is to find out the values of heat transfer coefficient ‘h’.

Control Panel consists of a dimmerstat, ammeter, voltmeter, and temperature indicators. The experimental setup is made to study on various configuration of pin fin (Inline and Staggered), manufacturing of Model with best Heat transfer, experimentation and validation of results. Fig. 1 and shows the inline and staggered fin combination respectively. Fig. 3 to 7 shows the experimental set up.

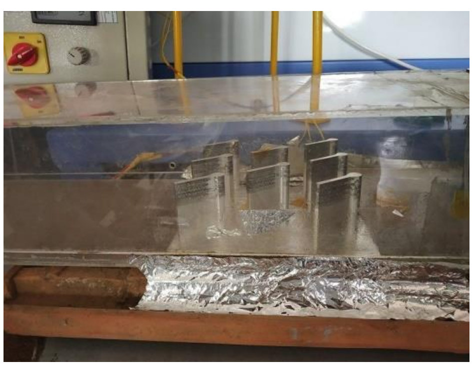


Figure 3. Heat sink in duct

Figure 4. Inside view of Duct

Design parameters were selected based on available literature. The dimensions are, base plate length 51 mm, base plate width 55 mm and splitter length 1D, 2D and 3D. Transverse spacing 10 mm, pin number 18, base plate thickness 2 mm. Longitudinal spacing 12 mm. Pin height 10 mm and pin diameter 2 mm. thermocouples used are P type with Range of thermocouple 0°C to 1450°C. An 8-channel temperature indicator

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with maximum operating temperature of 1400°C has been used in the experiment. It consists of ports where the thermocouple ends are connected and temperature is recorded of other end's junction. The dimmer-stat is used to control the output voltage given out to the plate heater.

Figure 6. Digital Anemometer

Figure 7. Full experimental setup

Figure 8. Scaled Model by VMC machine

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Heat sinks are the structures which are made from a good a material with very good thermal conductivity. Best suitable materials are copper and aluminum alloys. Aluminum is more popular due to its easy formability to have the ease of manufacturing very complex and unique cross sections possible. Aluminum is much lighter and cheaper than copper; it offers very less stress on the precise and delicate electronic gadgets.

3. RESULTS AND DISCUSSION

The results obtained by numerical analysis are mentioned below. Heat transfer coefficients at different splitter angles are shown in figure below (Fig. 9 to Fig. 14). In the numerical simulation, highest heat transfer coefficient is observed at 35° angle.

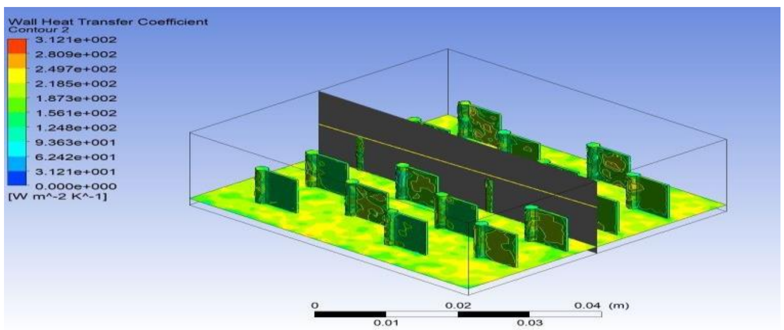

Figure 9. Numerical simulation at 0° angle

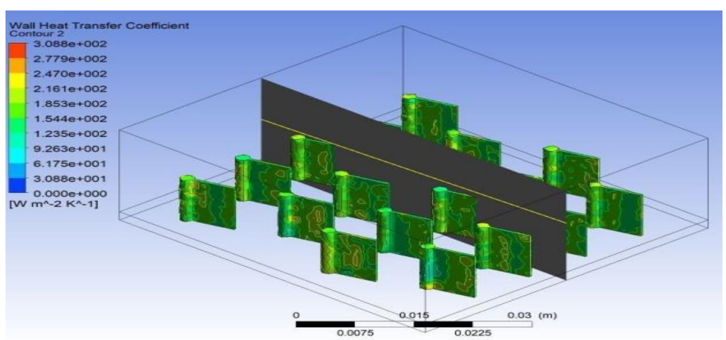

Figure 10. Numerical simulation at 15° angle

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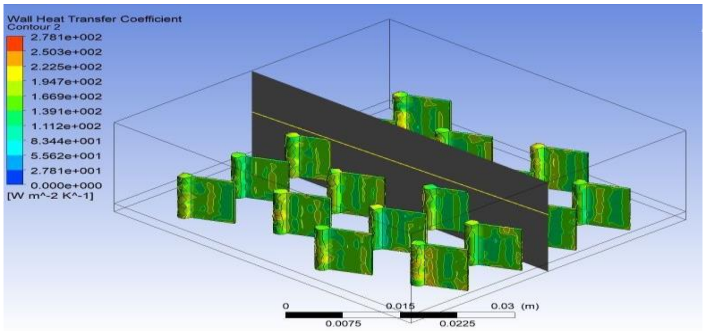

Figure 11. Numerical simulation at 25° angle

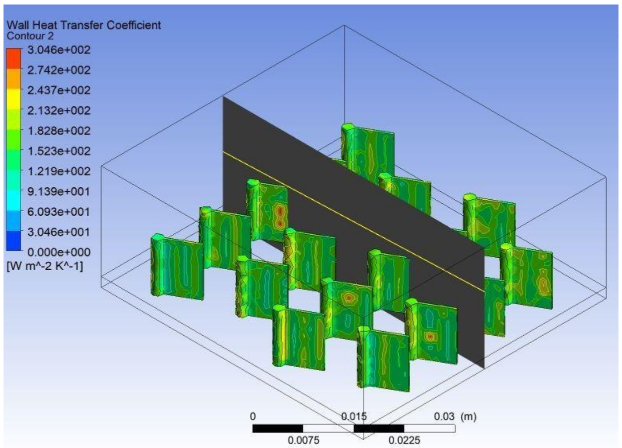

Figure 12. Numerical simulation at 30° angle

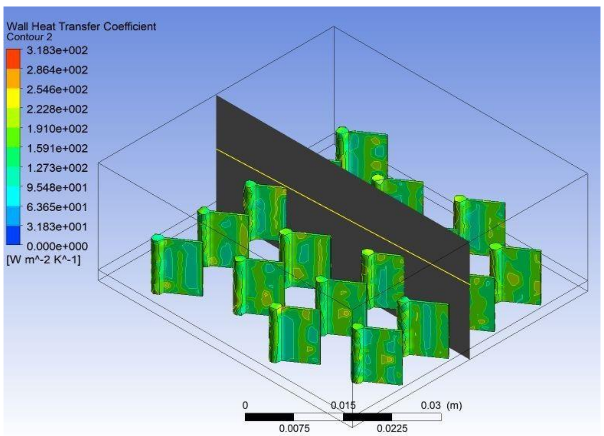

Figure 13. Numerical simulation at 35° angle

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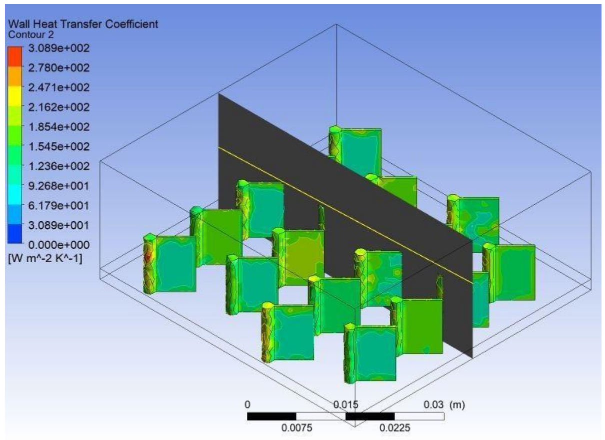

Figure 14. Numerical simulation at 45° angle

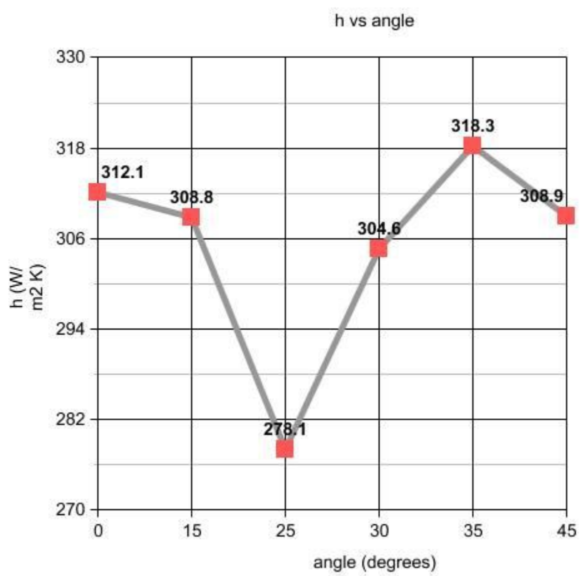

Figure 15. Heat transfer coefficient Vs Splitter angle

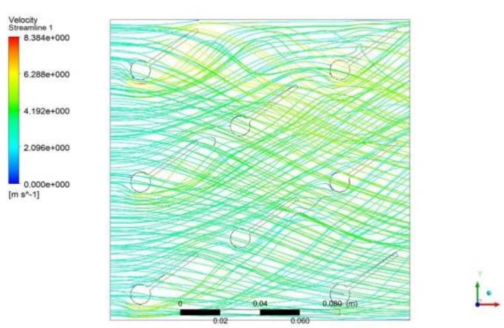

Figure 16. Velocity Streamline

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The experiment was carried out by keeping boundary conditions mentioned below. Power = 25 Watts, Voltage = 43 V, Current = 0.6 A, Speed in m/s and h in W/m^2 K, for Velocities (m/s): 1, 1.5, 2, 2.5, and 3.

T1= inlet temperature, T5= outlet temperature, T2, T3 and T4 = surface temperatures at different points. The results are shown in Table 1.

Table 1. Observation Table

Sr No	Velocity (m/s)	Temperatures (°C)					Voltage (V)	Current (A)
		T1	T2	T3	T4	T5		
1	1	37	76	71	74	48	42	0.6
2	1.5	38	66	65	65	45	43	0.6
3	2	38	61	61	60	44	43	0.6
4	2.5	38	60	59	59	44	43	0.6
5	3	38	55	55	55	44	43	0.6

Calculations

$Q_{supplied}$=V x I

=43 x 0.6 =25 W

Mass flow rate = ρ x A x V

Where, ρ is fluid density, A is area and V is velocity

= (1.128 x 0.015 x 1) =0.01692 kg/s

$Q_{abs} = C_p \, x \, (T_5 - T_1)$

$= 1.005 \, x \, (T_5 - T_1)$

$Q_{out} = h \, x \, A \, x \, (T_s - T_{mf})$

$$h = \frac{Qout}{(TS - Tmf) * A}$$

Table 2. Result Table

Velocity (m/s)	Area (m)	Q_{air} (W)	m (kg/s)	Q_{heater} (W)	T_s (°C)	T_f (°C)	h (W/m^{2}K)
1	0.015	187.0506	0.01692	5.65*h	75.33	42.5	33.1
1.5	0.015	178.5483	0.02538	4.101143*h	65.33	41.5	43.53
2	0.015	204.0552	0.03384	3.55679*h	60.667	41	57.3706
2.5	0.015	255.069	0.0423	3.15459*h	59.33	41	80.85
3	0.015	306.0828	0.05076	2.4094*h	55	41	127.0369

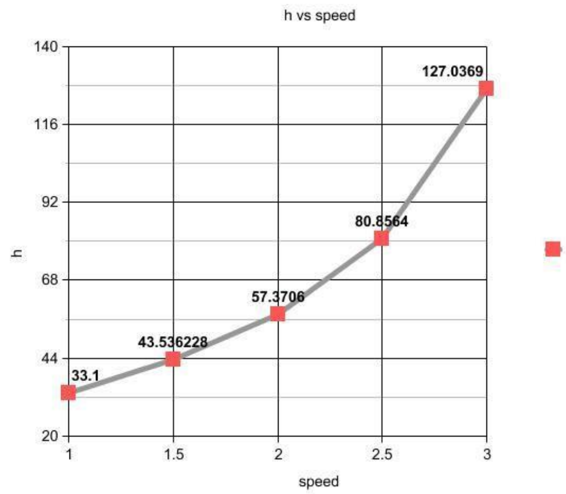

Figure 17. Graph of h vs speed

Experimental investigation was done on magnified geometry. With the scale: X-Y -> 1:5, Z -> 1:3. Maximum value of h, occurs at 3 m/s. Shown in Fig. 17. Results are shown in Table 2.

4. Conclusion

The results of numerical investigation prove that maximum heat transfer coefficient is observed at 35° splitter angle. The maximum heat transfer was found out for the configuration of splitters inclined at 35 degree angle with the direction of inlet air with heat transfer coefficient value of 318 W/m2 K using air velocity as 8 m/s. Experimentally, maximum value of h was found to be increasing as the speed of air is increased. The experimental value of 'h' at 2.5 m/s is 80.85 W/m2 K.

Acknowledgement

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