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Experimental Performance Analysis of Cylindrical Fins through Forced Convection

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***Abstract*: The overheating of an industrial component sometimes may leads to system failure. The convection heat transfer from a heated surface can be effectively enhanced by employing fins on that surface. This Paper emphasizes on the experimental investigation of temperature distribution along the length of pin shaped fin. The analysis is performed on a 100 mm long fin made up of brass with 19.6mm diameter having thermal conductivity as 111 W/mK. Temperature at different section of the fin along its length is evaluated experimentally and theoretically. The influence of convection mode viz. natural & forced convection and variable heat input on the temperature distribution is evaluated. The result outcomes are then compared with the widely accepted analytical relations. A comparison of convective heat transfer coefficient for uniform and non-uniform area fin is also presented. The results by experimental and analytical method are found to be in good agreement for free convection phenomenon.**

***Keywords*: Fins, Heat Transfer, Copper, FEA, Temperature Drop, Effectiveness**

1. Introduction

Fins play an important role in increasing the efficiency of heating systems which is achieved by increased extended surface area. In particular, fins are used in power generators, air conditioning, semiconductors, refrigeration, cooling of computer processor, exothermic reactors, and many other devices in which heat is generated and must be transported.

Heat transfer is a process that has significant application in day to day life as well as a wide range of industrial implications. All mechanical devices develop heat as they function due to energy interactions. This induces a need for effective heat dissipation in such devices. A sizeable amount of research has been done into the topic. Examples are pardeep singh who tested upon the effects of varying simple geometrical profiles. They conclusively prove that there are other profiles that have a better heat transfer efficiency than traditionally used rectangular profiles. Roody charles & chi-chuan wang have published a paper which compares the effectiveness of a regular trapezoidal fin, a traditional rectangular fin and an inverted trapezoidal fin. It proves beyond doubt that the inverted trapezoidal fin is the most effective of all the fin profiles compared. Ong et.al., prove that using forced convection is more effective than natural convection for better heat transfer characteristics. The paper published by a. Moralesfuentes & y.a. Loredo-sáenz demonstrates that surfaces with a high surface area to volume ratio are preferred. As such we may theorize that varying the profiles of the fin results in improved thermal properties.

Many of the industrial components generate some amount of heat when operated. There is a need of removal of this heat to surrounding atmosphere else this may elevate the temperature of the system which may lead to major heating problems also results in failure of that device. In order to the continuous and efficient working of any instrument, generated heat within the instrument must be dissipated to the surrounding. Various methods that are employed for cooling of heated instrument vary with its application and its cooling capacity. Fins are widely used to enhance the heat transfer rate in electronic circuits and vehicle engines. Fins can be related as a single or series of the extended surface provided on heated component's surface to intensify the heat dissipation from the surface to the surrounding cold fluid. These extended surfaces increase the total heat transfer area and thereby magnifies the heat dissipation rate. Depending on the application, different geometrical configurations of fins are available as uniform cross-section (rectangular and pin) fin and non-uniform cross-section (triangular, elliptical and trapezoidal) fin. From the earlier days, several kinds of research have been done in the area of heat transfer. Y. Pratapa et al. performed an experimental study to evaluate temperature distribution of a pin fin. The experimental results were validated with the findings of ANSYS using FEM technique. L. Chapman et al. experimentally analyzed the performance of differently shaped fin as elliptical, straight and cross-cut fins under the atmosphere of low air flow rate. They reported the lowest value of overall thermal resistance for the straight fin. Yang et al. reported an experimental heat transfer analysis for pin, circular, square and elliptical shaped fin. They evaluated the influence of fin density on the heat dissipation rate for both staggered

Fins are extensively used to improve the rate of heat

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dissipation from a hot surface especially in thermal engineering applications. There are many applications of heat transfer in porous media in thermal engineering problems such as heat exchangers, reactor cooling and solar collectors. Kiwan and Al-Nimr introduced the concept of porous fin and then considered the formulation of Darcy's model in heat transfer in porous fin. Several attempts have been made so far for accurate understanding of heat transfer in extended surfaces made of porous materials.

2. Experimental description

The experimental setup is represented schematically by Fig. 1. The apparatus is equipped with a blower that provides air flow at different rates. A control valve is also provided to regulate the flow from the blower. The equipment consists of a rectangular channel in conjunction with a nozzle attached to the blower. A 100 mm long pin fin of 19.6 mm diameter made up of brass is fitted at the base to a rectangular channel. The base of the fin is welded with a brass flange of 10 mm thickness and 47 mm diameter. A controlled amount of heat is supplied to the flange by means of an electric heater, which can be varied with the help of a variance. Six thermocouples were installed over the length of the fin as shown in fig. 2. The brass fin is kept inside a rectangular duct. An ammeter and voltmeter are also provided to record the current and voltage readings at a particular heat input. To vary the heat input the voltage may be increased or decreased with the help of a regulator.

Fig. 1. Experimental Set-up of Pin Fin

A. Forced Convection

In convection mode of heat transfer if the movement of surrounding fluid is provided by some external

Agents like fans, blower, pumps etc. Then it is termed as forced convection. The fluid flow may be of the laminar or turbulent type. The motion of fluid amplifies the heat transfer, flow with higher velocity will increase the heat dissipation rate. Forced convection is dominated by two dimensionless numbers named as Prandtl and Reynolds numbers.

3. Sample calculations

1. Average fin temperature (T_m)

$$= \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6}{6}$$

2. Average temperature of Fin and Fluid(T_{mF})

$$= \frac{T_m + T_F.}{2}$$

3. Properties of Air at (T_{mF}) = 30^{O}C

Thermal Conductivity (K_{air})

$= 26.75 \times 10^{-3}$ W/m ^{O}K

Density (ρ) = 1.165 Kg/m^3

Dynamic Viscosity (μ) = 18.63×10^{-6} N.S/m^2

4. Discharge of Air in the Duct (Q):

$$= C_d * \pi/4 * d^2 * \sqrt{2g(\frac{H.\varsigma w}{\varsigma a})}$$

5. Velocity of Air in the Duct at T_F (v):

$$= \frac{Q}{\text{duct c/s Area}} \text{ m/sec.}$$

6. Velocity of Air in the Duct at T_{mf} (V):

$$= V \times \frac{T_{mf} + 273}{T_f + 273} \text{ m/sec.}$$

7. Reynolds Number:

$$Re = \frac{\rho V D}{\mu}$$

8. Nusselt Number (Nu):

$$Nu = 0.165 (R_e)^{0.466} \ .... \ 40 < R_e < 4000.$$

9. Heat Transfer Co-Efficient (h):

$$= \frac{Nu \times K_{Air}}{D}$$

10. Slope (m):

$$= \sqrt{\frac{hc}{KA}}$$

11. Effectiveness of Fin (μ)

$$= \frac{Tanh(mL)}{mL}$$

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Table 1
Readings for Copper

S. no.	V in volts	I in amp	Manometer Readings			Temperature Readings					Ambient Temp	Re	HTC h	Q	€
			h_1	h_2	H	T_1	T_2	T_3	T_4	T_5	T_6	-	-	-	-
1.	100	0.2	2	14	12	76	73	70	67	64	36	1888.5	46.14	11.87	78.83
2.	100	0.2	2	13	11	85	81	77	74	70	36	1903.6	46.53	12.03	78.33
3.	100	0.2	2	13	11	86	83	79	75	72	36	1937.0	47.68	12.98	78.98
4.	100	0.2	2	13	11	84	81	78	74	70	36	1977.3	48.77	13.34	77.08
5.	100	0.2	2	13	1	92	88	84	80	76	36	1997.2	45.47	9.64	79.64

Table 2
Readings for Brass

S. no.	V in volts	I in amp	Manometer Readings			Temperature Readings					Ambient Temp	Re	HTC h	Q	€
			h_1	h_2	H	T_1	T_2	T_3	T_4	T_5	-	-	-	-	-
1.	100	0.2	2	12	10	73	78	65	64	68	36	1888.5	46.14	11.87	53.79
2.	100	0.2	3	13	10	85	81	73	74	75	36	1903.6	46.53	12.03	57.78
3.	100	0.2	3	13	10	83	83	75	75	75	36	1937.3	47.68	12.98	63.85
4.	100	0.2	3	15	12	84	81	78	74	70	36	1977.3	48.77	13.34	57.08
5.	100	0.2	4	16	12	92	88	84	80	76	36	1997.2	45.47	9.64	59.64

Table 3
Readings for aluminum + 6% iron oxide material

S. no.	V in volts	I in amp	Manometer Readings			Temperature Readings					T6	Re	HTC h	Q	€
			h1	h2	H	T1	T2	T3	T4	T5	-	-	-	-	-
1.	100	0.2	10	23	13	83	79	76	73	67	36	1888.5	36.26	6.87	73.33
2.	100	0.2	12	22	10	82	78	76	72	67	36	1903.6	36.69	6.85	73.12
3.	100	0.2	11	23	12	81	77	75	72	66	36	1937.0	36.8	6.89	74.12
4.	100	0.2	12	23	11	83	78	76	73	68	36	1977.3	37	6.9	74.32
5.	100	0.2	10	24	14	83	79	75	75	67	36	1997.2	36.89	6.89	74.4

Table 4
Readings for aluminum + 10% iron oxide material

Sl no	V in volts	I in amp	Manometer Readings			Temperature Readings					T6	Re	HTC h	Q	€
			h1	h2	H	T1	T2	T3	T4	T5	-	-	-	-	-
1.	100	0.2	10	23	13	65	62	50	57	47	36	1888.5	36.19	3.39	76.1
2.	100	0.2	11	22	12	74	70	54	63	51	36	1903.6	36.53	4.1	75.89
3.	100	0.2	11	22	11	82	78	58	71	55	36	1937.0	36.8	4	74.12
4.	100	0.2	10	23	13	90	86	63	78	58	36	1977.3	36.9	4.2	74.65
5.	100	0.2	10	21	11	92	87	68	76	59	36	1997.2	36.89	4.3	74.4

4. Possible outcomes

- We can increase the rate of heat transfer through cylindrical fins.
- Material cost of the set up can be decreased by alloys like aluminum 7075, aluminum 24345, and composite material.
- By using different geometry & material we can increase the efficiency of heat dissipation.
- Based on review study cylinder heat transfer rate also increase by changing the various types of geometry of fins mounted on it. That can be analyzed by CFD and validate results by conducting experimental work.
- The experimental findings were then compared with the analytical results. Investigations were also made to evaluate the effect of geometrical aspects on heat transfer characteristics of fin.

5. Conclusion

In this work, an experimental investigation has been performed to study the temperature distribution over the length of a 150 mm long pin shaped fin.

Temperature profile at the various section of fin length was studied under variable heat input for forced convection atmosphere. The experimental findings were then compared with the analytical results.

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