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Experimental and Numerical Examinations of Temperature Distributions along SSF Pin Fins Cast through Semisolid Materials Processing

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***Abstract:** Heat sinks or fins stand deployed for enhancing heat transfer. That's why, planned experiments remain fortified for examining the impacts of SSF pin fin on thermal dispersal concerning constant thermal value 6 W/cm^2. For that five chromel-alumel thermocouples are preferred, above and beyond, SSF pin fins materials of stainless steel and aluminum. As anticipated, for both the stated SSF pin fins, temperature declines for increasing length scale. Besides, both results are comparable with each other. However, temperature distributions over SSF aluminum pin fin declines relatively at faster rate comparable to that over SSF stainless steel pin fin. Obviously, it may be owing to higher thermal conductivity of SSF aluminum pin fin. Therefore, it carries superior, pleasant and momentous thermal performances.*

***Index Terms:** Temperature Distribution, SSF Pin Fin, Stainless Steel, Aluminum, Thermal, Cooling Behavior.*

I. INTRODUCTION

Heat sinks or fins are used for enhancing heat transfer. The whisper of firmness of electronic fragments implicate abnormally elevated power densities. Accordingly, electronics cooling desires have grown at enormous rapidity from the development of ICT. Orthodox cooling means used of free convection of air is deficient for huge heat energies. Alternating cooling exercise arresting boundless effort is use of fin. It engulfs strain of tall heat confrontation accompanying the aforesaid methods.

Equally, the air cooling is bluntly to convey the strength. Both numerical and experimental investigations of heat spreading on flat plate is prominent in the texts [1-2]. Computational enumerations as well as simulations are completely amazing in sorts [3-8].

Thoughtful valuation of the aforesaid relatable writings discloses no up-front experimental exploration on thermal characteristics about SSF pin fins cast through SSM processing. No such experimentation on influences of SSF pin fins of stainless steel (SS) and aluminum (Al) on cooling behaviors.

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With this outlook, the contemporaneous research institutes experimental and theoretical studies for the influences of SSF pin fins materials of SS and Al on cooling behaviors concerning constant thermal value 6 W/cm^2. Additionally, the witnessed results are evaluated/matched for escalating the prominence of SSF pin fins materials of SS and Al in accomplishing the sought after cooling.

II. TEST ARRANGEMENT

It expounds expansively about the particulars of contemporary physical model along with experimental setup.

A. Demonstration of Physical Problem

Fig. 1 displays the depiction of SSF pin fin physical model. It includes a heater connected with a SSF pin fin on which five chromel-alumel thermocouples are mounted with spacing of 2.5 cm amidst. Thermocouples got joined with data recording device to store thermal data successively during the experiments. Fig. 2 demonstrates exploded photo of the stated SSF pin fin.

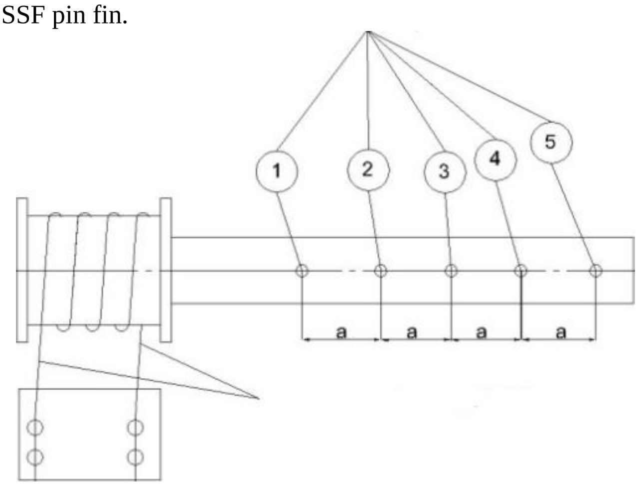

Figure 1. Schematic of SSF pin fin physical model

The SSF pin fins materials of SS and Al are delineated with five thermocouples each to estimate heat transfer coefficient (h) as well as Nusselt number (Nu). The under-mentioned equations 1-8, are used to figure the same.

$$h_i = \frac{Q_{out}}{A_h(T_{si} - T_a)} \; ; \; Q_{out} = VI \tag{1}$$

$$\bar{h} = \frac{\sum h_i A_i}{\sum A_i} \tag{2}$$

$$\bar{h}=\left[\frac{Q_{out}}{A_h^2}\right]\sum\left(\frac{A_i}{T_{si}-T_a}\right) \quad (3)$$

$$Nu_i=\frac{h_i d}{k} \quad (4)$$

$$\overline{Nu}=\frac{\bar{h}d}{k} \quad (5)$$

$$\frac{d^2\theta}{dx^2}-\frac{hp}{KA_{cs}}\theta=0 \quad (6)$$

$$\theta=C_1e^{mx}+C_2e^{-mx}\ ;\quad m=\sqrt{\frac{hp}{KA_{cs}}} \quad (7)$$

$$\frac{\theta}{\theta_0}=\frac{T-T_a}{T_0-T_a}=\frac{\cosh\{m(L-x)\}}{\cosh mL} \quad (8)$$

Figure 2. Exploded photo of SSF pin fin

B. Illustration of Experimental Setup

Figs. 3 and 4 elucidates the CAD model of experimental setup involving heater, motor, blower and fin rod assembly. Fig. 5 elucidates the unabridged assembly of experimental preparation. It implicates heater housing inside trial compartment, SSF pin fin in addition to thermocouples. Heater with tungsten thread is connected to D.C. drive vis-à-vis both voltage and current. The manometer is fixed to stretchy tube. The SSF pin fins materials of SS and Al are having channels beneath to hold thermocouples connected to data acquisition system.

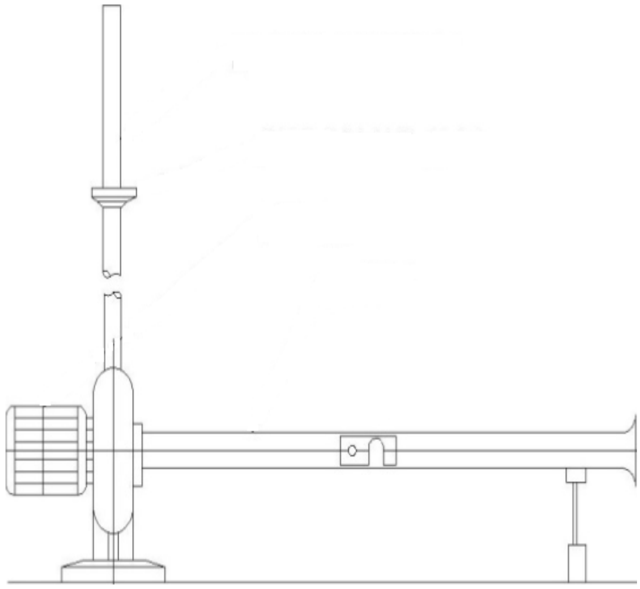

Figure 3. Front view of CAD model of experimental setup

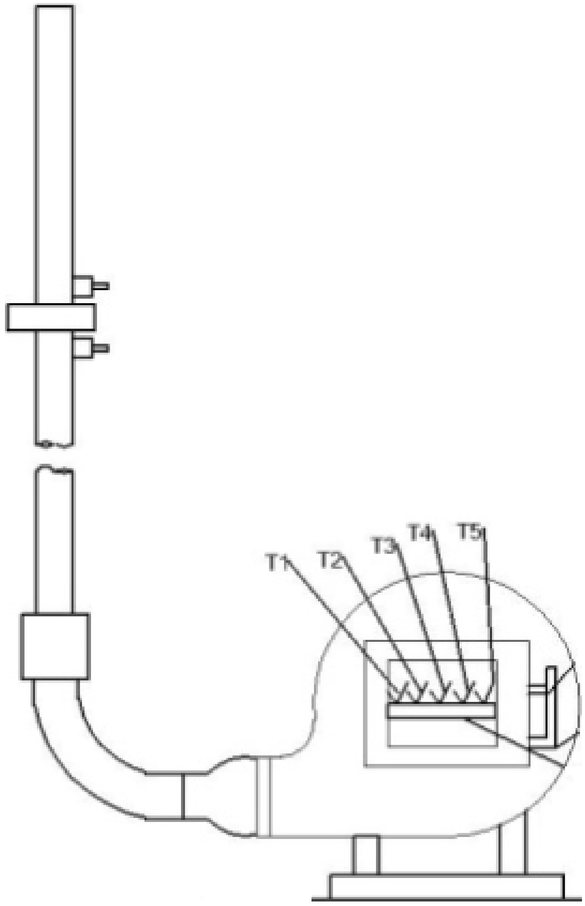

Figure 4. Side view of CAD model of experimental setup

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Figure 5. Exploded photo of experimental setup

III. EXPERIMENTAL TECHNIQUES

It embroils the measurements of below mentioned variables.

A. Air Flow Measurement

The flow rate of air is noted expending a manometer with very negligible uncertainty. Above and beyond, the adjustment of manometer is done for killing fluctuations. The air velocity is calculated from flow rate. The related air Reynolds number is calculated from said velocity as well.

B. Temperature Measurement

Chromel-alumel thermocouples (having response time of 0.8 sec) are used for measuring temperature at several plugs on SSF pin fins materials of SS and Al during the air blowing. Thermocouples are calibrated using Pt opposition thermometer. Julabo FH40-MH flow path remains aimed at current effort. Thermal facts got chronicled unceasingly through a PC with storing device. It includes a 40-channel thermocouple plug-in card to observe temperature growth.

IV. RESULTS AND DISCUSSION

Broad experimentations got effectuated to elucidate the appurtenances of SSF pin fins materials of SS and Al on thermal diffusion of air with constant thermal value 6 W/cm^2.

Influences of SSF Pin Fin Materials on Cooling Behaviors

Primarily picked SSF pin fins materials are SS and Al cast through SSM processing, for comparative appraisal of results as well.

A. Temperature Distributions along SSF Stainless Steel Pin Fin

The observed temperature distributions along SSF stainless steel pin fin at different interval are summarized in Table 1. Besides, the theoretically predicted temperature distributions along SSF stainless steel pin fin are also mentioned Table 2. Fig. 6 unveils changes in temperatures with length scales of SSF stainless steel pin fin. As anticipated, it displays, temperature declines for increasing length scale. Besides, both results are comparable with each other.

Table 1. The observed temperature distributions along SSF stainless steel pin fin at different interval

Sl. No.	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)
1	185	172	166	162	152	25
2	190	177	171	167	156	24
3	193	179	173	169	158	24
4	194	180	173	169	158	25

Table 2. The predicted temperature distributions along SSF stainless steel pin fin

T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)
194	150	120	101	91	25

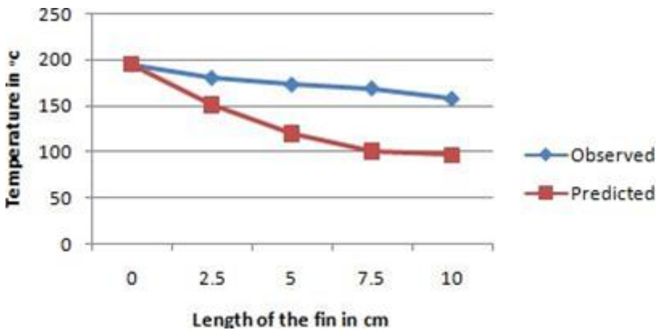

Figure 6. Temperature distributions along SSF stainless steel pin fin

B. Temperature Distributions along SSF Aluminum Pin Fin

The observed temperature distributions along SSF aluminum pin fin at different interval are summarized in Table 3. Besides, the theoretically predicted temperature distributions along SSF aluminum pin fin are also mentioned Table 4. Fig. 7 unveils changes in temperatures with length scales of SSF aluminum pin fin. As anticipated, it displays, temperature declines for increasing length scale. Besides, both results are comparable with each other.

Table 3. The observed temperature distributions along SSF aluminum pin fin at different interval

Sl. No.	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)
1	118	102	101	92	88	33
2	136	115	114	104	100	32
3	154	128	127	116	112	32
4	169	140	138	125	120	31

Table 4. The predicted temperature distributions along SSF aluminum pin fin

T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)
169	158	150	144	141	31

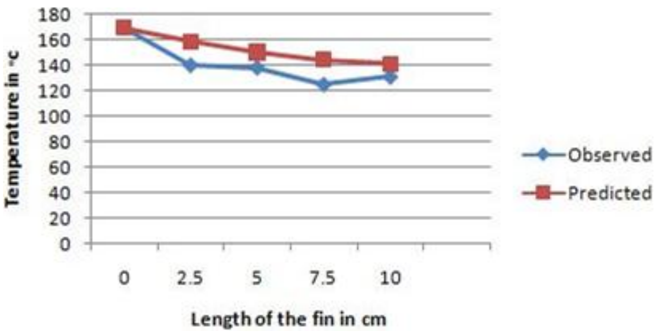

Figure 7. Temperature distributions along SSF aluminum pin fin

C. Comparison of Temperature Distributions along SSF Stainless Steel and SSF Aluminum Pin Fins

Fig. 8 unveils the abridged practice of the observed and theoretically predicted temperature distributions along SSF stainless steel and SSF aluminum pin fins with different length scales. As anticipated, it displays, temperature distributions over SSF aluminum pin fin declines relatively at faster rate comparable to that over SSF stainless steel pin fin. Obviously, it may be owing to quite higher thermal conductivity of SSF aluminum pin fin. Besides, all results are comparable with each other.

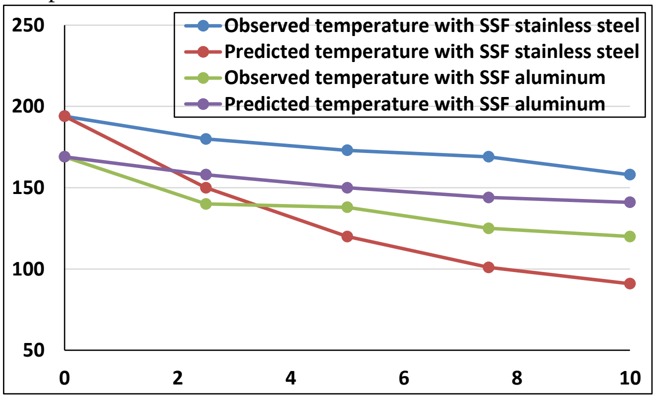

Figure 8. Comparison of temperature distributions along SSF stainless steel and SSF aluminum pin fins

V. CONCLUSION

Heat sinks or fins are used for enhancing heat transfer. Therefore, planned experiments remain fortified for examining the impacts of SSF pin fin on thermal dispersal concerning constant thermal value 6 W/cm^2. For that five chromel-alumel thermocouples are preferred, above and beyond, SSF pin fins materials of stainless steel and aluminum. As anticipated, for both the stated SSF pin fins, temperature declines for increasing length scale. Besides, both results are comparable with each other. However, temperature distributions over SSF aluminum pin fin declines relatively at faster rate comparable to that over SSF stainless steel pin fin. Obviously, it may be owing to quite higher thermal conductivity of SSF aluminum pin fin. Hence, it delivers better, congenial and significant thermal behaviors.

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