Thermal Analysis of Optimized Porous Fin on Various Profiles

Aditya Pratap Singh Jadaun[1] **Abhishek Arya**[2]
[1]M. Tech (Thermal Engineering) [2]Professor
[1,2]Department of Mechanical Engineering
[1,2]S.C.E/R.G.PV. Bhopal, India

Abstract— Mathematical evaluation is done by using Matlab and two parameters such as the porosity and thermal diffusivity of the fluid in a porous fin is done for satisfying a given temperature distribution. In order to derive heat transfer equation, energy balance and Darcy model are used Only three temperature measurements are assumed to be available on the surface of the fin and prediction of the parameters is calculated by using energy balance to the A domain decomposition method of porous fin. It is shown that the present problem is inherently ill-posed in terms of the retrieval of the value of fluid thermal diffusivity for which many possible solutions exist, which is expected to adapt the fin under different profiles. In the present work, two numerical examples provide thermal distribution into the problem of designing porous fins using good thermal conductors like aluminum and along with the working of ADM (Adomain Decomposition Method). Finally, the efficiency of ADM for the present problem is also shown by comparing its performance with few other optimization methods.

Key words: Porous fin heat sink, Temperature Distribution, Energy Equation

I. INTRODUCTION

One of the fast advancing technologies, used for stabilizing the temperature of high power density electronics experiencing power spikes, is the incorporation of PCM (Phase Change Material) into traditional heat sinks such as the standard pin fin and the longitudinal plate fins. The advantage of most PCMs is the relatively high thermal storage density which allows the design of a compact and passive LHTMS (latent heat thermal management system). Unfortunately, most of these PCMs have relatively low thermal diffusivities in both the liquid and solid phases. Thus combining pins or longitudinal plate fins inside the PCM improves its heat transfer capabilities due to the high thermal conductivity paths created by the incorporated metal elements. These paths decrease the thermal gradients in the PCM and allow the maintenance of the temperature across it closer to the melting temperature of the PCM.In electronic systems, a heat sink is a passive component that cools a device by dissipating heat into the surrounding air. In computers, heat sinks are used to cool electronic components. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronic devices such as lasers and light emitting diodes (LEDs), wherever the heat dissipation ability of the basic device package is insufficient to control its temperature.

II. OBJECTIVE OF WORK

The main objective of the current work is

1) Validation of the Matlab models by comparing the present simulated results with the Numerical result by Dipankar Bhanjaa,,, Balaram Kundub , Pabitra Kumar Mandala[7].
2) Darcy formulation is used to simulate the interaction between the porous medium and fluid.
3) The temperature inside the fin is only function of x.
4) Parameter sensitivity study of micro channel.
5) There are no heat sources in the fin itself and no contact resistance at the fin base.
6) To predict temperature distribution along the fin.

III. PROBLEM FORMATION

Fin is attached to a vertical isothermal wall from which heat has to be dissipated through natural convection. As the fin is porous, it allows fluid to penetrate through it. The porous fin increases the effective surface area of the fin through which the fin convents heat to the working fluid. The purpose of this study is to increase fin effectiveness and high thermal dissipation rate.

IV. RESULT AND ANALYSIS

The fin performance parameters depends on the following input parameters and relations which are used to calculation through MATLAB.

1) $\tau = \text{Porosiy}$
    a. The range of porosity varies from 0.05 to 1.
2) $\frac{k_s}{k_f}$ = Thermal conductivity ratio of solid to fluid
    a. For aluminium $k_s = 237\ \text{W/mK}$
    3) For air $k_f = 0.025\ \text{W/mK}$
4) Thermal conductivity ratio $\frac{k_{eff.}}{k_f}$
    a. $k_{eff.} = \tau k_f + (1-\tau)k_s$
    b. $k_r = \frac{k_{eff.}}{k_f} = \tau + (1-\tau)\frac{k_s}{k_f}$
5) Thickness to length ratio(ψ) = 0.10
6) $S = \frac{2R_aD_a}{k_r(\psi)^2}$
7) $m = \frac{2Nu(1-\tau)}{k_r(\psi)}$
8) Unknown tip temperature (θ_0). It is calculated from equation (2.16) by using Newton-Rapshon iterative method.
9) Dimensionless temperature variation equation

$$\theta = \theta_0 + (S\theta_0^2 + m\theta_0)\frac{X^2}{2!} + (2S^2\theta_0^3 + 3Sm\theta_0^2 + m^2\theta_0)\frac{X^4}{4!} + (10S^3\theta_0^4 + 20S^2m\theta_0^3 + 11Sm^2\theta_0^2 + m^3\theta_0)\frac{X^6}{6!} + (80S^4\theta_0^5 + 200S^3m\theta_0^4 + 162S^2m^2\theta_0^3 + 43Sm^3\theta_0^2 + m^4\theta_0)\frac{X^8}{8!}$$

Temperature gradient at base

$$\left(\frac{d\theta}{dX}\right)_{X=1} = (S\theta_0^2 + m\theta_0) + (2S^2\theta_0^3 + 3Sm\theta_0^2 + m^2\theta_0)\frac{1}{3!} + (10S^3\theta_0^4 + 20S^2m\theta_0^3 + 11Sm^2\theta_0^2 + m^3\theta_0)\frac{1}{5!} + (80S^4\theta_0^5 + 200S^3m\theta_0^4 + 162S^2m^2\theta_0^3 + 43Sm^3\theta_0^2 + m^4\theta_0)\frac{1}{7!}$$

10) Dimensionless actual heat transfer rate from fin

$$Q = k_r \,.\, \psi .\, (\frac{d\theta}{dX})_{X=1}$$

11) Dimensionless ideal heat transfer rate from fin

$$Q_i = 2[\frac{R_a D_a}{\psi} + Nu(1-\tau)]$$

12) Dimensionless heat transfer rate without fin

$$Q_w = Nu.\psi$$

13) Dimensionless maximum heat transfer rate with solid fin

$$Q_s = 2Nu$$

14) Efficiency $\eta = \frac{Q}{Q_i}$

15) Effectiveness $\varepsilon = \frac{Q}{Q_w}$

V. RESULTS BY USING MATLAB

Fins performance parameters results are obtained by using MATLAB at fixed input data. All results found are shown below in the tables.

Table (3.1) Variation of dimensionless temperature with axial length for different Darcy number
At $\tau = 0.8$, Da=0.04 S=4.2176, m=0.1054,$\theta_0 = 0.4249$
At $\tau = 0.8$, Da=0.004, S=0.4218,m=0.1054, $\theta_0 = 0.8074$

		θ
X	Da=0.004	Da=0.04
0.0	0.8074	0.4249
0.1	0.8092	0.4289
0.2	0.8146	0.4412
0.3	0.8237	0.4622
0.4	0.8365	0.4927
0.5	0.8532	0.5341
0.6	0.8738	0.5880
0.7	0.8985	0.6572
0.8	0.9277	0.7453
0.9	0.9614	0.8573
1.0	1.0000	1.0000

The data in the table (3.1) show the variation of dimensionless temperature with dimensionless axial length for different value of Darcy number and figure (3.1) shown below is drawn from this table and it revels the variation of temperature distribution with respect to axial length for different value of Da. As the value of axial length increases dimensionless temperature (θ) is increases. Darcy number=0.004 has higher dimemsionless tip temperature as compared to Da=0.04.

So variation of temperature distribution increases with increment in Darcy number, because for larger value of Darcy number permeability is more as compared to the lower value.

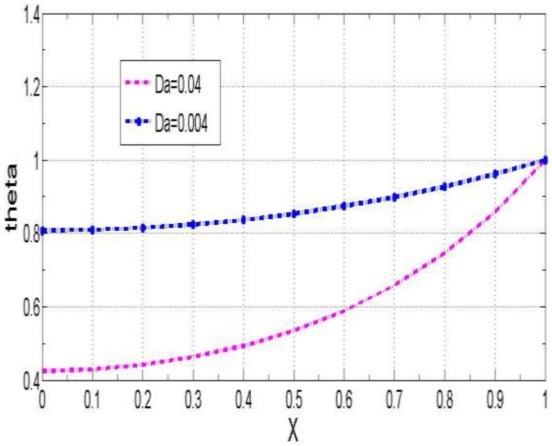

Fig. 3.1: Dimensionless temperature distribution vs dimensionless axial distance.

Table (3.2) Dimensionless tip temperature for different Rayleigh number
At τ=0.8, Da=0.04, $\psi = 0.10$, Nu=50

Ra	S	m	θ_0
10^2	0.4218	0.1054	0.8084
10^3	4.2176	0.1054	0.4249
10^4	42.1763	0.1054	0.1168

Table 3.3: Variation of dimensionless temperature with axial length for different Rayleigh number
At τ=0.8, Da=0.04, $\psi = 0.10$, Nu=50

		θ	
X	$Ra = 10^2$	$Ra = 10^3$	$Ra = 10^4$
0.0	0.8084	0.4249	0.1168
0.1	0.8102	0.4289	0.1198
0.2	0.8156	0.4412	0.1290
0.3	0.8247	0.4622	0.1454
0.4	0.8376	0.4927	0.1710
0.5	0.8543	0.5341	0.2092
0.6	0.8749	0.5880	0.2660
0.7	0.8997	0.6572	0.3514
0.8	0.9289	0.7453	0.4819
0.9	0.9627	0.8573	0.6843
1	1.0015	1.0001	1.0007

The data in the table (3.3) show the variation of dimensionless temperature with dimensionless axial length for different value of Rayleigh and figure (3.2) shown below is drawn from this tables and it revels the nature of temperature distribution through length for different value of Rayleigh number. When Rayleigh number (Ra) increases then, the heat transfer rate by convection increases and dimensionless temperature at the fin tip decreases.

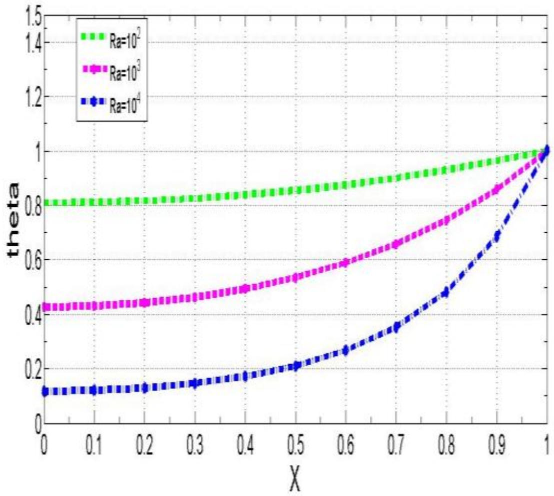

Fig. 3.2: Dimensionless temperature distribution vs dimensionless axial distance on the basis of Rayleigh number

Table (3.4) variation of fin performance parameters with porosity at Darcy number (0.04)

At Da=0.04,$\mathrm{Ra} = 10^3, \psi = 0.10$, Nu=50

$\boldsymbol{\tau}$	Kr	S	m	$\boldsymbol{\theta_0}$	$\left[\frac{d\theta}{dX}\right]_{X=1}$
0.05	9006	0.8883	0.1055	0.7072	0.6592
0.10	8532.1	0.9376	0.1055	0.6988	0.6821
0.15	8058.1	0.9928	0.1055	0.6896	0.7068
0.20	7584.2	1.0548	0.1055	0.6796	0.7338
0.25	7110.3	1.1251	0.1055	0.6688	0.7635
0.30	6636.3	1.2055	0.1055	0.6571	0.7966
0.35	6162.4	1.2982	0.1055	0.6442	0.8331
0.40	5688.4	1.4064	0.1055	0.6301	0.8744
0.45	5214.4	1.5342	0.1055	0.6144	0.9207
0.50	4740.5	1.6876	0.1055	0.5971	0.9743
0.55	4266.6	1.8751	0.1055	0.5776	1.0360
0.60	3792.6	2.1094	0.1055	0.5555	1.1083
0.65	3318.7	2.4106	0.1055	0.5303	1.1951
0.70	2844.7	2.8122	0.1055	0.5010	1.3009
0.75	2370.8	3.3745	0.1055	0.4665	1.4347
0.80	1896.8	4.2176	0.1054	0.4249	1.6109
0.85	1422.9	5.6225	0.1054	0.3730	1.8562
0.90	948.9	8.4308	0.1054	0.3051	2.2352
0.95	474.95	16.8439	0.1053	0.2076	2.9482
1.00	1.00	8000	0.00	0.0024	6.9335

Table 3.4: continued........

Q	Qi	Qw	Qs			Q/Qs
593.6756	895	5	100	0.6633	118.7351	5.9368
582.0033	890	5	100	0.6539	116.4007	5.8200
569.5822	885	5	100	0.6436	113.9164	5.6958
556.5002	880	5	100	0.6324	111.3000	5.5650
542.8616	875	5	100	0.6204	108.5723	5.4286
528.6169	870	5	100	0.6076	105.7234	5.2862
513.3932	865	5	100	0.5935	102.6786	5.1339
497.3791	860	5	100	0.5783	99.4758	4.9738
480.1067	855	5	100	0.5615	96.0213	4.8011
461.8765	850	5	100	0.5434	92.3753	4.6188
442.0160	845	5	100	0.5231	88.4032	4.4202
420.3073	840	5	100	0.5004	84.0655	4.2033
396.6176	835	5	100	0.4751	79.3235	3.9662
370.0704	830	5	100	0.4459	74.0141	3.7007
340.1312	825	5	100	0.4123	68.0262	3.4013
305.5508	820	5	100	0.3726	61.1102	3.0555
264.1106	815	5	100	0.3241	52.8221	2.6411
212.0952	810	5	100	0.2615	42.4190	2.1210
140.0237	805	5	100	0.1739	28.0047	1.4002
0.6934	800	5	100	0.0008 6	0.1387	00069

VI. CONCLUSION

It has found that the temperature distribution inside fin varies with different parameters. A lower tip temperature is maintained with the high value of the parameters Darcy number and Rayleigh number. The fin efficiency decreased as the value of Darcy number increased and effectiveness is increased as the Darcy number increased. The heat transfer decreases as the value of porosity increases. Finally, ratio of the heat transfer from porous to solid fin for different values of Darcy number and Rayleigh number is compared. This ratio must be greater than one for corresponding values of Darcy number and thermal conductivity ratio otherwise installation of porous fins on a prime surface do not beneficial.

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