Design and Analysis of a CPU Heat Sink using Metal Form to Enhance Heat Transfer Rate

Waghmare K.R[1], Yuvraj K.V[2], Ashutosh K[3], Vikash K.S.[4],Prof.Patil. R.S[5]
[1, 2, 3, 4, 5]Department of Mechanical Engineering
[1, 2, 3, 4, 5]Sinhgad Institute of Technology, Kusgaon (Bk), Lonavala

Abstract*-Metal-foam heat sinks made of copper or aluminium have proven to be appropriate for the cooling of high power electronic components with excellent cooling performance under forced convective conditions. The open-cell metal foam structure has the desirable qualities of a well-designed heat exchanger, i.e. a high specific solid–fluid interface surface area, good thermally conducting solid phase, and a tortuous coolant flow path to promote mixing. In this paper a heat sink designed for Processor Intel Core 2 duo E7500 is analysed experimentally. The sink is made from copper foam of 50 PPI and having porosity of 70 %.The dimensions of sink are derived from the datasheet provided by manufacturer. Performance of the sink is evaluated experimentally by placing it in forced convection setup. The results from the experiment are used to calculate the Nusselt's Number, convective heat transfer coefficient and overall thermal resistance of heat sink.*

Keywords:-Metal Foam, Heat Sink, Thermal Design Power

I. INTRODUCTION

Computer cooling is required to remove the waste heat produced by computer components to keep the within permissible operating temperature limits. A heat sink is passive type of heat exchanger which is designed to maximize its surface area in contact with the cooling medium surrounding it such as air. The thermal-hydraulic performance of the metal foams heat exchangers has been analysed. It is clear that pore diameter is an important parameter in determining the pressure drop and heat transfer rate. Both pressure drop and heat transfer rate increase as the face velocity increases [1]. Open-cell aluminium foams were compressed by various factors and then fashioned into heat exchangers intended for electronic cooling applications which dissipate large amounts of heat. The metal foam heat exchangers decreased the thermal resistance by nearly half when compared to currently used heat exchangers designed for the same application [2]. It appears that the foam finned surface efficiency plays a crucial role in the optimization of these enhanced surfaces. Furthermore, in the case of thermal management, the normalized mean wall temperature and the pumping power per unit of heat transfer area can be used to compare the different heat transfer behaviour of metal foams [3]. The heat-transfer characteristics of aluminium-foam heat sinks are investigated experimentally in this work. Both the porosity and pore density affect the cooling performance of aluminium-foam heat sinks. The Nusselt number increases with the increase of the porosity and the pore density [4]. Under a given pumping power condition, for MF heat sinks, the heat transfer is insensitive to the foam height; whilst for FMF heat sinks, the heat transfer increases as the foam height increases [5]. Heat transfer measurements inside samples of metal foam subjected to constant heat flux on one side, and cooled by a confined air flow, were presented. The model under-predicted the temperature close to the inlet of the foam [6]. Direct measurement of the fluid temperature inside a heated cylinder filled with metal foam was conducted using a specially designed technique. The experimental technique can be of utility for heat transfer designs, and for validating complex analytical and numerical modelling of the heat transfer phenomenon in open-cell meso-porous media [7].

II.WORKING PRINCIPLE OF HEAT SINK

The working principle of heat sink can be explained by Fourier's law of heat conduction which states that when there is temperature gradient in a body, heat will be transferred from the higher temperature region to a lower temperature region. The rate at which heat is transferred by conduction q, is proportional to the product of the temperature gradient and the cross-sectional area through which heat is transferred. Consider a heat sink in a duct, as shown in fig 1.Components with metal-foam heat sinks, the waste heat generated from electronic components goes through the metal foam, and then mostly dissipates convectively to the air. In engineering such a process, the heat-transfer characteristic, such as Nusselt number (Nu), is usually required. Nusselt number is defined as ratio of convective heat transfer rate to conductive heat transfer rate.

$$q = mC_p(Tout - Tin) \qquad \ldots\ldots\ldots\ldots (1)$$

$$q = \frac{T_{hs} - T_{avg}}{R_{hs}} \ldots\ldots\ldots\ldots(2)$$

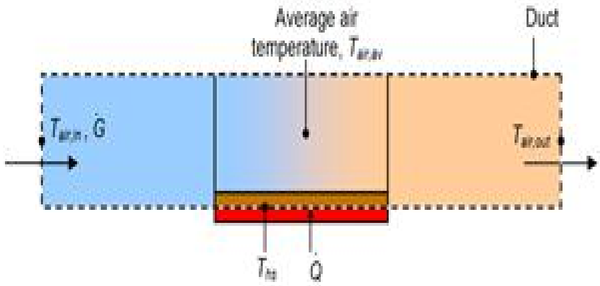


Fig 1:- Heat sink in a duct

The demand of high speed and increased power dissipation requirements for thermal management. Among various cooling techniques for electronic chips and/or modules, forced convective cooling with air features advantages of convenience and low cost. Limitation of the forced convective cooling with air, however, lies in the relatively low heat removal rates. In the past, extensive studies have been conducted to improve the heat removal rate of forced convective cooling with air by utilizing heat sinks with different shapes, materials, flow patterns, etc. Metal foams appear to have attractive properties for heat transfer applications and have been used for thermal applications in cryogenics, combustion chambers, geothermal systems, petroleum reservoirs, and catalytic beds, compact heat exchangers for airborne equipment, air-cooled condensers and compact heat sinks for power electronics. The foam provides an extended surface with high surface area and complex flow paths. That combination is expected to yield excellent convective heat transfer performance. In the convective cooling processes of electronic components with metal-foam heat sinks, the waste heat generated from electronic components goes through the metal foam, and then mostly dissipates convectively to the air. In engineering such a process, the heat-transfer characteristic, such as Nusselt number (Nu), is usually required. Nusselt number is defined as ratio of convective heat transfer rate to conductive heat transfer rate.

$$Nu = \frac{hL}{k} \quad \text{………… (3)}$$

$$h = \frac{q}{A(T_s - T_a)} \quad \text{……….... (4)}$$

III.METHOD OF APPROACH

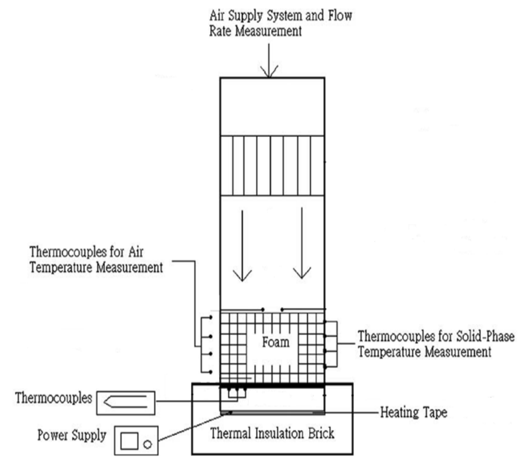


Fig 2:-Forced convection apparatus

The setup consists of a thermal insulating base which holds the heating plate and heat sink. Heating plate is provided to heat the foam block to suitable temperature. The sink is placed on base plate. Thermocouples are placed at various locations as shown in the Figure 2.The goal of the experiment is to measure the hydraulic and thermal performance of the open cell metal foam heat sink in a forced convection flow arrangement. The concept is to direct the air flow through a circular channel in which the metal foam heat sink is placed, occupying the entire cross-section of the channel. A heater is attached to the foam via the heat spreader plate through which the heat is conducted and eventually convected into the coolant stream. The characterization of the open-cell metal foam heat exchangers includes measuring the temperature of the heater block, the temperature of the heat spreader plate, the air temperature at inlet & outlet of heat sink, the power delivered to the heating device, flow rate of air In determining the convective heat transfer coefficient, Eq. 4is used with the substitution of measured T_s. In Eq. 4, q is the heat removed by the heat sink and is equal to the subtraction of heat loss through the thermal insulation brick to the ambient at the T_s from the waste heat generated by the heating tape. The experimental apparatus for the measurement of heat loss through the insulation brick is same as the one used for Nu measurement described above, except that the copper-foam heat sink is removed from the apparatus. The temperatures of the top surface of the copper plate and the ambient are both measured under natural convection and steady-state condition. The heat loss through the insulation brick at different (T_s-T_a) is calculated by the equations given below

$$q_{loss} = q_{in} - q_{natural\ convection} \quad \text{……….. (5)}$$

$$q_{in} = IV \text{………… (6)}$$

$$q_{natural\ convection} = hA(T_S - T_a) \quad \text{……….. (7)}$$

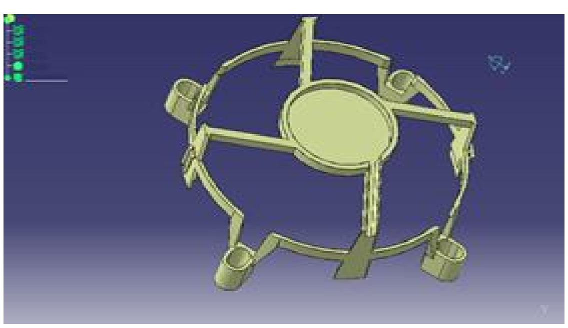
Where,

q_{loss} is the heat loss through the alumina brick to the ambient; $q_{natural\ convection}$ is the heat transfer through natural convection from the top surface of the copper plate to the ambient; **h** is the average natural convective heat transfer coefficient at the top surface of the copper plate, **A** is the top surface area of the copper plate; T_S is the top-surface temperature of the copper plate.

IV.TEMPERATURE SHEET

Time	Core 0			Core 1			Fan Speed Rpm
	Value	Min	Max	Value	Min	Max	
0.00	45	45	52	37	37	42	1164
0.30	51	44	64	49	36	65	1406
1.00	45	44	64	36	36	55	1125
1.30	47	44	64	39	35	55	1188
2.00	49	46	64	39	38	55	1223
2.30	43	42	52	33	33	41	1082
3.00	42	42	47	35	32	39	1075
3.30	43	41	57	32	34	39	1172
4.00	41	41	51	32	32	39	1042
4.30	38	38	58	30	30	51	1055
5.00	41	41	54	32	32	39	1029
5.30	39	38	50	30	30	41	0993
6.00	45	37	56	32	29	47	1048
6.30	42	41	50	33	32	50	1096
7.00	41	41	52	32	32	40	1061
7.30	51	39	61	41	30	53	1164
8.00	44	44	49	35	35	43	1241

V.CAD MODEL OF HEAT SINK FRAME



VI. LIST OF FORMULE

Parameter	**Formula**
Pressure drop	$\frac{\delta P}{L} = \frac{\mu}{K}V + \rho C V^2$
Nusselt Number	$Nu = \frac{hL}{k}$
Reynolds Number	$Re = \frac{\rho V D}{\mu}$
Heat transfer rate	$q = mC_p(T_{outlet-}T_{inlet})$

VII. CONCLUSION

Heat sink using metal foam was manufactured and tested in a forced convection apparatus. There was significant increase in heat transfer rate. Both the porosity and pore density affect the cooling performance of Copper-foam heat sinks. The Nusselt number increases with the increase of the porosity and the pore density. It can be seen from experimental results that copper foam heat sink perform well compared to fin sinks under optimum scenario.

VIII. NOMENCLATURE

q	Waste Heat Transfer Rate
h	Convective heat transfer coefficient
V	Air Velocity
ρ	Density
A	Area
k	Thermal Conductivity
μ	Viscosity
T	Temperature
m	Mass Flow rate
C_p	Specific heat
L	Length
δP	Pressure drop
K	Permeability

ACKNOWLEDGEMENT

I would like to express my gratitude and appreciation towards Mr.R.S.Patil, whose suggestions and encouragement, helped me to complete this paper. I gratefully acknowledge with much appreciation the crucial support of the staff of Mechanical Department, also many thanks to the Head of the Department, Dr. V.V Shinde for his kind cooperation.

REFRENCES

[1] Kashif Nawaz, JessicaBock, Anthony M. Jacobi "Thermal-Hydraulic Performance of Metal Foam Heat Exchangers"International Refrigeration and Air Conditioning Conference.pp. (2395-2406)

[2] K. Boomsma, D. Poulikakos, F. Zwick "Metal foams as compact high-performance heat exchangers". Mechanics of Materials 35 (2003) pp(1161–1176)

[3] Simone Mancin, Claudio Zilio, Andrea Diani, Luisa Rossetto "Air forced convection through metal foams: Experimental results and modeling"

[4] W.H. Hsieh,J.Y. Wu, W.H. Shih, W.C. Chiu "Experimental investigation of heat-transfer characteristics of aluminium-foam heat sinks" International Journal of Heat and Mass Transfer 47 (2004) pp(5149–5157)

[5] S.S. Feng , J.J. Kuang , T. Wen, T.J. Lu , K. Ichimiya"An experimental and numerical study of finned metal foam heat sinks under impinging air jet cooling" International Journal of Heat and Mass Transfer 77 (2014) pp.(1063–1074)

[6] NihadDukhan , Kuan-Chih Chen "Heat transfer measurements in metal foam subjected to constant heat flux" Experimental Thermal and Fluid Science 32 (2007) pp(624–631)

[7] NihadDukhan , Muntadher A. Al-Rammahi, Ahmed S. Suleiman "Fluid temperature measurements inside metal foam and comparison to Brinkman–Darcy flow convection analysis" International Journal of Heat and Mass Transfer 67 (2013) pp(877–884)

[8] Nawaz Kashif Jessica Bock Anthony M. Jacobi "Open-Cell Metal Foams for Use in Dehumidifying Heat Exchangers"International Refrigeration and Air Conditioning Conference (2012) pp(2480-2491)

[9] Shaolin Mao*, Norman Love, Alma Leanos, Gerardo Rodriguez-Melo "Correlation studies of hydrodynamics and heat transfer in metal foam heat exchangers" Applied Thermal Engineering 71 (2014) pp(104-118)

[10] Wamei Lin, BengtSundén, Jinliang Yuan "A performance analysis of porous graphite foam heat exchangers in vehicles" Applied Thermal Engineering 50 (2013) pp.(1201)

[11] Roman Dyga, MałgorzataPłaczek "Heat transfer through metal foam–fluid system" Experimental Thermal and Fluid Science 65 (2015)pp.(1–12)

[12] HenkHuisseune , Sven De Schampheleire, Bernd Ameel, Michel De Paepe "Comparison of metal foam heat exchangers to a finned heat exchanger for low Reynolds number applications" International Journal of Heat and Mass Transfer 89 (2015) pp.(1–9)