Computational Performance Analysis of Heat Sink with Pin Fin for Various Surface Profile

Devendra Chourey[1], Rana Manoj Mourya[2]

[1]*M.Tech. Scholar, Department of Mechanical Engineering, LNCT, Bhopal, India*
[2]*Assistant Professor, Department of Mechanical Engineering, LNCT, Bhopal, India*

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Abstract— Heat sink is a device is used to remove the amount of heat which is generated from processor of CPU in a computer system. It is installed above the CPU to extract maximum amount of heat generated on it.

Currently, the CAD model of heat sink has been developed by using UNI-GRAPHICS NX-8.0. Ansys software is used to develop the model on fluent domain 14.0 workbench to analyses various parameters affecting the thermal and hydraulic performance of heat sink channel. There are four types of configurations of pin fin heat sink are used with different profile namely type-1 pin dia. 1,1,1 mm, type-2 pin dia. 1,1,2 mm, type-3 pin dia. 1,2,2 mm, type-4 pin dia. 2,2,2 mm. An optimized model of heat sink with rectangular shaped roughness on fin wall is developed. The pins are drafted by an angle of 2^0. At constant heat input of 10W, the simulations have been performed, that is the heat flux of fin base of heat sink domain 3665 w/m^2 with different air velocities i.e. 6.5, 8, 10, 12.5, 15 m/s. Through the simulation of the optimized model results higher value of pressure drop, less thermal resistance, an increased Nusselt number and profit factor was reduced at moderate pumping power. The results are then validated with the experimental data which shows the configuration of type-4 gives maximum convergence on all parameters amongst all the configurations used.

Keywords: Pin Fin Heat Sink, pumping power, thermal conductivity, velocity, temperature difference, Nusselt Number, Reynolds Number, Profit Factor

Introduction

A heat sink is a device that absorbs heat generated on the processor of a computer system and dissipates it into the atmosphere by forced convection process to protect processor from excess amount of temperature. Heat sink acts as in a semiconductor device to transfer maximum amount of heat. So, the thermal conductivity of heat sink should high, so that maximum amount of the heat must be dissipated into atmosphere. The thermal conductivity of heat sink depends on the property of material by which it is manufactured. For example aluminium has better thermal conductivity, so commonly heat sinks are made up of aluminium. It has good manufacturing and economic to assemble or to optimized for better heat transfer during the work of processor to dissipate the heat in maximum amount to atmosphere. According to the configuration of heat sink, it is classified as follows:

- rectangular channel heat sink
- circular fin heat sink
- zigzag shaped heat sink
- stamped heat sink
- annular fin shaped heat sink

According to heat transfer of heat sink, it is divided into two types.

- Active heat sink
- Passive heat sink

According to type of Channel on Heat Sink:-

- open channel heat sink
- closed channel heat sink

In previous work heat sink was modelled with pin fin model and thermal hydraulic performance was predicted by pressure drop, thermal resistance, pumping power, Reynolds number, nusselt number for temperature distribution to increase performance of heat sink but the optimization work done on our present model is to improve thermal hydraulic performance compared to present model, thus artificial roughness in rectangular shape with drafted shaped pin fin model was developed due to this development of model surface area was increased, thus nusselt number increases and thermal resistance decreases and thermal hydraulic performance was improved, thus our model could be used on behalf of present paper model for future analysis.

Literature Review

E.M. SPARROW et.al. 1980[1]- in this experiment staggered array inline fin heat sink was analysed with increasing the fin height, to determine the pressure drop, heat flow with respect to pumping power, in this study we predict that pumping power high as compared to our study.

D.B TUCKERMAN et.al.1981[2]- in this study 71 c temperate generated in VLSI circuit at the density of 790W/cm^2 , the heat sink provided above the VLSI circuit, to determine the thermal resistance with the help of stream line flow was analysed, compare to our study thermal resistance is higher in present study.

KOICHI NISHINO et.al 1996[3]- in this study an excess symmetric stagnation region was created in the form of wall to analyse the heat transfer rate in the form of turbulent fluid flow compare to this study turbulent flow is high in our analysis.

Z. ZHAO et.al 1996[4]- in this present study the height of fin is optimized, the smallest height of fin is 2.54cm and maximum height of fin is 10.6cm and 800watt of heat flux is applied to determine the heat transfer rate compare to this study heat transfer rate is higher in our study.

C.P.TSO et.al. 1999[5]- in this experimental study heat sink analysed by variable Reynolds number by optimizing channel height and also to determine the prandtl number for differencing and air and water scaling compare to this study heat transfer rate is higher in our study.

OCTAVIO LEON et.al. 2002[6]- in this study the heat sink was analysed in fluent software , by optimizing the spacing of cooling fin by varying nusselt number compare to present study heat transfer rate is better in our study.

YONGMANN M. CHUNG et.al. 2002[7]- in this study nusselt number was analysed with respect to Reynolds number by applying in impingement nozzle flow on heat sink to determine the heat transfer rate compare to this study our results are better with respect to Reynolds number.

KWANG – SOO KIM et.al.2003 [8]- in this analysis heat transfer rate is analysed by an effect of pumping power compare to present study our results are better.

WEILIN QU et. Al 2003[9]- in this study a rectangular micro channel was analysed across a two face micro channel to determine the pressure drop in a sponginess flashing and chocking condition compare to the present study our analysis show a better pressure drop results.

XIAOLING YU et. Al. 2005[10]- in this study the simulation is performed on plate pin fin heat sink to determine the thermal resistance effect compare to the present study thermal resistance is less to the present study.

Y.M. LIE et.al. 2007[11]- in this experimental investigation the heat transfer was predicted in micro pin fin by optimizing the diameter of fins in the form of bubble compare to present study our heat transfer rate is higher in our analysis.

X.L XIE et.al. 2008[12]- in this investigation in integrated type pipe shape heat sink was preferred to analyse thermal performance and pressure drop compare to this study our thermal performance and pressure drop shows better results.

M.A ISMAIL et.al 2008[13]- in this study CFD analysis was performed to predict the temperature difference by varying Reynolds number to determine Nusselt number on heat sink compare to this study our present study shows better Nusselt number by variation of Reynolds number

HUIBIN RULE et.al. 2008[14]- in this analysis heat transfer coefficient was analysed on investigation of heat sink by effect of heat flux compare to the present study our results are good.

RAMI SABBOH et.al. 2008 [15]- in present investigation the heat transfer analysis was analysed on melting temperature of cooling fluid and pumping power was also analysed compare to this study our results shows good performance.

Ko – Ta CHIANG et.al. 2009[16]- in this analysis pressure drop and thermal resistance were calculated in plate fin heat sink and experimental work performed on it on comparison with this study to our analysis shows better pressure drop and less thermal resistance.

Hung – Yi Li et.al. 2009[17]- in this analysis the fin dimensions were increased with variable Reynolds number by increasing the impingement distance of flow to determine the thermal resistance compare to study our results shows better performance.

Yongping Subgenus Chen et.al. 2009[18]- in this study the fin shape was changed in triangular, rectangular and quadrilateral shaped to analysed heat transfer rate.

C.J. Ho et.al. 2009[19]- in this study nano fluid cooled heat sink is used to determine the thermal resistance , wall temperature and pumping power and also coefficient of viscosity by dispersing aluminium oxide nano particles in water.

M. R. Shaeri et.al. 2009[20]- in this analysis perforated fin were used to optimized the weight of fin and to determine the friction factor with comparison of the solid fins.

Yue-Tzu principle et.al. 2009[21]- in this study plate circular pin fin heat sink and plate fin heat sinks are compared with different configuration to determine their heat transfer performance.

Haishan Cao et.al. 2010[22]- in this study the micro channel heat sink are optimized on their further parameters i.e. channel dimensions, channel depth, fin width, mirror thickness to determine the heat transfer rate.

H.A. Mohammed et.al. 2010[23]- in this analysis the friction factor was analysed on heat sink or straight micro channel with identical cross section and also to determine pressure drop effect on micro channel.

Tian Shean Liang et.al. 2010[24]- in this experimental investigation the convective heat transfer analysis on heat sink for thermal improvement and reduced thermal resistance.

Chi-Chuan Wang net.al. 2011[25]- in this study the cannelure fins structured heat sink was analysed and heat transfer rate was predicted on the effect of cannelure.

H. A. Mohammed et.al. 2011[26]- in this study an identical cross section micro channel heat sink was used in zigzag form to analysed the pressure drop, friction factor and wall shear stress to determine the heat transfer rate.

A.K. abdul hakim et.al. 2013[27]- in this study the dimension less governing equation was investigated on heat sink to determine surface temperature.

Behzad Fani et.al. 2014[28]- in this study the rise of nano particles , volume fraction was analysed on heat sink , to determine viscous dissipation and pressure drop.

Hyungson Ki et.al. 2014[29]- in this study the carbon diffusion characteristic was analysed on thick plate heat sink, to determine the action of thermal phenomenon.

Vitor A.F. Costa et.al. 2014 [30]- in this study ANSYS CFX code was used to determine the thermal performance on heat sink.

Yanlong Li et.al. 2014[31]- in this study Y- shaped plates were used in straight micro channel heat sink with different angle to determine the thermal performance and thermal resistance by varying Reynolds number and pumping power was also determined.

Salma Gharbi et.al. 2015[32]- in this analysis solid liquid interface in a carbon matrix heat sink with well spaced heat sinks were analysed to predict thermal management.

Abdolreza Fazeli et.al. 2015[33]- in this study the bubble shaped hydrophilic structure was discharged in the form of flow to determine heat transfer rate on heat sink.

Chuan Leng et.al 2015[34]- in this study the conjugate heat transfer rate model was created for higher performance for better heat transfer rate.

Kuan-Cheng bird genus et.al. 2015[35]- in this study the metal foam heat sink was used for effective performance pumping power and thermal resistance were analysed in this study.

Amer Al- Damook et.al. 2015[36]- in this study the CFD code was employed on heat sink consists of circular perforation on heat sink, to determine the Nusselt number for better heat transfer.

Bin Li Chan Byon et.al. 2015[37] - in this study the fin height and the base was optimized by numerical and experimental approach to improve the higher thermal performance.

Chenhui Xia et.al. 2015[38]- in this analysis a T- pattern like channels were created on heat sink to determine the pressure drop and temperature fluid distribution on heat sink.

Xiaohong Vietnamese monetary unit et.al. 2016[39]- in this investigation a variable heat flux a applied on heat sink to determine thermal resistance.

Z. Azizi et.al. 2016[40]- in this study a nano particle of mass fraction was used experimentally on heat sink to determine the Nusselt number by varying Reynolds number.

Lei Chai et.al. 2016[41]- a numerical investigation was analysed on micro channel conductor heat sink for conjugate heat transfer and viscous heating.

Hansaem Park et.al. 2016[42]- in this investigation the organic rankine cycle heat transfer concept was applied on heat sink to determine the thermal performance

OBJECTIVE OF PRESENT WORK

The main objective work is:

1. The main objective of our proposed work is validation of CFD models by comparing the shows simulated outcome.
2. To predict thermal resistance, pumping power, profit factor, and pressure drop for different drafted pins with artificial roughened fin wall (rectangular shape).
3. To simulate the drafted pins with artificial roughened fin walls (rectangular shape) of the same rectangular roughened profile and different velocity (6.5, 8, 10, 12.2, 15 m/s) for constant heat input.
4. To define thermal hydraulic performance, pressure drop, pumping power and profit factor for the drafted pins with artificial roughened fin walls (rectangular shape) and different velocity (6.5, 8, 10, 12.2, 15 m/s) of constant heat input 3665 w/m$^{2.}$
5. Predict temperature distribution along the velocity (6.5, 8, 10, 12.2, 15 m/s).

RESEARCH METHODOLOGY AND SPECIFICATION

Modelling and Analysis

Modelling software UNI-GRAPHICS NX-8 creates the geometry and the geometry is imported to the ANSYS workbench 14.0 where meshing is done, and exports the mesh to FLUENT. The boundary conditions, material properties, and surrounding properties are set through parameterized case files. FLUENT solves the problem until either the convergence limit is met, or the number of iterations specified by the user is achieved.

THE PROCEDURE FOR SOLVING THE PROBLEM

- Create the geometry.
- Meshing of the domain.
- Fluent solver.
- Set the material properties and boundary conditions.
- Obtaining the solution.

FINITE VOLUME ANALYSIS OF HEAT SINK

- Analysis type fluent domain (CFD)

TYPE OF ELEMENT

- Tetrahedrons

Preparation of the CAD models

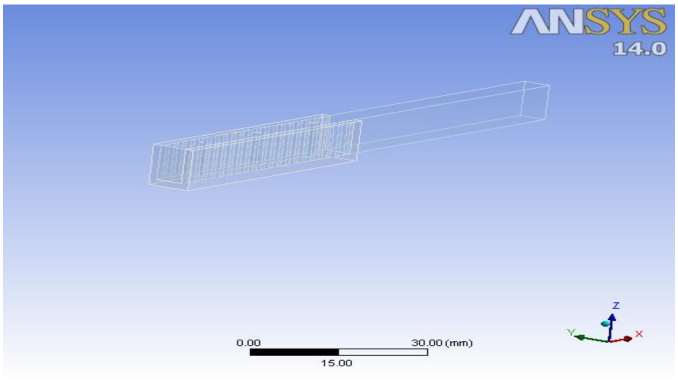
The dimensions of the computational domain heat sink were based on the work done by Wuhan Yuan author of base paper that was considered for present simulation of heat sink model [Numerical Simulation of the Thermal Hydraulic Performance of a Plate Pin Fin Heat Sink]. After this process the constraints are applied and this way the model is achieved in modelling software UNI -GRAPHICS NX-8. The following Table (4.1) & (4.2) are shows the design parameters of pin fin heat sink and artificially roughened pin fin heat sink.

Design parameters of heat sink models

The basic Parameters of Heat Sink Model: Four types of plate pin fin heat sink

Fin Length, L(mm)	Fin Height, H(mm)	Pin Height, H1(mm)	Fin Number, N	Fin thickness, t(mm)	Fin Spacing, δ(mm)
51	10	10	02	1.5	5

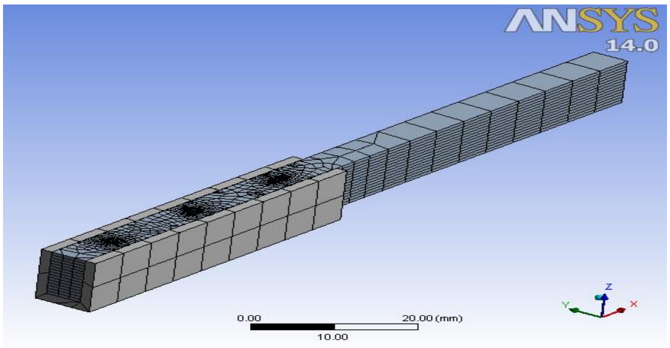
Type	**Diameter of pin fins (mm)**		
	Pin – 1	**Pin – 2**	**Pin - 3**
Type – 1	1	1	1
Type – 2	1	1	2
Type – 3	1	2	2
Type – 4	2	2	2



3D Model of artificially roughened pin fin heat sink (Type - 1)

Meshing of the Domain

Total number of elements 44096 & nods 616411 were employed to assess the grid independence in the PPFHS case. A total number of elements higher than above meshes were employed in the artificially roughened pin fin heat sink case. It is clear that the present results have good relations with the available data in the literature. The results of the grid refinement study showed that the simulations based on the PPFHS case and roughened pin fin heat sink case meshes provide satisfactory numerical accuracy and are essentially grid independent in these cases



Mesh of artificially roughened pin fin heat sink (Type - 1)

Boundary conditions

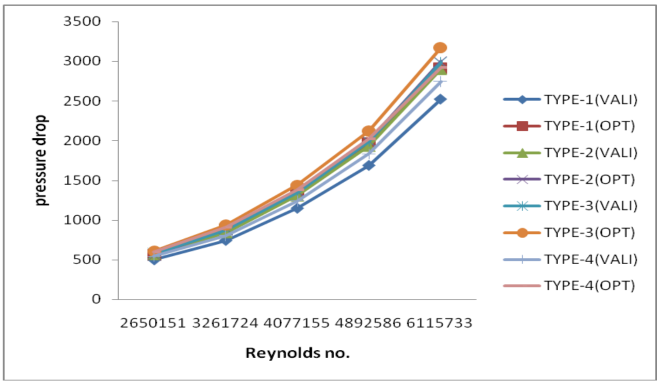
Given the periodic structure of the heat sinks, only one flow passage is investigated. The computational domain employed is shown in Table.4.4. The material of the heat sink is aluminium. The bottom of the computational domain is heated at a constant heat transfer rate of $3665 W/m^2$ and different velocity (6.5, 8, 10, 12.2, 15 m/s). The flow is assumed to be three-dimensional, incompressible, steady, turbulent, and since the heating is constant and Radiation effect is ignored.

Fin Profile	Fin type	Velocity (m/s)					Heating power(W/m²)	Periodic boundary condition
Artificially Roughened Pin Fin Heat Sink	Type – 1	6.5	8	10	12.2	15	3665	Translate in X direction
	Type – 2	6.5	8	10	12.2	15	3665	Translate in X direction
	Type – 3	6.5	8	10	12.2	15	3665	Translate in X direction
	Type – 4	6.5	8	10	12.2	15	3665	Translate in X direction

Validation and Optimization Result

Optimized comparative result of Pressure drop with artificially roughened drafted pin fin heat sink Nusselt no. variation for different artificially roughened drafted pin fin heat sink of Artificially roughened drafted pin fin heat sink with Reynolds no.

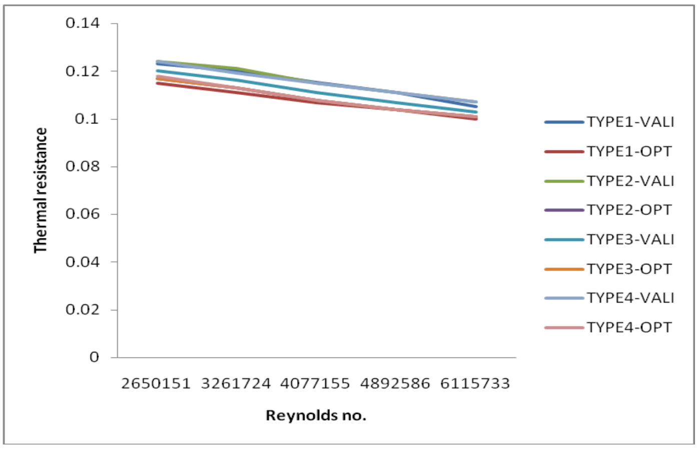
Optimization				Validation				Reynolds No.
Rth-1	Rth-2	Rth-3	Rth-4	Rth-1	Rth-2	Rth-3	Rth-4	
0.123	0.124	0.12	0.124	0.115	0.117	0.117	0.118	1841.962
0.12	0.121	0.116	0.119	0.111	0.113	0.113	0.113	2267.030
0.115	0.115	0.111	0.115	0.107	0.108	0.108	0.108	2833.788
0.111	0.111	0.107	0.111	0.104	0.104	0.104	0.104	3457.222
0.105	0.107	0.103	0.107	0.1	0.101	0.101	0.101	4250.683



The above figure shows the Pressure drop variations for different Artificially roughened drafted pin fin heat sink with compare them with Reynolds no. gives a constant deviation but in similar manner. This figure shows the increase in the pressure drop with increase in the Reynolds no.

Validation				Optimization				Reynolds No.
Type-1	Type-2	Type-3	Type-4	Type-1	Type-2	Type-3	Type-4	
Pressure Drop								
501	565	575	543	558	552	604	595	1841.962
745	844	879	805	873	887	933	904	2267.030
1150	1308	1348	1241	1340	1363	1439	1379	2833.788
1689	1933	1991	1832	1968	1997	2118	2025	3457.222
2522	2902	2989	2744	2918	3000	3171	2925	4250.683

Thermal resistance variations for different profile of artificially roughened drafted pin fin heat sink of artificially roughened drafted pin fin heat sink with reynolds no.

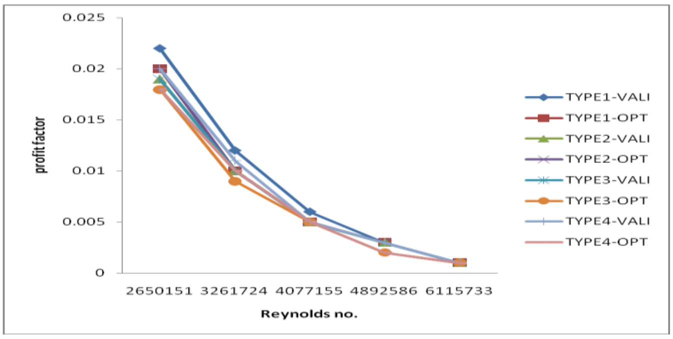


The above shows the Thermal Resistance variations for different profile of artificially roughened pin fin heat sink with compare the Reynolds no. gives a constant deviation in Heat sink optimized model but in similar manner of experimental results. This figure shows the decrease in the thermal resistance with increase in the Reynolds no.

Optimized comparative result of Profit factor with artificially roughened drafted pin fin heat sink

Validation				Optimization				Reynolds No.
J-1	J-2	J-3	J-4	J-1	J-2	J-3	J-4	
0.022	0.019	0.019	0.02	0.02	0.02	0.018	0.018	1841.962
0.012	0.01	0.01	0.011	0.01	0.01	0.009	0.01	2267.030
0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	2833.788
0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002	3457.222
0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	4250.683

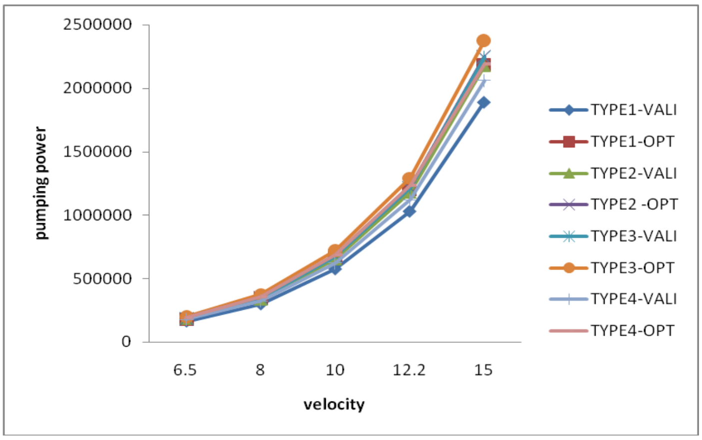
Profit Factor Variations for Different Profile of Artificially roughened drafted pin fin heat sink of Artificially roughened drafted pin fin heat sink with Reynolds no.



Above results shows comparison result between Profit factor and Reynolds no. with different configurations of artificially roughened drafted pin fin heat sink the results shows that type – 3 configured heat sink shows lesser profit factor results with respect to reynolds no.

Validation				Optimization				Reynolds No.
E-1	E-2	E-3	E-4	E-1	E-2	E-3	E-4	
162825	183625	186875	176475	181350	179400	196300	193375	1841.962
298000	337600	343600	321600	349200	354800	373200	361600	2267.030
575000	654000	674000	620500	670000	681500	719500	689500	2833.788
1030290	1179130	1214510	1117520	1200480	1218170	1291980	1235250	3457.222
1891500	2176500	2241750	2058000	2188500	2250000	2378250	2193750	4250.683

Pumping Power Variations for Different Profile of Artificially roughened drafted pin fin heat sink of artificially roughened drafted pin fin heat sink with Velocity.



Above results shows comparison result between pumping power and velocity with different configurations of artificially roughened drafted pin fin heat sink the results shows that type – 3 configured heat sink shows better pumping power results with respect to velocity.

Conclusion

1. The CFD model was developed on Unigraphics-8.0 and analysis was done by Fluent 14.0.

2. The prediction of CFD model show good relation with experimental result present in literature.

4. Simulated the artificially roughened pin fin heat sink having different constant draft angle at pin and roughness at fin wall velocity of (6.5,8,10,12.2,15m/s) and at constant heat input of 3665(W/m^2).

5. From the above result we have least profit factor in artificially roughened pin fin heat sink of Type - 3 i.e. 0.001

6. From the above result we have best Nusselt no. in artificially roughened pin fin heat sink of type - 3 of velocity 15m/s i.e. 2946.167

7. So, from the above we can conclude that the Type - 3 at constant velocity having better heat transfer rate due increase in nusselt no. and decrease in profit factor with compared experimental result.

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