DESIGN AND OPTIMIZATION OF RADIATOR FOR PC LIQUID COOLING USING MICRO CHANNELS

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ABSTRACT

The need to use micro channel in such radiator arise as a need to increase the heat transfer rate from the radiator to better cool down the working fluid. The current radiator are not efficient in this process and thus hamper the performance of cpu, solution employed currently include increase the length of radiators and to accommodate multiple fans over it.The method we employed to tackle the issue was to introduce micro channels in the tube of the radiator. Use of micro channels increases the surface area of the passage through which the fluid passes, the increase in surface area leads to increased heat transfer rate which causes more heat loss through the system. Thus, increasing the efficiency of the radiator.

Keywords—Micro channel, radiator, heat transfer rate, efficiency, surface area, temperature drop, pressure drop

INTRODUCTION

Heat Exchangers are devices designed to transfer heat between two or more fluids i.e., liquids, vapours, or gases of different temperatures. Depending on the type of heat exchanger employed, the heat transferring process can be gas-to-gas, liquid-to-gas, or liquid-to-liquid and occur through a solid separator, which prevents mixing of the fluids, or direct fluid contact. Finding application across a wide range of industries, a diverse selection of these heat exchanging devices is designed and manufactured for use in both heating and cooling processes

.Micro heat exchangers, Micro-scale heat exchangers, or microstructured heat exchangers are heat exchangers in which (at least one) fluid flows in lateral confinements with typical dimensions below 1 mm. The most typical such confinement are microchannels, which are channels with a hydraulic diameter below 1 mm.

Microchannel technology is being increasingly adopted by manufacturers in heating, air conditioning and refrigeration products, both for their enhanced energy efficiency, cost and reduced refrigerant charge.

The goal with microchannel heat exchangers is to improve overall heat transfer, which could potentially reduce the temperature difference between the air and a refrigerant. Additionally, the heat exchangers minimise airside pressure drop, which results in more energy savings gained from the fan energy consumption.

Heat transfer from a radiator occurs by all the usual mechanisms: thermal radiation, convection into flowing air or liquid, and conduction into the air or liquid.

To increase the surface area available for heat exchange with the surroundings, a radiator will have multiple fins, in contact with the tube carrying liquid pumped through the radiator. Air (or other exterior fluid) in contact with the fins carries off heat.

PROBLEM STATEMENT AND OBJECTIVE

Problem Statement

.The existing pc (AIO) cooling system rely on radiator with wide tubes to cool down the working fluid in the closed loop. The radiators used are not very efficient and thus for better performance bigger radiators are used. Cooling is required for cpu to give consistent performance. Using a Micro channels in radiator increases the surface area for heat transfer, thus providing better cooling effect at smaller size. Which will help in getting consistent performance from cpu..

Objective

The Major objectives were to increase the heat transfer rate to achieve higher temperature drop & to design micro channels of optimal diameter.

MATERIAL SELECTION

We have used DIGITAL LOGIC METHOD. In which numerous material properties are specified and the relative importance of each property is not clear, determinations of the weighting factors, can be largely intuitive, which reduces the reliability of selection. The digital logic approach can be used as a systematic tool to determine. In this procedure evaluations are arranged such that only two properties are considered at a time. Every possible combination of properties or goals is compared and no shades of choice are required, only a yes or no decision for each evaluation.

The procedure of Digital Logic Method is:

Screening

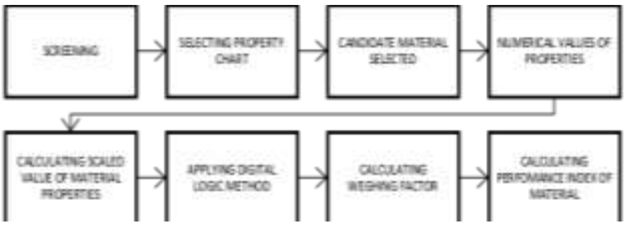
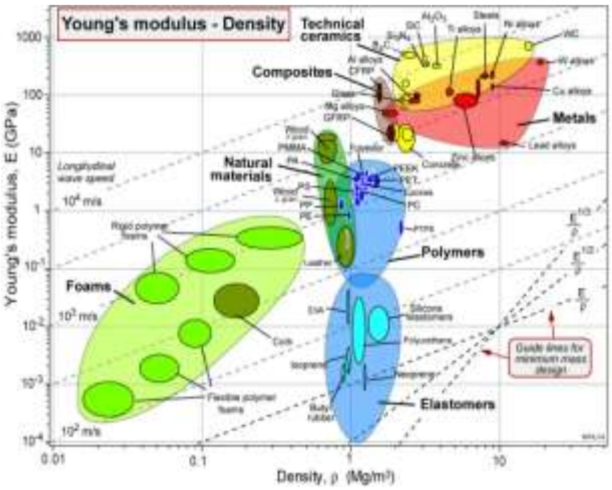


Figure I : Digital Logic Method

Function	To enable heat transfer
Objective	Increase in heat transfer rate
Variable	Wall thickness, tube diameter
Constraint	Shape and dimensions.

Selecting property chart



This chart guides selection of materials for light, stiff, components. The moduli of engineering materials span a range of 107; the densities span a range of 3000. The contours show the longitudinal wave speed in m/s; natural vibration frequencies are proportional to this quantity. The guide lines show the loci of points for which

• $E/\rho = C$ (minimum weight design of stiff ties; minimum deflection in centrifugal loading, etc)

• $E^{1/2}/\rho = C$ (minimum weight design of stiff beams, shafts and columns)

• $E^{1/3}/\rho = C$ (minimum weight design of stiff plates)

Candidate material selected.

Aluminum Alloy 3102

Aluminum Alloy 3003

Stainless Steel 304

Monel 400

Numerical values of properties

TABLE I: Numerical values of properties

Property Material	Tensile strength (MPA)	Young Modulus (GPa)	Thermal Conductivity (W/m-k)	Density (g/cm^3)
Al 3102	92	69	230	2.71
Al 3003	110	70	180	2.8
SS 304	580	200	16	7.8
Monel 400	540	160	23	8.8

E. Calculating scaled value of material properties

Scale property for friction co-efficient = (numerical value x 100 / max value in the list)

TABLE II: Scaled values of material properties

.Property Material	Tensile strength (MPA)	Young Modulus (GPa)	Thermal Conductivity (W/m-k)	Density (g/cm^3)
Al 3102	15.86	34.5	100	30.79
Al 3003	18.96	35	78.26	31.81
SS 304	100	100	6.95	88.63
Monel 400	93.103	80	10	100

F. Applying digital logic method.

In comparing two properties or goals, the more important goal is given numerical one (1) and the less important is given zero (0). The total number of possible decisions N = n (n-1)/2, where n is the number of properties or goals under consideration.

TABLE III: Digital Logic

Iteration Property	1	2	3	4	5	6	Total
Tensile Strength	1	0	0				1
Youngs Modulud	0			0	0		0
Thermal Conductivity		1		1		1	3
Density			1		1	0	2

G. Calculating weighing factor

A relative emphasis coefficient or weighting factor, for each goal is obtained by dividing the number of positive decisions for each goal (m) into the total number of possible decisions (N)

WEIGHTING FACTOR = POSTIVE DECISION / TOTAL

TABLE IV: Weighing factor

Properties	Positive Decision	Weighing Index
Tensile Strength	1	0.167
Youngs Modulus	0	0
Thermal Conductivity	3	0.5
Density	2	0.33
Total	6	1

H. Calculating Performance Index of material

Performance index is calculated as the sum of product of scaled value and weighing factor of all properties of a material.

TABLE V: Performance Index of Materials

Material	Performance Index
Al 3102	62.80
Al 3003	52.79
SS 304	49.423
Monel 400	53.54

DESIGN CALCULATIONS

Initial Inputs and Assumptions

FAN :

1.Speed : 900-2000rpm +- 10%
2.Airflow : 77 CFM
3.Dimension : 120*120*25mm

PUMP:

1.Flow rate : 1.5 L/min
2.Water Pressure : 1m+-0.2m

Initial design Assumptions

CPU Temperature : 75°C

Calculations

Velocity of Air Flowing Over:

Converting CFM to m^3/min = 0.0283168 * 77

= 2.1803 m^3/min

Converting /min to /sec = 2.1803/60

= 0.0363 m^3/s

Velocity of air = Flow rate / Area

= 0.0363/(0.12*0.13)

= 2.5208 m/s

b) Reynolds Number

$$Re = \rho * um * d / \mu$$

- ρ = density of fluid
- u_m = flow speed (m/s)
- d = characteristic linear dimension

- μ = dynamic viscosity

$$Re = \frac{1.225 * 2.5205 * 0.12}{1.872 * 10^{-5}}$$

Re = 19794.2

c) Prandlt Number

$$Pr = Cp*\mu / k$$

- Cp = specific heat
- μ = dynamic viscosity
- K = thermal conductivity

$$Pr = 0.7282$$

d) Nusselt Number

$$Nu = \frac{(f/8)(Re-1000)Pr}{1+12.7(f/8)^{1/2}(Pr^{2/3}-1)} \quad \left.\begin{matrix} \\ 3000 < Re < 5\times10^6 \\ 0.5 < Pr < 2000 \\ \end{matrix}\right\}$$
$$f = [1.82\log(Re)-1.64]^{-2}$$

Nu = 51.8

e) Nusselt Number Correlation

Convective heat transfer coefficient (h) can be found

using nusselt no. correlation.

Nu = hLc / k

h = Nu * k / Lc

h = (51.8 *0.02588) / 0.12

h = 11.17 W/m2k

f) Heat Transfer Rate(single tube)

Q = h*A*dt

Q = 11.17 * 0.006642 * (75-30)

Q = 3.33 W

g) Heat Transfer Rate (Total)

Q = no. of tubes * heat transfer rate of single tube

Q = 8 * 3.33

Q = 26.71 W

V. CAD & CFD

A. Basic Radiator model

Radiator used in the Antec ecosystem of liquid cooling peripherals.The dimensions of the design are based off of the radiator available in the market from Antec company

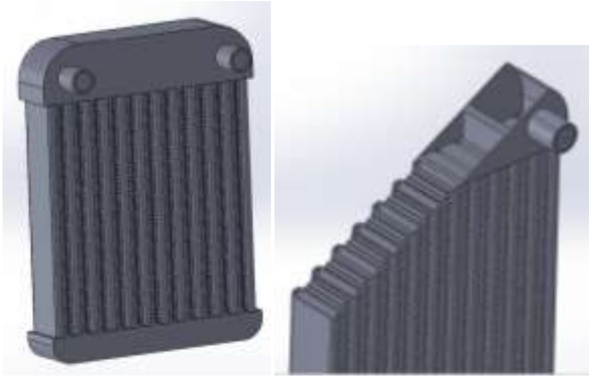


Figure III : Front & cross section view of basic radiator

Properties :

- □Material - Aluminium
- □Wall thickness - 0.28 mm
- □Dimensions - 169 x 120 x 27mm
- □Speed - (900 - 1600rpm) ± 100
- □Airflow - 77 CFM
- □Net Weight - 0.68 Kgs
- □Gross Weight - 1.5 Kgs (max.)
- □Water Pressure - 1m ± 0.2m
- □ Flow rate - 1.5L / min

a) Velocity flow trajectory

The flow trajectories represent the velocity flowing through the tubes.So as we can see, when the fluid enters the tubes the pressure decreases and hence the velocity increases. This is in accordance with the bernoullis principle.

Figure IV : Velocity cut plot 1

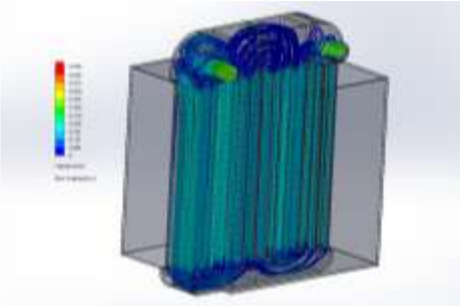


Figure V : Velocity flow trajectory

b) Temperature flow trajectory

The flow trajectories represent the temperature of fluid flowing through the tubes. So as we can see the initial inlet temperature is 75 degree celcius and as it passes through the tubes, the forced flow of the cold air around the tubes causes convection which leads to gradual fall in temperature throughout the tube. As we can see the temperature drop of 12-15 degree celcius is obtained at the outlet.

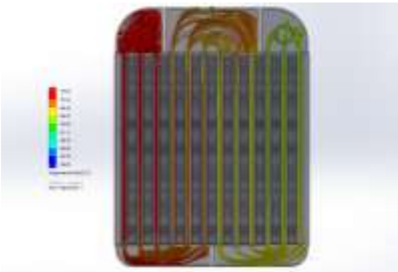


Figure VI : Temperature cut-plot 1

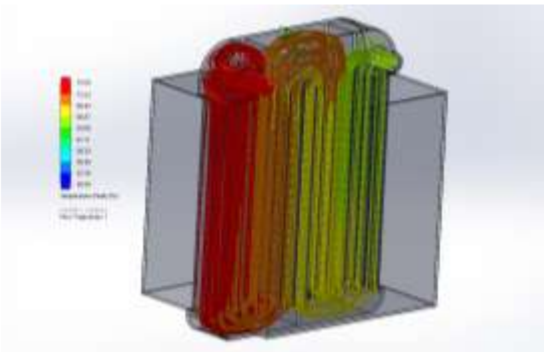
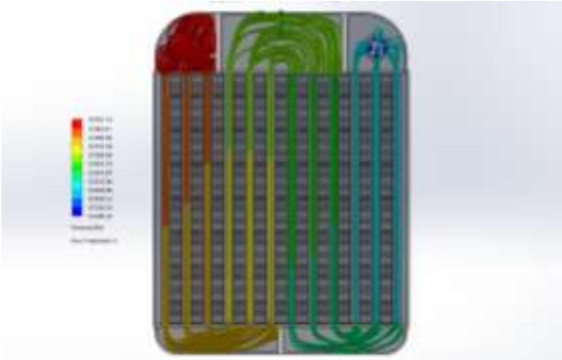
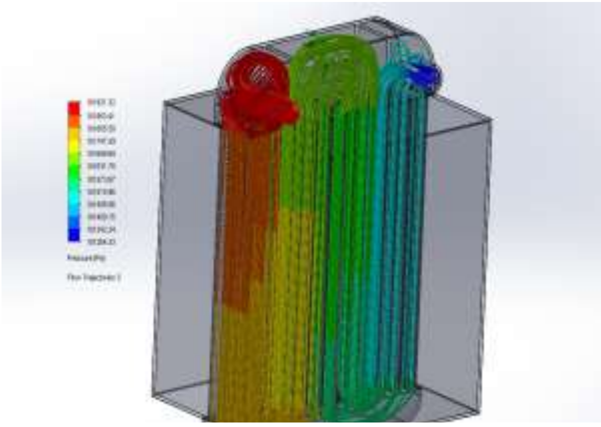


Figure VII : Temperature flow trajectory

c) Pressure flow trajectory

The flow trajectories represent the pressure throughout the tubes. So as we can see, when the fluid enters the tube the velocity and hence the pressure decreases.





B. Micro Channel Radiator

Radiator designed with microchannels to increase heat transfer. The dimensions of the design were based on the radiators available in the Industry(antec). The constraint involved in the process were to mount the standard 120x120mm fans which are standard in the industry.

Properties :

- Material - Aluminium
- Micro Channel diameter - 1mm
- Wall thickness - 0.28 mm
- Dimensions - 169 x 120 x 27mm
- Speed - (900 - 1600rpm) ± 100

- Airflow - 77 CFM
- Net Weight - 0.68 Kgs
- Gross Weight - 1.5 Kgs (max.)
- Water Pressure - 1m ± 0.2m
- Flow rate - 1.5L / min

d) Velocity flow trajectory

The flow trajectories represent the velocity flowing through the tubes.So as we can see, when the fluid enters the tubes the pressure decreases and hence the velocity increases. This is in accordance with the bernoullis principle.

Figure XI : Velocity cut plot 1

e) Temperature flow trajectory

The flow trajectories represent the temperature of fluid flowing through the channels. So as we can see the initial inlet temperature is 75 degree celcius and as it passes through the channels, the forced flow of the cold air around the tubes causes convection which leads to gradual fall in temperature throughout the tube. As we can see the temperature drop of 15-18 degree celcius is obtained at the outlet

Figure XIII : Temperature cut-plot 1

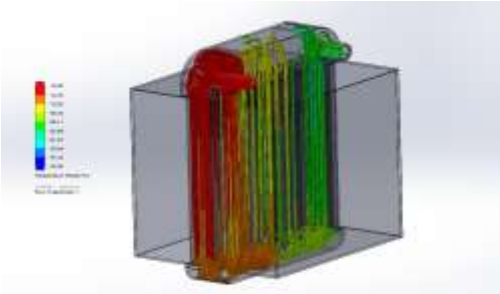
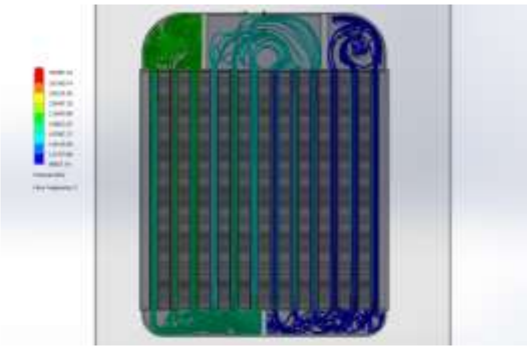
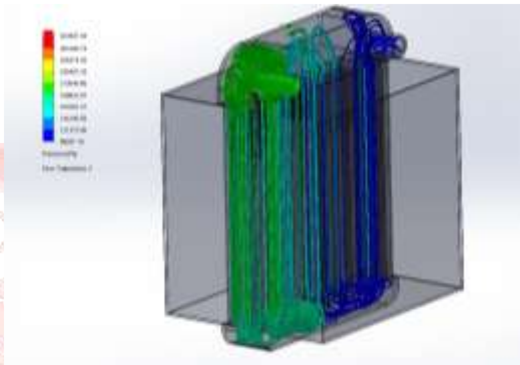


Figure XIV : Temperature flow trajectory

f) Pressure flow trajectory

The flow trajectories represent the pressure throughout the tubes. So as we can see, when the fluid enters the tube the velocity and hence the pressure decreases.





RESULTS

Different values of air flowing around the tubes were kept constant and the inlet velocity of the fluid entering the tubes constant and also determined the inlet temperature as 80 degree celcius and then after running the simulation we get the outlet temperature as follows

A. Basic Radiator Data

Iteration	Air flow rate (m3/s)	Flow rate (m3/s)	Inlet temp.	Outlet temp.	Temperature drop
1	0.025	0.01	80	61.32	18.68
2	0.025	0.005	80	50.6	29.40
3	0.025	0.001	80	45	35.00
4	0.1	0.005	80	42.5	37.50
5	0.05	0.005	80	45.74	34.26

B. Microchannel Radiator Data

Iteration	Air flow rate (m3/s)	Flow rate (m3/s)	Inlet temp.	Outlet temp.	Temperature drop
1	0.025	0.01	80	60.12	19.88
2	0.025	0.005	80	49.35	30.65
3	0.025	0.001	80	34.57	45.43
4	0.1	0.001	80	32.19	47.81
5	0.05	0.005	80	44.41	35.59

CONCLUSION

It was observed that introduction on micro channels in the radiator tubes, the rate of heat transfer increased. The cause of increase in heat transfer rate is the increase in surface area due to the introduction of multiple small/micro channels. But along with the increase in heat transfer rate which lead to greater drop of temperature at the outlet of Radiator, there was also observed a significant amount of pressure drop along the micro channels.Thus, we were able to increase the efficiency of the radiator, The increase in temperature drop was in the range of 1-5oC, this concluded that the use of using micro channels lead to increased heat transfer rate

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