BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Course No: ME 310

Course Name: Thermo Fluid System Design

Project Name: Design and analysis of a compact radiator

Group No: C26

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INDEX

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ABSTRACT

This project was an attempt to design a compact radiator to be used for automobiles. Radiator is a kind of heat exchanger which prioritizes cross flow heat exchange by forced convection for effective heat transfer. This kind of heat exchangers are observed in various industries, but one of it's most popular applications is in the automobile industry. The reason behind using this mostly in automotive industry is since it can cool the coolant coming from the engine in a very compact space. The radiators used in the automobiles are optimized for higher heat transfer with corrugations, antifreeze used as coolant and better air flow. This setup is not feasible for a single unit production with limitations, so the project was built keeping all the limitations in mind. The calculations were first done manually following all the things we learnt from our theory and sessional classes and also following different papers and books. We chose ANSYS 2022 R1 student version for our simulation software. We did the design and simulations and compared the results with our manual calculations. For the final part, we constructed our project physically. After the project was constructed, we conducted leak tests and temperature drop tests in the fluid and hydraulic labs of BUET. All the results, possible modifications were compared using numerical values to obtain a crystal clear concept of our project.

Chapter 1: Introduction

1.1 Introduction to Radiator

Radiators are heat exchangers used for cooling internal combustion engines, mainly in automobiles but also in piston-engined aircraft, railway locomotives, motorcycles, stationary generating plant or any similar use of such an engine.

Internal combustion engines are often cooled by circulating a liquid called engine coolant through the engine block, and cylinder head where it is heated, then through a radiator where it loses heat to the atmosphere, and then returned to the engine. Engine coolant is usually water-based, but may also be oil. It is common to employ a water pump to force the engine coolant to circulate, and also for an axial fan to force air through the radiator.

1.2 Scopes and Uses

Radiators can be used in various sectors and industries. The major scopes of uses are pointed out below:

- Automobiles
- Boilers
- Air drying devices as in food drying machine
- Devices used in hygienic air heating as in pharmaceutical industry
- Devices used in air heating in leather industry

1.3 <u>Our Objective</u>

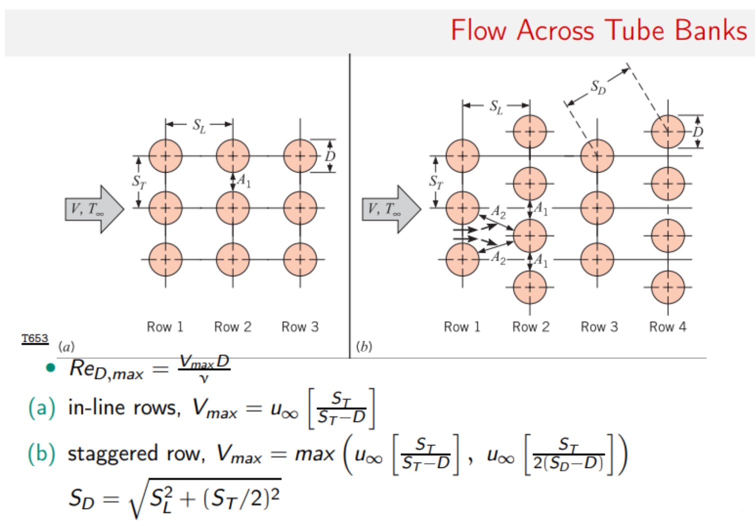
- ❑ To Design a radiator for cooling internal combustion engine (IC engine) of an automobile with a heat transfer rate of 3.2 kW using water as coolant.

Hand Calculations:

$$\dot{Q} = \dot{m} C_P \Delta T$$

=>ΔT= 10° C

For fluid,
Inlet temperature, Ti=80ºC
Exit temperature, To= 70º
Free stream air Temp= 30 C.
Free stream velocity = 5 m/s
For uniform flow and maximizing heat transfer, we are using staggered flow.



Standard Ratios are:

$\frac{s_T}{D}$=2

$\frac{s_L}{D}$= 1.5

$$\frac{s_L}{s_T} = \frac{3}{4}$$

$$s_D = 0 \cdot 9 s_T$$

$$V_{max} = \left(\bigcup_{\alpha} \left[\frac{S_T}{S_T - D}\right], U_{\alpha}\left[\frac{S_T}{2(S_D - D)}\right]\right)$$

$= (10{,}6 \cdot 25)$m/s=10 m/s

$$\text{Re}\, max = \frac{\rho V \max D}{\mu}$$ =3.73*10^3

Zukauskas: $N_L \geq 20$

$$Nu_m \equiv \frac{h_m D}{k} = C_1 Re_{D,max}^m Pr^{0.36} \left(\frac{Pr}{Pr_w}\right)^n$$

$0.7 < Pr < 500;\ 1000 < Re_{D,max} < 2 \times 10^6$

Zukauskas: N_L <20

$$Nu_m|_{(N<20)} = C_2 Nu_m|_{(N\geq 20)}$$

- $n = \begin{cases} 0.25 & \text{for liquids} \\ 0 & \text{for gases} \end{cases}$

Nusselt number for air, $N_u = c_1 R_e^m \max P_r^{0.36} \left(\frac{p_R}{P_R w}\right)^n$ (Zukauskas Analysis)

Configuratio	$Re_{D,\max}$	C_1	m
Aligned	10–10^2	0.80	0.40
Staggered	10–10^2	0.90	0.40
Aligned	10^2–10^3	Approximate as a single	
Staggered	10^2–10^3	(isolated) cylinder	
Aligned $(S_T/S_L > 0.7)^a$	10^3–2×10^5	0.27	0.63
Staggered $(S_T/S_L < 2)$	10^3–2×10^5	$0.35(S_T/S_L)^{1/5}$	0.60
Staggered $(S_T/S_L > 2)$	10^3–2×10^5	0.40	0.60
Aligned	2×10^5–2×10^6	0.021	0.84
Staggered	2×10^5–2×10^6	0.022	0.84

From table,
m=0.6
C1=.371
By using these we get
Nu=46.01

$$N_u = \frac{hD}{k}$$

h_m=198.46w/m^2K (air side)

Since our designed radiator needs to be accommodated inside a car and we have a limited space of 300x300mm. So, our lengths of the tubes are fixed. For ensuring the required heat transfer rate we must use fins with acceptable efficiency.

Assuming the temperature of surface is the temperature of water,

ΔT_{LM}=42.5 C

$Q = hA\Delta T_{LM}$=1.2KW (Convection heat transfer rate for tube walls)

Calculation For Fins

$v_{air} = 10ms^{-1}$

$R_e = \frac{\mu v W}{\mu}$=18653.85(Laminar)

$Nu = 0.664(R_e)^{0.5}(P_r)^{\frac{1}{3}}$ = 81.59 (For Laminar)

$h = \frac{Nk}{w}$= 84.53

$m = \sqrt{\frac{hp}{kA_c}}$=82.4

Efficiency,$\eta = \frac{\tan h(mL_c)}{mLc}$=0.89

Heat transfer from fins=3.2-1.2=2kW

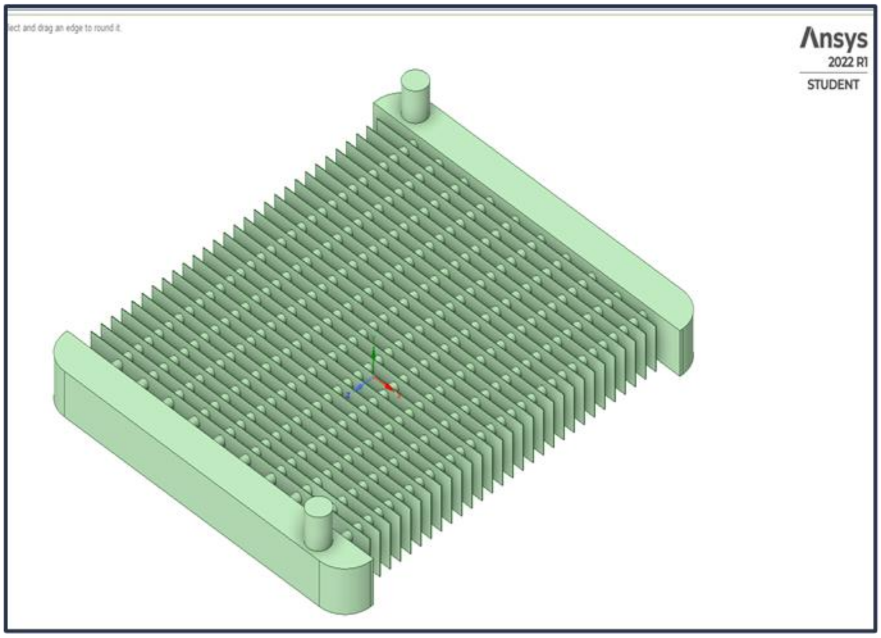
Q=$\eta\ hA(T_b - T_\alpha)$ =2kW

A=1.2m^2

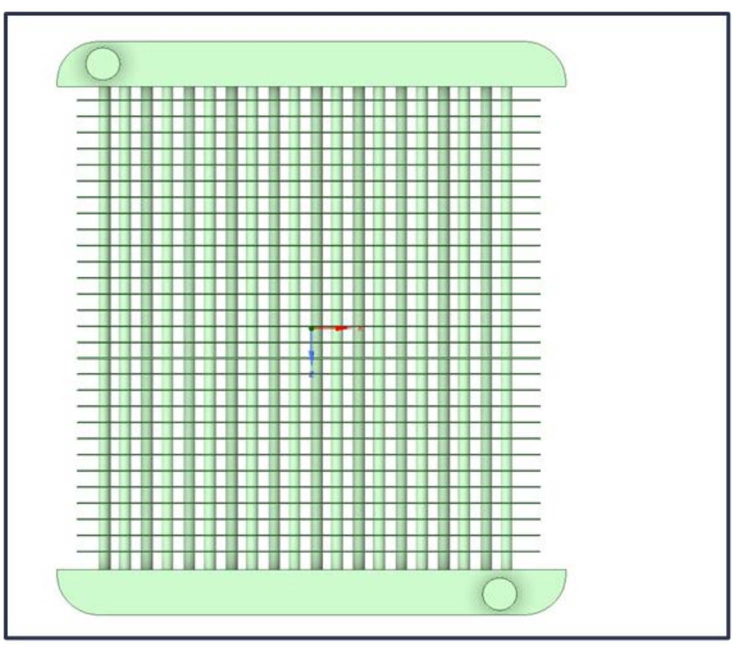
Number of fins=72.9 $\approx$75

Chapter 3: Design and Simulation

3.1 Design (Using Ansys SpaceClaim)



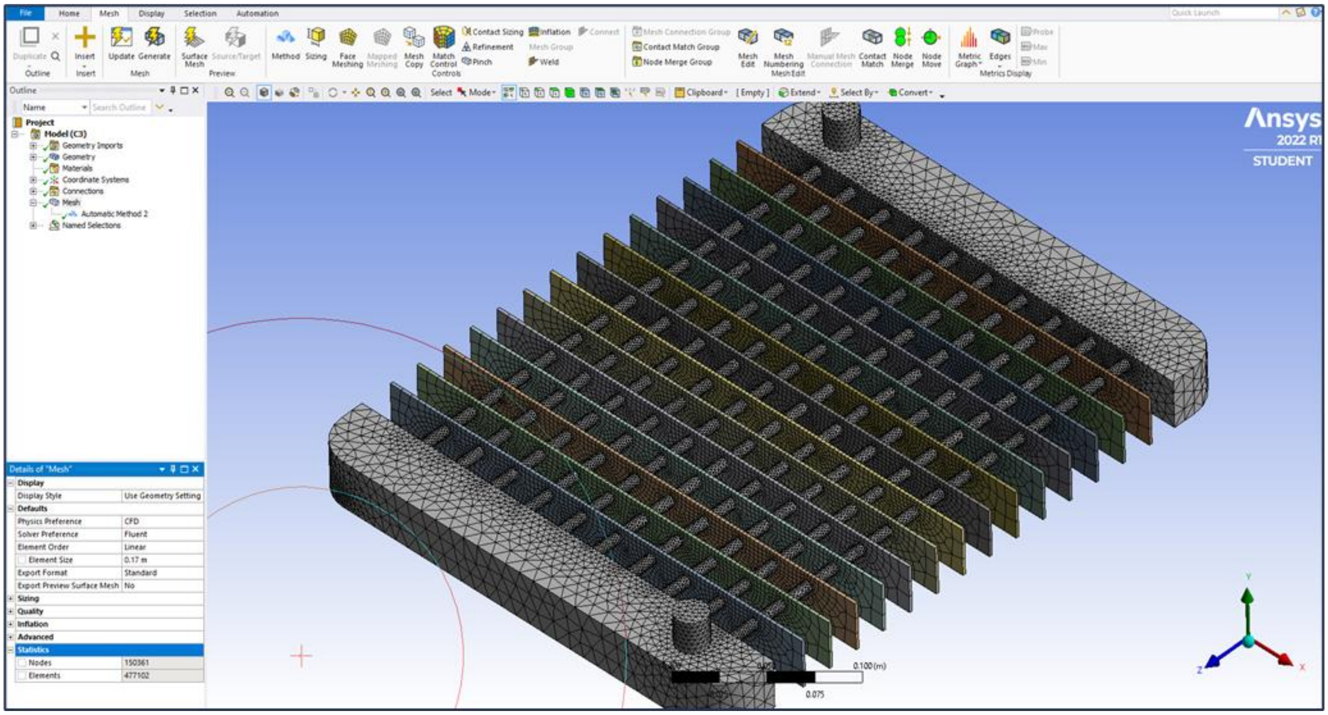
Isometric View



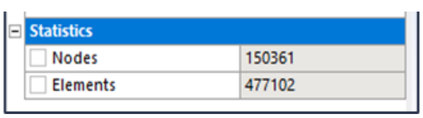
Front View

3.2 Mesh

A visual of our project after the meshing is done is shown below



The number of elements and nodes shown below

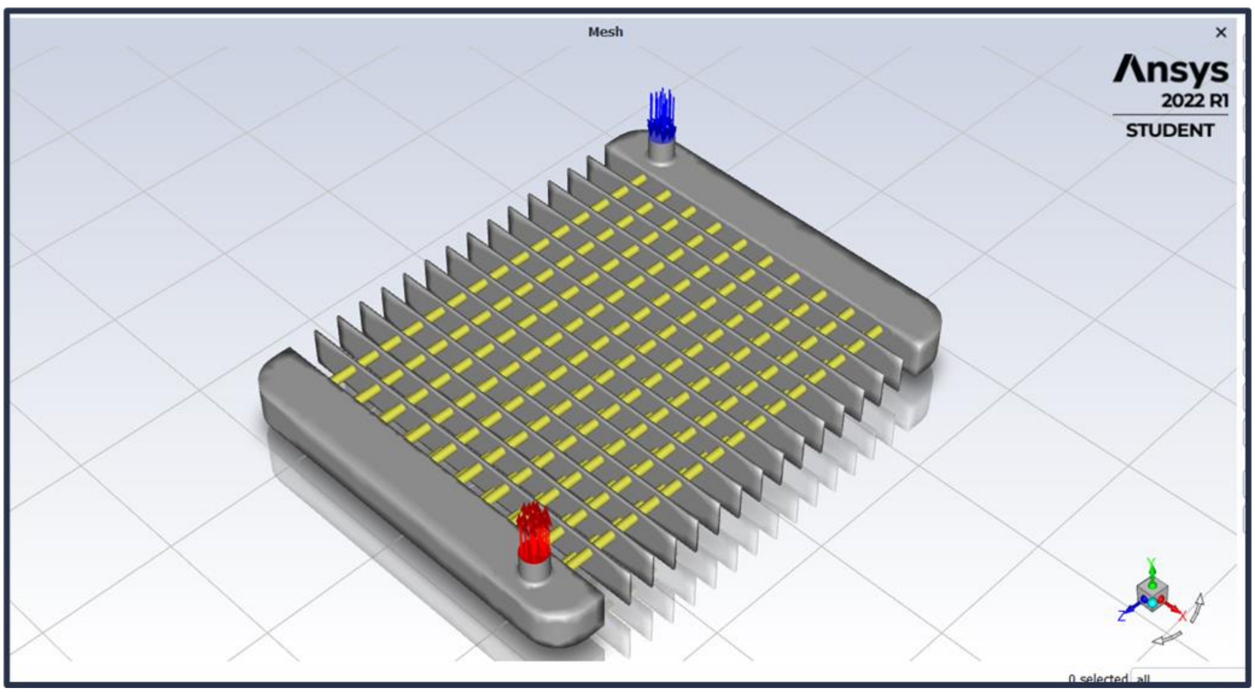


Statistics	
Nodes	150361
Elements	477102

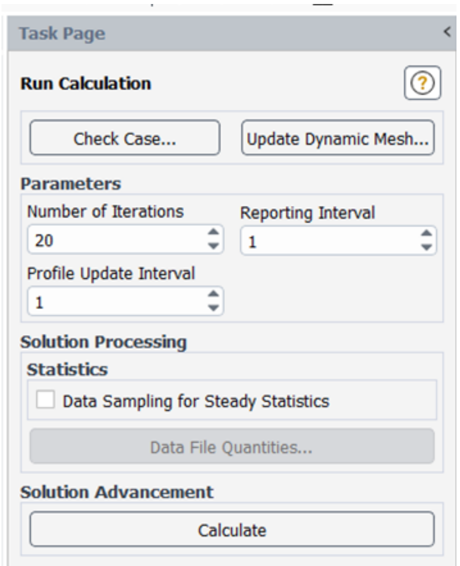
- <u>Observation: </u> Number of fins have been decreased since the use of ANSYS student version does now allow after a certain number of mesh elements is crossed.

3.3 Setup

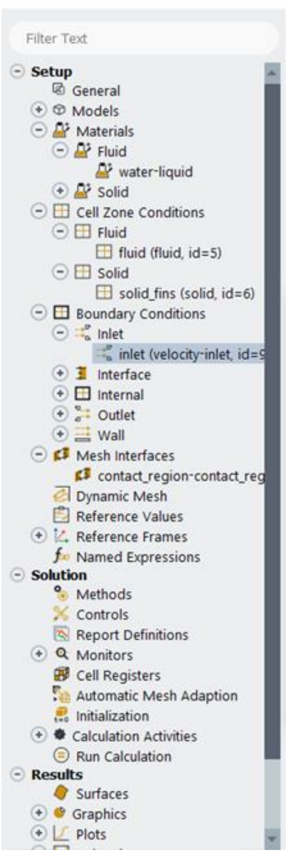
The finalized setup showing the inlet and outlet ports are shown in the picture below



The number of iterations done for calculation can be viewed here

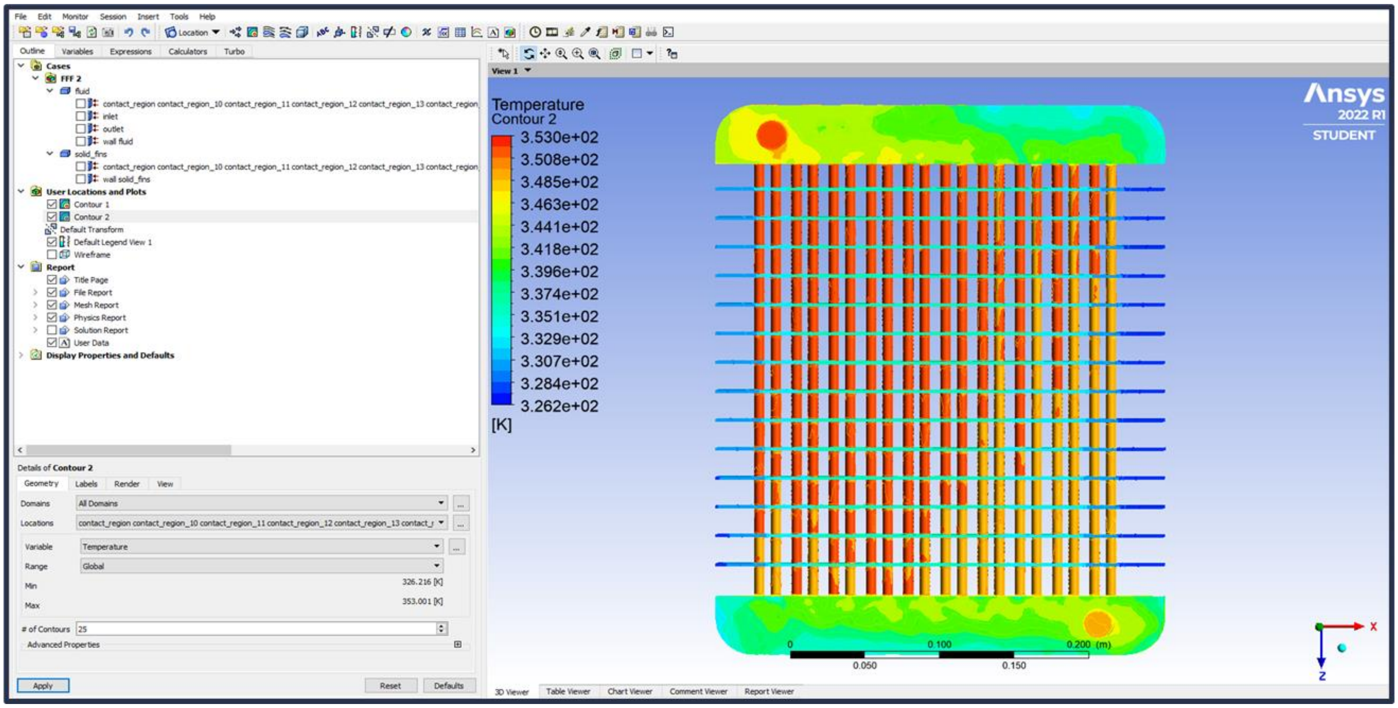


The overall boundary conditions and parameters used are shown here



3.4 Simulation

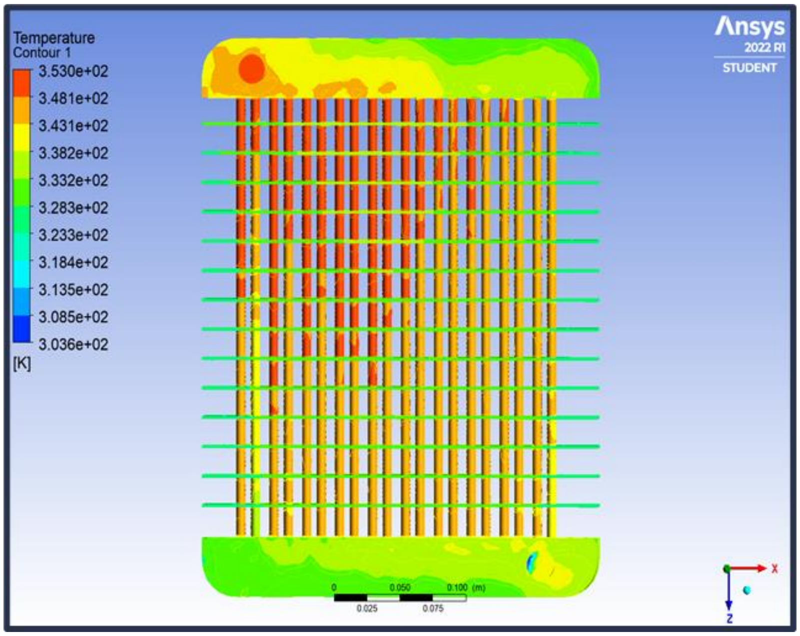
A contour from the final simulation is shown below from where we can get an idea about the temperature drop.



Chapter 4: Areas of Modification

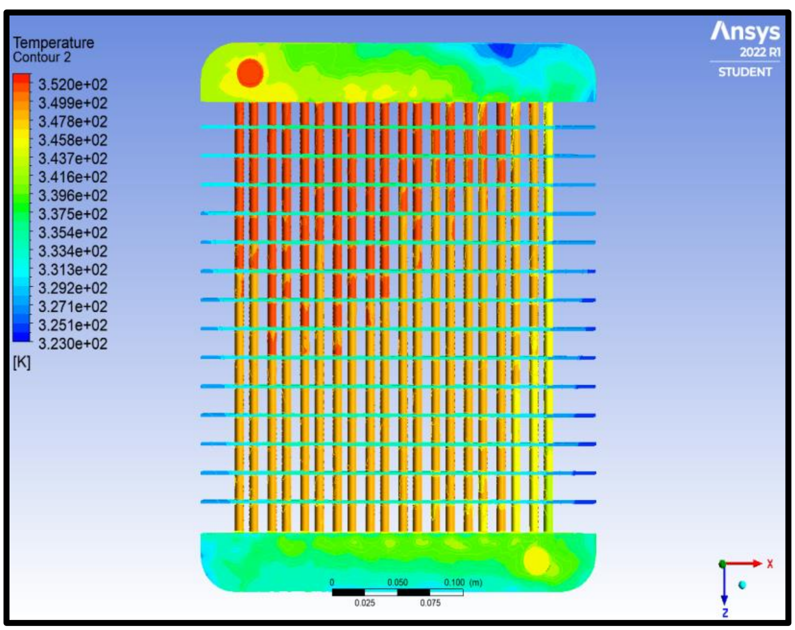
4.1 Inlet Velocity

Change in inlet velocity can show change in temperature drop. This statement can be verified from the contours below.



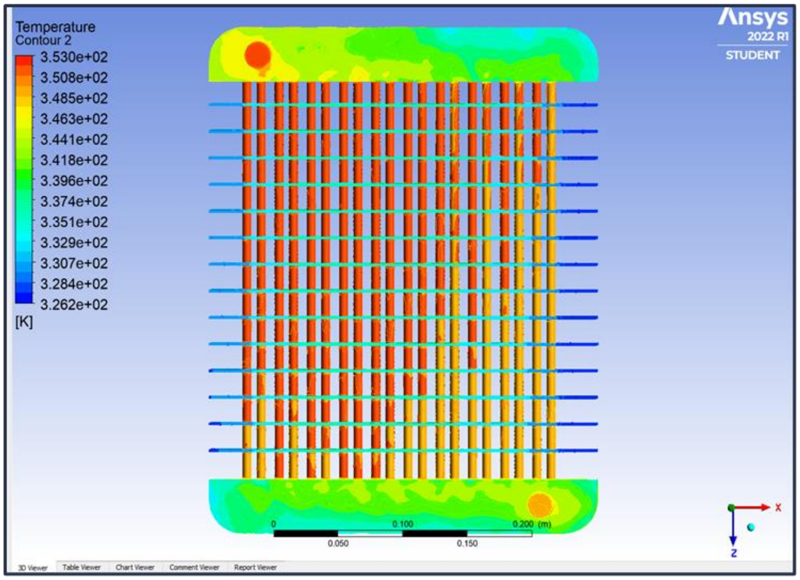
Inlet Velocity = 0.05 ms^{-1}

Temperature drop = 9.9 K



Inlet Velocity = 0.08 ms^{-1}

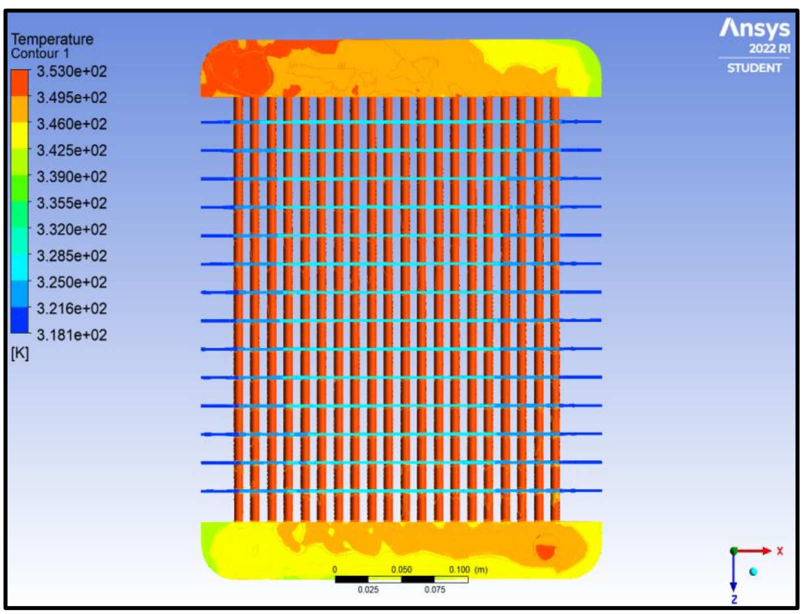
Temperature drop = 7.2 K



Inlet Velocity = 0.15 ms^{-1}

Temperature drop = 4.5 K

Our Case



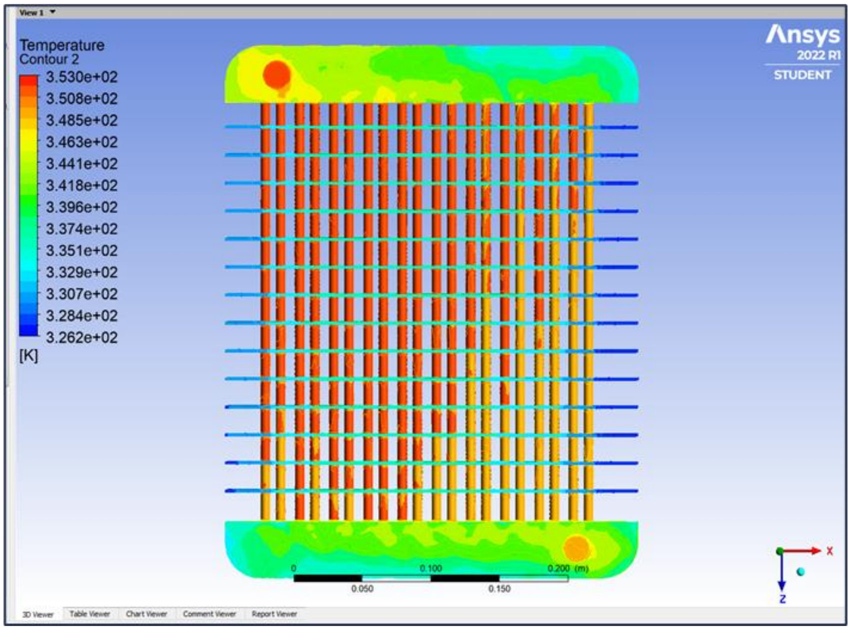
Inlet Velocity = 0.2 ms^{-1}

Temperature drop = 1.5 K

- Observation: We observe that, decrease in inlet velocity upto a certain point increases temperature drop. Considering the efficiency and overall availability, we chose a suitable velocity.

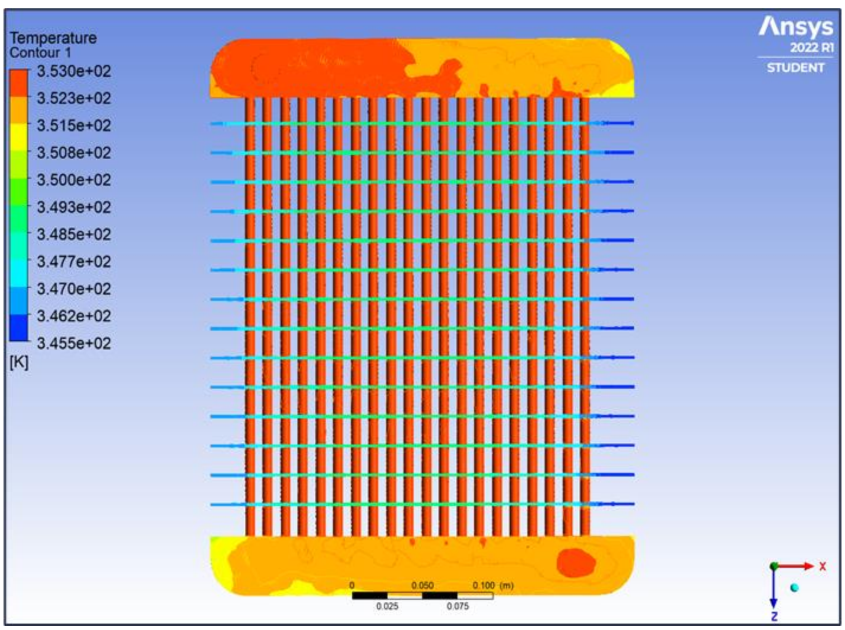
4.2 Convection Type

Change in temperature drop due to convection type is seen below from the illustrated contours.



Forced Convection

Temperature Drop = 4.5 K



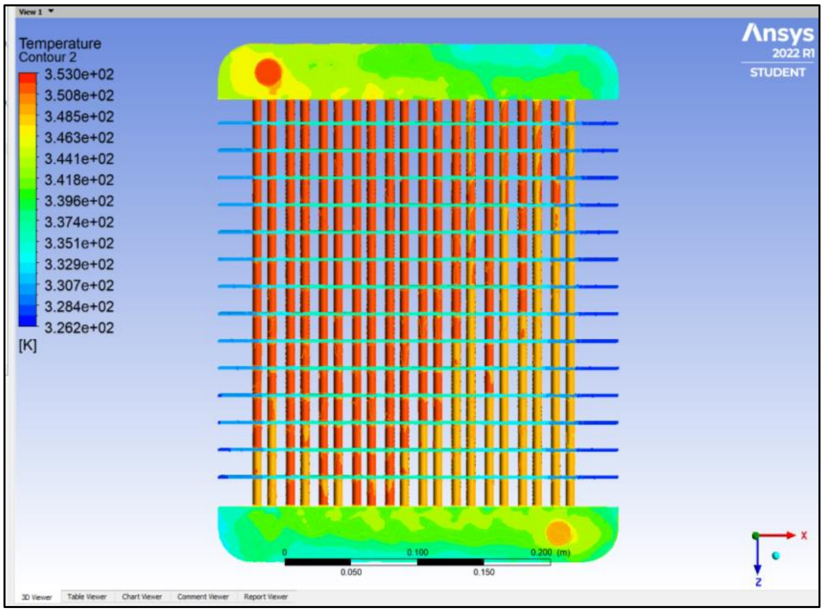
Natural Convection

Temperature Drop = 0.5 K

- Observation: Forced convection is the cause of a greater heat transfer coefficient, so the temperature drop is larger. The opposite scenario is seen in case of natural convection.

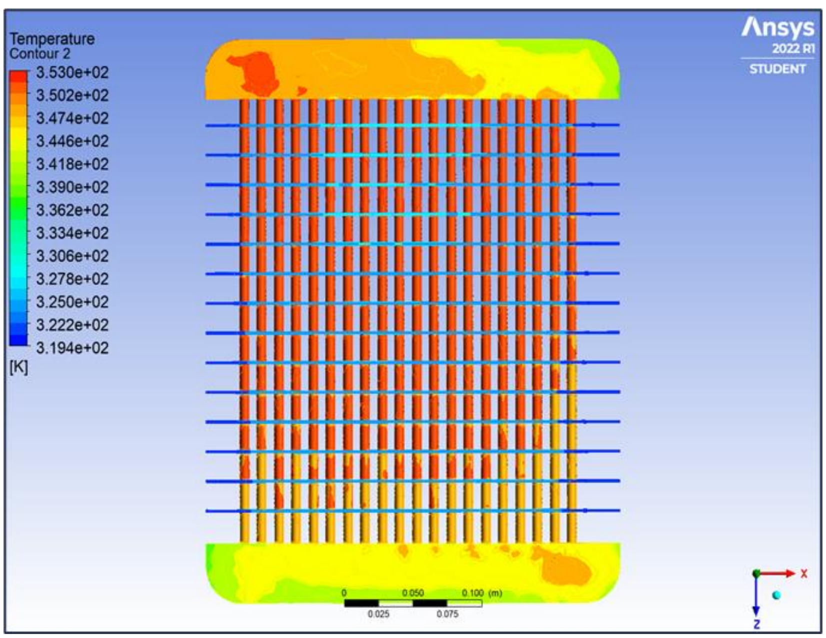
4.3 Solid Material Type

Changes in temperature drop due to changes in solid material type is shown below.



Aluminium

Temperature Drop = 4.5 K



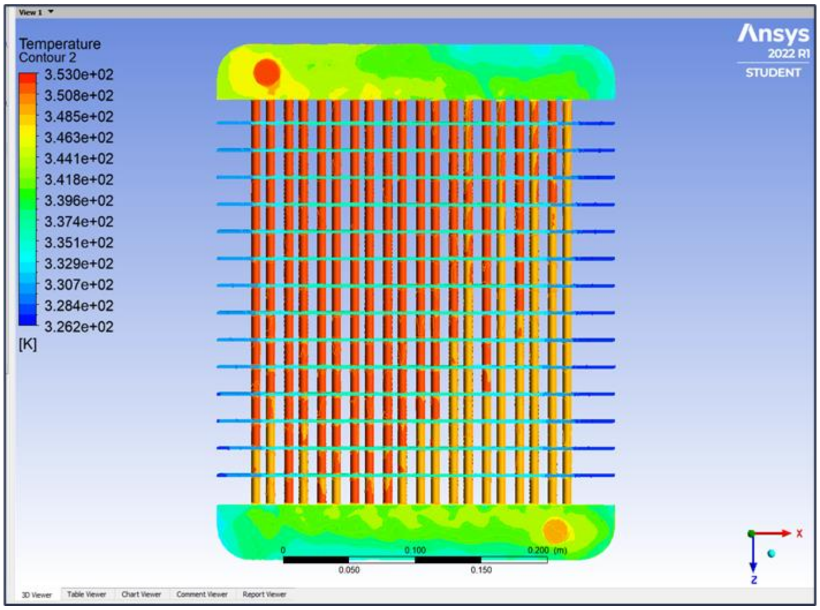
Copper

Temperature Drop = 7 K

- <u>Observation:</u> Change in solid material type may change temperature drop, but in case of aluminium we get- light weight, higher strength to weight ratio, high malleability and cost efficiency. So, we chose aluminium for our project.

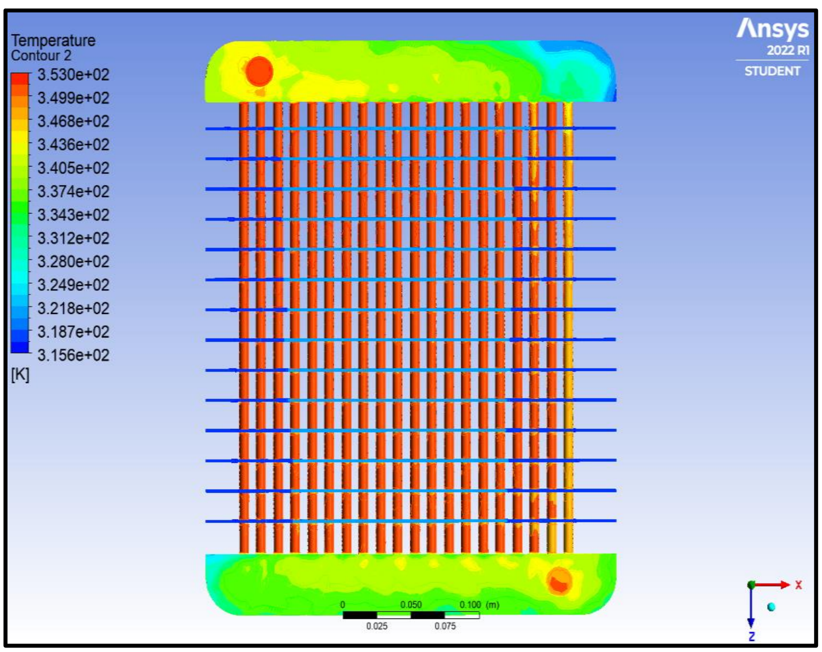
• 4.4 Liquid Material Type

Changes in temperature drop due to changes in liquid material type is shown below.



Water

Temperature Drop = 4.5 K



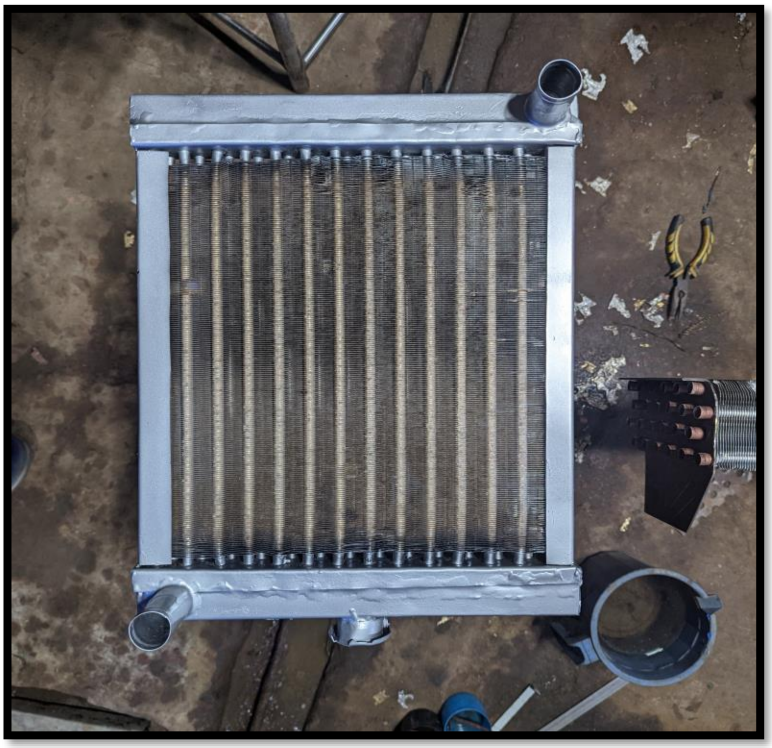
Ethylene Glucol

Temperature Drop = 4.5 K

- <u>Observation</u>: Change in temperature drop mostly occurs due to change in liquid type. We had to use water due to availability reasons. Current studies indicate a proportion of nano fluids can highly affect the heat transfer rate, which was not possible for our experiment.

Chapter 5: Project Demonstration

The image of the final product is shown below



Chapter 6: Final Result

6.1 Result Comparison

From our theoretical calculations , which have been done manually we assumed the temperature drop to be around 10^0 C. But, experimental results show a temperature drop of around 18^0 C.

6.2 Reasons for variation

The main reasons for variation are-

- Radiation: A lot of heat is transferred via radiation in case of the experiment, which was not included in the calculation.

- Ambient Temperature difference: The temperature considered in the calculations were around 30^0 C, which was much lower in case of the experiment

- Long pipe for water supply: The pipe used for water supply from the tank was very long, which was not taken into consideration during calculation.

- Inability to measure exact flow rate: During the experiment, a part of the water has been spilled and an exact result of the amount of water can not be taken. So, the flow rate measurement was not accurate.

Chapter 7: Conclusion

The main objective of this experiment was to design a compact radiator which can be used inside automobiles. The radiator which we designed is of low heat transfer rate, since different sectors have not been modified to increase the heat transfer due to limitations. But, our results and comparisons show that we were able to design a smaller, yet effective version of the radiator.

This project can act as a base for our future endeavor. This is because, we gained practical experience and learnt a lot of things. One of the most valuable learnings is learning the use of simulation to get a good idea about how the project will operate under varying boundary conditions and use of various elements. We hope that this knowledge and experience will be fruitful in the fields we want to participate in the future.