Design and Analysis of Plate fin Heat Exchanger used in Radar Systems

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Abstract— There is a wide application of plate fin heat exchanger in the field of cryogenics and other industrial Applications for its enhanced heat transfer characteristics and compact structure. There are various factors present that may affect the heat transfer characteristics of the heat exchanger. Here, the experiment has been done by varying the thickness of each of the fins in the heat exchanger and the velocity of the cooling liquid used. The thickness is varied from 0.2mm, 0.5mm and 1mm. The analysis has been done using SolidWorks simulation. Different parameters are calculated from the results obtained and graphs are plotted between various parameters such as Final Temperature of the cooling liquid used, which is in our case, Ethylene Glycol and Water (50:50 ratio). These graphs have been analyzed and discussed to find out the optimal result for which the heat exchanger would give the best performance.

Index Terms—Fins, Heat Analysis, Methods, Modelling, Plate fin heat exchanger, Performance, Simulation, Temperature.

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1 INTRODUCTION

THE plate-fin heat exchanger is a type of heat exchanger design that uses plates and finned chambers to transfer heat between fluids. It is often categorized as a compact heat exchanger to emphasise its relatively high heat transfer surface area to volume ratio. The plate-fin heat exchanger is widely used in many industries, including the aerospace industry for its compact size and lightweight properties, as well as in cryogenics where its ability to facilitate heat transfer with small temperature differences is utilized.

Aluminum alloy plate fin heat exchangers, often referred to as Brazed Aluminum Heat Exchangers, have been used in the aircraft industry for more than 60 years and adopted into the cryogenic air separation industry around the time of the second world war and shortly afterwards into cryogenic processes in chemical plants such as Natural Gas Processing. They are also used in railway engines and motor cars. Stainless steel plate fins have been used in aircraft for 30 years and are now becoming established in chemical plants.

Corrugations (Fins) are also made with heat transfer enhancement devices. Plain corrugation is the basic form and is used normally for low pressure drop streams. Perforated corrugation shows a slight increase in performance over plain corrugation, but this is reduced by the loss of area due to perforation. The main use is to permit migration of fluid across fin channels.

Corrugated metal fins are placed between flat plates. The structure is joined together by brazing (see later). The fins have the dual purpose of holding the plates together, thus containing pressure, and of forming a secondary (fin) surface for heat transfer. At the edges of the plates are bars, which contain each fluid within the space between adjacent plates.

2 RESEARCH METHODOLOGY

2.1 Design

Designing a plate-fin heat exchanger with offset strip fins with the help of Solidworks version 2019 Software.

2.2 Optimization

Optimizing the design parameters of a plate fin heat exchanger with the help of the Particle Swarm Optimization tools for various objectives like minimum pressure drop consideration, maximum heat transfer consideration, and minimum entropy generation consideration.

2.3 Analysis

Comparing the outcome parameters like temperature of cooling liquid and other parameters that are obtained experimentally with the values obtained by using the correlations developed by the previous researchers and by using tools like SolidWorks software to simulate and analyse the best outcome for a combination of inputs.

2.4 Estimation

Estimating the value of pressure drop as well as effectiveness of the cold and hot fluids with the mass flow rate.

3 MODELLING

The modelling is done using SolidWorks software. Here, we have to model 3 parts and eventually assemble them together. The 3 parts are:

- Frame
- Cover Plate
- Fins

3.1 Frame

The frame is modelled according to the dimensions provided in the assembly sheet. The thickness of the frame is around 13mm with the length and breadth of the frame being 440mm and 387mm respectively.

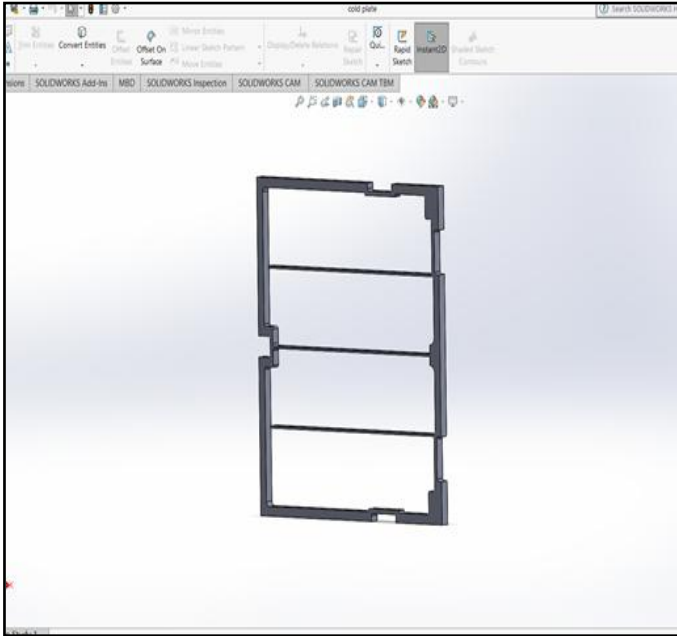thickness, which are:

1. 0.2 mm
2. 0.5 mm
3. 1 mm

Fig. 1 Frame

3.2 Cover Plate

The cover plate or the bottom plate is placed on either sides of the frame, once the fins are placed inside. On the other side of the plate, there are electronic components placed.
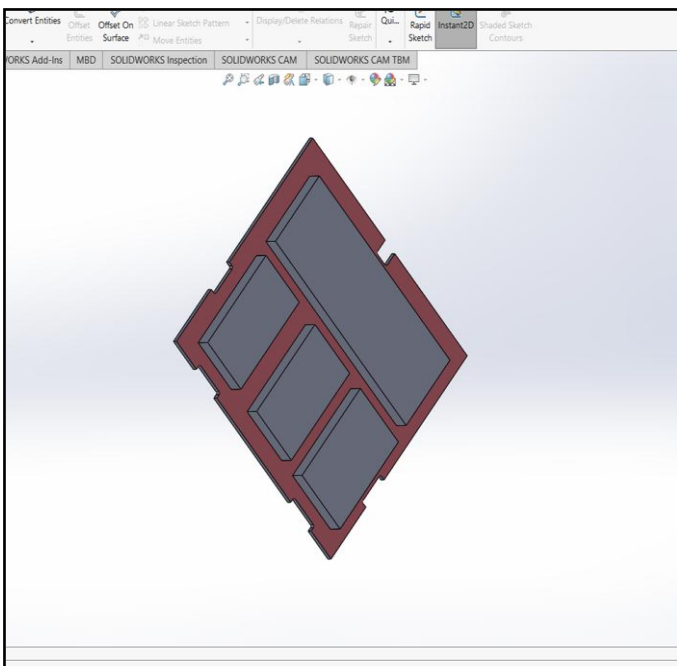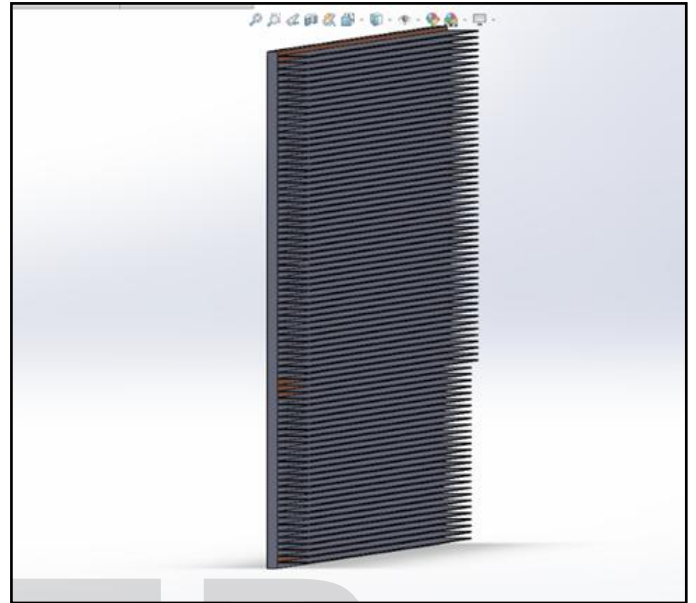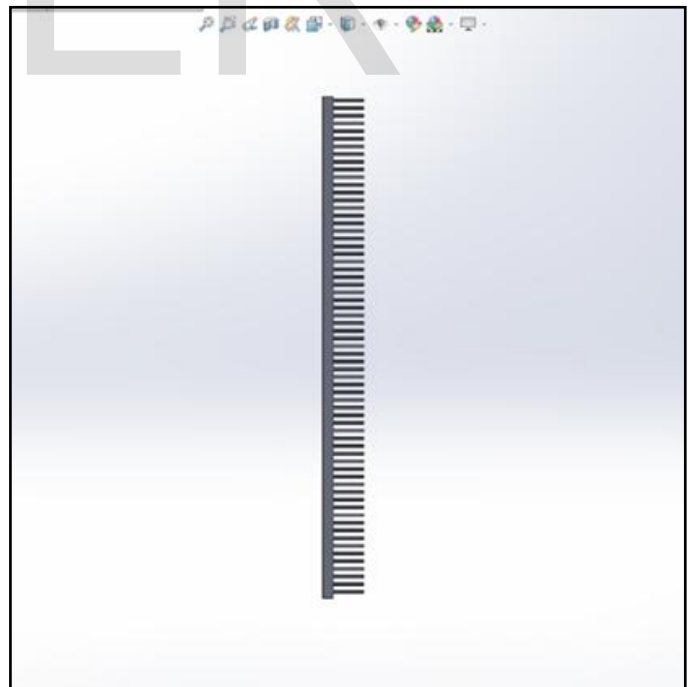

Fig. 3 Fin thickness=0.2mm

Fig. 2 Cover Plate

Fig. 4 Fin thickness=0.5mm

3.3 Fins

For analysis purpose, we have modelled fins of different
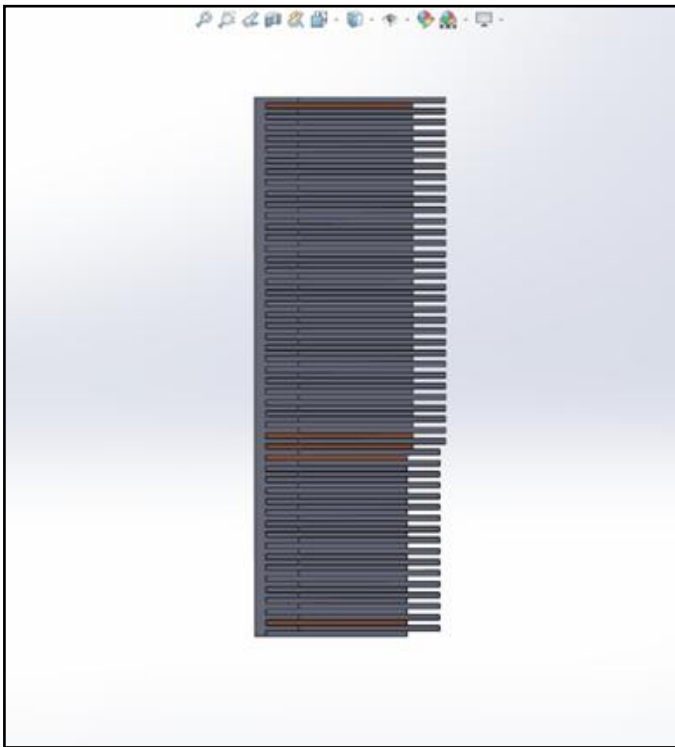
Fig. 5 Fin thickness=1mm

4 CALCULATION

The following are the steps followed in finding out the final temperatue of the liquid coolant used:

1. First the heat transfer coefficient(h) is found out using the values of thermal conductivity(K), characteristic length(L) and Nusselt Number(Nu).
2. Then the fin efficiency(η) of long insulated tip is found out.
3. The total effective area(A) through which the cooling liquid flows is found out.
4. Finally the surface temperature of the plate(T1) is found out by using the above parameters.

5 HEAT ANALYSIS

Once the modelling and the theoretical calculations are done, we have to do the analysis the results. For the heat analysis of the plate fin, the software used is SolidWorks Simulation.

ANSYS can also be used for the analysis, but it consumes a lot of time and a comuter with high capacity RAM is necessary. Hence, SolidWorks Simulation is preferred.

Steps followed for Simulation are as follows:

1. Click on Solidworks Add-Ons.
2. Select Simulation and click on New study. Then select Thermal simulation, under Advance simulation options.
3. Before we start the simulation, change the material by right clicking on the part and choose the desired material (i.e Aluminium 6061)

4. Click on thermal loads and apply heat power to the cover plate (i.e 400W)
5. Then select Convection and enter the values of Convection Coefficient (i.e 630.74W/(m^2.K)) and Bulk ambient temperature (i.e 293K) and select all exposed faces.
6. Right click on Mesh and select create mesh.
7. Select the Mesh parameters and add the desired cell size and number of cells.
8. Once meshing is done, click on run this study which solves the active study
9. Click on plot tools and then select probe which allows access to choose desired nodes on the model and the fins to shows the heat dissipation.
10. After the nodes are selected, click on the graph which displays the graph for the selected nodes.
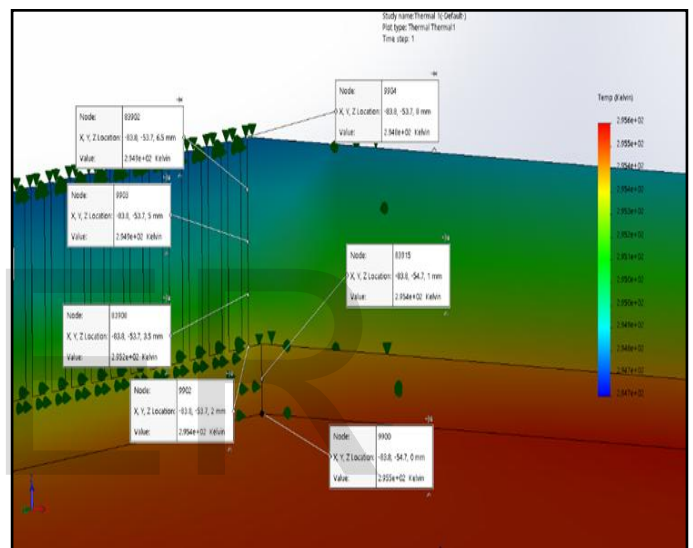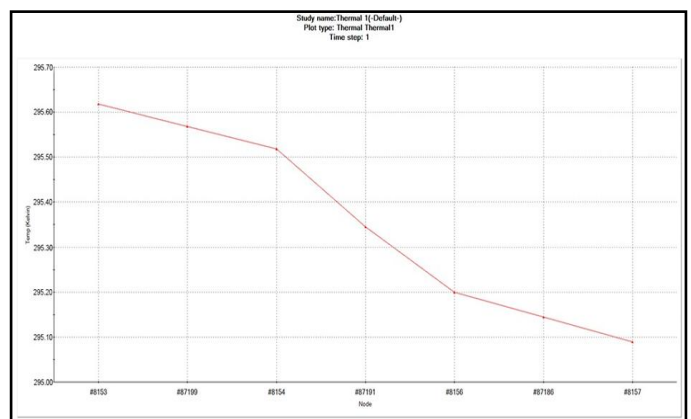
CASE 1: FIN THICKNESS = 0.2mm

Fig. 6

Fig. 7 As per the SolidWorks simulation, we get the temperature to be as : 22.6˚c

CASE 3: FIN THICKNESS = 1mm

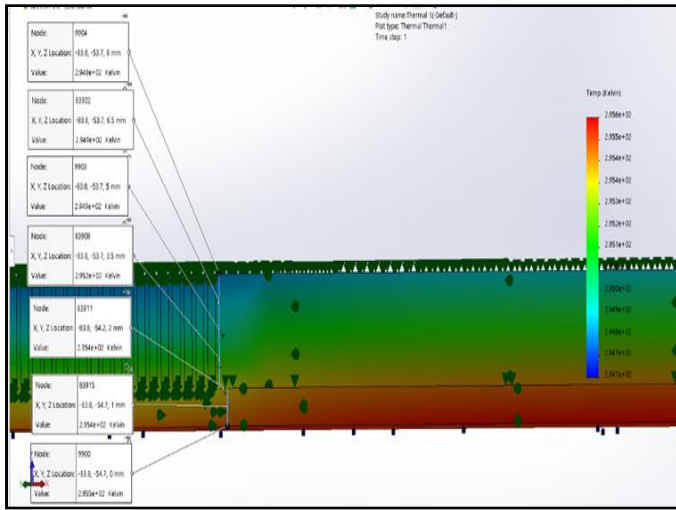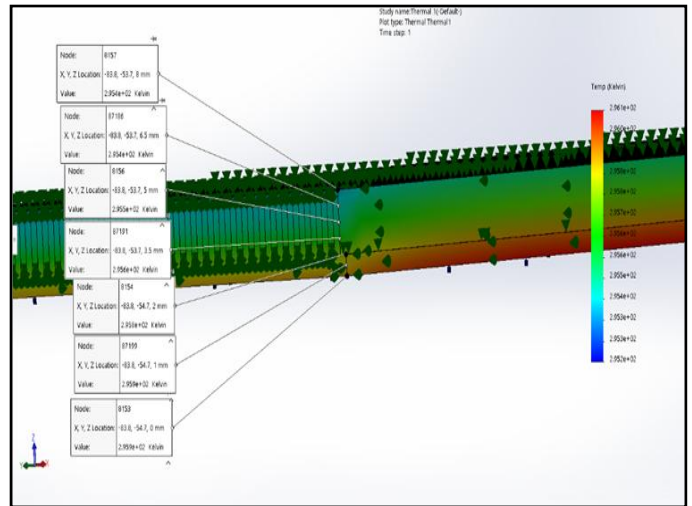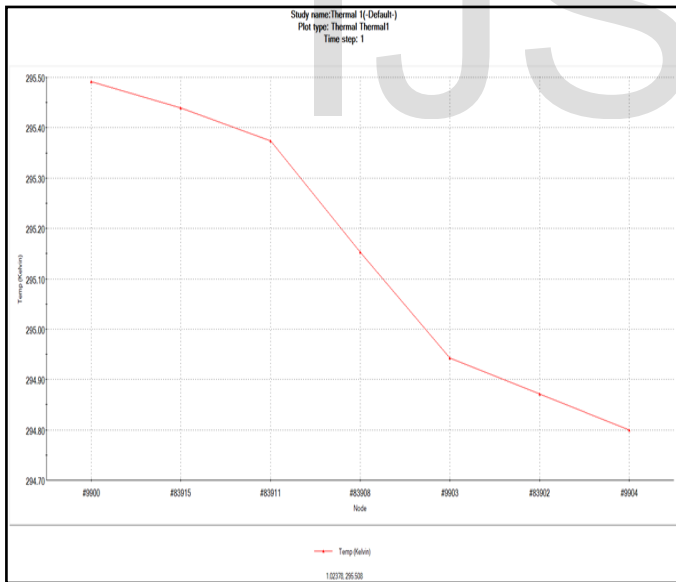**CASE 2: FIN THICKNESS = 0.5mm**

Fig. 8

Fig. 10

Fig. 9 As per the SolidWorks simulation, we get the temperature to be as : 22.5˚c
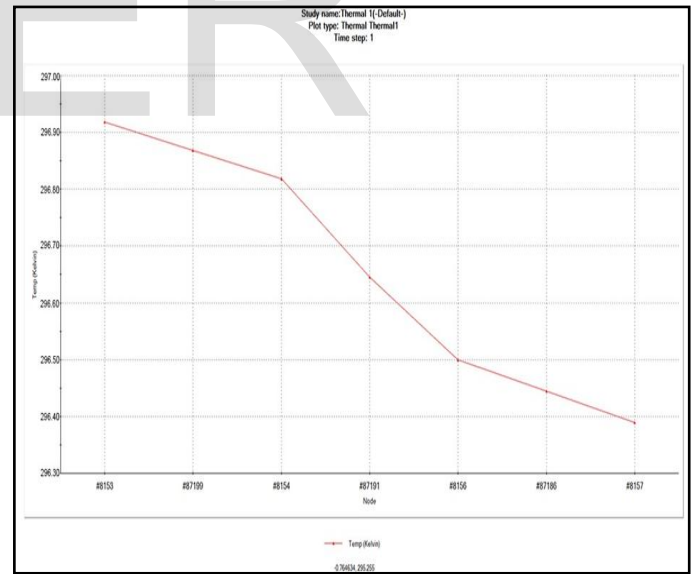
Fig. 11 As per the simulation, we get the temperature to be 23.9˚c

6 RESULTS AND DISCUSSIONS

The result of conducted research has been summarized below:
The Table 1 compares the data derived through modeling & simulation in SolidWorks and calculated values.

Sl. No.	Thickness (mm)	No. of fins	Temperature Value (Calculation) (°C)	Temperature Value (Simulation) (°C)
1.	0.2	91	22.67	22.6
2.	0.5	73	23.17	22.7
3.	1	55	24.13	23.9

Table 1: Calculated and simulation values for respective thickness

COMPARISON BETWEEN TEMPERATURE VALUES

■ Theoretical Values ■ Simulation Values
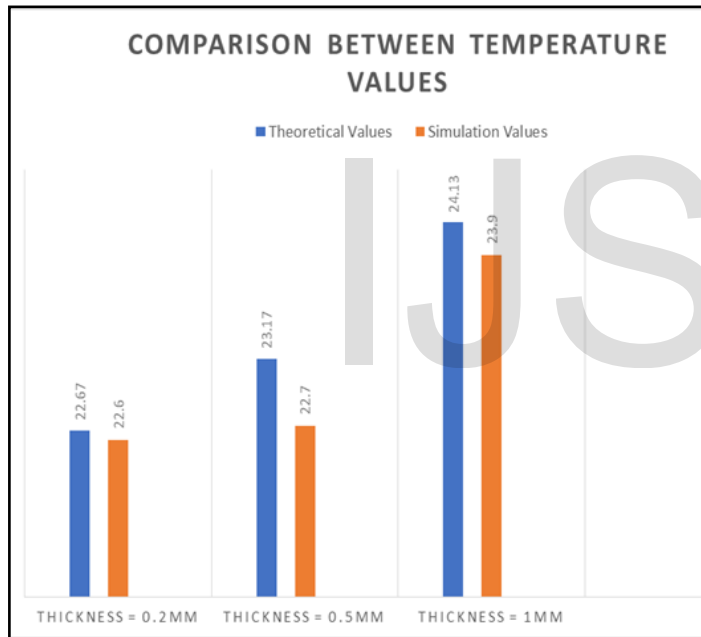
7 CONCLUSION

The purpose of this conducted research work was to do the modeling & simulation in SolidWorks to find the optimal results of compact heat exchanger. The first part of paper is about modelling the plate fin heat exchanger and later heat simulation is performed on the same. Simulation is a powerful tool which allows the students to manipulate the different variables and study the behaviour of the same model in different perspective. One of the key parameters in increasing the plate fins heat exchanger performance is to vary the thickness of the fins. As it was observed, by increasing the thickness of the fins in the given confined space the number of fins reduces.

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