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# Study and Comparison of Micro Channel Condenser with Metal Foam & Round Tube Finned Heat Exchanger

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***Abstract—*** *The microchannel condenser requires less space as compared to regular condenser and it also requires less amount of refrigerant. More surface area is available to reject the heat to surrounding air as thin tubes are used in micro channel condenser. The purpose of the present study is to develop a setup of a refrigeration system with micro channel condenser, performance comparison of conventional heat exchangers. For its performance, refrigeration set up is done to detect experimental performance of microchannel condenser. In this paper performance analysis of microchannel condenser is compared with coil tube. The analysis results on the micro channel condenser can be more effective at various loads and operating conditions. For review purpose, same size of micro channel and round tube condenser are considered. Also C.O.P & Efficiency of microchannel can be more with less usage of refrigerants.*

***Keywords- Microchannel condenser, Refrigeration, Round tube condenser, COP, Efficiency.***

## I. INTRODUCTION

Mini channel and micro channel aluminium tubes are becoming more popular as components used in heat exchangers. These heat exchangers are used in various industrial applications and are produced in large quantities with many different geometries and lengths and, therefore, they are relatively inexpensive. The ability to produce tubes with external or internal fins and with smaller wall thicknesses allows higher heat transfer area per unit volume of a tube. Therefore, mini- and microchannel tubes are ideal for use in compact and light weight heat exchangers. The use of minichannel or micro channel heat exchangers in refrigeration equipment, offers the possibility of low refrigerant charges as well as high heat transfer and compact designs. The estimation of heat transfer in condensation and boiling in minichannels is more difficult than that for single-phase flow. However, accurately estimated single-phase heat transfer coefficients will help to determine two-phase heat transfer coefficients. The distinction between minichannels or microchannels is given by Kandlikar, defines tubes with channel diameters between 0.01 and 0.2mm as microchannels, channel diameters between 0.2 and 3 mm as minichannels, and channel diameters greater than 3mm as conventional channels.

### *A. HEAT EXCHANGERS*

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The definition of heat exchanger is clear from its name itself as it is mechanical equipment that is utilized to exchange heat from one medium to another. It is widely used in various industries as well in domestic purposes but its size and type is varying as per the industry and application. Most of the industries which use heat exchangers include thermal power plant, paper mill, chemical plant etc.

#### *1) CLASSIFICATION OF HEAT EXCHANGER:*

The classification of heat exchanger is mainly based on the direction of flow, no of passes as per the requirement in various industries. As per the flow direction of the fluid the heat exchanger are classified are:

(a) Parallel flow: In this type of heat exchanger both the fluids are moving in same direction and the heat exchanging process takes place between them.

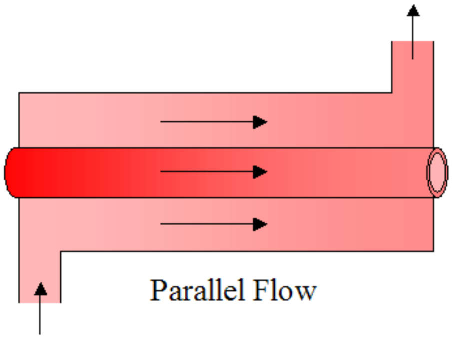


Fig.1 Parallel Flow Heat Exchanger

(b) Counter flow: In this type of heat exchanger both the fluids move opposite to each other.

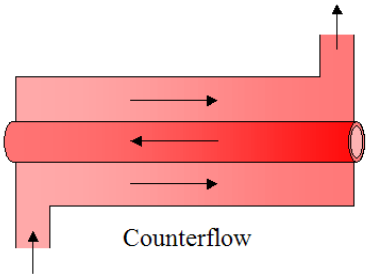


Fig.1. Counter Flow Heat Exchanger

(c) Cross flow: In this type of heat exchanger both the fluids flow 90 ˚ to each other. These types of heat exchanger are used for air heating purposes.

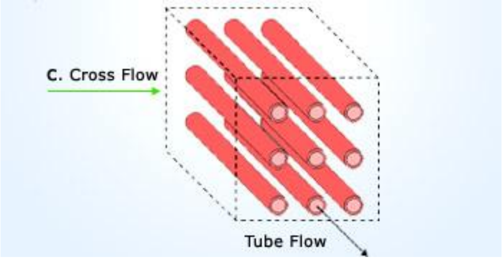


Fig.3. Cross flow type heat exchanger

## II. MINICHANNEL HEAT EXCHANGER

### A. *Construction*

The heat exchanger was made using 30 multiport extruded aluminium tubes. A picture of a tube cross-section is shown in Fig. 4.

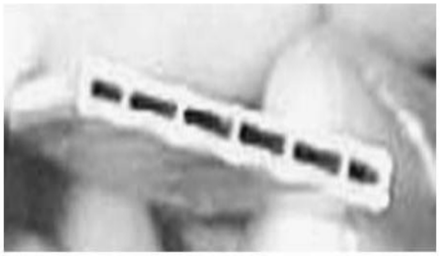


Fig. 4. Tube cross section

Each tube consisted of six channels. The four middle channels were equal in size: 1 mm in height and 2.65mm in width. The two channels at the edges were 1 mm in height with a width of 1.45mm plus a semi-circular part with a radius of 0.5 mm. The wall thickness of the tube was 0.5 mm. The cross-sectional area and wetted perimeter of a tube were taken as the total of all six channels when calculating the hydraulic diameter. The tubes, each with the length 661mm, with active heat transfer length, were arranged in two rows and held in place by 31 equally spaced 1-mm thick aluminium baffle plates. The ends of the tubes were fixed to two 5-mm thick aluminium end plates. The tube bundle was placed inside a shell made from four aluminium plates. The whole unit was brazed together at the connecting points. Each baffle plate was joined to three shell plates and a 4.5 mm gap was left to the fourth plate.

## III. LITREATURE REVIEW

**Tejas Pawar et. al. (2017)** developed a setup of a refrigeration system with micro channel condenser, performance comparison of conventional and microchannel condenser. For its performance, refrigeration set up was done to detect experimental performance of micro-channel condenser. They analyzed the performance of micro-channel condenser and compared with coil tube. In analysis of micro channel condensers it was found more effective at various loads and operating conditions.

**Shemal K. Parmar et. Al. (2017)** analyzed the characteristics of air conditioning system with minichannel and micro channel heat exchangers. Mini-channel and micro-channel heat exchangers have higher surface contact area to volume ratio. Minichannel and micro-channel heat exchangers are lighter in weight because they are made of aluminum only. Also the cost of mini channel heat exchanger is less because of aluminum structure. Mini channel uses less power and refrigerant charge so it is also good for environment. Effectiveness of mini channel heat exchanger is increased by using fin at both internal and external side. Mini-channel heat exchanger and micro-channel heat exchanger can be used in refrigeration and air conditioning system. In air conditioning system at both mini channel and micro-channel heat exchanger can be applied as both the condenser and evaporator. As mini and micro-channel heat exchangers are compact in size they are very much suitable for the automotive air conditioning system.

**Nguyen Van Trang et. Al. (2017)** presented the experimental study on innovative liquid cooling system of scooter using minichannel heat exchanger. The experiments were carried out to determine heat transfer efficiency and engine power with variation of operating conditions. The results shows that the heat transfer efficiency obtained from the minichannel heat exchanger was higher than or equal to that obtained from the original radiator. In addition, the engine power can be increased by using minichannel radiator together with removing the cooling fan that driven from engine crankshaft. The obtained results are in good agreement with relevant studies. The size of alternative minichannel radiator is reduced the by 30%, made it easy to manufacture, and cut down its cost approximately 40% compared to the original one. The study also illustrated the feasibility of the alternative minichannel heat exchanger for the conventional radiator of scooters.

**Priscila Forgiarini da Silva et. Al. (2017)** studied experimentally the local heat transfer coefficient and flow patterns during flow boiling of R-290 (propane) inside multiport extruded (MPE) mini channel tube made up of 7 channels with hydraulic diameter of 1.47 mm. The tests analyzed the effects of heat flux, mass velocity and vapor quality. The study were performed with heat fluxes from 5.3 to 20 kW/m2 , mass velocities varying from 35 to 170 kg/m2 and vapor quality between 0.07 to 0.98. As a result, heat transfer coefficients between 1-18 kW/m2K were obtained. Five types of flow patterns were observed, with predominance of plug and slug and churn. The results unveil the significant effect of flow patterns on heat transfer characteristics.

**Dariusz Mikielewicz et. Al. (2017)** presented new trends in the development of microchannel heat exchangers. The exchangers developed in this way can be applied in marine industry. Main attention is focused on heat exchanger design with reduced size of passages, namely based on microchannels. In authors' opinion, future development of high power heat exchangers will be based on networks of micro heat exchangers.

**Saravanan V et. Al. (2017)** studied that micro channel heat sink has been widely used for cooling of high heat flux device in variety of electronic application. In the present work, Influence of porous medium on fluid flow and heat transfer characteristics for Reynolds number ranging from 100 to 400 has been investigated numerically. A Three Dimensional Micro Channel Heat Sink of dimensions 16.5mm*6mm*1mm with water as coolant subjected to 6.9W is considered for the study. The performance of micro channel heat sink is studied by varying the position and thickness of porous medium for different porosity. A Non Dimensional parameter, Figure of Merit is used to access the performance. The hydraulic and thermal performance of Micro channel heat sink are obtained by solving the Navier -Stokes equation and energy equation. Results reveal that position and thickness of porous medium has more influence on hydrodynamic and heat transfer characteristics of micro channel heat sink .The entire study is carried out by using the commercially available software FLUENT.

**Kays A. Al-Tae'y et. Al. (2017)** did the research and found that the present experimental research use a minichannel heat sink manufactured from copper metal with a rectangular cross section area channels and hydraulic diameter 1.6667 mm. The de-ionized water is used as a coolant liquid to cool the 2.8 GHz computer processing unit chips in a real personal computer. This study discusses the effects of varying mass flow rates of the coolant water through minichannel, with changing the load operation conditions of the CPU chip, on CPU temperature of real personal computer, heat transfer rate, thermal resistance, Nusselt number, pressure drop. Also study the effects of junction temperature on failure rate and mean time to failure. The results have shown that the CPU temperature is dependent on the coolant fluid (water or air) temperature, which increases with the increase of coolant fluid temperature and vice-versa. The water cooling systems have proved to be successful in reducing the CPU temperature from 42˚C to 33˚C at 0.0044 kg/s.

**Eric C. Forres et. Al. (2016)** presented experimental results for single-phase heat transfer in a narrow rectangular minichannel heated on one side. The aspect ratio and gap thickness of the test channel were 29:1 and 1.96 mm, respectively. Friction pressure drop and Nusselt numbers are reported for the transition and fully turbulent flow regimes, with Prandtl numbers ranging from 2.2 to 5.4. Turbulent friction pressure drop for the high aspect ratio channel is well-correlated by the Blasius solution when a modified Reynolds number, based upon a laminar equivalent diameter, is utilized. The critical Reynolds number for the channel falls between 3500 and 4000, with Nusselt numbers in the transition regime being reasonably predicted by Gnielinski's correlation. The dependence of the heat transfer coefficient on the Prandtl number is larger than the predicted by circular tube correlations, and is likely a result of the asymmetric heating. The problem of asymmetric heating condition is approached theoretically using a boundary layer analysis with a two-region wall layer model, similar to that originally proposed by Prandtl.

**Sun Jian et. Al. (2015)** is developed a three-dimensional steady-state laminar flow and heat transfer model for fractal tree-like minichannel heat exchanger. The fluid flow and heat transfer process is studied by CFD software. Because of its symmetric structure, only half body of the heat exchanger is calculated. The fluid-solid coupled method is applied and the hexahedral grid is used on the control volume. The temperature distribution and velocity distribution for different heat flux on top boundary surface are obtained with an inlet hydraulic diameter of 3.2mm.The simulated results show that the fractal tree-like minichannel heat exchanger has good temperature uniformity and small pressure drop.

**Rupesh D. Khorgade et. Al. (2014)** studied that heat transfer augmentation technique refers to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. Minichannel heat sink is widely used as a heat exchanger to remove heat from electronic chips. Because of higher generation of heat in the electronic chips, there has been a wide use of liquid cooling systems. But as the technology growing day by day, more effective coolant needed for these systems. The invention of nanofluid has promised to enhance the effectiveness of the new liquid coolant. The mixture of solid particles to the liquid generally increases the thermal conductivity of the liquid because of its higher thermal conductivity itself. This paper contains review of different techniques used for heat transfer enhancement of minichannel heat sink using nanofluids.

**G.B. Ribeiroet.al. (2011)** researched that the thermal-hydraulic performance of micro-channel condensers with open-cell metal foams to enhance the air-side heat transfer is investigated in this paper. Three different copper metal foam structures with distinct pore densities (10 and 20 PPI) and porosities (0.893 and 0.947) were tested. A conventional condenser surface, with copper plain fins, was also tested for performance comparison purposes. The experimental apparatus consisted of a closed-loop wind tunnel calorimeter and a refrigerant loop, which allowed the specification of the mass flow rate and thermodynamic state of R-600a at the condenser.

## IV. OBJECTIVE

**Objective 1: Performance Evaluation of Micro-Channel Condenser with Metal Foam.**

1. Metal foam is a cellular structure consisting of a solid metal (frequently aluminium) with gas-filled pores

comprising a large portion of the volume. The pores can be sealed (closed-cell foam) or interconnected (open-cell foam). The defining characteristic of metal foams is a high porosity: typically, only 5–25% of the volume is the base metal, making this ultra-light material.

The effect of using metal foam with micro channel in condenser of vapor compression refrigeration system would be studied

**Objective 2: CFD Evaluation and analysis of Micro-channel condenser with metal foam and round tube finned condenser**

1. Micro-channel and round tube fins both are different methods used to enhance the heat transfer rate of the condenser
2. In this study performance evaluation and comparison of both ways used for heat transfer enhancement would be done.

## V. METHODOLOGY

Preparation of model: A CAD model is prepared in CATIA with dimension mentioned in the table 1 below.

Table.1. Mini-Channel Tube Dimension

| Dimension | Size |
|---|---|
| Length | 314mm |
| W | 19mm |
| Thickness | 0.4mm |
| No. of Ports | 10 |
| Cross sectional area of port | 4.6mm^2 |

Table.2. Outer Body Dimension

| Dimension | Size |
|---|---|
| Length | 259mm |
| Width | 28mm |
| Wall thickness | 4.5mm |
| Water inlet radius | 7.5mm |

### A. *STEPS OF WORKING*

Step 1: Collecting information and data related to Mini-channel.

Step 2: A fully parametric model of the mini-channel for both cases are created in CATIA V5R20

Step 3: Model obtained in Step 2 is analyzed using ANSYS 15. (FLUENT)

Step 4: Finally, we compare the results obtained from ANSYS.

### B. *STEPS OF ANSYS ANALYSIS*

The different analysis steps involved in ANSYS are mentioned below.

#### 1) *PREPROCESSOR*

The model setup is basically done in preprocessor. The different steps in pre-processing are

- Build the model
- Define materials
- Generation of element mesh

#### 1. BUILDING THE MODEL

To re-create mathematically the behavior of an actual engineering system is the ultimate purpose of a Computational fluid dynamics. The analysis must be an exact mathematical The ANSYS program provides the following approaches for model generation:

- Creating a solid model within Catia.
- Using direct generation
- Importing model created in a computer-aided design (CAD) system.

**Case-1 Design Model for 1st Case.**

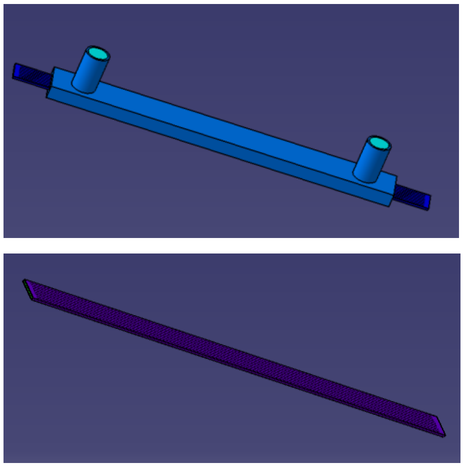


Fig.5. CAD model prepared in Catia

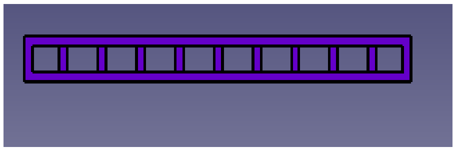


Fig.6. Cross-sectional view

**CASE-2 Design model for 2nd case.**

Implementation using Circular tubes and metal Foam ( Porous Zone)

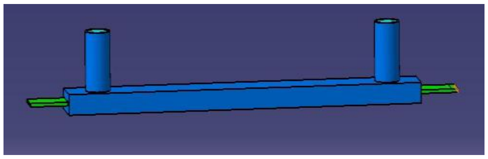


Fig.7. Circular tube model with metal foam for further analysis

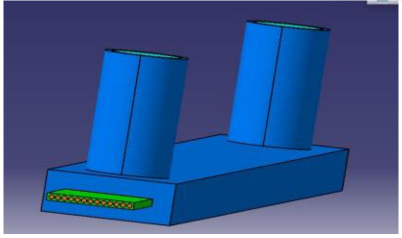


Fig.8. Circular tubes for further Improvement of Micro-channel Heat exchanger

### C. MESHING

The mesh created in this work is shown in figure No 4.7. Total Node is generated 61915& Total No. of Elements is 160624, it is clear from the mesh geometry the node numbers and element numbers are almost seven in digit which show that the mesh is very fine because the result accuracy depends on the mesh quality

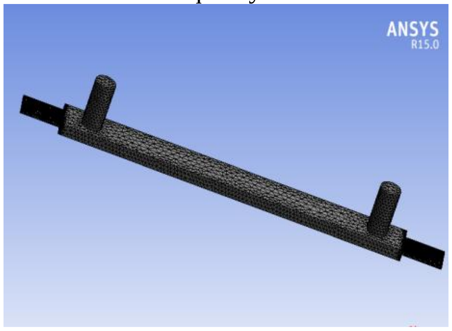


Figure 4.7: Meshing: Total No. of Nodes: 61915& Total No. elements: 160624

### D. DEFINING MATERIAL PROPERTIES

R32 is used as a refrigerant and supplied at different temperature with different mass velocity. Different properties of R32 are mentioned in below table

Table.3. R32 Properties

| Properties | Values |
|---|---|
| Density (kg/m^3) | 21.98 |
| Cp Specific Heat (j/kg-k) | 1250 |
| Thermal Conductivity (w/m-k) | 11720 |
| Viscosity (kg/m-s) | 0.0000151 |

Aluminum is used for mini-channel tubes

Table .4. Aluminum Properties

| Aluminum Properties | Values |
|---|---|
| Density (kg/m^3) | 2719 |
| Cp Specific Heat (j/kg-k) | 871 |
| Thermal Conductivity (w/m-k) | 202.4 |

Steel is allotted to the outer body

Table .5. Steel Properties

| Steel Properties | Values |
|---|---|
| Density (kg/m^3) | 8030 |
| Cp Specific Heat (j/kg-k) | 502.48 |
| Thermal Conductivity (w/m-k) | 16.27 |

### E. NAME SELECTION

Name was assigned to each part of the model with inlet and outlet

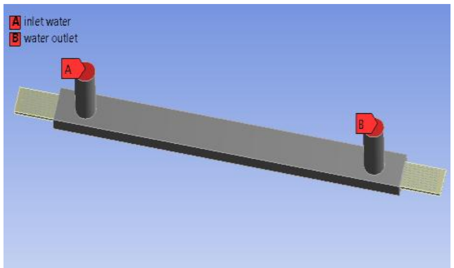


Fig.9: Inlet and Oulet for water body

Fig.10: Inlet and Oulet for R32.

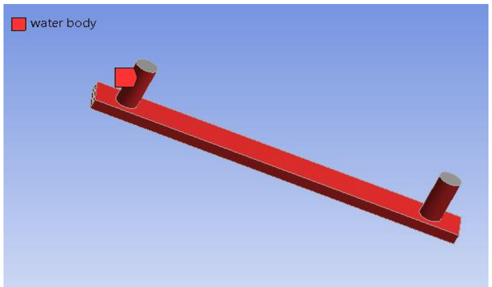


Fig.11: Water Body

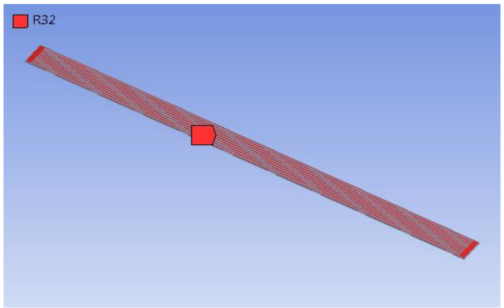


Fig.12: R32 Body

### *F. BOUNDARY CONDITION*

1. CFD analysis is carried out for three different cases of water saturation temperature and for 4 different mass velocities (flux) of R32 refrigerant.
2. R32 is supplied at a constant temperature of 35°C.
3. Four cases of mass velocities G= 350 kg/m^2-s, 470 kg/m^2-s, 590 kg/m^2-s, 710 kg/m^2-s.
4. Three cases of water temperature Tw= 20°C, 25°C, 30°C.

## VI. RESULT

### *A. RESULTS OF 1ST CASE*

#### *1) Pressure Contour at 30°C*

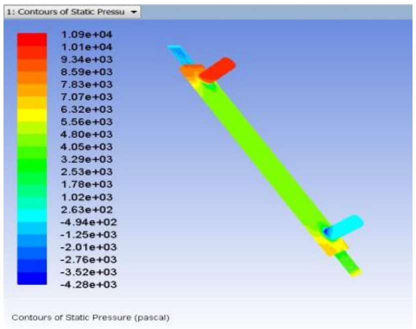


Fig. 13. Pressure Contour at mass flux 350 kg/m^2-sec

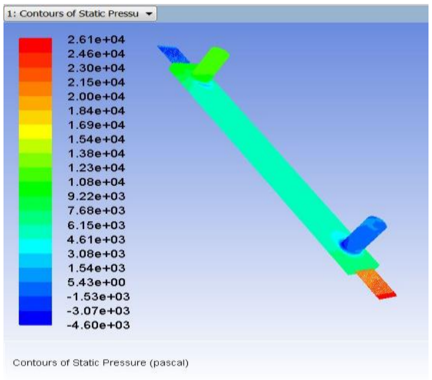


Fig.14. Pressure Contour at mass flux 470 kg/m^2-sec

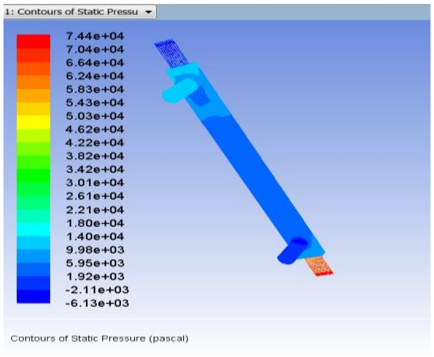


Fig.15. Pressure Contour at mass flux 590 kg/m^2-sec

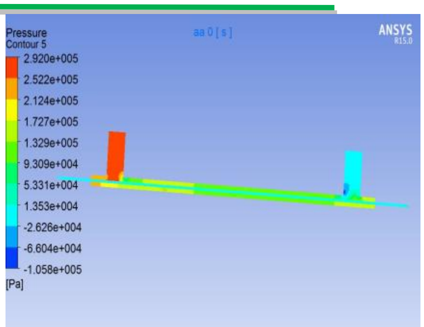


Fig.16. Pressure Contour at mass flux 710 kg/m^2-sec

#### *2) Pressure Contour AT 20°C*

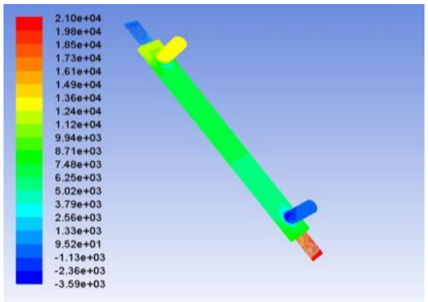


Fig.17. Pressure Contour at mass flux 350 kg/m^2-sec

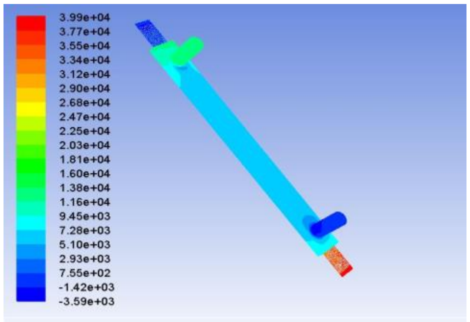


Fig.18. Pressure Contour at mass flux 470 kg/m^2-sec

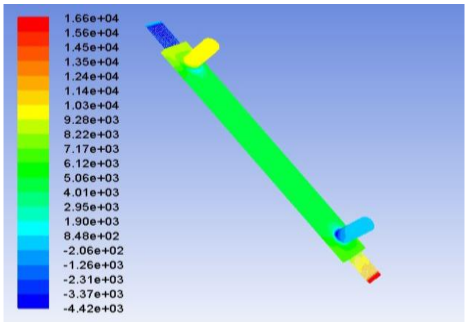


Fig.19. Pressure Contour at mass flux 590 kg/m^2-sec

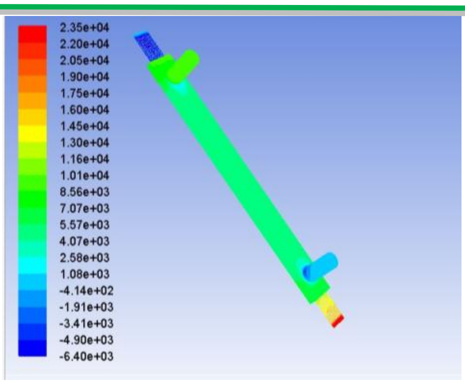


Fig.20. Pressure Contour at mass flux 710 kg/m^2-sec

### 3) *Pressure Contour AT 25°C*

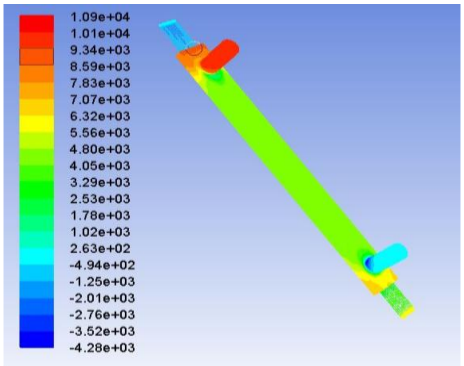


Fig.21. Pressure Contour at mass flux 350 kg/m^2-sec

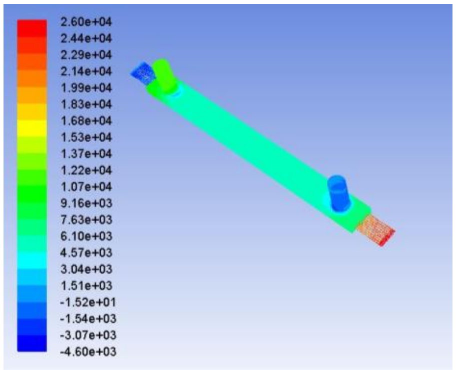


Fig.22. Pressure Contour at mass flux 470 kg/m^2-sec

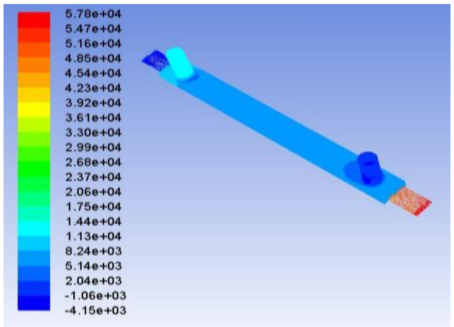


Fig.23. Pressure Contour at mass flux 590 kg/m^2-sec

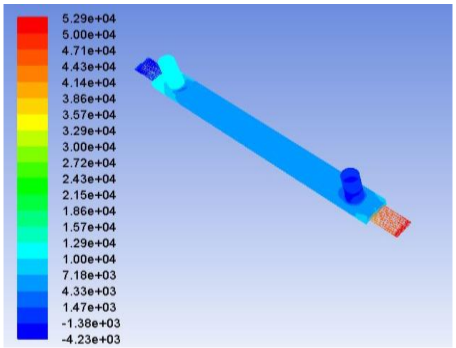


Fig.24. Pressure Contour at mass flux 710 kg/m^2-sec

## B. *RESULTS OF 2nd CASE*

### 1) *Pressure Contour at 20°C*

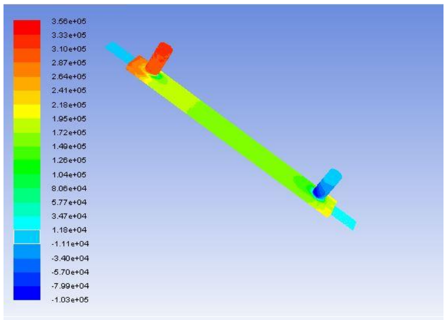


Fig.25. Pressure Contour at mass flux 350 Kg/m^2-sec

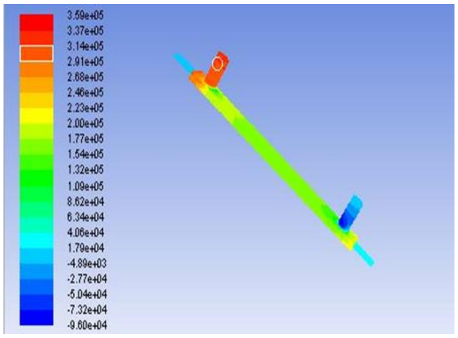


Fig.26. Pressure Contour at mass flux 470 Kg/m^2-sec

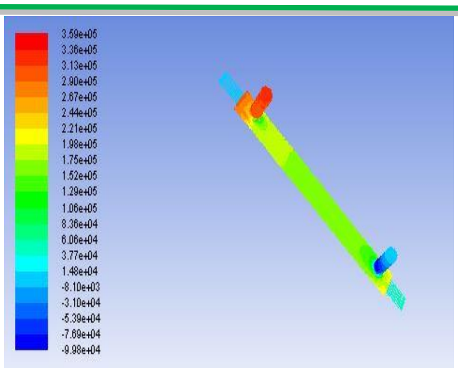


Fig.27. Pressure Contour at mass flux 590 Kg/m^2-sec

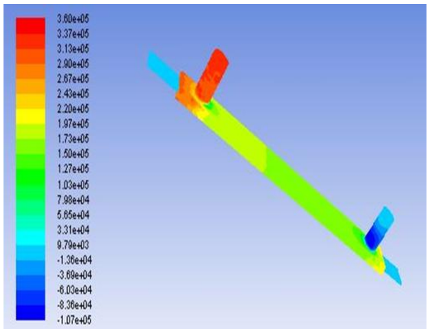
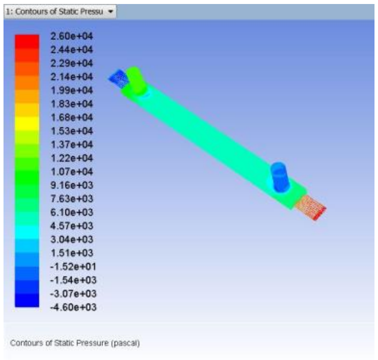


Fig.28 Pressure Contour at mass flux 710 Kg/m^2-sec



## 2) *Pressure Contour AT 30°C*

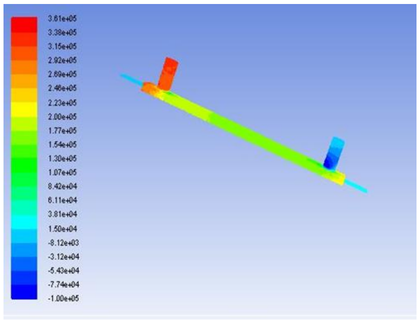


Fig.29. Pressure Contour at mass flux 350 Kg/m^2-sec

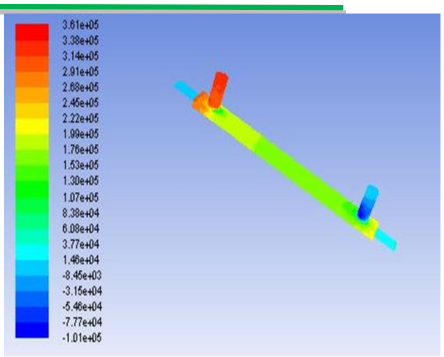


Fig.30. Pressure Contour at mass flux 470 Kg/m^2-sec

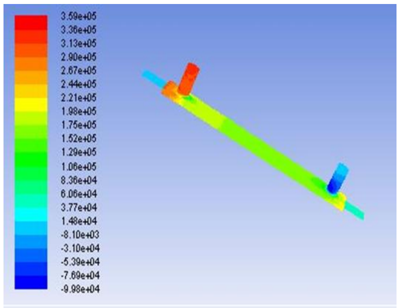


Fig.31. Pressure Contour at mass flux 590 kg/m^2-sec

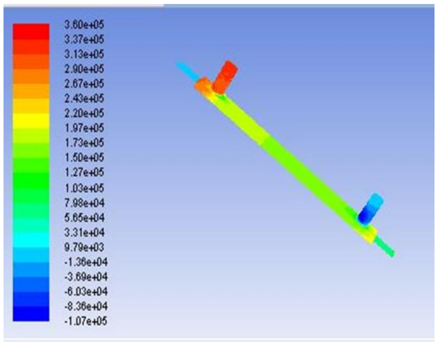


Fig.32. Pressure Contour at mass flux 710 kg/m^2-sec

## 3) *Pressure Contour AT 25°C*

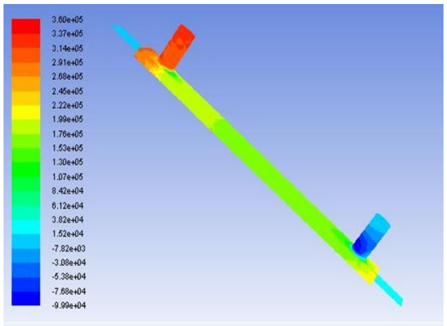


Fig.33. Pressure Contour at mass flux 350 kg/m^2-sec

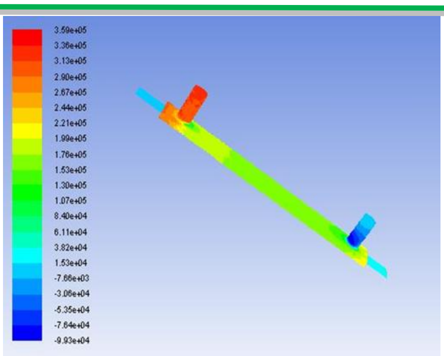


Fig.34. Pressure Contour at mass flux 470 kg/m^2-sec

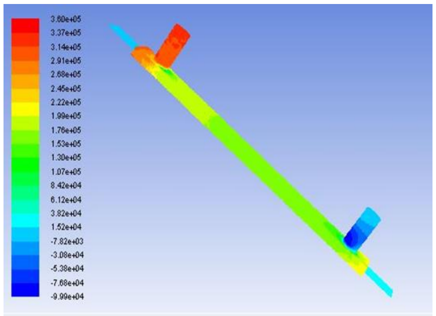


Fig.35. Pressure Contour at mass flux 350 kg/m^2-sec

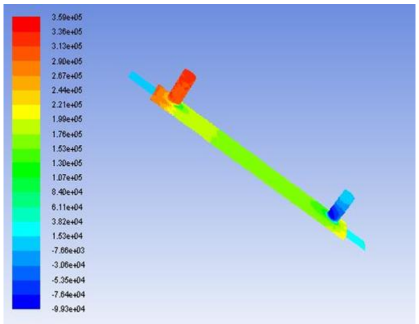


Fig.36. Pressure Contour at mass flux 470 kg/m^2-sec

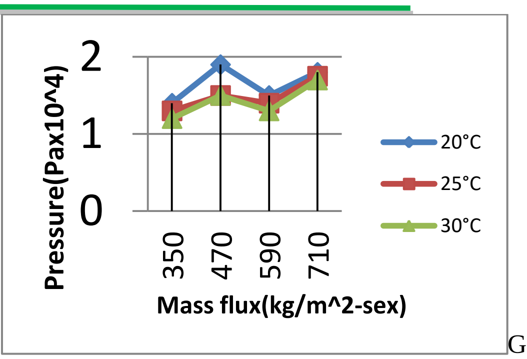
### C. *RESULTS OF 1ST CASE*

Comparison table of pressure drop based on CFD based result

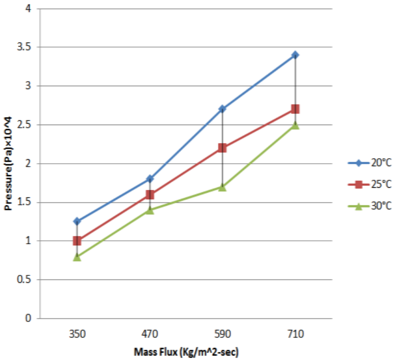
Table 5:- Results Based on CFD analysis

| s.no | AT 20$^0$C | AT25$^0$C | AT30$^0$C | MASS FLUX (KG/M$^2$S) |
|---|---|---|---|---|
| 1 | 1.4 | 1.3 | 1.2 | 350 |
| 2 | 1.9 | 1.5 | 1.5 | 470 |
| 3 | 1.5 | 1.4 | 1.3 | 590 |
| 4 | 1.8 | 1.75 | 1.7 | 710 |

Comparison based on Experimental and CFD based result



Graph .1:- Results Based on CFD analysis

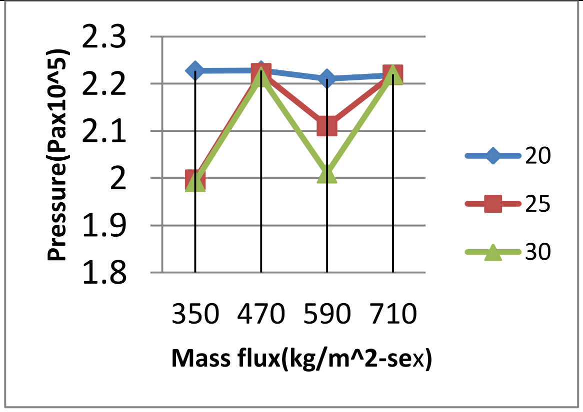


Graph .2:- Results Based on Experimental analysis in Base Paper

### D. *CFD based result for case 2$^{ND}$ :-*

Table 5.2:- Results Based on CFD analysis

| s.no | AT 20$^0$C | AT25$^0$C | AT30$^0$C | MASS FLUX (KG/M$^2$S) |
|---|---|---|---|---|
| 1 | 2.2 | 1.9 | 1.9 | 350 |
| 2 | 2.2 | 2.2 | 2.2 | 470 |
| 3 | 2.2 | 2.1 | 2.01 | 590 |
| 4 | 2.2 | 2.2 | 2.2 | 710 |



Graph .3: - Case 2nd Results

## VII. COUNCLUSION

In first case of CFD analysis results are varying with respect to experimental results. Pressure drop is increasing with first two values of mass velocity but with further increase in mass velocity pressure drop decreases especially in case of 20°C and 30°C. In first case of experimental analysis at each case of water temperature, with increase in mass velocity, pressure drop also increases. In second case of CFD analysis results are varying with respect to experimental results. Pressure drop is increasing with first two values of mass velocity but with further increase in mass velocity pressure drop decreases especially in case of 25°C and 30°C.comparing the result of case 1st and case 2nd .The value of pressure drop in case 2nd is higher than the case 1st and the overall efficiency of the system increase in case 2nd.

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