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Design and Development of an Experimental Set Up for Performance Evaluation of Plate Heat Exchanger under Parallel Conditions

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Abstract: Heat exchangers are widely used in thermal systems. Condensers, boilers, intercoolers, and preheaters are some examples of heat exchanger devices used in power plants. Heat exchanger performance can be characterized by finding its effectiveness. They are also used widely in many industries for heat recovery or cooling purposes. Performance of parallel flow heat exchanger considering changes in water to be studied. In this paper, we are going to study previous paper and conclude with the results. By going through research paper, we came to know that heat exchanger performed varies from fluid to fluid and temperature to temperature. Also, we have calculated LMTD by varying flow rate and temperature of hot water and cold water. The performance of such heat exchangers under different operating conditions is also discussed.
Keywords: Thermal, recovery, thermodynamic, gasketed, parallel flow, LMTD, Heat transfer coefficient.

I. INTRODUCTION

Heat exchanger is a mechanical device which is used in many industries like food industry, refrigeration system, petroleum industry, aircraft industry (To make aircraft cool during the flight.). Heat exchanger is used to transfer energy between two fluids, between a solid surface and fluid at different temperature and in thermal contact. Examples of heat exchanger: - 1) Boilers, super heater, reheats.2) Radiators of automobile. 3) Oil coolers of heat engine.4) Regenerator of gas turbine power plant.5) water and air coolers or heaters. This is the examples of heat exchanger.

Types of heat exchanger:

1) Shell and tube heat exchanger.
2) Plate heat exchanger.
3) Double pipe heat exchanger.
4) Condensers, evaporators, and boilers.

In these types, we choose Plate heat exchanger

For performance evaluation under parallel conditions. In this research paper only mention about experimental set up performance.

Plate heat exchanger is a type of heat exchanger. It is used to transfer the heat between two moving fluids. In this plate heat exchanger used two types of fluid i.e. hot fluid and cold fluid. Heat transfer between hot and cold fluid alternatively. In this plate heat exchanger (PHE) we are used corrugations type of plate because to improve the heat transfer rate.

PHE is build form frames, plates, and others parts cab be combined to form a number of different heat exchanger types. PHE basically build or assemble form frames, guide bar, removable cover, plate packs, fixed cover plate, carrying bar, gasket, etc. in this parts PHE assemble or build.

A. Parallel Flow

An Arrangement of a heat exchanger where the hot and cold fluids enter at the same end and flow to the exit is known as parallel flow.

II. EXPERIMENT SETUP

In this experimental setup consist of thermometer, flow measurement meter (Rota meter), stop watch, plate heat exchanger, hot water and cold-water tank, temperature sensors, pipes, stop vales, water flow regulator. We are used stainless steel 304 plate heat exchanger and plate heat exchanger has total 16 plates.gap between two plate is 1mm.We are used external pipes to carry hot and cold water. Inlet pipes are connected to top of heat exchanger and outlet pipes connected bottom of heat exchanger. Hot and cold-water flow through pipes and this water flow control the water flow regulator. It is connected on pipeline. Rota meter used to measure the flow rate of water and thermometer are placed to measure inlet and outlet temperature of hot and cold water. In this experiment we are perform parallel flow arrangement.

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A. Plate and Frame heat Exchanger

1) It is easy to dissemble and clean and also it is distributed heat evenly so that there are no hot spot.
2) Easy to added plates and removed easily.
3) High rate of heat transfer, low fouling, low fluid resistance time.

B. Safety Issue

We are used in this experiment hot water fluid that's why there are more chances to bust the pipe and leaking the water. So all piping checks before perform the experiment and be sure that all the electronics parts are turned off. For avoid the serious injuries.

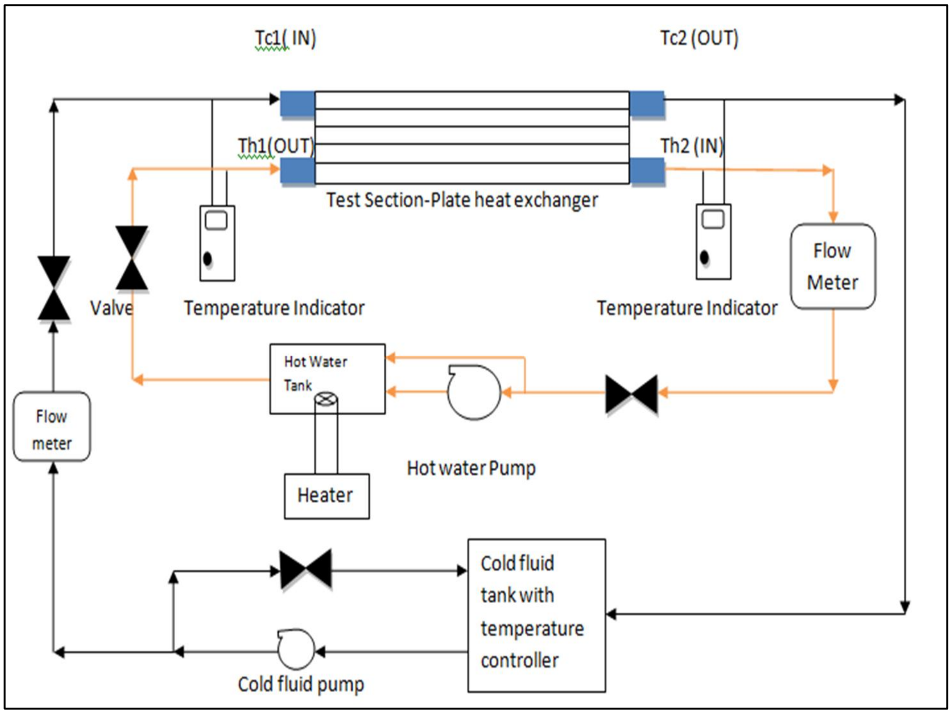

Fig.II.1 Experiment setup Flow Diagram

III. WORKING PRINCIPLE

A plate heat exchanger consists of a parallel flow arrangement. The plates are placed one above the others. So as to allow the series or parallel flow of fluid between them.

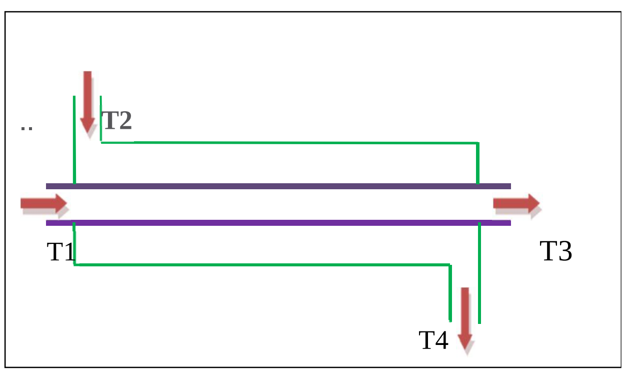

Fig.III.1 Parallel flow Diagram

Where,
T1 - Hot Water Inlet
T2 – Cold Water Inlet
T3 – Hot Water Outlet
T4 – Cold Water Outlet

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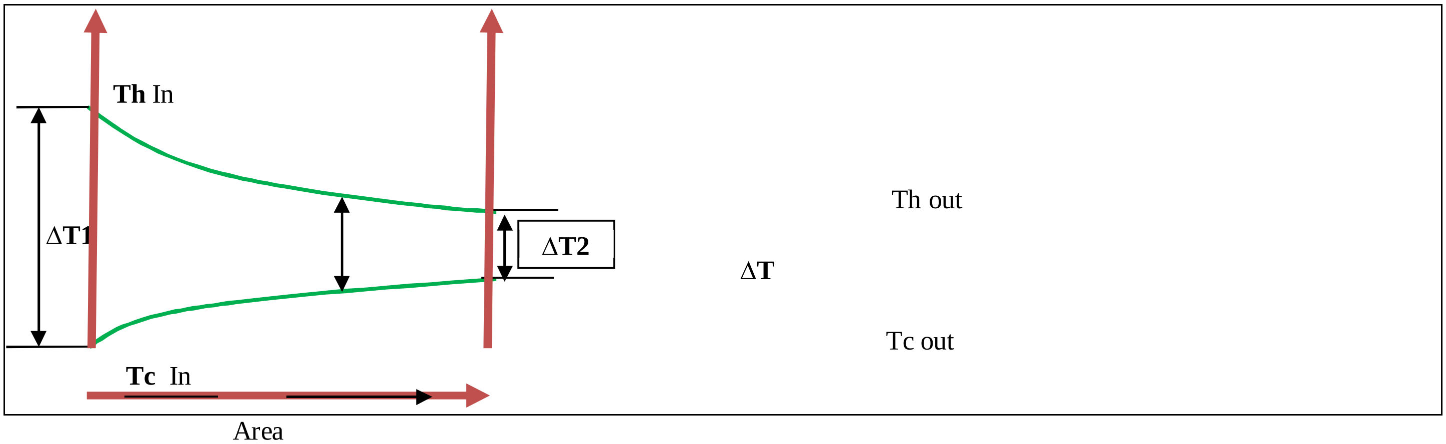

Fig.III.2 Temperature distribution in parallel flow

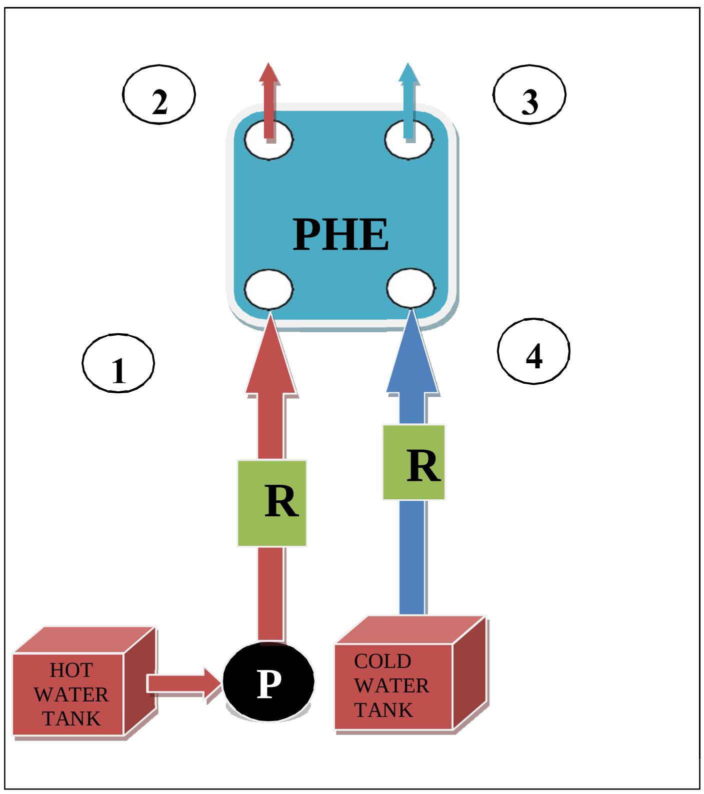

Fig.III.3 Parallel Flow Arrangement

Where,
R- Rota meter
P-pump
1 - Thi (Hot fluid inlet)

2 - Tho (Hot fluid outlet)

3 - Tci (Cold fluid Inlet)

4- Tco (Cold fluid outlet)

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IV.PROCEDURE

1) To check the inlet and outlet piping connections.
2) To fill the hot and cold water tanks.
3) After that to open the valve and start the flowing water.
4) Then to control the water flow rate through the valve.
5) Measure the water flow rate hot and cold water.
6) To control the water flow rate then to check the hot and cold water temperature with help of thermometer before entering the PHE.
7) Then water flow entering the PHE and process will start temperature distributes hot and cold water.
8) Then hot and cold water out through the outlet pipeline.
9) Then check the temperature of hot and cold water and calculate the temperature difference between hot and cold water.
10) Again same process will repeat for different temperature and different pressure.
11) This process will repeat for counter flow also.

A. *Plate heat Exchnager Setup*

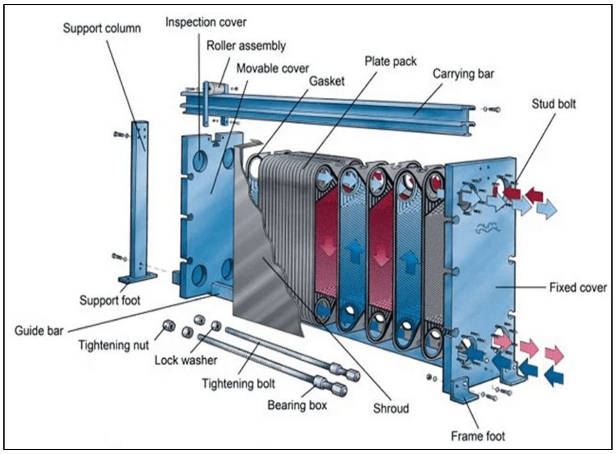

Fig.IV.1 Plate Heat exchanger

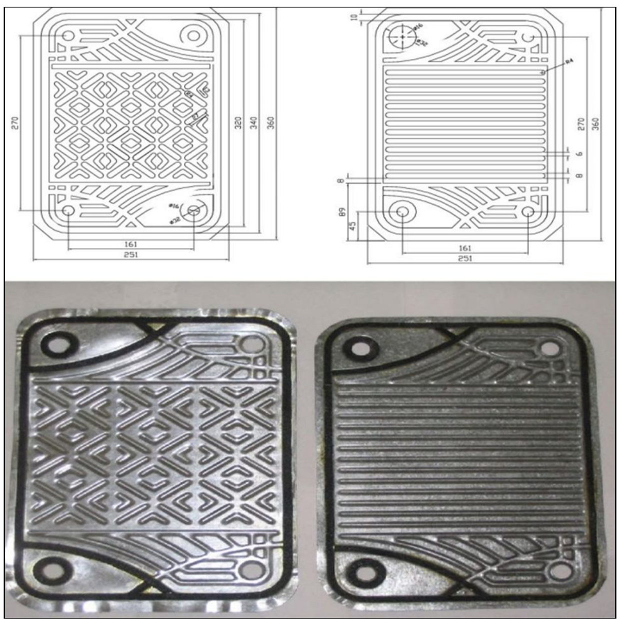

Fig.IV.2 Internal plates of heat exchnager

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V. CALCULATIONS

In this experiment we are calculated heat transfer rate, overall heat transfer coefficient, temperature difference using the LMTD (log mean Temperature difference) equation.

A. LMTD Equation for Parallel flow Arrangement

1) Assumptions of LMTD

a) Hot and Cold fluid flow rates are constant.
b) No heat loss or no heat gain from surrounding.
c) To apply steady state condition.
d) Hot and cold fluid specific heats are constant.
e) Kinetic energy and potential energy are constant.

➢ *LMTD Equation*

$$\delta Q = -mh.Cph.dTh \qquad [1]$$

$$\delta Q = mc.Cpc.dTc \qquad [2]$$

This equation [1] & [2] is rate of heat loss from hot and cold fluid at any section of heat exchanger is equal to the rate of heat gain by cold fluid section.

In equation [1] hot fluid temperature change in negative quantity so negative sign is added and to make the heat transfer rate (Q) is a positive quantity.

Solving the above equation for dTh and dTc, we get,

$$dTh = -\frac{\delta Q}{(mh.Cph)} \qquad [3]$$

and

$$dTc = \frac{\delta Q}{(mc.Cpc)} \qquad [4]$$

We are taking there difference ,we get,

$$d(Th - Tc) = -\delta Q \frac{1}{(mh.Cph)} + \frac{1}{(mc.Cpc)} \qquad [5]$$

So the heat transfer rate in different section of heat exchanger can also be expressed as,

$$\delta Q = U(Th - Tc)dAs$$

Substitute this equation in equation [5] , we get
Integrating from inlet and outlet of heat exchanger, we obtain

$$ln\frac{Th,out - Tc,out}{Th,in - Tc,in} = UAs\frac{1}{mh.Cph} + \frac{1}{mc.Cpc} \qquad [6]$$

Applying first law of thermodynamics that is required the rate of heat transfer from the hot fluid is equal to the rate of heat transfer to the cold fluid.

$$Q = mc.Cpc(T(c,out) - T(c,in))$$

And

$$Q = mh.Cph(T(h,in) - T(h,out))$$

We take the value of mCp From above equation and substituting the integrating solution,

We get,

$Q = UAs\Delta Tlm$

Where,

$$\Delta lm = \frac{(\Delta T1 - \Delta T2)}{\ln(\frac{\Delta T1}{\Delta T2})}$$

Where,
Q = Heat transfer rate
Cp= specific heat
δt = Temperature difference between inlet and out let on one end
m= mass flow rate
A= heat transfer area
LMTD = log mean temperature difference.

B. Overall heat Transfer Coefficient

$$\boldsymbol{q = UAdT}$$

$$U = \frac{Q}{A\Delta Tlm}$$

Where,

q = Heat transfer

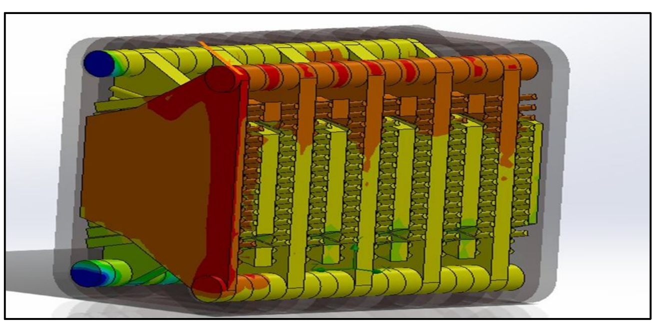
U = overall heat transfer coefficient

A = area of plate

dT= (T1-T2) temperature difference

VI. RESULT AND DISCUSSION

A. Computational Fluid Dynamics (CFD)analysis on Plate Heat Exchanger



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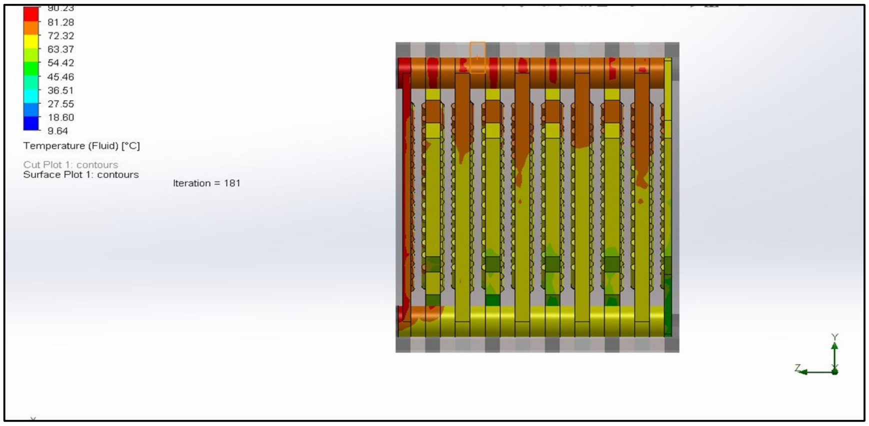
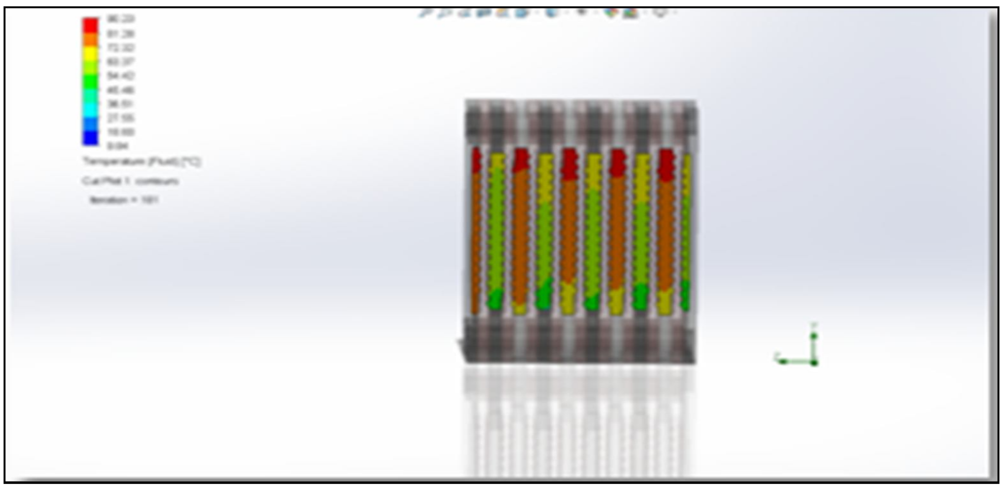
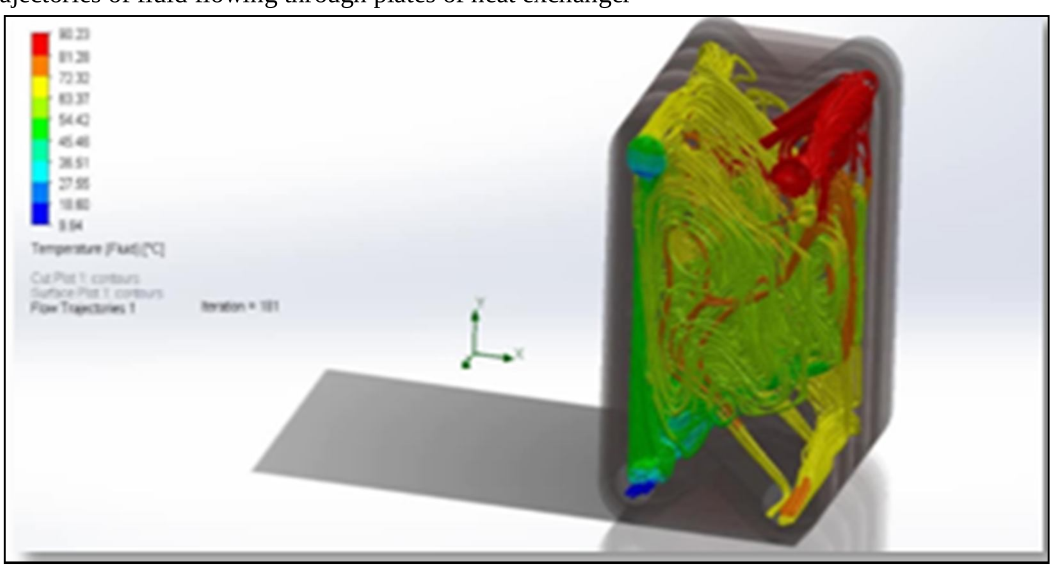
1) Visuals of surface plots on plates of heat exchanger



2) Visuals of temperature differences on plates from side



3) Visuals of trajectories of fluid flowing through plates of heat exchanger



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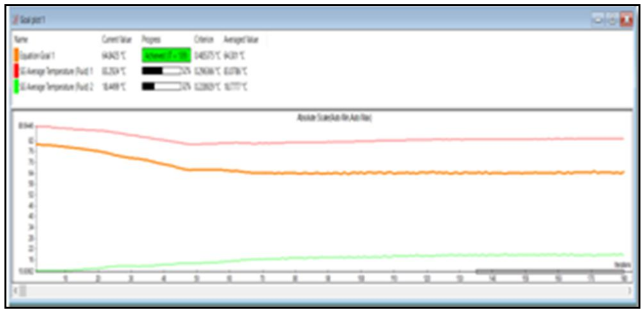
B. Graphs Result

These are the graphs resulted after the performance of the experimental set-up.

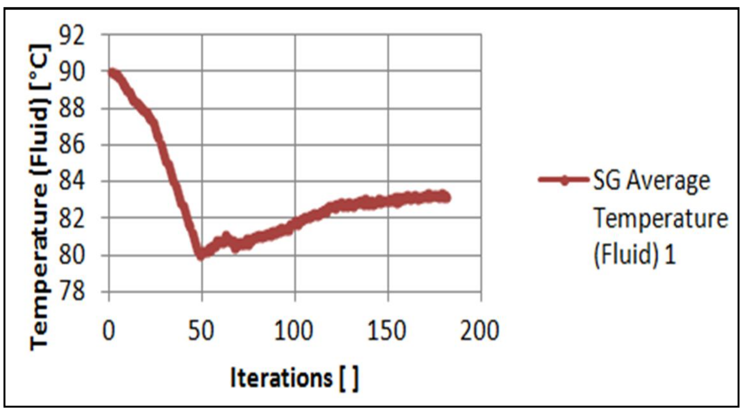
1) Average Temperature Difference



In this graph, each point represents the iterations if temperature i.e. 181 iterations. The Red line indicates the temperature changes of hot fluid. The green line indicates the temperature changes of cold fluid. The orange line indicates the temperature differences between hot fluid and cold fluid throughout the 181 iterations.

a) Chart 1

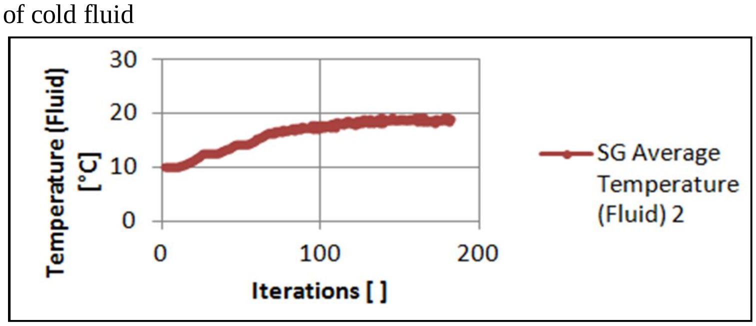
Results of temperature change of hot fluid



In this graph, X axis is temperature of hot fluid and Y-axis is no. of iterations. Each point of the line represents the temperature of hot fluid.

b) Chart 2

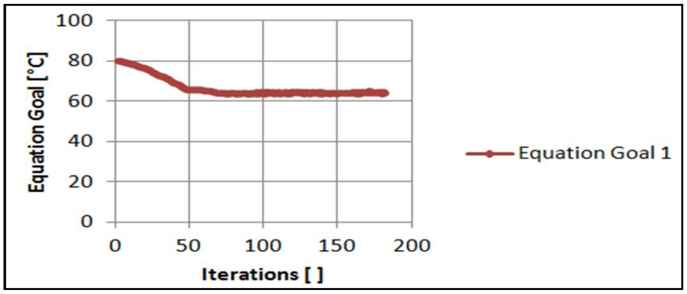
Results of temperature change of cold fluid



In this graph, X axis is temperature of cold fluid and Y-axis is no. of iterations. Each point of the line represents the temperature of cold fluid.

c) Chart 3

Results of average temperature differences:



In this graph, X axis is temperature changes between hot and cold fluid and Y-axis is no. of iterations. Each point of the line represents the temperature change between hot and cold fluid

VII. CONCLUSIONS

A. The heat loss of the heat exchanger increased as the cooling water flow rate is increased percentage of heat loss should remain constant.
B. Heat loss to the surrounding is around 24% to 32%.
C. Overall heat coefficient also increases with the cooling water flow rate.
D. Numbers of transfer units for heat transfers are 0.019.
E. Effectiveness of heat exchanger is approx. 0.085.
F. Overall heat coefficient observed during the experiment was 0.051 m2k.
G. Heat transfer of heat exchanger was 0.285 Kw.
H. The calculation and results of the simulated experiment and actual experiment are similar.

VIII. ACKNOWLEDGMENT

This Project is definitely not the effort of just a few individuals, but was made possible because of guidance and help from various people directly or indirectly. I express my sincere thanks and profound gratitude to the principal of our college, Head of Department Dr. R. R. Arakerimath, project guide Prof. Sanjay Mitkari all teaching staff or their valuable guidance and co-operation without which I would have found it unable to complete my report work. They not only retained construction service of initiative but also encouraging and constantly supervising in completion of project report.

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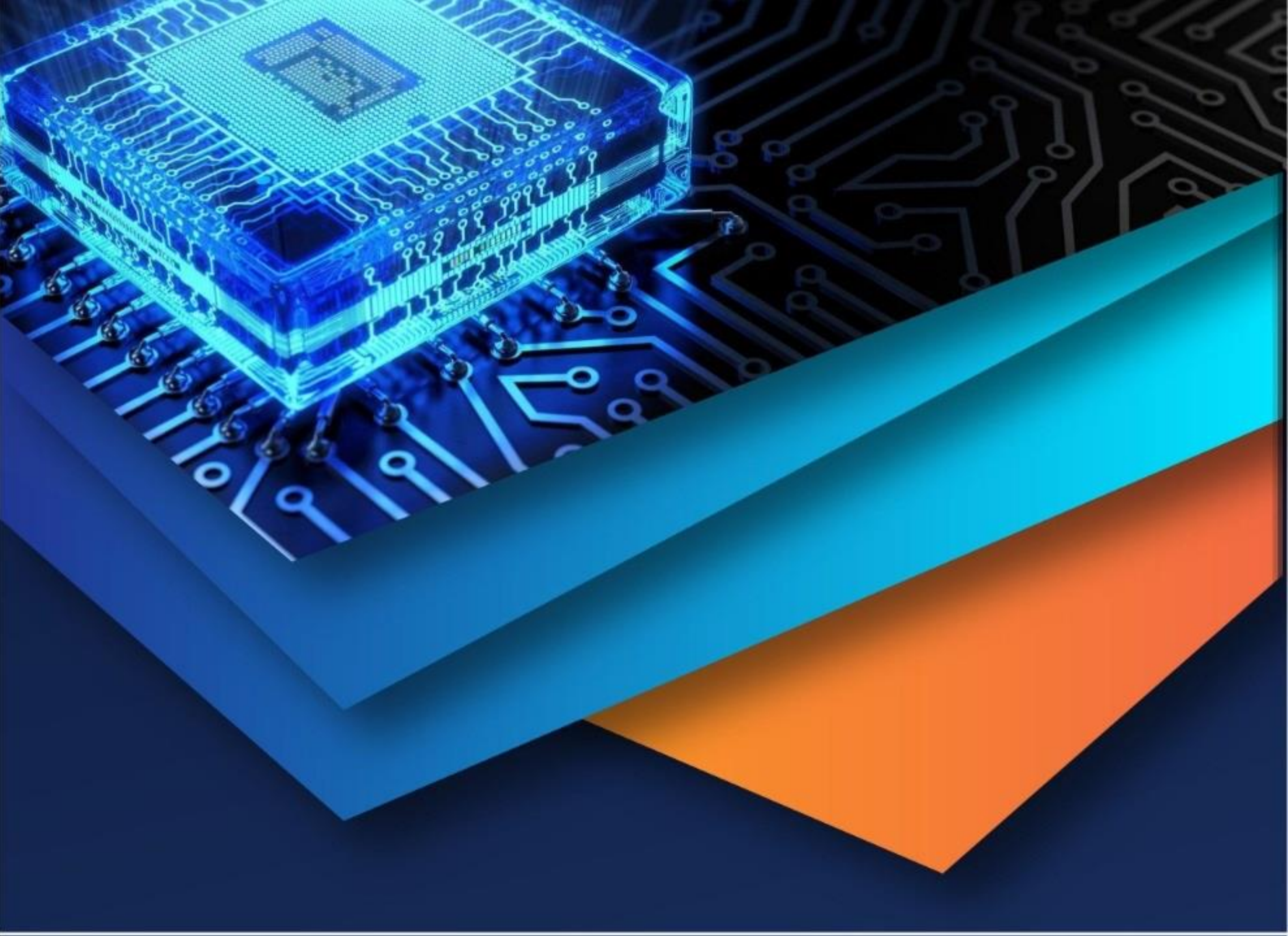

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