iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: XII Month of publication: December 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887
Volume 5 Issue XII December 2017- Available at www.ijraset.com

Design and Fabrication of Automotive Triple Tube Heat Exchanger (With Guided Sinusoidal Motion)

Arun Subramanian S.[1]
[1]*Mechanical Engineering, S.R.M. University, Chennai, India*

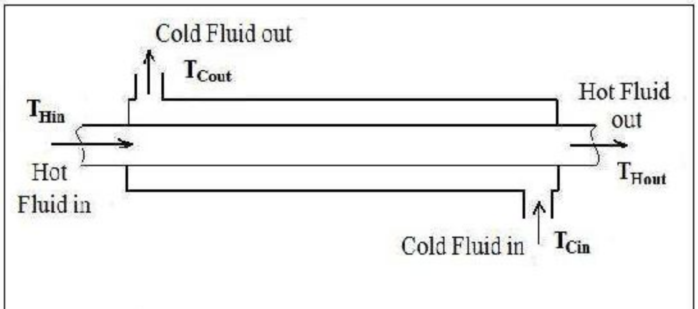
Abstract: Heat Exchangers are mechanical systems that are designed for absorbing heat from functional components of a mechanical system. Absorption of heat has several dimensions. In some places, it may be absorbed from the working fluid to reduce its temperature and in some places it may be absorbed by the fluid. In this backdrop, Heat Exchangers are designed according to the need. Presently, as a result of the advent of technology, several types of heat exchangers have come up. Most automotive heat exchangers are similar to shell and tube cross flow design, with multiple tube passes. But instead of having a defined shell around the tubes, with another controlled fluid forced across the tubes by means of a pump, there is no limited control volume for the shell. The tubes are open to the air and are dependent upon outside conditions. Upon the one based on fluids, the double pipe heat exchangers are widely used. In a double pipe, there is the hot fluid pipe and cold fluid pipe. How will the heat exchange process be impacted if a third pipe was added to the existing system and the fluid flow guided to follow a specific path? This is the solution we sought to find out through the triple pipe heat exchanger. The variations that we tried include a third pipe, double chamber approach and sinusoidal fluid flow. Thus this project arose from the curiosity to expand the existing the concept to achieve better efficiency and how further research may lead to impactful practicalapplications. This project report gives a comprehensive view of all the parameters involved, the several stages that lead to the completion of the project and the results thus obtained along with the conclusive note.

I. INTRODUCTION

Tubular heat exchangers are that class of heat exchangers which are widely used. They contain tubes through which the target fluid and cooling fluid pass through separated by a wall. These are designed based on the specific situation that arises. There are several types of tubular heat exchangers and they are analysed by several well established techniques. Tubular are heat exchangers can be classified upon several parameters and they are mentioned below.

Double pipe Heat exchanger:As conditions in the pipes change: inlet temperatures, flow rates, fluid properties, fluid composition, etc., the amount of heat transferred also changes. This transient behaviour leads to change in process temperatures, which will lead to a point where the temperature distribution becomes steady. When heat is beginning to be transferred, this changes the temperature of the fluids. Until these temperatures reach a steady state their behaviour is dependent on time. In this double-pipe heat exchanger a hot process fluid flowing through the inner pipe transfers its heat to cooling water flowing in the outer pipe.

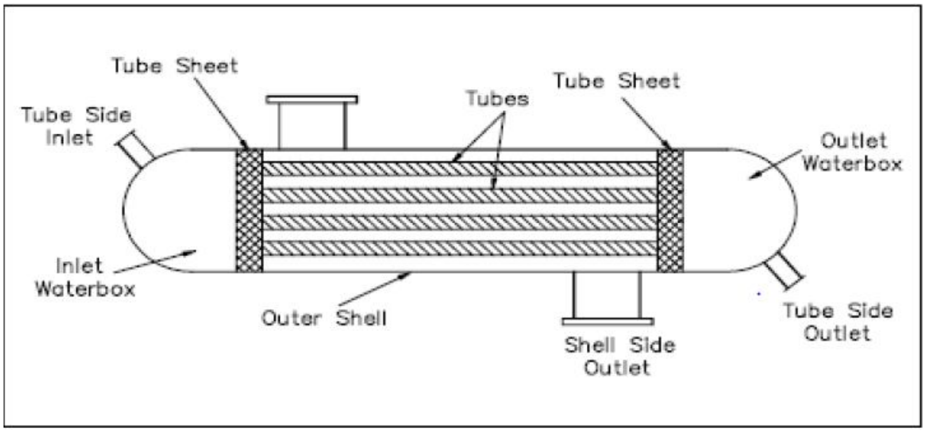
The system is in steady state until conditions change, such as flow rate or inlet temperature. These changes in conditions cause the temperature distribution to change with time until a new steady state is reached. The new steady state will be observed once the inlet and outlet temperatures for the process and coolant fluid become stable. In reality, the temperatures will never be completely stable, but with large enough changes in inlet temperatures or flow rates a relative steady state can be experimentally observed.



Counterflow Double Pipe Heat Exchanger

A. Shell and Tube Heat Exchanger

A Shell and tube heat exchanger is a class of heat exchanger designs. It is the most common type of heat exchanger in power plants, oil refineries and other large chemical processes. As its name implies, this type of heat exchanger consists of a shell (a large vessel) with a bundle of tubes inside it. In order to transfer heat efficiently, a large heat transfer area should be used, so there are many tubes. In this way, even waste heat can be put to use. This is a great way to conserve energy. Usually cylindrically-shaped shell-and-tube heat exchangers are preferred. The reasons for general acceptance of S&THX are several. The shell and tube heat exchanger provides a comparatively large ratio of heat transfer area to volume and weight. It provides this surface in a form which is relatively easy to construct in a wide range of sizes and which is mechanically rugged enough to withstand normal shop fabrication stresses, shipping and field erection stresses, and normal operating conditions. The shell and tube exchanger can be reasonably easily cleaned.Those components often subject to failure - gaskets and tubes – can be easily replaced. Shop facilities for the successful design and construction of shell and tube exchangers are available throughout the world. Coiled type heat Exchangers are an extension of shell and tube.



B. Problem Identification

Most automotive heat exchangers are similar to shell and tube cross flow design, with multiple tube passes. This causes a reduction in cost effectiveness and efficiency.

II. APPLICATIONS OF TUBULAR HEAT EXCHANGERS

Heat exchangers are widely used in industry both for cooling and heating large scale industrial processes. The type and size of heat exchanger used can be tailored to suit a process depending on the type of fluid, its phase, temperature, density, viscosity, pressures, chemical composition and various other thermodynamic properties. In many industrial processes there is waste of energy or a heat stream that is being exhausted, heat exchangers can be used to recover this heat and put it to use by heating a different stream in the process. This practice saves a lot of money in industry, as the heat supplied to other streams from the heat exchangers would otherwise come from an external source that is more expensive and more harmful to the environment. Heat exchangers are used in many industries, including:

A. Automobile
B. Waste water treatment
C. Refrigeration
D. Wine and beer making
E. Petroleum refining

III.DESIGN CONSIDERATIONS

There are three classes of design, namely- New, Adaptive and developmental design.

The subject that we undertook fell under the category of developmental designwhereby we took an existing model and brought in changes that could possiblyimprove process efficiency.Generally while heat exchangers (tubular) are designed, the following are taken intoaccount:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887
Volume 5 Issue XII December 2017- Available at www.ijraset.com

A. Analysis of Application

When an enquiry for a heat exchanger is received, the first step consists in analyzing the application. The design engineer must define correctly the type of heat exchanger that is necessaryand complies with the requirements of the application. As can be seen in our product portfolio, various types of heat exchangers can be used. The design temperature, design pressure and maximum allowable pressure drop must be defined for the product and service fluids.

B. Identifying The Fluid Properties

The next step is analyzing the fluids involved: the product side fluid and service side fluid. In order to do a correct design of a heat exchanger, four important physical properties of the fluids involved need to be known:

1) Densit
2) Specific hea
3) Thermal conductivity
4) Viscosity

The correct way to proceed is to obtain values for these four parameters for various temperatures in the heating or cooling curve of the application. The better we understand the physical properties of the fluids involved, the more accurate will be the design of the heat exchanger. Any mistake in the physical properties involved can lead directly to a wrong design of the heat exchanger.

C. The energy balance

Once correctly defined the physical properties, it is time to check the energy balance. Normally the customer defines the products flow rate and the desired entry and exit temperature of this product. He will have to indicate the type of serviced fluid to be used and define two of the following three parameters: service flow rate, service entry temperature or service exit temperature. With two of these known, solving the energy balance, the third parameter is calculated. Completing step 3 fixes the flow rates and entry and exit temperatures of the product and service side fluids.

D. Defining the geometry

In this step the design engineer defines the geometry of the heat exchanger. He will choose the shell diameter and will define the tube bundle that is placed inside the heat exchanger: nr of inner tubes, inner tube diameter and wall thickness and the length of the inner tubes. Secondly, the dimensions of the shell and tube side fluid connections are defined. At this stage also the choice of materials applied has to be made. By standard HRS Heat Exchanger applies stainless steels for shell and tubes side, but also other alloys can be applied.

E. Thermal Calculations

At this stage the design engineer performs a thermal calculation. The objective of this calculation is to obtain the shell and tube side heat transfer coefficients.

These coefficients depend basically on the four key fluid parameters and the velocity of the fluid. The relation between the parameters and the heat transfer coefficients is defined in a mathematical formula that is specific to the geometry applied (tubular heat exchanger, plate heat exchanger, corrugated tube).

HRS Heat Exchangers has derived its own specific mathematics as it works with corrugated tubes. With shell and tube side coefficients known, the overall heat transfer coefficient can be calculated. Knowing this value, it becomes possible to calculate the total heat transfer area needed for the application:

Area = Duty / [K x LMTD]

Where:

Area = Total heat transfer area required, m2.

Duty = Total heat transferred, kcal/hr (derived from energy balance).

K = Overall heat transfer coefficient, kcal/[hr.m2.°C].

LMTD = Log mean temperature difference, °C (the average logarithmic temperature difference between shell and tube side fluid over the heat exchanger length).

Another important parameter defined is the pressure drop which is calculated for the shell and tube side fluids. The pressure drop is a function of the Reynolds number, the type of flow (turbulent or laminar flow) and the roughness value of the shell and inner tubes.

IV. EXPERIMENT SETUP

A. Materials Used

1) Thermocouple

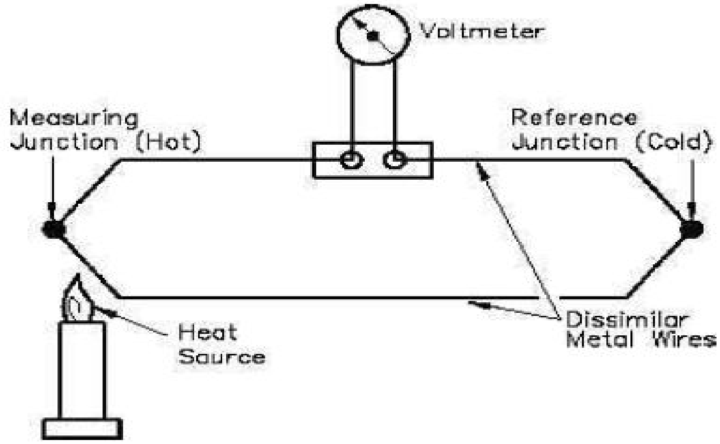
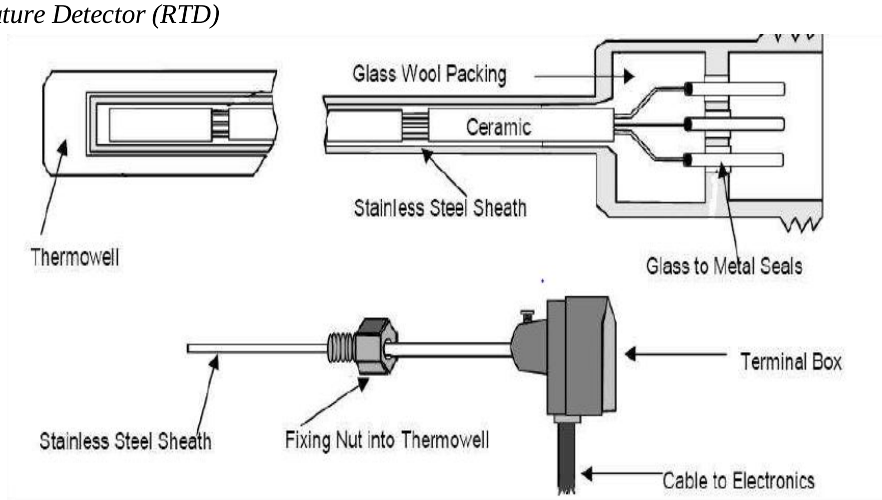


Fig: Principle of Thermocouple

When a temperature differential exists across the length of a metal, a small voltage differential will exist due to the migration of electrons in the metal. By joining two dissimilar metal wires together at one end, a small current will be induced at the junction due to differences in the molecular structure of the metals.For dissimilar metals at a given temperature, the density of free electrons is different. This results in an electron migration at junction (a), causing a small current to flow from one metal to other. This small induced electric differential, with proper signal

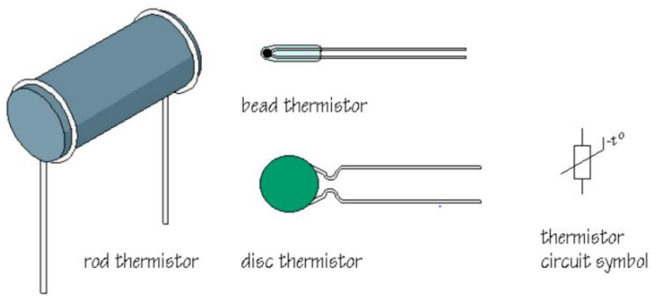
Conditioning is measured. The electric signal has the property of being linear with the temperature differential between points (a) and (b).

2) Resistance Temperature Detector (RTD)



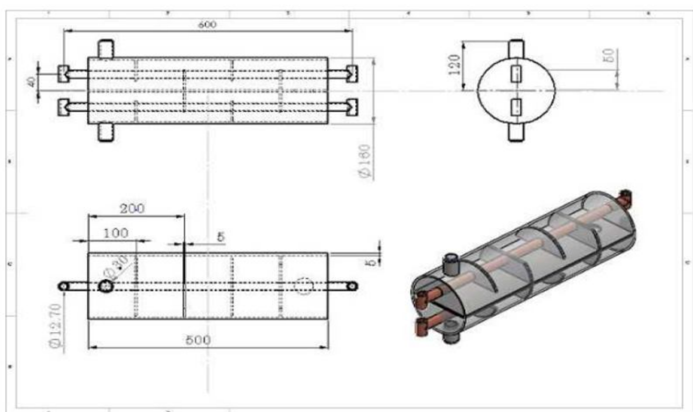
The RTD temperature sensor is based on a particular property of metals wherein their electrical resistance changes with temperature. In particular, as temperature increases, so does electrical resistance. This is due to the fact that a higher temperature in a metal results in electron vibrations that impede the flow of free electrons in the metal. The relationship between an RTD's resistance and the surrounding temperature is highly predictable, allowing for accurate and consistent temperature measurement. By supplying an RTD with a constant current and measuring the resulting voltage drop across the resistor, the RTD's resistance can be calculated, and the temperature can be determined.

3) Thermistor



A thermistor is made of a semiconductor material that exhibits a predictable and repeatable change in resistance as temperature is changed. Unlike a metal, the molecular structure of a semiconductor is such that increasing its temperature reduces its resistance. As the temperature of the material increases, electrons break free of their covalent bonds and conductivity is improved. The non-linearity of the thermistor response function makes its use limited only over the most linear range of the device. Manufacturers of Thermistor specify the useful range and the percent error over that range.

IV.DESIGN FOR THE STUDY OF HEAT EXCHANGER



Ours being a study project to analyze the effects of introduction of another cooling fluid pipe in the Automobile tube Heat Exchanger, we adopted a design that would be simple and descriptive. For reasons of ease of analysis and lack of access to high precision instruments, we adopted a larger size design. This large size helped us in the following ways:

A. Ease of fabrication
B. Adaptive to the facilities at college lab (for testing)
C. Better interpretation of parameters involved

Upon deliberations, it was concluded that our type of design can not only be used at factories where precision heating reduction is required, but also can be used for automobile Heat exchanging processes by slightly modifying the design specifications according to the need.

D. Characteristics of the Design

Usually in a multi-pass double pipe heat exchanger, the same cooling fluid is bent to pass through. Here, there are two distinctly separate pipes that can carry two different cooling fluids at two different pipes. This means that the target fluid comes in contact with two afresh cooling fluids before passing out. Its temperature is lowered by some amount on the first chamber and further by some amount in the second chamber. The baffle plate assembly was decided to ensure maximum contact of the fluid with the cooling pipes at the same time to not prolong or disturb flow. The middle separation layer has a vent at its end for the fluid to pass from one chamber to the other. The tube assembly was fit on the baffle plates in a manner depicted in the images in the gallery.

Materials and Specifications: (Note: Dimensions in millimetre)
Shell Outer Diameter: 110 mm
Shell Inner Diameter: 100 mm
Tube (both) outer Diameter: 30 mm
Wall thickness of the Shell: 10 mm
Wall thickness of Tube: 2 mm—
Length of shell: 600 mm
Length of tube: 800 mm
Middle plate thickness: 5 mm
Diameter of middle plate orifice: 50 mm

V. RESULT WITH TABULATION

S.NO	Hot Water Entry Temperature - H_i	Hot water Exit Temperature- H_o	Cold Water Exit - T_1	Cold water Exit- T_2
1.	61	51	35	36
2.	59	50	34	35
3.	58	49	35	34
4.	55	48	36	33
5.	52	45	34	35
6.	51	46	35	37
7.	48	42	33	35
8.	40	37	32	32

A. Note

1) All temperatures in Degree Celsius
2) Entry temperature of both the cooling pipe fluids was at room temperature.
Room Temperature = 31 Degree Celsius

VI. CALCULATIONS

Design Parameters:

Shell Internal Diameter $D_s = 100$ mm
Tube Length $L_t = 600$ mm
Tube External Diameter $d_o = 30$ mm
Tube Internal Diameter $d_i = 28$ mm
Baffle Spacing $= B$

Since the diameter ratio is given by:

$$d_r = \frac{do}{di}$$

Therefore, $d_o = 30/28 = 1.07$

The Tube Pitch Obtained is :

$P_t = 60$ mm

$C_t = 30$ mm

The Tube Pitch Ratio is given by:

$$P_r = \frac{Pt}{do} = 2$$

Given Information:

The Inlet Temperatures of Hot and Cold Fluid are Given as:

$T_{1i} = 59°C$

$T_{2i} = 29°C$

The Mass Flow Rates of Hot and Cold Fluid are given as:

$$m_{dot1} = 0.08 \text{ Kg/s}$$

$$m_{dot2} = 0.07 \text{ Kg/s}$$

The fouling factors for hot water end and cold water end are given as:

$$R_{fi} = 0.35 \times 10^{-3} \text{ m}^2\text{K/W}$$
$$R_{fo} = 0.18 \times 10^{-3} \text{ m}^2\text{K/W}$$

The Average Temperatures of Hot and cold Fluids are:

$$T_h = (59+50)/2 = 54.5^{\circ}\text{C}$$
$$T_c = (29+35)/2 = 32^{\circ}\text{C}$$

Tube Side Calculations:

1. The Cross Flow Area, Velocity and Reynolds Number are given as:

$$A_{c1} := \frac{\pi \cdot d_i^2}{4} \cdot \frac{N_t}{N_p}$$

$$= 1.223 \times 10^{-3} \text{ m}^2$$

$$v_1 := \frac{mdot_1}{\rho_1 \cdot A_{c1}}$$

$$= 0.07 \text{ m/s}$$

$$Re_1 := \frac{\rho_1 \cdot v_1 \cdot d_i}{\mu_1}$$

$$= 346.08$$

2. The Nusselt Number is given by the following Equation:

$$Nu_D(D_h, L_t, Re_D, Pr) := 1.86 \left(\frac{D_h \cdot Re_D \cdot Pr}{L_t} \right)^{\frac{1}{3}}$$

$$= 6.92$$

3. Heat Transfer Coefficient h_1 is given by:

$$h_1 := \frac{Nu_1 \cdot k_1}{d_i}$$

$$= 158.496 \text{ W/m}^2\text{K}$$

Shell Side Calculations:

1. Baffle Spacing is given by the following Equation:

$$B = \frac{L_t}{N_b + 1}$$

Thus,

$B = \frac{600}{8+1} = 66.7mm$

2. Cross Flow Area of the Shell A_c is given by:

$$A_c = \frac{D_s C_t B}{P_T}$$

Thus,

$A_c = \frac{100.30.66.7}{60} = 3335mm^2$

3. Number of Tubes can be calculated by the following formula:

$$N_t = (CTP)\frac{\pi D_s^2/4}{ShadeArea}$$

Where CTP is the tube count constant that accounts for the incomplete coverage of the shell diameter by the tubes, due to necessary clearance between the shell and the outer tube circle and tube omissions due to tube pass lanes for multiple pass design.
CTP = 0.93 for one-pass exchanger
CTP = 0.9 for two-pass exchanger
CTP = 0.85 for three-pass exchanger

$$ShadeArea = CL \cdot P_t^2$$

ShadeArea = 1 * 602 = 3600mm2
Where CL is the tube layout constant.
CL = 1 for square-pitch layout

Thus,

$N_t = \frac{0.93*3.14*100*100}{4*3600} = 2.02$ which is approximately equal to 2.

4. Velocity in the Shell is given by:

$V_2 = \frac{mDot2}{\rho 2\ Ac2} = 0.03$ m/s

5. Equivalent Diameter for this configuration is given by:

$$D_e = \frac{4\left(P_t^2 - \pi d_o^2/4\right)}{\pi d_o}$$

= 122.27mm

6. Renolds Number is given by:

$$\mathrm{Re}_D = \frac{\rho u_m D_e}{\mu} = \frac{\dot{m} D_e}{A_c \mu}$$

= 310

7. The Nusselt Number is given by:

$$Nu_D = \frac{hd_i}{k_f} = 1.86\left(\frac{d_i \,\mathrm{Re}\,\mathrm{Pr}}{L}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu_s}\right)^{0.14}$$

= 8.58

8. Heat Transfer Coefficient is given by:

$$h_2 := \frac{Nu_2 \cdot k_2}{D_e}$$

$= 43.075\ W/m^2K$

9. Heat transfer Areas:

$$A_i := \pi \cdot d_i \cdot L_t \cdot N_t$$

$$A_o := \pi \cdot d_o \cdot L_t \cdot N_t$$

Thus,

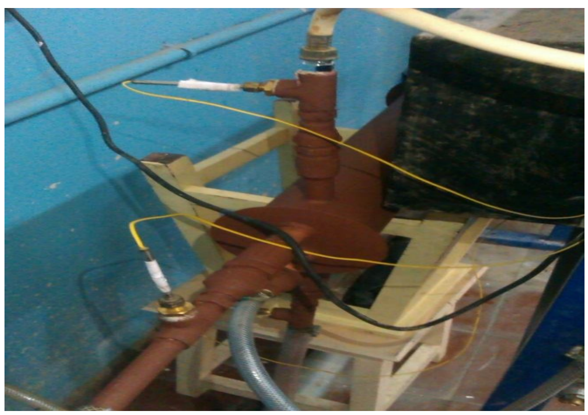
$A_i = 0.106\ m^2$

$A_o = 0.113\ m^2$

10. The Overall Heat Transfer Coefficient is given by:

$$U_o := \frac{\frac{1}{A_o}}{\frac{1}{h_1 \cdot A_i} + \frac{R_{fi}}{A_i} + \frac{\ln\left(\frac{d_o}{d_i}\right)}{2 \cdot \pi \cdot k_w \cdot L_t} + \frac{R_{fo}}{A_o} + \frac{1}{h_2 \cdot A_o}}$$

$= 162.19\ W/m^2\ K$



Effectiveness by NTU Method:

$C_1 = 334.64\ W/K = C_{max}$

$C_2 = 292.53\ W/K = C_{min}$

The Heat Capacity Ratio is given by:

$Cr = \frac{Cmin}{Cmax} = 0.87$

$NTU = \frac{Uo.Ao}{Cmin} = 0.07$

Effectiveness is given by:

$$\varepsilon = \frac{q}{q_{max}} = \frac{(\dot{m}_1 c_{p1})(T_{1i} - T_{1o})}{(\dot{m}c_p)_{min}(T_{1i} - T_{2i})} = \frac{(\dot{m}_2 c_{p2})(T_{2o} - T_{2i})}{(\dot{m}c_p)_{min}(T_{1i} - T_{2i})}$$

Thus, Effectiveness (ε)= **0.343**

Hence, The Heat Transfer Rate is given by:

$$q = \varepsilon(\dot{m}c_p)_{min}(T_{1i} - T_{2i})$$

Therefore, q = 0.343 x 292.53 x (332-302)

= **3.010 x10³ W**

VII. COMPARISON

A. Double Pipe vs. Triple Pipe – A comparative study of advantages and Disadvantages

Advantages of Double Pipe Heat Exchanger

1) Counter currents of the working fluid is obtained easily.
2) It has the capacity to withstand high Pressure and Temperature.
3) Heat transmission is large compared to the plate type Heat Exchangers.
4) Maintenance and repairs can be easily carried out.
5) It is equipped with a modular structure which facilitates in the heat transfer process.
6) it is easy to operate and is less expensive compared to Plate Heat Exchangers.
7) The Pressure Drop across the tube is less.
8) Disadvantage of Double Pipe Heat Exchanger:
9) The use of two single flow areas leads to relatively low flow rates and moderate temperature difference.
10) The use of only one cooling fluid limits its application to certain industries.

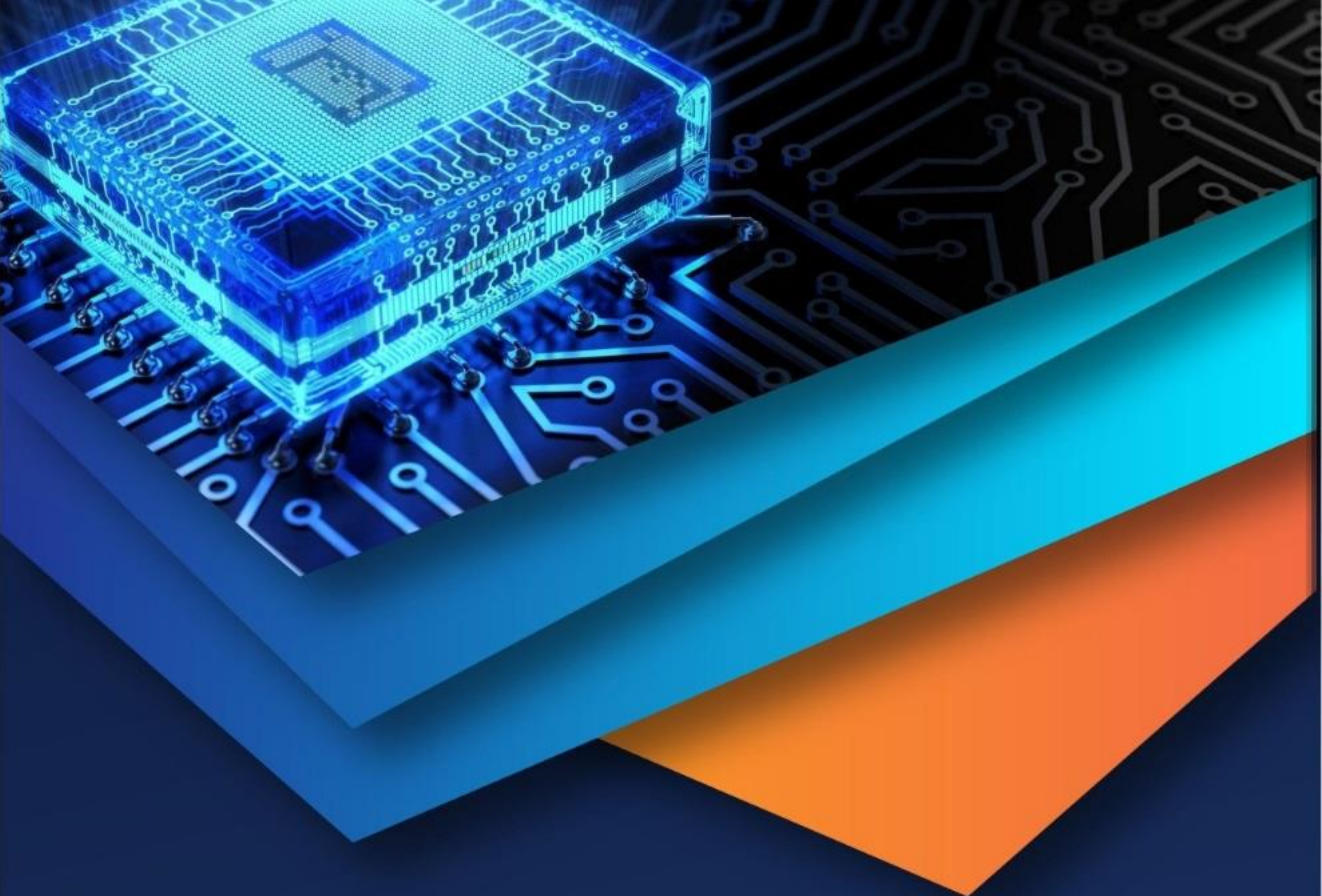
The Triple Pipe Heat Exchanger encompasses all the advantages mentioned above and also overcomes the drawbacks of the Double Pipe Heat Exchanger. Since the nature of flow, i.e. Parallel Flow and Counter Flow can be varied in each section as per the requirement, less heat transfer coefficient obtained. Changes can be made to the Triple Pipe Heat Exchanger's performance by utilizing a wide range of fluids and conditions that can be modified to adapt to the various design specifications. Also the usage of two cooling fluids in the tubes and the sinusoidal flow with the help of Baffle Plates leads to significant temperature difference and effective heat transfer.

VIII. CONCLUSION

Experiments were conducted on the Triple Pipe Heat Exchanger with Working Fluid as Hot Water at temperatures around 60oC and the cooling fluid as Water at different Cold Side Flow rates and at room temperature. The Effect of these parameters on the Shell Outlet Temperature and Tube Outlet Temperature were studied. Using these data, the overall Heat Transfer Coefficient was Determined. It was found that the Tube Outlet temperature increases slightly above room temperature and the Overall Heat transfer Coefficient increases with increase in flow rate of the Cold Fluid. The Overall Effectiveness of the Heat Exchanger was found to be Satisfactory. The Efficiency of the Triple Pipe Heat Exchanger was found to lie in between that of the Double Pipe Heat Exchanger and the Shell & Tube Heat Exchanger. However there is still much room for future Development that would enhance the usability of the device and improve its Effectiveness. Some Suggestions include using of Different Cooling Fluids in both the Tubes and increasing the turbulence of the Working Fluid through sending in pressurized fluids.

REFERENCES

[1] Partanen, Juho (2011). Hot property: Heat exchangers that optimize product reliability, decrease lifecycle costs and improve profitability are just the ticket for increasing the lifespan and performance of off-highway machinery; Industrial Vehicle Technology; March 2011;
[2] Shah, R., "Advances in Automotive Heat Exchanger Technology," SAE Technical Paper 2003-01-0533, 2003,
[3] Chang, Y. J. and Wang, C. C., 1997, "A Generalized Heat Transfer Correlations for Louver Fin Geometry," Int. J. Heat and Mass Transfer, Vol. 40, No. 3, pp. 533–544.
[4] Eichiseder, W. and Raab, G., 1993, "Calculation and Design of Cooling Systems,"SAE 931088.
[5] Won, J. P., 1999, "Thermal Flow Analysis of Automotive Compact Heat Exchangers," PhD. Thesis, Kyung Hee University.



doi crossref

10.22214/IJRASET

INDEX COPERNICUS

45.98

ISRA JIF

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY