Design and Development of a Trapezoidal Plate Fin Heat Exchanger for the Prediction of Heat Exchanger Effectiveness

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Abstract
A trapezoidal plate-fin exchanger has been designed and developed, and an experimental test rig fabricated to test the plate fin heat exchanger. The heat exchanger was constructed in a 5 layer cross-flow arrangement. The length of the trapezoidal fins between the layers were 380mm and its height, thickness, top width and bottom width were 40mm, 0.5mm, 20mm, and 80mm respectively. A hot fluid test has been conducted to determine the thermo-hydraulic performance of the given heat exchanger at different mass flow rates (4.975 kg/s to 9.751 kg/s) at a hot inlet temperature of 369K. The values of the effectiveness obtained were plotted against the corresponding values mass flow rate to compare and evaluate the variation of the results. Thus, the performance of a heat exchanger with trapezoidal fins has been studied experimentally and it has been determined that: the mass flow rate of the fluids is proportional to the temperature drop of the fluids after passing through the exchanger. Also Increase in mass flow rate, increases the effectiveness of the heat exchanger. Improper insulation influenced heat transfers in heat exchanger cores and caused energy imbalance in the heat exchanger. This study suggests that the calculated effectiveness of 0.98 using trapezoidal plate fin heat exchanger result provides benchmark data to evaluate and predicts the performance of a plate-fin heat exchanger with trapezoidal fins for energy recovery application.
Keywords: Heat exchanger development; trapezoidal fin, effectiveness, heat exchanger analysis; hot and cold fluids
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1.0 Introduction

A heat exchanger is a device used to transfer heat between a solid object and a fluid, or between two or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact *(Sadik and Hongtan, 2002)*. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Heat exchangers constitute the most important components of many industrial processes and equipment's covering a wide range of engineering applications (Alur,2012). They are broadly used in refrigeration, air conditioning, space heating, automobiles, power stations, petrochemical plants, petroleum refineries, chemical plants and natural gas processing etc. Within industrial plants and factories heat exchangers are required to keep machinery, chemicals, water, gas, and other substances within a safe operating temperature (Boda et al., 2017). They are also used to capture and transfer steam or heat exhaust that is released as a byproduct of a process or operation so that the steam or heat can be put to better use elsewhere, thereby increasing efficiency. For well over a century, efforts have been made to produce more efficient heat exchangers by employing various methods of heat transfer enhancement (Gupta and Bhatt, 2012). This is due to increased demands by industries for heat exchange equipment that is compact, light in weight and more efficient than standard heat exchange devices. For instance, when designing cooling systems for automobiles and spacecraft, it is imperative that the heat exchangers are especially compact and lightweight (Mori and Nakayama.,1980) and (Cowel and Achiachia., 1997). Also, the heat transfer enhancement of high heat duty exchangers found in power plants (i.e. air-cooled condensers, nuclear fuel rods) is very necessary for the improvement of its efficiency. These applications, as well as numerous others, have led to the development of various enhanced heat transfer surfaces.

Enhanced heat transfer surfaces are special surface geometries which cause heat transfer enhancement by establishing a higher heat transfer area per unit base surface area (Gupta and Bhatt, 2012). They are generally used for three purposes: to make heat exchangers more compact in order to reduce their overall volume, and possibly their cost, to reduce the pumping power required for a given heat transfer process, and to increase the overall heat transfer coefficient value of the heat exchanger. One of the most commonly employed enhanced heat transfer surfaces are extended surfaces known as fins. fins are widely used in industrial applications as extended surfaces attached to the walls of heat-transfer equipment for the purpose of enhancing the rate of cooling or heating. Over the years' different fin shapes have been developed depending upon the application, the geometry of the primary surface and materials (London, 1980). He observed that these materials are used for the secondary surface plate and corrugation construction which became established for aero engine radiators using dip soldered copper as the material of construction. Some common types of fin configurations are rectangular fins, trapezoidal fins, circular fins, hexagonal fins, wavy fins and off-set strip fin (Joshi and Webb, 1987). This project work will design, develop and analyze the performance of a heat exchanger with trapezoidal fins

2.0 Materials and Method

The materials used for the development of the experimental test rig were selected based on the functions and properties of the components, its cost was also considered. These includes centrifugal pumps, flow meter, pressure tap, thermometers, water heater, water containers, PVC (pipes, valves, bends and fittings). The materials include stainless steels, aluminum, nickel and copper alloys.

2.1: Design Considerations

The following factors were considered to allow an optimal design to be achieved.

Heat exchanger construction type and flow arrangement: The heat exchanger construction type and flow arrangement which is to be used for the project work was first considered and selected. In comparison to several types of heat exchangers and flow arrangements, a plate-fin heat exchanger with cross flow arrangement best fulfils the necessary criteria of high thermal effectiveness at low temperature with ease of manufacture. Thus it was adopted for the project work.

Heat transfer requirement: In other to design a heat exchanger with high thermal effectiveness, geometrical properties of the heat exchanger such as; Heat transfer area A, which includes both primary and secondary surface area, flow length, fin height, fin thickness, and core dimensions were carefully considered and selected so as to achieve desired heat transfer requirement.

Heat exchanger manufacture: The formability, malleability and weldability of the material used were considered before choosing the material, in other to select one that will ease manufacturing process. We also considered the type of joining process which would be used for joining the different parts of the heat exchanger without leakage or contamination of one fluid to the other. At first we considered brazing, but it was later discarded due to lack of equipment and technology to perform the brazing process. Cold welding method was later adopted because of the material's ability to bond together with one another by the use of adhesives.

2.2: Design Methodology

Design or sizing of heat exchangers can be done in two ways. It can either be done by determination of the heat exchanger dimensions for a specified heat transfer and pressure drop performance or by tentatively specifying the dimensions and then calculating the performance for comparison with the specified performance. The later was used in this project work using a correlation developed by Joshi and Webb (1987) for the design of plate-fin heat exchangers.

2.2.1: Input Data Analysis

Heat exchanger input data
Fluid used: Water
Temperature of hot fluid at inlet, = 345k
Temperature of cold fluid at inlet, = 284°C
Mass flow rate of both the fluids (hot and cold) = 0.5kg/s

2.2.2: Fin geometry

The heat exchanger was constructed from Aluminum Alloy A1 – 3003 with plain trapezoidal fins. The dimensions of the basic geometry are shown in table 1

Table 1: Basic Geometry

S/N	FIN GEOMETRY	HIGH PRESSURE SIDE (mm)	LOW PRESSURE SIDE (mm)
1	Fin length, l	380	380
2	Fin height, h	40	40
3	Fin thickness, t	0.5	0.5
4	Fin top width, w_t	20	20
5	Fin bottom width, w_b	80	80
6	Number of layers	3	2

2.2.3: Geometrical characteristics related to the fin geometry

Fin space s of (excluding fin thickness) was computed by Equation (1) as;

$$s = \frac{w_t + w_b}{2} \quad (1)$$

Free flow area to frontal area ratio is computed by Equation (2) as;

$$\sigma = \frac{aff}{afr} \quad (2)$$

Heat transfer area per fin, a_s is computed by Equation (3) as;

$$a_s = 2hl + 2ht + 2sl \quad (3)$$

Ratio of fin area to heat transfer area of fin is calculated by Equation (4).

$$\text{Ratio} = \frac{2h(l+t)}{2(hl+sl+ht)} \quad (4)$$

Equivalent Hydraulic Diameter is computed by Equation (5).

$$D_e = \frac{4\,x freeflowareaxlength}{heattransferarea} \quad (5)$$

Distance between plates is given by Equation (6) as;

$$b = h + t \quad (6)$$

b = 40 + 0.5 = 40.5mm = 0.0405m

Area of fin is given by Equation

$$a_f = s \times h = 50 \times 40 = 2000\text{mm2} = 2 \times 10{-}3\text{m2} \quad (7)$$

2.2.4: The design calculations for the given heat exchanger

Desired performance of heat exchanger

The desired effectiveness of the heat exchanger is given Equation (8) as;

$$\varepsilon = \frac{C_h(T_{hi}-T_{ho})}{C_{min}\,(T_{hi}-T_{ci})} = \frac{\dot{m}C_{ph}\,(T_{hi}-T_{ho})}{\dot{m}C_{pc}\,(T_{hi}-T_{ci})} \quad (8)$$

Heat load is given by Equation (9) as;

$$Q = C_h(T_{hi} - T_{ho}) \quad (9)$$

2.2.5: Estimation of dimensions of heat exchanger

i. length of the core, L = 380mm
ii. width of the core, W = 380mm
iii. Total no of layers, N = 5
iv. plate thickness, a = 1.5mm = 1.5 x 10^{-3}m

2.2.6: Calculation of heat transfer area A

The heat transfer area for hot side is calculated as

Total area between plates is given Equation (10) as;

$$A_{frh} = b \times Nh \times W \quad (10)$$

Total free flow area is given Equation (11) as;

$$,A_{ffh} = \sigma \times A_{frh} \quad (11)$$

Total heat transfer area is given Equation (12) as;

$$A_h = \frac{4\,xAffhxL}{De} \quad (12)$$

Heat transfer area for cold fluid is given Equation (13) as;

Total area between plates, $A_{frc} = b \times N_c \times W$ (13)

Total free flow area is given Equation (14) as;

$$A_{ffc} = \sigma \times A_{frc} \quad (14)$$

Total heat transfer area is given Equation (15) as;

$$A_c = \frac{4\,xAffc\,x\,L}{De} \quad (15)$$

2.2.7: Properties of Hot and cold fluid

Hot water at 345k; specific heat, c_{ph} = 4.191 KJ/kg-k, viscosity; μ = 3.89 x 10^5 KN. s/m^2; Prandtl number, Pr = 2.45; Density, ρ = 995 kg/m^3; K = 0.6 W/mK; Cold water at 285k; Specific heat, c_{pc} = 4.189KJ/kg.k; viscosity, μ = 1.225 x 10^{-6}KN.s/m^2; Prandtl number, Pr = 8.81; Density, ρ = 995 kg/m^3

2.2.8: Heat transfer coefficients and surface effectiveness of fins

Hot fluid

The core mass velocity is given Equation (16) as;

$$G = \frac{m}{A_{ffh}} \quad (16)$$

The Reynolds number is given Equation (17) as;

$$Re = \frac{GDe}{\mu} \quad (17)$$

Nusselt number is given Equation (18) as;

$$Nu = A \cdot Re^{1/2} \cdot Pr^{1/3} \quad (18)$$

Coefficient of convective heat transfer is given Equation (19) as;

$$h_h = \frac{Nu.k}{D_e} \quad (19)$$

The fin parameter is given Equation (20).

$$M = \sqrt{\frac{2xh_h}{k_f xt}} = \sqrt{\frac{2x319.83}{225x0.5x10^{-4}}} = 238.45m^{-4} \qquad (20)$$

The fin effectivenessη is given Equation (21).

$$\eta_{hi} = \frac{\tanh(Mle)}{(Mle)} \qquad (21)$$

But Le = effective length of fins for inner layers of hot fluid = b/2, L_e = effective length of fins for outer layers of hot fluid = b = 40.5mm = 0.04m. The fin effectiveness, η_{hi} is solved by equation (22) as;

$$\eta_{hi} = \frac{\tanh(Mle)}{(Mle)} \qquad (22)$$

The fin effectiveness for outer layers η_{ho} is 0.10. The overall surface effectiveness of fins on hot side is solved by equation (23) as;

$$\eta_{oh} = 1 - \left[\left(\frac{a_f}{a_s}\right)x(1-\eta_{hi})x\frac{(N_p - 2)}{N_p}\right] - \left[\left(\frac{a_f}{a_s}\right)x(1-\eta_{ho})x\left(\frac{2}{N_p}\right)\right]$$

$$\eta_{oh} = 1 - \left[\left(\frac{2}{68.44}\right)x(1-0.21)x\frac{(3-2)}{3}\right] - \left[\left(\frac{2}{68.44}\right)x(1-0.10)x\left(\frac{2}{3}\right)\right]; \eta_{oh} = 0.97 \qquad (23)$$

Cold fluid

The core mass velocity is given in equation (24) as,

$$G = \frac{m}{A_{ffc}} \qquad (24)$$

The Reynold number given in equation (25) as;

$$Re = \frac{GDe}{\mu}; \qquad (25)$$

Nusselt number is given in equation (26) as,

$$Nu = A \cdot Re^{1/2} \cdot Pr^{1/3} \qquad (26)$$

Coefficient of convective heat transfer, h_c is given in equation (27) as;

$$h_c = \frac{Nu.k}{De} = \frac{1652.51 \ x\, 0.6}{0.439} \qquad (27)$$

The fin parameter is given in equation (28) as;

$$M = \sqrt{\frac{(2\,xh_c)}{(k_f xt)}} \qquad (28)$$

The fin effectiveness, η

Le = effective length of fins for inner layers of cold fluid = 20.25 mm = 0.02m, Le = effective length of fins for outer layers of hot fluid = 40.5mm = 0.04m and the fin effectiveness, for inner layers η_{ci} for inner layers

$$\eta_{ci} = \frac{\tanh(Ml_e)}{Ml_e}$$

The fin effectiveness for outer layers ,η_{ci}= 0.04

The overall surface effectiveness of fins on cold side, η_{oc} is given in equation (28)

$$\eta_{oc} = 1 - \left[\left(\frac{a_f}{a_s}\right)x(1-\eta_{ci})x\frac{(N_p - 2)}{N_p}\right] - \left[\left(\frac{a_f}{a_s}\right)x(1-\eta_{co})x\left(\frac{2}{N_p}\right)\right]$$

$$\eta_{oc} = 1 - \left[\left(\frac{2}{68.44}\right)x(1-0.07)x\frac{(2-2)}{2}\right] - \left[\left(\frac{2}{68.44}\right)x(1-0.04)x\left(\frac{2}{2}\right)\right] \quad \eta_{oc} = 0.97 \qquad (28)$$

The overall heat transfer coefficient and number of transfer units and the overall heat transfer coefficient is given Equation (29).

$$\frac{1}{(UoAo)h} = \frac{1}{(\eta_{oh}h_h A_h)} + \frac{a}{(kA_w)} + \frac{1}{(\eta_{oc}h_c A_c)} \qquad (29)$$

Where, A_w= lateral condition area = W x L x ($2N_c$ + 2)

The overall heat transfer coefficient, $U_{oh} = \frac{(U_o A_0)}{A_{oh}}$; Number of transfer units, $Ntu = \frac{UoAo}{c_{min}}$

2.2.9: Effective of the heat exchanger

The effectiveness of the heat exchanger is given Equation (30).

$$\varepsilon = \frac{1-e^{-Ntu\,(1-c_r)}}{1-c_r e^{-Ntu\,(1-c_r)}} \qquad (30)$$

where, c_r is heat capacity ratio, $c_r = \frac{c_{min}}{c_{max}} = \frac{2.0945}{2.0955} = 0.995$, Therfore.

ε = 0.98
Table 2 shows the heat exchanger dimensions

Table 2: Heat Exchanger Dimensions

ITEMS	DIMENSIONS (mm)	ITEM (mm)	DIMENSIONS (mm)
CORE LENGTH	380	TOTAL LENGTH	430
CORE WIDTH	380	TOTAL WIDTH	430
CORE HEIGHT	208.5	TOTAL HEIGHT	211.5
PLATE THICKNESS	1.5	END PLATE THICKNESS	1.5

2.5: Development of Heat Exchanger Components

A graphic design and schematic diagram for the plate-fin heat exchanger and experimental test rig respectively was first done with the aid of a CAD software. After this, the different parts of the heat exchanger were fabricated. These parts include; corrugated fins, parting sheets, side bars, header tanks and nozzles. The corrugated fins with side bars and the headers were formed using a jig machined according to dimensions, and the parting sheets were cut to its dimensions. The separating plates (i.e parting sheets) were positioned alternatively with the layers of fins in a stack to form a containment between individual layers. These elements i.e. the corrugations, side bars, parting sheets were held together in a fixture and bonded with an adhesive to form the plate-fin heat exchanger block or core as in figs.1 and 2. Finally, the header tanks and nozzles were bonded to the block, taking care that the bonded joints remain intact during the process. After the heat exchanger was developed, the various components and materials for the test rig were assembled together to build up the experimental test rig and the manufactured heat exchanger was coupled to the test rig.

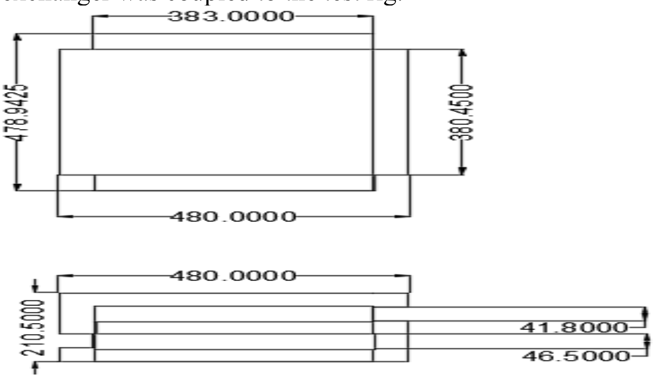

Fig. 1: Manufacturing details of the plate-fin heat exchanger

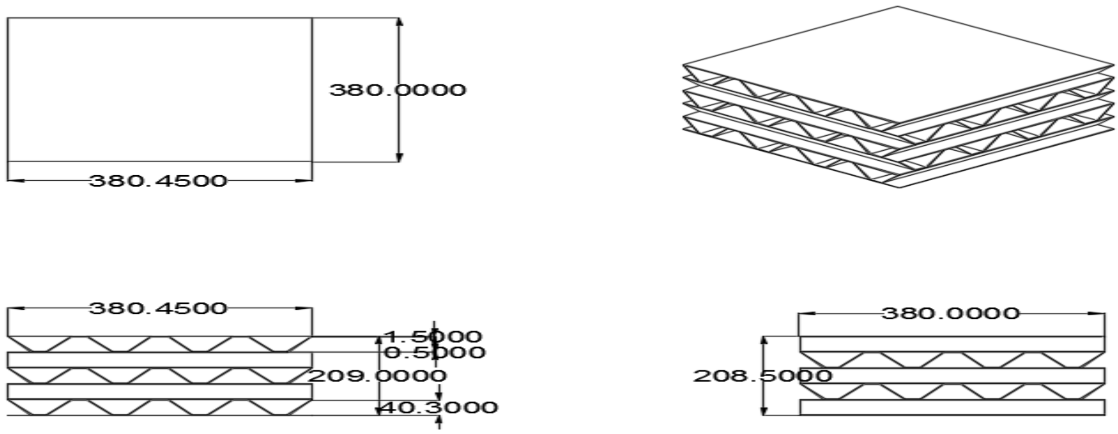

Fig. .2: Manufacturing details of the heat exchanger core.

The test section consists of a cross flow plate-fin heat exchanger with trapezoidal fin geometry and an experimental test rig. The plate fin heat exchanger consists of corrugated trapezoidal fins, parting sheets, side bars, header tanks and nozzles. The corrugated fins, parting sheets, side bars form the heat exchanger block or core. The core is the major part of the heat exchanger as it is the area where the heat exchange takes place. The parting sheets and corrugated fins provides the primary and secondary heat transfer surfaces respectively, while the side bars prevent leakage or the contamination of one fluid stream by another during heat exchange. Table 3 provides the details of the heat exchanger core.

Table 3: Details of plate fin heat exchanger core.

	HIGH PRESSURE SIDE (HOT SIDE)	LOW PRESSURE SIDE (COLD SIDE)
FIN	TRAPEZOIDAL	TRAPEZOIDAL
NO. OF LAYERS	3	2
NO. OF PASS	3	2
FLOW ARRANGEMENT	CROSS FLOW	CROSS FLOW

2.5.1: Experimental test rig

The experimental rig comprises of a cold and hot fluid tank, centrifugal pumps, PVC (pipes, valves, bends and fittings), electric heater, flow meter, pressure gauges, thermometers, and the heat exchanger core. They are described as follows; Cold and Hot fluid tank: The cold fluid tank is used to for storing the cold water while the hot fluid tank is used to store the hot water which is used to carry out test on the heat exchanger. Centrifugal pumps: A centrifugal pump is a mechanical device for moving water or other liquids. They were used for supplying water from the hot fluid and cold fluid tank into the core of the heat exchanger. After the heat exchange has taken place, the water flow back to the tanks through the aid of the pumps. PVC (pipes, valves, bends and fittings): The PVC (pipes, valves, bends and fittings) are used to contained the cold and hot water as they are being transported across the heat exchanger and measuring devices. Electric heater: The electric heater is used to provide a constant heat flux to the fluid inside the hot fluid tank. The heater is attached to the tank by means of a fastener. Thermometer: The thermometers are used at the inlet and outlet positions on the surface of the flow pipes to measure the temperature. Flow meter: The flowmeter is a fluid measuring device used to measure the volumetric flow rate of a moving fluid. It is used to measure the volume of water flowing through the circuit per time. The schematic diagram of the developed heat exchanger is shown in fig. 3.

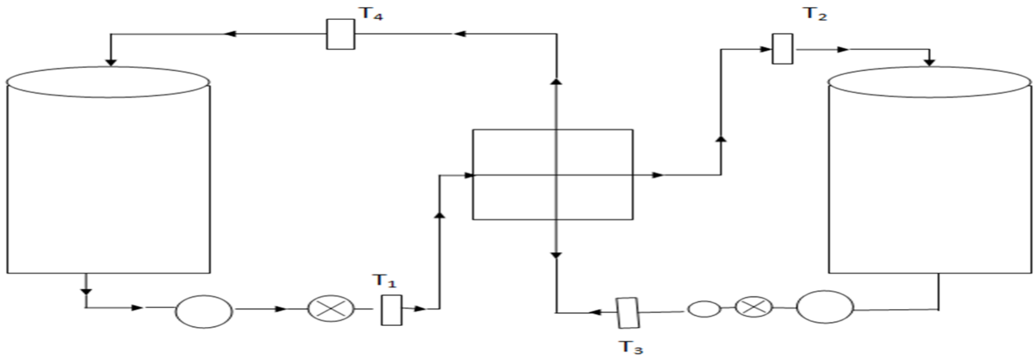

Fig 3: Schematic diagram of the heat exchanger experimental test rig

THE KEY TO THE SCHEMATIC DIAGRAM ABOVE

2, 7: Centrifugal pump	T_1, T_2, T_3, T_4 : Thermometer
3, 8: Control valve	5 : Heat exchanger
4: Flowmeter	1 : Hot fluid tank with heater
	6 : Cold fluid tank

2.5.2: Procedure Hot testing

Water was used as a working fluid in this experiment. The heat exchanger was connected to two centrifugal pumps which was capable of continuously supplying water from a hot and cold fluid tank. A control valve was used to regulate the flow rate of water through the heat exchanger. The cold water enters the heat exchanger from the bottom and gets heated as it passes through the exchanger. The water coming out then enters the hot fluid tank where it is further heated by a water heater. The hot water coming out of the heater was fed into the heat exchanger from the top end and gets cooled as it passes through the exchanger. The water coming out then enters the cold fluid tank where it was further cold by cold water remnant in the tank. It was ensured that there is no mass leak from the system. The fluid flow rate through the test section was set using the control valve, and the temperatures, across the heat exchanger were recorded using thermometers. A flow meter and a stopwatch was used to measure the volume of water flowing through the circuit per time, so that the mass flow rate is calculated later. The system was then allowed to run until the steady state is achieved. The system was considered to be at steady state when all the temperature readings steadily decrease and steadily increase for at least one minute. Once the steady state was achieved for a particular volume flow rate, the fluid flow rate and the temperature of the fluid stream across the core are accurately measured for estimating the effectives of the heat exchanger. Fig. 4 showed the photo of coupled trapezoidal heat exchanger.

Fig 4: Photograph of the experimental set up

2.5.3: Calculation procedure

In the steady state experiment, measurement of temperature and mass flow rates in the two sides provides the required information to compute the heat exchanger effectiveness.

The change in temperature of the cold and hot fluids, ΔT_C and ΔT_h respectively is calculated by;

$\Delta T_C = T_2 - T_1$; $\Delta T_h = T_3 - T_4$ and where, T_1 = Temperature at inlet of cold fluid (K), T_2 = Temperature at outlet of cold fluid (K), T_3 = Temperature at inlet of Hot fluid (K), T_4 = Temperature at outlet of Hot fluid (K). Volume flow rate of the fluids flowing through the heat exchanger is measured using a flow meter placed at the heat exchanger test rig and a stop watch. The mass flow rate is gotten by applying the relation;

Mass flow rate, m = $\rho \times Q$, Where, ρ = Density of the fluid (kg/m^3); Q = Volume flow rate (m^3/s); m = Mass flow rate (kg/s). The effectiveness of the heat exchanger according to (Ujam and Ngwaka, 2014) is given by equation 31 as;;

$$\text{Effectiveness, } \varepsilon = \frac{\text{Actual heat exchange rate}}{\text{maximum possible heat exchange rate}} = \frac{Q_h}{Q_{max}} = \frac{Q_c}{Q_{max}} \quad (31)$$

Where, $Q_h = c_h(T_3 - T_4)$ for hot fluid, $Q_c = c_c\,(T_2 - T_1)$ for cold fluid

$Q_{max} = c_{min}\,(T_3 - T_1)$; $c_h = \dot{m}_h c_{ph}$ = Hot fluid heat capacity flow rate; $c_c = \dot{m}_c c_{pc}$ = Cold fluid heat capacity flow rate; c_{min} = The minimum heat capacity flow rate (c_h or c_c) are given by equation 32 and 33 as;

$$\text{Effectiveness of hot fluid, } \varepsilon_h = \frac{c_h(T_3 - T_4)}{c_{min}\,(T_3 - T_1)} \quad (32)$$

$$\text{Effectiveness of cold fluid, } \varepsilon_c = \frac{c_c\,(T_2 - T_1)}{c_{min}\,(T_3 - T_1)} \quad (33)$$

For a balanced mass flow rate of hot and cold fluids, the effectiveness is given by;

$$\text{Effectiveness, } \varepsilon = \frac{(T_3 - T_4)}{(T_3 - T_1)} = \frac{(T_2 - T_1)}{(T_3 - T_1)}$$

$$\text{Mean effectiveness, } \varepsilon_m = \frac{\varepsilon_h + \varepsilon_c}{2}$$

3.0 Results and Discussion

3.1: Performance Analysis

Hot fluid test was conducted to determine the performance parameters such as effectiveness and pressure drop, across the core for both the fluids and compare them with the theoretical or predicted values. The experiment is conducted at different volume flow rates and hot inlet temperature of 369K and the amount of water entering the heat exchanger is controlled by a control valve placed at the inlet of the heat exchanger. The values of the experimentally observed data have been tabulated in tables 4 and 5.

Table 4. Experimentally observed data at different volume flow rates and hot fluid inlet temperature of 369K

S/N	Volume , V (m^3)	Time , T(s)	Flow rate, Q (m^3/s) × 10^{-3}	Cold fluid inlet temperature , T_1(K)	Cold fluid inlet temperature , T_2(K)	Hot fluid inlet temperature , T_3(K)	Hot fluid outlet temperature , T_4(K)	ΔT_h (K)	ΔT_c (K)
1	0.300	60	5	315.24	360.22	368.96	321.1	8.74	44.98
2	0.400	60	6.7	311.35	359.94	367.91	316.95	50.96	48.59
3	0.500	60	8.3	311.93	361.38	368.88	317	51.88	49.45
4	0.550	60	9.2	312.82	361.71	369.45	317.35	52.08	48.89
5	0.588	60	9.8	313.41	361.33	368.96	317.35	51.61	47.92

Table 5: Calculated values of mass flow rate and effectiveness

Mass flow rate, (kg/s)	Effectiveness, ε_h(Hot)	Effectiveness, ε_c (Cold)	Mean effectiveness, ε_m
4.975	0.89	0.84	0.86
6.667	0.90	0.85	0.88
8.259	0.91	0.86	0.89
9.154	0.92	0.87	0.90
9.751	0.93	0.86	0.90

Figs. 5 and 6 show the plots of effectiveness and mass flow rate of hot fluid and cold fluids, while fig. 7 shows the plot of mean effectiveness and mass flow rate.

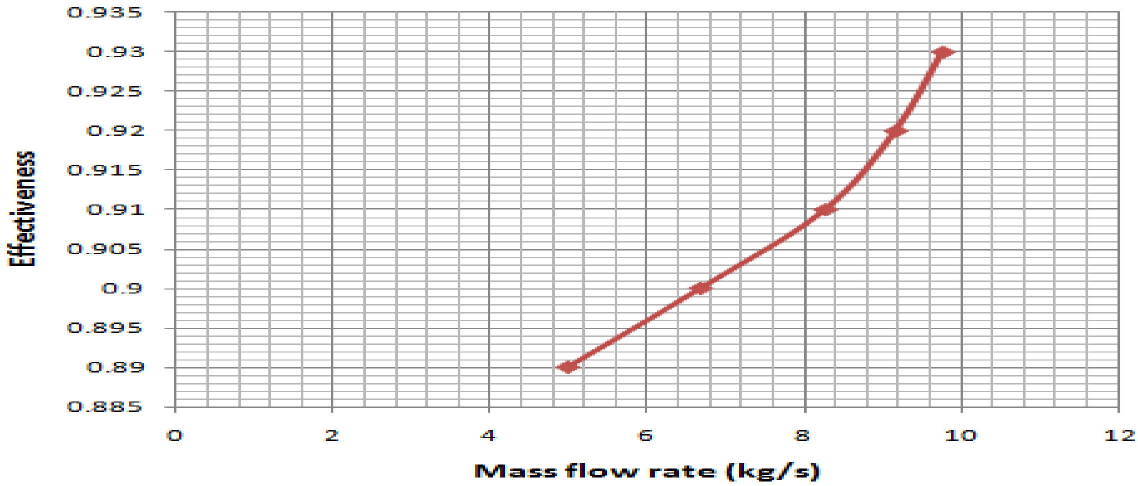

Fig 4.1: Graph of mass flow rate versus effectiveness (Hot)

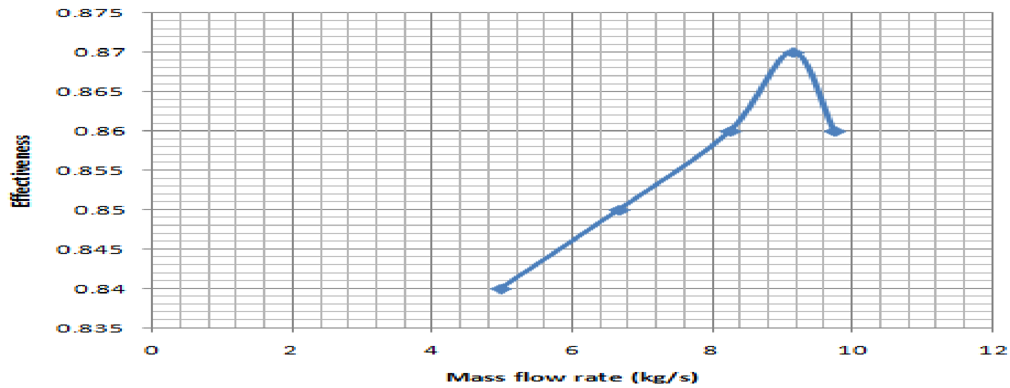

Fig 4.2: Graph of mass flow rate versus effectiveness (Cold)

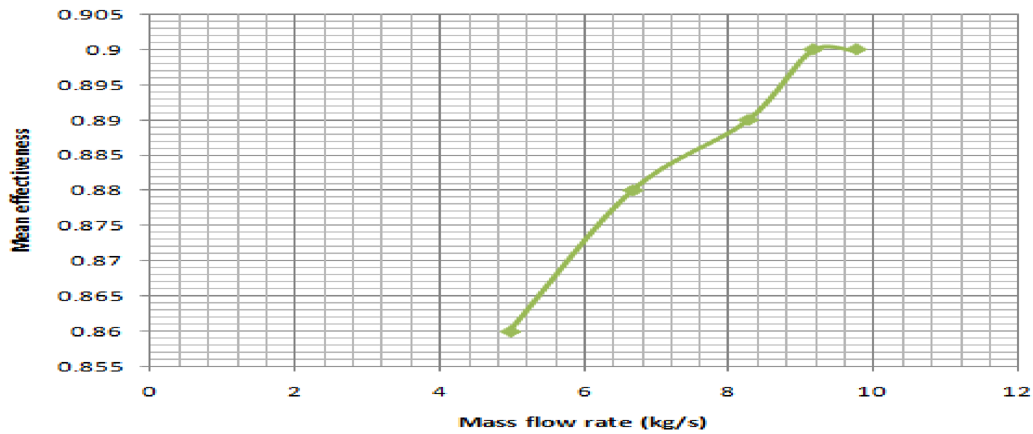

Fig 4.3: Graph of mass flow rate versus mean effectiveness

It was observed from the results that there is change in the inlet temperatures of the hot and cold fluids after passing through the heat exchanger. It was equally observed that the values of outlet temperature of the hot and cold fluids are not the same. It was also observed from the results that as the values of mass flow rate increases there was a corresponding increase in the values of effectiveness. It was equally observed from experiment that hot effectiveness, ε_h (effectiveness measured on the basis of hot fluid) increased with the mass flow rate whereas the cold effectiveness, ε_c (the effectiveness based on the cold fluid) increased up to certain mass flow rate, remained constant and then decreased with further increased in mass flow rate.

The difference in the values of temperatures at hot end and cold end indicates a loss. The increase in values of effectiveness with increases in mass flow rate occurs due to increase in Reynolds obtained when the mass flow rate was increased.

5.0 Conclusion

A plate-fin exchanger has been designed and developed, and an experimental test rig fabricated to test the plate fin heat exchanger. A hot fluid test has been conducted to determine the thermo-hydraulic performance of the given heat exchanger at different mass flow rates (4.975 kg/s to 9.751 kg/s) at a hot inlet temperature of 369K. The values of the effectiveness obtained were plotted against the corresponding values mass flow rate to compare and evaluate the variation of the results. Thus, the performance of a heat exchanger with trapezoidal fins has been studied experimentally and it has been determined that: The mass flow rate of the fluids is proportional to the temperature drop of the fluids after passing through the exchanger. Increase in mass flow rate, increases the effectiveness of the heat exchanger. Improper insulation influence heat transfers in heat exchanger cores by causing energy imbalance in the heat exchanger. The designed results provide benchmark data to evaluate and predict the performance of the heat exchanger for energy recovery application.

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