Design and Construction of a Double Pipe Heat Exchanger for Laboratory Application

C. E. Ebieto, R. R. Ana, O. E. Nyong, and E. G. Saturday

***Abstract* — Engineering education is incomplete without laboratory practices. One of such laboratory equipment necessary for all engineering students to have hands-on in the course of their undergraduate studies is the heat exchanger. This work presents the detailed design and construction of a laboratory type double pipe heat exchanger that can be used both in the parallel and counter flow configuration. The heat exchanger was constructed using galvanized steel for both the tube and shell. Experiments were designed and carried out to test the performance of the heat exchangers. The heat exchanger performance characteristics (logarithm mean temperature difference (LMTD), heat transfer rate, effectiveness, and overall heat transfer coefficient) were obtained and compared for the two configurations. The LMTD tends to be relatively constant as the flow rate was increased for both the parallel and counter-flow configuration but with a higher value for the parallel flow configuration. The heat exchanger has a higher heat transfer rate, effectiveness, and overall heat transfer coefficient and therefore has more performance capability for the counter-flow configuration. The overall heat transfer coefficient increased as the flow rate increased for both configurations. Importantly, as a result of this project, Mechanical Engineering students can now have hands-on laboratory experience on how the double pipe heat exchanger works.**

***Index Terms* — Design, Construction, Heat Exchanger, Tube, Heat Transfer, Fluid.**

I. Introduction

Engineering education is incomplete without laboratory practice. The overall goal of engineering education is to prepare students to practice engineering and in particular to deal with the nature of problems faced by society. The laboratory practice has been an important part of professional and engineering undergraduate education; a laboratory is an ideal place for active learning. It is important for engineers to understand the principles of thermodynamics (especially the first and second laws) and heat transfer, and to be able to use the rate equations that govern the amount of energy being transferred via the three different modes of heat transfer (i.e., conduction, convection, and radiation). However, the majority of students perceive thermodynamics and heat transfer as difficult subjects. Similarly, the integration of the present experiment into the undergraduate heat transfer laboratory would enhance and add another dimension to the teaching and learning of the subject of heat transfer.

Heat exchangers are devices built for efficient heat transfer from one medium to another. They are devices that assist the exchange of heat between two fluids at different temperatures while keeping them from mixing. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids-via thermal energy storage and release through the exchanger surface or matrix-are referred to as indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure differences and matrix rotation/valve switching.

A double pipe heat exchanger consists of a pair of pipes (tubes) one positioned concentrically within the other. Double pipe heat exchangers are often connected in series to provide an increased heat transfer surface. They may be connected to have a parallel flow arrangement to handle large process steam flow. The inner pipe is often finned. The double pipe heat exchanger is adopted for low flow rate, high temperature and high-pressure application. These types of heat exchangers found their applications in heat recovery processes, air conditioning and refrigeration systems, chemical reactors, and food and dairy processes. The double pipe heat exchanger would normally be used for many continuous systems having small to medium head duties. The double pipe heat exchanger is used in industry such as condenser for chemical process and cooling fluid process. A lot of research has been done on the design and analysis of a double pipe heat exchanger.

Shou-Shing et.al., [1] worked on single-phase forced convection in double pipe heat exchangers containing a two-dimensional helical fin roughness on the outer surface of the inner tube. In this study, the following parameters were used; a helical angle (α: 65°), a pitch to height ratio (p/e = 1.45), and three aspect ratios (shell side to tube side dia.) of Do/Di-2.68, 3.48 and 5.1.Three corresponding ratios are taken of roughness height to hydraulic dia. (e/Ds) of 0.192, 0.13 and 0.08, respectively. They found heat transfer performance is to be depended upon both the mass flow rate and the ratio of roughness height to hydraulic dia. (e/DH).They observed that the Nusselt numbers of the ratios of roughness height to hydraulic dia. of 0,192 and 0.13 are found nearly 60 and 40%, respectively, higher than that of the ratio of roughness height to hydraulic dia. of 0.08 for all the flow rates investigated.

Tsai, et.al. [2] studied heat transfer in a conjugate heat exchanger with a wavy fin surface. A three-dimensional computational study on conjugate heat exchangers was

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conducted. Attention was specially directed towards studying extended surfaces used to increase heat transfer. The strategy adopted in the present investigation of forced convection in a flow passage was to use the finite volume method. The implementation incorporated a SIMPLE based semi-implicit solution algorithm which was applied to working equations formulated within the single-phase catalogue. The analysis allowed for marked changes in thermodynamic and flow properties. To better illuminate the flow and heat transfer characteristics in a flow passage bounded by two fins having wavy geometries the solutions were plotted in three dimensions. Kadari, et. al. [3] designed and fabricated a double pipe heat exchanger where 1.8 m long copper pipe and galvanized iron pipe was utilized for tube and shell materials respectively. The experimental analysis was conducted by passing hot water in inner pipe and cold water in the annulus. The experiment was performed with both parallel and counter flow configurations under three mass flow rates conditions where cold water flow rate and hot water flow rate are changed. Inlet and outlet temperatures are measured by using thermocouple at various locations. The overall heat transfer coefficient was calculated and compared with both parallel and counter flow for the theoretical and actual performance of heat exchanger and found that counter flow heat transfer is more effective than parallel flow. The research takes into account different Nano-fluids for effective heat transfer in a double pipe heat exchanger. Madhav, et al., [4] carried out an experimental investigation of a double heat exchanger with triangular baffles. A set of experiments were carried out to investigate and compare the heat transfer behaviour in a double pipe concentric tube heat exchanger with and without triangular baffles for both parallel and counter flow arrangements. The authors concluded that effectiveness, heat transfer coefficient and heat transfer rate increases with the decrease in baffle spacing and baffled heat exchanger had better thermal performances than the smooth tube for both cases. From their investigations, insulation had a significant effect on heat exchanger performance. Rakesh, et al., [5] undertook the design and performance analysis of double pipe heat exchanger. In their work, a detailed theoretical and practical analysis with simulations of the design and performance of the double pipe heat exchanger was done. From comparison with the simulated model and experimental setup, the drop-in effectiveness exceeded the limit. And further, it was concluded that as the surface area increases the overall heat transfer coefficient increases and hence the heat exchanger effectiveness increases.

Dehankar, et. al. [6] worked on the fabrication of double pipe heat exchanger and standardization in a laboratory scale. It involved studying the theoretical and experimental values for parameters such as friction factor and Reynold number at different mass flow rate range between 0.02 Kg/sec – 0.033 Kg/sec. The fabricated double pipe heat exchanger was standardized using Wilson plot and was able to compute the value of the constant 'K' for the mass flow rate range between 0.02 Kg/sec – 0.033 Kg/sec. Kirti, et al., [7] designed a double pipe heat exchanger using galvanized iron for both the inner and outer tube. A set of experiments were carried out with the designed heat exchanger to investigate for counter flow and parallel flow to determine the heat transfer coefficient. Sathiya, et al. [8] undertook a review on the double pipe heat exchanger in a manner to identify the right performance characterization parameters. The work highlighted the art of introducing artificial intelligence in the field of heat exchangers. According to their review, heat exchanger based researchers are still trying to figure out an optimal design of heat exchangers that convert the given input into an effective output. They also noted that many researchers increased the rate of heat transfer by introducing inserts, by changing the configuration of the core tube of the heat exchanger and by the use of Nano-fluids. The purpose of this work is to develop and build a double pipe heat exchanger that can be used both in parallel and counter-flow setups. The designed and constructed double pipe heat exchanger is designed for use in the department of Mechanical Engineering Laboratory, University of Port Harcourt.

II. Design Methodology And Construction

The following are the materials used in the fabrication of the double pipe heat exchanger and the experimental analysis: Galvanized steel pipes, Thermocouples, Instant electric water heater, Control Valves, Wood, Hose (pipes), Reservoirs (hot and cold), Flowmeters, 1.5 X 1.5 square inch pipes, Surface water pumps, Electric sockets, switch and cables.

The following are factors that were considered during the selection of material to be used for the heat exchanger.

i Compatibility of the materials with the process fluids.

ii Compatibility of the materials with the other component materials.

iii Ease of manufacture and fabrication by using standard methods like machining, rolling, forging, forming, and metal joining methods such as welding, brazing, and soldering.

iv Strength and ability to withstand operating temperature and pressure.

v Cost.

vi Availability.

vii Type of fluid.

viii Fluid physical and chemical properties.

ix Thermal conductivity of the pipes.

x Heat capacity of the pipes.

xi Sizes and weights of the pipes.

A. Tube

The 0.02 m diameter galvanized steel pipe used for the tube was cut to a length of 0.7112 m. Braze coupling (nipple) was then welded on both ends of the pipe using oxyacetylene flame (gas welding) and boras flux. Tiny holes were drilled on the coupling using an electrically powered hand drilling machine with a drill bit of 0.0003968 m to insert thermocouple probe (temperature sensors). The braze coupling is to enable hose to be fastened to the tube at both ends. Frame sealant 151 was applied to all welded joints to prevent leakage of fluid.

B. Shell

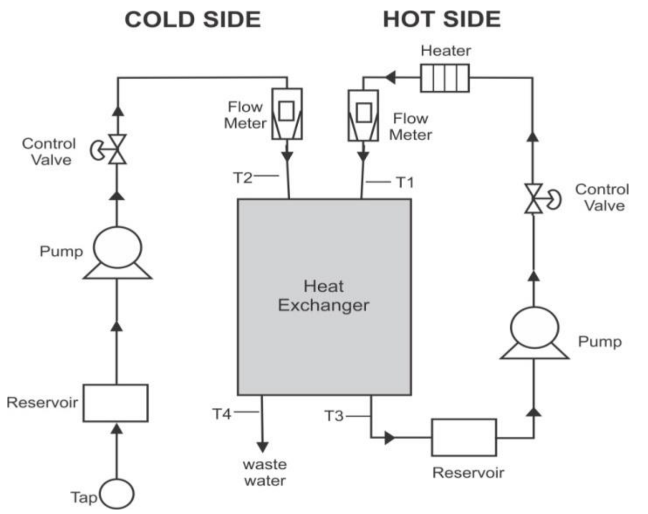
The 0.06 m diameter galvanized steel pipe used for the shell was cut to a length of 0.6096 m. Holes of 0.02 m were then made on the top (one end of the tube) and another at the bottom (another end of the tube). Tiny holes were drilled on the coupling using an electrical powered hand drilling machine with drill bit of 0.0003968 m in order to insert thermocouple probe (temperature sensors). The coupling was then mounted on the openings made on the top and bottom of the shell using oxyacetylene flame (gas welding) and boras flux. Four pieces of galvanized steel was then again cut to a length 0.06 m, unfolded and hammered to a flat surface. Two circles of outer diameter 0.06 m and internal diameter of 0.02 m where drawn on all four flattened steel surface using chalk. The circles where then cut off from the flattened galvanized steel using oxyacetylene flame. The tube was then inserted into the shell, centralized, and two cut out circle shape was then used to close both open ends of the shell, with the tube protruding out 0.0508 m from both ends of the shell. The cut out circle steel was then permanently attached to the shell using oxyacetylene flame (gas welding) and boras flux. Frame sealant 151 was applied to all welded joints to prevent leakage of fluid.

The experiments are:

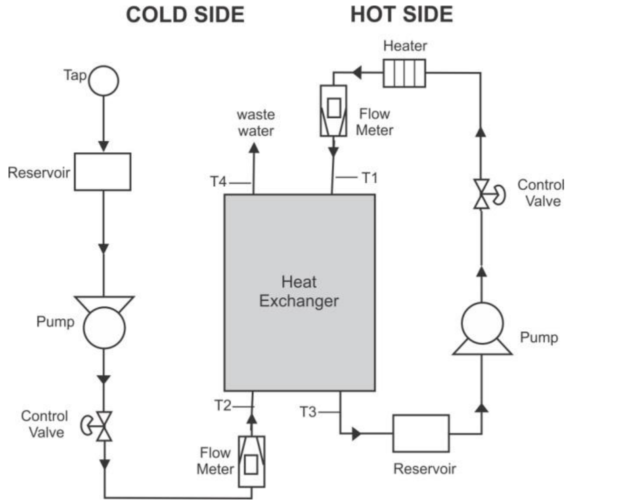
1. Parallel flow configuration while maintaining an equal flow rate for both the hot and cold fluid.
2. Counter flow configuration while maintaining an equal flow rate for both the hot and cold fluid.

The hot water side of the apparatus works as a recirculated loop so as the water leaves the exchanger, it is heated (by a 3kW electric heater) and then returns as the hot inlet to the exchanger. The inner pipe (Tube) containing the hot fluid steam is galvanized steel pipe (OD 0.02 m) with an outer (Shell) galvanized steel pipe of (ID 0.06 m) in which there is the cold stream. The active heat transfer surface area is 0.03142 m^2. This is the simplest form of the heat exchanger and is used as the basis for most heat exchanger theory. Fig. 1 (a and b) shows the schematics in the different heat exchanger configurations.

In the experiments, the first law of thermodynamics was used to determine (i) when the heat exchanger transfers the most heat (energy) and (ii) when the largest temperature difference in one of the streams is observed. To limit the number of experiments into a manageable quantity, the hot and cold flow rates are kept equal varying between 3.33×10^{-5} m^3/s (2 LPM) to 6.67×10^{-5} m^3/s (4 LPM) for a parallel flow configuration and a counter flow configuration.



(a)



(b)

Fig. 1. Sketch of experimental setup (a) Parallel flow (b) Counter flow.

C. Design Calculations

The following are the calculations required:

Area of Tube:

$$A_t = 2\pi r_t L_t \quad (1)$$

Annular Space:

$$A_a = \frac{\pi(Ds^2 - Dt^2)}{4} \quad (2)$$

Area of Shell:

$$A_s = 2\pi r_s L_s \quad (3)$$

Logarithm mean temperature difference (LMTD)

LMTD is defined as that temperature difference, which if constant, would give the same rate of heat transfer as occurs under variable conditions of temperature difference. The value of the LMTD depends on the relative direction of fluid motion.

Parallel Flow:

$$T_m = \frac{(T2 - T1) - (T4 - T3)}{ln\frac{(T2 - T1)}{(T4 - T3)}} \quad (4)$$

Counter Flow:

$$T_m = \frac{(T2 - T3) - (T4 - T1)}{ln\frac{(T2 - T3)}{(T4 - T1)}} \quad (5)$$

Heat Transfer:

$$Q = M_h C_h (T_2 - T_4) \quad (6)$$

$$Q = M_c C_c (T_3 - T_1) \quad (7)$$

Effectiveness:

$$\varepsilon = \frac{actual\ heat\ transfer}{maximum\ possible\ heat\ transfer} \quad (8)$$

$$\varepsilon = \frac{Ch(T2 - T4)}{Cmin(T2 - T1)} \quad (9)$$

$$\varepsilon = \frac{Cc(T3 - T2)}{Cmin(T1 - T2)} \quad (10)$$

Overall Heat Transfer Coefficient:

$$U = \frac{Q}{ATm} \quad (11)$$

where, r is the radius, L is the length, D is the diameter, T is the temperature, C is heat capacity, and subscripts $s, t, h, c, and\ m$, represents the shell, tube, hot, cold and mean respectively.

III. Results And Discussions

The results obtained from the experiments carried out on the designed and fabricated double pipe heat exchanger as shown in Fig. 2, are presented here. All graphs plotted and data analysis was done using Origin 2018 and Excel spreadsheet respectively.

Fig. 3 (a and b) shows the temperature differences between the hot and cold fluid as the fluid flows from the inlet to the outlet. Fig. 1(a) and Fig. 1(b) are for parallel flow and counter-flow configurations respectively at a flow rate of 3.33×10^{-5} m^3/s (2 LPM), 5.1×10^{-5} m^3/s (3 LPM), and 6.67×10^{-5} m^3/s (4 LPM). Trends are the same as in the literature, indicating that there has been a transition of heat from the hot fluid to the cold fluid with both parallel flow and counter-flow setups.

Though the heat transfer is small, this can be attributed to the fact that the tube and shell materials are the same, hence this was anticipated.

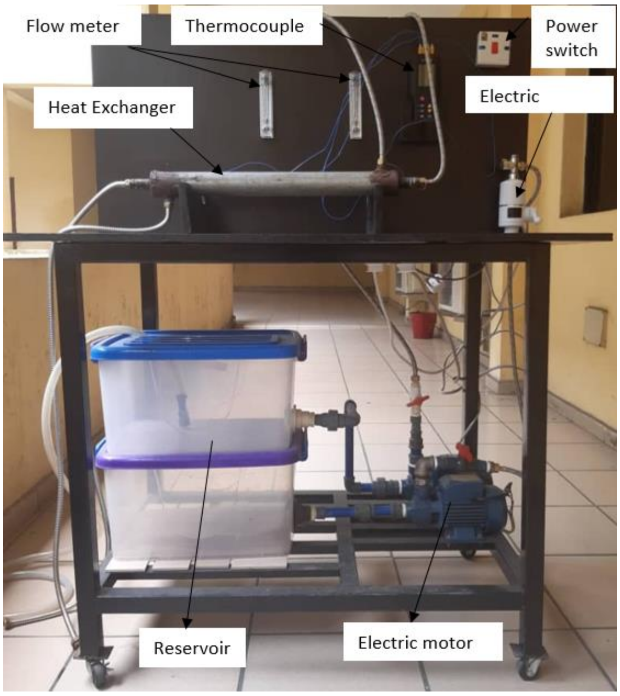
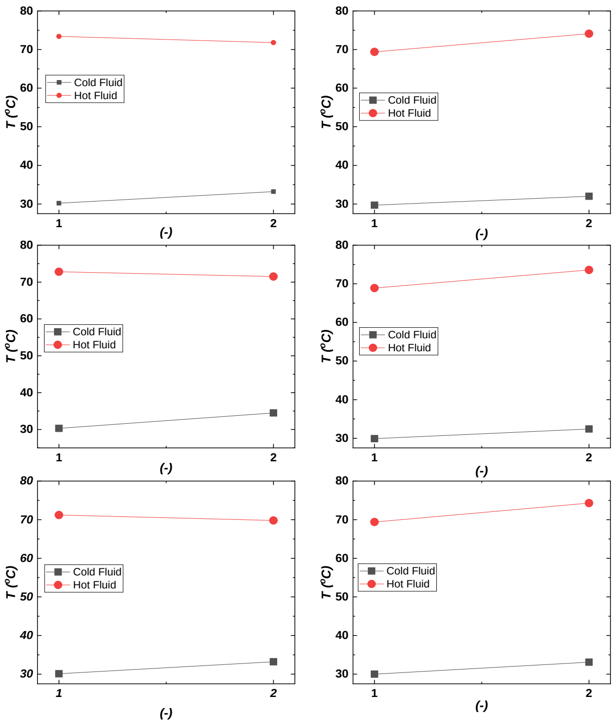


Fig. 2. Schematics of the double pipe heat exchanger.

Tables I and II show the result of the analyzed data for the double pipe heat exchanger for parallel and counter flow configurations respectively.

Fig. 4 shows the plot of the overall heat transfer coefficient against the flow rate. The overall heat transfer coefficient for both the parallel and counter flow configuration increased as the flow rate increased, though, the overall heat transfer coefficient for the counter flow is slightly higher than the parallel flow configuration.



(a) Parallel flow (b) Counter flow

Fig. 3. Graph of a temperature difference between hot and cold fluid.

TABLE I: Analyzed Data for Parallel Flow Configuration

SN	Parameter	Parallel flow configuration at 2LPM	Parallel flow configuration at 3LPM	Parallel flow configuration at 4LPM
1	Area of tube (m^2)	0.0447	0.0447	0.0447
2	Annular Space (m)	0.0025	0.0025	0.0025
3	Area of shell (m^2)	0.1149	0.1149	0.1149
4	LMTD (ºC)	40.8000	39.992	40.1673
5	Effectiveness of tube	0.0370	0.0306	0.0341
6	Heat transfer tube	0.2228	0.2718	0.3339
7	Heat transfer of shell	0.4178	0.8782	0.8364
8	Effectiveness of shell	0.0694	0.0988	0.0730
9	Overall heat transfer coefficient	0.1736	0.2180	0.3201
10	Active heat transfer area(m^2)	0.03142	0.03142	0.0314

TABLE II: Analyzed Data For Counter-Flow Configuration

SN	Parameter	Counter flow configuration at 2LPM	Counter flow configuration at 3LPM	Counter flow configuration at 4LPM
1	Area of tube (m^2)	0.0447	0.0447	0.0447
2	Annular Space (m)	0.0025	0.0025	0.0025
3	Area of Shell (m^2)	0.1149	0.1149	0.1149
4	LMTD (ºC)	38.4944	36.0481	36.1967
5	Effectiveness of tube	0.0320	0.0544	0.0657
6	Heat transfer tube	0.1810	0.4390	0.6963
7	Heat transfer of shell	0.1253	0.0690	0.3621
8	Effectiveness of shell	0.0222	0.0854	0.0341
9	Overall heat transfer coefficient	0.1497	0.3880	0.6122
10	Active heat transfer area(m^2)	0.03142	0.03142	0.03142

In theory, the gradient in the counter flow is constant, resulting in constant heat flow at each point. The gradient is initially large for the parallel flow but as the flow length increased, the temperature difference decreased which results in less heat flow.

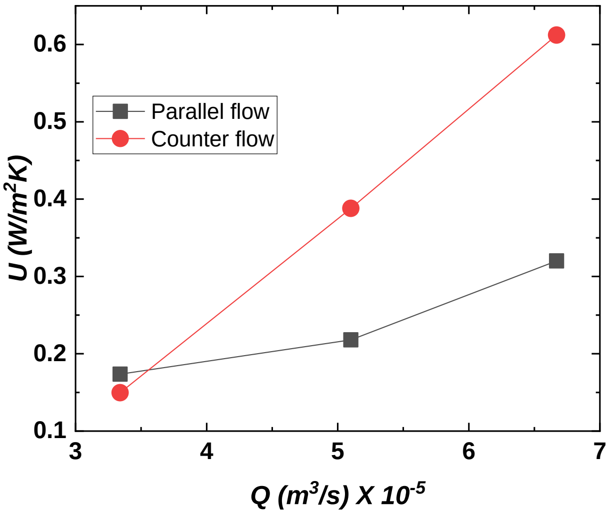


Fig. 4. Overall heat transfer coefficient against flow rate.

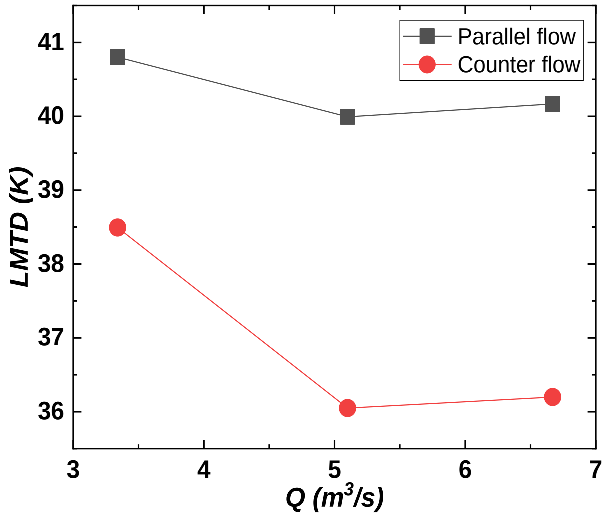


Fig. 5. LMTD against flow rate.

Fig. 5 shows the plot of the LMTD against the mass flow rate. In a heat exchanger, the heat flow depends directly on the difference in temperature of the hot and cold fluids. Because the temperature gradient is not linear but exponential, it is calculated using the logarithmic mean difference in temperature (LMTD). The LMTD of the counter flow heat exchanger is seen to be less than that of the parallel flow configuration. This phenomenon is the reverse of the ideal situation of a counter flow process of a heat exchanger. However, the LMTD is always higher in a counter flow heat exchanger than the LMTD of a parallel flow heat exchanger, thus the heat transfer in a counter flow exchanger will be higher than a parallel flow exchanger. The reason for the reversed condition could be as a result of the effect of using the same pipe materials for the shell and tube. In this present work, the Reynolds number of the flow was not estimated, but this would be capture in the next edition of this work. Thus the flow pattern in both the heat exchanger's tube and shell compartments might be laminar or turbulent. The turbulent pattern is responsible for the high Nusselts number values, with a higher Nusselts number for the shell side flow. This is an indicator that, as a result of the higher turbulence encountered; convective heat flow in the shell side is greater. This turbulence is important for efficient heat transfer and a way to increase turbulence is by increasing the number of tubes, the length of the tube, the shell diameter and using several shells either in series or parallel.

IV. Conclusion

Engineering education is incomplete without laboratory practices. One of such laboratory equipment necessary for all engineering student to have had hands on in the course of their undergraduate studies is the heat exchanger. This study presents the detailed design and construction of a laboratory type double pipe heat exchanger that can be used both in the parallel and counter flow configuration. The heat exchanger was constructed using galvanized steel for both the tube and shell. Experiments were designed and carried out to test the heat exchangers. To limit the number of experiments into a manageable quantity, the hot and cold flow rates are kept equal varying between 3.33×10^{-5} m^3/s (2 LPM) to 6.67×10^{-5} m^3/s (4 LPM) for a parallel flow configuration and for a counter flow configuration. The trends are the same as in literatures, showing that there was heat transfer from the hot fluid to the cold fluid for both the parallel flow and counter flow configuration. Though the heat transfer is small, this can be attributed to the fact that the tube and shell materials are the same, hence, was anticipated.

The heat exchanger performance characteristics (LMTD, heat transfer rate, effectiveness and overall heat transfer coefficient) were obtained and compared for the two configurations. The LMTD tends to be relatively constant as the flow rate was increased for both the parallel and counter-flow configuration but with higher value for the parallel flow configuration. The heat exchanger has a higher heat transfer rate, effectiveness and overall heat transfer coefficient and therefore has more performance capability for the counter flow configuration. The Overall heat transfer coefficient increased as the flow rate increased for both configurations.

V. Declaration

The authors declared that there is no potential conflict of interest with respect to the research, authorship, and/or publication of this article. Data for this research can be made available if requested.

VI. Acknowledgment

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References

[1] S.-S. Hsieh, C.-T. Liauh, and A. C. Ku, "Heat transfer coefficients of double pipe heat exchanger with helical type roughened surface," *Heat Recover. Syst. CHP*, vol. 7, no. 2, pp. 119–127, Jan. 1987.
[2] S. F. Tsai, T. W. H. Sheu, and S. M. Lee, "Heat transfer in a conjugate

heat exchanger with a wavy fin surface," *Int. J. Heat Mass Transf.*, vol. 42, no. 10, pp. 1735–1745, 1999.
[3] M. Petrik, G. Szepesi, and K. Jármai, "Optimal Design of Double-Pipe Heat Exchangers," in *Advances in Structural and Multidisciplinary Optimization*, 2018, pp. 755–764.
[4] U. K. N. Madhav Mishra, "Experimental Investigations of Double Pipe Heat Exchanger With Triangular Baffles," *Int. Res. J. Eng. Technol.*, vol. 03, no. 08, pp. 1137–1141, 2016.
[5] C. Rakesh, C. Nallode, M. Adhvaith, and A. H. A. Krishna, "Design and Performance Analysis of Double Pipe Heat Exchanger," pp. 12578–12584, 2017.
[6] P. P. B. Dehankar, "A Double Pipe Heat Exchanger – Fabrication and Standardization," *Int. J. Recent Innov. Trends Comput. Commun.*, vol. 3, no. 4, pp. 1845–1847, 2015.
[7] K. Kirti, B. Z. and Dipika, "Design of double pipe heat exchanger," *Int. J. Sci. Technol. Manag.*, vol. 5, no. 12, 2016.
[8] B. S. Sriram, A. S. Kumar, M. L. . V. Aristotle, G. Yogeshwaran, and M. Sridharan, "A Short Review on Double Pipe Heat Exchanger," *SSRG Int. J. Mech. Eng.*, no. March, pp. 4–7, 2019.

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