Experimental Investigation of Heat Transfer Enhancement Methods on the Thermal Performance of Double Pipe Heat Exchanger

Ehsan F. Abbas
The Supervisor

Sami R. Aslan
The Co-Supervisor

Taherah A. Ridha
Master Student

Kirkuk Technical College / Northern Technical College,
Kirkuk, Iraq

Abstract : **The aim of this study is to improve the heat transfer in a double tube heat exchanger by using four samples of the inner tube (smooth tube, half circular finned tube, circular finned tube and circular helical finned tube). The experiments were carried out by using the four kinds of fluids flow, namely, (a parallel flow of cold water inside the inner tube, a parallel flow of hot water inside the inner tube, the counter flow of cold water inside the inner tube and the counter flow of hot water inside the inner tube). The comparative results of the finned tubes with respect to the smooth tube showed the highest values of heat transfer coefficient obtained at the circular helical finned tube instate of hot water flow inside the tube. The convection heat transfer coefficient increased by (250 and 165)% for both flows (parallel and counter), respectively in case of turbulent flow, while in state of the hot water flow on the outer surface of the inner tube, the heat transfer coefficient increased by 230 % for parallel flow and in the case of the counter flow increased by 260 %. The fanning friction factor was affected by a condition of the working fluids where in the case of hot fluid flows outside surface of the inner tubes, the min. values of fanning friction factors was obtained from smooth tube sample which is ranged from 0.01 to 0.05 and other samples are ranged from 0.008 to 0.05.**

Keywords: Double Pipe Heat Exchanger, Finned Tube, Performance Of Heat Exchanger.

Nomenclature:

A: Cross section area m^2
c_p *: specific heat* *J/kg. ℃*
D: Diameter *m*
f: Fanning friction factor
h: heat transfer coefficient W/m^2. ℃
L: Length *m*
i: Enthalpy *J/kg*
$\dot{m}$*: Mass flow rate* *kg/s*
P: Perimeter *m*
ΔP*: Pressure drop*
q: Heat transfer rate *W*
T: Temperature *℃*
$\bar{T}$*: Temperature* *℃*
u: Velocity *m/s*

Subscribes
c:cool
f: Film
h: Hot
H: Hydraulic
i: Inside
in: Input
m: mean
o: outside
w: wall
1: inlet
2: outlet
Dimensionless Group
Re: Reynolds number
Greek letters
∞: Fluid
μ*:Dynamic Viscosity* *kg/m s*
ρ*: Density* *kg/m*^{3}

INTRODUCTION

Heat exchanger is considered one of the basic ingredients in industrial installations such as power plants, petrochemical plants, refrigeration and air conditioning systems, nuclear power plants and dairy plants... etc. The working principle of this engineering machine is to transfer the thermal energy or heat content (Enthalpy) between two or more substances at different temperatures through direct contact between them. In this case it is called the (Direct contact heat exchangers) or indirect contact through the wall of the high conductivity of heat to separate them which is called (Indirect contact heat exchangers). Heat exchangers are generally classified according to transfer process, number of fluids, surface compactness, construction features, flow arrangements and heat transfer mechanisms [1 to 3]. The concentric double tube heat exchangers are widely used in various industrial areas where they are used to improve thermal performance of the exchangers, for the significance of this kind of heat exchanger a number of researchers attempted to improve the thermal performance in different ways such as changing the heat transfer area or using composite fluids. The researchers [4 to 11] have presented practical and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

theoretical studies about the use of various forms of fins to increase the heat transfer to the outer surface of the tube space while researchers [12 to 17] have presented studies on improving the inner surface of the tube by entering spiral wires inside the tube. As for the use of composite fluids (Nano-Fluid), the researchers [18 to 21] have presented a practical study on the use of different types of Nano-Fluid in a double heat exchanger. In general, using different ways to increase the surface area for heat transfer has contributed significantly in increasing the thermal performance of heat exchangers when compared with its counterparts without the surface optimization, but there is a downside in which the increase in pressure drop for the surface optimization and thus for maintaining the flow requires the use of recycling fluid pumps in a larger capacity than normal situation. This study includes the use of surface optimization on the outer surface of the inner tube for the double pipe heat exchanger which is intended for this purpose, where three different types of the geometric shapes of the finned discs were used to compare the thermal performance with smooth tube which is no finned and is similar to them in the dimensioning and metal. It aims to conduct tests on the four models and two types of flow direction (parallel flow and counter flow) at different quantities of flow rates and to find the comparison for each of the heat transfer coefficient and pressure drop.

The Mathematical Model

a) Calculating the heat transfer coefficient by convection.

Heat transfer between the two fluids in the heat exchanger depends on many factors, and one of these factors is the manner of the flow between the two fluids in the heat exchanger. The flow in a double tube heat exchanger is used by two types (Parallel flow and Counter flow). The temperature difference depends on the manner of the flow of each fluid as well, depending on the temperature distribution along with the heat exchanger as it is noted in Figs1 and 2 which represent the temperature distribution within the heat exchanger with the counter and parallel flow respectively [1and 24].

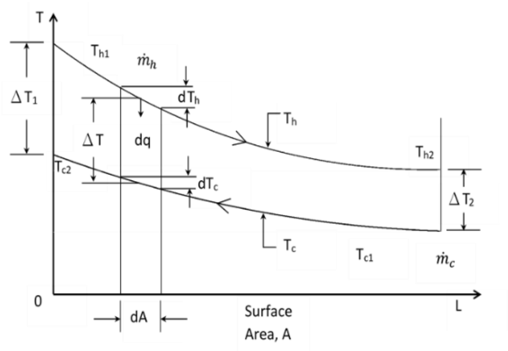


Figure (1) temperature distribution between fluids in the counter flow of heat exchanger

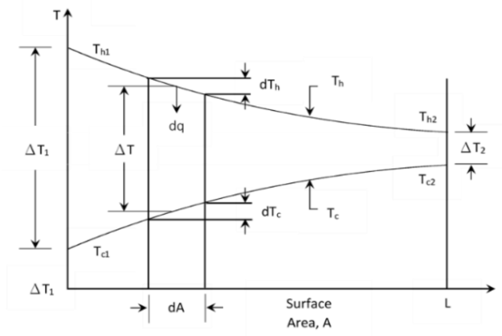


Figure (2) temperature distribution between fluids in the parallel flow of heat exchanger

The heat transfer in the heat exchanger is analyzed based on energy balance between both fluids by application of the first law of thermodynamic of the open system on the finite element control volume with the area (dA) under conditions of steady state, stable flow, thermally insulated system, neglected change in kinetic energy and neglected potential energy.

The amount of heat exchanged between the two fluids in the control volume is calculated by product of the mass by change of enthalpy, as given by:

$$dq = \dot{m}\, di \qquad (1)$$

By performing integration of the eq. (1) and within the limits of integration (1 to 2), the amount of the rate of heat transfer in the heat exchanger becomes;

$$q = \dot{m}(i_2 - i_1) \qquad (2)$$

In case of constant specific heat and single phase fluid, the change of enthalpy is calculated from:

$$di = c_p\, dT \qquad (3)$$

Substituting eq. (3) into eq. (2) yields:

$$q = (\dot{m} c_p)\, dT \qquad (4)$$

where eq.(4) expressed mathematically in two forms and according to the (hot and cold) fluids as in eqs. (5 and 6), respectively:

$$q_h = (\dot{m}\, c_p)_h (T_{h1} - T_{h2}) \qquad (5)$$

$$q_c = (\dot{m}\, c_p)_c (T_{c2} - T_{c1}) \qquad (6)$$

We assume ideal operation condition for heat exchanger,

$$q = q_h = q_c \qquad (7)$$

In the heat exchanger, the energy transferred between two fluids by three modes of heat transfer like conduction, convection and radiation where the amount of heat transfer rate between any fluids and surrounding wall can be calculated it by newton's law of cooling.

$$q^{"} \propto (T_w - T_\infty) \qquad (7)$$

when the proportionality constant is inserted,

$$q^{"} = h(T_w - T_\infty) \qquad (8)$$

The proportionality constant called is the convection heat transfer coefficient, which plays a very significant role in the heat transfer rate by convection. However, it does not look like the thermal conductivity because it is not the characteristic of the material, but it’s a function of (the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

geometry of the surface, fluid motion, the properties of the fluid and the temperature difference between the surface and the fluid). The convection heat transfer coefficient has been calculated for each side of the inner tube in the heat exchanger as given below:

$$q^{"} = h_h(T_{w,h} - \overline{T_h}) \quad (9)$$

$$h_h = \frac{q^{"}}{(T_{w,h} - \overline{T_h})} \quad (10)$$

$$q^{"} = h_c(T_{w,c} - \overline{T_c}) \quad (11)$$

$$h_c = \frac{q^{"}}{(T_{w,c} - \overline{T_c})} \quad (12)$$

The convection heat transfer is classified into two types according to the fluid motion as free convection when the fluid moves naturally and forced convection when the mechanical equipment is used for moving the fluid over bodies.

To collect all functions which affected the convection heat transfer coefficient in one dimensionless, the quantity named Reynolds number and can be expressed mathematically as:

$$Re_d = \frac{\rho u D_h}{\mu} \quad (13)$$

where

$$D_h = \frac{4A}{P} \quad (14)$$

$D_h = D_i$ for inner flow

and

$D_h = D_o - D_i$ for flow through the annular area, and he physical proper-ties of the fluid are evaluated at T_f,

$$T_{f,h} = \frac{T_{w,h} + \overline{T_h}}{2} \quad (15\text{-a})$$

$$T_{f,c} = \frac{T_{w,c} + \overline{T_c}}{2} \quad (16\text{-b})$$

b) Pressure drop calculation.

Pressure drop due to internal flow depends on following factors:

- Friction between the fluid and tube wall.
- Friction between the layers of fluid during flow.
- Loss due to accessories in the pipeline network.
- Loss resulting from the difference in the level of the flow.

Pressure drop due to internal flow in the inner tube calculated from,

$$\Delta P = 4f\frac{L}{D_i}\frac{\rho u_m^2}{2} \quad (17)$$

and

$$f = \frac{\Delta P}{4(L/D_i)(\rho u_m^2/2)} \quad (18)$$

While pressure drop in the annular side calculated from

$$\Delta P = 4f\frac{L}{D_h}\frac{\rho u_m^2}{2} \quad (19)$$

and

$$f = \frac{\Delta P}{4(L/d_h)(\rho u_m^2/2)} \quad (20)$$

Practical Aspect.

1. Description of experimental apparatus.

Fig.(3) shows a photographic of concentric double pipe heat exchanger which was used in this study and which consists of two pipes with a dimension of 20 mm inside diameter, 1 mm wall thickness, and 1800 mm length for inner pipe made of copper, while the outer pipe made of galvanized iron of 50 mm inside diameter and same length with copper tube. The outer pipe is insulated with 50 mm thick to prevent heat loss to the surrounding and two pumps are used to circulate the hot and cold water and two flow meters are used at each side of the heat exchanger for controlling to the water. The heat exchanger is supplied by two manometers for measuring the pressure drop at each side. The heat exchanger is supplied by two manometers for measuring the pressure drop at each side, while 16 channel temperature data logger was used for recording instantaneous temperature in the 16 position inside heat exchanger as shown in figure (4).

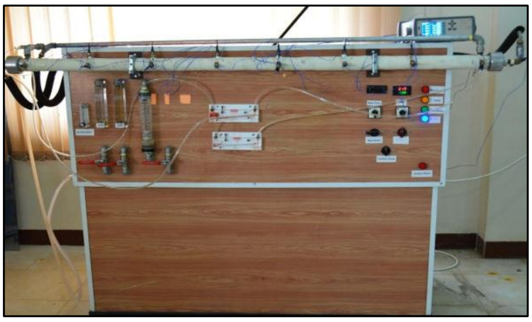
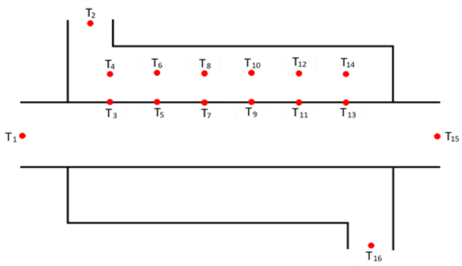


Figure (3) Photograph of Heat Exchanger



Figure(4) Distribution of 16 thermocouples type K inside the heat exchanger

2. The experiment samples

Fig.(5) shows a photographic and schematic diagram of four samples used in this study. One of these samples is a smooth pipe used as a reference sample and other samples are added to the outside with surface 58 fins, dimensions 22 and 40 mm inside and outside diameter respectively and 3 mm thick and they are made of galvanized iron. These fins are distributed along 1600 mm with a pitch of 30 mm leaving a distance of 100 mm on both ends of the pipe and they are used in three forms (annular, half annular and helical annular).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

(A)

(B)

(C)

(D)

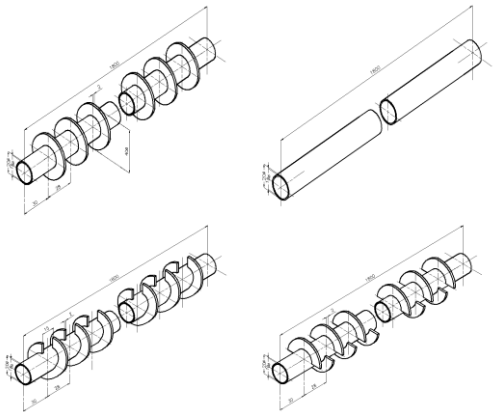


Figure (5) Photograph and schematic diagram of the samples:
(A) Smooth pipe. (B) Annular finned pipe.
(C) Half annular finned pipe. (D) Helical annular finned pipe.

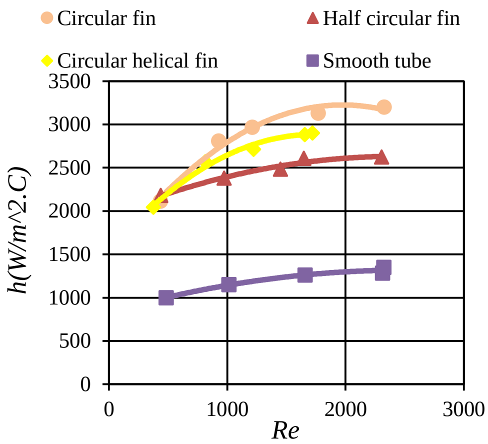
3. The methods of experiments execution.

The execution of the experiments on the samples depends on the four patterns of the flow illustrated below:

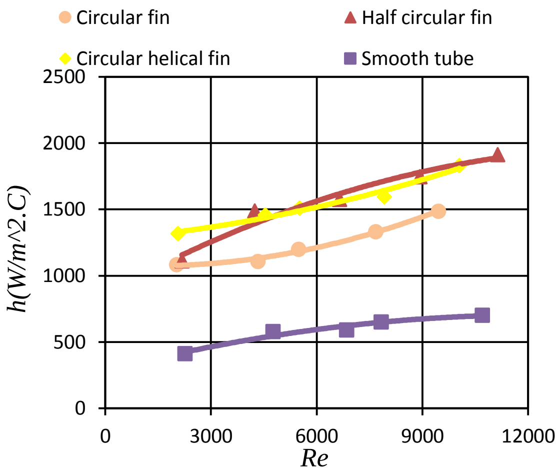
a) The hot fluid flowed inside inner tube in parallel flow with cold fluid that flows inside annular cross-section.
b) The hot fluid flowed inside inner tube in counter flow with cold fluid flowed inside annular cross-section.
c) The hot fluid flowed inside annular cross-section in parallel flow with cold fluid flowed inside inner tube.
d) The hot fluid flows inside annular cross-section in counter flow with cold fluid that flow inside inner tube.

RESULTS AND DISCUSSION

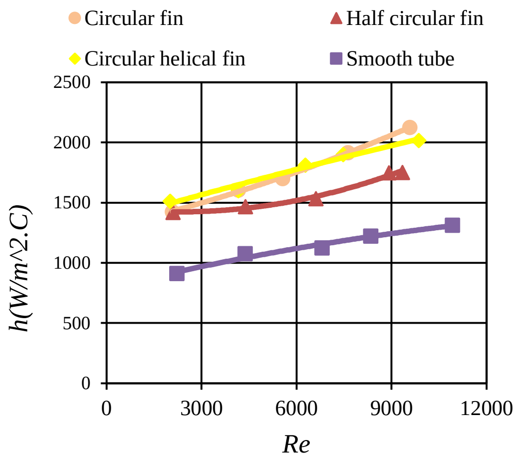
Figs. (6 to 9) show the relation of convection heat transfer coefficient against Reynolds number for all samples in each case of hot fluid flow. When hot fluid flows inside an inner pipe in the parallel condition the highest values of convection heat transfer are obtained at the sample of half annular finned tube, they ranged approximately from 1100 to 1900 $W/m^2.^oC$, while in the state of the counter flow the highest values were obtained at the sample of annular finned pipe they ranged from 1420 to 2125 $W/m^2.^oC$, as shown in figs.(6 and7) respectively. However, if the position of hot fluid is changed into the annular position, the hot fluid changed from turbulent state to laminar flow and the highest values of convection heat transfer coefficient were obtained at an annular finned pipe and ranged from 2050 to 3200 $W/m^2.^oC$ in parallel flow while in the state of the counter flow, the highest values obtained at the half finned pipe ranged from 2950 to 3400 $W/m^2.^oC$ $W/m^2.^oC$, as indicated in Figs. (8 and 9) respectively.



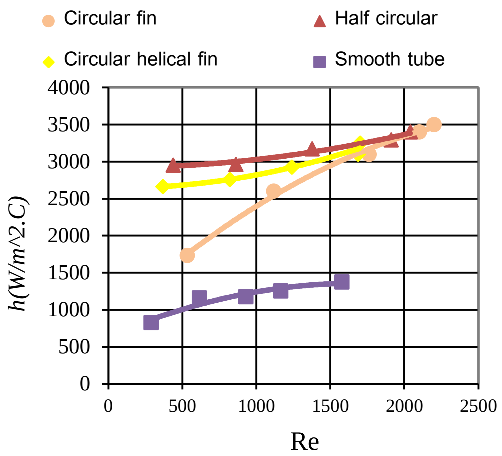
Fig(6) Reation of **h** with ***Re*** for parallel flow for all sample when cold water flows inside the inner pipe



Fig(6) Reation of h vs Re for parallel flow for all sample when hot water flows inside the inner pipe



Fig(7) Reation of ***h*** vs ***Re*** for counter flows for all sample when hot water flows inside the inner pipe



Fig(9) Reation of ***h*** vs ***Re*** for counter flows for all sample when cold water flows inside the inner pipe

In the study of influences of both of direction of flow and temperature on the fanning friction factor, we noted that the fanning friction factor is affected very little in both cases of cold water when it flows in the annular, where the fanning friction factors in the smooth pipe ranged approximately from 0.01 to 0.04 and in finned pipe samples the highest values obtained at circular finned pipe ranged from 0.01 to 0.05, as shown in Figs (10 and 11). When the hot water changes to the annular position and it flows over an extended surface, we noted that the minimum values of fanning friction factor in two cases of flow arrangements obtained at a smooth pipe and ranged from 0.01 to 0.03, but the highest values are obtained at half finned pipe in parallel flow and ranged from 0.01 to 0.048, while in counter flow obtained at annular finned pipe and ranged from 0.008 to 0.05, as shown in Figs.(12 and 13).

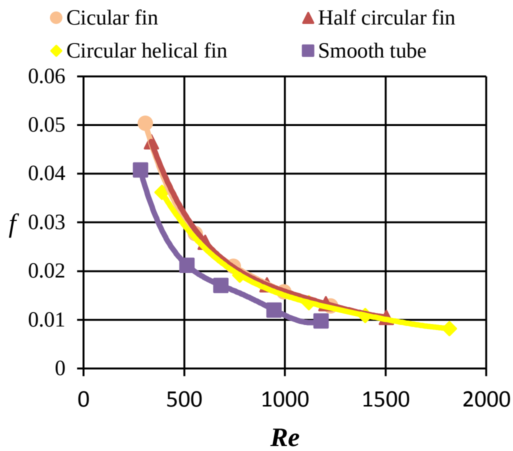


Fig. (10) Relation ***f*** vs ***Re*** for parallel flow when hot waters flow inside the inner pipe

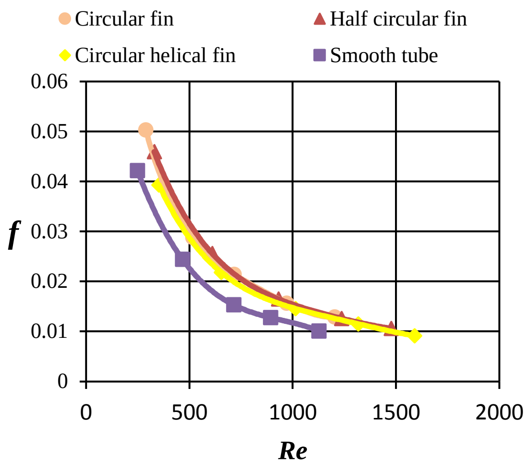
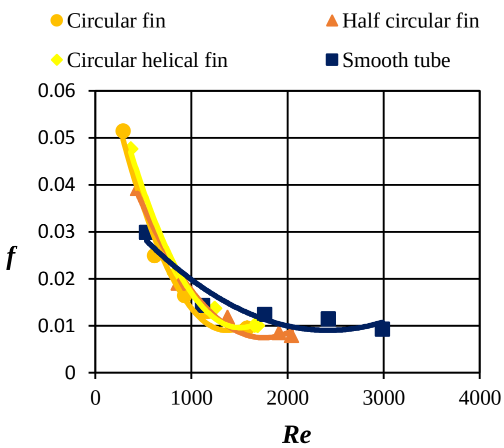


Fig. (11) Relation ***f*** vs ***Re*** for counter flow when hot water flows inside the inner pipe



Fig(12) Relation of ***f*** vs ***Re*** for parallel flow when cold water flows inside the inner pipe

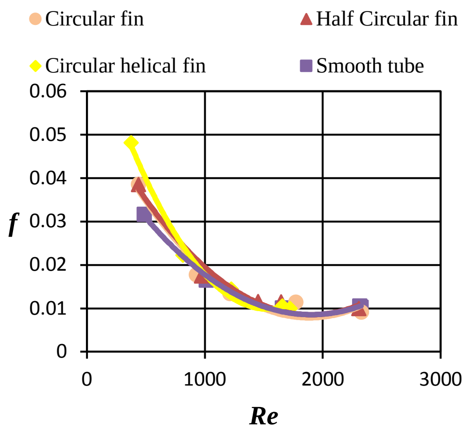


Fig. (13) Relation ***f*** vs ***Re*** for counter flow when cold water flows inside the inner pipe

CONCLUSION

from the results which were obtained , it is concluded that the surface enhancement has considerable influence on the heat transfer coefficient, and it is also observed from the results that the increase in the surface area contribute significantly to the heat transfer coefficient value in the hot fluid side. The higher values were obtained by using the circular helical sample by (250 and 165) % of the parallel and counter flow, respectively, in the case of turbulent flow in the pipe compared to the smooth tube. As in the case of hot water flow on the outside surface of the pipe, the heat transfer coefficient value increased by 230%. while in the case of counter flow, the heat transfer coefficient value increased by 260% comparing to the smooth pip. The results of the fanning friction factor indicated that flow direction has a minor effect when the cold water flows through outside surface and ranged from (0.01 to 0.05) almost in all cases. At the hot water flows through outside surface of the parallel and counter flow, it has been observed that the fanning friction factor for the smooth pipe ranged from (0.01 to 0.03) and the highest values obtained at the helical annular finned pipe (0.008 to 0.05).

REFERENCES:

[1] Ramesh K. Shah and Dosan P.Sekulic, "Fundamentals of heat exchanger design", Published by John Wiley & Sons, Inc., New Jersey, 2003.

[2] Hesselgreaves J. E., "Compact heat exchangers, Selection, Design and operation", An Imprint, New York, 2001.

[3] Kakac S. and Liu H., "Heat exchangers, Selection, Rating and Thermal design", 2nd edition, CRC Press, New York, 2002.

[4] Eiamsa-ard S., Pethkool S., Thianpong Sh., and Promvonge, "Turbulent flow heat transfer and pressure losses in a double pipe heat exchanger with louvered strip inserts", Communicated by W.J.Minkowycz, 2007.

[5] Rao P. Sankara, and Kumar K. Kiran, "Numerical and experimental investigation of heat transfer augmentation in double pipe heat exchanger with helical and twisted tape inserts", International Journal of Emerging Technology and Advanced Engineering, Vol.4, Issue 9, pp180-191, 2014.

[6] Kailash O. Pramod, Bishwajeet NK. Ch., Umang B.G., Sumit B P., and Gopal A. K., "Design and experimental of pipe in pipe heat exchanger", International Journal of Modern Engineering Research, Vol.5, Issue 3, pp42-48, 2015.

[7] Anipey P., Prasad L. S., Prasad B. S., and Murthy B. S. N., "Fabrication and experimental evaluation of heat transfer enhancement method in heat exchangers", International Journal of Advanced Engineering Application, Vol.6, Issue 1, pp17-25,2013.

[8] Sahiti N., Bunjaku F., and Krasniqi, "Assessment of single phase convection heat transfer enhancement", Trends in the Development of Machinery and Associated Technology, pp321-324, 2013.

[9] Abdal Hussein S. A., "Experimental investigation of double pipe heat exchanger by using semicircular disc baffles", International Journal of Computer Applications, Vol. 115 – No. 4, pp13-17, 2015.

[10] Omkar M. Sh., Pravin A. M., Hameed G. Sajid A., and Pradeep A. P., "Experimental investigation of double-pipe heat exchanger with helical fins on the inner rotating tube", International Journal of Research in Engineering and Technology, Vol.3, Issue 7, pp98-102, 2014.

[11] Indhe M. J., and Bhatkar V. W., "Optimization of longitudinal fin profile for double pipe heat exchanger", International Research Journal of Engineering and Technology, Vol.2, Issue 4, pp517-529, 2015.

[12] Mr.Kumbhar D.G., Dr. Sane N.K., "Heat transfer behavior in a tube with conical wire coil inserts", http://www.bvucoepune.edu.in/pdf's/Publications_2004-2011/Publications_9-10 / International_Conferece9-10/IC4-9-10.pdf.

[13] Patel M.J., Parmar K.S., and Soni U. R., "Enhance the performance of heat exchanger with twisted tape insert: A Review", International Journal on Recent and Innovation Trends in Computing and Communication, Vol.2, Issue 2, pp202-207, 2014.

[14] Gaikwad D., and Mali K., "Heat transfer enhancement for double pipe heat exchanger using twisted wire brush inserts", International Journal of Innovative Research in Science, Engineering and Technology, Vol.3, Issue 7, pp14741-14748, 2014.

[15] Pardhi C. K., and Dr. Baredar P., "Performance improvement of double pipe heat exchanger by using turbulator", International Journal of Engineering Science and Advanced Technology, Vol.2, Issue 4, pp881-885, 2012.

[16] Surendran R., and Suresh P., " Insert of passive techniques in double pipe heat exchanger for heat transfer enhancement", International Journal of Mechanical and Production Engineering Research and Development, Vol.4, Issue 2, pp107-110, 2014.

[17] Sarada S. Naga, Sita Rama Raju A.V., Radha K. Kalyani, and Sunder L. Shyam, "Enhancement of heat transfer using varying width twisted tape inserts", International Journal of Engineering, Science and Technology, Vol.2, No. 6, pp107-118, 2010.

[18] Luki A. A., and Ganesan M., "Flow analysis and characteristics comparison of double pipe heat exchanger using enhanced tubes", IOSR Journal of Mechanical and Civil Engineering, pp16-21,

[19] Mahdi Q. Saleh, Abbood S. A. Fattah, and Abbas F. A., "Investigation of heat transfer augmentation from U-longitudinal finned tube heat exchanger", Advances in Energy and Power, Vol.3, No.2, pp19-28, 2015.

[20] Mohamed M. A. El-Magid, Hanafy A.A., Hasan A-A., and El-Maghlany W. M., "Heat transfer enhancement in rotating tube in tube heat exchanger by using CU-water nanofluid", International Journal of Advanced Scientific and Technical Research, Vol.4, Issue 5, pp101-114, 2015.

[21] Mohammed H. A., and Abdul Wahid M., "Heat transfer enhancement of Nanofluids in a double pipe heat exchanger with louvered strip inserts", International Communications in Heat and Mass Transfer 40, pp36-46, 2013.