NUMERICAL ANALYSIS OF TRIPLE TUBE HEAT EXCHANGER USING ANSYS

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Abstract- This paper resembles a numerical approach for a new type of thermal energy exchange unit which is a triple concentric tube heat exchanger (TCTHE) .The performance of TCTHE for both parallel and counter flow type arrangements are investigated. Also temperature variation for different flow of the three fluid cold-hot-normal (C-H-N) and normal-hot-cold (N-H-C) along the length of triple tube are done using ANSYS 14. The fluid used is water, hot fluid always flows in the intermediate tube and hot and cold fluid in outer tube and inner tube respectively that may be interchanged. The results obtained shows better result in counter flow type with cold fluid in outer tube and normal fluid in inner tube (NHC arrangement).

Index terms: triple tube, heat exchanger, parallel flow, counter flow

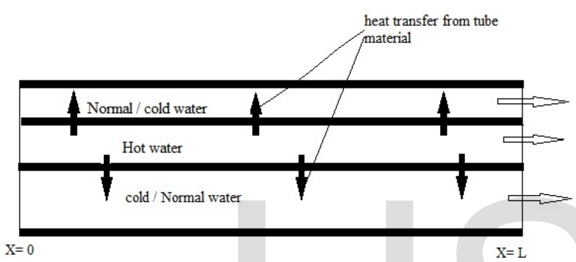
1 INTRODUCTION

There has been a frequent approach towards improvement in heat exchanger devices so that lesser heat energy would be lost to the surrounding and achieve a high efficient and effective heat exchanger device. In this race lots of designs for heat exchanger have been developed and still research is going on for further improvement in such units. Different types of augmentation technique, corrugation technique [1],[2]or fluid change or use of phase change material[3], use of nano-fluids[4] etc have been implemented to get better result. The type of heat exchanger to be used is determined by the process and product specification. Such as industrial process heating, pasteurization, sterilization[5], dairy industry, drying, cooling or heating process in food industries, power plants etc. One of such approach is modification of heat exchanger unit. There are different types of heat exchangers being used like shell and tube, tube in tube (double tube) and cross flow type [5], [6]. For the double tube heat exchanger where concentric tubes (one tube is inside another tube), In one tube hot fluid flows where as in the other tube cold fluid flows and heat transfer between from high temperature fluid to low temperature fluid occurs. Some researchers have worked on an idea of introducing an intermediate tube to the double tube that makes it triple tube [7], [8], [9] and the latter has shown some improvement in performance as compared to the double tube heat exchanger. The primitive function of the intermediate tube is to carry the hot fluid and expose to relatively cold fluids on both surface so that more heat transfer would occur with same unit length and hence more temperature fall in the hot fluid. more heat transfer would occur with same unit length and hence more temperature fall in the hot fluid.

The contribution of this paper is to undergo an investigation for working of triple tube heat exchanger. Previously a case study towards a triple pipe heat exchanger, a mathematical model for LMTD calculation [10], a model to calculate the effectiveness of the triple tube heat exchanger [12] has been approached. Also an experimental approach [11] has been done. In this paper a computational simulation work using ANSYS software as a tool for evaluating the performance of triple tube heat exchanger is approached by using other properties like density, specific heat, viscosity, thermal conductivity etc.

The present work

The triple tube heat exchanger has the hot fluid in the intermediate (middle) tube and the cold fluid or normal fluid in the outer or inner tube or vice-versa. The performance for both parallel flow and counter flow types has been evaluated for a length of 4 meter tube and the temperature distribution is obtained at different velocity of hot fluid but for cold and normal fluid at fixed velocity as for the inner tube and outer tube. The material of the pipe is steel. The fluid being used is water. The hot fluid is at temperature of 51°C, cold fluid at temperature of 10°C and normal fluid at temperature of 27°C at the inlets respectively. The flow arrangements are cold-hot-normal (C-H-N) and normal -hot-cold (N-H-C) for the both parallel and counter type flows. The outer tube is insulated towards surrounding. The outer diameter of outer pipe is 0.1015 meter, intermediate pipe is 0.076 meter, and inner pipe is 0.050 meter respectively. The thickness of each tube is 1.5 mm.



heat transfer for parallel and counter flow arrangments with different flow types

Figure 1

k-ε Model

Continuity:

$$\frac{\partial(u)}{\partial x}+\frac{\partial(v)}{\partial y}+\frac{\partial(w)}{\partial z}=0 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

X momentum:

$$\frac{\partial(\rho uu)}{\partial x}+\frac{\partial(\rho vu)}{\partial y}+\frac{\partial(\rho wu)}{\partial z}=\frac{\partial\sigma xx}{\partial x}+\frac{\partial\tau yx}{\partial y}+\frac{\partial\tau zx}{\partial z} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Y momentum:

$$\frac{\partial(\rho uv)}{\partial x}+\frac{\partial(\rho vv)}{\partial y}+\frac{\partial(\rho wv)}{\partial z}=\frac{\partial\tau xy}{\partial x}+\frac{\partial\sigma yy}{\partial y}+\frac{\partial\tau zy}{\partial z} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Z momentum:

$$\frac{\partial(\rho uw)}{\partial x}+\frac{\partial(\rho vw)}{\partial y}+\frac{\partial(\rho ww)}{\partial z}=\frac{\partial\tau xz}{\partial x}+\frac{\partial\tau yz}{\partial y}+\frac{\partial\sigma zz}{\partial z} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

Energy equation:

$$\frac{\rho Cp}{k}\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)+\frac{\mu}{k}\left\{2\left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial u}{\partial y}\right)^2\right]+\left(\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}\right)^2\right\} \quad \ldots\ldots\ldots\ldots\ldots (5)$$

In case of parallel flow arrangement with NHC type i.e normal in inner pipe and cold fluid in outer pipe, the hot fluid temperature falls to 31.5°C from 51°C at inlet. This is because of larger surface area of the hot fluid pert is exposed to the cold fluid as it is flowing in the outer pipe. The temperature of cold fluid at the outlet is 23°C and normal fluid outlet temperature is 31.75°C respectively. Flowing in the intermediate pipe is exposed to normal fluid so lesser temperature difference and thus lesser temperature fall. The outlet temperature of hot fluid is 35°C with inlet at 51°C. The cold and normal fluid outlet temperature is 20.3°C and 33°C respectively. For counter flow arrangement with NHC the temperature fall for hot fluid is more than the parallel flow types. It is about 28.5°C at outlet for hot fluid and for cold and normal fluid temperature attained is 23.5°C and 32.5°C respectively. Likewise for CHN arrangements the temperature of hot fluid at outlet is 30°C and for cold and hot fluid is 31°C and 22.5°C respectively. Above results obtained at hot fluid velocity of 0.2415 m/sec. the outer tube is insulated to surrounding.

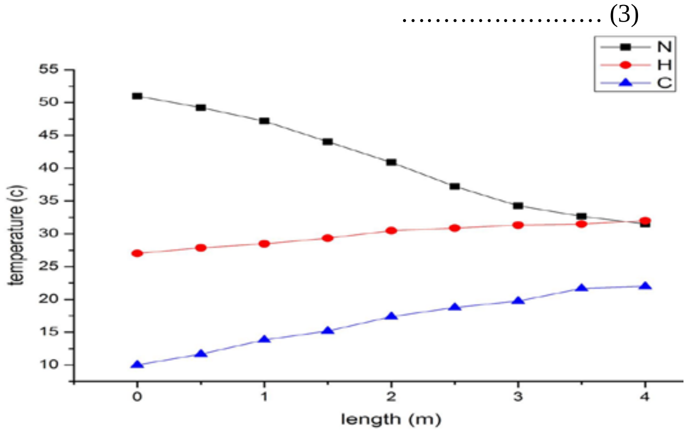


Figure 2.a temperature distribution wrt length for NHC arrangement in parallel flow.

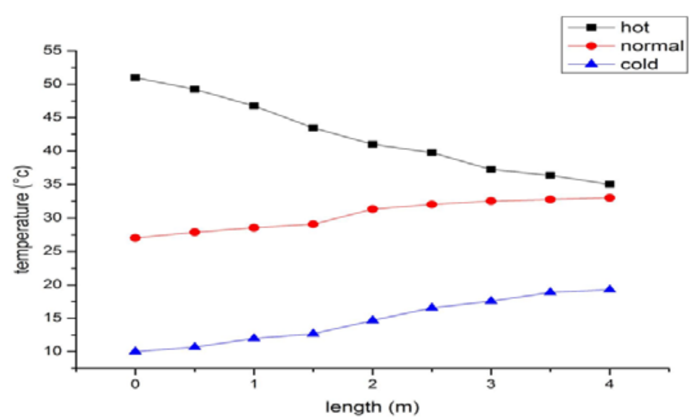


Figure 2.b temperature distribution wrt length for CHN arrangement in parallel flow

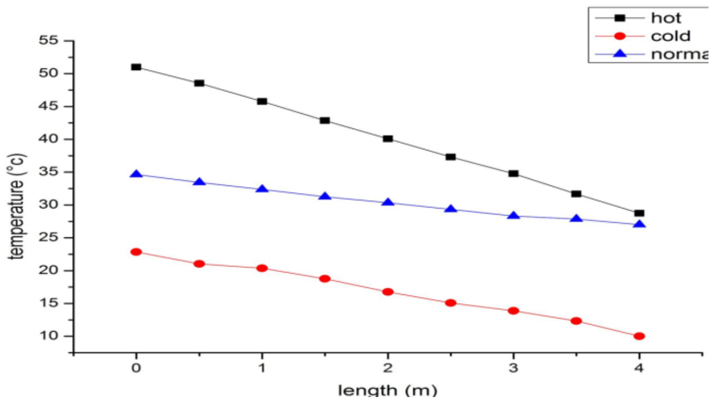


Figure 3.a variation of temperature wrt length for counter flow NHC

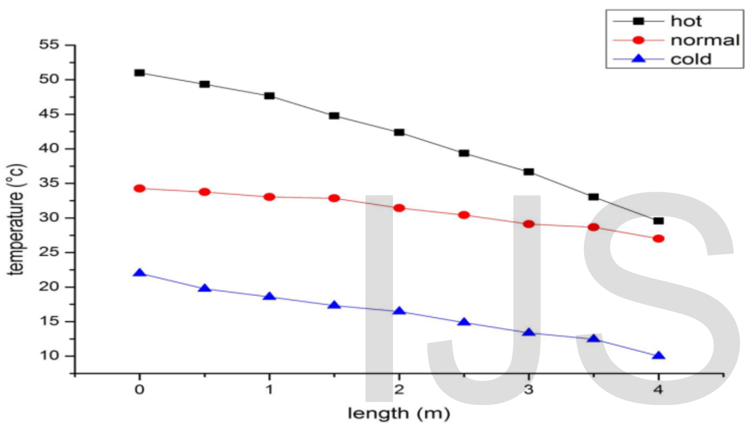


Figure 3.b variation of temperature wrt length for counter flow CHN

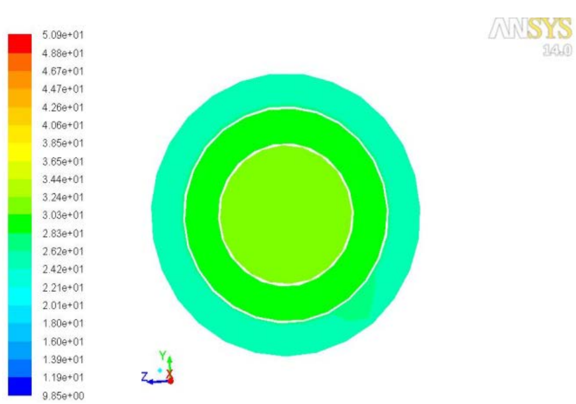


Figure 4.a parallel flow outlet temperature contour NHC

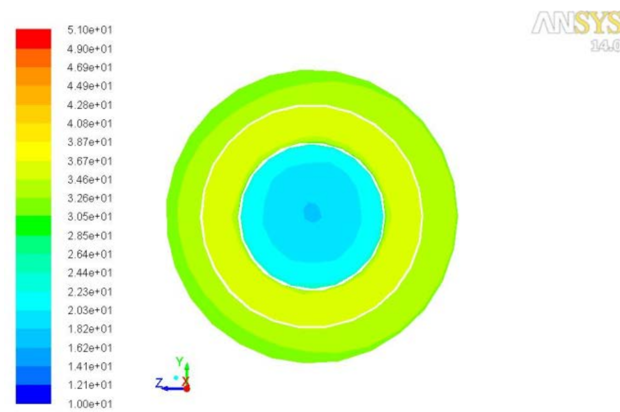


Figure 4.b temperature contour of outlet of parallel flow CHN

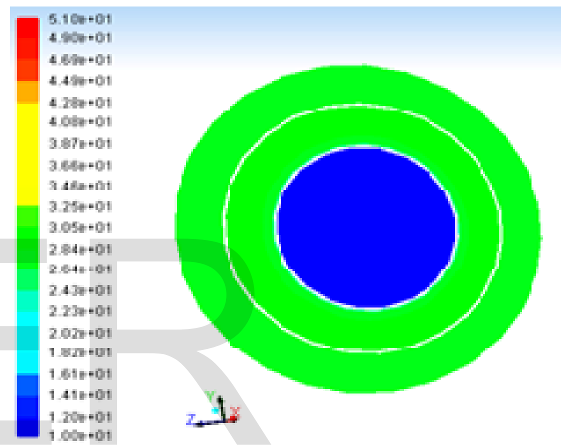


Figure 5.a counter flow NHC hot fluid outlet

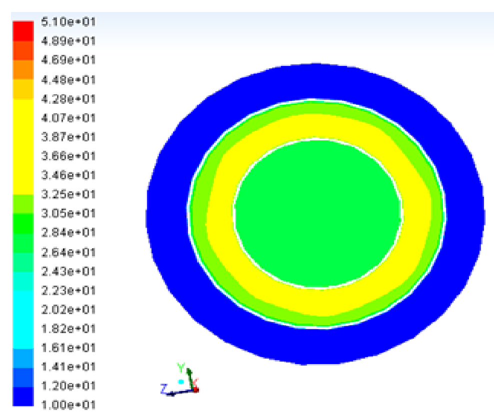


Figure 5.b counter flow CHN arrangement hot fluid outlet

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The inlet and outlet temperature contours of parallel and counter flow arrangements for both NHC and CHN arrangements are shown below. The fluid flowing in inner tube is at velocity 0.309 m/sec and for outer tube is 0.1789 m/sec.

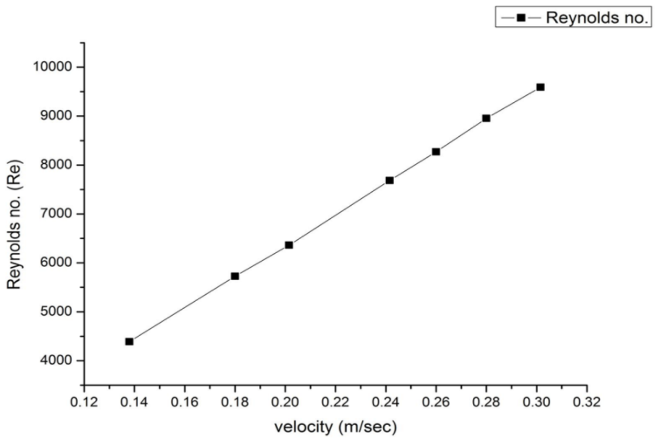

Figure 6 variation of Reynolds no. wrt velocity

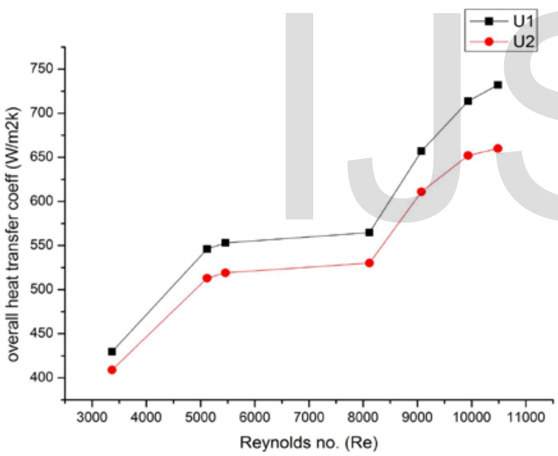

Figure 7.a variation of overall heat transfer coefficient wrt Reynolds no. for parallel flow in CHN

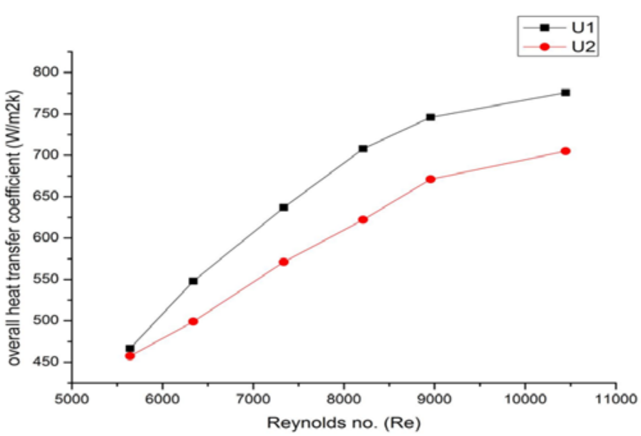

Figure 8.a variation of overall heat transfer coefficient wrt Reynolds no. for counter flow in NHC

$$U_1 = \frac{1}{\left(\frac{1}{h_m}\right) + \left(\frac{1}{h_o}\right)}$$

$$U_2 = \frac{1}{\left(\frac{1}{h_m}\right) + \left(\frac{1}{h_i}\right)} \quad \text{.....................(6)}$$

$$Nu = \frac{hD}{k} \quad \text{.............................. (7)}$$

$$\mathrm{Re} = \frac{dv\rho}{\mu} \quad \text{.............................. (8)}$$

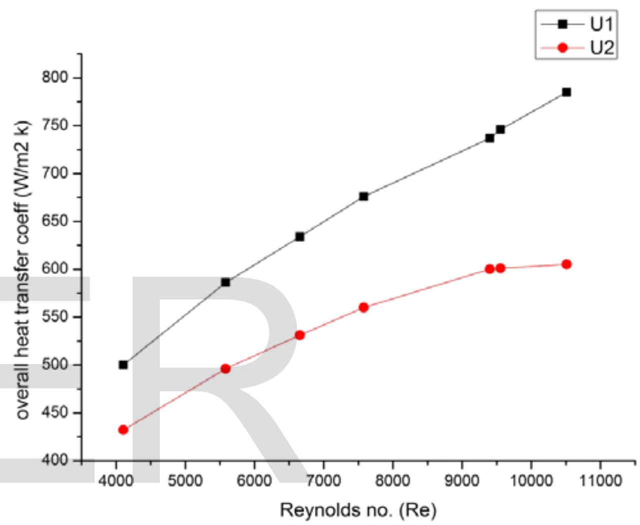

Figure 7.b variation of overall heat transfer coefficient wrt Reynolds no. for parallel flow in NHC

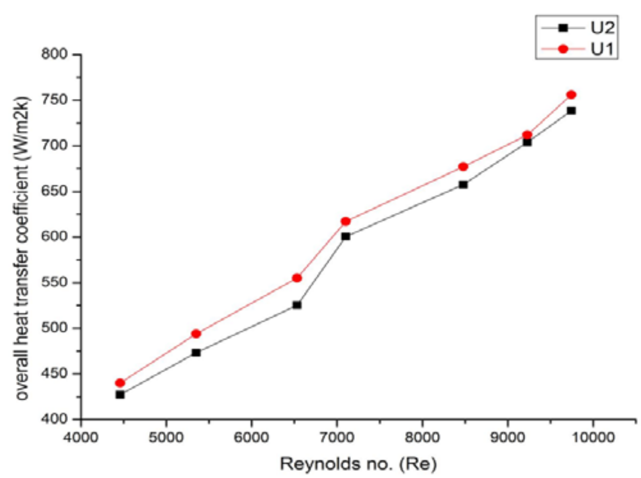

Figure 8.b variation of overall heat transfer coefficient wrt Reynolds no. for counter flow in CHN

The hot fluid flowing in intermediate tube is tested at various velocities from 0.138 m/sec, 0.18 m/sec, 0.2015 m/sec, 0.2415 m/sec, 0.26 m/sec, 0.28 m/sec and 0.3015 m/sec. the variation of Reynolds number with velocity for hot fluid is observed and calculated. The variation of overall heat transfer coefficient (U1) for hot fluid flowing in intermediate tube and the cold fluid flowing in outer tube in parallel flow obtained is higher than the overall heat transfer coefficient (U2) obtained from middle hot and inner cold fluid for both NHC and CHN respectively, whereas for counter flow its effect is vice-versa. It is observed that heat transfer coefficient achieved in NHC arrangement of counter flow is higher

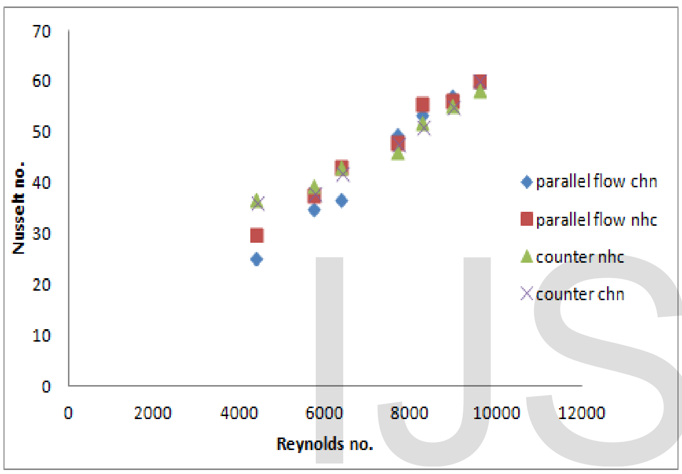

Figure 9 variation of Nusselt number wrt Reynolds number for both parallel and counter flow.

as compared to all other types of flows. The variation of Nusselt no. also obtained in NHC arrangement for counter flow is more for lesser Reynolds no. So, counter flow arrangement gives better result for same inlet conditions.

Conclusion:

A computational simulation on a triple tube heat exchanger has been carried out to investigate the heat transfer occurring in between three fluids at different temperatures. The results obtained are in terms of temperature distributions with respect to length, heat transfer coefficient variation with respect to change in Reynolds number i.e for different flow rates. It has been assumed that outer tube is insulated from surrounding to minimize the losses. The three fluids considered are the hot water in the middle annulus, cold water and normal tap water in the inner and outer tubes alternatively. The results shows heat transfer is more effective for NHC arrangements (normal in inner tube and cold in outer

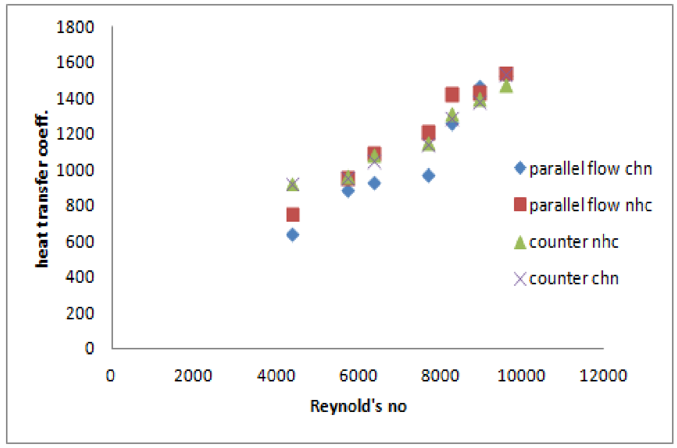

Figure 10 variation of heat transfer coefficient wrt Reynolds no for both parallel and counter flow arrangements in NHC and CHN.

tube) in both the parallel and counter flow cases. And heat transfer is more in counter flow NHC arrangements. It has been observed that in NHC arrangement cross-over points were achieved i.e temperature fall in hot fluid exceeds temperature rise in normal fluid. The velocity of fluid flowing in inner tube is fixed at 0.3 m/sec and for outer tube is at 0.1798 m/sec, whereas for hot fluid it is varied between 0.138 m/sec to .3015 m/sec. The crossover points occur when velocity for hot fluid is more nearer to velocity of normal fluid and for the flow arrangement for which in the outer tube cold fluid is flowing. This indicates heat transfer is predominant between cold and hot fluid as compared to normal and hot fluid due to greater temperature difference.

Nomenclature

A	area of heat transfer (m^2)
C_p	specific heat capacity (kJ/kg K)
D_H	equivalent hydraulic diameter (m)
f	friction factor
h	heat transfer coefficient (W/m^2 K)
k	thermal conductivity (W/m K)
v	velocity (m/sec)
Nu	Nusselt number
Pr	Prandtl number
Q	heat transfer rate (W)
Re	Reynolds number
P	pumping power (kW)
T	temperature (°C)
Lmtd	log mean temperature difference

μ dynamic viscosity (Ns/m^2)

ρ density (kg/m^3)

υ kinematic viscosity (m^2/s)

U overall heat transfer coefficient (W/m^2k)

ε turbulent dissipation rate(m^2/s^3)

ϵ heat transfer effectiveness

NTU number of transfer units

Subscripts:

C cold fluid
H hot fluid
n normal fluid
i inlet
o outlet
1 outer and middle
2 middle and inner

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