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Experimental Analysis Of Heat Transfer And Friction Factor For Counter Flow Heat Exchanger

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Abstract: This article reports experimental investigation of heat transfer and friction factor characteristics with different flow rates by means of CFD simulation. In this work is conducted by the double pipe heat exchanger with counter flow direction. The data acquire from the plain tube double pipe heat exchanger with the CFD simulation and ensure the validation results. The plain tube with dissimilar mass flow rates were also studied for comparison assessment. A commercial CFD package, Ansys CFD analysis was used in this study and 3D models of double pipe heat exchanger was generated in this simulation.

Keywords*:* Counter flow, CFD, Heat transfer

1. INTRODUCTION

Heat exchangers with convective heat transfer are widely used in many engineering application. Heat transfer enhancement or augmentation techniques refer to the improvement of thermo hydraulic performance of heat exchangers. Generally used to exchange heat between a gas and liquid, fin tube heat exchangers are widely used in chemical processing plants and power plants. These are two primary classifications of heat exchangers according to their flow arrangement; they are parallel flow and counter flow. In the parallel flow heat exchanges two fluids enters the exchanger at the same and travel in parallel to one another. In counter flow heat exchangers two fluids are enters the heat exchanger from opposite ends and travel in different direction. In this present work we are taken counter flow heat exchanger for refining the heat transfer and LMTD with different flow rates also found the exit temperature of heat exchangers. Sami[1], were discussed the numerical investigation of heat transfer and friction factor characteristic in a circular tube. Many Experimental investigation of heat transfer and friction factor were studied in the literature survey [2-6] .This experimental value is observed and compares the CFD simulation with the exit temperature.

2. COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics (CFD) is one of the branches of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. The Euler equations and Navier-Stokes equations both admit contact surfaces. The governing equations are solved on discrete control volumes. FVM recasts the PDE's of the N-S equation in the conservative form and then discretize this equation. Moreover this method is sensitive to distorted elements which can prevent convergence if such elements are in critical flow with regions. This integration approach yields a method that is inherently conservative (i.e. quantities such as density remain physically meaningful)

$$\frac{\partial}{\partial t}\iiint Q\,dV + \iint F\,d\mathbf{A} = 0,$$

After modeling the air duct given co-ordinates the model is meshed using Gambit Mapped mesh. Quadrilateral cells were used for this simple geometry because they can be stretched easily to account for different size gradients in different directions. The Spalart-Allmaras model was designed especially for aerospace applications involving wall-bounded has been shown to give good results for boundary layers subjected to adverse pressure gradients.

3. EXPERIMENTAL INVESTIGATION

The geometry configuration of plain tube with a thickness (t) 0.075cm, length (L) 220cm is used for simulation. In a double pipe heat exchanger is utilized as the main heat transfer test section which is insulated using asbestos to minimize heat loss to the surrounding. It consists of two concentric tubes in which hot water flows through the inner tube and cold water flows outer tube in counter flow through annulus. The outer tube is made of a cast iron having inside and outside diameters of 28mm and 32mm respectively. The inner tube made of an aluminum having inside and outside diameters of 20mm and 18mm respectively. Temperature data was recorded using data acquisition unit and tabulated in table 1. The experimental configuration illustrated in figure 1 and configuration of plain aluminum tube grid in figure 2.For experimental calculation the following equation used to calculate the Nusselt number (Nu) and Friction factor (f)

$$\mathrm{Nu} = \frac{hD_h}{k_f} \qquad \text{[Equ. 1]}$$

$$\mathrm{Re} = \frac{\rho \mathbf{v}_s D}{\mu}. \qquad \text{[Equ. 2]}$$

$$f = \frac{16}{\mathrm{Re}} \qquad \text{[Equ. 3]}$$

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4. NUMERICAL INVESTIGATION

The problem investigated is a three dimensional steady state laminar flow through a plain tube with constant heat fluxed tube using the following governing equation.

1. Continuity equation for an incompressible flow

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = \frac{\partial \rho}{\partial t} + \nabla \rho \cdot \mathbf{v} + \rho (\nabla \cdot \mathbf{v}) = 0.$$

The properties of the fluid as water and properties of aluminium material as a inner tube which were used in number of the simulations are given table 2 and table 3.

6. RESULTS AND DISCUSSION

6.1. Mass flow rate [kg/s] and Hot fluid temperature [C]

The evaluation of the experimental and simulated test results consisted in the comparison of the inlet and outlet properties in both cases. Fig. 3. Shows the results of an experimental data compared to the results simulated data at the same inlet condition. The figure illustrate mass flow rate and heat flux of experimental were predicted by simulation.

6.2. Mass flow rate [kg/s] and Heat flux [w/m^2]

The evaluation of the experimental and simulated test results consisted in the comparison of the inlet and outlet properties in both cases. Fig. 4. Shows the variations of heat flux with experimental and numerical simulated values are agree with each other and mass flow rate increases as well as heat transfer also augmented.

6.3. Reynolds Number and friction factor

Figure 5 shows the value of the Reynolds number and friction factor assessment. In this graph Reynolds number is increases friction factor is decrease and at the same time heat transfer coefficient and heat transfer is improved.

7. NUMERICAL SIMULATED CFD ANALYSIS:

Figure 6,7 and 8 shows pressure, Temperature and velocity profile of the plain tube of double pipe heat exchanger.

8. CONCLUSION

The scrutiny results shows that the enrichment of heat transfer and diminish the friction factor. In addition that plain tube compared with experimental and simulated records. It is found that plain tube confer improved performance with different mass flow rate. The Reynolds number is augmented with decrease of friction factor. The heat flux also improved with decreases mass flow rate. Heat transfer and friction factor experimental statistics as compared with Numerical facts is well validating.

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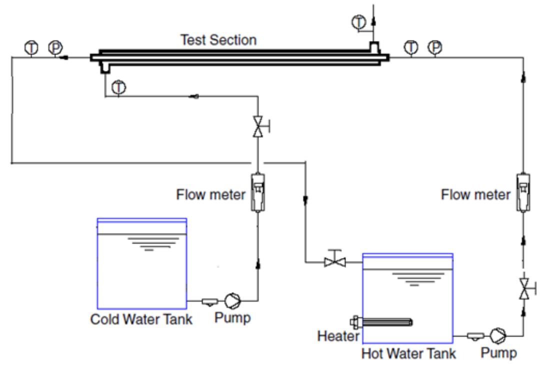

Fig 1. *Experimental arrangement of heat exchanger*

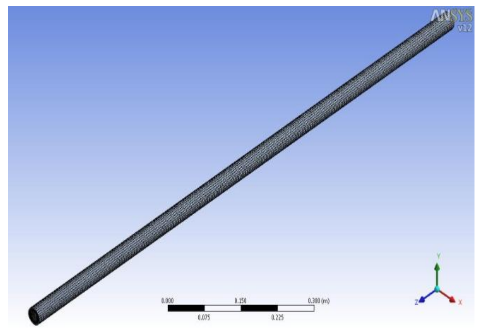

Fig 2. *Grid for plain tube*

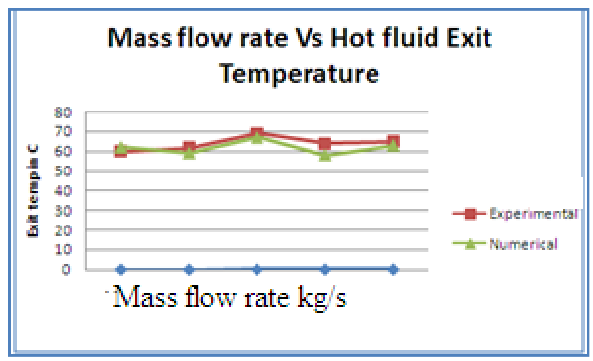

Fig 3. *Mass flow rate and hot fluid exit temperature*

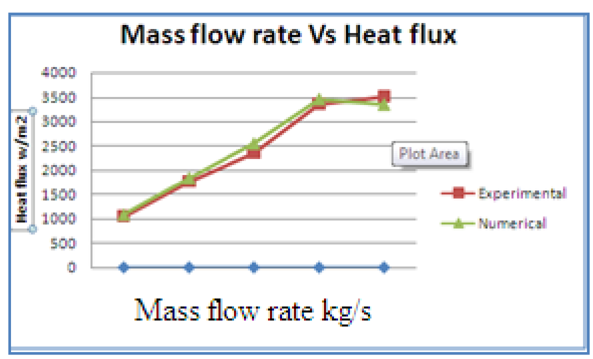

Fig 4. *Mass flow rate [kg/s] and Heat flux [w/m^2]*

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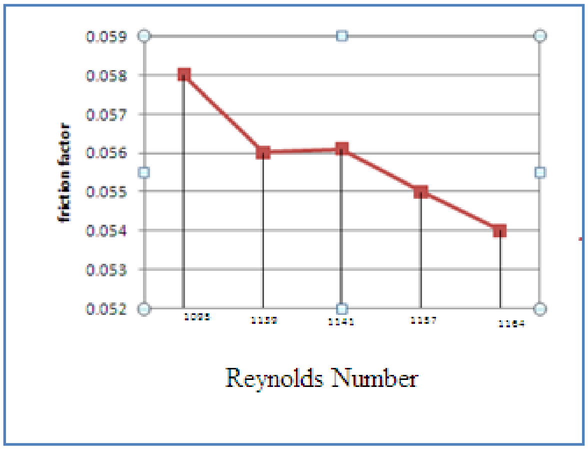

Fig 5. *Reynolds Number and friction factor*

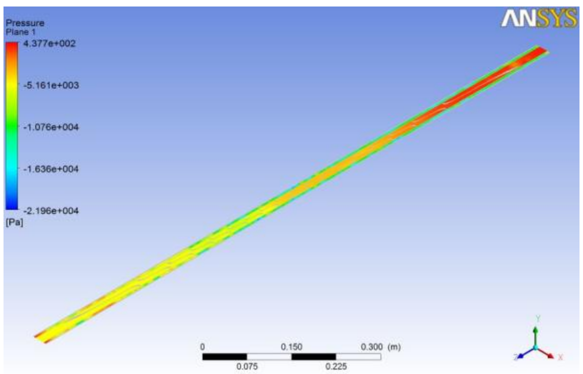

Fig 6. *Shows the CFD analysis of pressure variation*

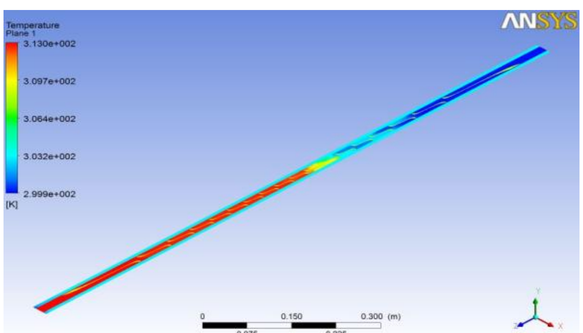

Fig 7. *Shows the CFD analysis of Temperature variation*

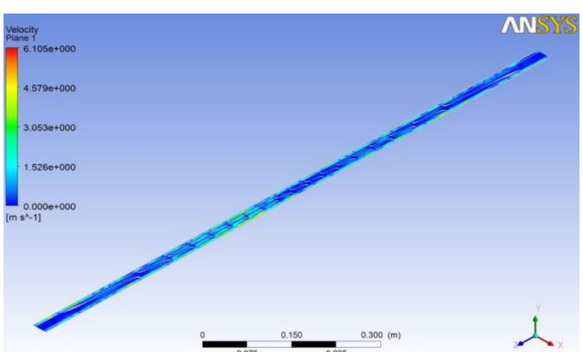

Fig 8*. Shows the CFD analysis of velocity profile*

Table 1
Experimental Values Of Exit Temperature Of Fluids

Mass flow rate [kg/s]	Hot fluid Inlet Temp ºC	Hot fluid Exit Temp ºC	Cold fluid Inlet Temp ºC	Cold fluid Exit Temp ºC
0.05	66	60	30	35
0.07	68	62	29	35
0.08	69	62	29	36
0.09	70	64	30	36
0.10	71	65	30	38

Table 2
Physical properties of materials

Material	Density (Kg/m^3)	Specific heat (J/KgK)	Thermal conductivity (W/mK)	Viscosity (Nm/s)
Water	999.1	4186	0.6	0.001002
Aluminium	2718	870	201.6	-

Table 3
Mass flow rate and Heat flux values used in simulations

Mass flow rate [kg/s]	Experimental Heat flux [W/m^2]	Numerical Heat flux [W/m^2]
0.05	1046.5	1090.96
0.07	1758.1	1845.58
0.08	2354.8	2552.23
0.09	3360.4	3461.25
0.10	3511.6	3354.21

Table 4
Comparison of Experimental and Numerical Exit temperature of hot fluid and cold fluid

Mass flow rate [Kg/s]	Experimental Exit Temp ºC		Numerical Exit Temperature ºC	
	Hot Fluid	Cold fluid	Hot Fluid	Cold fluid
0.05	60	35	62	38
0.07	62	35	59	37
0.08	69	36	67	37
0.09	64	36	58	38
0.10	65	38	63	40

Nomenclature

Pr	Prandtl Number
Nu	Nusselt Number
K	Thermal conductivity,W/mK
Q	heat transfer, W
T	Temperature,K
h	Heat transfer coefficient, W/m^{2}K

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Greek symbols

ϵ	Effectiveness
μ	Dynamic viscosity,kg/m s
ρ̇	Density, kg/m^3

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