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Research paper

Experimental Investigation of Counter Flow Heat Exchanger with Swirling

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Abstract

The objective of this experimental work is to investigate and compare the performance of counter flow heat exchanger without and with swirling flow. Heat exchangers are commonly used for heating and cooling of fluids. Heat exchangers are also critical component of thermal power plants and refrigeration systems that control their effectiveness. Generally, the performance of counter flow heat exchanger is better than parallel flow heat exchanger. In this experimental work, it has been tried to improve the performance of counter flow heat exchanger using cold fluid swirling flow arrangement inside the outer tube. The developed experimental set up consists of two concentric tubes. Outer tube is made of mild steel having inner and outer diameters of 32 mm and 36 mm respectively. Inner tube is made of copper with inner and outer diameter as 18 mm and 21 mm respectively. To measure the mass flow rate of hot and cold fluid two calibrated Rotameters were used. To take reading of temperature of hot and cold fluid, four digital thermometers were used. The experimental results revealed that the performance of counter flow heat exchanger with swirling is better than the performance of counter flow heat exchanger without swirling.

Keywords: *Counter flow heat exchanger, heat transfer, swirling flow, Performance etc.*

1. Introduction

Heat exchanger is the process equipment which is developed for the excellent transfer of heat from one fluid to another fluid. The objective of heat exchanger is to heat the fluid or to cool the fluid. In the boiler objective of heat exchanger is to heat the water and in condenser objective is to cool the steam. There are many number of configuration are available in the market like double concentric tube, shell and tube type, plate and shell type, plate and fin type, and phase change heat exchangers etc [1]. In the concentric tube if the hot and cold fluid is entering from same side, flowing in the same direction and leaves from same side, then it is known as parallel flow heat exchanger (figure 1). If the hot and cold fluid entering from opposite side, flow in opposite direction and leaves from opposite side, then it is known as counter flow heat exchanger (figure 2). In the figure 1, T is the temperature of fluids. Performance of counter flow heat exchanger is much better than parallel flow heat exchanger [1]. In other word counter flow heat exchanger are more compact than parallel flow heat exchanger. In this experimental work further performance of counter flow heat exchanger has been increased by making swirling flow of cold fluid. Heat exchanger finds application in the field of Cryogenics, air conditioning systems, chemical industries, nuclear power plant and surface condenser in power plants [2].

In this experimental work performance of counter flow heat exchanger were enhance by providing swirling flow of cold fluid. For making the swirling flow of cold fluid a copper wire of diameter 3mm is wrapped around the inner tube at a pitch of 25.4mm. Hence outer flow of cold fluid will be swirling. The flow direction of hot and cold fluid is shown in figure 2.

Now a day also objective of heat exchangers design is to reduce energy consumption for operation of heat exchangers.

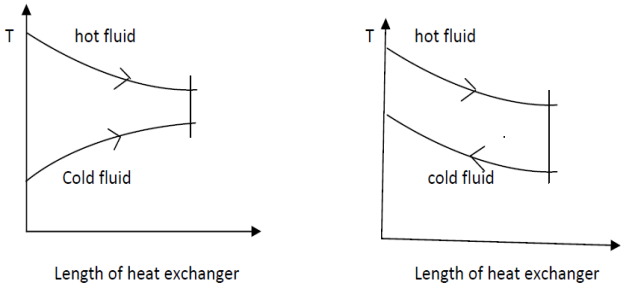


Figure 1: Parallel and counter flow heat exchanger

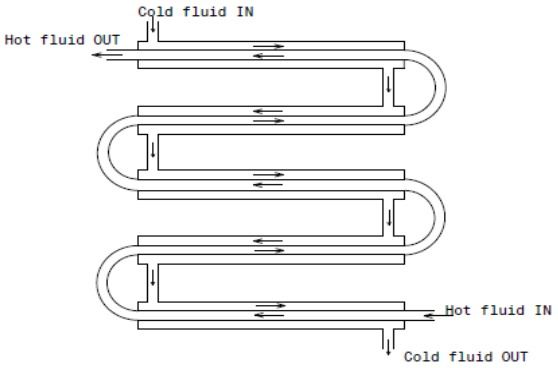


Figure 2: flow direction of hot and cold fluid in experimental setup

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Ruoxu jia et al. [2] have studied counter flow parallel plate heat exchanger. On the basis of experimental and computational analysis they have been reported that pressure, temperature and velocity distribution in the channel can be used as a guideline for optimum design of heat exchanger. Prabhat Gupta et al. [3] have done numerical and experimental analysis of performance of counter flow heat exchanger considering the effect of heat in leak and longitudinal conduction for low temperature application. Experimentally and numerically both they have concluded that performance of heat exchanger also depends upon heat leak, longitudinal conduction and level of temperature of hot and cold fluid. This analysis also cleared that due to increase in number of transfer unit, degradation due to heat in leak also increases.
Masitah et al. [4] have studied heat transfer rate and effectiveness study of cross flow heat exchanger for potential energy recovery application in hot and high humid condition. Based upon experimental analysis they have concluded that with increase in air velocity, effectiveness decreases and heat transfer rate increases.
W C Huang et al. [7] have experimentally investigated heat transfer enhancement of repeated ring-type ribs in circular tubes. They have concluded that due to ring type rib in circular tube heat transfer rate increases and heat transfer rate is maximum with rib pitch to inner tube diameter ratio (p/d) less than 4.35. Mohsen Sheikholeslami et al. [8] have reviewed heat transfer enhancement method specially with swirler. From the review of a number of papers they have concluded that any kind of swirler increases the heat transfer rate.

2. Experimental Set up

2.1. Experimental Test Equipment

Counter flow heat exchanger with swirling is shown in the figure 3. It consist of two concentric tube, inner tube is made of copper with inner and outer diameter of 18 mm and 21 mm and outer tube is made of mild steel with inner and outer diameter of 32 mm and 36 mm. In the first row outer tube is made of transparent material to visualise the swirling flow. A copper wire of diameter 3mm is wrapped helically on the outer of inner tube. The pitch between the copper wires is 25.4mm. This helical wire develops swirling of the outer flow which increases the turbulence. As turbulence in the outer flow increases, heat transfer rate also increases. Outer tube is insulated by insulating material to decrease the heat loss to the surrounding. Four calibrated digital thermometer are used to measure the inlet and exit temperature of hot and cold fluid. Two valves are used to control the mass flow rate of hot and cold fluid. To perform the experiments both hot and cold fluid are taken as water due to easy availability. Four container are used, two for storing the hot and cold fluid and two for storing the exit of hot and cold fluid.

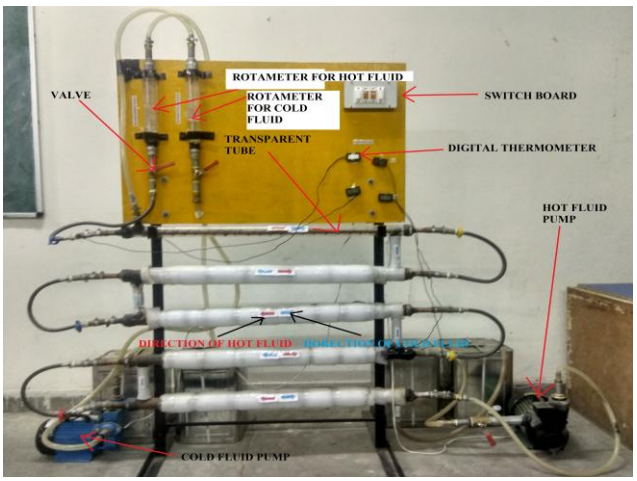


Figure 3: Experimental test equipment

2.2. Rotameters and Pump

In the experimental setup two calibrated Rotameters are used to measure the discharge of hot and cold fluid as shown in figure 4. The rating of Rotameters is 0 to 20 lpm. Two self priming mono block centrifugal pump are used to pump hot and cold fluid as shown in figure 5. Power ratings are 0.5HP and discharge capacity are 900 lph at 33meter head.



Figure:4: Rotameters



Figure 5: Pump

3. Result and Discussion

To run the heat exchanger both the hot and cold fluid is water. Water is heated to approximately 90^0C and cold water is taken from water cooler which is available at approximately 16^0C. First experiment are performed without swirling flow and mass flow rate of hot and cold fluid is recorded by Rotameters, inlet and exit temperature of hot and cold fluid is recorded by digital thermometer. This is repeated for three times and reading is noted. Then experiment is performed with swirling flow and again mass flow rate, temperature at inlet and exit is recorded. This experiment is repeated for three times and reading is noted.

3.1. Counter Flow Heat Exchanger without Swirling Flow

Table-1: Reading and Calculation without swirling

Exp. No.	Hot fluid (C_h = 4.2KJ/kg-k)			Cold fluid (C_c = 4.2kJ/kg-k			Heat transfer Q = m_hc_h(Thi-Tho)
	m_h (kg/s)	Th_i (^{0}C)	Th_o (^{0}C)	m_c (kg/s)	Tc_i (^{0}C)	Tc_o (^{0}C)	
1.	0.15	82.2	65.3	0.15	20.1	33.4	10.647kw
2.	0.15	63.1	46.3	0.15	19.2	32.8	10.584kw
3.	0.15	45.2	28.7	0.15	19.8	33.1	10.395kw
						Average heat transfer rate=	10.542kw

m_h , m_c = mass flow rate of hot and cold fluid
Th_i, Tho = Inlet and exit temperature of hot fluids
Tc_i, Tc_o = Inlet and exit temperature of cold fluids
C_h , C_c = Specific heat of hot and cold fluids
Heat transfer rate, Q = m_hc_h (Thi-Tho)

From the table 1 average heat transfer rate is found to be 10.542 kw. Heat taken by cold fluid is (8.4kw) less than heat given by hot fluid (10.542kw) and difference (10.542-8.4= 2.142kw) is dissipated to the surrounding. From the table 2 average heat transfer rate is found to be 12.588kw. Heat taken by cold fluid is (10.35kw) less than heat given by hot fluid (12.588kw) and difference (12.588- 10.35= 2.238 kw) is dissipated to the surrounding. Hence in both the case heat loss to the surrounding is approximately same.

3.2. Counter Flow Heat Exchanger with Swirling Flow

Table-2: Reading and Calculation with swirling

Exp. No.	Hot fluid (C_h = 4.2KJ/kg-k)			Cold fluid (C_c = 4.2kJ/kg-k			Heat transfer Q = $m_h c_h$(Thi-Tho)
	m_h (kg/s)	Th_i (^{0}C)	Th_o (^{0}C)	m_c (kg/s)	Tc_i (^{0}C)	Tc_o (^{0}C)	
1.	0.15	82.5	62.0	0.15	20.1	36.5	12.915kw
2.	0.15	61.2	41.5	0.15	19.2	37.8	12.411kw
3.	0.15	41.0	21.4	0.15	19.8	36.0	12.348kw
Average heat transfer rate=							12.588kw

% increase in heat transfer rate due to swirling = (heat transfer with swirling- heat transfer without swirling) x 100/heat transfer rate without swirling.

$$= \frac{(12.588 - 10.542)}{10.542} X 100$$

$$= 19.4\%$$

Due to swirling, mixing of fluid that is turbulence is better and hence heat transfer rate is better (19.4% more).

4. Conclusion

From the experimental investigation this has been concluded that heat transfer from hot to cold fluid by counter flow heat exchanger with the swirling is approximately 19.4% more compared to counter flow heat exchanger without swirling. Heat loss to surrounding is approximately same in both the case.

Acknowledgement

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