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ENHANCED HEAT TRANSFER WITH ALUMINIUM OXIDE NANO PARTICLES

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ABSTRACT

This study aims at experimental investigation on the effect of mixing of Al2O3 nanoparticles in water fluid on the heat transfer enhancement. The experiment was done in a 3 channel 1-1 pass corrugated plate heat exchanger. The plates had sinusoidal wavy surfaces with corrugation angle of 45°. Hot water at different inlet temperature ranging from 40°C to 70°C was made to flow through central channel to get cooled by water in outer channels. Experiment was measured in parallel and counter flow arrangement. The variations of hot fluid outlet temperature and effectiveness of heat exchanger were measured with rise of inlet hot fluid temperature. The required properties of the Al2O3 water mixture were measured at different concentration of Al2O3 nanoparticles from 0.0% to 0.1074 % by volume. It is observed that with volume percentage of Al2O3 increases in the cold fluid the effectiveness of heat exchanger increases substantially. The addition of Al2O3 nano particles in cooling water increases the effectiveness of heat exchanger by 0.87 in parallel flow and by 0.95 in counter flow.

Keywords: -Heat Transfer Enhancement, volume concentration, corrugated plate heat exchanger, Effectiveness, mass flow rate, Heat transfer rate

Nomenclature A = Cross sectional area, (m2). Cp = Specific heat at constant pressure, (J kg-1 K-1). C = Heat capacity rate, (W K-1). E = Exergy loss, (W). L = length, (m) m Mass flow rate, (kg s -1) Q Heat transfer rate, (W). T = Temperature, (K).

Suffixes C= Cold. E= Environment, ambient. h = Hot. i = Inlet. m = Mean min (Minimum), max (Maximum). o = Outlet.

1. INTRODUCTION Heat exchangers are one of the most commonly used process equipment in the industry and research. The work of a heat exchanger is to exchange energy from the body at higher temperature to the body at lower temperature. This transferred of energy may occur to a single fluid (as in the case of boiler where heat is transfer to water) or between two fluids that are at different temperature (as in the case of an automobile radiator where heat is transfer from hot water to air). In some case, there are more than two stream of fluid exchanging heat in a heat exchanger. It is of several designs heat in a variety of size varying from 'miniature' to 'huge' (with heat transfer area of the order of 5000 to 10,000sq. meter) have been developed over the year. In the 1930s corrugated type heat exchangers were introduced to meet the hygienic demand of the dairy industry. Now days' plate heat exchangers are mostly used in many fields like automobile industry, power industry, and dairy, food processing, chemical and petrochemical industries. In heat exchangers, there is usually no external heat and work interactions, typical applications involve heating or cooling of any fluid stream of concern and evaporation or condensation of single or multi component fluid streams. The objective can be to recover or reject heat, or sterilize, pasteurize, fractionate, distil, concentrate, crystallize, or control process fluid. In some heat exchangers, the fluid exchanging heat may be through direct or indirect contact. In many heat exchangers, transfer of heat between fluids takes place through a separating wall or into and out of a wall in a transient manner. Usually, the fluids in heat exchanger are separated by a heat transfer surface and ideally, they do not mix or leak. Some examples of heat exchangers are shell-and tube exchangers, automobile radiators, condensers, evaporators, air preheaters, and cooling towers. There could be internal thermal energy sources in the exchangers, such as in electric heaters and nuclear fuel elements. Combustion and chemical reaction may take place within the exchanger, such as in boilers, fired heaters, and fluidized-bed exchangers. Mechanical devices may be used in some exchangers such as in scraped surface exchangers, agitated vessels, and stirred tank reactors. Heat exchangers are devices used to transfer heat between two or more fluid streams at different temperatures. Heat exchangers find widespread use in power generation, chemical processing, electronics cooling, air conditioning, refrigeration, and automotive applications. A corrugated plate type heat exchanger, as compared to a similar sized tube and shell heat exchanger, is capable of transferring much more heat. This is due to the large area that plates provide over tubes. Corrugated plate heat exchangers are used for transferring heat for any combination of gas, liquid and two-phase streams. Fins or appendages added to the primary heat transfer surface (tubular or plate) with the aim of increasing the heat transfer area. The two most common types of extended surface heat exchangers are plate-fin heat exchangers and tube-fin heat exchangers. Consist of a stack of parallel thin plates that lie between heavy end plates. Each fluid stream passes alternately between adjoining plates in the stack, exchanging heat through the plates. The plates are corrugated for strength and to enhance heat transfer by directing the flow and increasing turbulence. These exchangers have high heat-transfer coefficients and area, the pressure drop is also typically low, and they often provide very high effectiveness. A corrugated plate type heat exchanger consists of plates instead of tubes to separate the hot and cold fluids. It would be misleading to consider only capital cost aspect of the design of a heat exchanger, since high maintenance cost increase the total cost during the service life of the heat exchanger. Therefore, exergy analysis and energy saving are very important parameters in the heat exchanger design.

2. ABOUT NANO PARTICLE OF ALUMINIUM OXIDE (AL2O3)

Table 1

Bulk Density	0.2-0.4 gm/cm^3
purity	99.9%
molecular weight	101.96 gm/mol
Particle size	30-50nm
CAS no	1334-28-1

3. ABOUT CORRUGATED PLATE HEAT EXCHANGER :The fluid dynamical and thermal phenomenon occurred in corrugated wall channel have been studied in different engineering sectors. Corrugated surface are for example utilised in compact heat exchanger. The corrugation allows the heat transfer surface between dissipaters and coolant fluids to be extended, maintaining at same time a reduced dissipater volume and weight. The study of heat transfer through corrugation surface is also particularly interesting for the cooling application in the electronic industry, aeronautic and automobile industry, food and dairy industry, chemical and cosmetics industry. In general the corrugation of the walls extends the heat transfer surface of the channels and generates turbulence at low Reynolds number. Moreover the corrugation of the walls, in some cases can induce the stagnation of the coolant fluid. As a consequence, the local convection coefficient s so reduced that even of the heat transfer surface between the wall and the fluids extended. The global heat transfer effectiveness does not overcome that of the flat wall channel of comparable size. Therefore, the heat transfer effectiveness of corrugated channel depends on many factors concerning the geometry of walls, the properties of the coolant fluid, and the nature of the flow. Moreover, it can only be correctly compared with the heat transfer effectiveness of the flat wall channels y also considering the external size, the wall volume or weight. Most of the studies performed on the fluid dynamical and thermal phenomena occurring in corrugated wall channels consider corrugations having a periodical pattern which is described by simple functions such as rectangular, triangular or sinusoidal. However due to the variety of thermal and fluid dynamical characteristics described in the literature under different conditions, the study of more complex corrugation profile can be useful to better evaluate the convenience of assigning to the channel walls corrugated rather than flat profiles.

3.1. Evaluation Parameter of Heat Exchanger :

Commonly used parameter to evaluate the performance of two-fluid heat exchangers is the heat transfer effectiveness, which is defined as the ratio of the heat transfer from either stream to the maximum possible heat transfer in the heat exchanger. Heat transfer effectiveness of a heat exchanger only indicates the relative magnitude of the heat transfer loading (not exergy transfer loading) in a process. The efficiency of the process in terms of exergy is completely irrelevant to the information of its heat transfer effectiveness.

4 EXPERIMENTAL SETUP

The photograph of the experimental setup was fabricated with 22-gauge GI sheets to investigate the heat transfer characteristics of the plate heat exchanger channels for same flow conditions with different inlet hot water temperatures are shown in (Figure 1). It includes a hot water loop, two coolant loop and a measurement system. The hot water loop comprises a water tank, a heater, and a submersible water pump. The cold-water loop comprises a water tank, and a submersible water pump. A digital temperature indicator with thermocouples is used to measure temperatures at inlet and exit of the hot and cold streams. The flow rate is measured by noting down time for collection of fixed volume of the fluid. The whole system is thermally insulated to minimize the energy loss.

Figure 1: Photographs of experimental setup

4.1. Specifications of the experimental setup.

Length of the test section =100 cm

Width of the test section = 10 cm

Height of a flow channel, i.e. gap between two successive corrugated plates = 5 cm. Chevron angle of the plate = 45°

Material of the plate is GI of 22 gauges.

5. EXPERIMENTAL PROCEDURE

Experimental procedure Hot water was made to flow through the central corrugated channel to maintain the channel surfaces at approximately constant temperature. Cold water is made to flow in the upper and lower channels. Thermocouples were inserted in the inlet and exit of the hot and cold streams, were used to record the corresponding fluid temperatures. Thermocouples were calibrated with ZEAL mercury thermometer And Infrared Digital Thermometer. Experiments were conducted for 40˚, 45˚, 50˚, 55˚, 60˚, 65˚, 70˚C inlet temperature of hot water in parallel and counter flow arrangement. The hot and cold water flow rate is maintained constant for all inlet hot water temperatures and for both parallel and counter flow arrangements. Mass flow rate of hot fluid (water) is maintained at 0.33 kg/s and that of the cold fluid (water) is 0.66 kg/s.

6. NUMERICAL METHODOLOGY

In the present experiment, the properties of $Al2O3$ nano particle dispersed in the water fluid was measured are given below.

The experimental data was used to calculate the heat transfer rate,

$Q= m_h C_h (T_{hi} - T_{ho})$

Each channel has equal flow area and wetted perimeter given by,

$A_o=H.W$, and $p=2(W+H)$

Specific Heat capacity

$C_h = m_h c_{ph}$

$C_c = m_c c_{pc}$

Logarithmic mean temperature difference.

$LMTD= [(T_{ho} - T_{ci}) - (T_{hi} - T_{co})]] / \ln[(T_{ho} - T_{ci})/(T_{hi} - T_{co})]$

Effectiveness of heat exchanger,

$\varepsilon =[C_c(T_{co} - T_{ci})]/[C_{min} \ln(T_{hi} - T_{ci})]$

The exergy changes for the two fluids are obtained as given below,

For hot fluid (i.e. water),

$E_h = T_e[C_h \ln(T_{ho}/T_{hi})]$

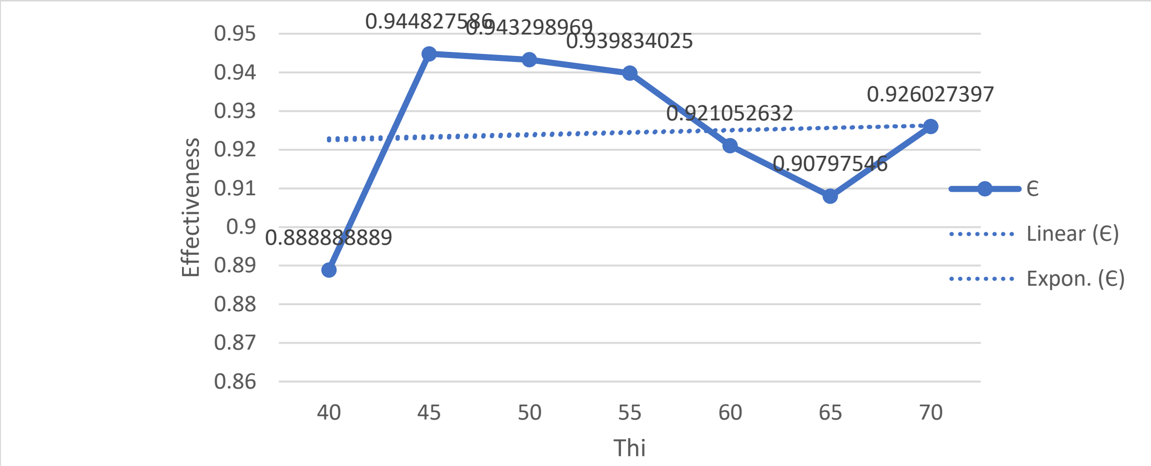
And for cold fluid

$E_c = T_e [C_c \ln (T_{co} /T_{ci})$

Exergy loss for steady state open system can be found as a sum of individual fluid exergy,

$E = E_h+E$

7. RESULTS AND DISCUSSION



In the above two figures ,It is observed that at different inlet temperature of hot fluid (400 to 700) temperature drop is maximum in counter flow than in parallel for water- water fluid combination. Drop in temperature of hot fluid for Corrugated Plate Heat Exchanger, in parallel & counter flow increases, as the inlet hot fluid temperature increases. Effect of Th1 from 40*C to 70* C is more significant onTh2 when plain cold water is used. As volume percentage of Al2O3 increases in cold water from 0.1475 to .275, the initial temperature of hot fluid becomes less or no significant. This is clear from all the lines converge at vol % of Al2O3 in the water.

SUMMARY AND CONCLUSIONS

A three channel 1-1 pass corrugated plate heat exchanger with corrugation angle of 45° is used in the present study. Water is taken as cold and hot fluid. The Al_2O_3 microparticles in different volume percentage were mixed in the cold fluid (water) in parallel and counter flow arrangements. The hot water inlet temperature range is selected from 40° C to 70° C. An attempt has been made in the present study to find the effect of Al_2O_3 nano particles on the performance of heat exchanger. The following conclusions are drawn from the present work.

1. Effect of T_{h1} from 40° C to70° C is more significant on T_{h2} when plain cold water is used. As volume percentage of Al_2O_3 increases in cold water from 0.01 to 0.350 the initial temperature of hot fluid becomes less or no significant.
2. At different inlet temperature of hot fluid (40^0 C to 70^0 C) temperature drop is maximum in counter flow than in parallel for water-water fluid combination.
3. Drop in temperature of hot fluid for Corrugated Plate Heat Exchanger, in parallel & counter flow increases, as the inlet hot fluid temperature increases.
4. As hot fluid inlet temperature T_h increases, ΔT (drop in hot fluid temperature) increases at a fixed inlet temperature of hot fluid.

5. At higher inlet temperature more drop in hot water temperature is obtained.
6. ΔT_h is more in counter flow than in parallel flow at every fixed inlet temperature of hot fluid.
7. The heat loss by hot fluid goes on increasing at a fixed inlet temperature of hot and cold fluids as the volume concentration of Al_2O_3 increases in the cold fluid.
8. Counter flow effectiveness is 18% higher than that in parallel flow in water-water combination of fluid.

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