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AN EXPERIMENTAL 2E ANALYSIS OF A TUBE IN TUBE HEAT EXCHANGER

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ABSTRACT

In The present study, the 2E (energy and exergetic) analysis of a tube in tube heat exchanger (TITHX) with parallel flow arrangement was experimentally studied. The Experiments were performed with the cold water flows in outer tube and hot water flows in inner tube. The mass flow rates of both the hot and cold water were varies from 0.017 kg/s to 0.105 kg/s .The effects of inlet temperatures (ranging between 20ºC and 26ºC) of cold water and inlet temperature (ranging between 50ºC and 60ºC) of hot water at various inlet flow conditions of hot water and cold water fluid flowing in TITHX on heat transfer performance, entropy generation and exergy analysis was done, based on conservation of energy and second law.

Key words: Exergy loss, entropy generation, effectiveness, heat exchanger

1. INTRODUCTION

Tube in Tube Heat exchangers (TITHX) are devices widely used to supply or extract thermal energy from various processes involved in refineries, food, chemical industries. Therefore, to make processes more efficient in terms of energy transfer ,the performance of heat exchanger has become a vital importance. The various types of energy losses (due to finite temperature difference, due to fluid friction, due to heat transfer to the environment) occur in a heat exchanger. In the recent decades, a thermodynamic analysis of various heat exchanging processes on the basis of two basic laws (1^{st} and 2^{nd}) of thermodynamics has aroused widespread interest. The 1^{st} law concerns with the energy conservation without providing any idea about the losses occurred due to irreversibilities. However, this limitation is meat out by 2^{nd} law which is more related with quality of heat energy, includes entropy generation and exergy. The entropy generation measures the extent of irreversibility present in the process. Therefore, to enhance the performance of the heat exchange process, we need to keep the entropy generated to a minimum.The amount of work which can be obtained from a process, when the process is in equilibrium with the environment is called Exergy. Exergy depend upon the condition of the reference environment. The analysis of exergy loss occurs in a heat exchanger can reveal the possibility of designing a more efficient system by reducing or removing the causes of existing inefficiencies. Bejan [[1, 2]] developed a term called entropy generation number (EGN) which can be used as a criteria to evaluate the performance of a heat exchanger. Can et al. [3] experimentally investigated performance of a double tube heat exchanger (DTHX) on the basis of exergy loss. Yilmaz et al.[4] discussed the 2^{nd} law based design procedure and entropy, exergy as performance parameter for heat exchangers. Ahmad et al.[5] investigated the performance of concentric double tube heat exchanger and found more entropy generation with varying mass flow rate of cooling water compare to that for varying mass flow rate of hot fluid. Dizaji et al. [6] experimental study found that corrugations of shell and tubes in a shell and tube heat exchanger results in increment of exergy loss. Akpinar and Bicer [7] used swirl generators having circular holes of various diameters, positioned in the inner tube of concentric double tube heat exchanger and observed an increased exergy loss, 1.25 times more in comparison with the exergy loss for without swirl generators. Dizaji et al. [8] experimentally investigated the effect of inlet temperature, coil diameter, shell and tube side flow rate and coil pitch on exergy loss and heat transfer in shell and coiled tube heat exchanger. At the fixed inlet flow rates and temperatures of both hot water and cold water, exergy loss was more at high coil pitch or coil diameter. Moreover, exergy loss increases with increase in inlet temperature of hot water, but decreases with increase in inlet temperature of cold water, at the fixed flow rates, coil diameter and coil pitch. Orhan et al.[9] studied the effectiveness and the exergy loss of heat exchangers to enhance the cycle efficiency. Nguyen and San [10] performed 2^{nd} law analysis of counter current spiral heat exchanger for obtaining an optimum ratio of flow capacity rate and obtained large net exergy rate at near balanced flow condition. Ahadi [11] performed an exergy analysis of helical coiled tube with laminar flow of Al_2O_3 nanofluid at constant heat flux. Naphon[12] experimentally investigated performance of a micro-fin tube heat exchanger and observed the exergy loss. An experimental study carried out to investigate the effects of metal oxide nanofluids on exergy destruction and heat transfer performance in the corrugated plate heat exchanger by Khairul et al. [13] used nanofluids to reduce the exergy loss by 24% to that of water. Kurtba et al. [14] experimentally studied exergy loss and entropy generation rate in the co-axial heat exchanger with propeller type tabulator positioned in the inner pipe. Naphon [15] perform experimental investigation and based on energy conservation equations developed a mathematical model, to study the exergy loss and entropy generation in a plain tube concentric heat exchanger .Therefore, to make heat exchange processes more energy efficient in terms of heat energy transfer, the stability and the thermo physical properties of the working fluid used in heat exchange have become a vital importance[16-17].

2. EXPERIMENTAL

The experimental setup of tube in tube heat exchanger unit is shown in figure 1.It consists of test section, two flow meter, heater, cooler, two reservoirs and two pump. The J-type thermocouples are used to measure the inlet and out temperatures of cold and hot fluid. The outer tube is provided with insulation to prevent the heat loss. Electric heater and cooler equipped with temperature controller were used to varying and control the hot and cold water temperatures, respectively. The hot water is circulated in the inner tube and the cold water is circulated in the outer tube by using two pumps. The cold or hot water mass flow rates (ranging between 0.017 kg/s and 0.105 kg/s) changed keeping anyone fluid mass flow rate constant. The inlet cold water temperatures are between 20ºC and 26ºC. The inlet hot water temperatures are between 50 and 60ºC. The test section details are presented in table 1.

Table1. Test section specification

Detail	Inner Tube	Outer Tube
Inner diameter	9.5 mm	28.5 mm
Outer diameter	12.5 mm	32.5 mm
Wall thickness	3.0 mm	4.0 mm
Length	1500 mm	1500 mm
Material	Copper	Galvanized Iron (G. I)

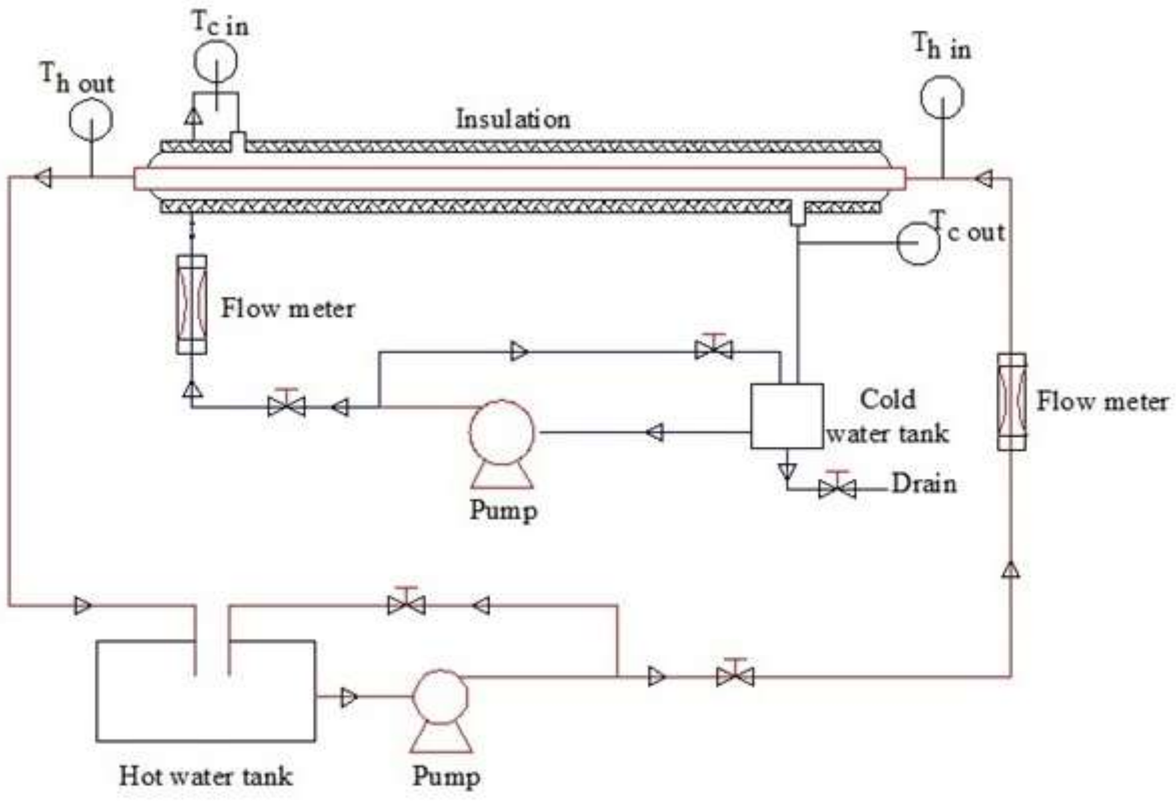

Fig.1. Schematic diagram of tube in tube heat exchanger

3. DATA REDUCTION

Heat energy given by hot fluid

$$Q_{hf} = (m_{hf}C_p)_{hf}.(T_{h,in} - T_{h,out}) \quad (1)$$

Heat energy taken by cold fluid

$$Q_{cf} = (m_{cf}C_p)_{cf}.(T_{c,out} - T_{c,in}) \quad (2)$$

Overall heat transfer coefficient

$$U_o = \frac{Q_{avg}}{A \times T_{LMTD}} \quad (3)$$

Heat exchanger effectiveness

$$\varepsilon = \frac{Q}{Q_{max}} \quad (4)$$

$$\varepsilon_{hx} = \frac{(m_{hf}C_p)_{hf}(T_{h,in}-T_{h,out})}{(mc_p)_{min}(T_{h,in}-T_{c,in})} = \frac{(m_{cf}C_p)_{cf}(T_{c,out}-T_{c,in})}{(mc_p)_{min}(T_{h,in}-T_{c,in})} \quad (5)$$

Entropy generation rate (EGR) is used to measure the degree of thermodynamic imperfection as,

$$S_{gen} = m_c(S_{c,out} - S_{c,in}) + m_h(S_{h,in} - S_{h,out}) \quad (6)$$

$$S_{gen} = (mc_p)_c ln\left(\frac{T_{c,out}}{T_{c,in}}\right) + (mc_p)_h \left(\frac{T_{h,out}}{T_{h,in}}\right) \quad (7)$$

The EGR depends upon heat transfer and pressure drop

$$S_{gen} = (S_{gen})_{\Delta T} + (S_{gen})_{\Delta P} \quad (9)$$

Entropy generation number (EGN)

$$N_S = \frac{S_{gen}}{C_{min}} \quad (10)$$

Exergy loss or irreversibility using the Gouy-Stodola formula

$$l = T_0 S_{gen} \quad (11)$$

T_o was the enviornmental temperature

4.RESULTS AND DISCUSSION

The experiment were perfomed considering the two cases for parallel flow conditions.In case I, the hot water mass flow rate was varied while keeping cold water mass flow rate constant.In case II, the cold water mass flow rate was varied while keeping hot water mass flow rate constant.All the observations were taken in the steady state. The exergy loss due to presuure drop was neglected.The overall heat transfer coefficient,heat transfer effectiveness, entropy generation, entropy generation number and exergy loss were calculated using Eqs. (1) to (11).

4.1 Overall Heat Transfer Co-efficient

The heat energy transfer rate depends upon heat capacity of hot water and that of cold water, variation in temperation difference of the two working fluid. From fig.2. it was obseved that in case I, overall heat transfer coefficient improved at higher mass flow rate of both the working fluid whereas in case II, the increment in overall heat transfer coefficient was less compare to that of case I due to limiting heat capacity of cold water.

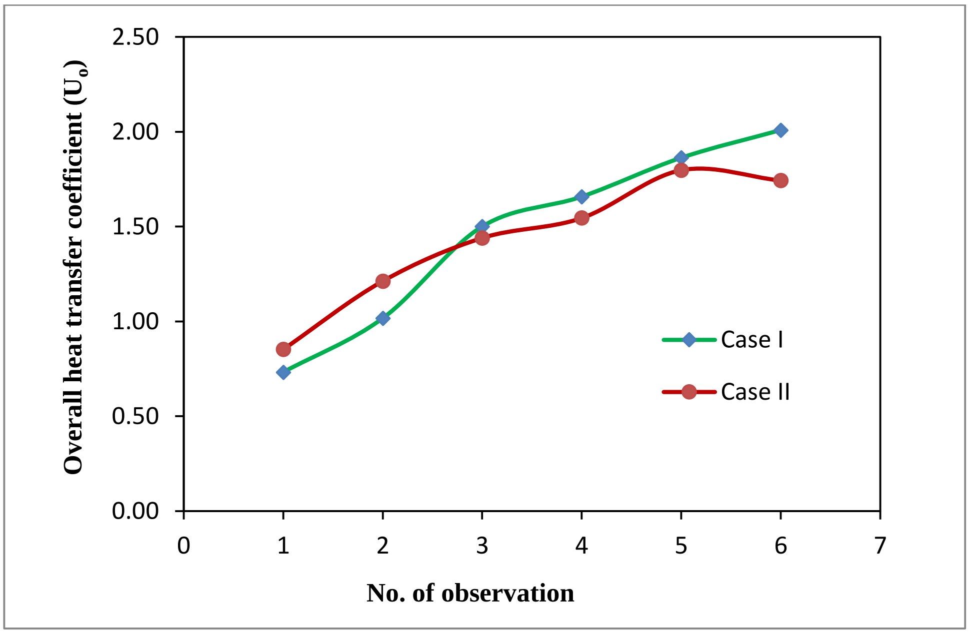

Fig.2. Overall heat transfer coefficient variation with no. of observation

4.2 Effectiveness

The capacity ratio of both the hot water and cold water, temperature difference at inlet of two fluid affects significantly the effectiveness.From fig.3 it can be observed that the effectiveness is higher at lower capacity ratio whereas it was obseved least when capacity ratio was about to 1.

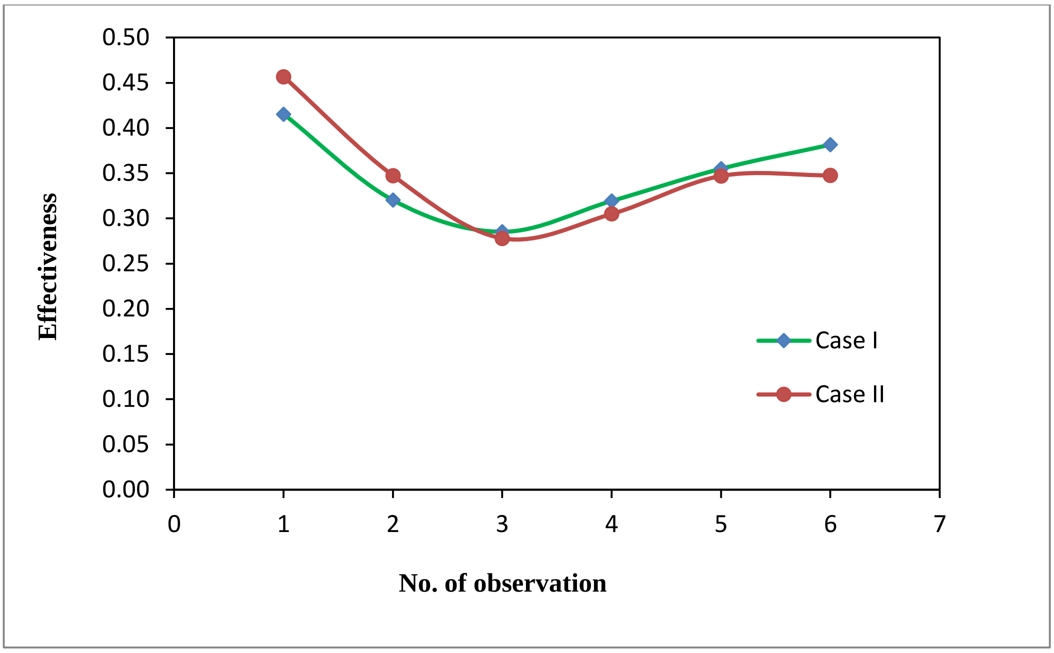

Fig.3. Heat transfer effectiveness variation with no. of observation

4.3 Entropy generation (EGR) and Entropy generation number (EGN)

Figure 4 shows the variation of EGR with various mass flow rate of hot water and cold water.It can seen from the graph that the cold water mass low rate has more significant effect on EGR comare to that of hot water.however, this effect tends to decrase at higher mass flow rate of hot water.

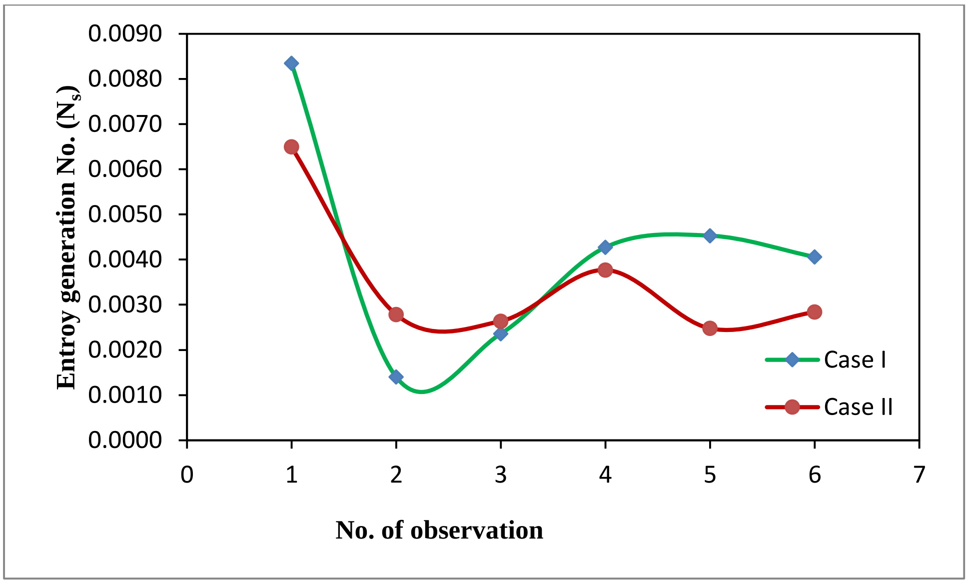

Fig.4. Entropy generation number variation with no. of observation

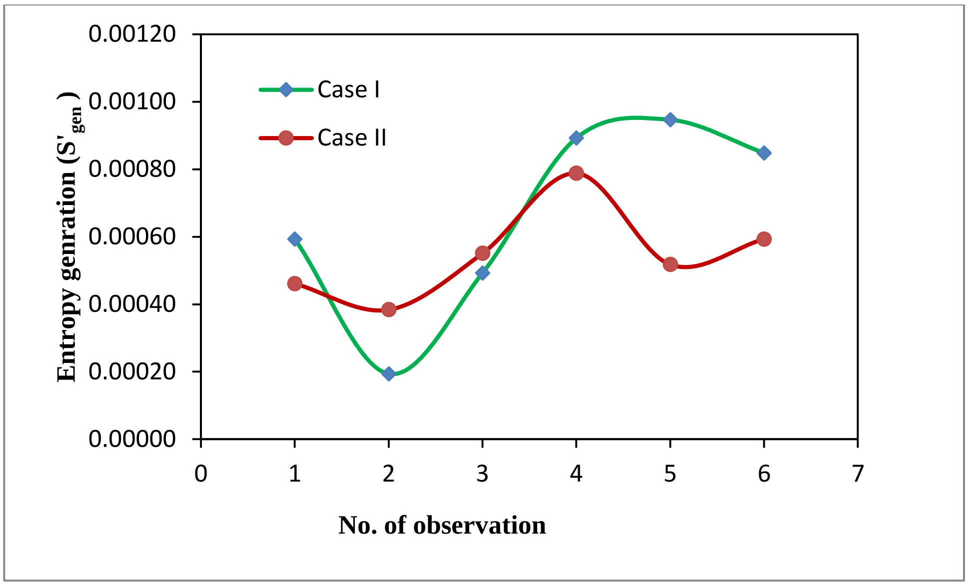

Fig.5. Entropy generation variation with no. of observation

Figure 5 shows the variation of entropy generation number with different flow parameters.It can be seen that the EGN increases with increase in mass flow rate of hot water when the minimum capacity rate in Eq.10 replaced by heat capacity of cold water.

4.4 Exergy loss

Figure 6 shows the tendency of exergy loss at different observation were similar to those of the entropy generation.

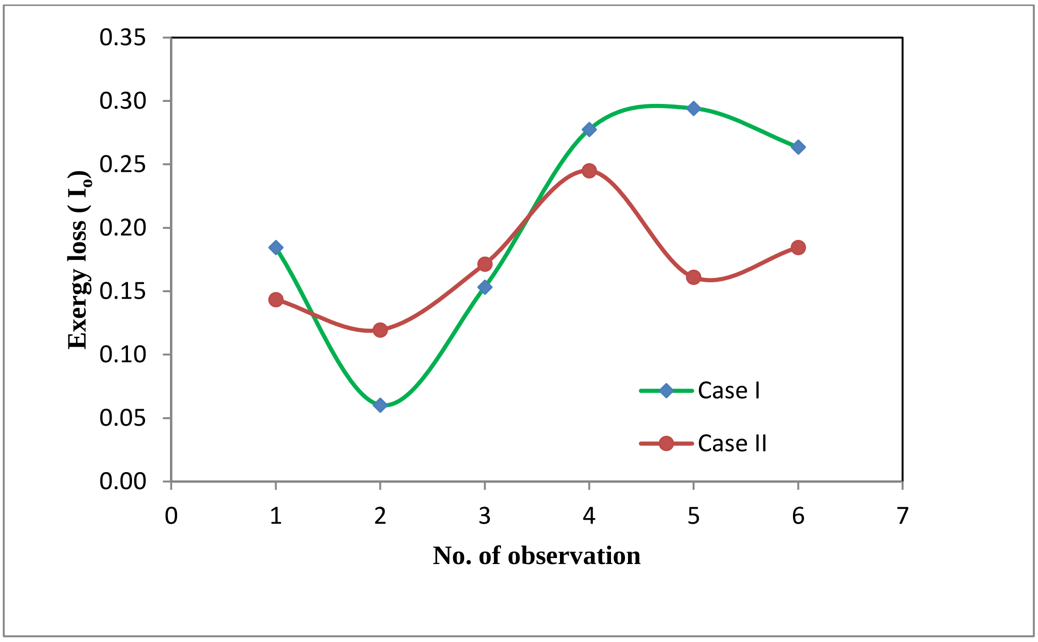

Fig.6. Exergy loss variation with no. of observation

5.CONCLUSION

The present experimental investigation is focused on study of the heat energy transfer and exery loss in a tube in tube heat exchanger considered.The result shows that both the entropy generation and exergy loss was more in case I to that of case II. The heat exchanger was less affected by external irrreveriblity when cold fluid become minimum heat capacity fluid.The average increment in entropy generation and exergy loss 0.01W/ºC and 0.05 kW, respectively.

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