PERFORMANCE EVALUTION OF FINNED TUBE HEAT EXCHANGER

[1]P Sree Lakshmi, [2]P.S.Kishore.

[1]Master of Technology, [2]Professor
[1,2]Department of Mechanical Engineering,
[1,2]Andhra University College of Engineering (Autonomous),
Andhra University, Visakhapatnam-530003,
Andhra Pradesh, India.

Abstract : Now a days to improve overall efficiency of thermal power plant, the boiler manufacturing companies mainly focusing on its design. It consists of many parts like burner, combustion chamber, heat exchanger, fuel source, maintenance and soon. Among them heat exchanger is one of the most important part of boiler. The present work is focusing on steam coil air pre heater which comes under compact heat exchanger. The main aim of this heat exchanger is to pre heat the ambient air to required process temperature by using the saturated steam taken from the recovery boiler. Steam flows inside the tube while air passes over the tube. The heat transfer takes place through convection and latent heat from steam to air. After heating, the hot air is used for combustion in boiler. Steam coil air pre heater is fitted between forced draft fan and air pre heater to avoid the acid due temperature in air pre heater.

***IndexTerms* – Saturated steam, ambient air, tube, fins, Air preheater,Steam coil air pre heater.**

I. INTRODUCTION

HEAT EXCHANGER

Heat exchanger is the process of transfer of thermal energy between two or more fluids, which are at different temperatures and are in thermal contact with each other. It is used as a component of a large thermal system, in a wide variety of applications. The improvements in the performance of the heat exchangers have attracted many researchers. The applications involve heating or cooling of fluid streams. Some examples of heat exchanger are Economizer, Super heater, Cooling tower, Air pre heater.

AIR PRE HEATER

Air pre heater is a heat transfer surface in which air temperature is raised by transferring heat from flue gases and other forms. Air pre heater is one of the type of heat exchanger in which heat transfer takes place between gas to gas. It is a heat recovery unit. The function of this heat exchanger is to absorb waste heat from exit flue gas in boiler and transfers the heat to the incoming cold air. In utility boilers it is used to heat the air required for combustion purpose as well as to dry and transport coal and the efficiency of boiler is increased by 1% for every 20^{o}C drop in flue gas temperature. Air pre heating helps to Igniting the fuel, Improving combustion, Drying the pulverized coal, Reducing the stack gas temperature and increasing the boiler efficiency

STEAM COIL

Steam coil is used to heat atmospheric air to the required process temperature by means of saturated steam. Steam is the preferred medium for heat transfer throughout the industry. Steam flows inside the tube while air passes over the finned tubes. Finned tubes are almost used in steam coil application and make use of latent heat of steam. It is a very effective way of heating air.

Dhumal[1] discussed about the increasing efficiency of boiler using steam coil air pre heater. The steam coil air pre heater is one of the types of heat Exchanger. It is the equipment particularly used to heat the atmospheric air to required process temperature by means of saturated steam. Steam passes inside the tubes while air passes over tubes. It is generally used for high capacity boilers, recovery boilers, sugar mills, and dryers.

Mishra and Arya[2] When the ambient temperature reaches below 0^{o}C to -280^{o}C, the fluid in heat exchanger freezes. The hot steam is used to increase the temperature of fluid up to the designed temperature. This makes use of latent heat that is released from steam. It is very effective way of heating air.

Wais[3] provided the accuracy of air-side correlations for a cross flow. The main objective of this research is to determine numerically the performance of the heat transfer process in a single row fin-tube cross flow heat exchanger for different fin configuration.

Thakre and Pachghare[4] experimental work done on CH_4type compact heat exchanger to get the parameter like heat transfer coefficient, effectiveness and to reduce the size of the heat exchanger as compact as possible. The results concluded that size of heat exchanger can be effectively reduced.

Padma and Kishore[5] Industrial waste heat refers to energy that is generated in industrial process without being put to practical use. By using these losses we can reduce by improving equipment efficiency or installing waste heat recovery technologies. Air Recuperator is present in plant for the purpose of waste heat recovery. The air is pre-heated using the flue gas which enters the recuperator at high temperature from furnace. Heat transfer coefficient, friction factor and pressure drop on both air side and flue gas are estimated effectiveness of air recuperator is calculated.

Sree Lakshmi[6] Thermal Analysis of steam coil air pre heater which comes under compact heat exchanger. The main aim of this heat exchanger is to pre heat the ambient air to required process temperature by using the saturated steam taken from the recovery boiler. After heating, the hot air is used for combustion in boiler.

Praveen and Kishore[7] Energy saving is one of the key issue, Large quantity of flue gases released from boiler. One of the efforts has been made for heat recovery in thermal power plants using rotary regenerators. So, performance of rotary air pre heater is studied.

Koilada Abhinash and Kishore[8] The most effective method for producing intense turbulence is by the impingement of one flame on another. The burner nozzles are so directed that the streams of coal and air are projected along a line tangent to a small circle, lying in a horizontal plane, at the centre of the furnace.

II . DESCRIPTION AND WORKING OF STEAM COIL AIR PRE HEATER

As shown in below diagram, the steam coil air pre heater makes use of steam enters into the tube which is taken from the recovery boiler or from the other sources. The atmospheric air is taken into the duct by using the fan and allowed to pass over the finned tubes. When the low temperature air passes over the high temperature tubes, the heat transfer takes place between the two fluids. Here, cross flow of two fluids considered for effective heat transfer rate. The hot air is collected and used for the combustion process in boiler.

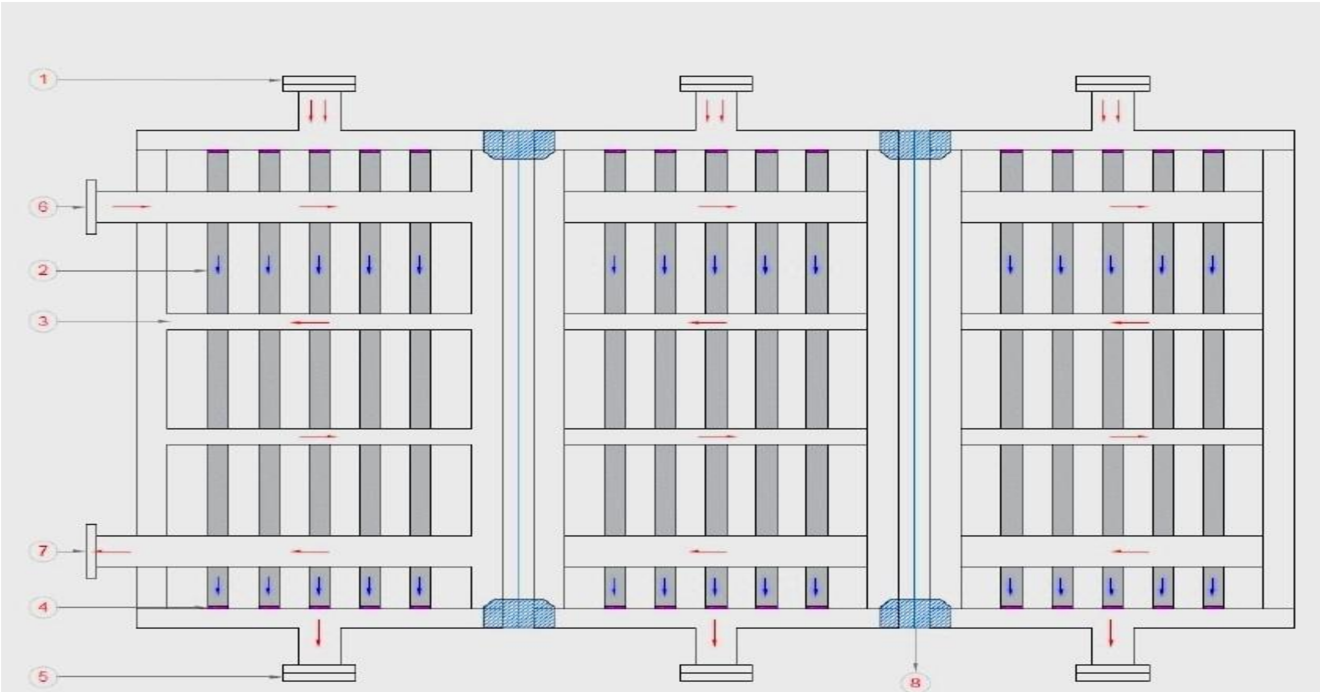

Fig.1.Steam coil air pre heater

1. Steam inlet **3. Air over tube** **5. Steam outlet** **7. Air outlet**
2. Steam tube **4. Gasket** **6. Air inlet** **8. Supporter.**

III. ANALYSIS OF STEAM COIL AIR PRE HEATER

1. Heat load

Heat load $(Q_{HL})_{air} = m_a c_p \Delta T$

Where, Q is heat transfer rate in KW

2. Tube resistance

$$A_0 R_0 = \frac{d_i \ln(\frac{d_0}{d_i})}{2.k.\frac{A_i}{A_o}}$$

Where, d_o is outside tube diameter, d_i is inside tube diameter

$$\frac{A_i}{A_o} = \frac{d_i}{d_0}\left(1 - \frac{A_{f,o}}{A_o}\right)$$

Where, $A_{f,o}$ is total area associated with fins, A_o is air side surface area.

3. Hydraulic diameter [D_h]

$$D_h = \frac{4\left(\frac{P_t^2\sqrt{3}}{4} - \frac{\pi d_o^2}{8}\right)}{\frac{\pi d_o}{2}}$$

Where, P_t is pitch ratio

4. Porosity [σ]

$$\sigma = \frac{\text{min. free flow area}}{\text{frontal area}} = \frac{(P_t-\delta)(b-\delta)}{P_t b}$$

Where, b is fin spacing, δ is fin thickness.

5. Frontal area [A_{fr}]

$$A_{fr} = P_t b$$

6. Mass velocity [G]

$$G = \frac{m_s}{\sigma A_{fr}}$$

Where, m_s is steam mass flow rate.

7. Reynolds Number [Re]

$$Re = \frac{GD_h}{\mu}$$

Where, μ is viscosity, kg/m-sec

8. Heat transfer coefficient, h_i [Tube]

$$\frac{h_i d_i}{K} = 0.023(Re)^{0.8}(pr)^{0.3}$$

Where, k is thermal conductivity W/m-K, Pr is Prandtl Number

9. Heat transfer coefficient, h_o [Air]

$$h_0 = j_h \frac{GC_p}{(Pr)^{2/3}}$$

Where, c_p is specific heat , J/kg-K

By j_h – Re Correlation, $j_h = 0.19\ (Re)^{-0.35}$

10. Over all heat transfer coefficient, [U]

$$\frac{1}{U} = \frac{1}{h_i} + A_0 R_0 + \frac{d_i}{d_0}\frac{1}{h_o}$$

11. Effectiveness[ϵ]

$$\epsilon = \frac{T_{hi}-T_{h0}}{T_{hi}-T_{ci}}$$

Where, T_{ci} , T_{h0} , T_{hi}, T_{co} are the temperatures of fluids.

We know equations, $c_c = m_c c_p$ and $c_h = m_h c_p$

By using these equations, we have to find out c_{min} and c_{max}

Ratio of $\frac{c_{min}}{c_{max}}$ has to be calculated

by graph,

Plotting $(\frac{c_{min}}{c_{max}})$ and ϵ in data book, NTU value is taken.

12. Number of transfer units

$$NTU = \frac{UA_h}{c_{min}}$$

Where, c_{min} is the minimum value obtained.

Ratio of total heat transfer area of one side to total heat exchanger volume is denoted by α

Therefore, $\alpha = \frac{\sigma}{r_h}$

Where, r_h is hydraulic radius, m

13. Friction factor f, (air)

f- Re Correlation, f = 1.7 $(Re)^{-0.5}$

14. Pressure dropΔp, (air)

$$\Delta p = \frac{G^2}{2\rho_i} \quad [f.\frac{A}{A_{min}}.\frac{\rho_i}{\rho_m} + (1+\sigma^2) \quad (\frac{\rho_i}{\rho_o} - 1)$$

Where, ρ_i ρ_o ρ_m are densities of air at inlet, outlet, mean temperatures respectively.

IV. RESULTS AND DISCUSSIONS

The performance evaluation of steam coil air pre heater is done analytically by varying mass flow rate of air from 1, 30,000 kg/hr to 1, 40,000 kg/hr with interval 2500 kg/hr. Based on results obtained, different parameters are calculated such as heat transfer coefficient, fin efficiency, useful heat gain rate, instantaneous efficiency, collector heat removal factor, collector efficiency factor and friction factor.

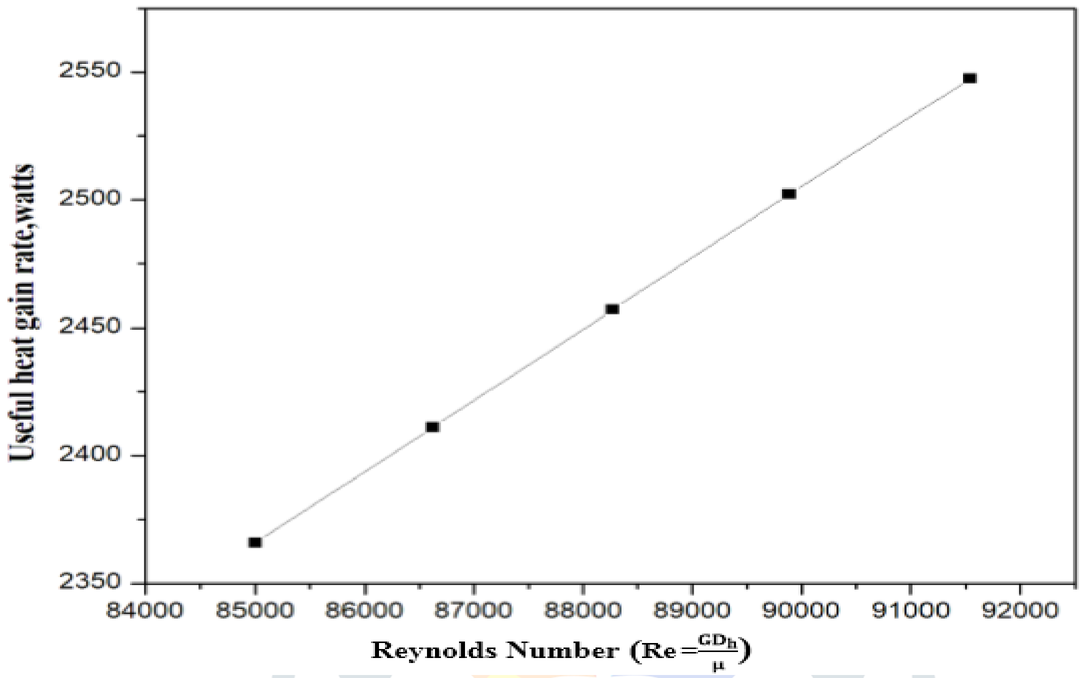

Fig 2.Variation of useful gain rate with Reynolds Number

Fig 2 shows variation of Reynolds number with useful gain rate, it is observed that as Reynolds number Increases, useful gain rate also increases. From graph, we can observe that the value is increasing from 2365.92 to 2547.41 KW and the percentage of increase is found to be 7.67% at high flow rates.

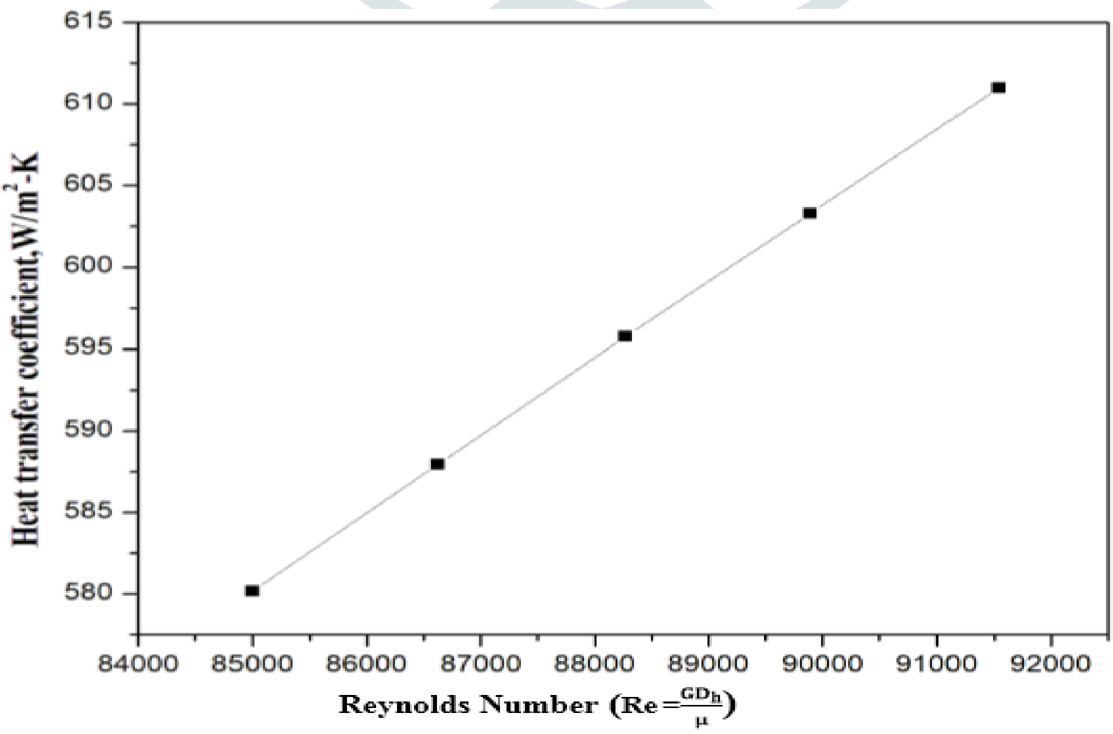

Fig 3.Variation of heat transfer coefficient with Reynolds number

Fig.3 shows variation of heat transfer coefficient with Reynolds number, it is observed that as Reynolds number increases, the heat transfer coefficient also increases. For developing flow, the Reynolds number has an influence the heat transfer coefficient increases with increasing mass flux (or Reynolds number). This is because higher velocity increases turbulence, which in turn provides a more efficient radial transport/mixing of heat. The heat transfer coefficient also increases from 580.16 to 610.99 W/m^2K and the increased percentage is 5.3%

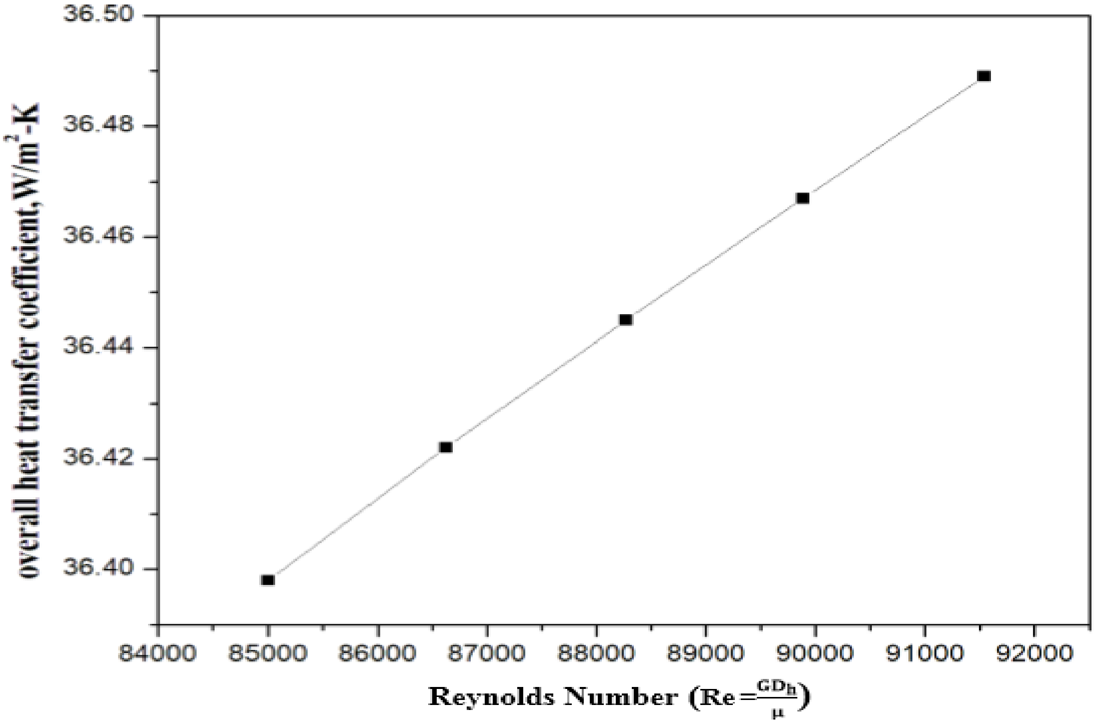

Fig 4.Variation of overall heat transfer coefficient with Reynolds number

Fig.4 shows variation of overall heat transfer coefficient with Reynolds Number, from the graph, it is seen that, overall heat transfer coefficient gets increased from 36.398 to 36.489 W/m^2K with increase of Reynolds number. Overall heat transfer coefficient is also dependent on convective heat transfer coefficient. So increase in Reynolds number results into higher heat transfer rates. The percentage of overall heat transfer coefficient is 0.25%

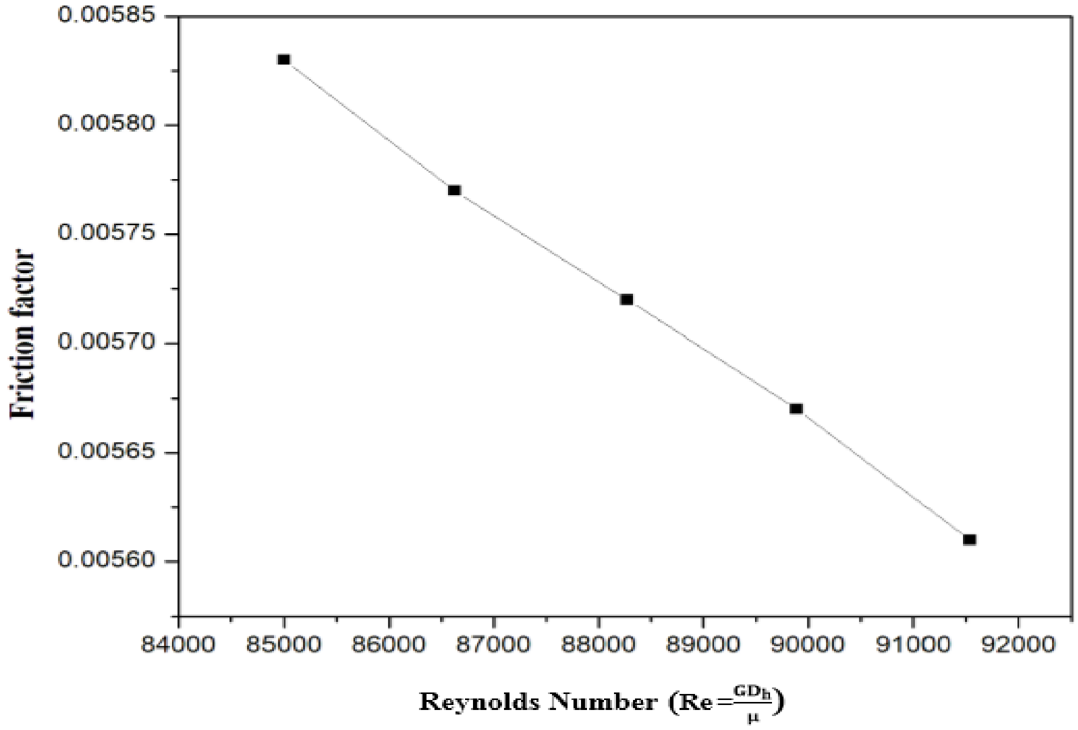

Fig 5.Variation of friction factor with Reynolds number

Fig 5 shows variation of Friction factor with Reynolds number, from the graph, it is seen that, friction factor gets decreased from 0.00583 to 0.00561 with increase of Reynolds number. By using the kays and London correlation, the friction factor value is determined.

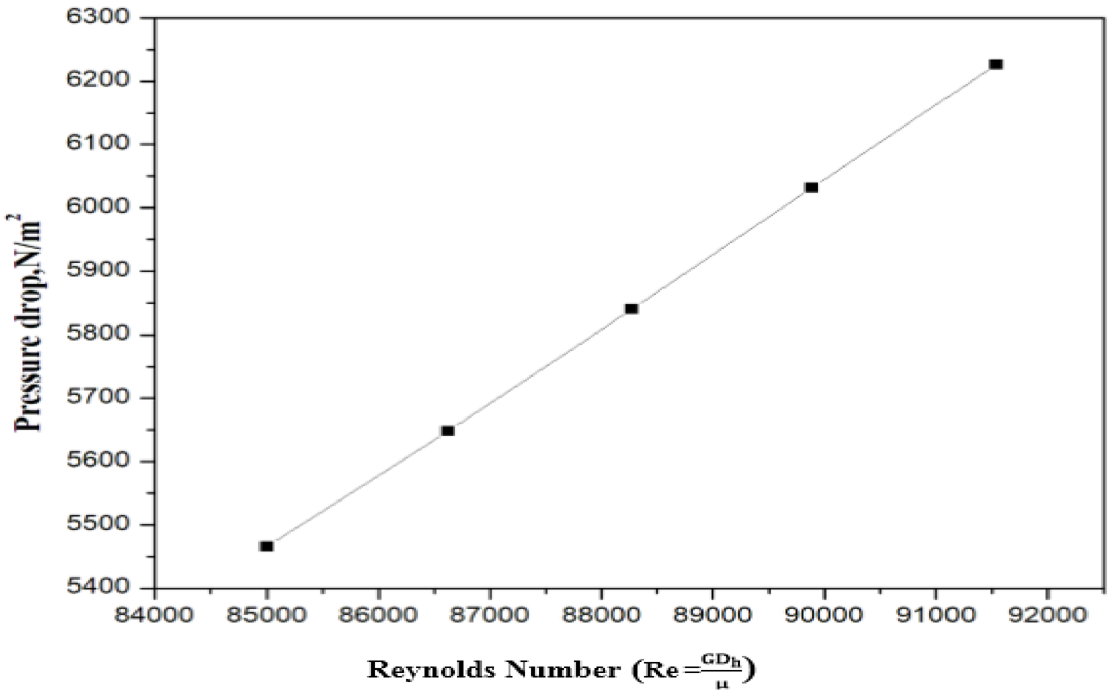

Fig 6.Variation of pressure drop with Reynolds Number

Fig.6.Variation of pressure drop with Reynolds number **i**ndicates the graph between friction factor and Reynolds number. It is concluded from the graph that the friction factor f, decreased with increase in Reynolds number. However, increasing Reynolds number can be achieved with high flow rates which will increase pressure drop dominantly more than friction factor because of the component of the square of mass velocity in equation and the observed percentage of increasing is observed as 13.9%.

V.CONCLUSIONS

The work is carried out on finned tube heat exchanger. The mass flow rate of air is varied from 1, 30,000 kg/hr to 1, 40,000 kg/hr with interval 2500 kg/hr. The performance evaluation of steam coil air pre heater is done analytically and following observations are discussed below.

1) The useful gain rate increases with increase in mass flow rate of air. The value is increasing from 2365.92 to 2547.41 KW i.e., the increase percent is 7.67%

2) As Reynolds Number Increases, the heat transfer coefficient also increases from 580.16 to 610.99W/m^{2}K and the increased percentage is 5.3%. This is because higher velocity increases turbulence, which in turn provides a more efficient radial transport or mixing of heat from the surface.

3) The overall heat transfer coefficient gets increased from 36.398 to 36.489 W/m^{2}K with increase of Reynolds number. Overall heat transfer coefficient is also dependant on convective heat transfer coefficient so increase in Reynolds number results into higher heat transfer rates. The percentage increase is 0.25%

4) The Friction factor gets decreased from 0.00583 to 0.00561 with increase of Reynolds number, the decreased percentage is 3.77% this is due to friction factor is inversely proportional to the Reynolds number by definition of the equation

5) The pressure drop increases with increase in Reynolds number, observed increasing percentage is 13.9% because of the square of the mass velocity in equation.

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