EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER ENHANCEMENT IN FIN AND TUBE HEAT EXCHANGER WITH WIRE TURBULATORS

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Abstract- **This work presents an experimental analysis of cylindrical copper wire vortex generator on the fin-and-tube heat exchanger. In this study, three different arrangement of heat exchanger are tested. In first case the heat exchanger without wire turbulators. In second case the heat exchanger with wire turbulators of diameter 0.2mm and third case, wire turbulators of diameter 0.5mm diameter. The heat transfer coefficient (h), the pressure drop of the air side, friction factor (f) against air velocity (0.5–1 m/s) and Reynolds number (7000–15000) have been discussed. The results shows that the heat transfer coefficient shows 18.4% increment in case of wire turbulators of 0.2mm diameter as compared to heat transfer coefficient without wire turbulators. Whereas it shows 26.52% of increment of heat transfer coefficient in case of wire turbulators of 0.5mm diameter as compared to heat transfer coefficient without wire turbulators. Whereas friction factor *f* and colburn factor *j* for heat exchanger with 0.2mm diameter turbulators to heat exchanger without turbulators increases about 12.08% and 15.68% respectively. In addition, friction factor *f* and colburn factor *j* for heat exchanger with 0.5mm diameter turbulators to without turbulators increases about 15.57% and 22.54% respectively. In summary, this study strongly suggests heat transfer coefficient with wire turbulators applied to the fin and tube heat exchanger is found to be more as compared to the heat exchanger without wire turbulators. Pressure drop for heat exchanger with 0.2mm and 0.5mm diameter turbulators to heat exchanger without turbulators increases by 21.3% and 35.62% respectively.**

1. INTRODUCTION

Fin and tube heat exchangers are used in automobile, air conditioning, power system, chemical engineering, electronic chip cooling and aerospace, etc. Air-side convective resistance to heat transfer is dominant, at 75% or more of the total thermal resistance. Enhancement of air-side heat transfer using passive vortex generators is a promising technique in a range of applications. Increasing demands are being placed on heat exchanger performance for reasons of compactness, economy in manufacturing and operating costs, energy conservation and even for ecological reasons. The importance of these issues continues to motivate the study of enhancement techniques.

Enhancement of air-side heat transfer using passive vortex generators is a promising technique in a range of applications. In this method, protuberances such as delta-wings are used to generate stream wise vortices that are carried through the heat exchanger by the main flow and induce bulk fluid mixing and a reduced thickness of the thermal boundary layer. This enhancement method has the important advantage of low cost and ease of implementation, with a usually modest pressure drop penalty. However, strategies for vortex-generator design and appropriate placement have not been described in the open literature for highly compact heat exchangers which are essential to fully exploit.

2. EXPERIMENTATION & MEASUREMENT

Heat exchanger is a device which is use to transfer the heat from one fluid to other without undergoing actual mixing of both the fluids. In fin and tube heat exchanger in the experiment, the fluid in the tube is water. Then the air is forced on the heat exchanger with the help of axial fan. The heat transfer is carried between the liquid and the air. Water reservoir attached with heater is used to supply the hot water to the heat exchanger.

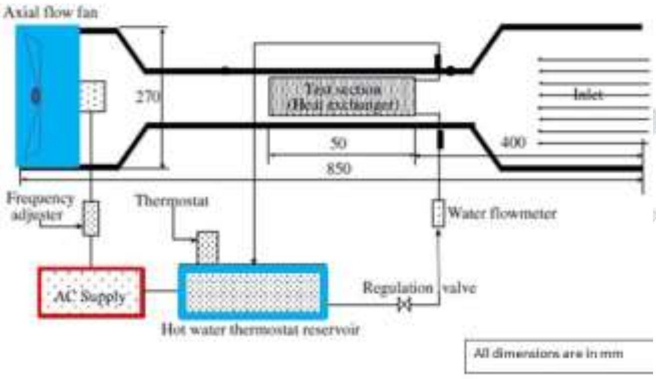
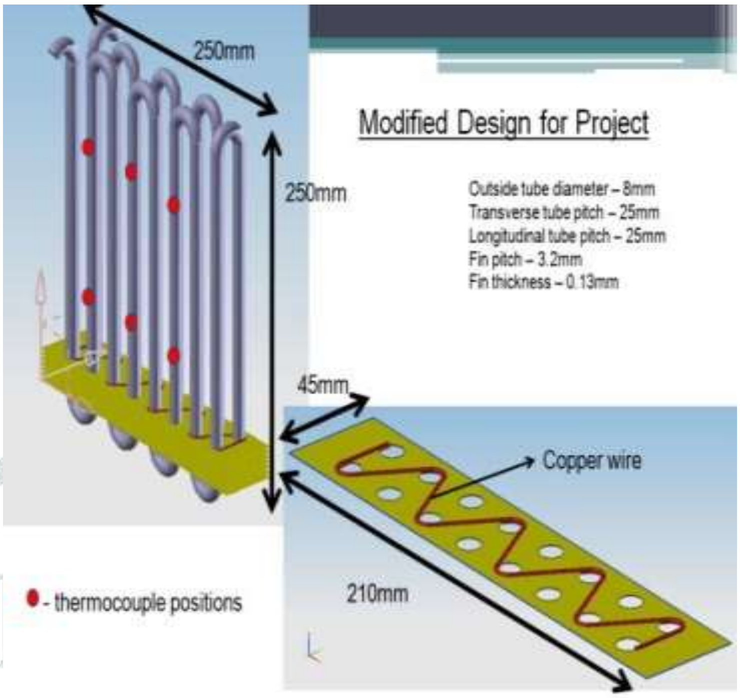


Figure 3.1 Experimental Setup

Figure 2.1 Corrugated tubes

[Figure 1.1 Design Modifications



3. EXPERIMENTAL PROCEDURE

1. Fill the tank with water and start the heater and wait until the temperature of water rise to a desired temperature.

2. Turnoff the heater and start the axial fan few minutes before to get the stable flow of the fluid.

3. Note down the temperature of inlet and outlet of the water.

4. Also note down the temperature of tube walls of heat exchanger on air side at various uniform location.

5. Note down the temperature of inlet and outlet of the air.

6. Note down the water column height difference of U tube manometer across the orifice meter.

7. Note down the water column height difference of U tube manometer across the heat exchanger or test section.

4. MEASURMENT TECHNIQUE

1. **Air flow measurement**
2. **Temperature measurement**
3. **Pressure Drop across the heat exchanger**

Constructional Features –

1. **Fan**
2. **Regulator**
3. **Thermocouple**

5.DUCT WITH HEAT EXCHANGER

4. **Heater**
5. **Digital Temperature Indicator**
6. **Orifice Plate**
7. **U Tube Manometer**

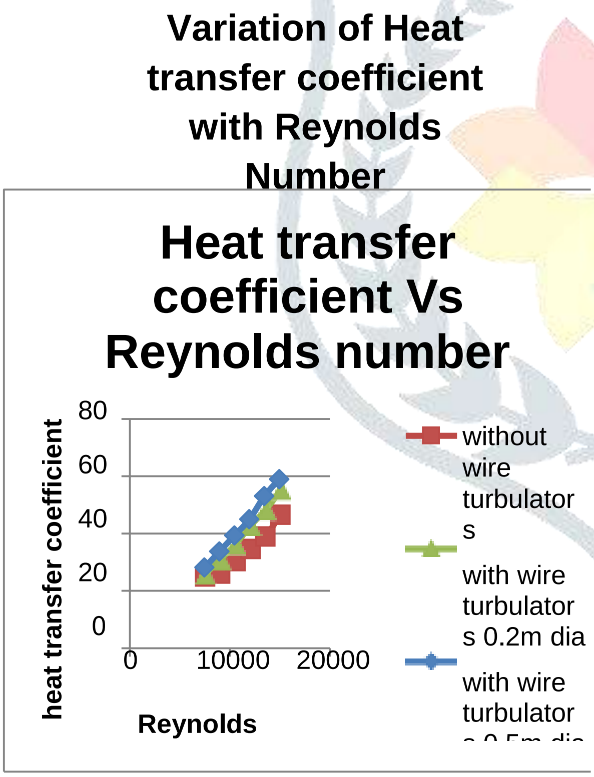


Figure 4.1 Heat transfer coefficient Vs Reynolds Number

From the **Figure 4.1**, it is observed that the heat transfer coefficient increases with increase in Reynolds no. As Reynolds no. increases, the air flow will cause more turbulence, so due to which the heat transfer rate will increase. From the Fig. it is observed that the heat exchanger without wire turbulators shows lower heat transfer coefficient values as compared to both the wire turbulators. It is because of the phenomenon called vortex generation. Same trend is observed by the delta winglet type vortex generator in numerical analysis of fin and tube heat exchanger by Y. L. He et al. **[1]**. In this phenomenon the vortex is generated by the barrier in the fluid flow path. In this project the barrier are copper wire. Increasing diameter have shown the increasing value of the heat transfer coefficient. It shows the increasing the diameter of the copper wire have increases the turbulence. Whereas it shows 26.52% of increment of heat transfer coefficient in case of wire turbulators of 0.5mm diameter as compared to heat transfer coefficient without wire turbulators.

Variation of Nusselt Number with Reynolds Number

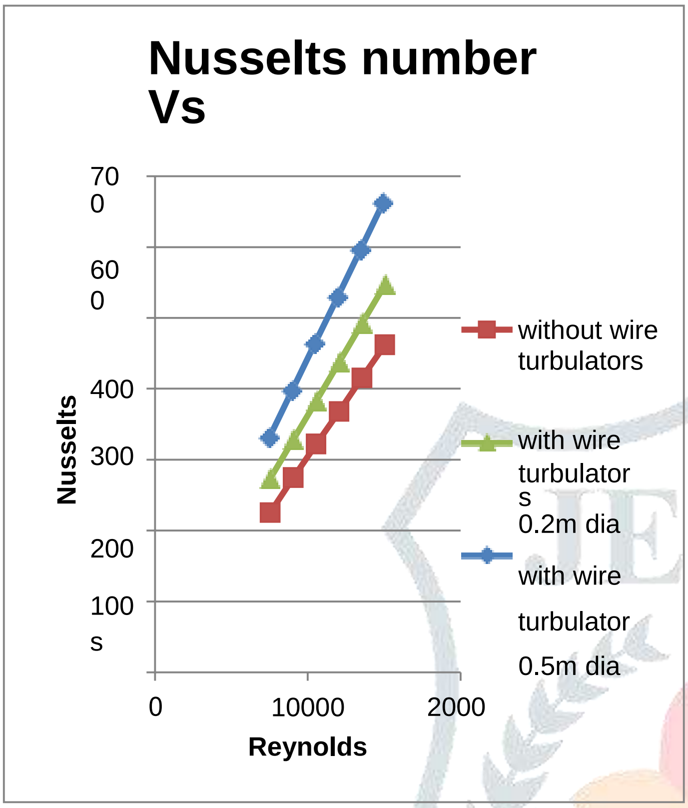


Figure 4.2 Nusselt Number Vs Reynolds Number

From the **Figure 4.2**, it is observed that there is increase in Nusselt number with Reynolds number. As Reynolds number increases the air flow will cause more turbulence due to which heat transfer rate will increase. As heat transfer coefficient is directly proportional to Nusselt number, $Nu=hD_h/K$ i.e. increase in heat transfer coefficient increases the Nusselt number. Same trend is observed by Jin Sheng Leu et al. **[2]** research topic. From **Figure 4.2** it is observed that maximum Nusselt number is obtained for heat exchanger with wire turbulators of 0.5mm diameter followed by 0.2mm diameter wire turbulators. The least Nusselt is obtained for heat exchanger without wire turbulators.

Variation of Friction factor with Reynolds Number

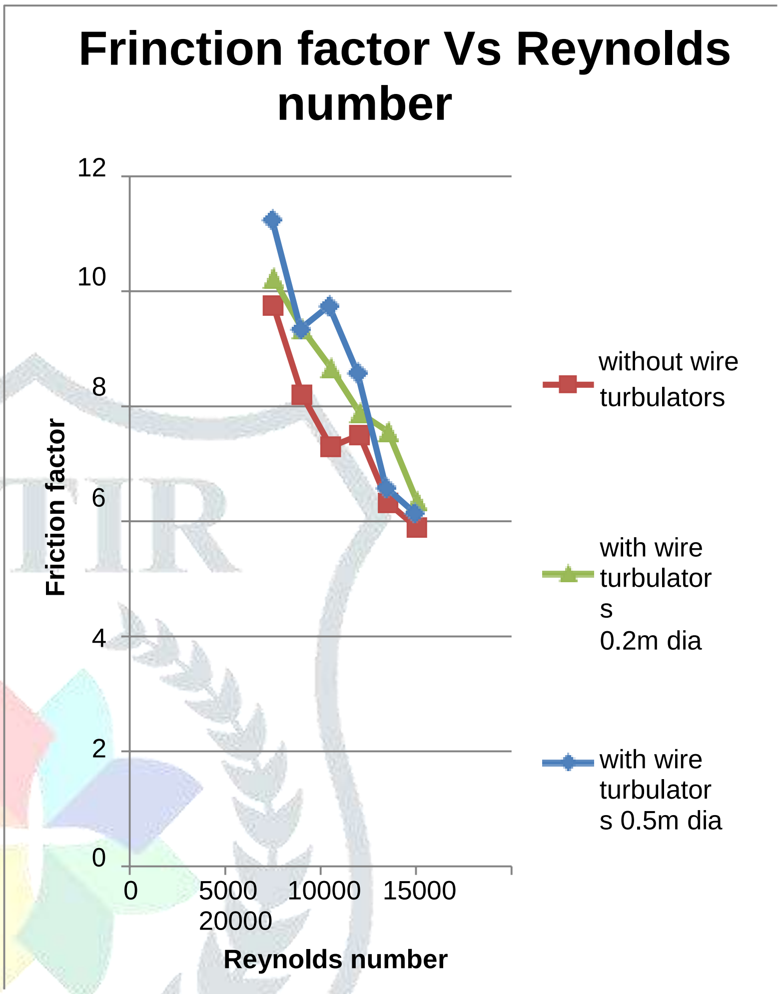


Figure - Friction factor Vs Reynolds Number

From the **Figure 4.3**, it is observed that, as Reynolds increases there is decrease in friction factor. This is because friction factor is inversely proportional to the velocity. Therefore, as velocity increases (i.e. Reynolds no.) friction factor will decrease. Same trend is observed by the delta winglet type vortex generator in numerical analysis of fin and tube heat exchanger by Y. L. He et al. **[1]**. From **Figure 4.3**, it is observed that least friction factor is obtained in duct for the heat exchanger without wire turbulators, as there is no other obstruction in the path of fluid flow other than the fins. Whereas friction factor *f* for heat exchanger with 0.2mm diameter turbulators to heat exchanger without turbulators increases about 12.08%. In addition, friction factor *f* for heat exchanger with 0.5mm diameter turbulators to without turbulators increases about 15.57%.

Variation of Colburn factor with Reynolds number

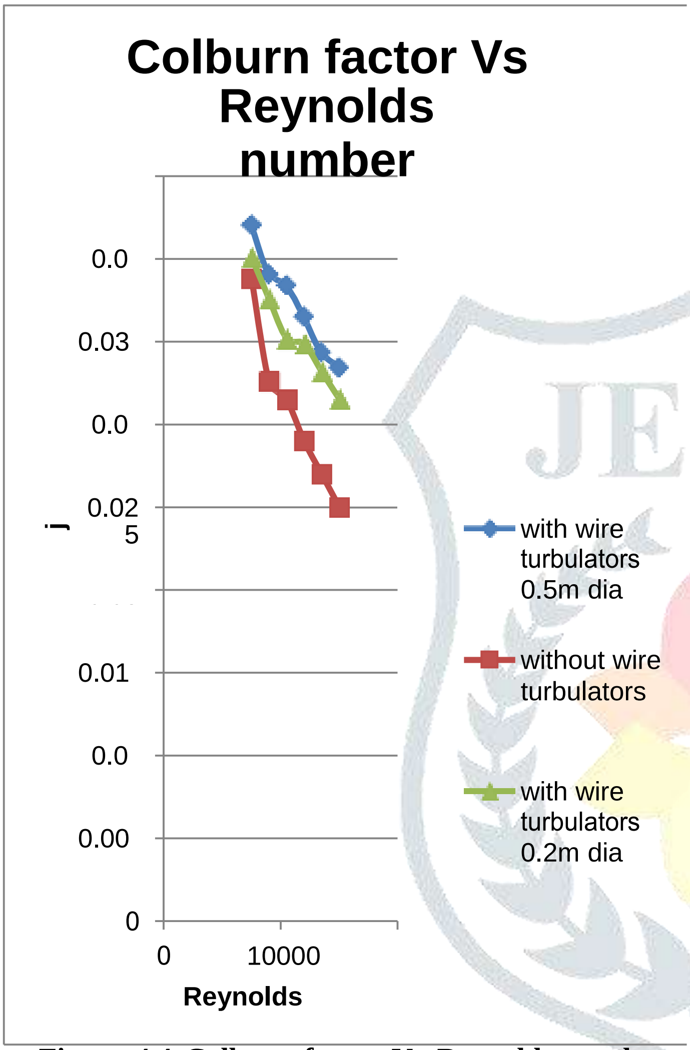


Figure 4.4 Colburn factor Vs Reynolds number

From the Figure 4.5, it is observed that as Reynolds increases there is decrease in Colburn factor is observed. This is because Colburn factor is directly proportional to heat transfer coefficient and inversely proportional to the frictional force. Same trend is observed by the delta winglet type vortex generator in numerical analysis of fin and tube heat exchanger by S.Selvam et al. **[4]**. Colburn factor is the parameter comparing the heat transfer coefficient with respect to the drag force acting on the fluid flowing. As j factor gives the comparative analysis between the heat transfer coefficient and frictional force it is widely used performance parameter for compact heat exchanger. Whereas colburn factor *j* for heat exchanger with 0.2mm, diameter turbulators to heat exchanger without turbulators increases about 15.68%. In addition, colburn factor *j* for heat exchanger with 0.5mm diameter turbulators to without turbulators increases about 22.54%.

6. CONCLUSION

1. The heat transfer coefficient with wire turbulators applied to the fin and tube heat exchanger is found to be more as compared to the heat exchanger without wire turbulators. The heat transfer coefficient shows 18.4% increment in case of wire turbulators of 0.2mm diameter as compared to heat transfer coefficient without wire turbulators. Whereas it shows 26.52% of increment of heat transfer coefficient in case of wire turbulators of 0.5mm diameter as compared to heat transfer coefficient without wire turbulators. Same trend is observed in the experimental analysis for longitudinal vortex generator or turbulators by Jiong li et al.[1].

2. Friction factor reduces as the Reynolds number increases this is because with increase in Reynolds number velocity increases and as friction factor is inversely proportional to velocity it decreases. This friction factor found to be maximum in case of heat exchanger with wire turbulators of 0.5mm diameter.

3. Friction factor *f* for heat exchanger with 0.2mm diameter turbulators to heat exchanger without turbulators increases about 12.08%. In addition, friction factor *f* for heat exchanger with 0.5mm diameter turbulators to without turbulators increases about 15.57%. Analogous pattern of increment is observed by Y. Chen et al. [2] in his study of longitudinal punched vortex generator.

4. Colburn factor *j* for heat exchanger with 0.2mm, diameter turbulators to heat exchanger without turbulators increases about 15.68%. In addition, colburn factor *j* for heat exchanger with 0.5mm diameter turbulators to without turbulators increases about 22.54%. Same trend can be observed in winglet type vortex generator, which are experimentally analyzed on compact heat exchanger by K. Torii et al. [3].

5. Wire turbulators produces obstruction for the flow of fluid and creates turbulence. Increase in diameter of wire diameter will result in more friction in the path of fluid flow.
Thus including wire turbulators gives more friction losses as compared to the heat exchanger without wire turbulators.

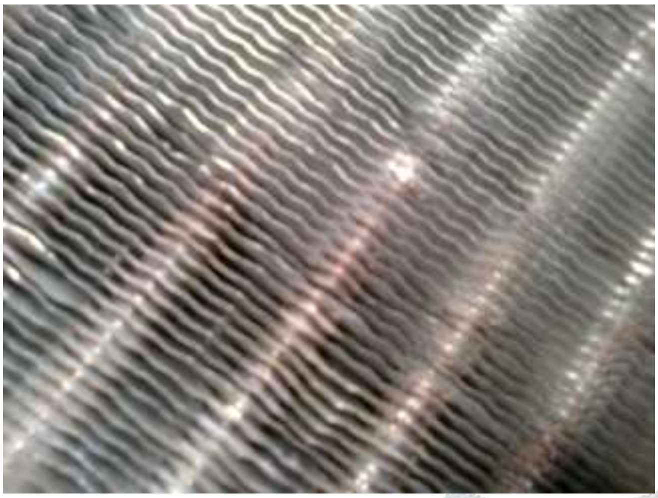
Table-Percentage increase in average values of Heat transfer coefficient as compared to the heat exchanger without wire turbulators

Sr. No.	Arrangement	Average heat transfer coefficient (W/m^2K)	Percentage increment in heat transfer coefficient
1	Heat exchanger without wire turbulators	46.63	----------
2	Heat exchanger with wire turbulators 0.2mm diameter	55.21	18.40%
3	Heat exchanger with wire turbulators 0.5mm diameter	59	26.52%

Figure E.1 Actual working setup

Figure E.2 Compact heat exchanger

Figure E.3 Compact heat exchanger with wire turbulators



7. REFERENCE

[1] Jiong Li, Shuangfeng Wang, Jinfang Chen and Yong- Gang Lei. 2011. Numerical analysis of a slit fin and tube heat exchanger with longitudinal vortex generator. International Journal of Heat and Mass Transfer. 54: 1743-1751.

[2] Y. Chen, M. Fiebig and N.K. Mitra. 2000. Heat transfer enhancement of finned oval tubes with staggered punched longitudinal vortex generators. International Journal of Heat and Mass Transfer. 43: 417-435.

[3] K. Torii, K.M. Kwak and K. Nishino. 2002. Heat transfer enhancement accompanying pressure-loss reduction with winglet-type vortex generators for fin tube heat exchangers. International Journal of Heat and Mass Transfer. 45: 3795-3801