RESEARCH ARTICLE OPEN ACCESS

Heat Transfer Enhancement through a Pipe by Inserting V-Shape Aluminium Turbulator

Pravin S.Nikam[1], Prof. R. Y. Patil[2], Prof. D.A. Patil[3], Prof.S.G.Chaudhari[4]

1(M.E Scholar SGDCOE Jalgaon (MS), India,)
2(Professor & Head of Mechanical Engg Department SGDCOE, Jalgaon (MS), India)
3(Asst.Prof. GHRIM Jalgaon (MS), India)
4 (Asst. Prof. SGDCOE Jalgaon (MS), India)

Abstract:

An experimental study of heat transfer in plane circular tube fitted with the V-Shaped Aluminum turbulators is performed for plane circular tube. The objective of this Project work is to analyses heat transfer coefficient and friction characteristics in a plane circular tube fitted with the V-Shaped Aluminum turbulators. The experimentations are firstly carried out on the plane circular pipe and heat transfer augmentation were recorded and then the v-shaped Aluminum turbulators are fitted in the same plane pipe and then again the heat transfer augmentation is recorded and then both of them is compared. Experimental investigations have been carried out to study the effects of the V-Shaped Aluminum turbulators on heat transfer, friction and enhancement efficiency, in a circular tube. We used the V-Shaped aluminum turbulators with the turbulator element length of 200mm, 160mm and 120mm.We found the heat transfer argumentation.The mean heat transfer rates obtained from using the V-Aluminum turbulators are 198%, 213% and 241% for turbulator element Length of 200mm, 160mm and 120 mm respectively. All of the experiments are carried out at the same inlet conditions with the Reynolds number, based on the tube diameter (Re), in a range of 3000 to 10000.

Keywords — **Enhancement; heat transfer; twisted tape inserts; pressure drop; flow; Aluminum turbulator.**

I. INTRODUCTION

The conventional sources of energy have been depleting at an alarming rate and it makes future sustainable development of energy use very difficult. Thus, the focuses on seeking ways to reduce the size and cost of heat exchangers have been conducted. Heat transfer enhancement technology has been developed and widely applied to heat exchanger applications over the past decades; for example, refrigeration, auto motives, process industry, solar water heater, etc., while the reduction in overall resistance can lead to a smaller heat exchanger. To date, there have been a large number of attempts to reduce the size and costs of heat exchangers. In general, enhancing the heat transfer can be divided into two groups. One is the passive method, without stimulation by the external power such as a surface coating, rough surfaces, extended surfaces, swirl flow devices, the convoluted (twisted) tube, additives for liquids and gases.

II.NOMENCLATURE:

A-	Heat transfer surface area, m^2
C_{pa}-	Heat capacity of air, kJ kg^{-1} K^{-1}
D-	Diameter of the test tube, m
f-	Friction factor
h-	Average heat transfer coefficient,
I-	Current, A
k-	Thermal conductivity of air,
L-	Length of the test tube, m
l-	Pitch length of the V-nozzle arrangement,
m-	Mass flow rate, kg s^{-1}
Nu-	Nusselt number
ΔP-	Pressure drop, Pa
PR-	Pitch ratio, (l/D)
Pr-	Prandtl number
Q_{air}	Heat transfer rate of the hot air, W
Q_{conv}	Heat transfer rate of the wall, W
Re-	Reynolds number
T_w	local wall temperature
t-	Thickness of the test tube, m
U-	Averaged axial velocity inside the test tube, m s^{-1}
V-	Voltage, V
v	Volume flow rate of the hot air, m^3/s

III.HEAT TRANSFERVENHANCEMENT TECHNIQUES:

In general, some kinds of inserts are placed in the flow passage to augment the heat transfer rate, and this reduces the hydraulic diameter of the flow passage. Heat transfer enhancement in a tube flow by inserts such as twisted tapes, wire coils, ribs and dimples is mainly due to flow blockage, partitioning of the flow and secondary flow. Flow blockage increases the pressure drop and leads to increased viscous effects because of a reduced free flow area. Blockage also increases the flow velocity and in some situations leads to a significant secondary flow. Secondary flow further provides a better thermal contact between the surface and the fluid because secondary flow creates swirl and the resulting mixing of fluid improves the temperature gradient, which ultimately leads to a high heat transfer coefficient.

Twisted tape generates a spiral flow along the tube length. A wire coil insert in a tube flow consists of a helical coiled spring which functions as a non-integral roughness. In a turbulent flow, the dominant thermal resistance is limited to a thin viscous sub layer. The wire coil insert is more effective in a turbulent flow compared with a twisted tape, because wire coil mixes the flow in the viscous sub layer near the wall quite effectively, whereas a twisted tape cannot properly mix the flow in the viscous sub layer.

For a laminar flow, the dominant thermal resistance is limited to a thicker region compared with a turbulent flow. Thus, a wire coil insert is not effective in a laminar flow because it cannot mix the bulk flow well, and the reverse is true for a twisted tape insert. Hence, twisted tapes are generally preferred in laminar flow.

Performance and cost are the two major factors that play an important role in the selection of any passive technique for the augmentation of heat transfer. Generally, twisted tape and wire coil inserts are more widely applied and have been preferred in the recent past to other methods, probably because techniques such as the extended surface insert suffer from a relatively high cost and a mesh insert suffers from a high pressure drop and fouling problems.

IV. PROBLEM IDENTIFICATION:

Energy saving considerations, as well as economic incentives, have led to efforts to Produce more efficient heat exchange equipment. Common thermal goals are to reduce the size of a heat exchanger required for a specified heat duty, to upgrade the capacity of an existing heat exchanger, following problems are identified.

- Lower rate of heat transfer
- Large size of heat exchanger due to lower rate of heat transfer.
- Increased Cost of heat exchangers.
- Heat losses due to friction in heat exchanger.

V. AIM AND OBJECTIVES:

On the basis of above mentioned identified problems the aim and objective of project work are obtained. Following are the objective identified to carry out the project work.

1. To analyse the Heat transfer characteristics in circular pipe fitted with V- shaped Aluminum Turbulators.
2. To enhance rate of heat transfer in circular tube.
3. To enhance enhancement factor of heat exchanger.

VI. METHODOLOGY:

The methodology to complete the project work is as follows.

1. To study the various heat transfer enhancement methods.
2. Selection of geometry (Turbulator).
3. Development of experimental set-up.
4. Conduction of experiments for plane pipe and then pipe fitted with turbulators.
5. Comparison of results.
6. Concluding the Project work.

VII. SYSTEM DEVELOPMENT:

In the present work, the air is used as working fluid and flowed through a uniform heat flux and insulation tube.

***Experimental Set-up.**

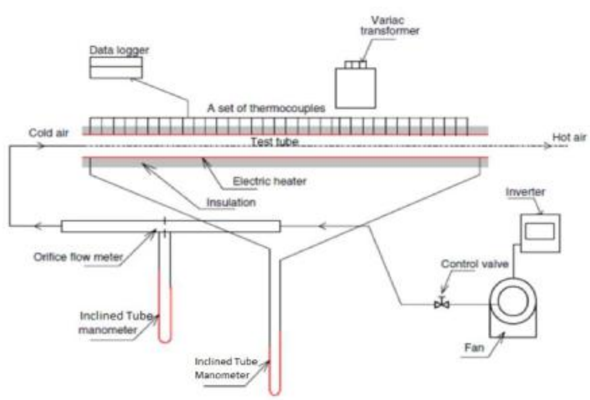

Fig.Experimental set-up

We proposed to carry out on experimental set-up as shown in the figure 3.5. The experiment setup will be an open-loop experimental facility as shown in figure 3.5. The loop consisted of a blower, and heat transfer test section. The test tube has a length of L=600 mm, with 52 mm inner diameter (D), 60 mm outer diameter (Do), and 4 mm thickness (t) as depicted in figure 3.5 the tube was heated by 3 heaters of 200 mm length each connected in parallel with combined capacity of 1000 watts to provide a uniform heat flux boundary condition. The electrical output power was controlled by a variance transformer to obtain a constant heat flux along the entire length of the test section. The outer surface of the test tube was well insulated to minimize convective heat loss to surroundings, and necessary precautions will be takes place to prevent leakages from the system. The inner and outer temperatures of the bulk air were measured at certain points with a multichannel temperature measurement unit in conjunction with the K type thermocouples Five thermocouples will be tapped on the local wall of the tube and the thermocouples were placed round the tube to measure the circumferential temperature. The mean local wall temperature was determined by means of calculations based on the reading of thermocouples.

VII. SPECIFICATIONS OF EXPERIMENTAL SET-UP:

Following are the specifications of the various components of experimental setup used.

- Air Blower 0.28 HP
- Orifice Meter To Measure The Flow Rate,
- Inclined Water tube Manometer
    - Range :- 0 to 50 MMW
- The Mild Steel test tube with length of
    - L=600mm, with 52 mm inner diameter (D), 60 mm outer diameter (Do), and 4 mm thickness (t).
- Pipe Heater
    - 3 Heaters of 200 MM Length each Connected in Parallel With Combined Capacity of 1000 Watts.
- 7 Channel Temperature Measurement Unit
    - Unit In Conjunction With 5 K-type Thermocouples at equal distance on heating Section wall and two for measuring Inlet and Outlet temperature of air.
- Dimmerstat
    - 6 Ampere Variance and 2500 Watt.
- Control Panel
    - Ammeter
    - Voltmeter
- V-Shaped Aluminum Turbulators
  The V-Shaped Aluminum Turbulators are used to increase the turbulence inside the circular tube.

The V-Shaped aluminum turbulators are made up of Aluminum Circular rod with Diameter 40 mm, and are manufactured by the turning process on the lathe machine. Three V-shaped turbulators with different pitch are fabricated and used.

Fig.Actual V-shaped Aluminium Turbulator

VIII. EXPERIMENTAL PROCEDURE:

For each experimental run, initially all the instruments viz., Voltmeter, Ammeter, Blower, Heater, Manometer is checked. All the joints were checked to ensure no leakage from the system. Also the correctness of the measuring instruments is performed before starting experimentation. Start the heater and then blower and after that set the flow of air by using valve. The system is allowed to reach the quasi-static state before the data recorded. The steady state is assumed to reach when no variation in temperature was recorded for the span of 30 min.

During the experimentation, the following parameters were measured for each set of the flow rate:

1) Pressure drop across the test section (PT).
2) Pressure drop across orifice plate (PO).
3) Temperature of test plate (Tw).
4) Temperature of air at inlet (Ti) and outlet (To) of the test section.

Steady state values of the test plate and air temperatures at various locations were obtained for a given heat flux and the mass flow rate of air. First of all this procedure is done for test section without any turbulator and after that same procedure is repeated for all turbulators. Heat transfer rate to the air, Nusselt number, friction factor have been computed

IX. PERFORMANCE ANALYSIS:

The series of experiments were carried out on the experimental test rig, the experiments were first carried out with the plane circular pipe and then the same experiments were repeated by using the v-shaped Aluminum turbulator fitted in the plane circular tube. The all experiments were performed by providing different mass flow rate of air by controlling the air flow by using the valve, the different opening of valves gives the different mass flow rate. Following are the results of the experiments.

***Heat Transfer Coefficient-**

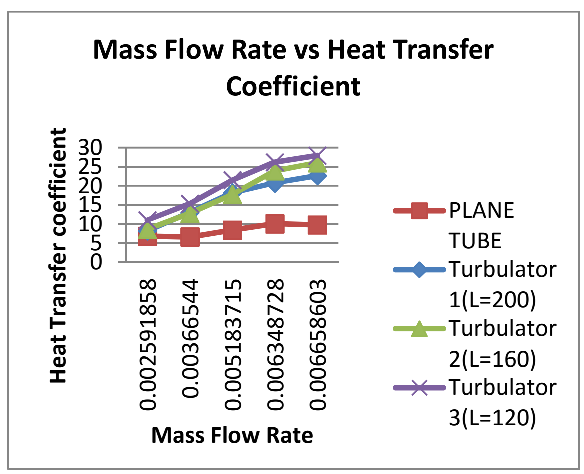

Fig.Mass Flow Rate Vs Heat Transfer Coefficient

The above graph is plotted for Mass Flow rate. Against the heat transfer coefficient. As shown in graph the mass flow rate is taken on the X-Axis and heat transfer coefficient on the Y- Axis. The heat transfer rate increases in the v-shaped Turbulators as shown in graph with a significant rate as compared to the plane circular tube.

*** Reynolds No.-**

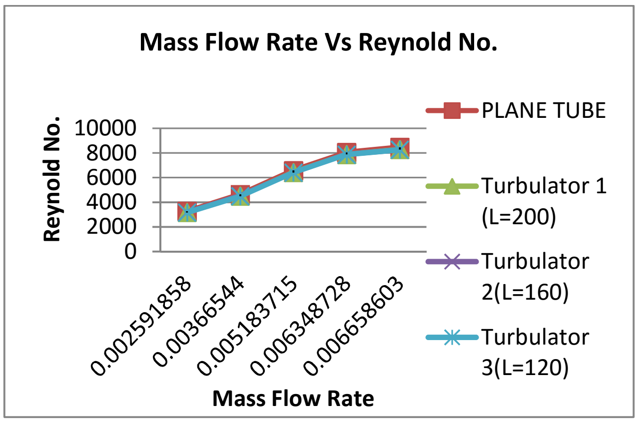

Fig.Mass Flow Rate Vs Reynolds No

The graph shows that the Reynolds No. for the various V-Shaped turbulators and for plane circular tube and there is the very small difference between Reynolds no. of all cases. This increases in the Reynolds No. occurred due to the turbulence.

***Heat Transfer Coefficient-**

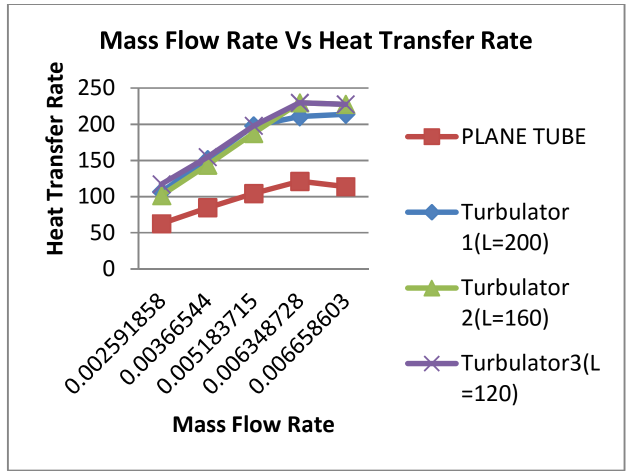

Fig.Mass Flow rate Vs Heat Transfer Rate

The below graph is shows relation between Mass Flow rate and heat transfer rate. As shown in graph the mass flow rate is taken on the X-Axis and heat transfer rate. On the Y- Axis. The heat transfer rate increases by using V-shaped. The below plot shows that the heat transfer rate for V-Shaped turbulators with length 120 is highest and it slightly reduces for Length 160 and 200 respectively.

***Friction Factor-**

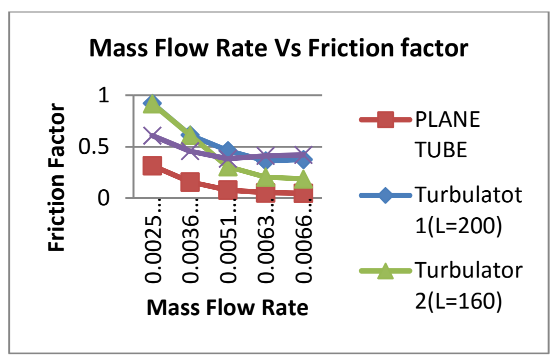

Fig.Mass Flow Rate Vs Friction Factor

The friction factor is most important factor for performance analysis of various heat transfer augmentation techniques. It is always observed that while using any inserts in the circular pipe it results in pressure drop because the increased fiction in pipes. This plot shows the friction factor for various V-shaped turbulators. The graph shows that the friction factor reduces as the mass flow rate increases. The friction factor for length of 120 mm is more and less for 150 mm and 200 mm length respectively.

Heat Transfer Coefficient Enhacement Factor

This plot shows heat transfer enhancement by using various V-shaped turbulators. The heat transfer coefficient enhance factor is increases by using V-shaped Turbulators as shown in graph with a remarkable rate as compared to the plane circular tube. This increase in the heat transfer is depends on the Reynolds No. and heat transfer coefficient. The average heat transfer rates obtained from using the V-turbulators are 198%, 213% and 241% for turbulator with the turbulator element length 200mm, 160mm and 120mm respectively over the plain tube.

In the following graph plot mass flow rate vs enhancement factor for the circular tube fitted with firstly 200 mm length turbulator secondly by inserting the turbulator of 160 mm lengh and lastly the turbulator of 120 mm is fitted by the pitch ratio of 5,4,3 respectively.

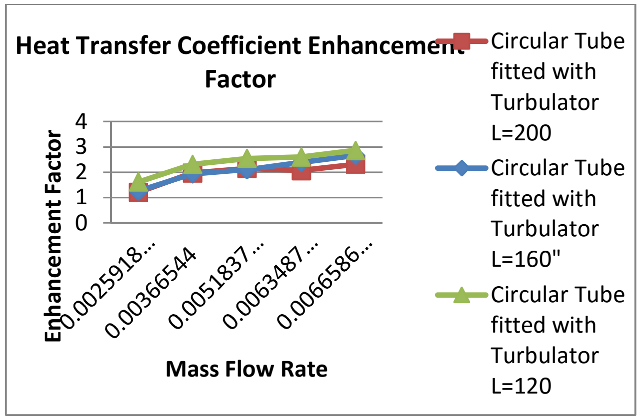

Fig.Heat transfer Coefficient Enhancement Factor

X. CONCLUSION:

Experimental investigations have been carried out to study the effects of the V-Shaped turbulators on heat transfer, friction and enhancement efficiency, in a circular tube. We used the v-turbulators with the element length 200mm, 160mm and 120mm we found the heat transfer argumentation. The results are

1. The heat transfer in the circular tube could be promoted by fitting with V Turbulators while it brings about the energy loss of the fluid flow.

2. The mean heat transfer rates obtained from using the V-turbulators are 198%, 213% and 241% for turbulator with the turbulator element length 200mm, 160mm and 120mm respectively over the plain tube.

3. The results shows that the heat transfer coefficient for the v-turbulator is more as compare to the plane circular tube. The

results shows that the heat transfer rate is increases as the Reynolds no. increases. This increases in the heat transfer rate occurred due to the turbulence.

4. The friction factor reduces with as the Reynolds no increases and this friction factor is slightly higher in v-turbulator when compared to the plane circular tube.

XI. APPLICATIONS:

Heat transfer is an essential process throughout a number of residential, industrial and commercial facilities. In order to increase the heat transfer rate the size of the heat transfer equipment increases, also the energy requirement is increases which reduce the efficiency of the equipment, that why the heat transfer augmentation techniques are used to overcome above said problems. V-shaped turbulators can be used in heat exchanger, recuperates, evaporators etc.

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