Heat Transfer Enhancement using Modified Vortex Generator

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Abstract
An experimental study of heat transfer enhancement is performed in smooth circular tube then same performed in smooth circular tube fitted with insert . The Reynolds number is varied in the range of 8,000 to 17,000. The bjective of this Project work is to analyses heat transfer enhancement and pressure drop in a tube fitted with the insert. The experimentations was firstly carried out on the smooth circular pipe and heat transfer augmentation were recorded and then the insert are fitted in the same pipe and then again the heat transfer augmentation is recorded and then both of them is compared. The heat trancfer enhancement and pressure drop in tubes with inserts to generate vortex are presented. All of the experiments are carried out at the same Reynolds number, in a range of 8,000 to 17,000.

NOMENCLATURE:-
A_s - Surface area of pipe, m2
C_{pa}- Specific heat capacity of air, kJ/kg K
D_i - Inner Diameter of the test tube, m
D_o - Outer Diameter of the test tube, m
L - Length of test tube, m
f - Friction factor of tube fitted with modified vortex generator.
f_s - Friction factor of plane tube
h_i - Average heat transfer coefficient, (w/m2)
K - Thermal conductivity of air, W/m K
P - Pitch length of the of inserts, m
m - Mass flow rate, kg/ s
Nu - Nusselt number
Nuc - Nusselt number on the basis of equal pumping power (Without vortex generator)
Nus - nusselt number on the basis of equal Reynolds number (Without vortex generator)
Q - Volume flow rate of the hot air, m /s

1. INTRODUCTION

The Heat Exchanger performance is always limited by the gas inside because heat transfer coefficient are inherently lower for gas side then foe liquid or two phase flow. this limitation of low heat transfer coefficient for gas & the desire to improve energy performance with reduced volume & manufacturing cost continue to motivate the research in gas side heat transfer enhancement. there is demand for high performance heat exchanger devices for application in small size and light weight. apart from this other objective are optimization of capital and operating cost, both can be positively affected by either increasing the heat transfer coefficient or

by increasing effective heat transfer surface area per volume or both. Heat transfer enhancement using inserts always gives penalty in terms of pressure drop for hear transfer enhancement in circular tube inserts inserts are most popular since they are very easy to install and do not required deformation of material on the inside surface of the tube. twisted tip and wire coil inserts are most widely used inserts.

1.1 HEAT TRANSFER ENHANCEMENT:-

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.

2. EXPERIMENTAL SET UP:-

An experimental test facility constriction to measure the heat transfer coefficient in smooth tube & tube with modified vortex generator is as shown. Air as working fluid is forced into test section by using boiler. The flow rate of air in the test section is controlled by regulating inlet valve. The mass flow rate & velocity of air in test section is measured by venturimeter placed before the inlet of test section. Toe pressure tops attached at the inlet and throat of venturimeter are connected to U-Tube manometer containing water as manometer fluid to measure differential pressure head across the venturimeter. The pressure drop across the test section is measured by pressure top across the inlet and outlet of the test section which are connected to U-Tube manometer containing water as manometer fluid.

The test section is 1000 mm long stainless steel tube of wall thickness 0.25 & 25 mm outside diameter. A nichrome wire is wounded around the test section. It is covered with cotton to avoid heat loss to the surrounding. The controlled power is supplied to the wire through dimmer which provide uniform heat flux for the test section. The bulk temperature of inlet and outlet flow of air in test section is measured by pre calibrated thermocouple.

The schematic of setup is shown in fig (1)

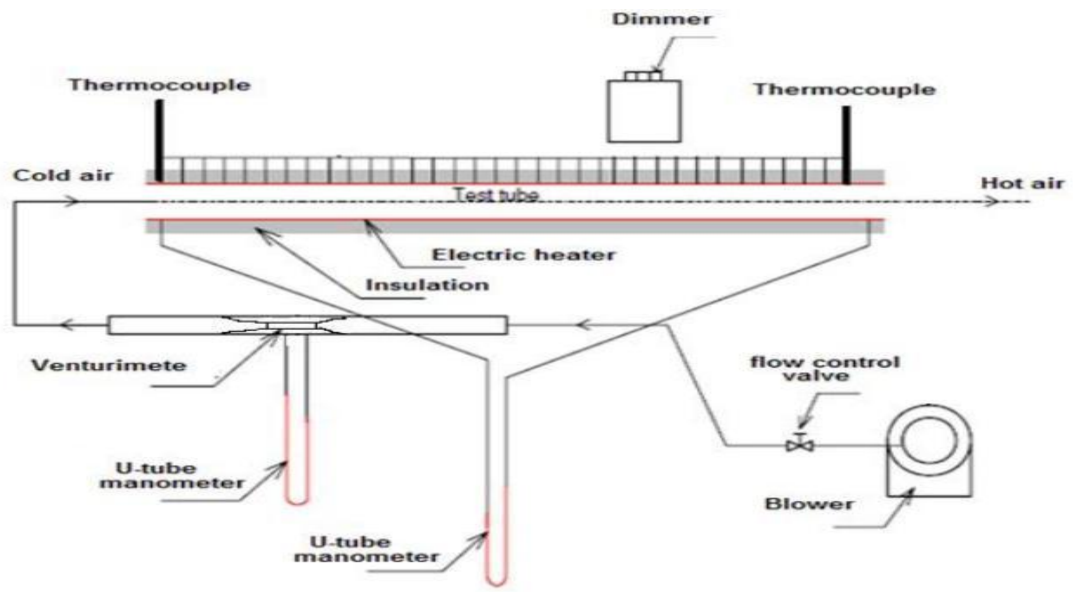


Fig 1 Schematic representation of experimental setup

The geometry of typical vortex generator is as shown in fig (2). The vortex generators have been designed to confirm to the geometry of test surface. They are made up of 0.25 mm thick aluminum sheets. The vortex generator is cut from the circle of radius 12.5 mm. they are attached on 3 mm stainless steel rod at a specified axial location & at a particular angle of attack to the flow direction.

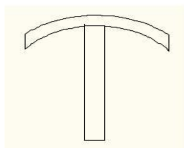


Fig. 2 Modified Vortex Generator.

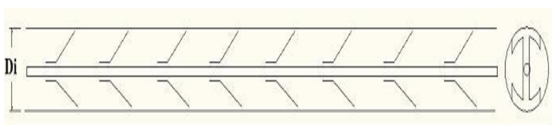


Fig. 3 Test tube fitted with Modified vortex generator at 45 .

The friction factor is determined in terms of pressure drop across experimental condition. It is normalized by the friction factor for fully developed flow in smooth tube proposed by Blausius as ($f_s = 0.3164/Re^{0.25}$)

The Nusselt no is calculated as

$Nu=\frac{q}{As}$

Heat carried by air flow from the test section is

$Q = m* c_p(T_o-T_i)$

Average heat transfer coefficient based on net heat transfer rate is given by

$$h = \frac{q}{As\ (To - Ti)}$$

The Nusselt no. for fully developed flow for the test section with inserts is calculated as

$$Nu = \frac{h * d}{k}$$

The experiment have been performed for different Reynolds number , pitch diameter, ratio & angle one such insert tube assembly with angle 45^o is as shown in fig (3). The heat transfer coefficient enhancement is reported in the form of the ratio of the measured Nusselt number to corresponding smooth tube Nusselt number at given Reynolds number(nu/nus).The Nusselt number at constant pumping power is also evaluated. This is the ratio of Nusselt number with a Nusselt number that would exist in smooth tube if the pumping power for the rough and the smooth tube were kept constant.

2.1 SPECIFICATIONS OF MODIFIED VORTEX GENERATOR:-

Thickness = 0.4 mm

Length of modified vortex generator at different angles is given below:

I. 90^o inserts=10.5 mm

II. 60^o inserts=12.12 mm

III. 45^o inserts=14.85 mm

IV. 30^o inserts=21 mm

V. 15^o inserts=40.57 mm

Material = Aluminium

Fig. 4 snapshot of experimental vortex generator

3. EFFECT OF SHAPE OF VORTEX GENERATOR:-

If the vortex generators are flat, large gap appears between inner tube surface and vortex generator. That allows fluid to bypass without generation vortices. This reduces the heat transfer enhancement. This problem is overcome by giving curved shape top vortex generators. Thus there is almost no gap between vortex generators and tube. This shape of vortex generators shows significant enhancement in heat transfer with small pressure drop. The flat and curved shape of vortex generators is shown in Fig. 5 and Fig 6

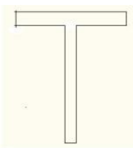


Fig. 5 Flat vortex Generator

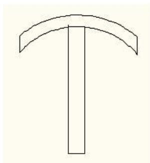


Fig. 5 Flat vortex Generator

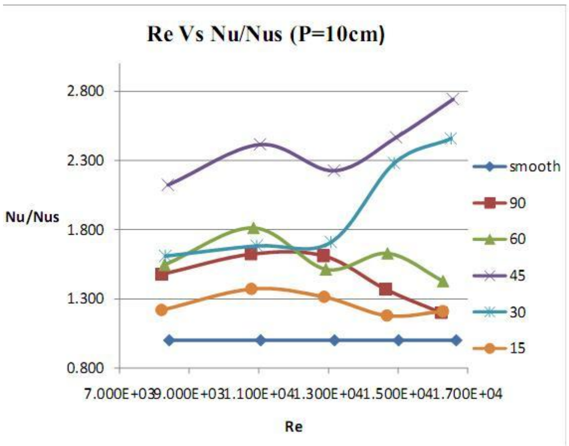
4. RESULT AND DISCUSSION:-

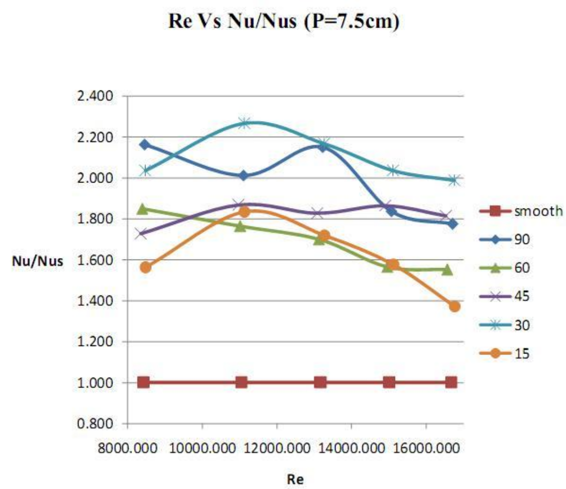
As the air flow is through tube, the hydraulic diameter is taken as being equal to the tube diameter. The flow is fully developed and smooth

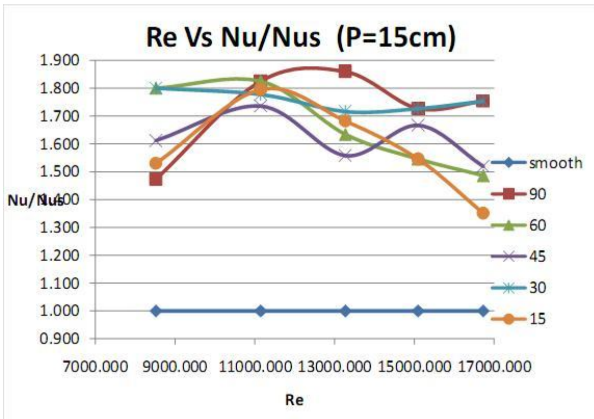
pipe values for friction factor and Nusselt number compare well with Blasius (f= $0.314/Re^{0.25}$) and Dittus Boelter relation (Nu=$0.023Re^{0.8}Pr^{0.4}$). Only the variation of axial pitch distance between vortex generate and flow angle of attack is studied. The result is obtained discussed for the Reynolds number ranging from 8000 and 16500.

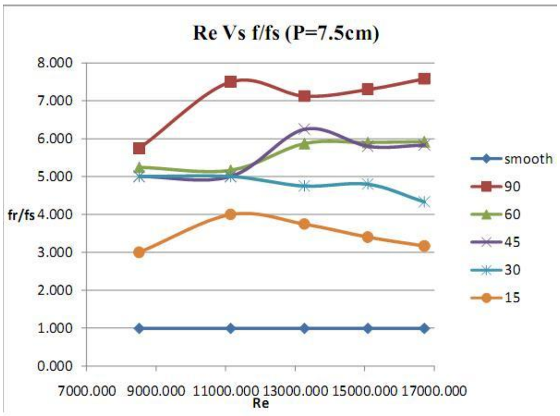
The result of this study is presented in term of Nusselt number and friction factor ratio as fuction of influencing parameter of vortex generators. The Nusselt number ratio based on equal Reynolds number is represented as Nu/Nus where as that based equal pumping power represented as Nu/Nus. Nu is experimental value of Nusselt number in presence of vortex generate, Nus and Nue are corresponding Nusselt number values for smooth tube on the basis of equal Reynolds number and equal pumping power respectively.

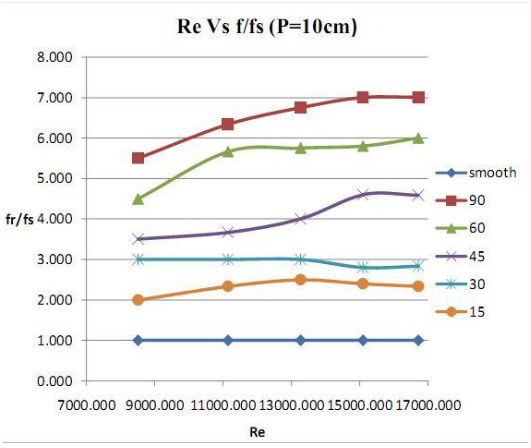
4.1 EFFECT OF PITCH LENGTH AND INSET ANGLE: ON RATIO OF NUSSELT NUMBER EFFECT ON RATIO OF FRICTION FACTOR:-

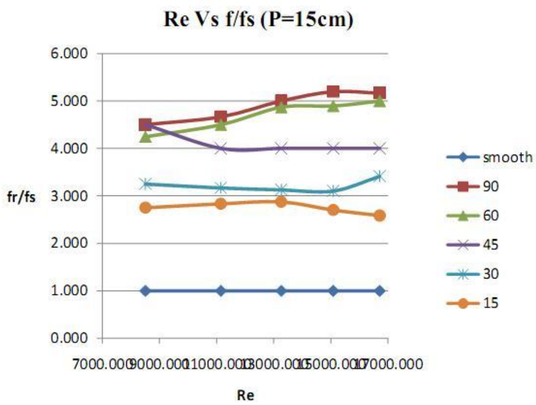












5. CONCLUSION:-

Experimental investigations have been carried out to study the effects of the modified vortex generator on heat transfer, friction and enhancement efficiency, in a circular tube. We used the modified vortex generator with the pitch of P=7.5 cm, P=10 cm and P=15 cm.

The heat transfer in the circular tube could be promoted by fitting modified vortex generator while it brings about the energy loss of the fluid flow. The best result is obtained by experimental analysis using modified vortex generator at different pitch and angles. The friction factor reduces as the insert angle reduces and this friction factor is slightly higher at 90o of modified vortex generator when compared with the other angles of modified vortex generator. The enhancement efficiency approximately remains constant with increasing Reynolds number.

6. REFERENCES:-

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