

An Experimental Study of Thermo-Hydraulic Performance of Modified Double Pipe Heat Exchanger Using Mesh Inserts

Prof.A.M.Patil ¹, M.R.Todkar ²Professor, Department of Mechanical Engineering, PVPIT, Budhgaon, Sangli, India¹Assistant Professor, Department of Mechanical Engineering, TKIET, Warananagar, Kolhapur, India²

ABSTRACT: Heat exchangers have commonly used in a wide range of applications such as refrigeration, air-conditioning systems, food industry, and chemical processing plant and in large power production plants. The design of heat exchangers is quite crucial topic and difficult, as it needs exact analysis of heat transfer rate and pressure drop estimations along with issues such as long life performance and the economic aspect. The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power. These factors have led to increase efforts aimed at producing more efficient heat exchanger equipment through the augmentation of heat transfer.

KEYWORDS: Heat transfer enhancement, Mesh Inserts, Porosity, Nusselt's Number, Pressure Drop etc.

I. INTRODUCTION

In recent years, considerable emphasis has been placed on the development of various augmented heat transfer surfaces and devices. Different methods of heat transfer improvements are classified as Passive, Active and Compound methods. The passive methods are generally used amongst all as they do not need any external power input and give more heat transfer rate. The different passive techniques given by Bergles A. E. and Manglik R. M. are extended surfaces, swirl flow devices, rough surfaces, coiled tubes, treated surfaces, displaced enhancement devices, surface tension devices, additives for liquids and gases.

The swirl flow devices include twisted tape inserts, coil wire inserts, brush inserts, mesh inserts, strip inserts etc. Amongst all inserts, lots of researches have been done on twisted tape and coil wire insert but there is no considerable attention on mesh inserts. They have large surface area per unit volume and much stronger radiation emittance to the upstream side which causes the temperature to drop sharply along the flow direction [7]. Due to this, mesh inserts have found important applications in heat exchanger where the convection and radiation modes of heat transfer are both important. The present study is faithfully and loyally devoted to the heat transfer characteristics with different mesh inserts in heat exchanger.

II. EXPERIMENTAL WORK

Following steps are used to perform the experimental investigation:

- [1] Manufacturing of proper experimental setup for performing the experimental work on heat exchanger.
- [2] Manufacturing of mesh inserts with different thickness, pitch, ratio of mesh material and porosity.
- [3] Analysis of thermo hydraulic performance with conventional tube in tube heat exchanger.
- [4] Analysis of thermo hydraulic performance with mesh inserts of different thickness, pitch, ratio of mesh material and porosity.
- [5] Result analysis and interpretation of the experimental work.

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III. PROBLEM DEFINATION

There are many passive techniques which are used to enhance heat transfer rate. Twisted tape, swirls flow analysis, nozzle operated are used in many heat exchangers. But research on mesh insert is not very much developed. By using mesh insert we can increase heat transfer rate as compared with the twisted tape and the cost of this mesh is also less as compared with other techniques. So in our project we use this wire mesh with working fluid as a water.



Fig. 1 Experiment set up photograph

- For this experiment we used one tank for hot water and another tank for cold water.
- It consists of two pumps and two rotameters for adjusting the flow rate. For inner tube pump P_2 used and for outer tube pump P_1 used.
- In this experiment tube in tube type heat exchanger used in which inner tube is for hot water and outer tube is for cold water.
- In this experiment 8 thermocouple are used, 4 thermocouple for inlet and outlet of inner tube and outer tube and 4 thermocouple for surface temperature of inner tube.
- In hot water tank one heater is used which is 2000 W and after each rotameter 2 heaters are used of 1000 W , in which one is fixed another is variable which is control by dimmerstat.
- On the control panel ON/OFF of all pump, heater and dimmerstat for variable heater as well as digitally thermocouple reading and pressure transmitter readings are as shown.



Fig.2 Mesh inserts manufacturing

Above fig. shows Mesh Inserts that are made from Aluminum alloy with 25 mesh

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• **Porosity Calculation:**

1) Mesh area = $\pi/4 (D_i)^2$
= $\pi/4 (18.5)^2$
= 268.80 mm²

2) Open space area for single mesh (Ao)
= (larger diagonal of parallogram × smaller diagonal of parallogram)/2
= $3.26 \times 1.53/2$
= 2.4939 mm²

3) Consider,
No of hole on a mesh n=50

4) Total open area = n × Ao
= 50×2.4939
= 124.695mm²

5) Space between inner tube and outer diameter of mesh
= $[\pi/4 (D)^2] - [\pi/4 (D_i)^2]$
= $[\pi/4 (21)^2] - [\pi/4 (18.5)^2]$
= 77.52mm²

6) Void volume at single mesh = $t \times [(n \times A_o) + \pi/4 (D^2 - D_i^2)]$
= $0.54 \times [124.695 + \pi/4 (21^2 - 18.5^2)]$
= 109.1961 mm³

1. For 15 mesh

Porosity $\epsilon = 0.9966$

2. For 20 mesh

Porosity $\epsilon = 0.9955$

3. For 25 mesh

Total void volume = $t \times N \times [(n \times A_o) + \pi/4 (D^2 - D_i^2)] = 109.1961 \times 25$
= 2729.90 mm³

Porosity $\epsilon = \text{void volume} / \text{total volume}$
= $[346185 - (268.80 - 124.695) \times 0.54 \times 25] / [346185]$
= 0.9944

1. Experimental work for insert with 25 meshes (Pitch 0.0388m) with porosity 0.9944

[a] For third test, a set of 25 mesh screens had selected.

IV.

OBSERVATION TABLE OF 25 MESH

Sr. No	Hot Fluid Temp. °C (inner Fluid)		Cold Fluid Temp. in °C (outer Fluid)		Flow Rate in m3/s		Surface Temperature in °C				Avg. Temp of Surface	Pressure Transmitter Reading		Flow Rate in LPH	
	Thi T7	Tho T8	Tci T1	Tco T6	Qh (inner)	Qc (outer)	T5	T4	T3	T2		Inlet in mWC	Outlet in mWC	Inner Fluid	Outer Fluid
1	57.87	50.07	30.8	32.4	0.000115	0.000336	32.9	32.2	31.9	31.4	32.16	0.82	0.55	415.36	1208
2	55.37	49.27	32.35	33.8	0.000135	0.000336	34.5	33.8	33.4	32.9	33.68	1	0.65	484.59	1208
3	54.57	49.47	33.95	35.5	0.000154	0.000336	36.1	35.6	34.9	34.5	35.32	1.2	0.77	554.28	1208
4	54.37	49.67	35.35	37.2	0.000171	0.000336	37.8	37.2	36.4	35.9	36.90	1.55	1.03	617	1208
5	54.07	49.87	36.15	38.1	0.000191	0.000336	38.9	38.2	37.3	36.8	37.86	2.1	1.4	688.85	1208

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Result Table:

Sr. No.	Mass Flow Rate in Kg/s	Velocity in m/s	Rate of Heat Transfer in W	Convective Heat Transfer Coefficient in w/m ² K	Reynold Number	Prandtl Number	Expt. Nusselt Number	Dittus Boelter Equation Nu	Plain Tube Nu
1	0.11380	0.333283	3677.9791	2556.8491	13465.02	3.2958	83.304565	68.55218	57.12097
2	0.13389	0.388833	3356.5811	2730.1456	15221.28	3.41355	89.245197	76.49749	73.05874
3	0.15201	0.444752	3209.9054	2914.0487	17410.29	3.41355	95.566772	85.1787	77.09454
4	0.16921	0.49507	3292.8798	3301.6539	19380.37	3.4135	107.927122	92.80594	88.12247
5	0.18891	0.552731	3585.2378	3529.6934	21637.23	3.4135	115.381460	101.3555	91.10775

V. RESULT DICUSSION

1 Heat Transfer Characteristics:

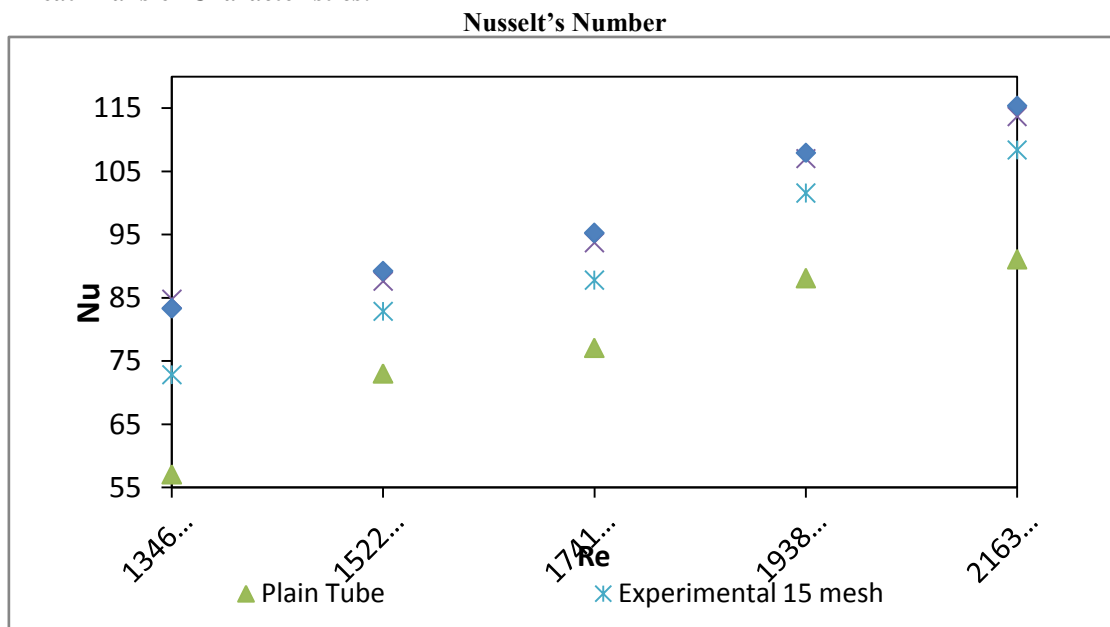


Fig.3 Graph of Nusselt's Number and Reynold number for different wire mesh inserts

We can conclude on this graph of Nusselt's Number and Reynold number for different wire mesh inserts as 15, 20 and 25 mesh screens the Nusselt's Number goes on increases as increase in Reynold number. As compared with plain tube the Nusselt's Number of 15 mesh is increased by 15, for 20 mesh it increased by 30 and by using 25 mesh the Nusselt's Number is increased by 30 to 35.

1. Friction Characteristics for Different Mesh Inserts:

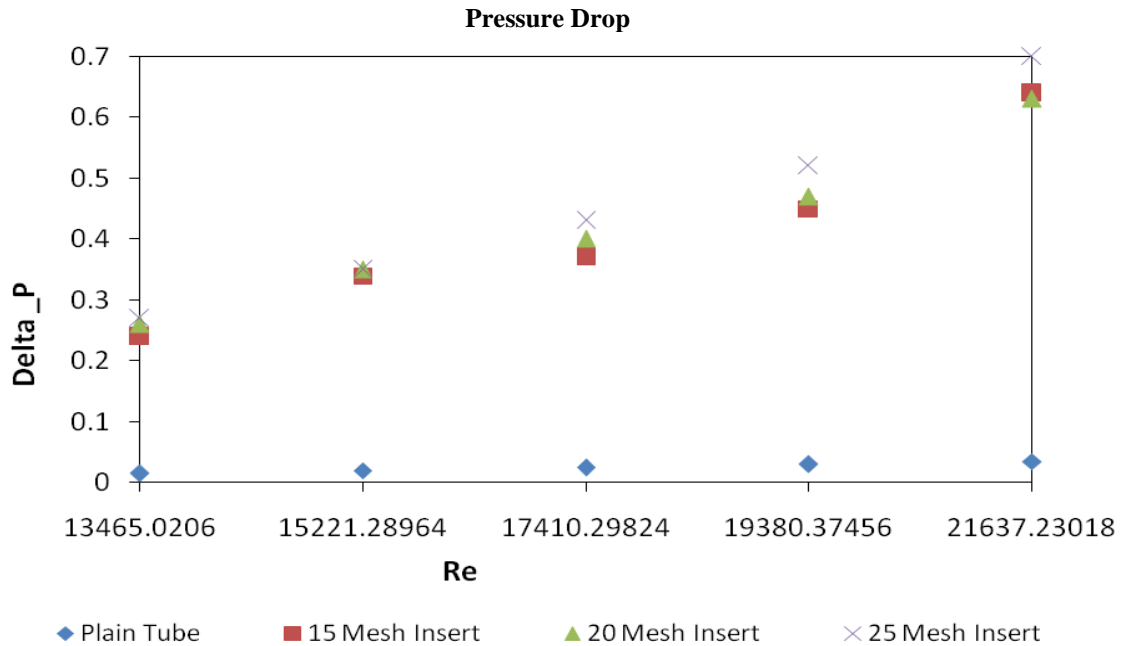


Fig.4 Graph of Pressure Drop and Reynold's number for different wire mesh inserts

The graph gives the relation between Pressure Drop and Reynold number for different wire mesh inserts. As we compare the pressure drop for plain tube and different mesh, the difference is very high hence we have to work on this for future scope.

2. Darcy Weisbach Friction Factor

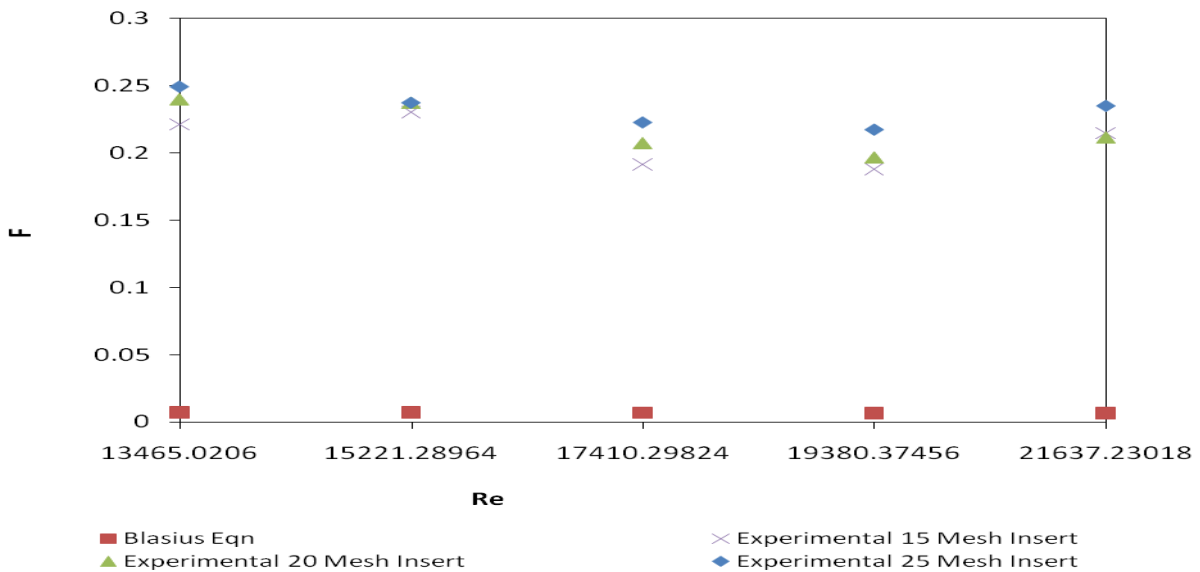


Fig.5 Graph of Friction Factor and Reynold number for different wire mesh inserts

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The graph gives the relation between Friction Factor and Reynold number for different wire mesh inserts. As we compare the pressure drop for plain tube and different mesh inserts, the difference is very high hence we have to work on this for future scope.

VI. CONCLUSION

The effect of wire mesh inserts on three rods with different number of mesh such as 15, 20 and 25 with pitch 64.8mm, 48.5mm and 38.8mm respectively and porosity 0.9966, 0.9955, 0.9944 respectively inserted are described. For test of inserting different mesh using water as the working fluid the heat transfer enhancement and friction factor behaviors in turbulent flow ($9000 \leq Re$) are described. The conclusions which are getting given as follows:

1. With increase in number of mesh, Nusselt's Number increases but at the same time pressure drop also increases. When the pressure drop increases, the pumping power cost also increases, thereby increasing the operating cost. So depending on the requirement, one of the above mentioned inserts can be used for heat transfer augmentation.
2. The Nusselt's Number which we getting from 25 mesh screens is higher as compared with Nusselt's Number getting from 20 and 15 mesh screens because of increase in degree of turbulence.
3. The pumping power is less as compare with active and compound techniques also mesh manufacturing cost is less.

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