Heat Transfer Enhancement In Pipe With Passive Enhancement Technique

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***Abstract*— The heat exchangers are used to enhance heat transfer by providing high heat fluxes or heat transfer coefficient. One of the most important techniques used is passive heat transfer enhancement technique. These techniques when adopted in Heat exchanger proved that the overall thermal performance improved significantly .Helical wire coil insert in plain tube have been experimentally studied in order to improve the heat transfer and overall thermal performance of heat exchanger The present experimental work are carried out with copper and aluminum wire coil inserts by varying pitches of 1 cm, 2cm and 3 cm respectively. The work includes the determination of heat transfer coefficient for various wire coil inserts with varying pitches and different materials. A performance comparison between wire coils inserts and plain tube has shown that wire coil inserts perform better than plain tube to enhance the high heat transfer.**

***Keywords*— Heat transfer enhancement, wire coil inserts, passive enhancement technique.**

I. INTRODUCTION

Heat transfer enhancement techniques are developed to improve and to intensify the thermal performance of heat transfer system, such as heat exchangers, evaporators, thermal power plants, chemical reactor, air-conditioning equipment and refrigerators, and lately they have been applied widely in industrial application. Recently, large numbers of attempts have been made to develop enhancement techniques to reduce the size and costs of heat exchangers in order to improve the overall performance of heat exchangers. The heat transfer rate can be improved by introducing a disturbance in the fluid flow thereby breaking the viscous and thermal boundary layer. Enhancement techniques essentially reduce the thermal resistance in a conventional heat exchanger by promoting higher convective heat transfer coefficient with or without surface area increases .As a result, the size of a heat exchanger can be reduced, or the heat duty of an existing exchanger can be increased, or the pumping power requirements can be reduced, or the exchanger's operating approach temperature difference can be decreased.

1.1 Different techniques of heat transfer enhancement

The convective heat transfer enhancement techniques represent an important research task in the heat transfer field. They are broadly classified into three different categories:

A. Active Techniques
B. Passive Techniques
C. Compound Techniques.

A. Active Technique

The active method involves external power input for the enhancement in heat transfer; for examples it includes mechanical aids and the use of a magnetic field to disturb the light seeded particles in a flowing stream, etc.

B. Passive Technique

The Passive heat transfer methods does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. By Using this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layers which increase effective surface area, residence time and simultaneously heat transfer coefficient increases in an existing system. Methods generally used are, extended surface, displaced enhancements devices, rough surfaces surface tension devices, Inserts etc.

C. Compound method

A compound method is a hybrid method in which both active and passive methods are used in combination. The compound method involves the complex designs and hence it has limited applications.

Although there are hundreds of passive methods to enhance the heat transfer performance, the following nine are most popular used in different aspects:

• Treated Surfaces: They are heat transfer surfaces that have a fine-scale alteration to their finish or coating. The alteration could be continuous or discontinuous, where the roughness is much smaller than what affects single-phase heat transfer, and they are used primarily for boiling and condensing duties.

• Rough surfaces: They are generally surface modifications that promote turbulence in the flow field, primarily in single-phase flows, and do not increase the heat transfer surface area. Their geometric features range from random sand-grain roughness to discrete three-dimensional surface protuberances.

• Extended surfaces: They provide effective heat transfer enlargement. The newer developments have led to modified fin surfaces that also tend to improve the heat transfer coefficients by disturbing the flow field in addition to increasing the surface area.

• Displaced enhancement devices: These are the insert techniques that are used primarily in confined force convection. These devices improve the energy transfer indirectly at the heat exchange surface by displacing the fluid from the heated or cooled surface of the duct/pipe with bulk fluid to the core flow.

• Swirl flow devices: They produce and superimpose swirl flow or secondary recirculation on the axial flow in a channel. These devices include helical strip or cored screw type tube inserts, twisted tapes. They can be used for single phase or two-phase flows heat exchanger.

• Coiled tubes: These techniques are suitable for relatively more compact heat exchangers. Coiled tubes produce secondary flows and vortices which promote higher heat transfer coefficient in single phase flow as well as in most boiling regions.

• Surface tension devices: These consist of wicking or grooved surfaces, which directly improve the boiling and condensing surface. These devices are most used for heat exchanger occurring phase transformation.

• Additives for liquids: These include the addition of solid particles, soluble trace additives and gas bubbles into single phase flows and trace additives which usually depress the surface tension of the liquid for boiling systems.

All these methods of heat transfer enhancement techniques had been developed and widely applied to several industrial and engineering applications in pipe heat exchanger such as Power plant, Air-conditioning, Petrochemical industry, Refrigeration Process industry, Solar water heater, Chemical reactors, Shell and tube heat exchangers, Nuclear reactor etc.

II. LITERATURE REVIEW

Garimella et al. 1988: analyzed the heat transfer coefficients for laminar and transition flows for forced convective heat transfer in coiled annular tubes. The results showed that the convective heat transfer coefficients in the case of coiled ducts, in particular in the laminar region, are higher than the ones obtained with straight tube.

Garcia et al. 2005: He was experimentally studied in order to characterize their thermohydraulic behavior in laminar, transition and turbulent flow when helical-wire-coils fitted inside a round tube, by using water and water–propylene glycol mixtures at different temperatures, a wide range of flow conditions have been covered. Reynolds numbers from 80 to 90,000 and Prandtl numbers from 2.8 to 150. Six wire coils were tested within a geometrical range of helical pitch $1.17 < p/d < 2.68$ and wire diameter $0.07 < e/d < 0.10$. and he found that In laminar flow wire coils behave mainly as a smooth tube but accelerate transition to critical Reynolds numbers down to 700. Within the transition region, if wire coils are fitted inside a smooth tube heat exchanger, heat transfer rate can be increased up to 200% keeping pumping power constant. In turbulent flow ,wire coils cause a pressure drop increase which depends mainly on pitch to wire- diameter ratio p/e.

S.Gunes et al. 2010: The paper presents the experimental investigation of heat transfer and pressure drop in a tube with coiled wire inserts placed separately from the tube wall in turbulent flow regime. The experiments were performed with a constant wire thickness of a = 6 mm, three different pitch ratios (P/D = 1, P/D = 2 and P/D = 3) and two different distances between wire and test tube inner wall (s = 1 mm, s = 2 mm) at which the coiled wire inserts were placed separately from the tube wall. Uniform heat flux was applied to the external surface of the tube and Reynolds numbers varied from 4105 to 26400 in the experiments. The experimental results obtained from a smooth tube were compared with those from the studies in literature for validation of experimental setup. The use of coiled wire inserts leads to a considerable increase in heat transfer and pressure drop over the smooth tube. The Nusselt number and friction factor increase with decreasing pitch ratio (P/D) and distance (s) for coiled wire inserts

Paisarn Nephon et. al. 2006: Have studied the heat transfer characteristics and the pressure drop of the horizontal double pipe with coil-wire inserts in April 2006 .Finally concluded that the heat transfer rate and heat transfer coefficient depend directly on the mass flow rates and effect of coil-wire insert on heat transfer tends to decrease as Reynolds number increase.

Alberto Garcia et. al. 2007: studied on three wire coils of different pitch inserted in a smooth tube in laminar and transition regimes in March 2006, the heat transfer Enhancement obtained with the wire coils will be quite higher than the one obtained with the twisted tapes.

III. EXPERIMENTAL SETUP AND METHODOLOGY

A) Experimental procedure

The schematic diagram for forced convection heat transfer is shown in fig.1. The experimental setup that will be used to enhance the heat transfer in forced convection is as shown in below fig.1.it consist of blower, data logger, heater input voltmeter, and ammeter, data acquisition system (DAS) with computer, thermocouples etc.

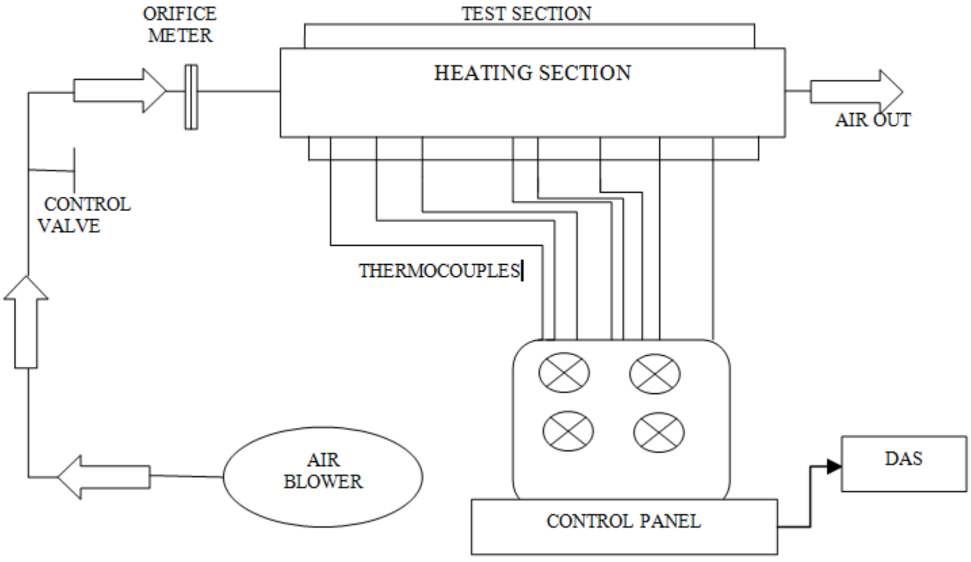

Fig1: Experimental set up layout

While performing the experimental work,

- Heat exchanger is made up of metal pipe which is thermally insulated outside to prevent heat transfer losses to atmosphere.
- Heat regulator is used to supply regulated power input to heater.
- Data logger is used to measure the temperature, voltmeter, current and air flow rate.
- Thermocouples are used at suitable position to measure necessary temperature.
- Blower unit used to blow the air through heat exchanger with orifice meter and control valves are used to control air flow rate.

B) Insert type

The helical inserts are new addition to the family of inserts for enhancement of heat transfer. For the helical taps, the swirl moves in one direction along the helical and induce swirl in the flow, which increase the retention time of the flow and consequently provide better heat transfer performance. The high heat transfer with helical inserts is also accompanied by a higher pressure drop across the flow. However inserts of different configuration are being used to meet the needs of higher heat dissipation rates. Wire coil inserts are currently used in the applications such as oil cooling devices, pre heaters or fire boilers etc.

Fig.2 shows a cross sectional view of helical wire coil insert fitted inside plain tube, where p stands for helical pitch and e for wire diameter and d for inner diameter of tube.

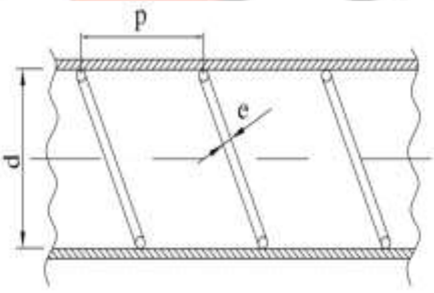

Fig.2: Sketch of helical wire coil fitted inside a smooth tube

C) Mathematical modeling to be carried on inserts:

Thermal performance or mathematical modeling to be carried on inserts is generally used to evaluate the performance of different inserts such as twisted tape, wire coil, etc., under a particular fluid flow condition. It is a function of the heat transfer coefficient, the friction factor and Reynolds number. For a particular Reynolds number, if an insert device can achieve significant increase of heat transfer coefficient with minimum raise of friction factor, the thermal performance factor of this device is good.

In the present work, air was used as the test fluid. The steady state heat transfer rate is assumed to be equal to the heat loss in the test duct:

$Q_{air} = Q_{conv}$ (1)

$Q_{air} = \dot{m}\, c_{p,air} (T_o - T_i)$ (2)

Where, T_o & T_i Temperature at outer and inner wall of pipe

The heat supplied by electrical heater plates in the test duct is found to be 3% to 5% higher than the heat absorbed by the fluid for thermal equilibrium test due to convection and radiation heat losses from the test duct to surroundings. Thus, only the heat transfer rate absorbed by the fluid is taken for internal convective heat transfer coefficient calculation. The convection heat transfer from the test duct can be written by

$Q_{conv} = hA(T_s - T_b)$ (3)

Where, $T_b = (T_o + T_i) / 2$ (4)

Ts = average surface temperature

h can be calculated by comparing equation 2 and 3 number,

i.e, $h = Q_{air} / A(T_s - T_b)$ (5)

Nu are estimated as follows,

$Nu = hD/k$ (6)

The Reynolds number is given by,

$Re = \rho UD/\mu$ (7)

Friction factor f can be written as,

$f = \Delta P / (L\, \rho v^2 / 2D)$ (8)

In which,

Δp is the pressure drop across tapings

V mean air velocity in the duct.

The overall enhancement efficiency is expressed as the ratio of the Nusselt number of an enhanced tube with wire coil insert to that of a smooth tube, at a constant pumping power is introduced by Webb [19]

$PEC = \eta = (Nu_{with} / Nu_{w/o}) / (f_{with} | f_{w/o})^{1/3}$ (9)

Where, PEC is Performance evaluation criteria

IV. RESULT AND DISCUSSION

Table.1 Result table at an heater input of 48 V,0.55amps

Type of insert	Heat transfer coefficient h w/m²k	R_e	Nu	f	PEC
WITHOUT INSERT(WOI)					
WOI	12.16	1.40E+04	10.2	0.029	1
WITH INSERT MATERIAL=AL					

Al 10	14.67	1.39E+04	12.56	0.034	1.17
Al 20	16.34	1.40E+04	13.42	0.032	1.27
Al 30	17.9	1.43E+04	15.11	0.03	1.46
WITH INSERT MATERIAL=Cu					
Cu 10	17.06	1.30E+04	14.17	0.033	1.34
Cu 20	17.5	1.32E+04	14.55	0.03	1.38
Cu 30	18.21	1.33E+04	14.95	0.027	1.57

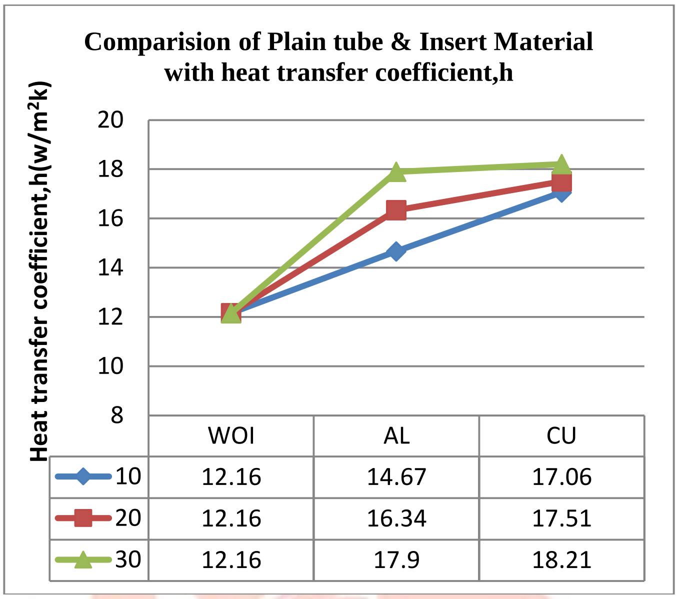

Fig.3.Comparision of Plain tube & Insert material with Heat transfer coefficient at various pitches.

From Table.1 it was found that Nusselt number increases with increase of Reynolds number, Nusselt number obtained for tube with helical wire insert was more than that of plain tube and heat transfer rate is higher for tube fitted with wire coil insert than the plain tube, This is because of coil wore insert interrupt the boundary layer of the fluid flow near the wall of test section hence it increases the fluid temperature in the radial direction .due to high contact surface area the heat transfer rate increases also it create turbulence and whirling motion inside the test section, this motion makes flow highly turbulent, which leads to improved convection heat transfer and it conclude that as Re increases for a given coil inserts the Nu also increases which shows an enhanced heat transfer and also observed that Nusselt number for different pitch is higher for Copper coil wire insert than Aluminum coil wire insert. Copper coil wire insert causes an higher heat transfer enhancement about 1.36 times as compared with plain tube and Al coil wire insert gives high heat transfer enhancement about 1.28 times of plain tube respectively. It can be clearly seen that the friction factor continues to decrease with increased of Reynold number. it seen that friction factor for coil wire inserts are significantly higher than plain tube for given Reynolds number

From fig it can be seen that heat transfer increases with increasing pitch and Heat transfer coefficient is higher for copper coil wire insert than that of Aluminum and plain tube

V. CONCLUSION

Experimental investigation of the convective heat transfer in pipe heat exchanger fitted with wire coil inserts made up of different materials as Copper and Aluminum of different Pitches have been studied successfully for Reynolds number ranging of 5000 – 13000 and conclusion are as follows.

1) The maximum Nusselt number is obtained for copper coil wire insert than aluminum coil wire insert. The copper and Aluminum coil wire insert causes heat transfer enhancement up to 1.36 & 1.28 respectively as compared to plain tube.
2) Wire coil inserts perform better in transition and turbulent region flow. Within the transition region, if wire coils are fitted inside a smooth tube heat exchanger, heat transfer rate can be increased up to 150% keeping pumping power constant
3) In turbulent flow, wire coil inserts causes an increase in the depends upon pitch to wire diameter ratio of wire coil insert.
4) From above experimental investigation it concludes that copper can be used as coil wire insert material for higher heat transfer enhancement than Aluminum.

If wire coils are compared with a smooth tube at constant pumping power, an increase in heat transfer is obtained, especially at low Reynolds number. The coiled circular wire should be applied instead of the smooth one to obtain higher heat transfer and performance, leading to more compact heat exchanger. We observed that the heat transfer in case of the helical wire coil is highest as compare to the plain pipe and the pipe containing the coil of different pitches. The enhancement efficiency increases with the decreasing pitches

VI. NOMENCLATURE

A Heat transfer surface area of test section, m2
f Friction factor
h Heat transfer coefficient, W/m^2k
K Thermal conductivity of air, W/mk
Nu Nusselt number (Nu = hD/k)
Pr Prandtl number
Q Heat transfer, W
Re Reynolds number
V Air velocity, m/s
ρ Density of air, kg/m^3
L Length of the test section,mm
c_p Specific heat of air , J/kg.k
m Mass fow rate,kg/s
T_O,T_i Temperature of outer and inner wall of pipe,^{o}c
T_S Average surface temperature, ^{o}c
∇P pressure drop, Pa
L length of the test tube
Pr prandtl number

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