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# Heat Transfer Enhancement in Pipe Flow using Wire Coil Inserts in Forced Convection

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***Abstract*— Present work is extensively focused on the experimental study on convective forced heat transfer enhancement using wire coil inserts. Passive heat transfer enhancement techniques are utilized in order to improve the heat transfer or thermal performance of forced convention heat exchanger and to improve overall performance of heat exchanger. The thermal parameter which is calculated experimentally has been compared successfully with and without coil insert. 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, heat exchanger, passive enhancement technique.***

## I. INTRODUCTION

For well over a century, efforts have been made to produce more efficient heat exchangers by employing various methods of heat transfer enhancement. The study of enhanced heat transfer has gained serious momentum during recent years, however, due to increased demands by industry for heat exchange equipment that is less expensive to build and operate than standard heat exchange devices. Savings in materials and energy use also provide strong motivation for the development of improved methods of enhancement. When designing cooling systems for automobiles and spacecraft, it is imperative that the heat exchangers are especially compact and light weight. Also enhancement devices are necessary for the high heat duty exchangers found in power plants (i.e. air-cooled condensers, nuclear fuel rods). These applications, as well as numerous others, have led to the development of various enhanced heat transfer surfaces. In general, enhanced heat transfer surfaces can be used for three purposes, to make heat exchangers more compact in order to reduce their overall volume, and possibly their cost, is to reduce the pumping power required for a given heat transfer process and to increase the overall heat transfer coefficient of the heat exchanger.

### *1.1 Different methods of heat transfer enhancement*

The convective heat transfer enhancement techniques represent an important research task in the heat transfer field. They can be classified into two main categories: active and passive 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

Inserts requires additional arrangements to make to fluid flow which enhance the heat transfer. The types of inserts are: twisted tape, wire coils, ribs, baffles, plates, helical screw insert, mesh inserts, convergent – divergent conical rings, conical rings etc.

Coiled wire inserts is one of the passive heat transfer enhancement technique used in various heat transfer application such as air conditioning, cooling device, preheater, refrigeration system heat recovery processes ,good and dairy process etc.

The advantages of wire coil inserts in comparison to other heat exchanger performance enhancement techniques are-

1. Easy installation & removal
2. Simple manufacturing process with lowest cost.
3. Possibility of easy installation in an existing smooth tube heat exchanger.
4. they do not change mechanical strength of original plain tube

## II. LITERATURE REVIEW

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.

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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.

Jung-Yang San et. al. [2015] has performed experiment on heat transfer and fluid friction correlations for circular tubes with coiled-wire inserts. The wire diameter-to-tube inner diameter ratio (e/d) and coil pitch-to-tube inner diameter ratio (p/d) are in the ranges of 0.0725 to 0.134 and 1.304 to 2.319respectively. It is found that the Nusselt number (Nu) increases with the e/d value, where as it increases with a decrease of the p/d value.

Alberto Garci et.al., [2005] Performed an experiment on heat transfer enhancement with wire coil inserts in laminar-transition –turbulent regimes at different prandtl numbers in which researchers used helical wire coils fitted inside round tubes. Researchers studied their thermo hydraulic behavior in laminar, transition and turbulent flow. Researchers used Reynolds numbers from 80,000 to 90,000 and prandtl number from 2.8 to 150, in which six wire coils were tested within a geometrical range of helical pitch $1.17<p/d<2.68$ and wire diameter$0.07<e/d<0.10$.Researchers concluded that in turbulent flow wire coil increased pressure drop up to nine times and heat transfer up to four times compared to empty smooth tube.

## III. EXPERIMENTAL APPARATUS AND METHOD

The schematic experimental apparatus that will be used to enhance heat transfer is as shown in Fig 1a. Which consist of voltmeter, ammeter, pressure gauge orifice, blower switch, main power switch, data acquisition system (DAS) with computer, thermocouples, data logger, heater input etc. fig1b shows an cross sectional view of helical wire fitted inside smooth tube, where p stands for helical pitch, e for wire diameter and d for inner diameter of tube. The main function of different apparatus is as follows:-

1. Heat exchanger is made up of metal pipe which is thermally insulated outside to prevent heat transfer losses to atmosphere.
2. Heat regulator is used to supply regulated power input to heater.
3. Data logger is used to measure the temperature, voltmeter, current and air flow rate.
4. 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.

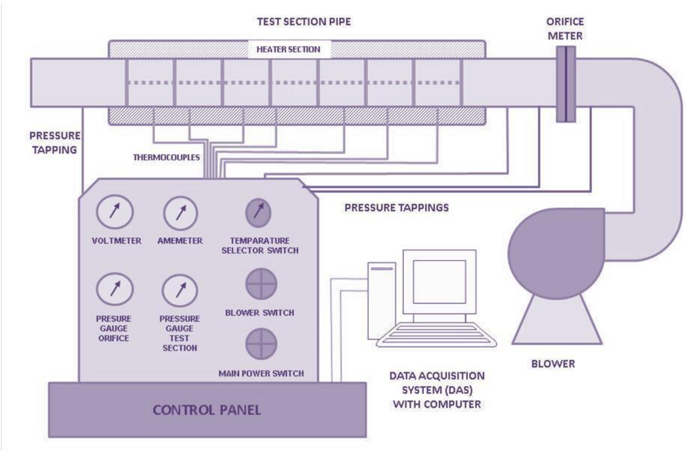


Fig1a: A Schematic of Proposed experimental set up

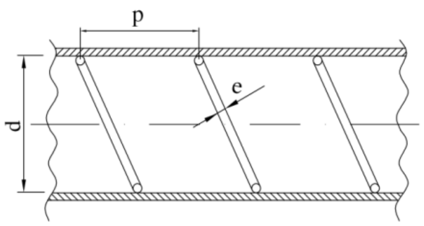


Fig1b: Sketch of helical wire coil fitted inside a smooth tube

### *3.1 Thermal performance analysis*

Thermal performance 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:

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

In which

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

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

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

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

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Ts = average surface temperature

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

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

Nu are estimated as follows,

$$Nu = hD/k \quad (5)$$

The Reynolds number is given by,

$$Re = \rho UD/\mu \quad (6)$$

Friction factor f can be written as,

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

In which V mean air velocity in the duct.

## IV. RESULT AND DISCUSSION

*4.1 Effect of coil wire insert on heat transfer enhancement: -* Fig.2 shows variation of Nusselt number with Reynolds number for tube without and with coil wire inserts i.e. Aluminum and Copper material. From fig.2 it seen that Nusselt number for tube fitted with coil wire insert is higher than that of plain tube for given Reynolds number. 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.

From fig 2. 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 given Reynolds number is higher for Copper coil wire insert than Aluminum coil wire insert. Copper coil wire insert causes an higher heat transfer enhancement about 1.43 times as compared with plain tube and Al coil wire insert gives high heat transfer enhancement about 1.37 times of plain tube respectively.

*4.2 Effect of coil wire insert on Heat transfer coefficient (h):-* Fig.3 shows a variation of heat transfer coefficient with Reynolds number. From fig3 it can be seen that heat transfer increases with increasing Reynolds number. Heat transfer coefficient is higher for copper coil wire insert than that of Aluminum and plain tube. i.e. Cu insert has higher heat transfer enhancement of 1.43 times as compared to plane tube. On other hand Aluminum insert has heat transfer enhancement of 1.34 as compared to plain tube respectively.

*4.3 Effect of coil wire insert on Friction factor: -* In general the friction factor decreases with increase in Reynolds number for different pitch. From fig.4 it seen that friction factor for coil wire inserts are significantly higher than plain tube for given Reynolds number. Indicates that friction factor for a given Reynolds number increases with decrease of a pitch due to swirl flow generated by coil wire insert. From fig.4 it seen that lesser friction factor for higher pitch this is due to lesser contact with an surface and maximum area is available for fluid to flow in the test section. Thus friction factor for coil wire insert of 10mm pitch is 1.13 times that of plain tube.

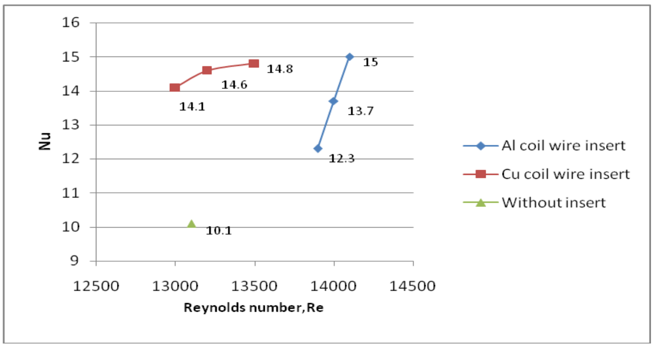


Fig.2.Comparision of Nusselt number with Reynolds number with various coil wire insert.

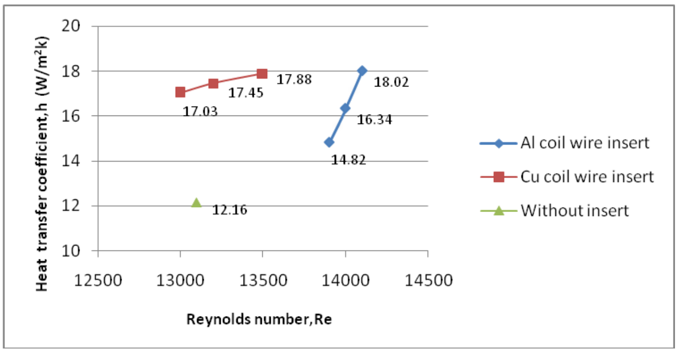


Fig.3.Comparision of Heat transfer coefficient with Reynolds number with various coil wire insert.

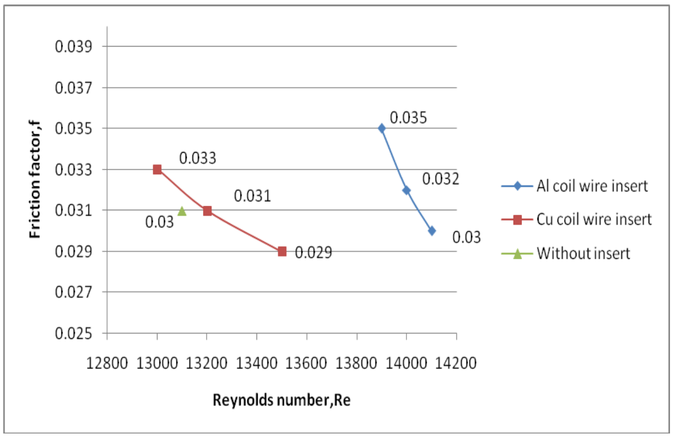


Fig.4.Comparision of friction factor with Reynolds number with various coil wire insert.

## V. CONCLUSION

Experimental investigation of the heat transfer and friction factor characteristics of an 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 – 14000 and conclusion are as follows.

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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 1.43 & 1.37 respectively as compared to plain tube.
2) Friction factor found to be increasing with decreasing pitch of coil wire insert. Thus friction factor for coil wire insert of 10mm pitch is 1.13 times that of plain tube.
3) From above experimental investigation it concludes that copper can be used as coil wire insert material for higher heat transfer enhancement than Aluminum.

## 6. 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 |
| $\rho$ | 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,°c |
| $T_S$ | Average surface temperature, °c |

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