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Intensification in Convective Heat Transfer by using Wire Coil Insert

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Abstract*: This project explores enhancing convective heat transfer through the implementation of wire coil inserts. Investigating how these inserts intensify heat transfer could lead to improved efficiency in various applications. In the current study, a numerical method is used to investigate the thermal energy transfer and pressure drop augmentation in helically coiled tube heat exchanger with a coiled wire insert made from mild steel. The impact of geometrical parameters of the inserts like diameter and cross sectional form on the intensification of the Nusselt and the friction factor number is studied. The Transition SST model is used to simulate the impact of turbulence. The model validation is performed by comparing the results with the empirical equations of prior experimental works. Furthermore, using inserts with concentric circular cross section with diameter of 0.008 m and two rectangular cross sections are recommended for the intensification of heat transfer at the inlet mass flow rate 0.05 kg/s while, all inserts are suggested at the inlet mass flow rate of 0.075 kg/s. As a part of the study, a correlation is proposed for estimating the Nusselt number of these heat exchanger.*

Keywords: Reynolds Number, wire coiled insert, passive technique

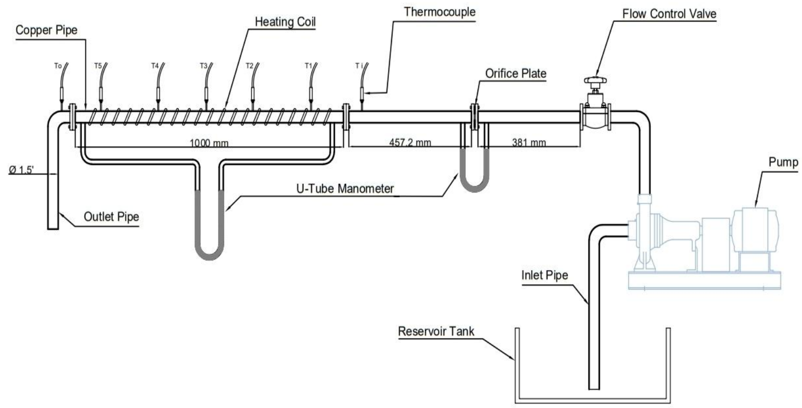
I. INTRODUCTION

Intensification in convective heat transfer through the application of wire coil inserts represents a compelling advancement in thermal management technology. This innovative approach enhances heat transfer efficiency by strategically manipulating fluid flow patterns within a system, thereby maximizing the exchange of thermal energy. Through the introduction of wire coils into the fluid flow path, turbulence is induced, promoting better mixing and disrupting the boundary layer, leading to increased heat transfer rates.Intensification in convective heat transfer using wire coil inserts is a sophisticated engineering technique aimed at improving the efficiency of heat exchange in a wide range of industrial applications. By strategically inserting wire coils into fluid flow systems, this approach enhances heat transfer rates, leading to increased energy efficiency, better temperature control, and cost savings. In this introduction, we will explore the fundamental principles and applications of this method, shedding light on how wire coil inserts are transforming heat transfer processes in various industry.

II. PROBLEM DEFINATION

The problem statement for a research project on a Study of Investigate the enhancement of convective heat transfer in a circular tube by inserting This problem definition sets the stage for a detailed experimental investigation aimed at understanding and quantifying the intensification of convective heat transfer through the use of a wire coil insert in a circular tube.

III. STRUCTURE



Working Of Intensification in Convective Heat Transfer :

Enhanced Turbulence and Mixing:

- The wire coil insert disrupts the laminar flow inside the tube, promoting turbulence.
- Turbulent flow enhances mixing of the fluid, which in turn improves heat transfer efficiency by increasing the contact area between the fluid and the tube wall.

Increased Surface Area:

- The presence of the wire coil increases the effective heat transfer surface area within the tube.
- This additional surface area allows for more heat exchange between the fluid and the tube wall, thereby increasing the convective heat transfer coefficient.

Induced Swirl and Vortex Formation:

- The geometry of the wire coil insert induces swirl and vortex formation in the fluid flow.
- These swirling motions help in breaking boundary layers and enhancing heat transfer by bringing fresh fluid into contact with the heated surface more effectively.

Promotion of Secondary Flows:

- The coil insert creates secondary flows such as Dean vortices, which further mix the fluid across the tube cross-section.
- These secondary flows contribute to improved convective heat transfer by distributing heat more evenly and reducing thermal boundary layers.

Thermal Performance Enhancement:

- Overall, the combination of increased turbulence, enhanced mixing, additional surface area, and induced secondary flows results in a higher convective heat transfer coefficient.
- This enhancement leads to improved thermal performance of the heat exchanger or the tube system where the coil insert is employed.

Experimental Approach:

- **Setup and Measurement:** Use experimental setups to measure temperature profiles along the tube with and without the coil insert.
- **Data Acquisition:** Utilize sensors to capture data on flow rates, pressure drops, and temperature differentials.
- **Analysis:** Analyze the acquired data to calculate Nusselt numbers and convective heat transfer coefficients for both cases.
- **Comparison:** Compare results to determine the effectiveness of the coil insert in enhancing convective heat transfer.

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IV. RESULT AND DISCUSSION

4.1 Introduction

Convective heat transfer is crucial in various engineering applications, and enhancing its efficiency is vital for improved system performance. Wire coil inserts offer a promising method to intensify convective heat transfer by disrupting flow patterns. In this study, we experimentally investigate the effectiveness of wire coil inserts in a copper pipe. By varying insert configurations,we aim to identify optimal setups for maximizing heat transfer enhancement. Our results provide valuable insights into the efficacy of wire coil inserts and their practical implications for engineering design.

4.2. Sample Calculations:

To find Nu for Re=4000,

To find velocity (v) -

We have-

Diameter of Copper pipe, D = 0.025 m,

Density, ρ = 12.6 kg/m3

Dynamic viscosity of water, μ = 0.001002 kg/m-s

$$Re=\rho vD/\mu$$

$4000=(1000\times v\times 0.025)/0.001002$

$v=0.157795276$ m/s

To find Heat Transfer (q) -

Area of copper pipe -

$A=〖\pi/4\ D〗^2$

$A=〖\pi/4(0.025)〗^2$

$A= 0.000506451\ m^2$

Heat Transfer -

$q=A\times v$

$q=0.000506451\times 0.157795276$

$q=7.99155E-05$

To find (x) –

Area of GI pipe -

We have-

Diameter of Copper pipe, d1 = 0.015 m

$A1=〖\pi/4(d1)〗^2$

$A1=〖\pi/4(0.015)〗^2$

$A1=0.000176625\ m^2$

Area of Orifice plate -

We have-

Diameter of Copper pipe, d2 = 0.008 m

$A2=〖\pi/4(d2)〗^2$

$A2=〖\pi/4(0.008)〗^2$

$A2= 0.00005024\ m^2$

For Manometric deviation (x) -

$q=Cd\times((A1\times A2))/\sqrt{(A1^2-A2^2)}\times\sqrt{(2g\times x)}$

$x=q^2/(2g\times Cd^2\times((A1^2\times A2^2)/(A1^2-A2^2)))$

$x=((7.99155E\text{-}05)^2)/((2\times9.81)\times(0.6)^2\times((0.000176625^2\times0.00005024^2)/(0.000176625^2-0.00005024^2)))$

x=0.329245683 m of H_2O

To find Heat Transfer Coefficient (h) –

We have-

Heater Voltage, V = 150v

Current, I = 1.2 amp

Volume flow rate (Q) –

Q=V×I

Q=150×1.2

Q=180 m3/s

Average Temperature at Surface of Pipe (Tavg) –

Tavg=((T1+T2+T3+T4+T5)/5)

Tavg=((40+43+39+40+42)/5)

Tavg=40.8 ℃

Average Temperature at Inlet and Outlet of pipe (Tavg1) –

Tavg1=(Tin+Tout)/2

Tavg1=(37+39)/2

Tavg1=38 ℃

Heat Transfer Coefficient (h) –

Q=h×π×0.0254×(Tavg-Tavg1)

180=h×π×0.0254×(40.8-38)

h=806.0298195 W/m2-K

Nusselt Number (Nu) –

We know that,

Thermal Conductivity of Water, k = 0.555 W/m-K

Nu=(h×D)/k

Nu=(806.0298195×0.0125)/(0.555)

Nu=36.88857192

Nu by using Corelation -

We know that,

Prandtl Number, Pr = 6.9

Nu=0.023×(Re)^0.8×(Pr)^0.4

Nu=0.023×(4000)^0.8×(6.9)^0.4

Nu=37.92411592

Thus, in a similar way calculations were carried out for each and every experimental run and then further represented on the graphs for the further discussions and chalking down of conclusions.

V. RESULTS

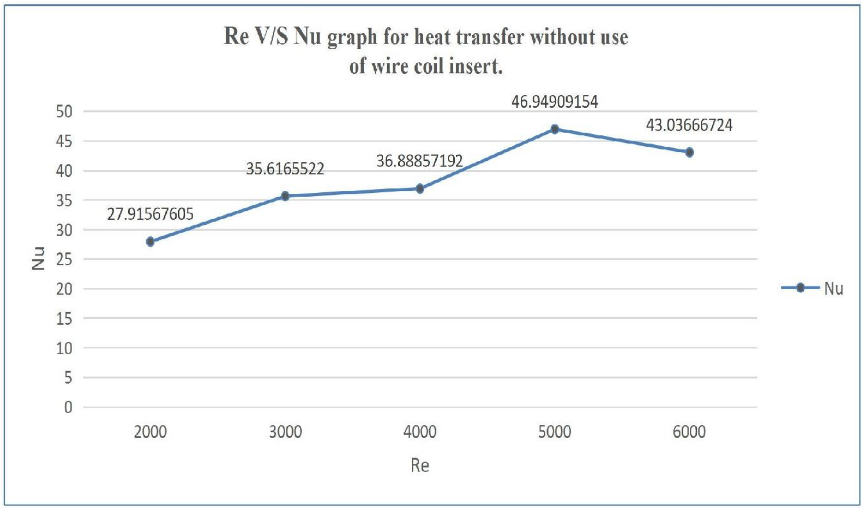

Fig . Variation in Reynolds Number (Re) for pure water.

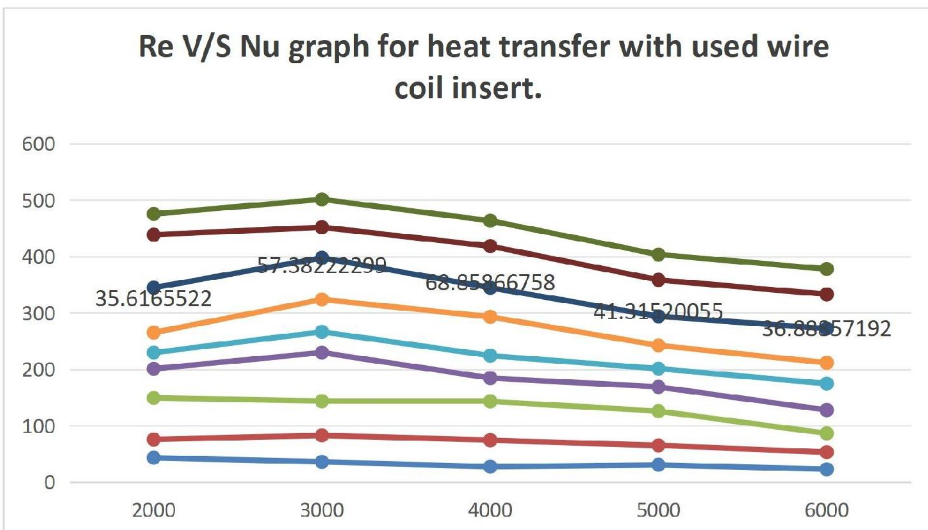

Fig . Variation in Reynolds Number (Re) for wire coil insert

VI. CONCLUSION AND FUTURE SCOPE

CONCLUSION

Introducing wire coil inserts to enhance convective heat transfer has proven to be a promising approach in various engineering applications. Through this study, it is evident that wire coils effectively intensify heat transfer by promoting turbulence and disrupting boundary layers withinthe fluid flow. As a result, the convective heat transfer coefficient is significantly increased, leading to improved thermal performance.

In conclusion, the utilization of wire coil inserts offers an efficient and cost-effective method for enhancing convective heat transfer in various systems, including heat exchangers, boilers, and refrigeration units. Further research and experimentation are recommended to optimize the designparameters and understand the underlying mechanisms better. With continued exploration and innovation, wire coil inserts hold great potential for addressing heat transfer challenges in diverseindustrial and environmental settings, ultimately contributing to energy efficiency and sustainability.

FUTURE SCOPE

The density of hot water is less than that of cold water. By using this principle we can optimize the current working system by arranging the system in a vertical manner. When the system will start working then due to lower density, hot water will move upwards and will directly pass through the outlet. Use of external power such as pump will make the process more optimum. and maximum efficient output can be generated.

If the inlet of hot water is placed at the bottom of the horizontal set-up and hot water outlet to the other end but at its top side; this sort of set-up creates uniform flow of coldand hot water throughout the set-up.

In the process of optimizing the system the next step will be to optimize the magnetic field. An oscillator circuit can be introduced in series with the electro-magnet in order to vary the frequency of AC current. Through trial and error method an apt frequency could be found out and set for which the nanofluid shows highest results. This becomes possible because the nano-particle oscillate for a longer duration inside the copper tubefor a particular frequency so as to increase the turbulence in the hot fluid and in the endincrease the heat transfer.

VII. ACKNOWLEDGMENT

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