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Enhancement Of Heat Transfer Rate In Copper Coiled Tube Heat Exchanger With Nano Fluids

P.Pradeep, S.Gopinath, S.Kabil, T.Neelamegam

Abstract— **Heat transfer is the predominant phenomenon in the engineering fields. It has created the huge challenge for dissipating the heat from one substance to another. Many researchers have found the different methodologies for increasing the heat transfer rate with the application of various research. In this paper we have proposed a new methodology for the heat exchanger in various aspects. We considered the two main aspects on the basis of design of the fluid flow and enhancement of thermal conductivity of coolant fluid by changing the chemical properties of the fluid. The properties are changed by the application of nano particles addition in the fluid. We have proposed the changes in the base fluids of nano fluids as the base fluids play an important role in the characteristics of nano fluid. The proposed design is that the tube inside the exchanger is helical coiled tube to increase the area which ensures the high compactness and mobility. The proposed design in our project leads to easier manufacturing of the parts thus making it cost effective. The preparation of the nano fluids is really a challenging one, as that purely based on the concentrations and mixing ratio of the nano powder with its base fluids. In our papper we have clearly explained about the mixing conditions of the nano particle. Our article compare the result of the overall heat transfer co-efficient between water and nano fluids.**

Index Terms— **Heat transfer, helical coiled tube, nano fluids, overall heat transfer co-efficient**

I. INTRODUCTION

In a heat exchanger, heat energy is transferred from one body or fluid stream to another. In the design of heat exchange equipment, heat transfer equations are applied to calculate this transfer of energy so as to carry it out efficiently and under controlled conditions. The equipment goes under many names, such as boilers, pasteurizers, jacketed pans, freezers, air heaters, cookers, ovens and so on. The range is too great to list completely. Heat exchangers are found widely scattered throughout the food process industry.

A spiral heat exchanger is more compact than many other types of heat exchangers. It has two concentric spiral channels, one for the hot fluid and the other for the cold fluid. The main advantages of a spiral heat exchanger are its high overall heat transfer coefficient, compact size for a given heat exchange area, relatively low pressure drop, and ease of cleaning. Spiral heat exchanger flow may be countercurrent flow, co-current flow, or cross flow.

This helical coiled tube is made of the copper and rolled in an open die to form spiral tube and it is enclosed in a closed spherical chamber. This chamber can be made of mild steel and insulated outside to reduce the heat transfer to the surroundings. The design is made in order to allow the flow of the hot fluid in the spiral tube the coolant is allowed to flow over the spiral tube as there is no another tube which is built concentrically over the tube.

P.Pradeep, S.Gopinath, S.Kabil, T.Neelamegam, Mechanical Engineering, MRKIT, Cuddalore

S.No	Physical properties	Water
1	ρ (kg/m^3)	990
2	μ (kg/ms)	0.0005494
3	K (w/mk)	0.633
4	C_p (j/kg)	4182

Table1. Properties of water

II. LITERATURE REVIEW

K.ABDUL HAMID & G.NAJAFI [1] in their article they have proposed about the increment of thermal conductivity of the coolant fluid by the addition of nano particles in the base fluids. And also provided mixing ratio of nano particles and base fluids.

SAURABH KUMAR & NEHA MAHESHWARI [2] these authors have studied the heat exchanging properties of double tube helical coil heat exchanger and provided the solution mixing fluctuations in nanofluids.

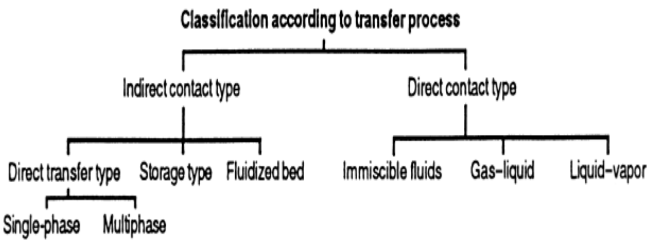
P.PRABHU & S.PUNGAIYA [3] they studied the characteristics of Tio2 with sesame oil nano fluid in turbulent flow through the spiral tube heat exchanger and detected heat transfer coefficient due to present of nano particles is much higher than the base fluid properties.

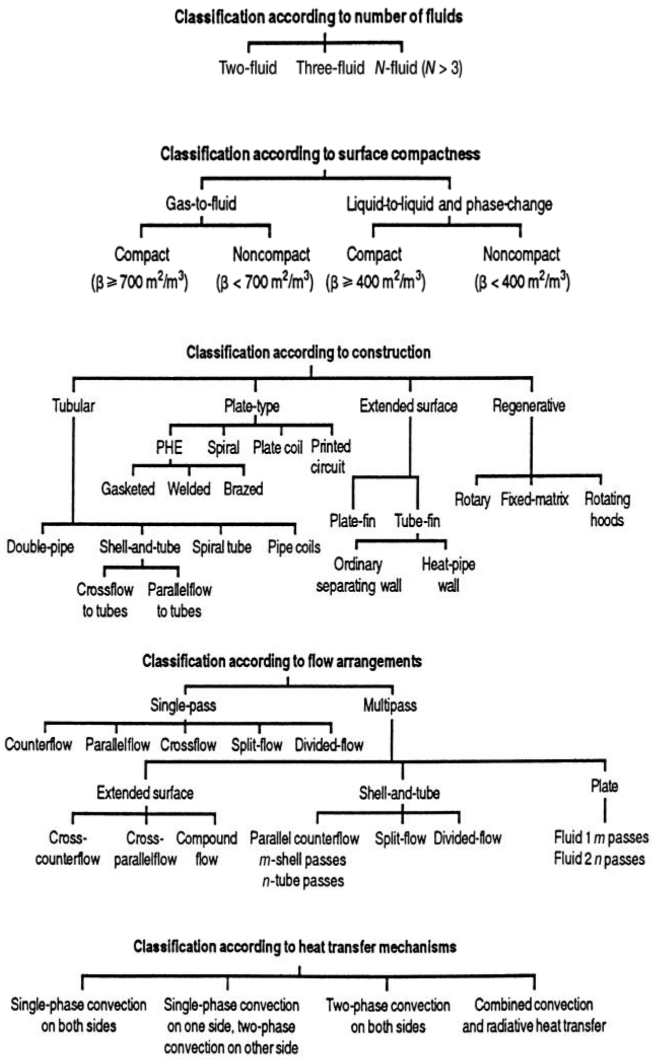
T.SRINIVAS & A.VINOTH [4] they studied thermal performance of shell and helical coiled heat exchanger using CuO nano fluid with variety of oils.

V.MANOJ & P.GOPAL [5] in their article they proposed heat transfer enhancement in spiral plate heat exchanger and compared heat transfer coefficient of conventional fluid and nano fluid.

S.MANIKANDAN & B.GOVINDARAJAN [6] investigated the effect of nano particle volume fraction of TiO_2 – water nano fluid and observed that by increasing the volume fraction of nano particle increases nusselt number thereby increasing the haet transfer rate.

III. CLASSIFICATION OF HEAT EXCHANGER





IV. Existing and Proposed System

Existing system:
In the existing system the manufacturing of the spiral plate concentrically or rounding the plate is very difficult as shown in figure.

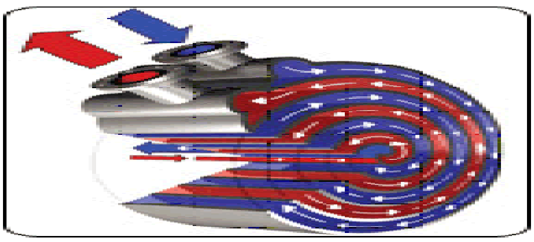


Fig 1. Spiral plate heat exchanger

Fig 2. Cross sectional view of spiral plate.

An another method of design is also very difficult and tedious one to manufacture such as the double tube helical coil in which a coil is placed concentrically on one above the other as shown in figure. Here one fluids flow through the inner tube and other fluid flows through an another tube.

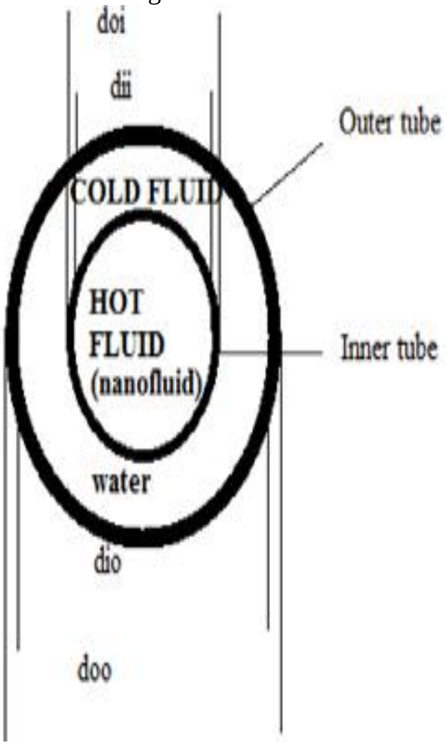


Fig 3. Double tube helical coiled tube

Proposed system:
In order to overcome the difficulties in the existing system in terms of production and cost we have made design which reduced the manufacturing difficulties. We have designed the single tube helically which replaces the concentric tube. In this single helical coiled tube the hot fluid is allowed to flow. The coolant is circulated over the surrounding of the spiral tube which covered by outer cover made up of mild steel`
Next thing proposed is the preparation of nano fluid with different base fluids by mixing water with the ethylene glycol with mixing volume percentage. The ethylene glycol is used as a industrial coolant as it is having good thermal conductivity under the correct mixing ratio with the water.

V. Nano Fluid Preparation

Researchers have also tried to increase the thermal conductivities of base fluid by suspending micro or nano-size solid particles in fluids since the thermal conductivity of solid is typically higher than that of liquids.

I. Water
II. Mineral oil
III. Vegetable Oil (natural oil)
IV. Synthetic oils
V. Ethylene glycol

The aluminium oxide (Al_2O_3) or Alumina nano powder is used in this paper which is prepared by dispersing the nano powder in the base fluid. The size of the nano particle we used is 30nm with 99.8% purity. The density value of aluminium oxide nano powder is 4000 kg/m^3.
The base fluids are prepared by mixing the water with the Ethylene glycol by anyone of the ratio (60:40, 50:50, 40:60).

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But we have taken the ratio of 60:40 combination because the thermal conductivity increases with decreased concentration of ethylene glycol in the base fluid.

The volume concentrations required for mixing the nano powder is based on various percentages like 0.5%, 1%, 1.5%, 2%. We have taken 1% of nano powder which is mixed with the 100 ml base fluids and continuously stirred for 1 to 2 hours to get the homogeneous solution to prolong the stability of the solution.

VI. ALUMINA PROPERTIES

Density	2.70 g/cm^3	0.0975 lb/in^3
Molar mass	26.98 g/mol	_

Table 2.Alumina properties

Items	APS	Purity	Crystal Form	Morphology	Color
EPRUI-L30	30-60nm	99.99%	Alpha	Amorphous	white
EPRUI-L100	100-150nm	99.99%	Alpha	Amorphous	white
EPRUI-L150	150-200nm	99.99%	Alpha	Amorphous	white
EPRUI-L500	500nm	99.99%	Alpha	Amorphous	white

Table 3.Alumina structure and sizes

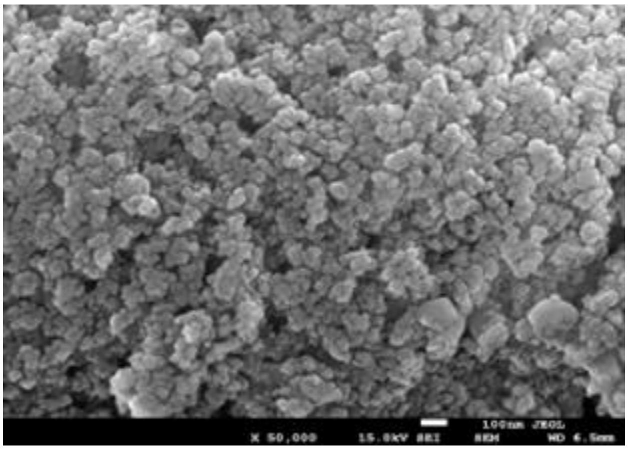

Fig 4. Microstructure of alumina

Thermal Properties

The thermal properties of aluminium/aluminum nanoparticles are provided in the table below.

Properties	Metric	Imperial
Melting point	660.32 °C	1220.58 °F
Boiling point	2519 °C	4566.2 °F

Table 4.Alumina thermal properties

VII. METHODOLOGY

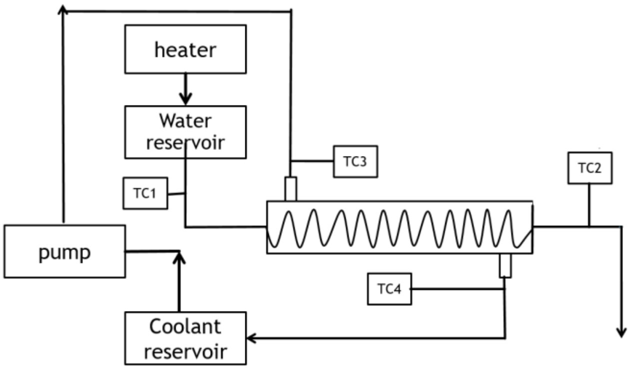

Fig 5. Block diagram of heat exchanger

The first thing in the methodology is the allowance of the fluids inside the tube. The unit contains heating unit connected to the water reservoir. TC denotes the thermocouple arrangements for measuring the temperatures at four places which are inlet and outlet of the hot fluid and other two are inlet and outlet of cold fluid. The fluid is heated for the constant temperature and the valve is opened and allowed to flow inside the tube. Simultaneously the cold fluid is pumped through the system. The coolant passes over the helical tube thereby absorbing the heat from the hot fluid and leaves through the other opening and it is recirculated to coolant reservoir.

Nomenclature

A   Heat transfer area (m^2)
T_1 inlet temperature of hot fluid (°C)
T_2 outlet temperature of hot fluid (°C)
U   overall heat transfer coeffiecient (w/m^{2o}C)
C_p specific heat capacity (kj/kgk)
D   mean diameter of the tube (mm)
Di   inner diameter of the tube (mm)
Do   outer diameter of the tube (mm)
ΔT_m logarithmic mean temperature difference (°C)
Q   heat transfer rate (w)
M   mass flow rate (kg/s)

The following data are adopted for the design of spiral tube heat exchanger is given below.

Length of the heat exchanger (l) = 600mm
Outer diameter of copper tube (Do) = 50mm
Tube diameter of copper (d) = 12mm
No of coils in copper coiled tube (n) = 10
Pitch of the coil (p) = 24mm

The amount of heat transfer rate is calculated by the energy balance equation,

$$Q = m \times c_p \times (T_1 - T_2) \quad [1]$$

Areaof heat transfer can be given as,

$$A = \pi \times D \times l \quad [2]$$

$$D = (Do + Di)/2 \quad [3]$$

Here the flow arrangement selected is parallel flow accordingly the LMTD for this stage is calculated as,

$$\Delta T_m = \{[(T1-T3)-(T2-T4)]/\ln[(T1-T3)-(T2-T4)]\} \quad [4]$$

Overall heat transfer coefficient,

$$U = Q/ (A \times \Delta T_m) \quad [5]$$

VIII. MEASURED READINGS

Here are the readings taken for the same temperature so as to easily compare the result of the three various cold fluids. The various fluids are normal water, water with aluminum oxide nano powder, water and ethylene glycol mixed with the alumina nano powder and are listed in the table

S. no	Time taken for hot fluid flow	Time taken for cold water flow	Hot water inlet temp	Hot water outlet temp T2	Cold water inlet temp (T3)	Cold water temp outlet (T4) deg
	1kg (sec)	I (lt) (sec)	T1 deg	deg	deg	
WATER						
1	29	23	43	42	33	35
WATER AND ALUMINA						
2	19	23	43	41	33	36
WATER & ETHYLENE GLYCOL AND ALUMINA						
3	23	25	43	37	32	37

Table 5.Experimental readings

IX. CALCULATION

For water,

Mean diameter of the tube,

D = (50+48)/2

= 49mm. [6]

Heat transfer area,

A = Лx(49)x600

= 92362 mm^2. [7]

Heat transfer rate,

Mass flow rate, m = (1/ time taken for 1 kg) = (1/29)

= 0.0345 kg / s [8]

Q = 0.0345 x 4.178 x (43-42)

= 0.144 w. [9]

Logarithmic mean temperature difference (LMTD)

ΔT_m = [(43-33)-(42-35)]/ ln [(43-33)-(42-35)]

=2.73 ^{o}C. [10]

Overall heat transfer coefficient,

U_w = 0.144 / (0.092362 x 2.73)

= 0.571 $w/m^2 \, ^oC$. [11]

For water and alumina,

Mass flow rate, m = (1/ time taken for 1 kg) = (1/19)

= 0.0526 kg / s [12]

Heat transfer rate,

Q = 0.0526 x 4.178 x (43-41)

= 0.439 w. [13]

ΔT_m = [(43-33)-(41-36)]/ ln [(43-33)-(41-36)]

=3.106 ^{o}C. [14]

U_{wa} = 0.439/ (0.092362 x 3.106)

= 1.5302 $w/m^2 \, ^oC$. [15]

For water & ethylene glycol and alumina,

Mass flow rate, m = (1/ time taken for 1 kg) = (1/23)

= 0.0434 kg / s [16]

Heat transfer rate,

Q = 0.0434 x 4.178 x (43-37)

= 1.08 w. [17]

ΔT_m = [(43-32)-(37-37)]/ ln [(43-32)-(37-37)]

= 4.587 ^{o}C. [18]

U_{eg} = 1.08/ (0.092362 x 4.587)

= 2.55 $w/m^2 \, ^oC$. [19]

X. RESULTS AND DISCUSSION

For water,

From [11]

U_w = 0.571 $w/m^2 \, ^oC$.

For water and alumina,

From [15]

U_{wa} = 1.5302 $w/m^2 \, ^oC$.

For water & ethylene glycol and alumina,

From [19]

U_{eg} = 2.55 $w/m^2 \, ^oC$.

The above result shows the differences in the overall heat transfer coefficient of the various mixtures of the cold fluid. These differences are made based on the chemical properties alteration in the fluids. However mixing of ethylene glycol proved to be greater effect on heat transfer rate due to its extraordinary thermal properties when combined with the aluminum oxide.

XI. CONCLUSION

It is concluded that the thermal properties are changed by the application of ethylene glycol as a base fluid with alumina nano particle provides the good effectiveness for the heat exchanger. The idea of the proposed design is very compact and proved to be better design as there is no disturbance in the heat transfer phenomenon. The proper mixing ratio of the nano fluid dispersions are concluded.

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