Heat transfer enhancement in Concentric Tube Heat Exchanger by using Twisted Tape Inserts and Nanofluids - A Review

Senthil Kumar.B[1], Nithin Kanna.C.R.K[2], Magesh.K[3], Ramanarayanan.V[4]

[1,2,3,4] *Department of Mechanical Engineering*
Sri Ramakrishna Engineering College, Coimbatore-22.

Abstract - *Concentric Heat exchanger is a device which enables the transfer of heat energy between two different liquids at various temperature. The main requirement in manufacturing and production field is to enhance the heat transfer rate. Heat exchangers play a important role in Air conditioning system and Refrigeration system. The working fluid plays an important role in enhancement of heat transfer between liquids. The thermophysical properties of liquid is low when compared with the solids, so nanofluids are introduced as working fluid. As the setup is of small scale contact time has to be increased between the fluids. Turbulent flow can be created by introducing twisted tape inserts inside the inner cylinder of heat exchanger. Overall an attempt is made to study the increase in efficiency of heat exchanger with help of nano fluids and twisted tape inserts.*

Key Words: **Heat exchanger, Twisted tape inserts, Nanofluids, Concentric tube, Heat transfer, Proliferation, Enhancement.**

1.INTRODUCTION

Heat exchanger equipment involves the principle of transfers of heat energy between fluids at different temperatures. The main criteria that has to be selected in a heat exchanger is working fluid. The heat exchanger's performance and heat transfer enhancement can be improved drastically by choosing appropriate working fluid.

ROHIT.S.KHEDKAR et.al discussed about the increase in reliability by restricting mixing of fluids exchanging heat [1]. Due to low thermo physical properties, heat transfer efficiency of liquids is limited when compared to solids. This is why nanoparticles are used. A solid metallic or non metallic nanoparticles are dispersed in base fluids such as water, glycerol and ethylene glycol. Due to usage of nanoparticles, the cost involved is comparatively higher but it compensates with the increase of efficiency of heat exchanger.

In our research literature survey, there are three sections. First section is introduction which explains the basic concepts of heat exchanger and nano fluids usage. Second section is literature review which explains about the experimental setup of the heat exchanger, dimension, working fluid, selection of nanofluids, selection of twisted tape inserts and the reason to use nano fluids in heat exchangers. Third section is conclusion where the idea to use nano fluids in heat exchangers and increase of heat transfer enhancement is justified.

2. LITERATURE REVIEW

2.1 HEAT EXCHANGERS

Heat exchangers are widely used in industries for the application of heating and also for cooling liquids. The thermal energy is exchanged between physical systems in heat exchangers.The direction of heat transfer in heat exchanger is from a region of high temperature to the region of low temperature. Second law of thermodynamics is the governing law involved in heat exchanger. When the entropy of collection of the system increases, the heat transfer will occur in that particular direction. When the thermal equilibrium is reached the heat transfer ceases.

2.2 CONCENTRIC TUBE HEAT EXCHANGER

It consists of cylinder inside which there are two concentric tubes. The cold fluid flows through the outer most tube and the hot fluid flows through the inner tube. The collecting tanks are present separately for the supply and collection of both the cold and hot fluids. Temperature at various sections in concentric tube heat exchanger is measured using thermocouples located at inlet, outlet of the cold and hot tubes and as well as in the middle of the cylinder in order to measure the atmospheric temperature.

YIMIN XUAN et.al investigated on convective heat transfer and flow features of nanofluids, the experiment was conducted on a convective heat exchanger as shown in figure 2.1 [2].

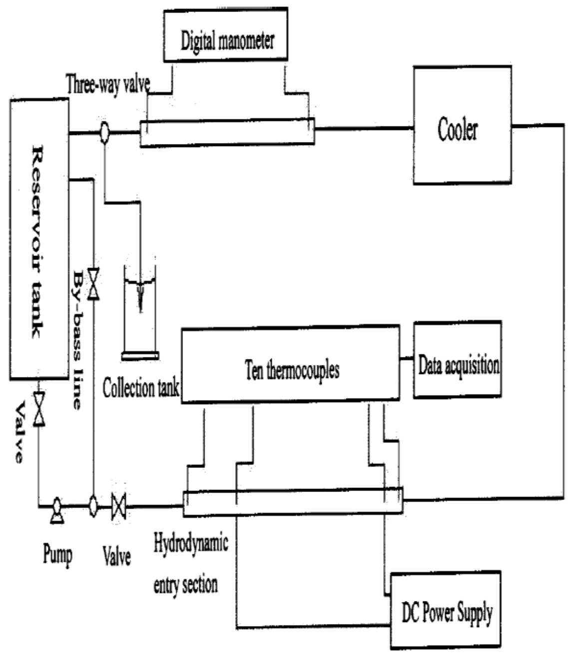

Fig 1. Block diagram of Convective heat exchanger

2.3 HEAT TRANSFER PROLIFERATION TECHNIQUES

C.NITHIYESH KUMAR et.al discussed about the implementation of passive methods. Twisted tapes are being used in passive method in order to augment the heat transfer [3].

There are three techniques that are involved in heat transfer proliferation. They are

- Active techniques
- Passive techniques
- Compound techniques

ACTIVE TECHNIQUES -

This techniques mainly rely on design point of view where any external power input modifications is made to improve the heat transfer rate. Some of the active techniques are mechanical aids, surface vibration, fluid vibration, electrostatic fields, injection and suction. This technique is more complex to design, so it is not used when compared to passive techniques since it is difficult to provide external power in any cases.

COMPOUND TECHNIQUES -

This is the combination of two or more techniques that are involved simultaneously to enhance the heat transfer rate. This includes method of treating of extended surfaces or using rough surfaces with additives.

PASSIVE TECHNIQUES -

This techniques mainly rely on geometrical or surface modifications that are done to the flowing channel by introducing inserts or other additional external devices. The disturbance or alternations caused in the flow behaviour are the main reason for higher heat transfer. They cause the delay in the flow time and also the behaviour of fluid flow is changed to laminar or turbulent flow. Inserts shape can be modified according to the need. More turbulence is created to the flow by more complex modifications like twisting of inserts.

MUKESH.P.MANGTANI discussed about the twist angle, twist ratio, various geometry of of the twisted tapes used and also the variation of nusselt number with reynolds number [4]. Due to the advantage of property of turbulence, twisted tapes are preferred at the most. These tapes are twisted in such a way that higher transfer rate are produced due to the turbulence caused by the swirl of flowing fluid inside it.The mostly used twist angle is 15°3’, 24°4’, 34°3’.

The ratio of pitch length onside diameter of the tube is twist ratio. The twist ratio values can vary from 3.5 to 7. The twist ratio value 3.5 gives highest heat transfer coefficient i.e 1.39 times higher than the heat transfer coefficient produced by twist ratio value 7. So the lower the twist ratio value, higher the heat transfer coefficient.

2.4 WORKING FLUID

The fluids flowing through the heat exchanger tubes are the working fluids. The fluid from which heat is to be removed is considered as the hot fluid and it is mostly made to flow through the inner tubes. The fluid to which the heat is to be transferred is considered as cold fluid. The properties of working fluid are important in case of heat transfer enhancement process. The working fluid are selected by considering chemical stability, freezing point, boiling point, latent heat of vapourisation, surface tension, viscosity, thermal conductivity, wetting characteristics, corrosion resistance, environmental acceptability, cost, toxicity and availability.

2.5 NANOFLUIDS

ROHIT.S.KHEDKAR et.al made an observation that 3% nano fluids has shown optimum performance with overall transfer coefficient 16% higher than water [1]. Thermo physical properties of liquids are limited when compared to solids. So this is the main reason why the solids are dispersed into the liquid. These solids are nothing but the nanoparticles. They have sizes from 1 to 100 nanometers.

The nanoparticles infused fluids are known as nanofluids. Nanofluids consists of a base fluid and nano sized particles. The most commonly used base fluids are water, ethylene glycol and oil. The most commonly used nano fluids are TiO2 in water, CuO in water, ZnO in ethylene glycol, Al2O3 in water.

S. EIAMSA-ARD et.al designed a heat exchanger tube equipped with overlapped dual twisted tapes to enhance the heat transfer using TiO2-water nanofluid[5].

- Density of nanofluid (kg/m3) is found using

$$\rho_{nf} = (1-\phi)\rho_{water} + \phi\rho_{np}$$

- Specific heat of nanofluid (J/kgK) is found using
- Thermal comductivity coefficient of nanofluid (W/mK) is found using
- Viscosity of nano fluid (Pa s)is found using

2.6 SELECTION OF NANOFLUIDS

R.Dharmalingam et.al tabulated the values of thermal conductivity for most commonly used nanomaterials.[6]

S.No	Nano materials	K (w/mk)	Temperature(^{0}C)
1.	Water	0.61	25^0C
2.	Ethylene glycol(EG)	0.26	25^0C
3.	Al_2O_3	35	25^0C
4.	CuO	20	25^0C
5.	ZrO_2	2	25^0C
6.	SiO_2	1.4	25^0C
7.	Fe_3O_4	9.7	25^0C
8.	Au	317	25^0C
9.	Ag	429	25^0C
10.	Al	237	25^0C
11.	Fe	80.2	25^0C
12.	Carbon nanotubes	2000	25^0C
13.	Diamond	600	25^0C

Table 1. Thermal conductivity values of various nano materials.

- F.S.JAVADI et.al discussed about the property comparisons of SiO2, Al2O3, TiO2 as working fluids and found out
- The increment of thermal conductivity by adding TiO2 and Al2O3 is almost the same and it was higher than SiO2.
- Heat transfer coefficient increases on increasing the volume concentration of nanoparticles. The increment of heat transfer coefficient by adding TiO2 and Al2O3 is almost the same and it was higher than SiO2.
- The Prandtl number which occurred at 0.2% volume concentration are SiO2=0.415, Al2O3=0.406, TiO2=0.382 [7].

$$c_{p,nf} = \frac{\phi\rho_{np}c_{p,np} + (1-\phi)\rho_{water}c_{p,water}}{\rho_{nf}}$$

$$\frac{k_{nf}}{k_{water}} = \frac{k_{np} + 2k_{water} + 2\phi(k_{np} - k_{water})}{k_{np} + 2k_{water} - \phi(k_{np} - k_{water})}$$

$$\mu_{nf} = \mu_{water}(1+\eta\phi)$$

ρ	fluid density, kg m^{-3}
δ	tape thickness, mm
μ	fluid dynamic viscosity, kg s^{-1} m^{-1}
η	thermal performance factor
ϕ	concentration of nanofluid, % by volume

The most commonly used nano fluids are TiO2 in water, CuO in water, ZnO in ethylene glycol, Al2O3 in water.

2.7 PREPARATIONS OF NANO-FLUIDS

YIMIN XUAN et.al presented a procedure for preparing a nano fluid which is a suspension consisting of nano phase powders and a base liquid. For example, Oil-Cu nanoparticles suspension are explained . Cu nano particles are mixed with the transformer oil by 2 and 5 vol% respectively.

To stabilise the suspension, oleic acid is selected as the dispersant to cover the nanoparticles. The amount of fixed oleic acid is calculated with weight percentage of Cu particles. Several percentages of Oleic acid have been tested. The suspension is vibrated for 10 h in a ultrasonic vibrator. The experimental results show that in the case that the percentage of oleic acid amounts to 22 wt% of the particles, the stabilisation of suspension can last about 1 week in the stationery state and no sediments is found.

The distribution and cluster of the ultra-fine copper particles have been examined by HITACHI H8 electron microscope. The electron microscope shows that the particles are dispersed in the fluid and some clustering occurs.

By suspending nano phase particles in heating or cooling fluids, the heat transfer performance of the fluid can be significantly improved.

The reasons are

- The suspended nanoparticles increase the surface area and heat capacity of fluid.
- The suspended nanoparticles increase the effective thermal conductivity of the fluid.
- The interaction and collision among particles, fluid and the flow passage surface are intensified.
- The mixing fluctuation and turbulence of the fluid are intensified.
- The dispersion of nanoparticles flattens the transverse temperature gradient of the fluid.[8]

Gargee.A.Pise et.al prepared nano fluids by using two-step method to produce uniform and stable fluid.Nanoparticles of Al_2O_3 were purchased from Intelligent Materials Pvt Ltd. Haryana (India) with nominal average particle diameter of <50 nm. Nanofluid preparation of Al_2O_3–water, is as follows:

(1) weight the mass of Al_2O_3 nanoparticles by a digital electronic balance.
(2) put Al_2O_3, nanoparticles into the weighed distilled water gradually and agitate the Al_2O_3–water mixtures separately.
(3) sonicate the mixtures continuously for 2 h at 1500 RPM and 24 kHz to produce uniform dispersion of nanoparticles in distilled water.

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The nanofluids were made in different mass fractions (0.05%, 0.25%, and 0.5%) and no surfactant was used as they may have some influence on the thermo physical properties of nanofluids.[9]

3.RESULT

S.EIAMSA-ARD et.al performed an experiment using TiO_2 and twisted tapes in heat exchanger. The study encompassed the twisted tapes with twist ratios(y/yo) of 1.5,2.0,2.5 and nanofluids with TiO_2 volume concentrations of 0.07%,0.14% and 0.21%.

The obtained results indicated that twisted tapes induced overlapped swirling flows which played an important role in improving fluid mixing and heat transfer enhancement.

Nusselt number, friction factor and thermal performance increase with decreasing overlapped twist ratio and increasing TiO_2 volume concentration.

The maximum thermal performance factor of 1.18 was obtained by the use of twisted tapes with smallest overlapped twist ratio (yo/y =1.5) and nanofluid at the maximum TiO_2 volume concentration of 0.21 %. Thermal performances of the tubes with twisted tapes at yo/y=1.5, 2.0 and 2.5 varied between 0.94 and 1.18, 0.92 and 1.16, 0.89 and 1.12 respectively. For the present range , the use of TiO_2/water nano fluids resulted in 1.7 - 4.5% higher thermal performance factor than the use of the water[5].

KULWANT DHANKAR et.al concluded that the significant amount of increase (approximately 50% for convective heat transfer coefficient of nano fluid at concentration of 5% compared with water at 90°C. The increase in heat transfer rate is directly proportional to increase in volume concentration of nanoparticles[10].

V.MURALI KRISHNA calculated experimentally and theoretically the overall heat transfer coefficients. The overall heat transfer coefficient is increased by 17% with the volume fraction 0.5% of Al_2O_3 nano particles compared with normal water[11].

CONCLUSION

The research has clearly explained that the suspension of nanoparticles can increase the thermophysical property of the fluid which can lead to the proliferation of overall heat transfer rate. In addition to it, the flow inside the cylinder can be modified in order to achieve turbulence to the flow which leads to the higher contact time of the hot fluid and the cold fluid. The nano fluids with very low volume fraction of suspended nanoparticles does not create any change in the system.Therefore the nano fluids with high volume fraction of suspended nano particles are used in order to enhance the thermal

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