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Enhancement of Heat Transfer Rate in Double Pipe Heat Exchanger Using Surface Modification and Nano-Fluid: A Review

Santosh Kumar Ramji Gupta1, Dr.P.M. Meena2
1PG Student Department of Mechanical Engineering, MBM Engineering College, Faculty of Engineering, Jai Narain Vyas University, Jodhpur, Rajasthan.
2Professor, Department of Mechanical Engineering, MBM Engineering College, Faculty of Engineering, Jai Narain Vyas University, Jodhpur, Rajasthan.

Abstract: *The Overview of an experimental and CFD analysis of concentric conduit heat exchanger by using spherical dimpled tube and plain tube by varying the mass flow rate by of working fluid consider as water is presented in this Review paper. The Heat transfer enhancement methodology refer to employment of different techniques to improve the overall heat transfer rate without much affecting the total performance of the system. Previously many studies have been done on passive techniques to enhance the heat transfer rate. In this Review paper we consider the modification in the inner tube of concentric tube heat exchanger with the help of dimpled tube. The consequences of using as a dimple tube on the heat transfer coefficient, effectiveness of heat transfer and heat transfer rate, are equated with the plain tube having different mass flow rate. In this review paper we come to know that by The experimental and CFD analysis of spherical dimpled tube having water as the working fluid results obtained shows that increases the overall heat transfer coefficient, heat transfer rate, and also effectiveness of dimpled tube heat exchanger when compared to plain tube.*
Keywords: CFD, Dimple, Tube, Concentric, Heat.

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I. INTRODUCTION

In A present scenario very large amount of energy is used for production of thermal energy for electricity production or for industrial use.as we know the energy resources are limited on the earth because of this the energy resources are depleting at a very high rate. Which is the matter of concern for sustainable use of energy resources available on the earth. for which Energy conservation become an important aspect. Due to this The high-performance heat exchanger is designed with the help of heat transfer enhancement techniques for many areas of the industrial use is, one of the promising energy-saving manners.in most of heat transfer enhancement method utilises one or more combinations of this favourable conditions for the enhancement in heat transfer rate with an interruption of boundary layer development undesirable increase in friction, and growing degree of turbulence, producing swirling or secondary Flows, and by increasing the net heat transfer surface area. Numerous heat transfer enhancement techniques have been introduced, for example rough surfaces, swirling flow devices, coiled tubes, and surface tension devices and treated surfaces.

1.1Heat Exchanger

Heat exchanger is an instrument that is used to transmission of thermal energy occurring between two or more fluids, on a solid surface and fluid, or between solid particulates matters and fluid, at altered temperatures and in thermal contact. No outside heat and work interactions are considered in heat exchangers. It finds applications generally where a heating or cooling of a working fluid and evaporation or condensation of single- or multicomponent fluid streams is required. In other applications, the aim can be to recover or reject heat, fractionate, concentrate, crystallize, or control a process fluid. The heat transfer takes place in three modes namely, conduction, convection and radiation. Radiation can transfer heat through empty space, while the other two modes require some form of matter-on-matter contact for the heat transfer.

1.1.1: Types of Heat Exchangers based on Construction and Design

- Plate heat exchanger
- Plate fin heat exchanger
- Plate and shell heat exchanger
- Shell and tube heat exchanger

- Concentric tube heat exchanger
- Adiabatic wheel heat exchanger
- Direct contact type Heat Exchanger
- Fluid heat exchangers

1.concentric tube heat exchanger: Concentric tube heat exchangers are used in a variety of industries for purposes such as material processing food preparation and air-conditioning. They create a temperature driving force by passing fluid streams of different temperatures parallel to each other separated by a physical boundary in the form of a pipe. This induces forced convection, transferring heat to and from the product. The thermodynamic behaviour of concentric tube heat exchangers can be described by both empirical and numerical analysis. The simplest of these involve the use of correlations to model heat transfer however the accuracy of these predictions varies depending on the design. For conditions where thermal properties vary significantly such as for large temperature differences the seidertate correlation is used. This model takes into consideration the differences between bulk and wall viscosities.

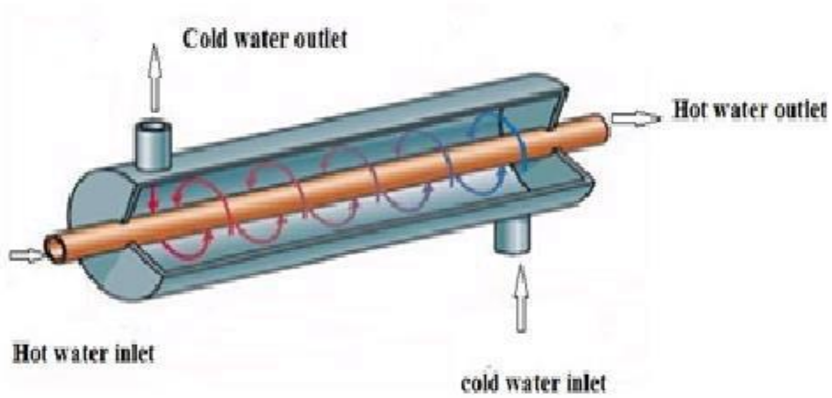

Fig. 1.1: Concentric Tubes Heat Exchanger

1.1.2 Types of Heat Exchanger (Fluid Motion)
The types of heat exchanger according to the fluid motion are classified as follows
a. Parallel flow heat exchanger
b. counter flow heat exchanger
c. Cross flow heat
Parallel flow heat exchangers: In these types of heat exchanger both cold and hot fluid enters from the same side of the heat exchanger and they flow parallel to each other in the same direction and heat is transferred from hot fluid to cold fluid.
Counter flow heat exchangers: in this heat exchanger each fluid enters from opposite sides of heat exchanger the hot and cold fluid travels parallel to each other but in opposite direction.
Cross flow heat exchangers: In cross flow heat exchangers, the two fluids travel perpendicular to each other. It is mainly used in air or gas heating purpose

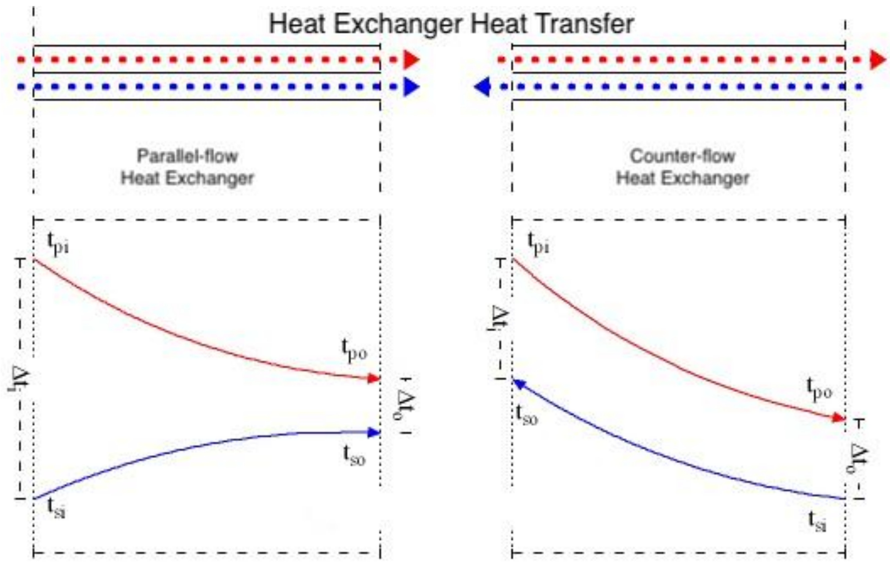

Fig.1.2:of parallel and counter flow heat exchanger

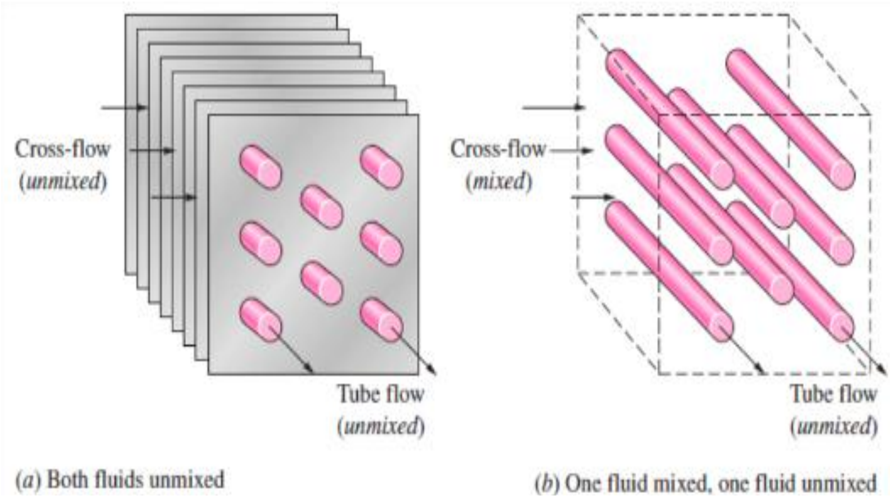

Fig.1.3: Cross Flow Heat Exchanger [5]

1.1.3 Dimpled Tube

The dimpled tubes provide heat transfer rates that are higher than the rates found in smooth tubes under similar conditions. This is an important development for the energy conversion and process industries. It was demonstrated that more heat Dimpled surfaces can create one or more combinations of the following conditions that are favourable for increasing the heat transfer coefficient with a consequent increase in the friction factor:
Interruption of the development of the boundary layer and increase of the degree of turbulence. Effective heat transfer area increase, and Generation of rotating and/or secondary flows. Two different dimpled shapes are used

- Spherical dimpled tube
- Ellipsoidal dimpled tube

The enhanced structure for both the ellipsoidal and spherical dimple could disturb, swirl, break the boundary layer developing, and enhance the mixing of the hot and cold fluid and then improve the heat transfer of the tubes

1.1.3.1 Dimpled Tube Manufacturing Methods To increase the heat transfer rate, dimple was produced on the inner side of the tube over the length of tube. Dimples were produced with the help of die having similar shape and size of the dimple

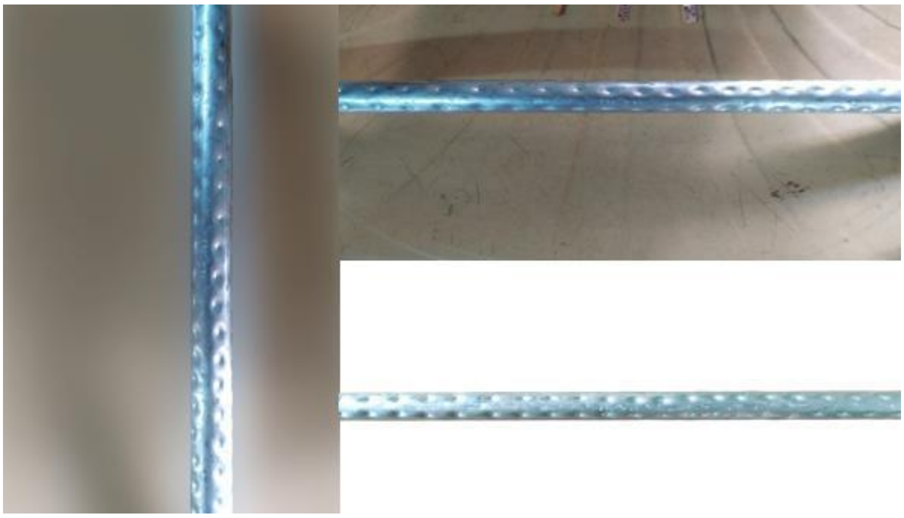

Fig.1.4: Dimpled Tube

1.2: Requirement of Heat Transfer Improvement and Future scope of present study:

In the present era due to energy crisis, available energy resources are depleting day by day and scientists are trying to develop a technique to utilise every bit of available energy on the earth. In heat exchanger design industries tries to maximise the efficiency of heat exchanger and to minimise the energy losses to minimum Also, in many occasions, the need of alteration in an existing system arises. For such instances, the concept of tabulator's or inserts had been proposed. The process through which the efficiency of a present heat exchanger is increased are known as heat transfer enhancement techniques. Following are the key points why heat transfer methods are required.

1. Reducing total capital cost of new heat exchangers
2. Reducing size of heat exchanger
3. Increasing efficiency of existing systems
4. Reducing fouling effects
5. Reduction in maintenance costs

1.3: Methods of heat transfer enhancement: There are various mechanism by which the heat transfer rate can be improved in a heat exchanger. Some of the method that can be followed for heat transfer augmentation are.

1.Incorporating secondary heat transfer surface
2.producing disturbance to laminar sub layer
3.By improvement of boundary layer separation that produces high turbulence
4.By improving the thermal conductivity of the working fluid
5.By increasing the time of boundary layer development
6.By increasing the fluid flow rate
7.producing turbulence in the fluid flow path due to which there will be better mixing of the fluid

1.4: Selection of Heat Exchanger: There are many types of heat exchangers available in the market but not any one can fit into any application. Hence, for different areas of application, different types of heat exchangers are used. Therefore, the proper selection of heat exchanger must be done, and it depends on several factors which are described below.

1.Heat Transfer Rate
2.Cost of H.E
3.Pumping Power Required
4.Size and weight of H.E.
5.Type of H.E
6.Construction material of H.E.

1.5: The Heat Transfer Rate Enhancement Techniques: Classification of heat transfer improvement methods: A lot of investigation has been done in earlier and many investigators are also working these days on the methods that can improve the heat transfer efficiency of heat exchangers. Numerous methods have been recommended and examined mathematically as well as experimentally. In the broad scenario, heat transfer augmentation techniques can be classified into three categories.

1. Active Techniques
2. Passive Techniques
3.Compound Techniques

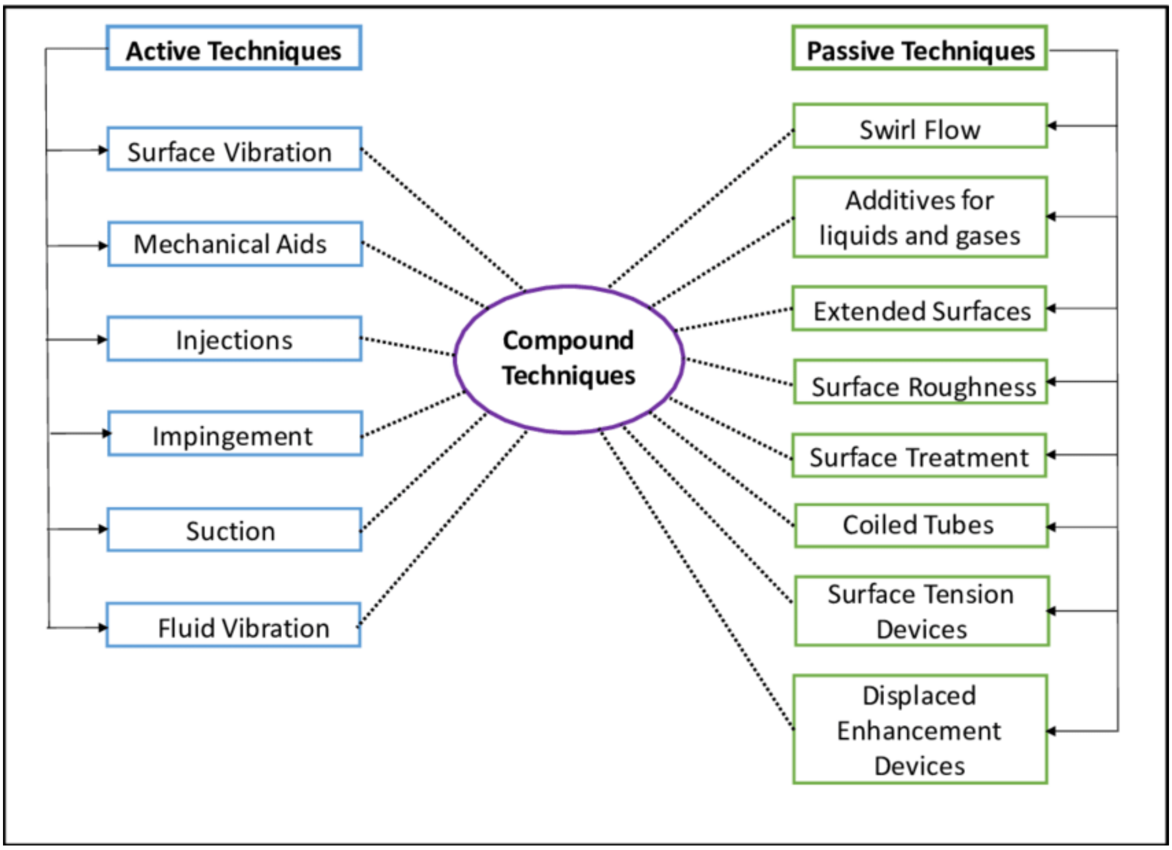

Fig.1.5: The Heat Transfer Rate Enhancement Techniques

1.Active Technique: Active techniques involve an exterior power supply which is used to produce the required flow adjustment and the enrichment in the rate of heat transfer. The following active techniques can be used to the increase of heat transfer which are as follows:

1.Jet impingement
2.Mechanical aids
3.Electrostatic field
4.Surface vibration
5.Fluid vibration

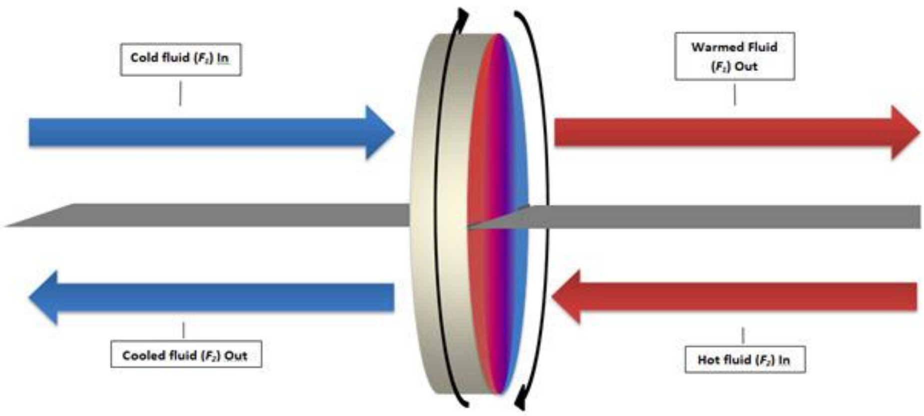

Fig.1.6: Active Heat Enhancement Technique

a) In mechanical aids, the fluid is agitated by mechanical method or by rotating the surface. Mechanical surface scrapers, are used for viscous liquids in the chemical process industry and can be used in duct flow of gases. The rotating tubes are a general example of this type.
b) To augment the heat transfer is distinct phase, surface vibration methods can be used. To promote spray cooling, a piezoelectric instrument is used which produces vibration on the surface and impinges small droplets on a heated surface.
c) Fluid vibration is mainly used in single phase flows and are feasibly the most practical type of vibration enrichment technique.
d) The heat exchanger in which the working fluids used is a dielectric material, in which electrostatic fields will be generated. Bulk mixing can be produced. Forced convection can be induced. Electromagnetic pumping used to enhance the heat transfer rate. Injection is provided by supplying gas through a porous heat transfer surface to a flow of liquid or by introducing the same liquid upstream of the heat transfer section. It leads to the escalation of single-phase flow.
e) Jet impingement forces a single-phase fluid normally or obliquely toward the surface. Single or multiple jets may be used, and boiling is possible with liquids.

2. Passive Technique: In the passive methods of heat transfer improvement, there is not required any external source of power. The heat transfer improvement is obtained by varying the geometry of the heat exchanger surface or by making changes in design of the heat exchanger. This can also involve mixing of some additives in the fluids that results in improved thermal conductivity and hence there will be increased in heat transfer rates. Numerous methods adopted under passive category are:

1.swirl flow
2.additives for liquid and gases
3.Extented surface
4.Surface Roughness
5.SurfaceTreatment
6.Coiled Tubes
7.Surface Tension Devices

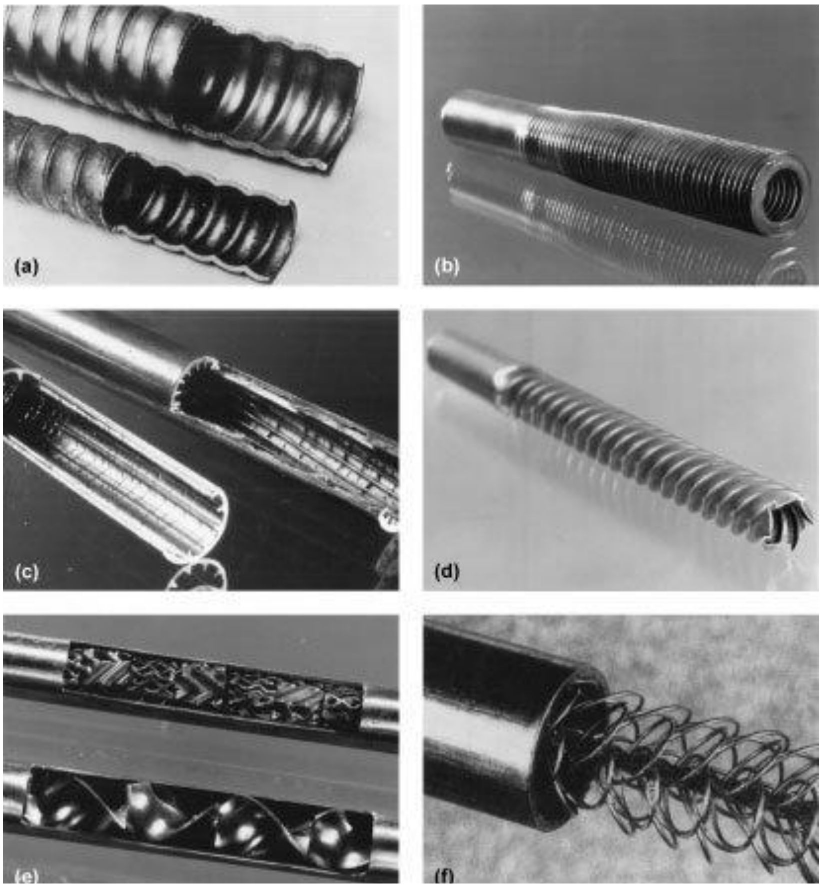

Fig.1.7:Passive Heat Transfer Enhancement Technique

3.Compound Technique: When any two or more of the above are utilised, for the increment in amount of the heat transfer which are greater than the magnitude of heat transfer which is produced by any one when utilised exclusively, is termed as a compound augmentation. This technique requires difficult design and finds inadequate application

1.5 OBJECTIVES OF THE REPORT REVIEW

1. To study the concentric heat exchangers with plain tube and dimple tube and to determine the tube wall temperature variation along the flow length and the pressure difference across the tube wall by CFD analysis.
2. To study the effect on heat transfer rate in concentric heat exchangers with plain tube and dimple tube.
3. To Review the overall Heat transfer coefficient and Effectiveness of hot and cold streams of water for a plain tube and dimple tube in concentric heat exchanger at different flow regimes.

II. LITERATURE REVIEW

This review is done to justify the requirement of the work undertaken and is based on the literature in the topic of interest, the concerned subjects and works of other researchers in this field. Various methods and strategies adopted by different researchers and research papers on enhancement of Heat Transfer Technique have been reviewed.

2.1 Introduction

These days, heat transfer improvement for achieving thermally efficient industrial equipment is a key parameter to conserve energy. Hence, the method of enhancement of heat transfer are as follows.

(a) Introducing of a secondary heat transfer surface.
(b) Interference of unenhanced fluid velocity.
(c) Interruption of laminar sub boundary layer in turbulent flow.
(d) Use of secondary flows.
(e) Stimulating boundary layer separation.
(f) Indorsing flow attachment/reattachment.
(g) Augmenting effective thermal conductivity of fluid under dynamic and static conditions.
(h) Increasing boundary layer formation time.
(i) Thermal dispersion of fluid molecules.
(j) Increasing randomness of fluid molecules.
(k) Change in distribution of flow.
(l) Alteration of radioactive characteristics of convective medium.
(m) Increment in surface and fluid temperature.
(n) Enhancing thermal conductivity of solid phase using nanotechnology.
(o) Fins can be used as passive device.
(p) Passive increment in fluid flow rate.

Heat exchanger is used to transfer heat from one fluid to another fluid. To aggrandize the heat, transfer in a heat exchanger, Active and Passive techniques are implemented. The active methods require an external power source to run a device such as electric fields and vibration, of surface and fluid particle etc. Passive technique involves modifying the heat transfer surfaces like extended surfaces, inserting twisted tapes or coils, dimpled tube etc., which disrupt the boundary layer and increase the turbulence. There were many studies on pipe flows with modified surfaces, only few studies were carried out on double pipe heat exchangers.

A. García.et.al, The influence of artificial roughness shape on heat transfer enhancement: Corrugated tubes, dimpled tubes and wire coils, corrugated tubes, dimpled tubes and wire coils are compared. Water as working fluid in the range of Reynolds numbers between 200 and 2000.Laminar, transition and turbulent flows are used. The heat transfer co-efficient on maximum Nusselt number augmentations of 250% can be expected at low Prandtl numbers. While for Reynolds numbers higher than 2000, the use of corrugated and dimpled tubes is favoured over the wire coils.

J.Kukulka.et.al, Development and evaluation of enhanced heat transfer tubes, Enhancement tube and smooth tubes are compared and material is enhanced 304 L stainless steel tube and steel. This experiment under performed by Turbulent flow in the range of Reynolds Numbers near 2900. Water as working fluid. Increases in heat transfer for most Enhancement tubes are in excess of 120% over smooth tubes and minimize the fouling rate. Inlet water flow was a constant rate of 6 L/min. After the prescribed time, the tubes were drained, samples dried and measurements made. Rate of fouling for the smooth stainless-steel tubes were compared to the average values of the four dimpled tubes. Dimpled tubes minimize the fouling rate and also provide heat transfer performance gains in excess of 100%.

Deshmukh and Vedula[2014] performed investigation on friction factor and heat transfer rate for turbulent flow through the circular tube fitted with vortex generator inserts. The vortex generator has been produced by joining curved delta wing vortex generators on the rod. The vortex generators have been introduced axially on the opposite sides of the central rod. The consequence of height to pipe inner diameter ratio, pitch to projected length ratio, and angle of attack on the heat transfer performance was obtained practically. the working fluid is air for experimental investigation and the test was performed for turbulent fluid flow region. The Reynolds number was altered from 15000 to 55000. the increase in Nusselt number have been obtained around 1.4 to 1.6 times for various setups as compared to plain tube without inserts. For the same value of Reynolds number. For the same amount of pumping power, the increase in Nusselt number changed from 1 to 1.9 times as compared to the tube without vortex generators. Empirical correlations were obtained for the dependence of Nusselt number on angle of attack height to tube inner diameter ratio and pitch to projected length ratio.

J.E.Kim.et.al, Numerical study on characteristics of flow and heat transfer in a cooling passage with protrusion-in-dimple surface, Four different protrusion heights were considered and protrusion height to channel height (h/H) of 0.05, 0.10, 0.15, and 0.20. This experiment under performed by turbulent flow. Water as test fluid. CFD analysis and Experimental method and 40% negligible pressure drop, 24% increase heat transfer, increase friction factor up to 5–6% and volume goodness factor slightly increases by 4%.

JuinChen.et.al. Heat transfer enhancement in dimpled tubes, Coaxial-pipe heat exchanger using Six dimpled copper tubes of varying geometries were used for comparison with a standard smooth tube. This experiment under performed by turbulent flow. Water as test fluid and experimental method. Best dimpled tube was tube 6, which had the largest dimple depth-to-tube inside diameter ratio, dimple depth to- pitch ratio, dimple depth-to-dimple diameter ratio, and number of dimple columns. Tube 6 have high heat transfer coefficient are significantly larger (between 1.25 and 2.37 times) than those for the smooth tube. Friction factor for all the dimpled tubes are 1.08 to 2.3 times higher than the value for the smooth tube.

Chinaruk Thianpong.et.al, Compound heat transfer enhancement of a dimpled tube with a twisted tape swirl generator, Dimpled tube with twisted tape and plain tubes are compared. The Reynolds numbers are ranged from 12,000 to 44,000 with hot/cold water as working fluid. Twisted tapes were made of straight aluminium tape with thickness (δ) of 0.5 mm, width (w) of 22 mm, and twist ratios y/w=3, 5 and 7. The experimental results reveal that both heat transfer coefficient and friction factor in the dimpled tube fitted with the twisted tape, are higher than those in the dimple tube acting alone and plain tube. It is also found that the heat transfer coefficient and friction factor in the combined devices increase as the pitch Heat transfer rate and friction factor dimpled tube with twisted tape, are respectively 1.66 to 3.03 and 5 to 6.31 times of those in the plain tube.

S.Vignesh.et.al, This project focused on investigating whether the use of Spherical dimples can enhance heat transfer characteristics for a circular tube. The simulation of the concentric heat exchangers with plain tube and dimple tube was done in CFD analysis and it shows that temperature and velocity increases in the dimple tube as compared with plain tube. The pressure is reduced in dimple tube as compared with plain tube. The dimpled geometries on the wall of a tube and plain tube were tested experimentally for different flow rates by keeping inlet temperature as constant. The Inside and Outside overall heat transfer coefficient of concentric dimple tube heat exchanger was increases to 56% to 64% as compared with concentric plain tube heat exchanger. The Effectiveness obtained by concentric dimple tube heat exchanger was increases to 55% as compared with concentric plain tube heat exchanger. Thus, the CFD results and experimental results shows that the dimpled tube is used in concentric tube heat exchanger will give high heat transfer and it can be used in various applications.

Kim et al. compared CFD analysis with the experiment done on heat exchanger for heat transfer characteristics for aqueous Al_2O_3 Nano fluid in heat exchanger tube. The volume concentrations used were 0.25, 0.5, and 1% by weight. Obtained test Results point out that the heat transfer coefficient and Nusselt number increased with Reynolds number and it also known that the Prandtl number was getting down when the concentration of Nano fluids enlarges and showed the equation by the linear method of the result value.

Nishant et al. investigated paraffin, ethylene glycol and water based Al_2O_3 Nano fluid with a volume concentration ranging from 0.01% to 0.08% in a step of 0.01% in a shell and tube heat exchanger. Various parameters like sonication time, temperature, base fluids, pressure difference were considered for calculation of heat transfer coefficient. And it has been seen that with increasing volume concentration of Nano fluid, the heat transfer was significantly increased.

Azmi et al. examined the heat transfer rate in forced convection for Al_2O_3 based Nano fluids in different ratio of ethylene glycol (EG) and water (W) based mixture. The Al_2O_3 Nano fluids were prepared for three based mixture ratios of 60:45, 60:50 and 50:60 (Water: Ethylene Glycol) by volume. The experiments had shown that Nano fluids in 60:45 base mixture had the best results as compared with the other two. Also, he concluded that the thermo-physical characteristics and the forced convection heat transfer for Nano fluids in various base mixture were significantly influenced by concentration, temperature and base ratio of mixture.

Durga Prasad et al. performed an experimental study to improve the rate of heat transfer with Al_2O_3 and water-based Nano fluid in u-shaped tube exchanger with inserts, and the volume concentrations used were 0.01% and 0.03% and different twist ratios ranging from 5-20 for twisted tapes were used. The best performance was observed with a twist ratio of 6 and 0.03% volume concentration of Nano fluid, and correlations were also developed.

Somchai et al. Furthermore, Nano fluids are likely to be theoretically appropriate for practical applications as its application produces very less pressure drop due to Nano particles are in very small in size. Therefore, it works like a single-phase fluid compare to solid–liquid mixture. The very fine size particles called Nano particles has been used to produce Nano fluids in the studying the reviewed literature paper are: copper (Cu), copper oxide (CuO), silica, silver (Ag), gold (Au), aluminum oxide (Al_2O_3), Nano particles and carbon Nano tube.

Mujumdar et al. done study on recent investigation performed in research paper on heat transfer and fluid flow characteristics of Nano fluid in free convection and forced convection flow. Recognized the prospects for future research. Convective heat transfer rate would be increased by passively by altering changing boundary conditions, flow geometry, or by increasing thermal conductivity of the fluid. Various method is employed to increase the heat transfer performance of fluids. copper oxide and Alumina (Al_2O_3) are mostly used and inexpensive Nano particles taken into consideration for investigation by many researchers. All the experimental study has been established the improvement of the thermal conductivity by the use of Nano particles.

Das et al: done mathematical study on heat transfer rate and turbulent flow for three different Nano fluids (Al_2O_3, SiO_2 and CuO), in an ethylene glycol and water mixture having flow through circular pipe under constant heat flux. Introduced new viscosity correlation for nano fluids as a function of temperature and volume concentration. Calculated results are authenticated with present well-known correlations. as size of Nano particle reduces its viscosity and Nusselt number increases. with increase in volume concentration of Nano fluids and Reynolds number the heat transfer coefficient increases. with increase in the volume concentration of the Nano fluids pressure loss increases

III. CONCLUSION

A large portion of energy being consumed in industry processes and the energy resources are depleting at an alarming rate. Energy conservation is therefore, become an important issue. In many areas of the industries, using of high-performance heat exchanger is one of the promising energy-saving manners. The high-performance heat exchangers can be obtained by utilization of heat transfer enhancement techniques. So, developing efficient and inexpensive heat exchanger is important for efficient use of available thermal energy resources on earth. So in this study I have learned various method emphasises to enhance the heat transfer rate.

Related to my study I learned more about the theory of heat Exchanger in which I have studied types of heat exchanger and their application and various method employed to enhance the heat transfer rate for example Active heat transfer enhancement Technique, Passive heat transfer enhancement technique and compound technique.

In this study, heat transfer enhancement in a heat exchanger with the dimpled tube has been studied with two working fluids namely DI water and DI water based Al2O3 Nano fluids. It is found that the presence of Al2O3 nanoparticle in DI water can enhance the heat transfer rate. from the study we found that the degree of the heat transfer enhancement depends on the quantity of nanoparticles added to the base fluid.

In This study we found that the use of Spherical dimples can enhance heat transfer characteristics for a circular tube. The simulation of the concentric heat exchangers with plain tube and dimple tube was done in CFD analysis and it is found that temperature and velocity increases in the dimple tube as compared with plain tube. The pressure is reduced in dimple tube as compared with plain tube. We studied how the dimpled geometries on the wall of a tube and plain tube were tested experimentally for different flow rates by keeping inlet temperature as constant. The Inside and Outside overall heat transfer coefficient of concentric dimple tube heat exchanger was increases to 56% to 64% as compared with concentric plain tube heat exchanger. The Effectiveness obtained by concentric dimple tube heat exchanger was increases to 55% as compared with concentric plain tube heat exchanger.

a. In present study we found that in comparison to plain pipe, heat exchanger with dimpled tube has shown an increase in Overall heat transfer coefficient, and heat transfer rate because of disturbance of boundary layer, hence leading to better mixing, and increased turbulence.

b. the study shows that Heat transfer rate increased from 13% to 18% when dimple tube was used in double pipe heat exchanger in place of plain tube. Heat transfer rate was maximum at volume flow rate of 15 LPM of Nano fluid.

c. the study shows that overall heat transfer coefficient on the inner side of the dimpled tube increases from 17% to 23% as compared to plain tube.
d. the study shows that overall heat transfer coefficient on the outer side of the dimpled tube increases from 16% to 22% as compared to plain tube.
e. the study shows that pressure is reduced in dimple tube as compared with plain tube.

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