Heat Transfer Enhancement with Al_2O_3 Nanofluid in Shell and Tube Heat Exchanger using Twisted Tapes: A Review

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Abstract— The objective of this paper is to review on the investigation made by different researchers for heat transfer enhancement in shell & tube heat exchanger by using Al_2O_3 nanofluid and the design modification with twisted tapes. The twisted tape insert is incorporated in tubes within the system. The use of the twisted tapes causes the swirl flow that enhances the heat transfer coefficient considerably. Basically heat exchanger is equipment which transfers the energy from hot fluid to a cold fluid, with maximum rate, minimum investment and running cost. Now due to the limitation of fossil fuels, subject to energy consumption optimization in various industrial processes becomes very important. The authors found that variously developed twisted tape inserts are popular researched and used to strengthen the heat transfer efficiency for heat exchangers.

Key words: Heat Exchanger, Twisted Tapes, Nanofluid, Heat Transfer Enhancement

I. Introduction

Thermal performance of heat transfer system increases with heat transfer enhancement, such as in heat exchangers, evaporators, thermal power plants, chemical reactor, air-conditioning equipment and refrigerators, and lately they have been applied widely in industrial application. Meanwhile, many attempts have been made to develop enhancement techniques to reduce the size and costs of heat exchangers in order to improve the overall performance of heat exchangers. An extensive literature survey of research is done on all types of enhancement technique.

Generally, enhancement techniques can be classified in three broad categories:

- Active method: Active augmentation has been studied extensively, involves some external power input to bring about the desired flow modification for enhancement. But it has not shown much potential owing to complexity in design. Furthermore, external power is not easy to provide in several applications.
- Passive method: In this method, the system does not need any external power input. The additional power needed to enhance the heat transfer is taken from the available power in the system. Tube insert devices including twisted tape, wire coil, extended surface and wire mesh inserts are considered as the most important techniques of this group; in which, twisted tape and wire coil inserts are widely applied than others.
- Compound method: a compound method is a hybrid method in which both active and passive methods are used in combination. The compound method involves the complex designs and hence it has limited applications. Wire coil inserts have been utilized as one of the passive enhancement techniques and are widely utilized in heat transfer equipment's. They show several advantages in relation to other enhancement techniques:

1) Easy installation and removal.
2) Simple manufacturing process with low cost.
3) Preservation of original plain tube from mechanical strength.
4) Possibility of installation in an existing smooth tube heat exchanger (retrofit).
5) Fouling mitigation (in refineries, chemical industries and marine applications. [17]

A. *Passive Heat Transfer Augmentation Methods*

Passive heat transfer augmentation methods as stated earlier 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 repository time of the fluid in the effective region. The passive methods are based on the same principle. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase effective surface area, residence time and consequently heat transfer coefficient in existing system [7]. The Heat transfer augmentation by these techniques can be achieved by using:

1) *Treated Surfaces*

This technique involves using pits, cavities or scratches like alteration in the surfaces of the heat transfer area which may be continuous or dis continuous. They are primarily used for boiling and condensing duties.

2) *Rough Surfaces*

These surface modifications particularly create the disturbance in the viscous sub-layer region. These techniques are applicable primarily in single phase turbulent flows.

3) *Extended Surfaces*

Plain fins are one of the earliest types of extended surfaces used extensively in many heat exchangers. Finned surfaces have become very popular now a day owing to their ability to disturb the flow field apart from increasing heat transfer area.

4) *Displaced Enhancement Devices*

These inserts are used primarily in confined forced convection. They improve heat transfer indirectly at the heat exchange surface by displacing the fluid from the heated or cooled surface of the duct with bulk fluid from the core flow.

5) *Swirl Flow Devices*

They produce swirl flow or secondary circulation on the axial flow in a channel. Helical tape, & various forms of altered (tangential to axial direction) are common examples of swirl flow devices. They can be used for both single phase and two-phase flows.

6) *Coiled Tubes*

In these devices secondary flows or vortices are generated due to curvature of the coils which promotes higher heat transfer coefficient in single phase flows and in most regions of boiling. This leads to relatively more compact Hear Exchanger.

7) Surface Tension Devices

These devices direct and improve the flow of liquid to boiling surfaces and from condensing surfaces. Examples include wicking or grooved surfaces.

8) Additives for Liquids

This technique involves addition of solid particles, soluble trace additives and gas bubbles added to the liquids to reduce the drag resistance in case of single phase flows. In case of boiling systems, trace additives are added to reduce the surface tension of the liquids. [13]

B. Twisted Tape

Twisted tapes are the metallic strips twisted with some suitable techniques with desired shape and dimension, inserted in the flow.

Fig. 1: A typical view of twisted tapes. [13]

Following are the main categories of twisted tape which are analyzed in this study:

1) Full length twisted tape: These tapes have length equal to length of test section.
2) Varying length twisted tape: These are distinguished from first category with regards that they are not having the length equal to length of test section, but half length, ¾ th length, ¼th length of section etc.
3) Regularly spaced twisted tapes: These are short length tapes of different pitches spaced by connecting together.
4) Tape with attached baffles: Baffles are attached to the twisted tape at some intervals so as to achieve more augmentation.
5) Tapes with holes: Slots and holes of suitable dimensions made in the twisted tape so as to create more turbulence. [7]

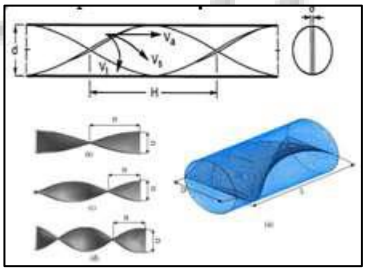

Fig. 2: Structure of the Twisted Tape. [12]

II. EXPERIMENTAL SETUP OF SHELL AND TUBE HEAT EXCHANGER

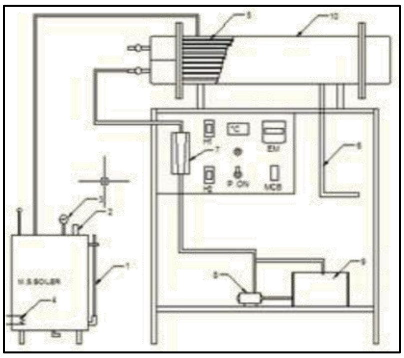

Fig. 3: Schematic Diagram of Shell and Tube Heat exchanger. [12]

A. Components of Shell & Tube Heat Exchanger

The principal components of an STHE are:

- Shell: Shell diameter should be selected in such a way to give a close fit of the tube bundle. In this setup the shell diameter is usually taken as 0.2m and is made of Stainless steel.
- Tubes: Tube OD of ¾ and 1“““ are very common to design a compact heat exchanger. With increase in number of tubes, the heat transfer coefficient is increased. Stainless steel is commonly used tube materials.
- Tube pitch: Tube pitch is the shortest centre to centre distance between the adjacent tubes. The tubes are generally triangular patterns (pitch).
- Tube passes: The number of passes is chosen to get the required tube side fluid velocity to obtain greater heat transfer coefficient and in this setup 2 passes is chosen.
- Baffles: Baffles are used to increase the fluid velocity by diverting the flow across the tube bundle to obtain higher transfer co-efficient. In this experiment four baffles are used.
- Rotameter: In this setup two rotameter are used. One is for measuring mass flow rate on shell side and another for tube side. The readings will appear in digital form.
- Pumps: Two pumps are used of half HP pump.
- Heater: heater is provided on one side of tank, to heat water. The hot water is supplied to shell or tube depending upon requirement. [12]

III. NANO FLUIDS

Nano fluid, first suggested by S.U.S. Choi of Argonne National Lab in 1995, innovative working fluid for heat transfer created by dispersing highly thermal conducting solid particles smaller than 50 nano meters in diameter in traditional low thermal conducting heat transfer fluids such as water, engine oil, and ethylene glycol. [9]

A. Emergence of Nanofluids

Nanofluid is a new kind of heat transfer medium, containing nanoparticles (1–100 nm) which are uniformly and stably distributed in a base fluid. These distributed nanoparticles, generally a metal or metal oxide greatly enhance the thermal conductivity of the nanofluid, increases conduction and convection coefficients, allowing for more heat transfer.

Nanofluids have been considered for applications as advanced heat transfer fluids for almost two decades. However, due to the wide variety and the complexity of the nanofluid systems, no agreement has been achieved on the magnitude of potential benefits of using nanofluids for heat transfer applications. Compared to conventional solid–liquid suspensions for heat transfer intensifications, nanofluids having properly dispersed nanoparticles possess the following advantages:

- High specific surface area and therefore more heat transfer surface between particles and fluids.
- High dispersion stability with predominant Brownian motion of particles.
- Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification.
- Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization.

- Adjustable properties, including thermal conductivity and surface wettability, by varying particle concentrations to suit different applications.

The first test with nanofluids gave more encouraging features than they were thought to possess. The four unique features observed are listed below:

- Abnormal enhancement of thermal conductivity. The most important feature observed in nanofluids was an abnormal rise in thermal conductivity, far beyond expectations and much higher than any theory could predict.
- Stability. Nanofluids have been reported to be stable over months using a stabilizing agent.
- Small concentration and Newtonian behaviour. Large enhancement of conductivity was achieved with a very small concentration of particles that completely maintained the Newtonian behaviour of the fluid. The rise in viscosity was nominal; hence, pressure drop was increased only marginally.
- Particles size dependence. Unlike the situation with micro slurries, the enhancement of conductivity was found to depend not only on particle concentration but also on particle size. In general, with decreasing particle size, an increase in enhancement was observed.

The above potentials provided the thrust necessary to begin research in nanofluids, with the expectation that these fluids will play an important role in developing the next generation of cooling technology. The result can be a highly conducting and stable nanofluid with exciting newer applications in the future. [4]

B. Applications of Nanofluid

The novel and advanced concepts of nanofluids offer fascinating heat transfer characteristics compared to conventional heat transfer fluids. There are considerable researches on the superior heat transfer properties of nanofluids especially on thermal conductivity and convective heat transfer. Applications of nanofluids in industries such as heat exchanging devices appear promising with these characteristics. Kostic reported that nanofluids can be used in following specific areas:

- Heat-transfer nanofluids.
- Tribological nanofluids.
- Surfactant and coating nanofluids.
- Chemical nanofluids.
- Process/extraction nanofluids.
- Environmental (pollution cleaning) nanofluids.
- Bio- and pharmaceutical-nanofluids.
- Medical nanofluids (drug delivery and functional tissue–cell interaction).

Nanofluids can be used to cool automobile engines and welding equipment and to cool high heat-flux devices such as high power microwave tubes and high-power laser diode arrays. A nanofluid coolant could flow through tiny passages in MEMS to improve its efficiency. The measurement of nanofluids critical heat flux (CHF) in a forced convection loop is useful for nuclear applications. Nanofluids can effectively be used for a wide variety of industries, ranging from transportation to energy production and in electronics systems like microprocessors, Micro-Electro-Mechanical Systems (MEMS) and in the field of biotechnology. Recently, the number of industrial application potential of nanofluids technology and their focus for specific industrial applications is increasing. [4]

IV. LITERATURE SURVEY

Anil Singh Yadav (2009) here influences of the half-length twisted tape insertion on heat transfer and pressure drop characteristics in a U-bend double pipe heat exchanger have been studied experimentally. In the experiments, the swirling flow was introduced by using half-length twisted tape placed inside the inner test tube of the heat exchanger. The results obtained from the heat exchangers with twisted tape insert were compared with those without twisted tape i.e. Plain heat exchanger. The heat transfer coefficient was found to increase by 40% with half-length twisted tape inserts when compared with plain heat exchanger. It was also observed that the thermal performance of Plain heat exchanger was better than half-length twisted tape by 1.3-1.5 times. [1]

S. Gh. Etemad and B. Farajollahi (2010) here an experimental system was designed and constructed to investigate heat transfer behaviour of γ-Al_2O_3 nanofluid in a shell and tube heat exchanger. Heat transfer characteristics were measured under the turbulent flow condition. The experiments were done for wide ranges of Peclet numbers, and volume concentrations of suspended nanoparticles. Addition of nanoparticles to the base fluid causes the significant enhancement of heat transfer characteristics and results in larger heat transfer coefficient than that of the base fluid at the same Peclet number. [2]

Veeresh Fuskele and Dr. R. M. Sarviya (2012) described the experimental work on heat transfer augmentation in double pipe heat exchanger using a new kind of insert called twisted wire mesh. Inserts when placed in the path of the flow of the liquid, create a high degree of turbulence resulting in an increase in the heat transfer rate and the pressure drop. The work includes the determination of friction factor and heat transfer coefficient for twisted wire mesh having different twist ratios of y=5 and y=7. The experimental data obtained from plain tube were verified with the standard correlation to ensure the validation of experimental results. For twisted wire mesh, it was observed that the heat transfer coefficient varied from 2.09 to 1.69 and the friction factor increased to 4.3 to 4.0 times the smooth tube value. The results obtained leads to the conclusions that higher heat transfer rates can be achieved using insert at the expense of a reasonable pressure drop. [3]

P. Sivashanmugam (2012) had done the detailed description of the state-of-the-art nanofluids research for heat transfer application in several types of heat exchangers. Preparation of nanofluids was an important step in experiments on nanofluids. Having successfully engineering the nanofluids, the estimation of thermo physical properties of nanofluids captures the attention. Research works on convective heat transfer using nanofluids is found to increase exponentially in the last decade. Almost all the works showed that the inclusion of nanoparticles into the base fluids has produced a considerable augmentation of the heat transfer coefficient that clearly increases with an increase of the particle concentration. The increase in the effective thermal conductivity and huge chaotic movement of nanoparticles with increasing particle concentration is mainly responsible for heat transfer enhancement. [4]

Bodius Salam, Sumana Biswas, Shuvra Saha and Muhammad Mostafa K Bhuiya (2013) carried an experimental investigation for measuring tube-side heat transfer coefficient, friction factor, heat transfer enhancement efficiency of water for turbulent flow in a circular tube fitted with rectangular-cut twisted tape insert. A copper tube of 26.6 mm internal diameter and 30 mm outer diameter and 900 mm test length was used. A stainless steel rectangular-cut twisted tape insert of 5.25 twist ratio was inserted into the smooth tube. The rectangular cut had 8 mm depth and 14 mm width. A uniform heat flux condition was created by wrapping nichrome wire around the test section and fiber glass over the wire. Outer surface temperatures of the tube were measured at 5 different points of the test section by T-type thermocouples. Two thermometers were used for measuring the bulk temperatures. At the outlet section the thermometer was placed in a mixing box. The Reynolds numbers were varied in the range 10000-19000 with heat flux variation 14 to 22 kW/m^2 for smooth tube, and 23 to 40 kW/m^2 for tube with insert. Heat transfer enhancement efficiencies were found to be in the range of 1.9 to 2.3 and increased with the increase of Reynolds number. [5]

Maughal Ahmed Ali Baig, Ibrahim Nouzil, Azzam Sheik, Ferraz Mohammed and Thameez (2013) studied results of an experimental investigation carried out to find the overall performance of suitably designed concentric tube heat exchanger with passive heat transfer augmentation technique. The desired augmentation was attained with the help of twisted tape inserts. In addition to this, the performance of twisted tapes with holes and with baffle plates was carried out to find the suitable design for the heat transfer augmentation. The effect of twisted tape inserts on effectiveness of heat exchanger was analyzed at different mass flow rates. The full length twisted tape increases heat transfer by a percentage of 8.9%. [6]

Jaafar Albadr, Satinder Tayal and Mushtaq Alasadi (2013) did an experimental study on the forced convective heat transfer and flow characteristics of a nanofluid consisting of water and different volume concentrations of Al_2O_3 nanofluid (0.3–2) % flowing in a horizontal shell and tube heat exchanger counter flow under turbulent flow conditions were investigated. The Al_2O_3 nanoparticles of about 30 nm diameter are used in the present study. The results showed that the convective heat transfer coefficient of nanofluid is slightly higher than that of the base liquid at same mass flow rate and at same inlet temperature. The heat transfer coefficient of the nanofluid increases with an increase in the mass flow rate, also with the increase of the volume concentration of the Al_2O_3 nanofluid. However, increasing the volume concentration cause increase in the viscosity of the nanofluid leading to increase in friction factor. [7]

Kamaldeep Singh, Sumeet Sharma and D. Gangacharyulu (2013) studied that nanofluids were a new class of solid- liquid composite materials consisting of solid nanoparticles, with sizes typically on the order of 1–100 nm, suspended in a heat transfer liquid. Here the experimental work had been done at different temperature range (30 to 80°C) with varying different volume concentration (0.1%,0.2%,0.5%), 20nm size of Al_2O_3 nanoparticle in base fluid water to study the behaviour of thermophysical properties of nanofluid and compare with the base fluid. It was found that the thermal conductivity increases significantly with the nanoparticle volume fraction. With an increase of temperature, the thermal conductivity increases for a certain volume concentration of nanofluids, but the viscosity decreases. The temperature and volume fractions have significant effects on the thermal conductivity and viscosities were investigated. Viscosity of nanofluid (Al_2O_3/water) is less than base fluid water. Specific heat of nanofluid decreases with the concentration as increases. (0.1 to 0.5%).[8]

Alpesh V Mehta, Nimit M Patel, Dinesh K Tantia and Nilsh M Jha (2013) studied Cooling performance maintaining the desired performance and reliability very huge variety of product like car, computer and high power laser system. Whenever there was a increase the heat load and heat fluxes caused by more power and smaller size for these product cooling is one of the technical challenge faced by the industries. There were many single-phase liquid cooling techniques such as micro channel heat sink and two-phase liquid cooling technology like heat pipes, thermosyphones, direct immersion cooling and spray cooling. Development of the nano materials technology has made it possible to structure a new type of heat transfer fluid formed by suspending nanoparticles (dia. < 100 nm).In conventional base fluid like water and ethylene glycol choi coined the term nanofluid to refer the thermal properties superior to those of their base fluids. Due to rapid fluid mixing effects strengthens the energy transport inside the nano fluids by modifying the temperature profiles. Experimental data indicates that particle size, volume fraction and properties of the nanoparticles influence the heat transfer characteristics of nano fluids. This paper shows the research work on Mini heat exchanger using Al_2O_3- Water Based nano fluid. [9]

Parag S. Desale and Nilesh C. Ghuege (2014) had studied to improve the performance of the heat exchangers in terms of heat transfer rate, keeping pressure drop in limit. This paper was a review of techniques keeping focus on passive augmentation techniques used in heat exchangers. The thermal performance behaviour for tube in tube heat exchanger is studied for wire coil inserts, twisted tape inserts and their combination. The research was carried for constant/periodically varying wire coil pitch ratio. The wide range of Reynolds number was selected for allowing the inserts to be tested for different flow conditions from laminar to turbulent. The improved performance was found in the increasing order for wire coil inserts, twisted tapes and combined inserts. [10]

Dhanraj S. Pimple, Shreeshail.B.H. and Amar Kulkarni, (2014) studied heat transfer and friction factor data for single -phase flow in a shell and tube heat exchanger fitted with a helical tape insert. In the double concentric tube heat exchanger, hot air was passed through the inner tube while the cold water was flowed through the annulus. The flow considered was in a low Reynolds number range between 2300 and 8800. The heat transfer enhancement increased due to increased turbulence of water. It was due to the swirl flow motion provided by conical tapes. The friction factor increased with the decrease of conical ratio again due to swirl flow exerted by the conical tape. The performance of conventional shell and tube heat exchanger can be improved by the use of conical tape. [11]

K. Anand, V. K. Pravin and P. H. Veena (2014) investigated the heat transfer rate of a shell& tube heat exchanger with the use of twisted tapes in the tubes of the heat exchanger. The investigation is made in a circular tube with twisted tape inserts using KERN method. It was found that the heat transfer coefficient and the pressure drop in the tubes with the longitudinal twisted tape inserts were 7–16% and 100–170% greater than those of plain tubes without inserts. When the longitudinal strip inserts with holes were used, the heat transfer coefficient and the pressure drop were 13–28% and 140–220%, respectively, higher than those of plain tubes. The heat transfer coefficient and the pressure drop of the tubes with twisted-tape inserts were 13–61% and 150–370%, respectively, higher than those of plain tubes. [12]

Kiran K., Asalammaraja, Manoj and Umesh C. (2014) this research emphasizes on the performance of Heat Exchanger with various types of inserts. Since Heat Exchanger were widely used in different industries, hence there was a need of utilization of various types of Heat Transfer enhancement Techniques (Active, Passive, combined), which in turns optimizes the performance of available Heat Exchanger setup with different types of turbulators. This resulted in transformation of fluid flow characteristics from Laminar to Turbulent flow which leads to increase in Heat Transfer characteristics. [13]

Majid Hayati (2014) studied on the KERN method for shell and tube heat exchanger. The objective of this paper was to investigate the heat transfer rate of a shell & tube heat exchanger by using KERN method. Here the step wise formulation was given for getting the results. [14]

B. Kirubadurai, P. Selvan, V. Vijayakumar and M. Karthik (2014) studied varying factor affecting the thermal conductivity of Nano fluid at different conditions. Thermal conductivity is considered important factor for rapid cooling and heating application. Base heat transfer fluid normally having low thermal conductivity, so we go to Nano fluid for increases the heat transfer rate. Nano fluid is nanometre sized particle such as metal, oxide, and carbide etc., dispersed into base heat transfer fluid. Heat transfer rate increases with increasing concentration of nanoparticle. The fine grade of Nano particles increases the heat transfer rate but it’s having poor stability. Spherical shaped nanoparticles increases the heat transfer rate of Nano fluid compared with other shaped nanoparticles. Boiling was to reduce the enhancement of heat transfer rate. Spiral pipe having higher heat transfer rate compared with the circular plain tube. [15]

Ramesh R. and Dr. R. Vivekananthan (2014) studied the heat transfer rate of shell and tube heat exchanger in temperature process station by using Al_2O_3 nanofluid and Ethylene glycol. Al_2O_3 and copper nano particles were found to have good thermal conductivity for the heat transfer in shell and tube heat exchanger in Temperature process station. Al_2O_3 has been mixed with water as a base fluid to increase the heat transfer rate. The experimental and numerical investigation had been performed and the results been compared to validate the performance of the heat Exchanger. Heat transfer coefficient increases by increasing the concentration of nanoparticles in nanofluid up to certain level. At 2% volume fraction Nusselt number increases up to 30% for different Reynolds number. The increase in heat transfer coefficient due to presence of Al_2O_3 nanoparticles was much higher than the conventional fluids and hence the shell and tube heat exchanger using nanofluid as a coolant has higher heat transfer rate than the conventional shell and tube heat exchanger. [16]

Prabhakar Ray and Dr. Pradeep Kumar Jhinge (2014) reviewed experimental works taken by researchers, on this technique wire coil insert in tubes to enhance the thermal efficiency in heat exchangers and useful to designers implementing passive augmentation techniques in heat exchange. The authors found that variously developed wire coil inserts were popular researched and used to strengthen the heat transfer efficiency for heat exchangers. In wire coiled tube the pressure drop increases as compared to an empty tube. It was observed that the heat transfer in case of the conical coil was highest as compared to the plain pipe and the pipe containing the coil of different pitches. The enhancement efficiency increased with the decreasing pitches and found highest in the conical sets. [17]

Vinay Kumar Patel and N. K. Sagar (2015) investigated for augmentation of heat transfer rates inside circular tubes, particularly when turbulent flow is considered. CFD investigations on enhancement of turbulent flow heat transfer with twisted tape inserts in a horizontal tube under forced convection with air flowing inside was carried out using ANSYS FLUNT. The variations of heat transfer coefficients; Nusselt number in the horizontal tube fitted with twisted tape was studied. The conclusion showed that there was a definite increase in heat transfer through heat exchanger with twisted tape inserts with increase in friction to the flow. [18]

K. Sivakumar, K. Rajan, S. Murali, S. Prakash, V. Thanigaivel and T. Suryakumar (2015) analysed the experimental and numerical investigation of heat transfer, heat transfer co-efficient and friction factor with twisted tape insert using CFD simulation. An experimental data obtained from the heat exchanger both plain tube and twisted tape inserts. The experimental setup was made with mild steel pipe on outside with 28mm inner diameter and 32mm outer diameter. The inner pipe made on aluminum tube with 18mm inner diameter and 20mm outer diameter. The results showed that the considerable amount of heat transfer enhancing with several of heat transfer co-efficient and Reynolds number. [19]

T. Srinivas and A. Venu Vinod (2015) studied forced convective heat transfer in an agitated shell and helical coil heat exchanger using CuO/water nanofluid. Experiments had been carried out in a shell and helical coil heat exchanger concentration of CuO nano particles in water (0.3, 0.6, 1.15, and 2% wt.), stirrer speed (500,1000 and 1500) and shell side fluid (heating medium) temperatures (40, 45 and 50°C). Enhancement in heat transfer due to the use of nanofluid had been reported in terms of heat transfer rate. [20]

Pramod R. Hande and K. Karunamurthy (2015) here an experimental study of In-Pond heat exchanger was done to enhance the heat transfer rate using twisted tapes(TT) of different twist ratios and twisted tapes with different geometries like square cut and v cut. The geometries of the twisted were also modified for the above mentioned three different twist ratios. The different geometries of the twisted tapes adopted were square cut and V cut in the profile of the twisted tapes. It was observed that in-pond heat exchanger with twisted taped performed better than without twisted tapes. Comparing the geometries along the profile of the twisted tape, V cut twisted tape resulted with increased degree of temperature rise. The thermal analysis was carried out for a constant flow rate of 0.0333 kg/s corresponding to Reynolds number of 6296. [21]

Dhiraj Tiwari and Amitesh Paul (2015) did experimental study on the forced convective heat transfer and flow characteristics of alumina nanofluid consisting of water and different volume concentrations of Al_2O_3 nanofluid (0.1–3) % flowing in a horizontal double tube counter flow heat exchanger under turbulent flow conditions were investigated. Effects of temperature and concentration of nanoparticles on Reynolds number and heat transfer coefficient in a heat exchanger with counter turbulent flow were investigated. Experimental results showed a considerable increase in heat transfer coefficient and Reynolds number. The results also showed that the convective heat transfer coefficient of nanofluid was slightly higher than that of the base liquid at same mass flow rate and at same inlet temperature. The heat transfer coefficient of the nanofluid increases with an increase in the mass flow rate, also the heat transfer coefficient increases with the increase of the volume concentration of the Al_2O_3 nanofluid. [22]

Kazem Mahanpour et. al. (2015) did the experimental and theoretical investigations to determine the effective thermal conductivity, electrical conductivity and viscosity of Al_2O_3/water nanofluid are presented. Nano Al_2O_3 particles with particle composition and microwave assisted chemical deposition method were distributed in distilled water by sonic device. In this study, nano particles of aluminum oxide with a partial thickness of about 20nm in different volumetric concentrations of (0.15.5-3%) at constant temperature were used. So far, few studies to measure the rheological properties of nanofluid at constant temperature had been performed .thermal conductivity, electrical conductivity and viscosity of nanofluid increases at constant temperature with particle volume fraction. Al_2O_3 Nano particles in water for different volume concentrations show Newtonian behaviour at 15.5℃. Theoretical models to predict the thermal conductivity and viscosity of nanofluids are the HC model and Einstein model. The proposed model has good agreement with experimental results. [23]

Arunachala U.C., Ambuj B., Eklavya S. and Vinay J. R. (2015) did experimental investigation was carried out to determine the effect of concentration (up to 2 % by volume) of water based Al_2O_3 as a nano fluid tube on heat transfer characteristics of shell and tube heat exchanger. The laminar flow based results with 2 % concentration showed an increase in heat transfer rate of 34 %, 44.8 % and 57.6 % for the shell side flow rate of 2 lpm, 3 lpm , 4 lpm and tube side flow rate of 1 lpm, 2 lpm, 3 lpm respectively. For different flow rate of fluids at shell and tube side, the various energy parameters attained maximum values at concentration of 2 %. This upward trend being continued till the viscous force dominates in the flow path. If turbulence was created by adding inserts in the flow path, further rise in heat transfer rate was with higher percentage of nano fluid concentration at the cost of pressure drop. [24]

Kurhade Anant Sidhappa, Sonal S. Hande, Swarup B. Patil and Vivekanand R.Maske (2016) studied heat transfer and friction factor properties were experimentally by using copper wavy twisted tape inserts with circular holes in forced convection. The turbulent flow was created by inserting the wavy twisted tape inserts into the test pipe. The tape consists of the circular holes and the twisting with various twist ratios (TR=5.5, 6.5, 8.5). The length and width of insert was 500 mm and 16 mm respectively. The outside diameter & inside diameter of test pipe is 32 mm & 28 mm respectively. The length of test section is 500 mm. The Reynolds number is varied from 2000 to 12000. It showed that the highest heat transfer rate was achieved for the wavy twisted tape with twist ratio 5.5. [25]

Qasim S. Mahdi and Ali Abdulridha Hussein (2016) studied the use of variant twisted tapes fitted in a double pipe heat exchanger to improve the fluid mixing that leads to higher heat transfer rate with respect to that of the plain-twisted tape. Two different variant twisted tapes which include V cut-twisted tape and Horizontal wing cut-twisted tape with twist ratios of y = 2.0, 4.4 and 6.0 are used. Based on studies, the major conclusion had been arrived the Nusselt number, friction factor and thermal enhancement factor of variant twisted tapes are higher than that of plain twisted tape for the twist ratios of 2.0, 4.4 and 6.0 respectively so among the variant twisted tapes used in the work, the horizontal wing cut-twisted tape give better performance due to the effect of increased turbulence which improves the fluid mixing near the wall of the test tube. By increasing volume concentration of nanoparticles, thermal conductivity increases while the thermal boundary layer thickness decreases. The Maximum thermal enhancement factor for P-TT, V-TT and HW-TT are 3.903, 4.269 and 4.488 respectively and enhancement plain twisted tape was better than CuO-nanofluid be three times. [26]

V. Murali Krishna (2016) stated conventional heat transfer fluids such as water, mineral oil, and ethylene glycol play an important role in many industries such as power generation, chemical production, air conditioning, transportation, and microelectronics. However, their low thermal conductivities have hampered the development of energy-efficient heat transfer fluids that were required in a plethora of heat transfer applications. It had been found from literature survey that the heat transfer properties of these conventional fluids can be significantly enhanced by dispersing nanometer-sized solid particles. The suspended metallic particles change the transport properties and heat transfer characteristics of the base fluid. Thus the research had been focused on the preparation of nanofluids using metal and metal oxide nanoparticles. In the present work Al_2O_3-water nanofluid was prepared at different volumetric concentration. The experiments were conducted in a concentric tube heat exchanger to study the heat transfer rates of Al2O3-water nanofluids for different flow rates and volume fractions of nano-particles in the base fluid. The experimental results were compared with the base fluid. The nanofluid properties were evaluated with correlations available in the literature to find the theoretical heat transfer coefficients. [27]

N. N. Bhosale, D. B. Gade, S. Y. Gonda, V. J. Sonawane and A. A. Keste (2017) focused on previous work comprising performance of heat exchangers using nanofluids experimentally as well as numerically for different flow rates and different volume concentrations. The results showed variation in overall heat transfer coefficient ratio and pressure drop ratio for different nanofluids. Secondly it gives an idea about applications of nanofluids in heat exchangers along with usefulness of nanofluids based on experimental and numerical investigations. The review of previous works by researchers suggested that nanofluids have great potential in augmentation of heat transfer of a heat exchanger. The overall heat transfer augmentation ratio in the range of 1.22 to 1.596.heat transfer enhancement goes in increasing with increasing nanoparticle volume concentration. [28]

Rajesh Choudhary, Deepak Khurana, Aditya Kumar and Sudhakar Subudhi (2017) studied the stability analysis of Al_2O_3/water nanofluid. The stability was investigated with the help of zeta potential and visual inspection methods. The effects of pH and sonication time for the stability of nanofluids were studied in detail. The visual inspection method was used to calculate the stability period of nanofluids. The zeta potential was directly related to stability period of nanofluids; higher the absolute value of zeta potential, higher the stability period. The stability was also analysed by using sodium dodecyl sulphate, a surfactant, with respect to the time elapsed after the preparation of nanofluids. [29]

V. Conclusion

This paper reviews all types of swirl flow devices and made comparison amongst all. The heat transfer augmentation, Pressure drop variation, friction factor and overall thermal performance of a tube inserted with wire coil inserts, twisted tape inserts and the combined devices between the twisted tape and constant or periodically varying wire coil pitch ratio are studied.

– The heat transfer enhancement increases due to increased turbulence of water.
– The enhancement of Nusselt number is much higher than that of enhancement in friction factor for the same ratio that justifies the usage of twisted tape.
– Heat transfer rate is directly proportional to the Reynolds number and Peclet number of Nano fluid.
– Concentration of nanoparticles increases the pressure drop of Nano fluid.

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