International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 12, December-2018

A Review On Double Pipe Heat Exchangers Using Corrugations

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Abstract: The paper presents a brief of the experimental work carried out on enhancing the performance of heat exchangers. Research is being carried out to increase the efficiency of heat exchange using by using a mix of different fluids. Further, the flow pattern through the heat exchangers has been given attention to enhance the wetting area of the fluid with solid components of the heat exchanger. In addition, micro-heat exchangers developed till date employ twisted tape inserts, baffles and fins to add to the surface area of the heat exchangers still keeping the effective dimensions of the heat exchangers to be low. Effect of external cone rings in various orientations on the heat transfer performance are also studied. Owing to their limited space occupation and compact size double pipe heat exchangers are reviewed as a possible solution to augment the heat transfer performance of heat exchangers by various active as well as passive techniques. One of the techniques that is providing corrugation on the tube walls is studied. The effects of varying the various geometric parameters of corrugated tubes viz. their depth, pitch, orientation, diameter is reviewed. Possibilities of employing corrugations on both inner and outer tubes were exploited as well as the effects of providing a convex and concave corrugation alternatively along the tube length were also analyzed effects of flow parameters on the heat transfer and pressure drop in the pipes were also studied. The possibility of exploiting CFD techniques and the results obtained thereof were considered. The effects of flow parameters and geometric variations in pipes on various dimensionless numbers and factors were studied.

Key terms: Computational Fluid Dynamics (CFD), heat transfer, heat exchanger, pressure drop, Convective heat transfer coefficient, Corrugated heat exchanger.

I. INTRODUCTION

In a variety of processes, we have to swap temperature for a number of jobs (as cooling, heating, vaporizing) between various fluid channels in different hardware such as condensers, evaporators, drinking water coolers, in short wherever high heat trades involving 2 fluids. For all these processes a device called Heat exchanger is used. A Heat exchanger is a device in which 2 fluids channels enter into high temperature communication with the objective of transferring the heat from very hot fluid to cold fluid stream.

1.1 Double pipe heat exchanger

The double pipe heat exchanger (DPHE) alternatively called a concentric pipe, hairpin heat exchangers, jacked pipe and jacketed U-tube exchanger have two concentric tubes one mounted inside other, both having fluids flowing in them. To take advantages of economy of space and heat transfer effectiveness Double pipe heat exchangers are employed against a conventional shell and tube heat exchanger. Typical usages of double pipe heat exchangers are where low rates of fluid flow, very large temperature cross or small duties with high flow rates are to be realized.

- Their compact size enables them to be used in applications where there is dearth of space. Series or parallel connections can be made with multiple units of heat exchangers and can be mounted in upright position
- Owing to the small diameter of the tubes higher pressure units with thinner walls can be built which is difficult with a shell and tube heat exchangers.
- Pure counter current flow can be achieved with these heat exchangers which makes it possible to obtain a temperature cross where the exit temperature of cold fluid can be above that of the hot fluid.
- The different pipes are connected by flanges which makes their dismantling as well as cleaning and maintenance convenient.

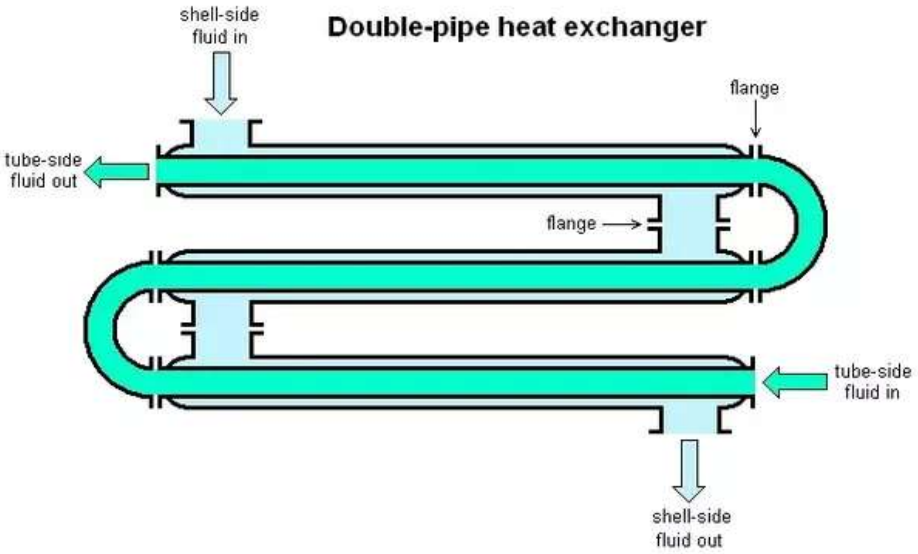

Figure 1 Schematic of a double pipe heat Exchanger

1.2 Double pipe Corrugated heat exchanger

Two fundamental techniques are used to bolster the heat transfer effectiveness in devices, First is passive technique which involves modifying surface geometries of conduits or adding substances called fluid additives. The second method is the active method which requires certain external sources for bolstering effectiveness.

One of the various passive alternatives to increase the heat transfer effectiveness in energy transfer devices is Corrugated tube geometry which when used in heat exchangers leads to improvement of their performance by

intermittently breaking up the momentum and thermal boundary layer between the interfaces of the two fluids. The various advantages of Double pipe Corrugated heat exchanger (DPCHE) design are

- To increase heat transfer coefficient on the tube side with correspondingly negligible decrements of pressure.
- High viscosity liquids as well as liquids with large fibers or particulates can be easily subjected to heat exchange

II. CURRENT STATUS OF RESEARCH

Saeedan et al. [1] have explored numerically the heat execution of a helically perplexed Heat exchanger joined with a 3D fine tube worked with Nano-liquids. At various volume concentrations Nano-particles of Cu, CuO, and CNT have been considered in water-based Nano-liquids. It has been examined that how temperature change and pressure drop are influenced by the Reynolds number and volume fixation. It has been found from the outcomes that both Heat exchange and weight drop increments with the expansion in the volume fixation and Reynolds number. The estimation of Nusselt number increments with the expansion in volume fixation for CuO/water and Cu/water Nano-liquid, while for CNT/water, it diminishes as the volume fixation expanded. **Sheikholeslami et al**. [2] have done numerical and test examination on turbulent stream and Heat move in a twofold pipe air to water exchanger has been finished utilizing cone shaped ring. Two clusters (Direct cone shaped ring (DCR) exhibit and Reverse conelike ring (RCR) exhibit) are considered. Exploratory investigation has been done in the wake of considering diverse estimations of Reynolds number (6000-12,000), open zone proportion (0-0.0833), conelike point (0°-30°) and pitch proportion (1.83-5.83). Measurable examination with a specific end goal to produce a relationship for rubbing factor, Nusselt number and heat execution factor has been finished. Likewise, to accomplish the ideal plan, Non-Sorting Genetic Algorithm II has been connected. Limited volume technique has been used for numerical segment keeping in mind the end goal to foresee physical conduct. It has been seen from the outcomes that the Nusselt number found to diminish with increment in open territory proportion and pitch proportion while it grows with improves of Reynolds number. Likewise, it has been discovered that rubbing factor diminishes with increase in open territory proportion, pitch proportion and Reynolds number. It has been finished up from the examination that heat execution ascends with enlargement of funnel shaped plot for tapered ring exhibit. **Zarrella et al.** [3] have completed a relative examination among a helical pipe and a twofold U-tube. Heat conduct of the ground heat exchangers has been examined when the two setups were introduced at a shallow profundity and the interface among the ground surface and the surrounding circumstance have been considered. By thinking about an equal electrical circuit of thermal resistance and capacitances, the trouble identified with heat exchange were fathomed. To contain Heat conduction in the ground and the borehole, same numerical reproduction instrument was utilized on a twofold U-tube heat exchanger. By thinking about the thermal characteristics of the ground, the energy required and the impacts of climate, analysis was done on two borehole heat exchangers for both long-and short-term period. **Demir et al**. [4] completed a computational examination by taking constant temperature of wall performed on forced convection stream of Nano-liquids comprising of water with TiO_2 and Al_2O_3 Nano-particles in a flat tube. To decide the Nano-liquid properties, Palm's connections have been considered. So as to consider the heat and

hydrodynamic conduct of the Nano-liquid stream, single-stage display having two-dimensional conditions have been utilized with either steady or temperature dependent properties. After the approval of the model by methods for the trial information of Duangthongsuk and Wongwises with TiO_2 nanoparticles, the numerical investigation is carried out for a consistent molecule size of Al_2O_3 as a contextual analysis. The profiles of temperature as well as the velocity computed at the inlet and fully developed region have been drawn. The varieties of the liquid temperature, nearby Heat exchange coefficient and weight drop along tube length have been exhibited. Amount of nanoparticles as well as the Reynolds number are major influencing parameters affecting the divider shear stress, Nusselt number, heat exchange coefficient and weight drop. Numerical outcomes demonstrate the Heat exchange improvement because of quality of the Nano-particles in the liquid as per the aftereffects of the test think about utilized for the approval procedure of the numerical model. **Zhan et al**. [5] presented the thermodynamic investigation, in view of the perfect gas state condition and energy preservation condition to understand the working of Thermodynamic vent System (TVS). After approving trial outcomes, the relation given by Kandlikar's for boiling Heat exchange has been used to understand stream boiling procedure because of the less mass stream rate and low Heat transitions has been engaged with stream bubbling of the annular pipe liquid. Keeping in mind the end goal to foresee the Heat exchange attributes of twofold pipe heat exchanger under typical gravity, a semi enduring state demonstrate has been perceived, with the mass liquid normal convection, double-stage boiling in the annular region. Built upon the nearby weight as well as temperature, it has been discovered that the thermophysical properties of the liquid vary with the length of pipe as well as time. Both the static examination as well as the transient heat execution of this particular heat exchanger are explored with the variable liquid thermophysical properties. **Mehran et al.** [6] have revealed that as opposed to utilizing cylindrical shaped tube, cone shaped tube has been utilized as a novel enhanced geometry for twofold pipe heat exchangers. Different funnel shaped tube clusters with assorted stream headings were explored. A comprehensive examination has been done keeping in mind the end goal to look at the impact of hydraulic, geometrical and thermodynamic properties in heat exchanger. It has been discovered that entropy generation, entropy generation number, heat exchanger reversibility norm (HERN), heat exchange change number and effectiveness– NTU are the imperative ideas which have been considered for cases. The outcomes indicate 55% and 40% augmentation in effectiveness and Heat exchange change number at the ideal condition. **Han et al**. [7] thought about the procedure parameters, the characteristic numbers for heat exchange (Nu), obstruction(f) and general Heat exchange efficiency(n) computed by CFD, and are filled in as target capacities to the RSM (Nusselt number for folded tube (Nuc), Nusselt number for smooth tube (Nus), fanning factor for ridged tube (fc), Nuc/Nus, fc/fs and general Heat exchange coefficient (η)). The outcomes of optimal design are an arrangement of different optimal arrangements, called 'Pareto optimal arrangements'. As per the Pareto ideal bends, the ideal parameters of twofold pipe heat exchanger with inward corrugations with of $Nuc/Nus \geq 1.2$ are observed to be $P/D = 0.82$, $H/D = 0.22$, $r/D = 0.23$, $Re = 26{,}263$, comparing to the most extreme estimation of $\eta = 1.12$. **Appadurai et al**. [8] have examined the Heat exchange utilizing Nano liquids in a twofold tube heat exchanger utilizing Computational Fluid Dynamics (CFD) approach. Heat exchange execution of an inside balance in a round tube has been tentatively investigated. For various Reynolds number running from $2.0x10^4$ to $5.0x\ 10^4$, wall temperature, mass liquid temperature, and weight drop along the axis of the finned tube were estimated. It has been found from the investigation that there is

increment of the heat execution of Nano liquids contrasted with water. **Huminic and Huminic** [9] have completed a 3-D examination in to ponder the Heat exchange attributes of a twofold tube helical Heat exchangers utilizing nanofluids. Nanoparticles with volume groupings of 0.5– 3 vol.% like CuO and TiO_2 having breadths of 24 nm scattered in water has been utilized as the working liquid. The mass stream rate of the water from the annulus was set at either half, full, or twofold the esteem and the mass stream rate of the Nano-liquid from the inward tube was kept steady. Nano liquids and water temperatures varieties alongside heat exchange rates and Heat exchange coefficients at the inward and external tubes have been appeared. For a similar mass stream rate through the internal tube and annulus, it has been discovered that the Heat exchange rate of Nano liquid was about 14% more prominent than the unadulterated water when 2% of CuO Nano-particles were included the water. From the examination, it has been presumed that the convective Heat exchange coefficients of the Nano-liquids and water is found to increment with expanding of the mass stream rate and with the Dean number. The outcomes have been approved by examination of recreations with the information by experimental conditions. **Sivakumar and Rajan** [10] examined the execution of Heat exchange and adequacy of the twofold pipe heat exchanger with two stream headings (one is parallel stream and counter stream). A business CFD bundle (ANSYS) has been utilized for this examination to create the 3D demonstrate heat exchanger. As a last point the exploratory appraisal is approve with the numerical qualities. **Erika et al.** [11] have learned high temperature transfer attributes computationally associated with a non-Newtonian material moving within constant laminar routine by way of a plate high heat exchanger during frequent wall structure heat. Single-pass U type plate high heat exchangers with a number of level plates with as well as with no baffles are utilized. Exploration has been carried out on the temperature transfer as well as the stress fall by thinking about the outcome of plate's distance and quantity in between plates as adjustable. A statistical correlation for your friction element as a characteristic of the ratio and Reynolds quantity involving the friction distinctive measurements as well as the flow trajectory measurements was designed. It's likewise been discovered that this reliance on the Nusselt selection on the Peclet selection could be illustrated through the revised Sieder Tate situation. **Mohanty et al.** [12] studied computationally the design associated with a pipe in pipe heat exchanger with specific input parameters at the inlet side of the heat exchanger. Studies are performed for various heat exchanger layouts involving twisted tape insert with different twist ratios, often spaced twisted tape, and then tapes twisted in the middle and with protrusion in the external. It has been analyzed that the performance of heat exchanger affected by the configurations. Graphical and tabular representation of the results showing improved performance has been presented. **Hasan et al.** [13] investigated numerically, the process of heat transfer while carrying out melting and solidification of paraffin wax which is studied as a Phase Change Materials (PCM) flowing through a horizontal pipe heat exchanger having triangular cross section, using 2D transient buoyant model. An enthalpy porosity technique is applied for solving the melting/solidification problem in the mushy regions. Improvements which are computed time wise regarding the patterns of flow as well temperature spreads and liquid/solid fractions and also stored or discharged electric energy are offered for various winter problems of the working fluids used in heat transfer. It's been realized after studying the simulated success that this particular research grants several methods for system winter performance, top power storage and recovery attributes for a concentric tube type Latent Heat Thermal Energy Storage Systems (LHTESS). **Wang et al**. [14] incorporated

numerical simulation technique in order to investigate the heat transfer and flow resistance characteristics of shell side of the double-pipe heat exchanger equipped with helical baffles. The study has been done by considering 5 heat exchangers having helical baffle at the helical angle of 40°. The baffle space height is considered to be b, 3b/4, b/2, b/4 and b/8 (where b refers to the helix pitch) were simulated. The influence of baffle space height on fluid flow and heat transfer of the shell side was examined. It has been found from the results that with the increase in baffle space, the heat transfer per unit area, heat transfer coefficient and friction factor found to increase under the same volume flow rate, however the pressure gradient found to decrease. It has been concluded from the study that in order to enhance the comprehensive heat exchange of shell side of single-tube heat exchanger with helical baffle, the partition height should be between 0.5b and 0.75b. **Sheikholeslami and Ganji** [15] did an experimental hydrothermal forced convective turbulent analysis on double pipe heat exchanger in which perforated turbulators have been utilized in annulus region. Number of parameters like pitch ratios, open area ratios and Reynolds number have been varied in order to find their effect. From the results it has been found that thermal performance enhances with increase in open area ratio. Temperature gradient reduces with increase in pitch ratio. **Ozden and Tari** [16] conducted an analysis by numerical modeling, associated with a tiny shell-and-tube high temperature exchanger to be carried out to take a look at the impact of baffle spacing, baffle cut as well as shell diameter on the temperature transfer coefficient as well as stress fall. Utilizing CFD method, the flow as well as heat areas within the shell were solved. Some CFD simulations are done for one shell as well as individual tubing pass high heat exchanger having an adjustable number of baffles and also turbulent flow. It's been discovered that these outcomes are actually vulnerable to the turbulence version choice. The most effective turbulence type with those thought of before is actually driven by evaluating the CFD outcomes of high temperature transfer coefficient, outlet heat as well as stress fall together with the Bell Delaware way benefits. For 2 baffle lower values, the outcome of ratio of baffle spacing to diameter of shell on the temperature exchanger efficiency is actually examined by altering flow fee.

III. CONCLUSIONS

Following conclusions were drawn from literature survey

- The changes in geometric parameters like diameter and depth of corrugation influence the heat exchange efficiencies
- The Rate of mass flow is a factor that majorly effects the efficiencies of transfer of heat along with the temperature and pressure of hot and cold fluid.
- Various fluids as well and their mixtures are also analyzed in different flow settings.
- Different shapes of pipes as well as external heat exchange enhancing technique are also studied.
- Very little analysis is performed on convex corrugated double pipe heat exchangers owing to intricacies in manufacturing processes.

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