INVESTIGATION OF DIFFERENT TYPES OF BAFFLES USED IN HEAT EXCHANGER: A REVIEW

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***Abstract*: The heat transfer capacity of heat exchanger can be increased without changing physical size of the exchanger. In order to increase the heat transfer rate of heat exchanger different types of baffles were used inside the heat exchanger. This paper provides some methods for increasing compact heat exchanger's performance. The methods consider whether the exchanger is performing correctly to begin with, excess pressure drop capacity in existing exchangers, there-evaluation of fouling factors, and the use of augmented surfaces, and enhanced heat transfer. here in this paper it review the different methods which is used to increase the heat transfer and also review the different types of baffles used in heat exchanger.**

Keywords: Heat exchanger, Turbulator, Methods, Heat Transfer Rate, Optimization

1. Introduction

A heat exchanger is a device used to transfer heat between a solid object and a fluid, or between two or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Another example is the heat sink, which is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant.

2. Applications

Heat exchangers are widely used in industry both for cooling and heating large scale industrial processes. The type and size of heat exchanger used can be tailored to suit a process depending on the type of fluid, its phase, temperature, density, viscosity, pressures, chemical composition and various other thermodynamic properties. In many industrial processes there is waste of energy or a heat stream that is being exhausted, heat exchangers can be used to recover this heat and put it to use by heating a different stream in the process. This practice saves a lot of money in industry, as the heat supplied to other streams from the heat exchangers would otherwise come from an external source that is more expensive and more harmful to the environment. Heat exchangers are used in many industries, including:

- Waste water treatment
- Refrigeration
- Wine and beer making
- Petroleum refining
- Nuclear power

In waste water treatment, heat exchangers play a vital role in maintaining optimal temperatures within anaerobic digesters to promote the growth of microbes that remove pollutants. Common types of heat exchangers used in this application are the double pipe heat exchanger as well as the plate and frame heat exchanger. And it is comparably used for aircraft purposes as In commercial aircraft heat exchangers are used to take heat from the engine's oil system to heat cold fuel. This improves fuel efficiency, as well as reduces the possibility of water entrapped in the fuel freezing in components.

3. Existing Research work

1. **Ramtin Barzegarian et.al [2017]** In this paper, the researcher experimentally investigated the Al_2O_3-Water nanofluid to be used as a heat transfer medium in a Shell and Tube Heat Exchanger having segmented baffles with forced circulation. The nanofluid consisted of the Al_2O_3-gamma nanoparticles suspended in the base fluid which is water having Sodium Dodecyl Benzene Sulphonate (SDBS) as surfactant at various volume concentrations. The effects of Heat transfer characteristics of the hot fluid were investigated on the basis of Reynolds Number, volume concentrations and friction factor. Their results showed that there was an increase in the Nusselt Number and heat transfer coefficient, with the increase in the Reynolds Number. The Nusselt Number and the heat transfer coefficient increased as the volume concentration of the nanoparticles increased. These comparisons were carried out with and without nanofluids. Furthermore little penalty was found in the pressure drop of the nanofluid. Also the thermal performance factor enhanced as the concentration of the nanoparticles increased.

2. **Daneshipour and Rafee et.al [2017]** This analysis investigated the effects of the CuO water and Al_2O_3 water nanofluids as the working fluids in Geothermal Borehole Heat Exchangers. Using numerical simulation methods they investigated the thermal performances of the given system. For this purpose, the Reynolds Averaged Navier-Stokes (RANS) equations with SST k-ω turbulence model were used. Based on these models equations were developed and the numerical simulation was obtained. The results thus obtained were compared with available data in the literature surveys. They developed a parameter called "special diameter ratio" to know the minimum pressure losses. Also CuO-water nanofluid exhibited better heat transfer capabilities than that of the alumina-water, but at the expense of higher pressure loss and higher pumping power.

3. **Wilk et.al [2017]** In this analysis, the researcher experimentally investigated the effects of the Copper nanofluid in a Coiled Heat Exchanger at various volume concentrations. The copper nanoparticle was suspended in the pure water as the base fluid. One of the heating coils was filled with the refrigerant and surrounding it was the nanofluid coil mounted over it as a buffer layer. The thermo physical properties of the nanofluid such as density, viscosity and thermal conductivity were measured experimentally and the obtained results were compared to the data available in the literature surveys. They concluded that the relative density and the viscosity of the nanofluids increased as the concentration of nanoparticles increased.

4. **Kabeel et.al [2017]** In the present paper it has experimentally investigated the effects of Al_2O_3-Water nanofluid as a heat transfer media in a Plate Heat Exchanger (PHE) with corrugated plate design. For this purpose an experimental rig was built and the thermophysical properties of the nanofluid such as heat transfer coefficient, effectiveness, transmitted power and pressure drop were measured and compared with the values obtained from the theoretical models. It was observed that with the increase in concentration of the nanoparticles in the base fluid, the heat transfer coefficient and the transmitted power also increased. The heat transfer values corresponded to an increase of 13% at a volume concentration of 4 wt %. The pressure drop and the pumping power also increased with the concentration of nanoparticles. It was observed that at a volume concentration of 4 wt %, the pressure drop was 45% and the corresponding pumping power increased to 90% in comparison to that of pure water.

5. **Vasconcelos et.al [2016]** In this analysis the scholars investigated experimentally the effects of Single Walled Carbon Nano Tubes (SWCNT)/Water nanofluid when it is employed as a secondary loop in the evaporator of the Indirect Vapor Compression Refrigeration System. For this purpose the experimental rig consisted of an evaporator having the brazed plate exchanger in which the refrigerant HCFC-22 extracted heat from the nanofluid. The compressor was of the semi-hermetic type and condenser of air-cooled type whereas an Electronic Expansion Valve (EEV) was employed to complete the refrigeration cycle. The nanofluid was allowed to flow in various concentrations ranging from 0-0.21 % by volume concentrations. The inlet temperature and mass flow rate were also altered in order to analyze the behavior of the nanofluid.

6. **Bajestan et.al [2015]** In the present analysis it has reviewed that nanofluids were not only limited to be used in refrigeration cycles as additives in refrigerants and lubricating oils, but they were being also studied and analyzed to be used in solar cycles also. And for this purpose, they carried out experiments to study the behavior of TiO_2/Water based nanofluid when it is allowed to flow in laminar manner, through a uniformly heated tube. Based on the experiments the thermal conductivity and dynamic viscosity were measured. The obtained results were compared to that of pure water and it was observed that there was an increase of 21 % in the average heat transfer coefficient. Also these results were compared and modeled with the existing single-phase model and two-phase model. Based on their analysis they concluded that the single-phase model underestimated the results whereas the two-phase model overestimated it. Hence several modifications in the two-phase models were done in order to predict the accurate results for the heat transfer characteristics of the nanofluids.

7. **Ndoye et.al [2014]** In such analysis the scholars performed a numerical study on the energy performances of nanofluids which are used in the refrigeration systems of cold chain refrigeration plants. For this they developed a mathematical model based on the combination of Effectiveness-NTU method and classical heat transfer fluid hydrodynamic correlations. Also they took into account a tubular heat exchanger to perform experiments with a variety of nanoparticles namely Al_2O_3, Co, Cuo, Fe, SiO_2 and TiO_2 suspended within base fluids to draw results for the effective energy performances. It was noticed that, with the increase of nanoparticle concentration, the heat transfer coefficient and the pressure drop both increased. And with the increase in pressure drop the pumping power also increased. On the basis of the PEC value, which is a global approach for the energy performance criterion for nanofluids in refrigeration systems, the values obtained showed that Al_2O_3, SiO_2 and TiO_2 nanoparticles were less efficient in comparison to that of the Co, CuO and Fe nanoparticles. The model very well familiarized with the data published in various literature surveys.

8. **Aghayari et.al [2014]** In this paper the researcher deals with the double tube heat exchanger with nanofluid. This paper inspects the improvement of heat transfer coefficient and Nusselt number of a nanofluid containing nanoparticles (γ-AL_2O_3) with a particle size of 20nm and volume fraction of 0.1%–0.3% (V/V). Effects of temperature and concentration of nanoparticles on Nusselt number changes and heat transfer coefficient in a double pipe heat exchanger with the counter turbulent flow are inspected. Evaluation of experimental results with effective theoretical data based on semi-empirical equations shows a satisfactory result. Experimental results show a significant increase in heat transfer coefficient and Nusselt number up to19%–24%, respectively. Many researchers have investigated the effect of nanoparticles on different process parameters like hydrodynamic and thermos-physical properties. In the experiment, the heat transfer rate was measured in the turbulent flow of a nanofluid containing 20 nm aluminium oxide suspended particles with the volume concentration of 0.1–0.3% (V/V) in water.

9. **Abbas et.al [2013]** In the present research it has experimentally investigated the performance of Carbon Nano Tube (CNT) based nanorefrigerants in refrigeration systems. For this purpose, a Refrigeration laboratory unit (R713) purchased from P. A. Hilton Ltd was used for performing the experiment. Here environmental friendly R134a refrigerant was used with 0.01-0.1 wt % of CNT suspended in Polyolester (POE) oil system. Results were drawn and it was concluded that the volume concentration of 0.1 wt % gives the maximum rate of heat transfer with highest heat transfer coefficient giving rise to a COP increase of 4.2 % compared to that of pure POE oil system.

10. **Koca et.al [2013]** In such analysis it has reviewed the viscosity of the nanofluids in view of their particle size, temperature and concentration. They evaluated various nanofluids for this purpose based on their surfactant type, type of synthesis and method of measurement. They studied the effects of viscosity based on the particle size of the nanoparticles present in the nanofluids. They also discussed effective viscosity models. They concluded that there was a discrepancy regarding the effective particle size on the viscosity of nanofluids.

11. **Tiwari et.al [2013]** This paper experimentally carried out the comparison between the heat transfer performances of the various types of nanofluids in a Plate Heat Exchanger. The nanofluids under scrutiny were CeO_2, Al_2O_3, TiO_2 and SiO_2. The comparisons were carried out on a number of parameters such as overall heat transfer, heat transfer coefficient, pressure drop, pumping power, effectiveness ratio and performance index ratio. After drawing the results they came to a conclusion that CeO_2 exhibited the best results out of the tested nanofluids. Also they observed that on adding the nanoparticles the thermal conductivity, viscosity and density increases, but the specific heat capacity decreases.

12. **Celen et.al [2013]** This analysis presented a review on adding of nanoparticles in the refrigerants to make nanorefrigerants which would be used in various applications such as in refrigeration, air conditioners, heat pumps etc. They discussed various aspects of nanorefrigerants types on their sizes and concentrations and compared them with pure refrigerants in order to know their difference in the thermophysical properties, flow and pool boiling characteristics. It was seen that the heat transfer was enhanced in most of the cases giving rise to the thermal conductivity. But a penalty was observed in the case of pressure drop due to the enhancement of heat transfer. Hence if pressure drop is ignored on account of high heat transfer then nanorefrigerants can be beneficial to replace the pure refrigerants.

13. **Singh et.al [2012]** This research investigated the nanofluids to be used as heat transfer fluids used in automobiles. They suspended Multi-Walled Carbon Nano Tubes MWCNTs in Ethylene Glycol (EG) at various concentrations in order to study the dynamic viscosity and thermal conductivity. The dynamic viscosity was measured by a rheometer. They observed that as the temperature of the nanofluids was increased, its viscosity decreased. Moreover, with the increase of concentration of the CNTs in base fluid, the viscosity also increased. The nanofluid behaved as Newtonian fluid. Also a linear rise of thermal conductivity of the nanofluid was observed as the concentration of CNT was increased.

14. **Saidur et.al [2011]** This paper reviewed the nanoparticles suspended in refrigerants and lubrication oils, which are used in refrigeration systems. Various parameters such as heat transfer rate at different concentrations, pressure drop, pumping power, pool boiling heat transfer performances of the nanofluid was studied. Moreover future challenges and scope of future research work was also presented in that paper. It has been seen that nanorefrigerants have a very strong temperature dependent thermal conductivity at low concentrations of nanoparticles in the base fluids. Then experiments were carried out for a refrigeration system containing HFC134a with Polyolester (POE) oil system, which was compared to the HFC134a and a mineral oil having TiO_2 nanoparticles and results were drawn which indicated a decrease of 26.1% of energy consumption with a concentration of 0.01 % of TiO_2 suspended in mineral oil.

15. **Ferrouillat et.al [2011]** In this analysis it has performed experiments on an experimental rig containing a horizontal tube section with a finite wall temperature. The nanofluid used was SiO_2/Water, at different volume concentrations. The results were compared with that of the pure water. For the experiment, different inlet temperatures and flow rates were considered and Reynolds number and Nusselt number were deduced on the basis of these numbers. Also the thermal conductivity and the viscosity of the nanofluid were measured with respect to their temperatures. They concluded that heat transfer rate increases to a value up to 10 – 60 % as in the case compared to that of pure water. The suspension stability at higher temperatures was also discussed. A criterion called Performance Evaluation criterion, PEC was defined to evaluate the properties obtained by the nanofluid under consideration.

16. **Chandrasekar et.al [2010]** In this analysis it has experimentally investigated and theoretically validated the behavior of Al_2O_3/water nanofluid that was prepared by chemical precipitation method. For their investigation, Al_2O_3/water at different volume concentrations was studied. They concluded that the increase in viscosity of the nanofluid is higher than that of the effective thermal conductivity. Although both viscosity and thermal conductivity increases as the volume concentration is increased, increase in viscosity predominate the increase in thermal conductivity. Also various other theoretical models were also proposed in their paper.

17. **Here's et.al [2006]** In this paper, they deal with the experimental investigation of convective heat transfer of Al_2O_3/water nanofluid in a circular tube. The main aim of the experiment to compare the rate of heat transfer with and without nanofluids

in circular tube and flow is laminar with constant wall temperature. The Nusselt number of nanofluid were obtained for different nanoparticles concentration and Reynolds and Peclet number. By the result of various experiments the heat transfer coefficient increases by increasing the concentration of nanoparticle in the nanofluid. In this experiment the nanofluid flow in the circular tube with constant wall temperature for laminar flow with variation in Renolds number and Peclet number they conclude that increase in thermal conductivity is not the single reason for heat transfer enhancement in the nanofluid. Dispersion and chaotic movement of nanoparticles, particle migration and Brownian motion have also participated in heat transfer enhancement. Particle motion and interaction, especially in higher Peclet number may cause the change in flow structure and lead to augmented heat transfer due to the presence of nanoparticles.

18. **Yimin et.al [1999]** In the given study, they examine procedure for the preparing of nanofluids by dispersing nanoparticles in a base fluid to create nanofluid and measure the thermal conductivity of nanofluids by hot-wire method and examine the thermal conductivity variation with concentration. They conclude that the thermal conductivity of nanofluids is increase with the increase in the concentration of ultrafine particles. For example, the water base copper nanofluids the ratio of thermal conductivity of the nanofluid to that of the base fluid varies from 1.24 to 1.78 if the concentration of nanoparticles varies from 2.5% to 7.5%. For the preparation of the nanofluids, the various technique was used i.e. Brownian diffusion, sedimentation, the dispersion may exist simultaneously but dispersion model has been used for analyzing the mechanism of heat transfer enhancement. By the analyzing of the mechanism of heat transfer, they also get the relationship with Nusselt number help in the calculation of heat transfer coefficient, through which them get the heat transfer.

19. **Choi et.al [1995]** In this analysis, the aim of enhancing thermal conductivity of fluid with nanoparticles they start to experiment and get very important result .the resulting "nanofluids" are expected to exhibit high thermal conductivity of nanofluids with copper nanophase material are given new era of research and also we get the one more benefits of nanofluids will reduce the heat exchanger pumping power. They were conclude that the concept of nanofluids is an innovative idea and get feasibility of high thermal conductivity of fluids and the potential benefits of nanofluid with copper nanophase particles have been estimated. They find that the reduction in heat exchanger pumping power, he found that for two times increase in heat transfer, the pumping power with conventional fluid should be increased by a factor of 10, however if nanofluid are used then thermal conductivity is increased by three times of conventional fluid without increase in pumping power .this invention of nanofluids give new opportunity for thermal scientist and engineers.

20. **Masuda et.al [1993]** The thermal conductivity of metal compared to the fluid is much higher, with that information they started the measurement of thermal conductivity of nanoparticle. They are taken nanoparticles due to the high surface area to volume fraction And these nanoparticles are used in the base fluid, known as nanofluids, They have shown experimentally that the thermal conductivity of nanofluid with Y-Al_2O_3 particles at a volume concentration of 4.3% can increase the thermal conductivity of base fluid water by 30%.the relation between the estimated and experimental measured conductivities is satisfactory. But at that time, no credit given to that experimental research due to the problem arises in production.

21. **Saidur et.al [10]** To investigate the behaviour of nanofluid, related to viscosity and pumping power, examine the performance of nanoparticles in the refrigeration system and lubricating oil. Due to their remarkable improvement in their heat transfer rate, it have capability to enhance the coefficient of performance of refrigeration system. In this paper they discuss about the thermal and physical properties of nanofluid, they also review the Heat transfer rate of various nano refrigerants with varying concentrations. After they examine various result in the literatures, it has been found that nano refrigerants have a greater reliability on temperature-dependent thermal conductivity at very low particle concentrations than conventional refrigerant. Experimental result show that HFC134a and mineral oil with TiO2 nanoparticles works normally and safe lying the refrigerator with better performance. The power required of the HFC134a refrigerant using mineral oil and nanoparticles mixture as lubricant saved 26.1% energy with 0.1% weight concentration of TiO_2nanoparticles compared to the HFC134a and POE oil system. Ithas been found that the thermal conductivities of nano refrigerants are greater than traditional refrigerants.

22. **Kamyar et.al [11]** For investigating the properties of nanofluid, we used the computational fluid dynamics to investigate the properties of nanofluid. With the help of experimental result we validate the result with software system and after validating the result we get the more result related to the property of nanofluid with two-phase system. From the previous result, in this article shows that from a numerical point of view, nanofluids achieve an important improvement in the heat transfer performance, which is in a better result with experimental works. On the other hand, some more modifications made to achieve precision results from numerical analysis. From the researchers, some claim that in order to have the exact results to reality, a two-phase model needs to be used. With the help of some slip mechanisms such as thermophoresis or Dufour effect that lead to the increase in heat transfer, solving a two-phase model for a nanofluid is preferred. The effect of Brownian motion on properties of nanofluids is to be examined further. Using temperature-dependent properties i.e. thermal conductivity or dynamic viscosity could also enhance the exactness of the results. Type of flow regime i.e. laminar or turbulent, also an important property in developing the results as for turbulent flow, greater growth is observed. Some more numerical methods such as Lattice Boltzmann Method (LBM) are also accomplished of exhibiting a flow of nanofluid in different geometries.

23. **Mohammad et.al [12]** The outcome of using louvered strip inserts placed in a circular double pipe heat exchanger using various types of nanofluids is studied numerically. The continuity, momentum and energy equations are solved by means of a finite volume method (FVM).Pipes heated with a uniform heat flux boundary condition. Two different louvered strip insert

arrangements (forward and backward) are used in this study with a Reynolds number varies from 10,000 to 50,000. The effects of various louvered strip slant angles and pitches are also examined. Four different types of nanoparticles, Al_2O_3, CuO,Sio_2andZnO with different volume concentration varies from 1% to 4% and different nanoparticle diameters in the range of 20 nm to 50 nm, dispersed in a water. The numerical results indicate that the forward louvered strip arrangement can enhance the heat transfer by approximately 367% to 411% at the highest slant angle of α=30° and lowest pitch of S=30 mm.

24. **Kabeel et.al [13]** The application of nano-fluids is thought to have a strong potential for enhancing the heat transfer characteristics of the corrugated plate heat exchanger-PHE. The corrugated PHE is one of the most versatile and wide using types of heat exchangers. In this study, an experimental test loop has been constructed to study the PHE thermal characteristics; heat transfer coefficient, effectiveness, transmitted power and pressure drop at different concentrated volume fractions of AL_2O_3 nano-material (1-4%) in pure liquid water as a base fluid. The maximum increase in heat transfer coefficient is reached 13% for a nano-fluid concentration of 4% vol. However, the increase in heat transfer coefficient is up to 13% under an uncertainty of 9.8%, at constant Reynolds number. If it is compared at constant flow rate, this marginal enhancement will be further reduced. So the application of nanofluids as a strong potential for enhancing the heat transfer in the corrugated PHE is doubtful for the current study.

Conclusion

1. In heat exchanger heat transfer depends on the mass flow rate of cold fluid and also depends on the type of fluid used.
2. Different types of turbulators were used to increase heat transfer rate which increases the performance of heat exchanger.
3. Flow behaviors of hot and cold fluid flowing inside the heat exchanger also affect the performance of heat exchanger.
4. For measuring the performance of heat exchanger thermal performance, heat transfer rate, nussel numbers were calculated.

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