A Review on Different process parameters and Turbulators used in nano fluid heat exchanger

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***Abstract*: Heat exchanger is a device used to transfer heat from one medium to other. To increase heat transfer rate in small region different working fluid were used to increase heat transfer rate. Researcher uses nano particles of metals oxide to increase heat transfer. Many of the researcher used different nano fluids like TiO_2, ZnO, Fe_2O_3, MgO, CuO and many others. To increase the heat transfer in nano fluid heat exchanger different geometrical shape baffles were used inside the heat exchanger to increase turbulence inside the heat exchanger so that heat transfer gets increased.**

***Keywords*: heat exchanger, turbulators, nano fluids, concentration, and heat transfer enhancement**

1. Introduction

Nanotechnology is a branch of science and technology which makes use of the particles in the nano scale order, namely in the molecular and atomic order respectively. In this field, the particles considered are analyzed individually from their bulk specifications. The properties of the bulk materials on the whole are expected to remain unchanged, whereas at the nano scale order these properties alter. When these solid particles (of nano scale order) are dispersed in any fluid medium (known as the base fluids) collectively they are known as "nanofluids", a term coined by Choi et al. [1] in 1995 at Argonne National Laboratory, USA.

Here in this paper different heat exchanger using nano fluid as a working material was discussed. Different parameter on which the performance of nanofluid heat exchanger depends, were also mentioned in this paper and different process of heat transfer was deeply reviewed here. Here the behavior of different nanofluids is analyzed when they are used in the heat exchangers. It discuss the synthesis of nanofluids in the below section, but before beginning the synthesis of nanofluid, first let us understand nanofluid heat exchangers.

Due to the limitations faced by the conventional heat transfer fluids used in the industries such as DM water, engine oil, mineral oil and ethylene glycol because of their low thermal conductivities, constant researches were being carried out in order to enhance the effective heat transfer capabilities of these fluids with a minimum change in their chemical composition. Solids on the other hand like metallic oxides, metals and even nonmetals organic compounds had better thermal conductivity than these conventional heat transfer fluids. Also it was a known fact from Maxwell's theoretical work that the effective thermal conductivity of suspensions having spherical particles increases with the volume fraction of the solid particles. Hence this generated an idea of suspending the solid metallic or nonmetallic particles into the conventional heat transfer fluids in order to create a suspension, having higher effective thermal conductivity.

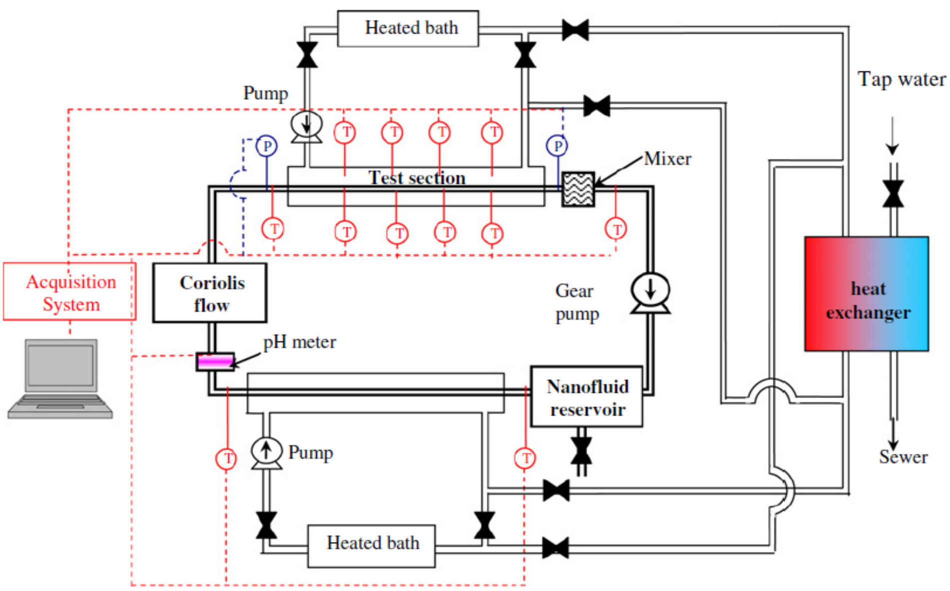

Fig. schematic diagram of heat exchanger using nano fluid [11]

2. Existing Research work

Many of the researchers have done work to optimize the different process parameters of heat exchanger. Some of the research work were mention in the below section

Choi and Eastman [1] in 1995 performed a theoretical study on thermal conductivities of nanofluids. They proposed the idea of enhancing the thermal conductivity of the base fluid by suspending metallic nanoparticles in it. It happened so because in 1881, Maxwell's theoretical work showed that effective thermal conductivity of suspensions that contain spherical particles increases with the volume fraction of the solid particles. And because micro meter sized particles would pose severe clogging problems in the thin tubes of exchanger therefore, their attention was drawn to the nano scale sized particle. Their results concluded that there would be dramatic reductions in heat exchanger pumping power if the conventional heat transfer fluids were replaced by the nanofluids. Though they proposed various theoretical models of making nanofluids, that are now obsolete, and therefore due to advancement in science and technology newer methods are being proposed.

Abbas et al. [2] in 2013 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.

Koca et al. [3]in 2013 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.

Hady et al. [4] in 2017 experimentally investigated the performance on the effect of alumina-water (Al_2O_3/H_2O) nanofluid in a chilled water air conditioning unit. They made use of various concentrations ranging from 0.1-1 wt % and the nanofluid was supplied at different flow rates. Their results showed that less time was required to achieve desired chilled fluid temperature as compared to pure water. Also reported was a lesser consumption of power which showed an increase in the cooling capacity of the unit. Moreover the COP of the unit was enhanced by 5 % at a volume concentration of 0.1 %, and an increase of 17 % at a volume concentration of 1 % respectively.

Harooniet. al [5] in 2017 reviewed various literature surveys and came to a conclusion that viscosity is an important property for the prediction of the behavior of the nanofluid. Hence they proposed four reliable models for the prediction of viscosity in nanofluids. These were based on Multilayer Perceptron Neural Networks (MLP-NNs), Least Square Support Vector Machine (LSSVM), Adaptive Neuro Fuzzy Inference System (ANFIS) and Gene Expression Programming (GEP). The proposed models were based on the nanofluids that exhibited Newtonian behavior. These models were then compared with the results obtained from the existing literature researches and were found to be accurate. They concluded that out of the four models the best results were shown by the LSSVM model.

Han et.al [6] in 2017 performed experiments on an experimental rig of double pipe heat exchanger in order to investigate the effect of Al_2O_3/Water nanofluid at various concentrations and at different inlet temperatures. The hot fluid used was steam. They compared their results with distilled water at the cold side and came to a conclusion that, heat transfer rate increases with increase in the temperature of the nanofluid. It was also observed that heat transfer increases with respect to the increase in the volume concentration of the Al_2O_3/Water nanoparticles. Also Nusselt number was reported to be increased substantially which meant a higher rate of heat transfer.

Ferrouillat et al. [7] in 2011performed 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.

Ndoye et al. [8] in 2014 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.

Bajestan et al. [9] in 2015 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.

Vasconcelos et al. [10] in 2016 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.

Table.1 Existing Research work to increase heat transfer using nano fluid

S no.	Researcher(s)	Year	Nanoparticle Used	Flow and Geometry	Findings
1	S.U.S. Choi and J.A. Eastman	1995	Cu-Water	Theoretical Model	k of nanofluid depends on vol. conc. and shape
2	Abbas et al.	2013	CNT-POE	R713 lab unit	h is max. at 0.1 vol. conc.
3	Koca et al.	2013	Various	Review	Effects of μ on various particle size
4	Hady et al.	2017	Al_2O_3/H_2O	Water-air conditioning unit	Lesser power consumption and increased COP of the unit
5	Ali Barati-Harooni et. al	2017	Various nanofluids	Theoretical Models	Proposed 4 models for measuring μ
6	Han et.al	2017	Al_2O_3/Water	Double Tube Heat Exchanger	h increases with vol. conc. and temperature. Nu also increased
7	Ferrouillat et al.	2011	SiO_2/Water	Horizontal Tube section	μ & k calculated wrt temperature. PEC defined
8	Ndoye et al.	2014	Various	Model based on Effectiveness-NTU method	With increase in vol. conc. h, Pressure Drop & pumping power increases
9	Ebrahimnia-Bajestan et al.	2015	TiO_2/Water	Laminar flow through a uniformly heated tube	With increase in vol. conc. heat transfer increases
10	Vasconcelos et al.	2016	SWCNT/Water	Indirect-VCRS	Better Refrigeration Capacity and COP

3. Conclusion

- After going through the investigation of heat exchanger using nano fluid it is found that the heat transfer depends as the volume concentration of nano particles increases in nano fluid.
- Also found that the specific heat capacity of fluid carrying heat increases after adding nano particles.
- After adding the nano particle in fluid the thermal conductivity of the fluid increases which helps in increasing the heat transfer rate.
- To increase the performance of heat exchanger different nano particles where used at different volume fraction at different nano particle size range.
- Also addition of nanoparticles increases the density of the fluid. This increased density results in higher pumping power.
- Also addition of nanoparticles results in pressure drop. But the effect of pressure drop is negligible at lower concentrations.

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