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Heat Transfer Analysis Of Shell And Tube Heat Exchanger Using Aluminium Nitride - Water Nanofluid

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Abstract— Heat exchanger plays a major role in the industrial process heating. Heat is transferred between fluids by convection and conduction through the walls of the heat exchanger. Heat transfer fluids have low thermal conductivity that greatly limits the heat exchanger efficiency. Many research activities are carried out to improve the thermal properties of the fluids by adding thermally conductive solids into liquids.Liquid mixed with nanoparticles known as "nanofluid", exhibit substantially higher thermal conductivity than those of the corresponding base fluids.In this work a new nanofluid system has been developed by synthesizing aluminium nitride nanoparticles with water and applied in a shell and tube heat exchanger. The thermal transport properties of this nanofluid, including thermal conductivity and heat transfer coefficient are characterized.The results show that this nanofluid possesses higher thermal transport properties and it has been experimentally proved that this nanofluid has the potential to be used as advanced heat transfer fluid.

Keywords: Thermal Conductivity,Nanofluid,Heat Exchanger.

I. Introduction

Heat transfer plays an important role in numerous applications. For example, in vehicle, heat generated by the prime mover needs to be removed for proper operation. Similarly, electronic equipment dissipate heat, which requires a cooling system. Heating, ventilating and air conditioning systems also include various heat transfer processes. Heat transfer is the key process in thermal power stations. In addition to these, many production processes include heat transfer in various forms; it might be the cooling of a machine tool, pasteurization of food, or the temperature adjustment for trigerring a chemical process. In most of these applications, heat transfer is realized through some heat transfer devices; such as, heat exchangers, evaporators, condensers, and heat sinks. Increasing the heat transfer efficiency of these devices is desirable, because by increasing efficiency, the space occupied by the device can be minimized, which is important for applications with compactness requirements. Furthermore, in most of the heat transfer systems, the working fluid is circulated by a pump, and improvements in heat transfer efficiency can minimize the associated power consumption.There are several methods to improve the heat transfer efficiency. Some methods are utilization of extended surfaces, application of vibration to the heat transfer surfaces, and usage of micro channels. Heat transfer efficiency can also be improved by increasing the thermal conductivity of the working fluid. Commonly used heat transfer fluids such as water, ethylene glycol, and engine oil have relatively low thermal conductivities, when compared to the thermal conductivity of solids.

High thermal conductivity of solids can be used to increase the thermal conductivity of the fluid by adding small solid particles to that fluid. The feasibility of the usage of such suspensions of solid particles with sizes on the order of millimetres was previously investigated by several researchers and significant drawbacks were observed. These drawbacks are sedimentation of particles, clogging of channels and erosion in channel walls, which prevented the practical application of suspensions of solid particles in base fluids as advanced working fluids in heat transfer applications.

Sidi El Becaye Maıga , Samy Joseph Palm, Cong Tam Nguyen,Gilles Roy, Nicolas Galanis[1]. investigated that the present paper, the problem of laminar forced convection flow of nanofluids has been thoroughly investigated for two particular geometrical configurations, namely a uniformly heated tube and a system of parallel, coaxial and heated disks. Numerical results, as obtained for water–cAl2O3 and Ethylene Glycol–cAl2O3 mixtures, have clearly shown 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.

Yimin Xuan , Qiang Li [2]. Showed that the paper presents a procedure for preparing a nanofluid which is a suspension consisting of nanophase powders and a base liquid. By means of the procedure, some sample nanofluids are prepared. Their TEM photographs are given to illustrate the stability and evenness of suspension. The theoretical study of the thermal conductivity of nanofluids is introduced. The hot-wire apparatus is used to measure the thermal conductivity of nanofluids with suspended copper nanophase powders. Some factors such as the volume fraction, dimensions, shapes and properties of the nanoparticles are discussed.

S. Bhanuteja, D.Azad [3]. paper reports the thermal performance of a Counter-flow Shell and Tube Heat exchanger using nanofluids as the working fluids. Finite volume Method was used to solve the three dimensional steady, turbulent developing flow and conjugate heat transfer in a Shell and tube heat exchanger. The nanofluids used were Ag, Al2O3, CuO, SiO2, and TiO2 and the performance was compared with water. The thermal performance and flow of the Shell and tube heat exchanger was analyzed using different nanofluids. Temperature profile, heat transfer coefficient, pressure profile, was obtained from the simulations. The results are evaluated in terms of effectiveness, heat transfer rate, and Overall heat transfer coefficient.

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Andre L.H. Costa, Eduardo M. Queiroz [4]. studied that the design optimization of shell-and-tube heat exchangers. The formulated problem consists of the minimization of the thermal surface area for a certain service, involving discrete decision variables. Additional constraints represent geometrical features and velocity conditions which must be complied in order to reach a more realistic solution for the process task.

B. Farajollahi, S.Gh. Etemad , M. Hojjat [5] experimentally investigated that the heat transfer characteristics of c-Al2O3/water and TiO2/water nanofluids were measured in a shell and tube heat exchanger under turbulent flow condition. Based on the results, adding of naoparticles to the base fluid causes the significant enhancement of heat transfer characteristics. For both nanofluids, two different optimum nanoparticle concentrations exist. Comparison of the heat transfer behavior of two nanofluids indicates that at a certain Peclet number, heat transfer characteristics of TiO2/water nanofluid at its optimum nanoparticle concentration are greater than those of c-Al2O3/water nanofluid while c-Al2O3/water nanofluid possesses better heat transfer behavior at higher nanoparticle concentrations.

P.C. Mukeshkumara, J. Kumarb, S. Sureshc, K. Praveen babuc [6]. studied the heat transfer coefficients of shell and helically coiled tube heat exchanger using Al2O3 / water nanofluid were studied. This study was done by changing the parallel flow configuration into counter flow configuration under laminar flow regime. The Al2O3 / water nanofluid at 0.4% and 0.8% particle volume concentration were prepared by using two step method. The nanoparticles were characterized by X-Ray diffraction (XRD) and Scanning Electron Microscope (SEM). It is found that the overall heat transfer coefficient of counter flow was 4-8% higher than that of parallel flow at 0.4% nanofluid. The overall heat transfer coefficient was found to be 5-9% higher than that of parallel flow at 0.8% nanofluid.

Prof. Alpesh Mehta, Dinesh k Tantia , Nilesh M Jha , Nimit M Patel [7]. showed the research work on heat exchanger using nano fluid. In this paper we are using compact heat exchanger as heat transferring device while Al2O3 as a nano fluid. The effect of the nano fluids on compact heat exchanger is analyzed by using 6 –NTU rating.

The literature survey gave an idea for approaching this project work efficiently.

II. METHODOLOGY

EXPERIMENTAL SETUP DETIALS

The setup consists of inner tube and outer tube. The inner tube is provided with an external fin, to improve the active surface area.The total length of the inner tube is 1000mm.The total length of outer tube is1100mm.The inner and outer pipe are made of G.I& Copper.The outer tube is insulated with asbestos rope to minimize heat loss to the surroundings. Four thermometers are used to measure the inlet and outlet temperature of the hot and cold water.

Fig.1 Experimental Setup

Table 1 Aluminium Nitride Nanoparticle Properties

Appearance	Gray powder
purity	99.5%
Crystal phase	Solid
Bulk density	0.05 g/cm^3
Melting point	2200^{o}C
Boiling point	2517^{0}C
Thermal conductivity	320 W/m.K
Thermal expansion coefficient	3.5*10^{-6} K^{-1}
Solubility	Soluble in water

III. RESULTS AND DISCUSSION

Table 2 Experimental Data For Water as a Cooling Fluid

Time taken for one litre water collection	Hot water inlet temperature	Hot water outlet temperature	Cold water inlet temperature	Cold water outlet temperat ure
Litre/sec	^{o}c	^{o}c	^{o}c	^{o}c
44	50	46	28	31
43	60	52	28	34
42	70	55	28	35
40	80	60	28	36
37	90	65	28	38

Table 3 Water As A Cooling Fluid Numerical Data

Temperature	Mass flow rate	Heat transfer rate	LMTD
^{o}c	Litre/sec	W/m2	
50	0.0227	0.3109	18.4955
60	0.0233	0.7629	24.9867
70	0.0238	1.1047	30.8272
80	0.0250	1.5035	37.6821
90	0.0270	2.2834	44.0754

Table 4 Water as a Cooling Fluid Numerical Data

Temperature	Overall heat transfer rate	NTU	Effectiveness
^{o}c	W/m^{2}K		%
50	0.3437	0.2162	18.18
60	0.5224	0.3202	25
70	0.8108	0.4866	35.71
80	0.9290	0.5307	38.46
90	1.0722	0.5672	40.32

Table 5 Experimental Data For Nanofluid As A Cooling Fluid

Time taken for one litre water collection	Hot water inlet temperature	Hot water outlet temperature	Cold water inlet temperature	Cold water outlet temperature
Litre/sec	^{o}c	^{o}c	^{o}c	^{o}c
45	50	45	28	34
44	60	48	28	35.4
43	70	53	28	36
41	80	58	28	39
38	90	59	28	41.5

Table 6 Experimental Data For Nanofluid As A Cooling Fluid

Temperature	Mass flow rate	Heat transfer rate	LMTD
^{o}c	Litre/sec	W/m2	
50	0.0222	0.3801	16.4949
60	0.0227	0.7805	22.2207
70	0.0232	1.4946	29.2697
80	0.0244	2.0934	35.2141
90	0.0263	2.8260	39.0995

Table 7 Experimental Data For Nanofluid As A Cooling Fluid

Temperature	Overall heat transfer rate	NTU	Effectiveness
^{o}c	W/m^{2}K		%
50	0.3152	0.3032	22.73
60	0.5741	0.5400	37.5
70	0.6311	0.5808	40.48
80	0.7140	0.6248	42.31
90	0.9766	0.7929	50

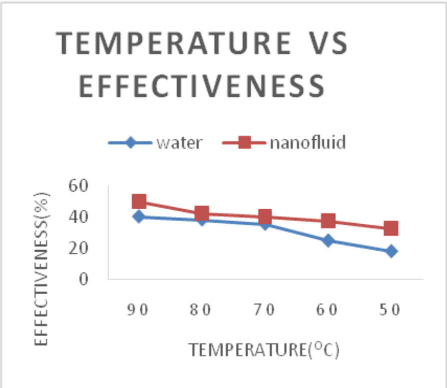

Figure 2 shows the effectiveness variation with respect to the temperature water and nanofluid as a cooling fluid

Above figure 2 shows the variation of effectiveness with different temperature. Effectiveness is decreasing with decreasing the temperature, but nanofluid effectiveness is high comparing with water. Because heat transfer rate of nanofluid is high, metal particle added into water, so increasing the heat absorbing rate of nanofluid and increasing the effectiveness comparing with water.

IV. CONCLUSION

In this work the convective heat transfer of nanofluids which depends on many parameters such as particle size, particle material, temperature and base fluid type are considered. A systematic study about these aspects of nanofluid heat transfer provides valuable information for the optimization of heat transfer enhancement with nanofluid.In this work aluminium nitride-water nanofluid is used because of its high melting point, low density and high structural stability. An increase of 9.68% of effectiveness is obtained, where aluminium nitride nanoparticles are used than with water.

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