A Review on Fin and Tube Heat Exchanger with Nanofluids as a Coolant

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Abstract--- Finned-tube heat exchangers are one of the types of heat exchanger in which it is one of the most and vital components in many energy systems such as heating, ventilating, refrigeration and in air conditioning systems. In recent days many advancement in the heat exchanger have been done in order to increase the heat transfer rate in which nanofluids play a major role in today's research. A nano fluid is a fluid containing nanometre sized particles, called nanoparticles. These fluids are engineered colloidal suspension of nanoparticles in a base fluid. Nanofluids have special properties that make this fluid to potentially useful in many applications in heat transfer system, in domestic refrigerator, in heat exchanger and so on. This paper reveals the characteristics performance of fin and tube heat exchanger by using various Nanofluids and there by analysing the corresponding heat transfer rate for different Nanofluids. Since the nanoparticles used in Nanofluids are typically made of materials such as metals, oxides, carbides, or carbon nanotubes.

Keywords--- Fin and Tube Heat Exchanger, Nanofluids, Nanoparticles.

I. INTRODUCTION

Heat transfer is considered to be the one of most important feature in the thermal and engineering field. By looking into the past histories many researches and efforts have been done in order to enhance the heat transfer rate. By enhancing the heat transfer rate corresponding increase in energy and fuel efficiency can be obtained for this purpose fins are used. Fins are extended surfaces which are used to increase the heat transfer by convection by increasing the surface area. In recent day's heat exchangers with large fin spacing and an inline tube pattern are used because of their relatively low cost and tolerance to condensate and frost accumulation, in comparisons to more compact designs. A.Jordar and A.M.Jacobi studied that for the contemporary plain-fin heat exchanger, the thermal resistance in air-sides is very much greater than other thermal resistance. They also studied that it is important to increase the air side pressure drop in order to improve the heat transfer rate by vortex generator. They found that the increase in heat transfer coefficient from 29.9% to 68.8% with Reynolds number in the range of 220 to 960 with the pressure drop of 26% at Re=960 and 87.5% at Re=220 for three row vortex generator [1]. However the average heat transfer coefficient on the gas side of a fin and tube exchanger can be obtained by introducing the longitudinal vortices on the flow. The researchers also found that the air-side thermal resistance was reduced to about 35 to 42% by using vortex generator for the Reynolds number between 500 to 1300 [2][3]. Whereas for the different fin pitches at 3.6, 4.2, and for 6.2 mm the heat transfer rate was increased in spiral fin and tube heat exchangers for the Reynolds number in the range of 4000 to 15000 in which this type of heat exchangers was now a days was used in the economizer heat exchanger [4]. Junqi dong, Lin su, Qian Chen and Weiwu xu investigated an experimental study on thermal hydraulic performance for fin and tube heat exchangers with wavy fin and found a pressure drop using multiple regression method [5]. However the presence of

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rectangular winglets in compact fin and tube exchanger the researchers found that significant increase in the performance of heat transfer rate with a medium pressure loss [6]. In recent days many researchers done a research on nano fluid to use it as a coolant in fin and tube heat exchanger by replacing water in which nano fluid has a higher efficiency than the water. This review paper explains the characteristics performance of nano fluid in fin and tube heat exchangers.

II. NANO BASED FLUIDS

In recent days enhanced heat dissipation is obtained using nano coolant. The coolant with high heat dissipation is used to enhance the cooling efficiency. There are numerous researches have been done on this to use a nano material as coolant. The main purpose of using nano fluid is to obtain excellent thermal conductivity and to enhance the heat transfer rate [7]. The author observed that thermal conductivity of nano fluids increased by increasing the solid particle concentration in Base fluids [21]. The authors Y.Vermahmoudi and S.M.Peyghambarzadeh had done a research under laminar flow conditions by using 0.15, 0.4, and 0.65 vol % of stabilised Fe_2O_3 and water nano fluid with varying flow rates in the range of 0.2 to 0.5 m^3/h under varying working temperature between 50^0 C to 80^0 C , they found improvement in the heat transfer performance [8]. While using carbon nano tubes, coated rectangular brass fins the scientist achieved the improvement in the heat transfer rate of about 12% while comparing it to the ordinary rectangular fins [9]. Whereas the scientist Hwa-Ming Neigh, Tun-Ping Teng, Chao-Chieh Yu draw a comparison between aluminium oxide (Al_2O_3) and titanium oxide (TiO_2) found a heat dissipation rate of titanium oxide (TiO_2) is higher than the aluminium oxide (Al_2O_3) [10]. Whereas in the case of copper-water nanofluid in different plate-fin channels the authors M.Khoshvaght-Aliabadi, F.Hormozi, and A.Zamzamian found that the decrease in the values of pressure drop for the corresponding increase in the nanoparticles weight fraction. They produced the copper-water nanofluid by using electro-exploded wire technique [11]. However the nanofluids having blades and platelets shapes of nanoparticles have found to have the very low overall heat transfer coefficient as compared to the cylindrical shape nanofluid [12]. Also, under several experimental conditions the author found that the base fluid (water) has very low thermal conductivity than the corresponding nano fluids [14].

A. Properties of Nanofluids

The following chemical and physical properties of the nanofluids are

Fe_2O_3 nanoparticle:

Mean size	: 40nm [8]
Density (Kg/m^3)	: 5250
Specific heat (J/Kg K)	: 650
Thermal conductivity (W/m K)	: 20
Water adsorption	: less than 0.2%
Purity	: 99%

Carbon Nano Tubes Coated on Brass Fin

Type of nano tubes used	: MWNT [9]
Outer diameter of tube	: 10 – 20 nm
Purity	: greater than 95%
Method used for coating	: Physical Vapour Deposition

Oxide Nanofluid

Nano particle type	: TiO_2
Nano particle size	: 20 – 30nm [10]
Density	: 3900 Kg/m^3
Nano particle type	: Al_2O_3
Nano particle size	: 10 – 20nm [10]
Density	: 3880 Kg/m^3
Specific heat	: 765 J/Kg/K
Nano particle type	: CuO [14]
Thermal conductivity	: 400 W/m K
Density	: 89.33 Kg/m^3
Specific heat	: 385 J/Kg K

Ethylene Glycol Nano Fluids

Density : 1030 Kg/m^3

Specific heat : 3.90 KJ/Kg K

Thermal conductivity : 0.512 W/m K

These are some of the nano fluids in which it is commonly used in the heat exchanger as a nano coolant because of its higher thermal conductivity and higher heat transfer efficiency than the water [14]. Still many researches are done on nano fluids to enhance its physical and chemical properties for quick and fast heat dissipation rate without affecting the system.

III. EXPERIMENTAL ANALYSIS OF FIN AND TUBE HEAT EXCHANGER

Author	*Fin type*	*Fin size*	*Reynolds number*	*Result and observation*
A.M.Jacobi[1]	Compact plain fin and tube heat exchanger	101.6*177.8mm 0.375mm dia of tube	220-960	Found 40% increase in the heat transfer coefficient than in single winglet arrangement.
H.A.Mohammed [6]	Fin and tube compact heat exchanger.	Thickness of winglet 0.2mm and attack angle is 30^0.	400-800	They found that the heat transfer performance is improved by using wavy rectangular winglet.
Jianlin Yu [3]	Perforated fin-tube heat exchanger	Fin thickness 0.2mm and perforated dia 4. 5 and 6mm	750-2350	Found reduced in the heat transfer rate by 6.5% at Re=750.
Somachi Wongwises [4]	Spiral fin and tube heat exchangers	Fin thickness 1mm and tube inside diameter is 21.2mm	4000-15000	For a given Reynolds number and a fin pitch they found increasing in pressure drop with decrease in fin pitch.
Jiin-Yuh Jang [13]	Plate-fin and tube heat exchanger		400-3000	Improved heat transfer rate in the wake region at 45^0.

IV. PERFORMANCE OF HEAT EXCHANGER WITH NANOFLUIDS:

Author	**Nanofluids type**	**Proportion**	**Base fluid**	**Nanoparticles size**	**Result and observation**
S.M.Peyghambarzadeh [8]	Fe_2O_3	0.65vol % at Re=600	Water	40nm	Overall heat transfer coefficient is found be about 13% more than the distilled water.
Rajendran Senthilkumar [9]	Carbon nanotubes with brass coated				Found to be increase in the heat transfer rate of about 12% in coated tubes than the non coated tubes.
Tun-ping Teng [10]	Oxide nano-coolant (Al_2O_3 & TiO_2)	Both the nano-coolant and EG was mixed in the 1:1 ratio	Ethylene Glycol	Al_2O_3= 50nm & TiO_2= 50nm	Heat dissipation capacity of oxide nano-coolant is found to be more efficient than EG/W nano-coolant.
Dr.Dhananjaya D.A [14]	CuO		water		Observed that the thermal conductivity of water is lesser than the nano fluids.
Hwang et al [15]	Al_2O_3	0.3 vol % at Re=200-1400	water	30nm	Found increase in the heat transfer coefficient of above 8%.
Heris et al [16]	Al_2O_3 & CuO	3.0 vol % at Re= 650-2050	Water	Al_2O_3 =20nm & CuO=50-60nm	They found the increase in the performance of Al_2O_3 nanofluid than the performance of CuO nanofluid at large volume fractions.
Nguyen [17]	Al_2O_3	6.8 vol % at Re=3000-7000	Water	36nm	Performance of Al_2O_3 is found to be enchanced about 40% than the base fluid.
D.Madhesh [18]	Ag	0.2-2.0 vol % at Re=350-700	Ethylene Glycol	10-65nm	They found increase in the pressure drop of about 22.2%
He et al [19]	TiO_2	1.1 vol % at Re=700-6500	Water	95nm	They observed that the performance of heat transfer coefficient is found to be more efficient in turbulent condition than in laminar condition.

By seeing the above results and observation it is very well confirmed that the heat exchanger using nano fluids as coolant is high efficient than ordinary coolant such as distilled water. It is also observed that increasing the concentration of nano particle in base fluid will increase the surface area [20] hence heat transfer will be more.

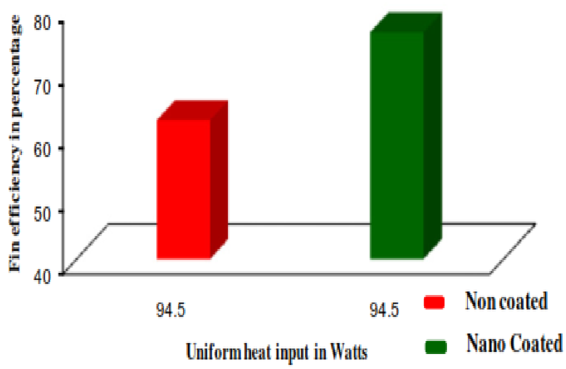

Figure 1: Comparisons between Fin with Nano Coated and Non-coated [9]

This result was obtained by the author Rajendran Senthikumar et al by doing the research with nano coolant [9], under the same heat input for two different heat exchanger in which one of the heat exchanger is coated with nanoparticle. In which result showed the increase in efficiency for the heat exchanger coated with nanoparticle in comparison with the other which is not coated.

V. Application of Nano Fluid

Nanofluids are liquid-solid suspensions in which particles with the size of 1-100nm are suspended in a heat transfer fluid. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. Nanofluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficients compared to those of base fluids like oil or water.

Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/ vehicle thermal management, domestic refrigerator, heat exchanger, nuclear reactor coolant, in grinding, machining, and in boiler flue gas temperature reduction. The applications of nanofluids are as follows:

Heat Transfer Applications

Industrial Cooling Applications

Using nanofluids for industrial cooling could result in great energy savings and also result in emissions reductions.

Nuclear Reactors

Nanofluids can be utilised in nuclear applications for improving the performance of any water-cooled nuclear system that is heat removal limited. Possible applications include pressurized water reactor (PWR) primary coolant, standby safety systems, accelerator targets, plasma diverters and so forth.

VI. Result and Conclusion

From the above research papers it is confirmed that the heat exchanger working with nanofluid has better efficiency and enchanced hear transfer coefficient rate than the ordinary heat exchanger. The researchers also studied that the nanofluids mixed with different material of base fluid has better thermal performance thus conventional heat transfer fluids limitation is overcomes by it. When increasing the Reynolds number the velocity of the flow will be increased. Due to this, increasing of Nusselt number leads to more convective heat transfer rate. Hence increasing the Reynolds number leads to increasing the outlet temperature.

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