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Review Article

A Review on Use of nanofluids for heat exchangers

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Abstract

A heat exchanger is a device that is used for thermal energy exchange. It may be within the solid or solid fluid interface or within the gas itself having temperature gradient. Heat exchanger is vital from industry point of view having good efficiency and also having an economic running cost. Study is been conducting on enhancing the heat transfer rate. The paper proposes the research and practical work done on tube heat exchanger by using nanofluids which is a heat transfer augmentation technique.

Keywords: *Heat exchanger, nanofluids, thermal conductivity, effectiveness*

1. Introduction

From industry point of view, it is important to increase the efficiency of heat transfer equipment which are been installed. Heat exchanger is a device which is majorly used for heat transfer applications in areas like power engineering, food industries, petroleum refineries, chemical industries, refrigeration, air conditioning, power plants, sewage treatment, natural gas processing and so on. Heat exchanger is an device equipped for transferring heat from one medium to another in an efficient manner. Transfer of heat from one medium to another is nothing but the energy transmission from one region to another region because of temperature difference between them. Second law of thermodynamics plays an vital role among the several laws which governs the heat transfer. Second law of thermodynamics states that,"Heat cannot flow from body at lower temperature to body at higher temperature" High thermal conductivity is an important requirement for better heat transfer. Use of nanofluids for enhancing the heat transfer capacity of heat exchanger has increased in recent years because of their anomalously high thermal conductivity. Nanofluids are recent advancements in the field of nanotechnology. Nanofluids have very high thermal conductivity compared to the base fluids from which they are formed. Many studies have been conducted for enhancing the heat transfer capacity of heat exchanger but owing to the good thermal properties and advancement in the nanotechnology in recent years nanofluids are considered by many researchers for their studies.

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2. Literature Review

It is the only quest to increase the efficiency of heat exchanger which has encouraged researchers to take up the study in the direction of use of nanofluids. Study has been conducted to analyze use of various types of nanofluids in the heat exchangers. The thermal properties of various nanofluids are studied and comparative study has been conducted by many researchers in recent years.

Adnan M. Hussein,R.A. Bakar, K. Kadirgama and K.V. Sharma performed experiments to study thermal properties of nanofluids. Basically three nanofluids and their properties were studied. Alumina (Al_2O_3), Titania (TiO_2) and Silica (SiO_2) in water were conducted in the 1 to 2.5% volume concentration. Viscosity and thermal conductivity were calculated for all the three nanofluids and results were analyzed. Hot wire method and viscometer were used for thermal conductivity and viscosity measurement. The results showed that alumina has highest thermal conductivity followed by silica and titania whereas silica has highest viscosity followed by alumina and titania. The study also showed that the thermal conductivity of nanofluids increased with rise in temperature and volume concentration. M. Hasanuzzaman, R. Saidur and N.A. Rahim performed study for enhancement in effectiveness of heat exchanger by using nanofluids. As heat is transferred in heat exchanger by convection from working fluid and conduction through wall so convective heat transfer coefficient plays an important role in the enhancement of effectiveness of heat exchanger. The convective heat transfer coefficients of nanofluids like Cu-water, Al-water, Al_2O_3-water, TiO_2-water having 2% nanoparticle concentrations were calculated and compared with pure water. It was found that the convective heat transfer coefficient of CuO-water was 81% higher than water followed by Al_2O_3-water, TiO_2-water and Al-water having convective heat transfer 66%, 64% and 63% higher than pure water respectively. Also overall heat transfer coefficient of Cu-water was highest as 23% followed by Al_2O_3 with 21% compared to pure water. The overall heat transfer coefficient of Al-water and TiO_2-water was 20% higher than that of pure water. Increase in convective heat transfer coefficient increases the overall heat transfer coefficient which enhances the effectiveness of heat exchangers. Increasing the nanoparticle volume concentration is one of the effective way to increase the convective heat transfer coefficient. Hence the use of nanofluids increased the effectiveness of heat exchanger compared to the base fluids. Chandrashekhar and others carried out the experimental studies for investigation of Thermal conductivity and viscosity of the Al_2O_3-water nanofluid. It was observed that thermal conductivity as well as viscosity both increased with increase in volume concentration of nanoparticle. Nanoparticles were prepared by microwave assisted chemical precipitation method. The prepared nanoparticles are then distributed in distilled water using sonicator. Sonicator is the device which works by applying sound energy to agitate particles in a sample of ultrasonic frequencies. Theoretical and experimental values were in a good agreement with each other.

The use of metallic nanoparticles for increasing the heat transfer in heat exchanger was studied by several researchers and obtained good positive results. The thermal conductivity of metallic liquids is higher than non metallic fluids. Hence thermal conductivities of the fluids having suspended metallic nanoparticles have higher values than that of conventional heat transfer fluids.

Hussein and others carried out experiments to calculate thermal properties of various materials at room temperature for studying their applications in heat exchanger. Results obtained by this study clearly depicted that metals have very high thermal conductivity than non metals. Hence metallic nanoparticles are preferably suitable for heat transfer application.

Sen Gupta and others performed experimental study for measurement of thermal conductivity in graphene nanofluids with the use of hot wire method. The hot wire method is based on measurement of temperature rise in a defined distance from a linear heat source (Hot wire). Thermal conductivity can be derived directly from the resulting change in temperature over known interval of time.

3. About nanofluids and heat exchangers

Nanofluids are the liquid which contain particle having size smaller than 100μm to form a suspension. Nanofluids have a very useful properties for the transfer of heat from one medium to another. They have higher conductivity and viscosity than their base fluids. This favorable properties of nanofluids for heat transfer has attracted many researchers for the past decade. This thermal behavior of nanofluid can bring a huge transformation and innovation in the heat transfer. Heat transfer has major importance in number of industrial sectors which includes micro manufacturing, power generation, transportation, heating, air conditioning, refrigeration as well as chemical and metallurgical sectors. Hence this innovation in the nanofluids can make big transformation in various engineering sectors.

Heat exchanger is simply a device which transfers heat from hot medium to cold medium with maximum rate.The use of nanofluid in place of traditional working fluid in heat exchanger increases the heat transfer rate in a significant manner.

4. Preparation of nanofluid

Basically there are two ways of preparing nanofluid. They are

-Two step method
-One step method

In two step method, nanoparticles are first prepared as powder. This powdered nanoparticles are then dispersed in base fluids like water or ethylene glycol to form nanofluids. Two step method is basically preferred nowadays as nanopowders are commercially available. Nanoparticles formed are of spherical, rod shaped, tube shaped or disc shaped.

5. Modes of heat transfer in nanofluids

Jang and Choi derived four modes of heat or energy transfer in nanofluids.

1. Collision between base fluid molecules
2. Thermal diffusion in nanoparticles in fluids
3. Collision between nanoparticles due to Brownian motion(neglected),
4. Thermal interaction of dynamic or "dancing" nanoparticles with the base fluid molecules.

Figure 1 shows the modes of heat transfer in nanofluids

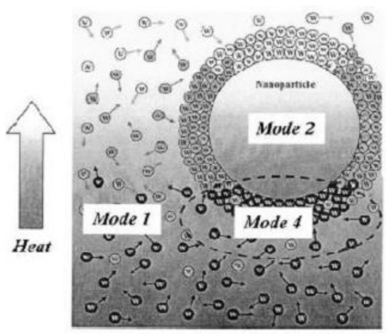

Fig 1 Modes of heat transfer in nanofluids

6. Thermal properties calculations for nanofluids

Density of nanofluid can be calculated as

$$\rho_{nf} = (1-\varphi)\rho_f + \rho_p$$

The specific heat is calculated from following

$$(\rho C_p)_{nf} = (1-\varphi)(\rho C_p)_f + \varphi(\rho C_p)_p$$

Heat transfer rate can be defined as

$$Q = mC_p\Delta T$$

The logarithmic mean temperature difference is

$$\Delta T_{lm} = \frac{(T_{wi} - T_{no}) - (T_{wo} - T_{ni})}{\ln (T_{wi} - T_{no})/(T_{wo} - T_{ni})}$$

The overall heat transfer coefficient is

$$Q = UA_s\Delta T_{lm}$$

The thermal conductivity is given by,

$$K_{nf} = k_f \frac{K_p + 2K_f - 2\emptyset(K_f - K_p)}{K_p + 2K_f + \emptyset(K_f + K_p)}$$

The viscosity of the nanofluid is given by

$$\mu_{nf} = (1+2.5\,\varphi)\mu_w$$

7. Effects of some parameters on thermal conductivity of nanofluids

Experimental studies show that thermal conductivity of nanofluids is affected by many factors like particle volume fraction, particle material, particle size, particle shape and temperature. A short summary of this parameters and their effects are discussed here.

a) Particle volume fraction:

Many authors stated that thermal conductivity of nanofluid increases with increase in particle volume fraction. Relation found between thermal conductivity and particle volume fraction was linear.

b) Particle material:

The particle material which forms larger clusters have low thermal conductivity. Since the main mechanism of thermal conductivity enhancement is accepted to be the Brownian motion of nanoparticles and the effect of Brownian motion diminishes with increasing particle size.

c) Particle size:

It is general observation that thermal conductivity increases with decreasing particle size and it shows a non linear relation. Brownian motion of nanoparticles also supports this finding.

d) Particle shape:

Spherical and cylindrical shaped nanoparticles are commonly used in nanofluid applications. Studies conclude that cylindrical nanoparticles provide higher thermal conductivity than spherical particles. One of the possible reasons of this is the rapid heat transport along relatively larger distances in cylindrical particles. At the same time it is to be considered that the viscosity of cylindrical shaped nanoparticles is relatively high and hence require large pumping power which reduces their feasibility.

e) Temperature

In nanofluids, change in temperature affects Brownian motion of nanofluids as well as the clustering phenomena which results in drastic changes in thermal conductivity of nanofluids.

Conclusion

1) In the present study, basics of nanofluids technology are explained on the basis of the work of some previous researchers.
2) Focus is given on factors by which effectiveness of heat exchangers can be enhanced by use of nanofluids.
3) Selection and preparation of nanofluid is important thing when one deals with nanofluids. Glimpses are given on methods of preparation of nanofluid as well as parameters that affect nanofluids are discussed in present study.
4) Thermal properties relations of the nanofluids are given which are essential for design purpose of heat exchangers.

Future scope

At present, there is a huge discrepancy in the studies of enhancement of thermal conductivity of the nanofluids. For the practical heat transfer applications like in heat exchangers, this gaps are needed to be eliminated for enhancing the heat transfer rate. Physical mechanisms of heat exchangers can also be studied for the better heat transfer rate. The use of twisted strip insert in heat exchanger and extending the research by taking the effects in account can also be done. The figure 2 and 3 given below shows a metallic twisted strip which can be inserted in the heat exchanger and its effects can be studied.

Fig 2. Metallic twisted tape insert

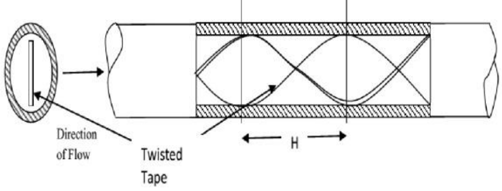

Fig 3. Twisted tape insert in tube

Nomenclature

ρ_{nf}- density of the nanofluid,
$\emptyset$ - particles volume concentration
ρ_f -density of the base fluid
ρ_p - density of the nanoparticles
Cp_{nf} - heat capacity of the nanofluid
Cp_f - heat capacity of the base fluid
Cp_p-heat capacity of the nanoparticles

Q - heat transfer rate
m - mass flow rate
ΔT - temperature difference of the cooling liquid
ΔT_{lm}- logarithmic temperature difference
T_{wi} - inlet temperature of the water,
T_{wo} - outlet temperature of water
T_{ni} - inlet temperature of the nanofluid
T_{no}-outlet temperature of the nanofluid
U - overall heat transfer coefficient
A_s- surface area
K_{nf} -thermal conductivity of the nanofluid
K_p- is thermal conductivity of the nanoparticle
K_f - base fluid thermal conductivity
μ_{nf} - nanofluid viscosity
μ_w - water viscosity

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