Role of Nano-Fluids on Heat Transfer Enhancement in Heat Exchangers: A Review

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ABSTRACT
The main aim is to study the different effects of nanofluid on heat transfer characteristics of heat exchanger. It is known that the importance of heat transfer in different industrial process is evident. Hence it becomes necessary to find ways to enhance this process. This is fulfilled by use of Nano-fluids. In this paper, the experimental results were investigated based on different parameters like volume concentration, particle size, different particles, base fluid material. Enhancement of heat transfer using different methods were studied and results were compared with conventional processes.

Keywords: Nanofluids, one step process, step process, volume fraction, twisted tapes, Nusselt no., MgO particles, Al2O3 particles, convective heat transfer coefficient.

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1. INTRODUCTION

Nanofluid is one of the nanotechnology applications which created by suspensions of nanoparticles (1-100) nm of high thermal conductivity materials into base fluid (water, oil) to improve the overall thermal conductivity and the convective heat transfer characteristics of the base fluid. Nanoparticles shapes are spherical or cylindrical. Nanofluid appears to be a very remarkable and new heat transfer fluid, it's used to enhance the heat transfer rate for many thermal systems. One process of the following are used to prepare the nanoparticles:

- Physical processes: this process including mechanical grinding and condensation of the inert gas.
- Chemical processes: this process including chemical precipitation of the particles, spray pyrolysis, and thermal sterilizing.

There are various **advantages** of nanofluid which are as follows:
1. Higher thermal conductivity, excellent stability, little penalty due to an increase in pressure drop and little damage in pipe wall due to increase of suspensions nanoparticles abrasion.
2. Even with small proportion the enhancement is promising.
3. The pressure drop across the tubes of heat exchanger remains almost constant.
4. Adjustable properties, including thermal conductivity and surface wettability, by varying particle concentrations to suit different applications.

However, there are some **limitations** which are listed below:
1. Higher production cost of nanofluids is among the reasons that may hinder the application of nanofluids in industry. Nanofluids can be produced by either one step or two steps methods. However, both methods require advanced and sophisticated equipment's.
2. Another difficulty encountered in nanofluid manufacturing is its tendency to agglomerate into larger particles, which limits it’s benefit of the high surface area. To counter these additives, have to be added.
a. Most studies to date have been limited to sample sizes less than a few hundred milliliters of nanofluids. This is problematic since larger samples are needed to test many properties of nanofluids and, in particular, to assess their potential for use in new applications.
b. Additives lead to change in surface properties, hence it is a limitation. Thereby they must be added in limited amount.

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2.THERMO-PHYSICAL PROPERTIES

- According to Maxwell, **thermal conductivity** of nanofluid is given by following equation:

  $(nf - nanofluid, bf - basefluid, p - nanoparticle)$

$$k_{nf} = \frac{k_p + 2k_{bf} + 2(k_p - k_{bf})\phi}{kp + 2k_{bf} - (k_p - k_{bf})\phi}$$

- Specific Heat ($(C_p)_{n_f}$, $nf - nanofluid, b - basefluid$) is expressed as:

$$(C_p)_{n_f} = (1 - \phi)(Cp)b + \phi(C_p)_p$$

- Density (ρ_{nf}, $n - nanofluid, b - basefluid$) is expressed as:

$$\rho_{nf} = (1 - \phi)\rho_b + \phi\rho_p$$

- Viscosity (μ_{nf}, $nf - nanofluid, \quad b - basefluid$) is expressed as:

$$\mu_{nf} = (1 + 2.5\phi)\mu_b$$

- Volume Fraction (ϕ)is expressed as:

$$\phi = \frac{\left(\frac{w_p}{\rho_p}\right)}{\left(\frac{w_b}{\rho_b} + \frac{w_p}{\rho_p}\right)}$$

Table no. 1 **Thermal conductivities of various solids and liquids [6]**

Types	Material	Thermal Conductivity (W/m-K)
Metallic solids	copper aluminum	401 237
Nonmetallic solids	silicon alumina (Al_2O_3)	148 40
Metallic liquids	sodium (644 K)	72.3
Nonmetallic liquids	Water ethylene glycol (EG)	0.613 0.253 0.145

Table no. 1 **Thermal conductivities of various solids and liquids [6]**

3. PREPARATION OF NANO-FLUIDS

There are mainly two methods for preparation of Nano-fluids which are namely:

a. One step technique

b. Two-step technique

 In the*two-step technique*, the first step is the production of nanoparticles and the second step is the dispersion of the nanoparticles in a base fluid. This method is widely used in the production of Nano-fluids. By this method, it can be produced in large quantity. The major disadvantage of this method is the Nano-particles form clusters during production which provide hindrance during its dispersion in base fluid.

 In*one-step technique*, combines the production of nanoparticles and dispersion of nanoparticles in the base fluid into a single step. Here the dispersion characteristics are better as compared to One step process. The main disadvantage of this method is that it is not suitable for mass production. Hence it is very difficult in its commercialization.

4. MATERIAL USED AS NANO-FLUIDS & BASE FLUID

Materials which are used as nano-fluids are listed below:

o Oxide ceramics – Al2O3, CuO

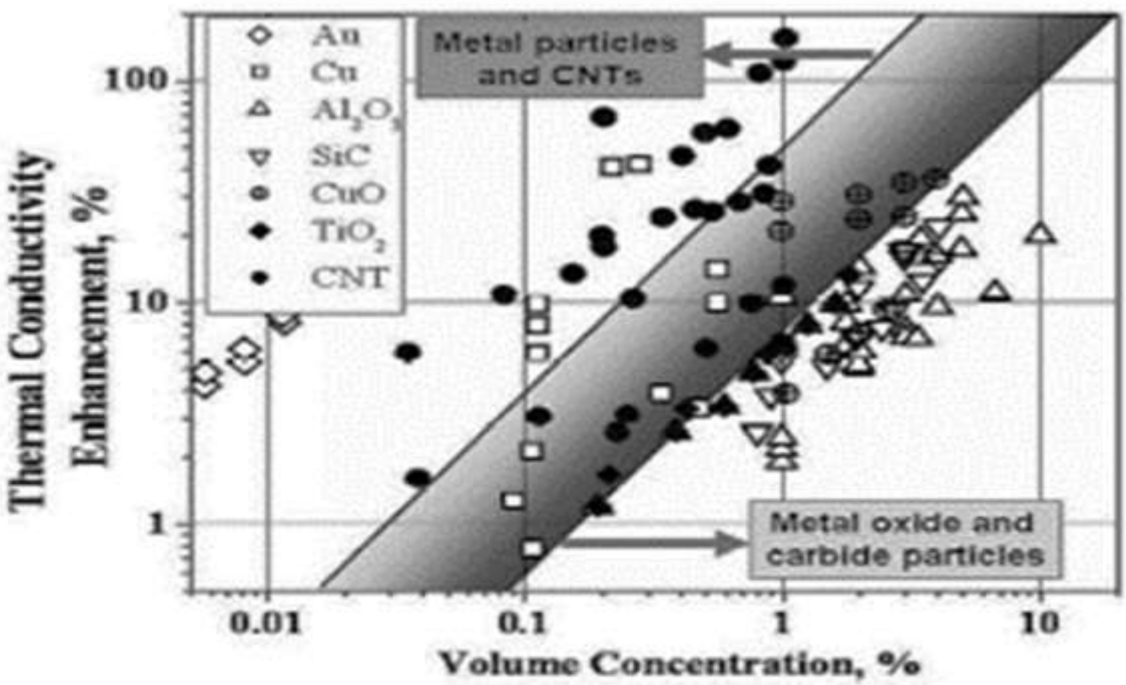
o Metal carbides – Sic

o Nitrides – AlN, SiN

o Metals – Al, Cu
o Non-metals – Graphite, carbon nanotubes, silica
o Layered – Al + Al2O3, Cu + C
Materials which are used as base-fluids are listed below:
o Water
o Ethylene- or tri-ethylene-glycols and other coolants
o Oil and other lubricants
o Bio-fluids
o Polymer solution

Table:2 Nanofluids with their Thermal conductivities, increase in nanofluids conductivity over base fluid thermal conductivity and synthesis procedure [5]

Base fluid with conductivity	Nano particles, average diameter and concentration	Method used for synthesis	Max. thermal conductivity ratio
Water 0.613	*Al2O3*, <50 nm, up to 4.3	2-step	1.08
Water 0.613	*CuO*, < 50 nm, up to 3.4	1-step	1.10
Water 0.613	*C*-MWNT 50 nm, 5 um 3 urn, 0.6 vol%	2-step	1.38
EG 0.252	*Fe*, <10 nm, 6.0 vol %	2-step	1.18
Water 0.613	*TiO2*, <15 nm,	2-step	1.30
Water 0.613	*Cu*, 18 nm, up to 5.0 vo l	2-step	1.60
Thiolate	*Au*, 10-20 nm, 0.1 vol %	2-step	1.09
Cirate	*Ag*, 6-80 nm, 0.1 vol %	2-step	1.85
EG 0.252	*Al2O3*, <50 nm, up to 5.0,vo	2-step	1.18



5. MgO NANOFLUID IN INTEGRAL HEAT EXCHANGERS [1]

• The MgO Nanoparticles used in this heat exchanger is prepared by Two-step Method. The particle was then mixed with the fluid using ultrasonic vibration device.

5

• Specifications of Mgo Nano-particles used in experimentation are:

Nanoparticle	Mean diameter (nm)	Density kg/m^3	Thermal conductivity W/m. °C	Specific heat J/kg.°C
MgO	40	3580	48.4	877

Graphs representing effect of MgO:

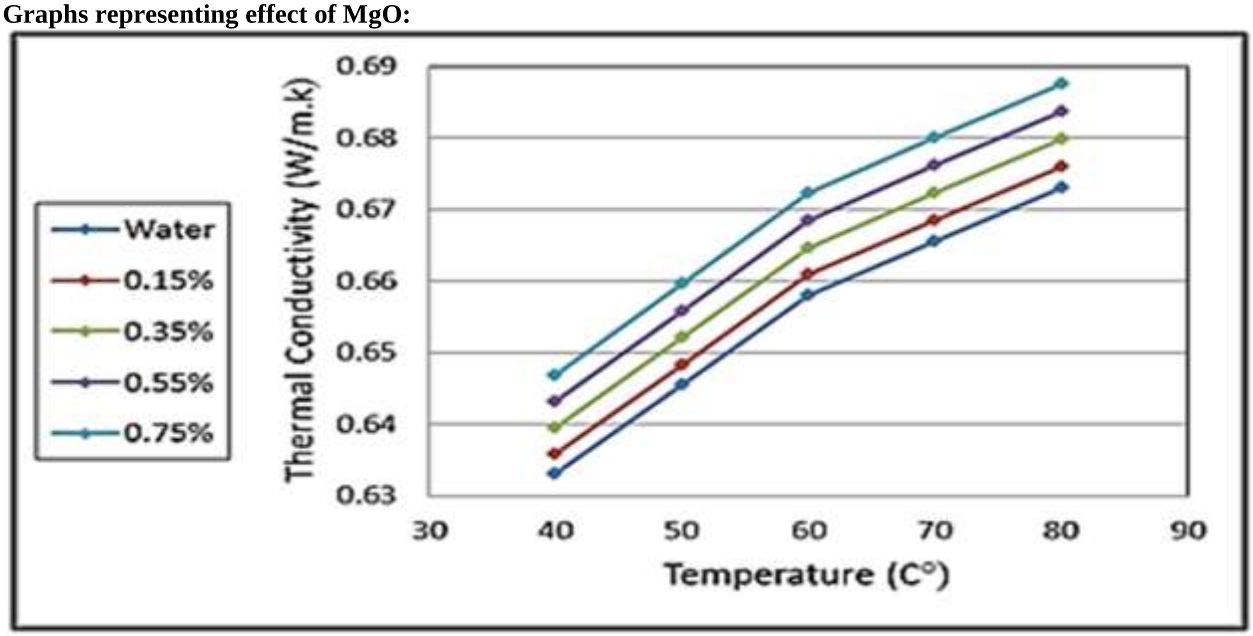


Fig.2 Effect of Vol. Concentration On

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Thermal Conductivity [1]

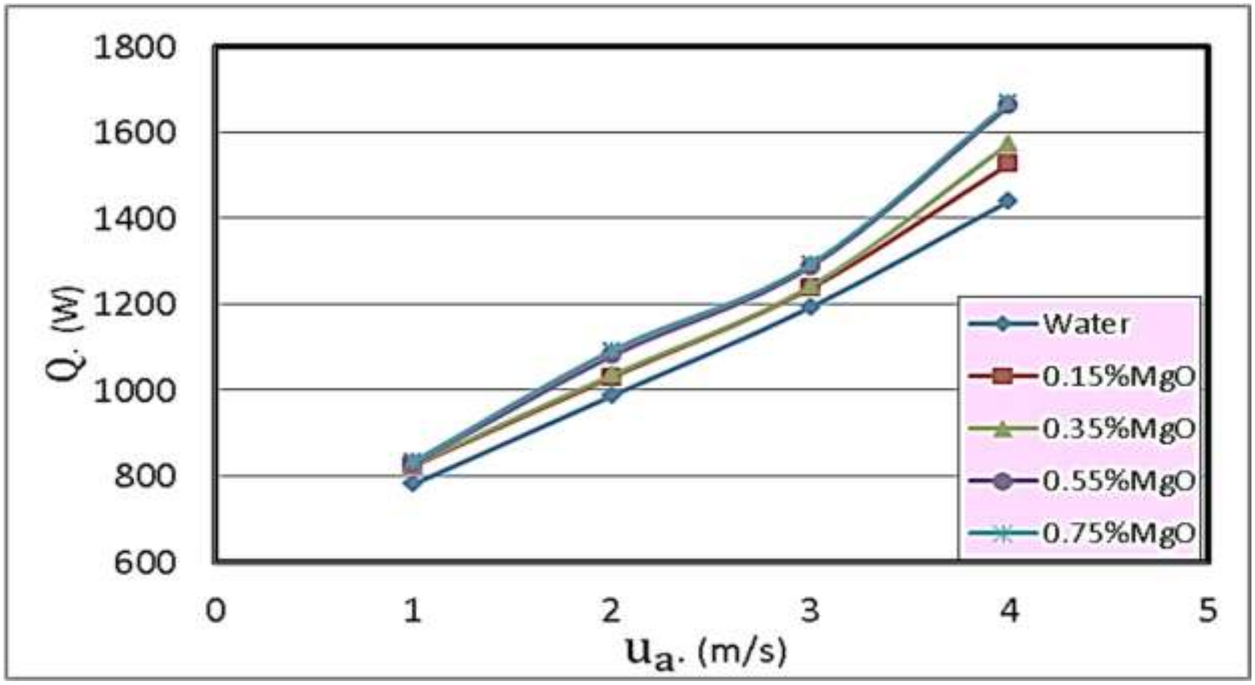

Fig.3 Variation of heat dissipation rate with water and different Nano concentration [1]

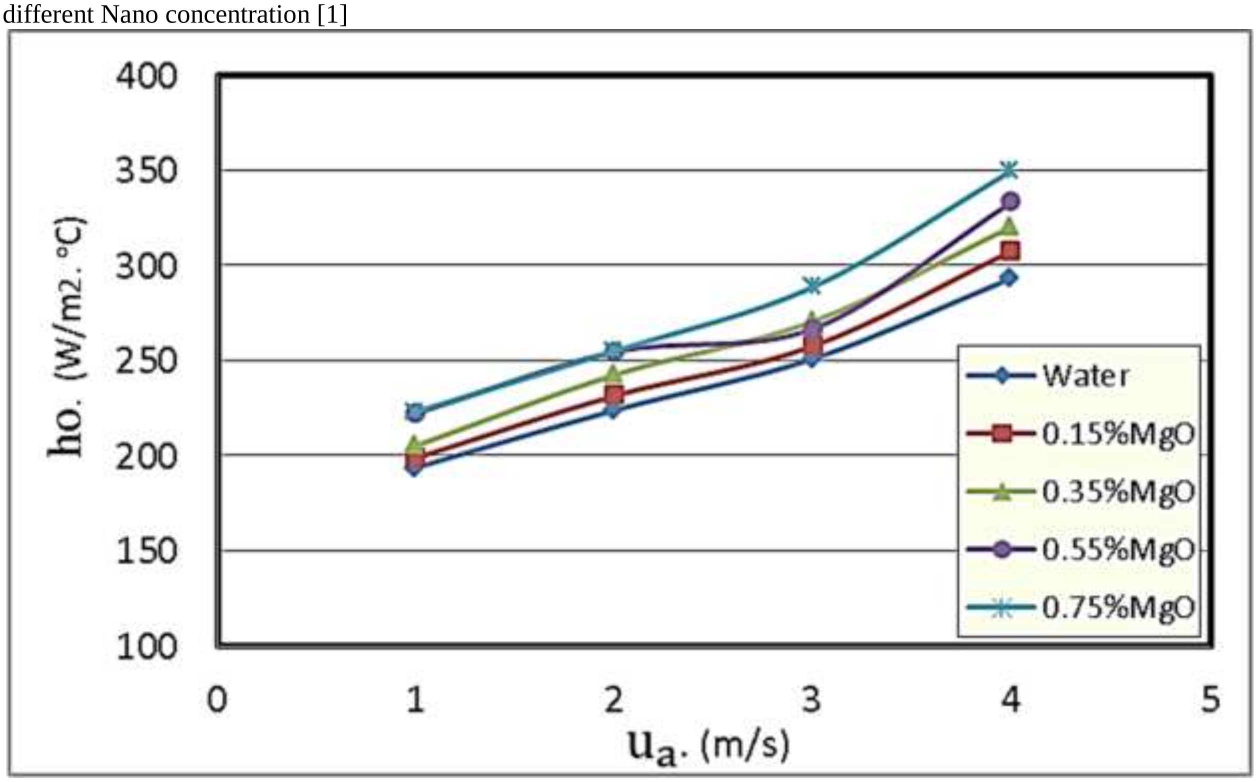

Fig.4 Variation of air side heat transfer coefficient with water and different Nano concentration [1]

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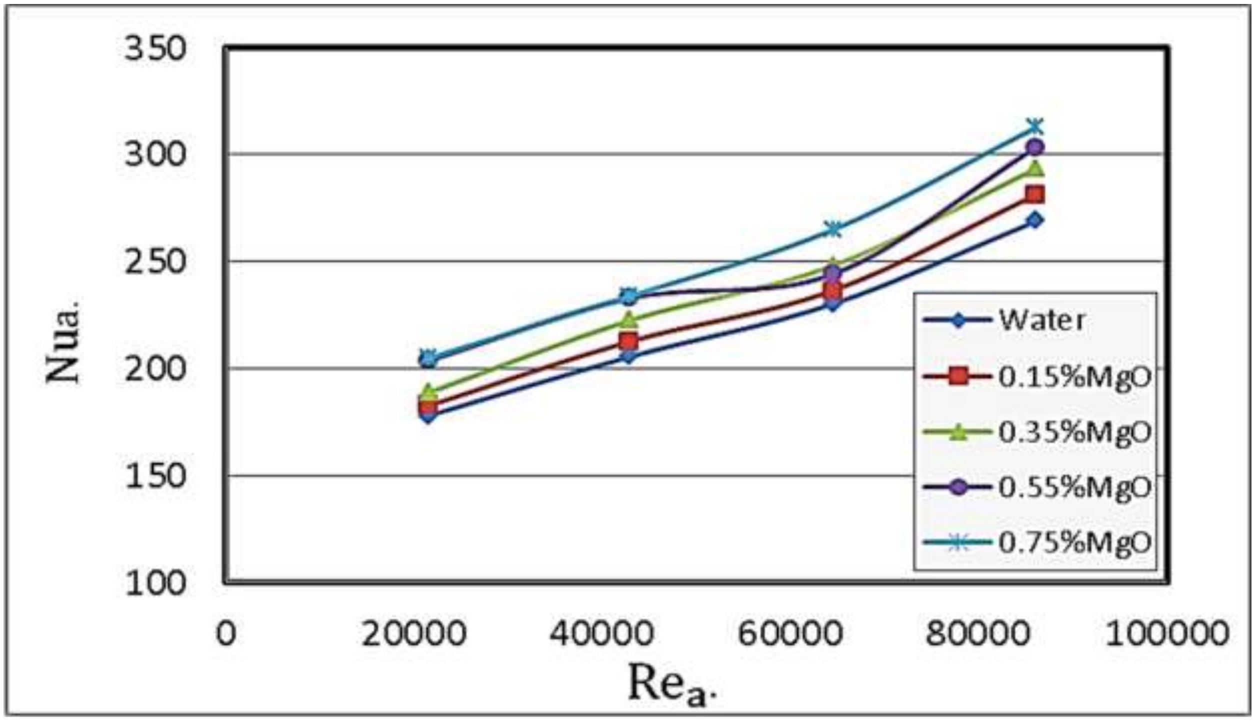

Fig.5 Variation of air side Nussle's number with water and different Nano concentrations [1]

6. AL2O3 NANOFLUID IN CIRCULAR FINNED TUBE HEAT EXCHANGER [2]

- The AL2O3 nanoparticles are also prepared using Two-Step Process.
- The produced particles are then mixed with Distilled Water To make the required fluid.
- Specifications of AL2O3 Nano-particles used in experimentation are:

Particle	Mean diameter nm	Density kg/m^3	Thermal conductivity w/m.°C	Specific heat J/kg.°C
Al_2O_3	20-30	3970	40	765

7. ENHANCEMENT OF HEAT TRASFER BY DIFFERENT METHODS & OTHER NANOFLUIDS: [3]

- It has been experimentally found that the heat transfer in heat exchangers with nano-fluids can be further increased by using some methods which are listed below:
- Use of twisted tapes fitted inside tube of heat exchangers. Shapes of such twisted tapes are:

a) Plain-Twisted Tapes(P-TT)
b) V Cut-Twisted Tapes(V-TT)
c)Horizontal wing cut-Twisted Tapes(HW-TT)

The Enhancement Factors obtained by using above tapes are:

- (P-TT) -- 3.903
- (V-TT) -- 4.267
- (HW-TT) – 4.488

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COMPARISON OF VARIANT TWISTED TAPE INSERTS:

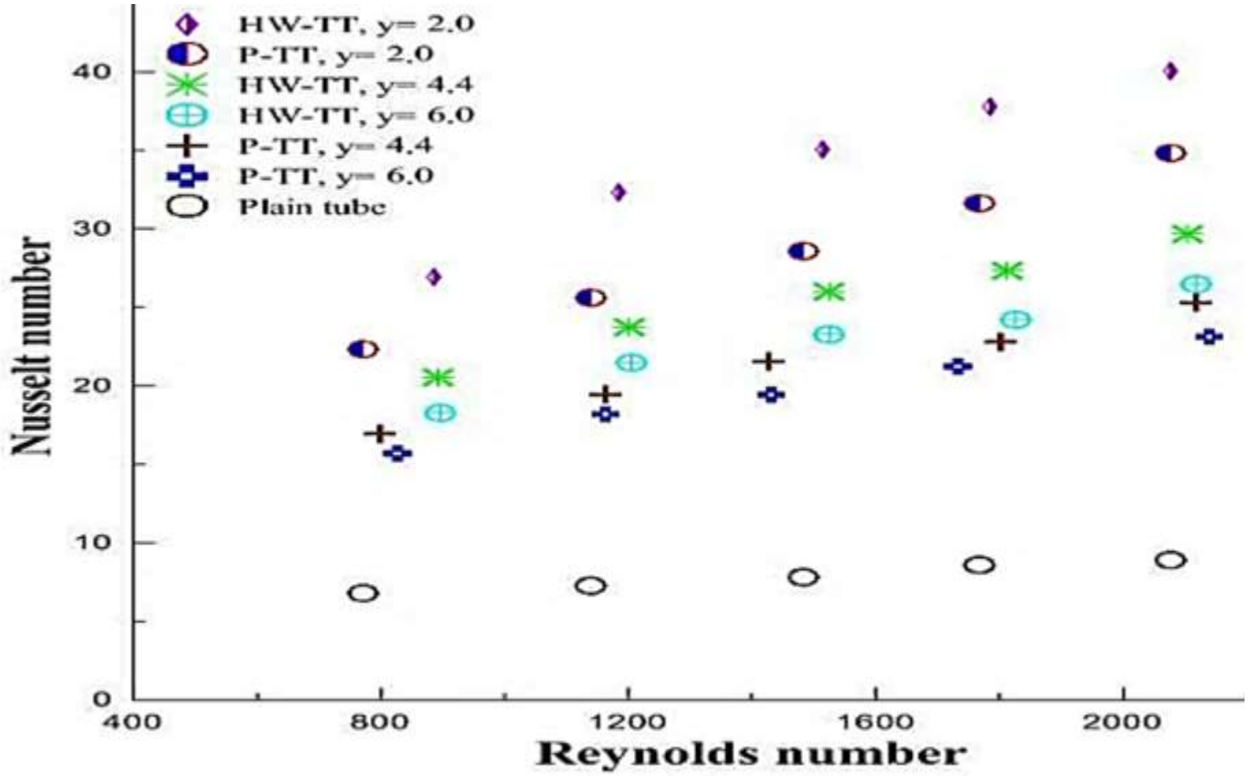

Fig.6 Nusselt No. V/S Reynolds No. for HW-TT, P-TT with different twist ratio(y) and plain tube [3]

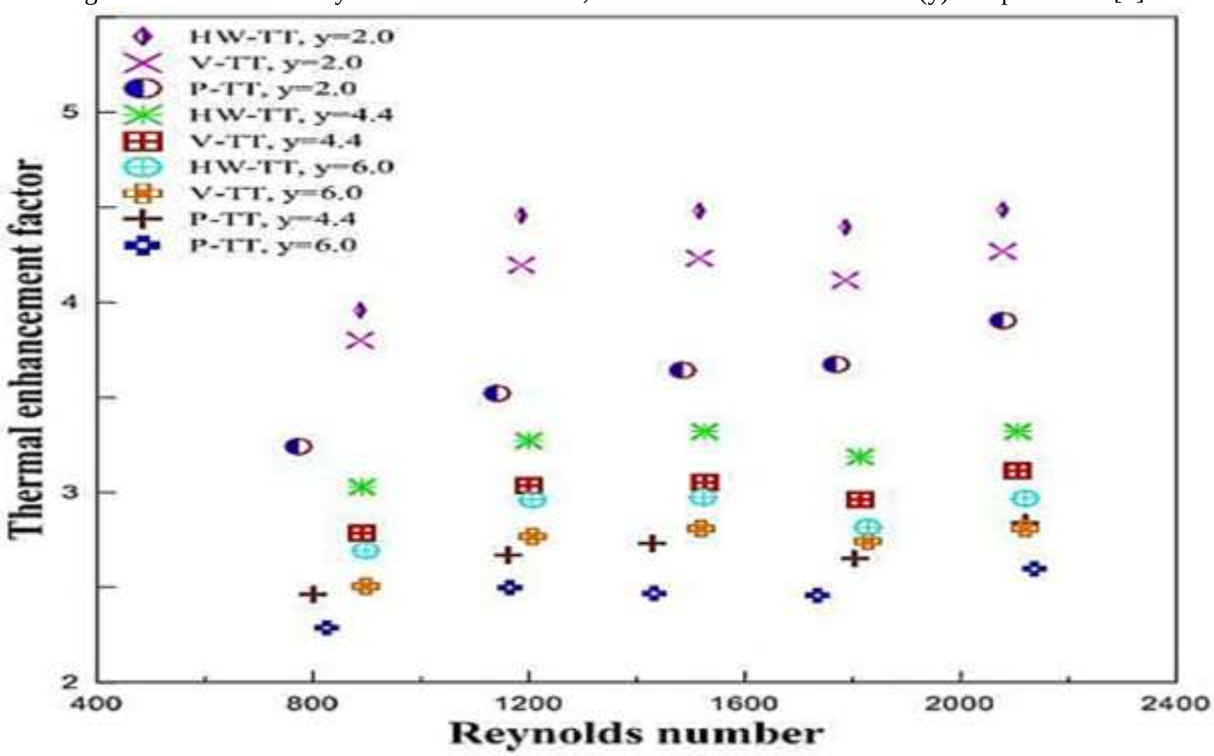

Fig.7 Thermal enhancement factors **V/S** Reynolds number for PTT, -TT and HW-TT [3]

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EFFECT OF OTHER NANO-FLUIDS

• The other Nano-fluids which are being use are:

Ag-H2O, CuO-H2O , SiO2 -H2O , TiO2 -H2O

Table No. 3 Thermo Physical properties of Nano-fluids at vol. conc. Of 2%

Nano fluids	Density (kg/m3)	Heat capacity (J/kg K)	Viscosity (N s/m3)	Thermal conductivity (W/m K)
H_2O	998.2	4182	0.001003	0.613
Ag–H_2O	1188.23	3484.436	0.00105315	0.650366928
Al_2O_3–	1057.63	3925.475	0.00105315	0.648823843
CuO– H_2O	1108.23	3754.264	0.00105315	0.647218493
SiO_2–	1022.23	4032.254	0.00105315	0.621942641
TiO_2–	1063.23	3902.529	0.00105315	0.643637682

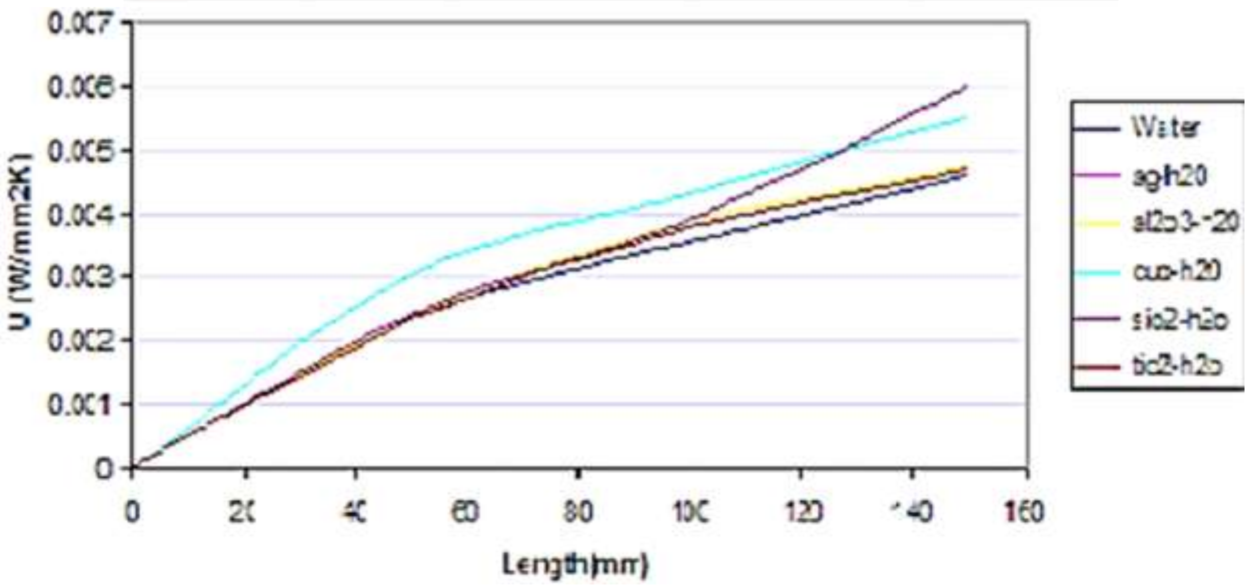

Fig.8 Overall heat transfer coefficient of nanofluids[3]

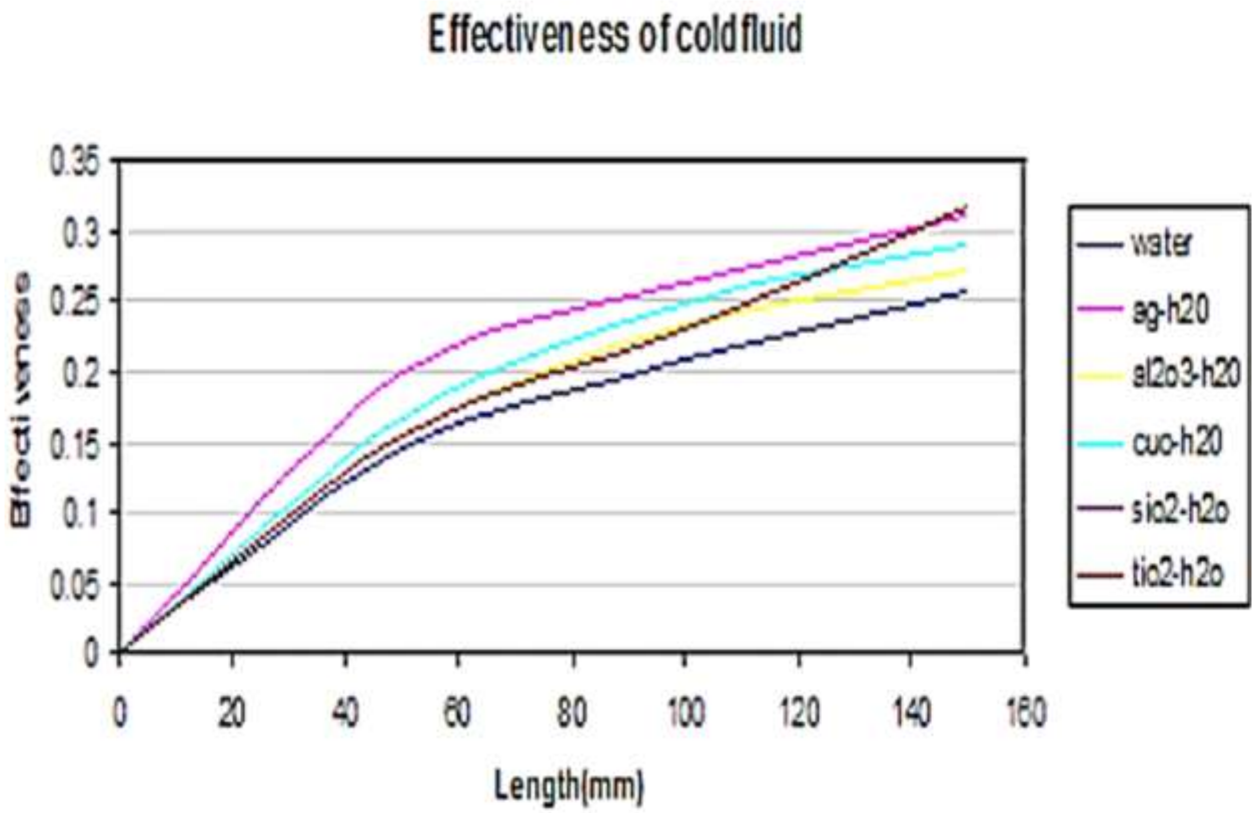

Fig.9 Effectiveness of various Nano fluids[3]

After experimentations, it was found that silver- water Nano-fluid gives best results in terms of heat transfer.

8.APPLICATIONS OF NANO-FLUIDS

- Nuclear system cooling:

Nano-fluids are being used in nuclear reactors as a coolant for removal of heat during reaction.

- Cooling of Microchips in Electronic Systems:

A principal limitation on developing smaller microchips is the rapid heat dissipation. However, nanofluids can be used for liquid cooling of computer due to their high thermal conductivity.

- Automobiles:

The latest use of nano fluid is in Automobiles for Engine cooling where Nano particles are dispersed in the regular coolant, in order to increase the cooling rate and reduce boiling of the coolant at high temperatures.

- Medical Application:

Nano cryosurgery:

Cryosurgery is a procedure that uses freezing to destroy undesired tissues. Introduction of nanoparticle enhanced freezing could also make conventional cryosurgery more flexible in many aspects such as artificially interfering in the size, shape, image and direction of ice ball formation. The concepts of Nano cryosurgery may offer new opportunities for future tumor treatment.

9. CONCLUSION

- It has been seen that Nano-fluids can effectively increase heat transfer in not only heat exchangers but also automobile, industrial & medical applications.
- Exact mechanism of enhanced heat transfer for nanofluids is still unclear as reported by many researchers.
- Nanofluids stability and its production cost are major factors that hinder the commercialization of nanofluids. By solving these challenges, it is expected that nanofluids can make substantial impact as coolant in heat exchanging devices.
- Nanofluids employed in experimental research have to be well characterized with respect to particle size, size distribution, shape and clustering so as to render the results most widely applicable, nanofluids further research

still has to be done on the synthesis and applications of nanofluids so that they may be applied as predicted.

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