بسم الله الرحمن الرحيم

“ENHANCEMENT OF HEAT TRANSFER USING NANO FLUID”

A thesis submitted to the department of Mechanical and chemical Engineering (MCE), Islamic University of Technology (IUT), in the partial fulfillment of the requirement for degree of Higher Diploma in Mechanical Engineering.

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CERTIFICATE OF RESEARCH:

The thesis title "**Enhancement of Heat Transfer by Nanofluids**" submitted by Faizan Sikandar **Student Id: 141310** has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Higher Diploma in Mechanical and Chemical Engineering on May, 2017.

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CANDIDATE'S DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma

Signatures of the Candidate.

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We seek excuse for any errors that might be in this report despite of our best efforts.

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ABSTRACT:

Researches in heat transfer have been carried out over the previous several decades, leading to the development of the currently used heat transfer enhancement techniques. The use of additives is a technique applied to enhance the heat transfer performance of base fluids. Recently, as an innovative material, nanometer-sized particles have been used in suspension in conventional heat transfer fluids. The fluids with these solid-particle suspended in them are called ‘nanofluids’

In our present study we focused and reviewed previous researches

CHAPTER 1

1. INTRODUCTION:

Natural convection heat transfer is an important phenomenon in engineering systems due to its wide applications in electronic cooling, heat exchangers, and thermal systems.

Enhancement of heat transfer in such systems is very essential from the industrial and energy saving perspectives. The low thermal conductivity of conventional heat transfer fluids, such as water, is considered a primary limitation in enhancing the performance and the compactness of such thermal systems.

A reduction in energy consumption is possible by enhancing the performance of heat exchange systems. Heat transfer is one of the most important processes in industrial and consumer products and it is worth addressing its influence over carbon footprints. For instance, the present telecommunication demand for enhanced functionality in circuit boards, results in high process density circuit boards. In such cases, the company spends more than 50% of the total electricity on the thermal management of electronic cooling systems.

The dozens of methods such as Fin-Foam Heat Sink, Minicanals, Microchannel, Novel interface materials, Dielectric mist cooling, forced convective boiling, etc. and their combinations are limited to heat removal of up to 1000 W/cm2. Some of the electronic systems like ultra-high heat flux optical devices, high-powered X-rays and lasers demand as high as 2000 W/cm2 of heat removal.

Further, enhancement in heat transfer is always in demand, as the operational speed of these devices depends on the cooling rate.

The use of solid particles as an additive suspended into the base fluid is a technique for the heat transfer enhancement. Improving of the thermal conductivity is the key idea to improve the heat transfer characteristics of conventional fluids. Since a solid metal has a larger thermal conductivity than a base fluid, suspending metallic solid fine particles into the base fluid is expected to improve the thermal conductivity of that fluid.

The enhancement of thermal conductivity of conventional fluids by the suspension of solid particles, such as millimeter- or micrometer-sized particles, has been well known for more than 100 years However, they have not been of interest for practical applications due to problems such as sedimentation, erosion, fouling and increased pressure drop of the flow channel.

1.1 NANO FLUIDS:

The problem associated with suspension of solid particles in conventional fluids can be solved by using Nanofluids

“Nanofluids are stable suspension of ultrafine particles in a conventional base fluid which tremendously enhances the heat transfer characteristics of the original fluid”.

Suspended Nanoparticles in base fluids can alter the fluid flow and heat transfer characteristics of base fluids.

Nanofluids exhibit larger thermal properties than conventional fluids. The much larger relative surface area of nanoparticles, compared to those of conventional particles, not only significantly improves heat transfer capabilities but also increase the stability of suspension.

Several published articles show that the heat transfer coefficient of nanofluids are much higher than the common-base fluid and give little or no penalty in pressure drop. The main reasons for the heat transfer enhancement of the nanofluids may roughly be listed as follow:

The suspended nanoparticles increase the thermal conductivity of the fluids, and the chaotic movement of ultrafine particles increases fluctuation and turbulence of the fluids which accelerates the energy exchange process

1.2 Materials used for nanoparticles and base fluids:

Nanoparticle material include:

Oxide ceramics
Metal carbides
Nitrides
Metals
Nonmetals

Base fluids include:

Water
Ethylene or tri-ethylene glycols
Oil and other lubricants
Bio-fluids

1.3 Preparation of nanofluids

The nanoparticles were used to produce nanofluids in the reviewed literature are: aluminum oxide (Al2O3), copper (Cu), copper oxide (CuO), gold (Au), silver

(Ag), silica nanoparticles and carbon nanotube. The base fluids used were water, oil, acetone, decent and ethylene glycol.

Nanoparticles can be produced from several processes such as gas condensation, mechanical attrition or chemical precipitation techniques [1].

Gas condensation processing has an advantage over other techniques. This is because the particles can be produced under cleaner conditions and its surface can be avoided from the undesirable coatings.

However, the particles produced by this technique occur with some agglomeration, which can be broken up into smaller clusters by supplying a small amount of energy [1]. The preparation of a nanofluid begins by direct mixing of the base fluid with nanoparticles. The delicate preparation of a nanofluid is important because nanofluids need special requirements such as an even suspension, durable suspension, stable suspension, low agglomeration of particles, and no chemical change of the fluid

1.4 THEORETICAL STUDY OF THERMAL CONDUCTIVITY OF NANOFLUIDS:

Because of the absence of a theory for the thermal conductivity of nanofluids, two existing models that were developed for conventional solid-liquid systems with fine particles are used in this study to estimate the effective thermal conductivity of nanofluids. Bachelor and O'Brien (1977) have developed an expression for the effective thermal conductivity keff, which is applicable to two phase systems that contain metal powders with particle diameters on the order of micrometers, i.e.

Keff/ko = 4 1 n ((km / k 0) - l l. (1)

where k m is the thermal conductivity of the metallic particle and k0 is the thermal conductivity of the reference fluid.

However, it should be noted that the theory of Batchelor and O'Brien (1977) was originally developed for a point-contact porous medium. When there is no contact between the particles, the effective thermal conductivity is independent of the conductivity ratio. Thus, for values of the conductivity ratio ranging from 100 to 10,000, the effective thermal conductivity of noncontracting systems is estimated from the equation

$$keff/ko = 4$$

If it is assumed that this expression is applicable to nanofluids, nanoparticles are expected to increase the thermal conductivity of the base fluids by a factor of 4. However, this expression seems unfeasible for nanofluids because it does not involve the particle volume fraction or particle shape. Hamilton and Crasser (1962) have developed a more elaborate model for the effective thermal conductivity of two component mixtures as a function of the conductivity of the pure materials, the composition of the mixture, and the shape of the dispersed particles. For mixtures in which the ratio of conductivities of two phases is > 100, the effective thermal conductivity of two-component mixtures can be calculated as follows:

$$keff/ko = [km+ (n-1)\, ko - (n-1)\, a\, (ko - km)] / [km+ (n-1)\, ko + a\, (ko -km)] \quad (3)$$

Where a is the particle volume fraction and n is the empirical shape factor given by

$$n = 3 / y, \quad (4)$$

where \|/ is the sphericity, defined as the ratio of the surface area of a sphere with a volume equal to that of the particle to the surface area of the particle. This model shows that no spherical shapes (all other circumstances being the same) will increase the conductivity above that of spheres. Applying the Hamilton and Crasser model to copper nanoparticles in water, the effective thermal conductivity of the copper-water system has been estimated for three values for y. The effects of particle volume fraction and sphericity on the thermal-conductivity ratio for a copper-water system are plotted in Fig. 6. The results clearly show that the thermal conductivity of the fluid-particle system depends on both the particle volume fraction and the shape. Assuming that the sphericity of copper nanoparticles is 0.3, the thermal conductivity of water can be enhanced by a factor of 1.5 at the low volume fraction of 5% and by a factor of almost 3.5 at the high-volume fraction of 20%. This finding demonstrates, theoretically, the feasibility of the concept of nanofluids, i.e., metallic nanoparticles are capable of significantly increasing the thermal conductivity of conventional heat transfer fluids. Furthermore, Masuda et al. (1993) have shown experimentally that y-Al 20 3 particles at a volume fraction of 4.3% can increase the effective thermal conductivity of water by =30%. The agreement between the estimated and measured conductivities is satisfactory.

CHAPTER 2

2.1 LITERATURE REVIEW

The influence of nanofluid on heat transfer enhancement was studied by B. Farajollahi, S.Gh. Etemad in **Convective Heat Transfer of TiO2/Water Nanofluid in a Shell and Tube Heat Exchanger** it was concluded that base fluid provide lower heat transfer enhancement as compared to the different nanofluid fraction. [1]

IMPACT OF NANOFLUID FRACTION ON ENHANCEMENT OF OVERALL HEAT TRANSFER COEFFICIENT:

The fig 1 below depicts the relation between overall heat transfer coefficient and Peclet number for various fraction of TiO_2. It can be seen that base fluid gives lowest overall heat transfer coefficient as compared to the nanofluid, it can also be noted that as the fraction of nanofluid rises overall heat transfer coefficient increases for increasing Peclet number. The 0.3percent of TiO_2 is our optimum fraction which increases suddenly and starts decreasing when Peclet number approaches to 45000 and finally meets to the other

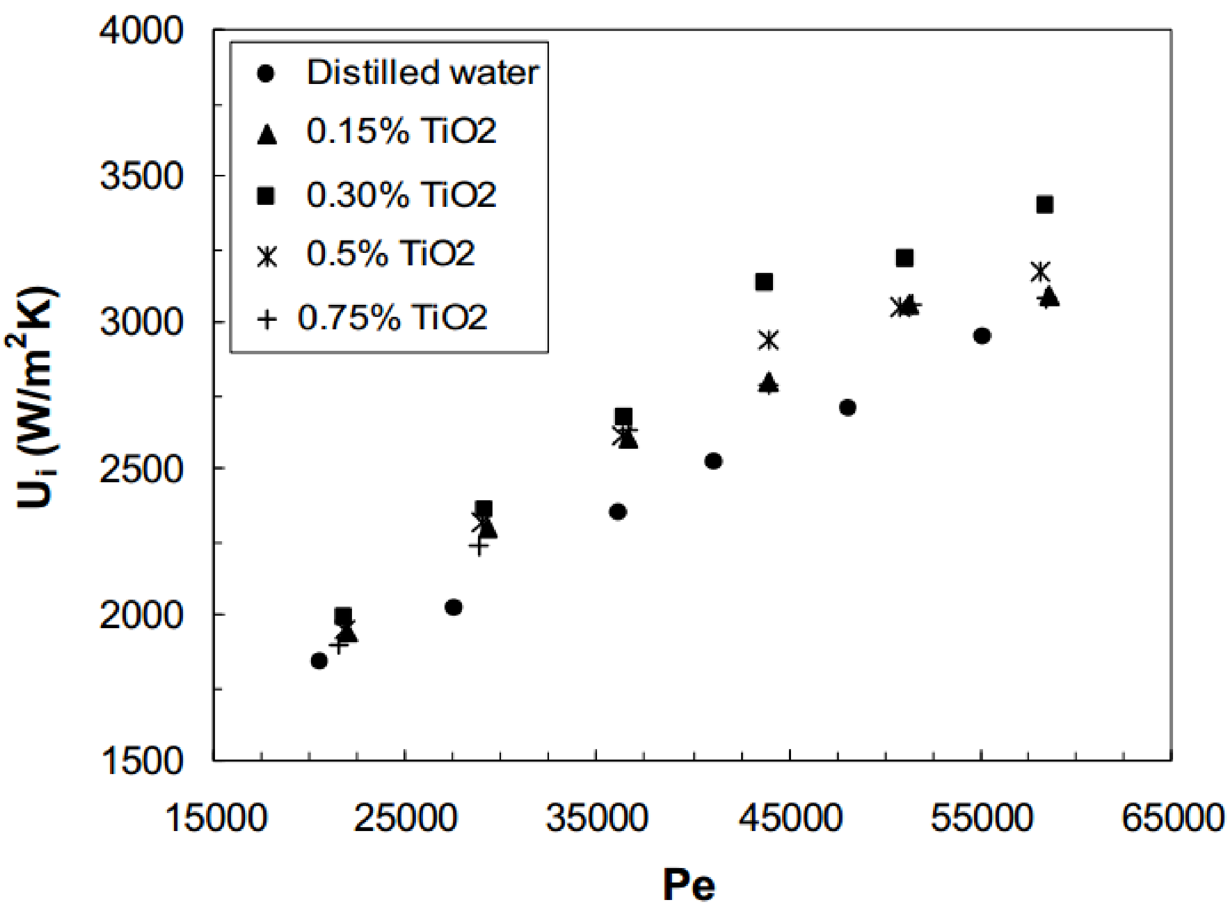

Figure 1: Relation between overall heat transfer coefficient and Peclet number for various fraction of TiO2

REFERENCES:

[1]: B. Farajollahi, S.Gh. Etemad "**Convective Heat Transfer of TiO_2/Water Nanofluid in a Shell and Tube Heat Exchanger**"

Figures 2 present the overall heat transfer coefficient of the γ-Al2O3/water nanofluid versus Peclet number for various volume concentrations. From the results, the overall heat transfer coefficient of nanofluid increases significantly with Peclet number. The overall heat transfer coefficient at a constant Peclet number increases with nanoparticle concentration compared to the base fluid as clearly shown in figure 2, the maximum enhancement of the overall heat transfer coefficient of γ-Al2O3/water nanofluid occurs at 0.5% volume concentration.

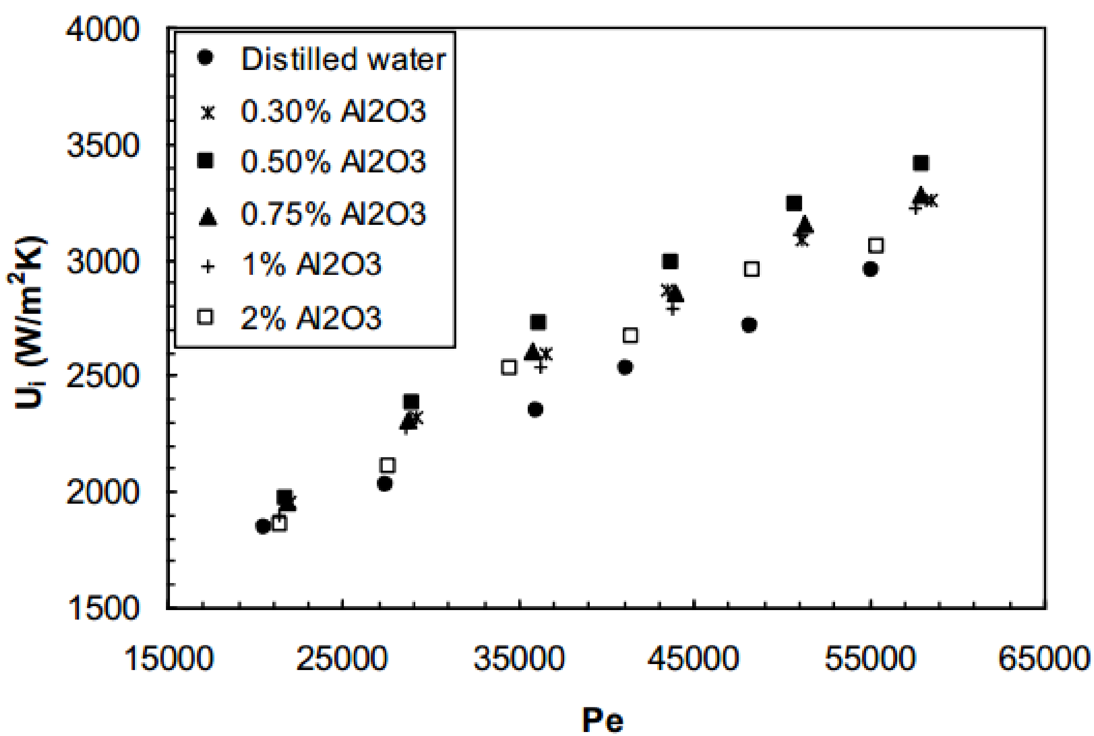

Figure 2: Relation between overall heat transfer coefficient and Peclet number for various fraction of TiO2

Figures 3 illustrates variation of convective heat transfer coefficients with Peclet number for different volume concentrations of Al2O3 nanoparticles. As shown in figures 3, addition of nanoparticles has strong influences on the convective heat transfer coefficient of nanofluid. The maximum enhancement of convective heat transfer coefficient with 0.5 vol. % γ-Al2O3/water nanofluid exceeds 50%.

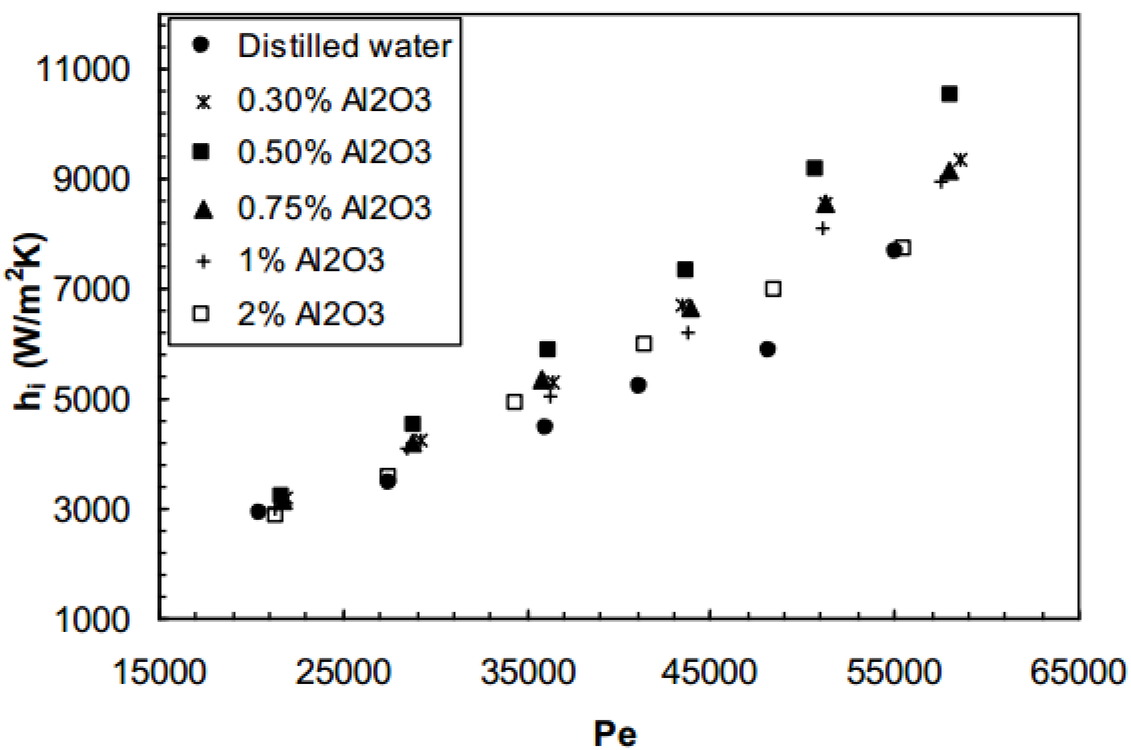

Figure 3: Relation between heat transfer coefficient and Peclet number for various fraction of TiO2

EFFECT OF PARTICLE SIZE ON THE CONVECTIVE HEAT TRANSFER IN NANOFLUID IN THE DEVELOPING REGION

The influence of nanofluid on heat transfer enhancement was studied by **K.B. Anoop, T. Sundararajan, Sarit K.** Das in Effect of particle size on the convective heat transfer in nanofluid in the developing region [2]

An experimental investigation on the convective heat transfer characteristics in the developing region of tube flow with constant heat flux is carried out with alumina–water nanofluids. The primary objective of this article is to evaluate the effect of particle size on convective heat transfer in laminar developing region. Two particle sizes were used, one with average particle size off 45 nm and the other with 150 nm.

Relation between heat transfer coefficient (h) and Reynolds number (Re)

Heat transfer coefficient variation with Re at x/D = 147 for 150 nm based nanofluid

Figure 4 shows variation of heat transfer coefficient with different Re at an axial location, x/D = 147 for nanofluid with 150 nm particle size at various particle concentrations. This shows the effect of particle concentration. It is evident that nanofluids give higher heat transfer coefficients compared to the base fluid. With the increase in concentration the heat transfer coefficient gets increased.

x/D= Axial location

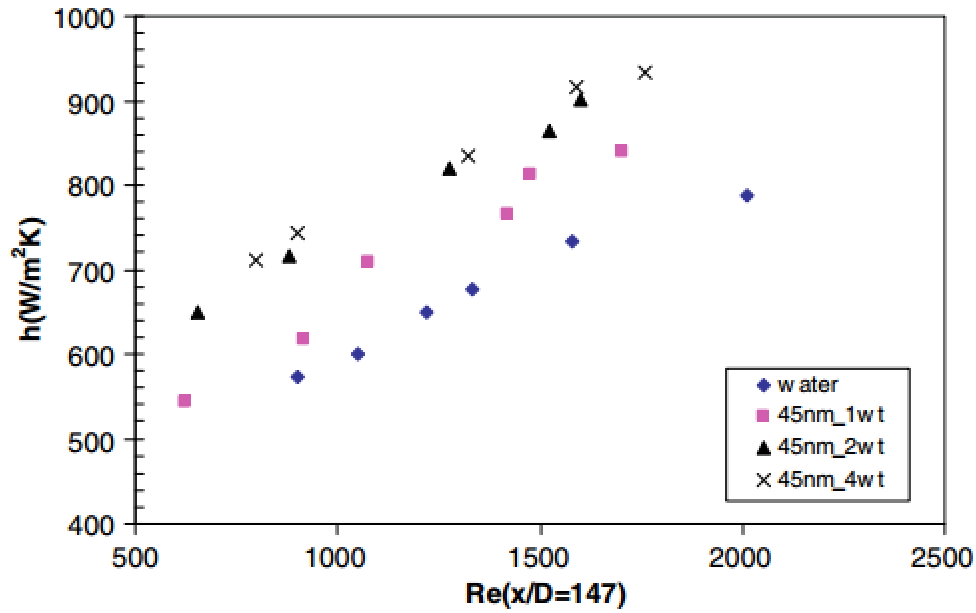

Figure 4: Relation between heat transfer coefficient and Reynold number for various base nanofluids

Effect of particle size on heat transfer coefficient at Re~1550.

Figure 5 shows the variation of heat transfer coefficient along the length of the tube for 4 wt% concentration for the two particle sizes.

The Re is of the order of 1550 and the values beyond x/D = 50 are only considered. It may be observed here that as particle size reduces the heat transfer coefficient increases. Also, the increase is more predominant in the entrance region, i.e., at lower x/D. Nanofluids with 45 nm particle size gave more enhancement in heat transfer coefficient than that of 150 nm based nanofluid as well as water. In order to conclude whether the increase in heat transfer coefficient is brought about by increase in thermal conductivity or other thermophysical properties, a dimensional and a non-dimensional plot of heat transfer coefficient is made and compared.

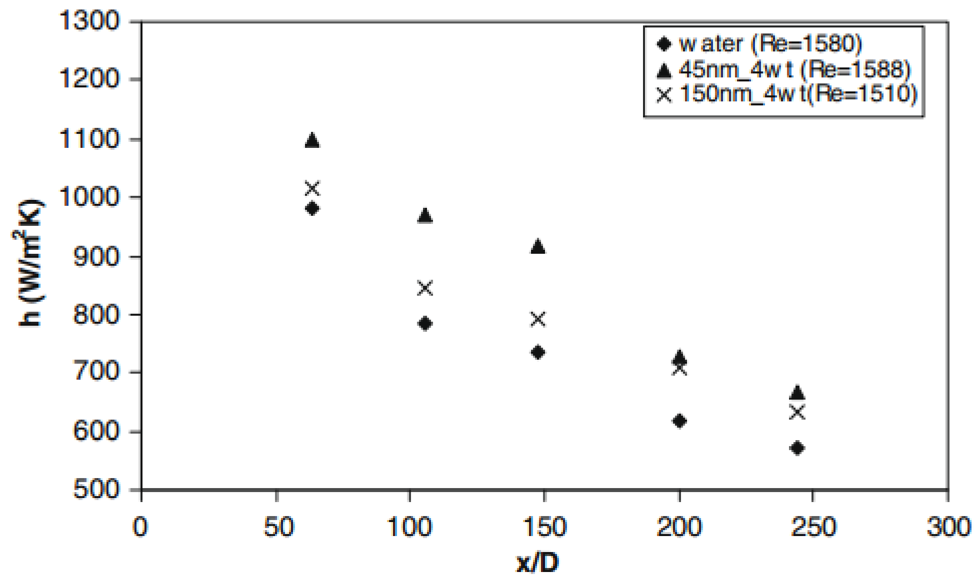

Figure 5: Effect of particle size on heat transfer coefficient at Re ~1550

3. RELATION BETWEEN CONDUCTIVITY RATIO AND PARTICLE VOLUME FRACTION:

The influence of nanofluid on heat transfer enhancement was studied by **Stephen U. S. Choi** and **J. A. Eastman** in **ENHANCING THERMAL CONDUCTIVITY OF FLUIDS WITH NANOPARTICLES**

The effects of particle volume fraction and sphericity on the thermal-conductivity ratio for a copper-water system are plotted in Fig.6

The results clearly show that the thermal conductivity of the fluid-particle system depends on both the particle volume fraction and the shape. Assuming that the sphericity of copper nanoparticles is 0.3, the thermal conductivity of water can be enhanced by a factor of 1.5 at the low volume fraction of 5% and by a factor of almost 3.5 at the high-volume fraction of 20%. This finding demonstrates, theoretically, the feasibility of the concept of nanofluids, i.e., metallic nanoparticles are capable of significantly increasing the thermal conductivity of conventional heat transfer fluids.

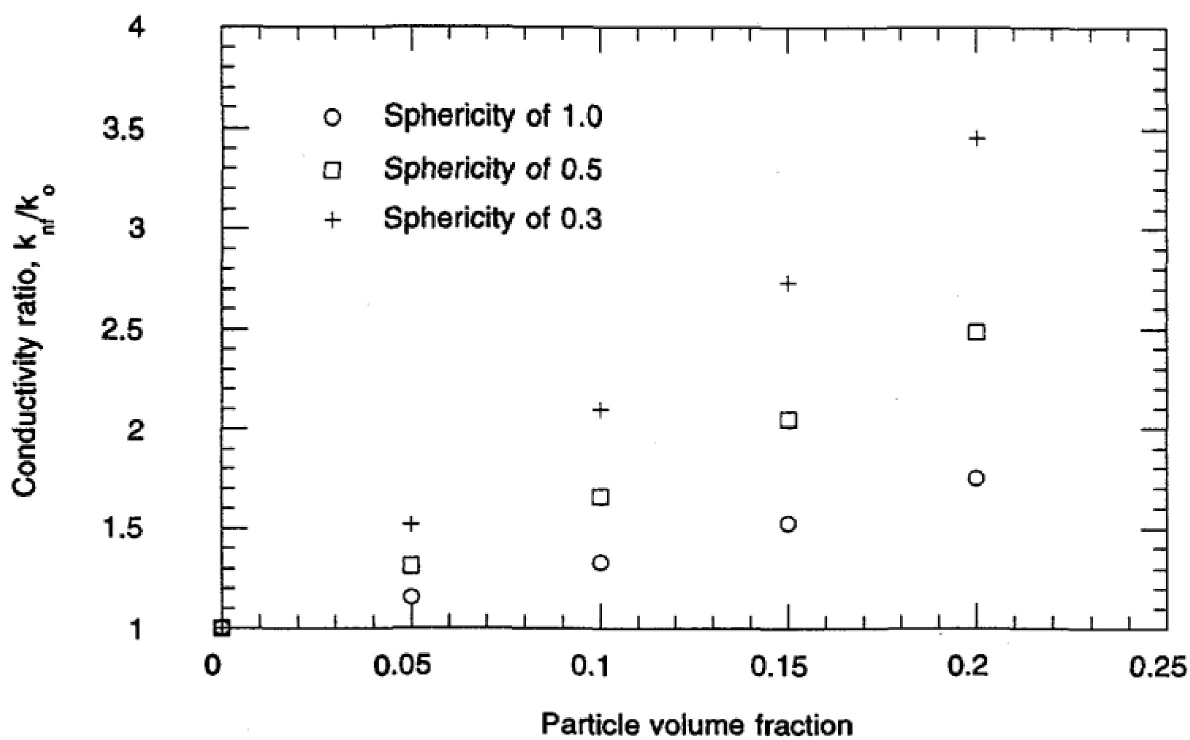

Figure 6: Effect of particle volume fraction and sphericity on thermal conductivity ratio copper water system

TITLE: REVIEW OF CONVECTIVE HEAT TRANSFER ENHANCEMENT WITH NANOFLUIDS.

The results for these three models are shown in Fig. 7 for various values of the particle volume fraction /. The figure shows that that all of the models predict increasing thermal conductivity ratio with increasing particle volume fraction. A linear relationship is present for all of the models. Highest values are obtained by using Hamilton–Crosser model. Models of Hamilton– Crosser and Yu and Choi are relatively comparable whereas Maxwell predicts much lower thermal conductivity ratios than these two models. The discrepancy between the models increases with increasing particle volume fraction

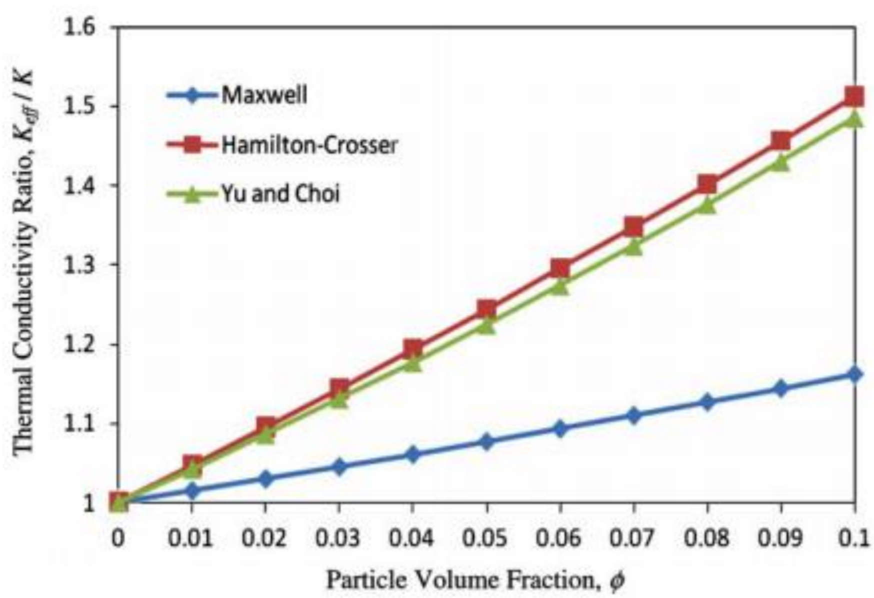

Figure 7: Relation between thermal conductivity ratio and particle volume fraction

EFFECTS OF THERMAL CONDUCTIVITY AND PUMPING POWER ON HEAT TRANSFER:

The effects of thermal conductivity and pumping power on heat transfer are plotted in Fig. 8 In heat exchangers that use conventional fluids, heat transfer can only be improved by significantly increasing flow rates. For example, to improve the heat transfer by a factor of 2, the pumping power should be increased by a factor of =10. However, if a nanoparticle-based fluid with a thermal conductivity of =3 times that of a conventional fluid were used in the same heat transfer equipment, the rate of heat transfer would be doubled.

Enhancement of heat transfer due to increased pumping power can be estimated from the following equation:

$$h/h_0 = (P/P_0)^{0.29}$$

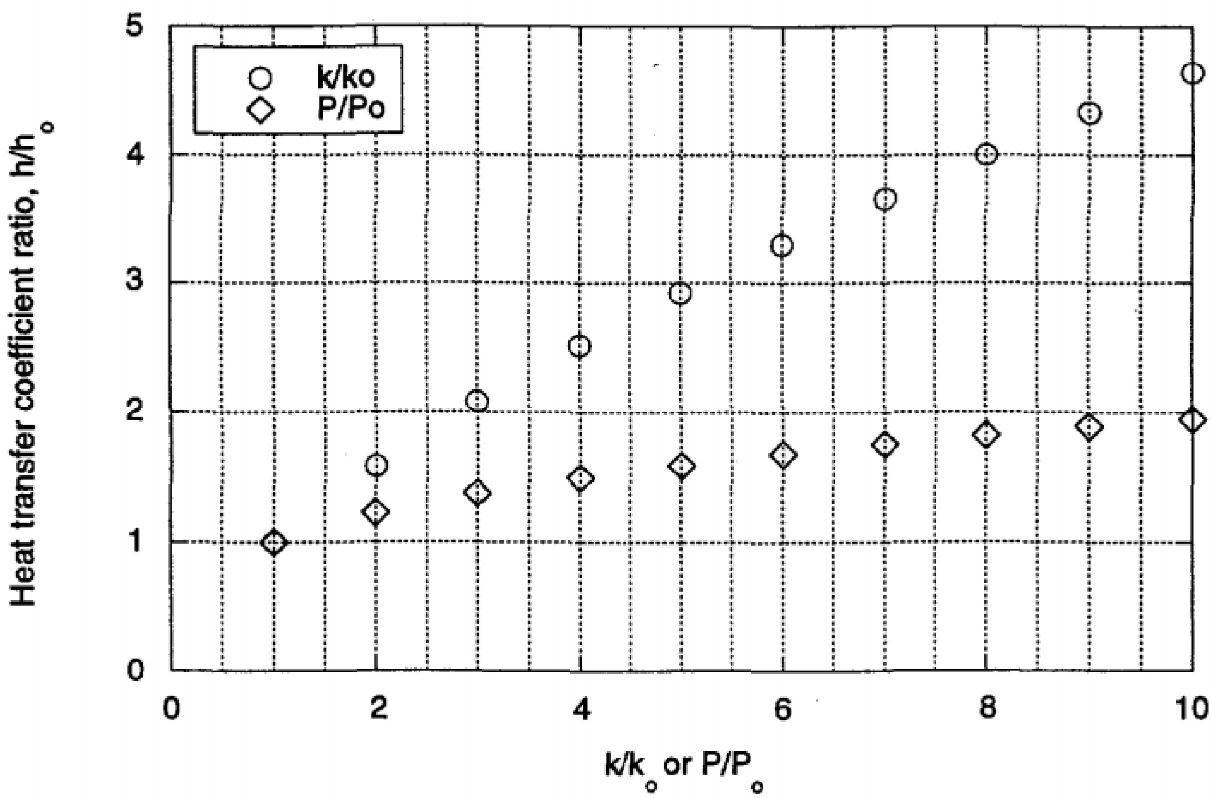

Figure 8: Effects of thermal conductivity ratio and pumping power on heat transfer

POTENTIAL PUMPING POWER SAVINGS WITH NANOFLUIDS:

From the previous researches it is reasonable to assume that the nanofluid pressure drop behaves like that of a single-phase fluid at volume fractions up to 20%. Then, the potential savings in pumping power is particularly significant as the heat transfer enhancement ratio is increased, as shown in Fig. 9

This could lead to a major technological breakthrough in the development of energy efficient industrial heat transfer fluids. Therefore, the potential benefits of nanofluids could provide tremendous performance, size/weight, and cost advantages.

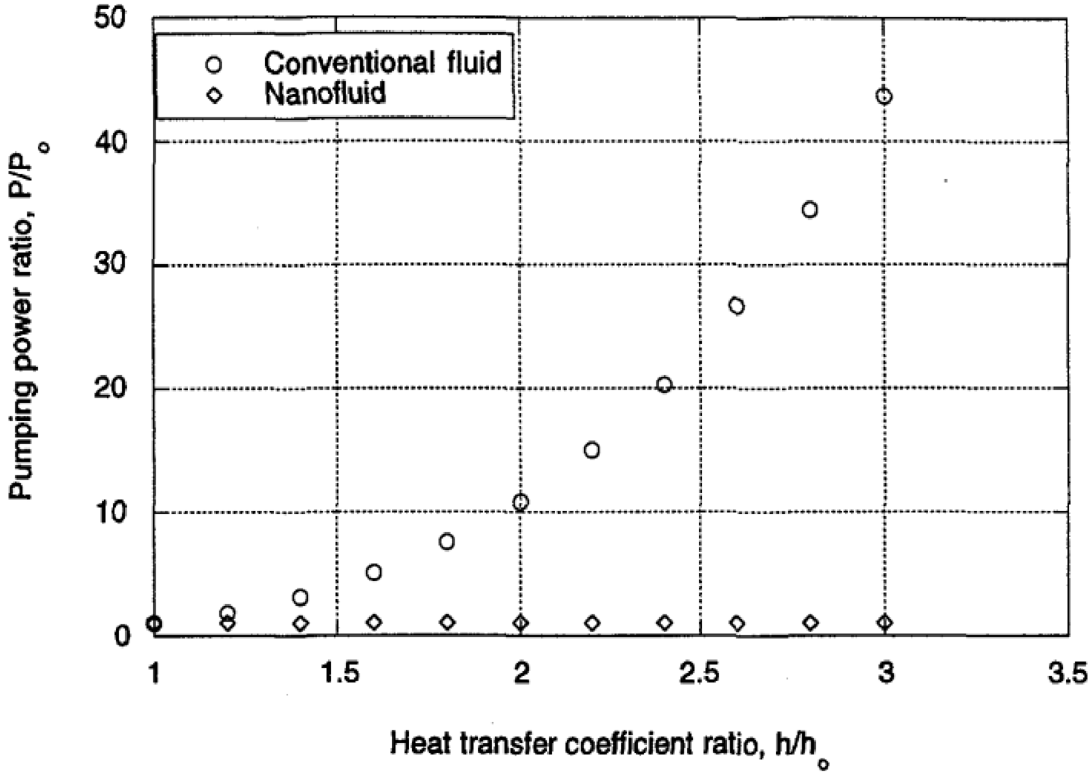

Figure 9: Potential pumping power saving with nanofluids

RELATION BETWEEN H (EXPR)/H(THEORY) AND PECLET NUMBER FOR DIFFERENT CONCENTRATIONS

The influence of increasing nanoparticles concentrations as well as Peclet number on heat transfer enhancement was studied by **S. Zeinali Heris, S.Gh. Etemad , M. Nasr Esfahany**
in Experimental investigation of oxide nanofluids laminar flow

This paper presents the experimental results of the convective heat transfer of CuO/water and Al2O3/water nanofluids. The experiments carried out for the laminar flow regime under constant wall temperature boundary condition. The experimental results indicate that for both nanofluid systems, heat transfer coefficient enhances with increasing nanoparticles concentrations as well as Peclet number. But the Al2O3/water nanofluids show more enhancement compared with CuO/water. Also, an optimum concentration can be found for each nanofluid systems in which more enhancements available. It is concluded that heat transfer enhancement by nanofluid depends on several factors including increment of thermal conductivity, nanoparticles chaotic movements, fluctuations and interactions.

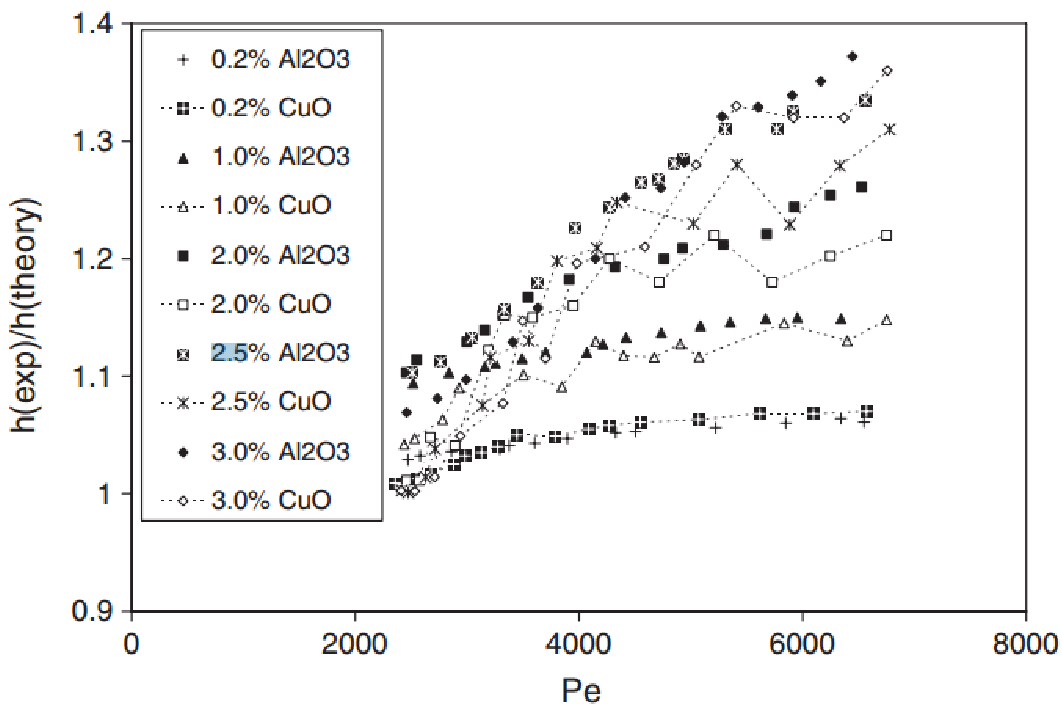

Figure 10: The ratio of experimental heat transfer coefficient to Seider–Tate equation prediction for Al2O3/water and CuO/water nanofluids versus Peclet number for different concentration

Conclusions:

After careful thorough study of nanofluid's preparation and its application we are able to extract following crucial information. We found that nanofluid which is suspension of ultrafine particles in a base fluid such as liquid water, ethylene glycol, is being prepared in industry by mainly three methods i.e. gas condensation, mechanical attrition or chemical precipitation techniques. It was concluded that nanofluid has most impeccable influence on the enhancement of heat transfer performance and reduction of pressure by keeping the optimum amount of nanofluid in base fluid. However, different types of nanofluid has their own impacts on outcomes. It also helps to prevent clogging and avoid rusting. Its application varied widely when it comes to industrial point of view. However, for the past several decades it is being used in electronic industry and power industries. Enhancement of heat transfer in all types of heat exchangers at the expense of certain pressure loss nanofluid is playing significant role.