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# “Experimental Study of the Effect of Distilled Water, R O Water, Lubricating Oil, Ethanol and Tio$_2$nanofluid Concentrations on Pool Boiling Heat Transfer”

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***Abstract – This paper focuses on two methods using nanofluids to deposit nanoparticles for the creation of enhanced surfaces for boiling heat transfer and changing the base fluid along with adding some quantities of nanoparticles to base fluids. Recent research has confirmed a buildup of a thin layer of nanoparticles on the heated surface during nucleate boiling in nanofluids. Most of these studies report no change of heat transfer and even worse, the presence of heat transfer deterioration. However, a few others report a heat transfer enhancement. In order to understand these controversial results, experiments were conducted to explore the mechanism of surface coating during nucleate boiling in nanofluids, changing the base fluidswith different Tio2nanofluids concentrations and to study the pool boiling curve. The recent report showed that the thickness of the nanoparticle layer was observed to depend on the nanoparticles concentration and the experiment duration. Compared to a clean surface, the wettability of the surfaces with a TiO2 nanoparticle layer has been significantly improved. However, up to 50% of heat transfer coefficient deterioration was observed with TiO2nanofluids fluid concentration in water pool boiling. When tested in pure water, the addition of nanoparticle-concentration to base liquid showed significant increase in critical heat flux compared with the critical heat flux in pure water.***

***Keywords: Critical Heat Flux (CHF), Reverse Osmosis (RO), Titanium Oxide (TiO2 ).***

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## 1. INTRODUCTION

Boiling heat transfer is an effective and efficient process for transferring heat at low values of the wall superheat, i.e. the temperature difference between the boiling fluid and the heater surface. It is a widely used phenomenon in chemical industries; especially in the power sector where large amount of heat is produced due to the burning of fossil and nuclear fuels. The complexity of the boiling process makes it difficult to fully understand the mechanism and improve the heat transfer facility. In other words, the enhancement in the efficiency of the boiling equipment is still a big challenge for the researchers. Many efforts have been made to improve the boiling heat transfer during the last fifty years. The boiling heat transfer enhancement leads to decrease the equipment size, which results in low capital investment. Furthermore, it makes the process more efficient thermodynamically and this leads to higher cycle efficiency, reduced running and maintenance cost of the equipment. Past researchers employed many techniques for the enhancement of boiling heat transfer, which can be divided into three categories namely; active technique, passive technique and compound technique. A number of different modified surfaces were used by the researchers in the past.

Namely; emery polished, sanded, finned and porous surfaces. It was observed that the surface modification can provide a platform for bubble generation, i.e. potential nucleation sites or cavities, which can play an important role in the heat transfer process.was stored in proportional to its battery capacity.

Boiling is a most often understood as a phase transition from liquid to vapor state involving the appearance of vapor bubbles on a hot surface. In this respect, forced convection boiling and pool boiling are common. When a liquid is in contact with a surface maintained above the saturation of the liquid, boiling will eventually occur at that interface. Conventionally, based on the relative bulk motion of the body of a liquid to the surface, boiling is divided into two categories namely pool boiling and convective boiling. Pool boilingis the process in which the heating surface is submerged in a large body of stagnant liquid. The relative motion of the vapor produced and the surrounding liquid near the heating surface is due primarily to the buoyancy effect of the vapor.

### 1.1 What is the need to Enhance the Heat Transfer

Due to the ever-growing demand for new materials with advanced thermal properties, 21st-century research is mainly targeting means and methods of enhancing heat transfer. With increasing heat transfer rate of the heat exchange equipment, the conventional process fluid with low thermal conductivity can no longer meet the requirements of high-intensity heat transfer. The following are the some fields those always demands enhancement in the heat transfer rate –

1. Power production (mainly in nuclear reactors).
2. Process chemical food industries.
3. Cooling of electronic equipments.
4. Environmental engineering.
5. Manufacturing industry.
6. Air conditioning and refrigerators.
7. Waste recovery.
8. Petroleum refining.

### 1.2 Pool Boiling Regimes

The classical pool boiling curve is a plot of heat flux(q) versus excess temperature($\Delta T=T_w-T_{sat}$). As the value of the excess temperature increases, the curve traverses four different regimes:

I. Natural or free convection

II. Nucleate Boiling

III. Transition Boiling

IV. Film boiling

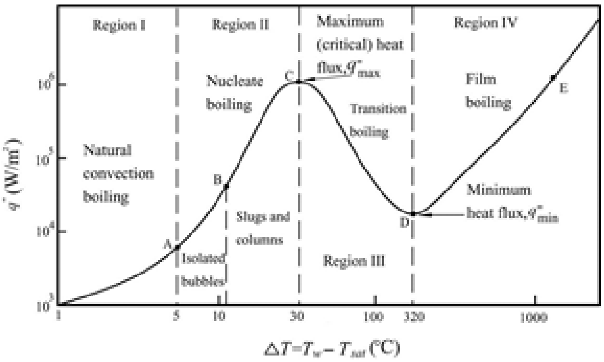

Figure 1: Pool Boiling Curve for Saturated Water

### 1.3 Why Nanofluids?

Nanofluids are a relatively new class of fluids which consist of a base fluid with nano-sized particles (1–100 nm) suspended within them. These particles, generally a metal or metal oxide, increase conduction and convection coefficients, allowing for more heat transfer out of the coolant. Nanofluids are colloidal suspensions of nano-sized solid particles in a liquid. Before the advent of nanotechnology, the study of colloidal suspensions with micron-sized particles was quite common, but their size posed significant corrosion and erosion hazards in engineering applications. When the manufacture of nano-sized particles became possible, it was noticed that, unlike micron-sized particles, nano-suspensions could form stable systems with very little settling under static conditions. Most importantly, recently-conducted experiments have indicated that nanofluids tend to have substantially higher thermal conductivity than the base fluids. This is both surprising and significant, and is the reason why the study of properties of nanofluids is important. Among other advantages of nanofluids over conventional solid–liquid suspensions, the following are worth mentioning:

- Higher specific surface area, and hence more heat transfer surface between particles and fluid.
- Higher stability of the colloidal suspension, mostly dominated by Brownian motion of the particles.
- Lower pumping power required to achieve the equivalent heat transfer.
- Reduced particle clogging as compared to conventional colloids, hence promoting system miniaturization.
- Higher level of control of the thermodynamics and transport properties by varying the particle material and its concentration, size, and shape.

- These particle properties can be utilized to develop stable suspensions with enhanced flow and heat transfer.

## 1.4 Literature Review

The brief summary of literature survey shows that there are controversial results in nanofluids nucleate boiling. To explain this, Narayan underlined the role of the ratio of particle size to surface roughness. The authors found that the heat transfer coefficient increased by 70% in the case of a heater with an average roughness of 524nm and suspensions with an average particle size of 47 nm. But when the ratio of the average surface roughness to the average particle size became close to unity, the pool boiling heat transfer deteriorated significantly. Until now, only a few studies related to the effects of surface coating by nanoparticles deposition under pool boiling heat transfer conditions have been initiated. Vemuri and Kim deposited a nanoporous coating with a thickness of about 70mm onto the plain surface using Omegabond200 high-thermal-conductivity epoxy. They observed a reduction of about 30% in the incipient superheat for a nanoporous coated surface compared to that of a plain surface.

The present study provides new experimental data to explore the mechanisms of nanoparticle deposition and to correlate the nanoparticle layer thickness to boiling duration. We also propose an explanation for controversial results in the literature by linking heat exchanges to adhesion energy changes. Thermal behavior of nanoporous coating by nanofluids will be tested in a pool of boiling water. The surface wettability will be analyzed in order to understand the effects of nanoparticle deposition on heat transfer co-efficient.

## Experimental Setup:

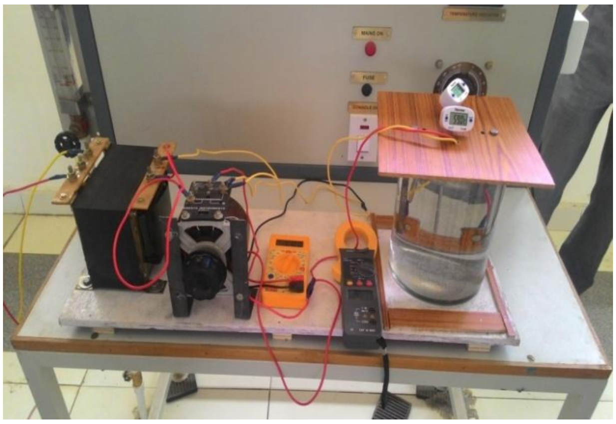

**Figure 2: Critical Heat Flux Apparatus setup**

## Observation:

- Diameter of test wire (D) : 0.3 mm
- Length of test wire (L) : 80mm
- Test wire used : Nichrome wire
- Nanoparticle used : Titanium oxide ($TiO_2$)
- Base fluids: Distilled water, RO Water, Nanofluid, Ethanol, Lubricant oil, Normal water.
- In our experimental study we have used different base fluids such as normal water, distilled water, reverse osmosis (RO) water, lubricant oil and ethanol along with adding the $TiO_2$ nanoparticles to these base fluids. The results obtained from above analysis are compared the heat transfer per unit area and heat transfer coefficient.
- The $TiO_2$ nanoparticles supplied by Nano Wings Pvt.Ltd Telangana and particles have 99.9% purity and 25±5 nm size. The base fluid Ethanol provided by sugar factory Shree Doodhaganga Krishna S.S.K located in Chikodi, Dist: Belagavi. Ethanols have 99.5% purity.

## Working Procedure

- Connect test wire to heat terminals and place it in the container having base fluid.
- Switch on the main heater and heat the water to the desired temperature.
- Now switch on the test heater gradually increase the voltage across the test heater by using dimmerstat.
- Note down the voltage, current , water bath temperature and surface temperature of test wire respectively.
- Repeat the same experiment for different excess temperature.
- The above procedure followed for different base fluids and nanofluid concentration.
- Calculate power supply, heat flux and heat transfer coefficient.
- Plot the graph of excess temperature versus heat flux.

## 1.5 Results and Dissussions

**Table 1:Critical heat flux values for different base fluids.**

| SI. No | Base fluid | Heat Input (W) | Heat flux (w/m$^2$) | Heat transfer coefficient (w/m$^2$K) |
|---|---|---|---|---|
| 1 | Normal water | 75.6 | 1.002 | 0.0654 |
| 2 | Distilled water | 202.56 | 2.680 | 0.233 |
| 3 | RO water | 178.5 | 2.367 | 0.2784 |
| 4 | Lubricating oil | 103.36 | 1.37 | 0.0259 |
| 5 | Ethanol | 75.6 | 1.002 | 0.0654 |

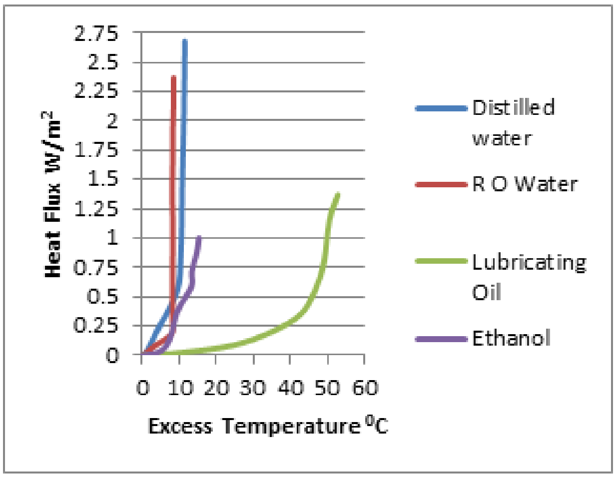

**Fig.3: Pool boiling curves for different base fluids.**

The above figure shows the effect of distilled water,Reverse osmosis water, lubricating oil and Ethanol on heat flux.From the experimental results it isfound that, the maximum or critical heat flux occurs for distilled water when compared to the other R O Water, lubricant oil and ethanol.The rate of heat transfer per unit area is maxumum for distilled water.

**Table 2: Critical heat flux values for different $TiO_2$ nanofluid concentrations in Distilled water.**

| SI. No | Base fluid With nanofluid concentration | Heat Input (W) | Heat Flux (w/m$^2$) | Heat transfer coefficient (w/m$^2$K) |
|---|---|---|---|---|
| 1 | 3 grams | 155.04 | 2.055 | 0.1851 |
| 2 | 5 grams | 159.6 | 2.116 | 0.251 |
| 3 | 11 grams | 176.4 | 2.344 | 0.2858 |

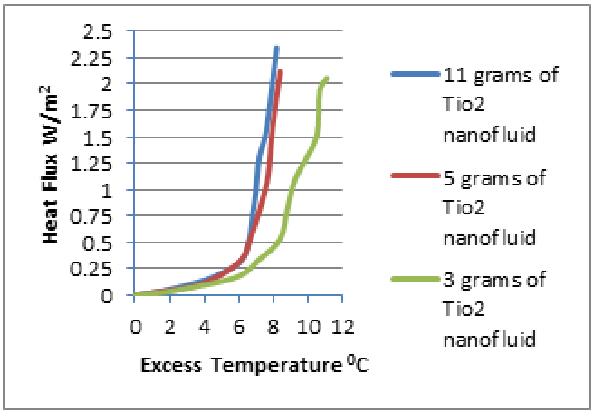

**Fig.4 Effect of $TiO_2$nanofluid concentrations on heat flux.**

The above figure shows the TiO2 nanofluid concentrations on heat flux.As we conducted experiment by adding 3 grams, 5 grams and 11 grams of $TiO_2$ nanoparticle to 2.7 liters distilled water as a base fluid, from the experimentit is found that, the 11 grams of TiO2 concentration of nanoparticles in the distilled water increases with increase heat transfer rate per unit area orheat flux.The increase in nanofluid concentrations in the distilled water increases the surface wettability and more deposition of nanofluids the on the heater surface.

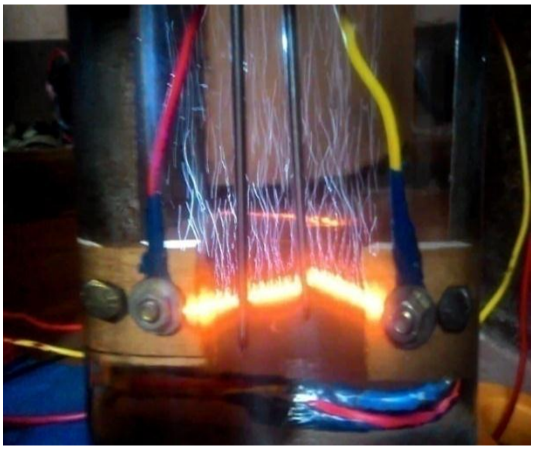

**Fig.5 Experiment Conducted on Ethanol as a Base Fluid.**

## CONCLUSION

As per the above experimental analysis we conclude that:

Compare to using normal water and Nanofluid as a base fluid, the heat transfer rate increases in distilled water.Many research reports stated that maximum heat transfer take place in nucleate boiling regime this is due to formation of nuclei sites on heater surface. These nanoparticle capable to deposited on heater surface and increases number of nucleate sites, hence its increases heat transfer rate at minimum temperature rise.Our experiment results shows that nanoparticle concentration influences the heat transfer rate but very less. And positive point is that less increase in the temperature, maximum heat flux compare to normal water.As we conducted experiment by adding 3 grams, 5 grams and 11 grams of $TiO_2$ nanoparticles to 2.7 liters distilled water as a base fluid, it is found that, the concentration of nanoparticles in the base fluid increases with increase heat transfer per unit area.Lubricant is substance introduce to reduce the friction which ultimately reduces the heat generation. When experiment conducted using base fluid as a wasteoil or used lubricant oil it is found tha, there is reduction in the heat flux value compare to other base fluids.

## REFERENCES

Hai Trieu Phan, Nadia Caney, Philippe Marty, StephaneColasson& Jerome Gavillet (2010) Surface Coating with Nanofluids: "The Effects on Pool Boiling Heat Transfer, Nanoscale and Microscale";Thermophysical Engineering, 14:4, 229-244.

R.N. Hegde, S.S. Rao and R.P. Reddy (2012): "Investigation on Boiling Induced nanoparticles Coating, Transient Characteristics and Effect of Pressure in Pool Boiling Heat Transfer on a Cylinder Surface, Experimental Heat Transfer"; A Journal of Thermal Energy Generation, Transport, Storage and Conversion, 25:4, 323-340.

S.J. Kim, I.C. Bang, J. Buongiorno, and L.W. Hu: "Surface Wettability Change during PoolBoiling of Nanofluids and Its Effect on Critical Heat Flux"; International Journal of Heat andMass Transfer, vol. 50, pp. 4105–4116, 2007.

G.P. Narayan, K.B. Anoop, and S.K. Das: "Mechanism of Enhancement/Deterioration ofBoiling Heat Transfer Using Stable Nanoparticle Suspensions over Vertical Tubes"; Journal of Applied Physics, vol. 102, p. 074317, 2007.

S. Khandekar, Y.M. Joshi, and B. Metha: "Thermal Performance of Closed Two-PhaseThermosyphon Using Nanofluids"; International Journal of Thermal Science, vol.4, pp. 659–667, 2007.

H.D. Kim, J. Kim, and M.H. Kim: "Experimental Studies on CHF Characteristics of NanoFluids at Pool Boiling"; International Journal of Multiphase Flow, vol.33, pp.691-706, 2007.

I.C. Bang and S.H. Chang: "Boiling Heat Transfer Performance and Phenomena of Al2O3-Water Nano-Fluids from a Plain Surface in a Pool"; International Journal of Heat and Mass Transfer, vol.48, pp.2407–2419, 2005.

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