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“Pool Boiling CHF Enhancement with Al_2o_3-Cuo/H_2o Hybrid Nan fluid”

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ABSTRACT

Phase-change heat transfer is an important process used in many engineering thermal designs. Boiling is an important phase phenomena as it is a common heat transfer process in many thermal systems .Phase change processes are critical thermodynamic cycles as most closed loop systems have an evaporator, in which the phase change process occurs. There are many applications/ processes in which engineers employ the advantages of boiling heat transfer ,as they seek to improve heat transfer performance . Recent research efforts have experimentally shown that nanofluid can have significantly better heat transfer properties than those of the pure base fluids, such as water This paper described the effect of Al_2O_3-CuO/H_2O hybrid nanofluid on critical heat flux (CHF) enhancement using an Ni-Cr wire in pool boiling. All experiments were performed at a saturated condition under atmosphere pressure for two different nichrome wire sizes as 30gauge and 39 gauge. The CHF values between water and hybrid nanofluid with several volume concentration were compared to evaluate the effect of the hybrid nanofluid on the CHF enhancement. The CHF values of the hybrid nanofluid were enhanced from approximately 13% to 120% of pure water as the nanoparticle concentration increased. In addition , the CHF for the hybrid nanofluid showed the nearer to highest value among the evaluated nanofluids. The maximum CHF enhancement was obtained for 1 %(by volume) nanofluid to be about 90% for 36 gauge nichrome wire. This represents a first important step towards applicability of Al_2O_3-CuO/H_2O hybrid nanofluid in pool boiling.

Keywords : Critical heat flux (CHF),Pool boiling, Hybrid nanofluid.

1. INTRODUCTION

Nucleate pool boiling phenomenon is very effective & efficient mode of heat transfer, due to its ability to transfer large amounts of heat with relatively small temperature differences. Conventional and enhanced boiling of liquids have a wide range of industrial applications that include power generation, chemical and petrochemical industries, air conditioning, refrigeration and cryogenics, metallurgical quenching process, desalination of seawater and in nuclear power plants, either for heating or electricity generation. Recent applications of boiling heat transfer in cooling of electronics devices show many promises.

The critical heat flux (CHF) is defined as the heat flux when the boiling heat transfer coefficient between a heated surface and fluid is dramatically dropped as the phase of fluid near the heated surface changes from liquid to vapor due to a rise of heat flux or surface temperature, or a change of flow rate, pressure, etc. [1]. When CHF occurs in a heat flux control system, the heater surface temperature is sharply increased as a result of a drop of the boiling heat transfer coefficient, and this could lead to catastrophic failure of the heated surface. CHF enhancement allows higher limits of operation conditions such that heat transfer equipment can be operated safely with greater margins and better economy. Accordingly, many researchers have been developing methods to enhance the CHF, including induction of a swirl flow by twisted tape or a ribbed tube, increase of the heat transfer surface by the implementation of fin structures, enlargement of turbulent flow, flow vibration, nano-fluids, etc.

Nanofluids are a new type of engineered fluids that contain nano sized particles less than 100 nm. These nano-sized particles can improve thermal hydraulic properties of a fluid such as thermal conductivity, heat transfer coefficient, wettability, etc. [2]. Modern nano-technology provides many opportunities to utilize nano-sized particles in this size range and thus nano-fluids have enormous potential for practical application.

While numerous studies on CHF enhancement using nano-fluids in pool boiling have been reported, there is little data about CHF in flow boiling using nano-fluid. The main objective of the present study is to conduct CHF experiments at low flow and low pressure using a nano-fluid and confirm CHF enhancement. Possible mechanisms underlying CHF enhancement via application of a of Al_2O_3 nano-fluid are also explored.

Most CHF experiments using nano-fluids were conducted in pool boiling conditions, and CHF was enhanced by up to 200%. The mechanism underlying this enhancement has yet to be clarified and is still under discussion. Meanwhile, relatively few CHF experiments using nano-fluids in flow boiling condition have been conducted, primarily due to stability and cleaning problems.

Kim et al. conducted an experimental study on the CHF characteristics of nano-fluids in pool boiling. Their results showed that the CHFs of nano-fluids containing TiO2 or Al2O3 were enhanced up to 100% over that of pure water. Also, SEM observations subsequent to the CHF experiment revealed that nano-particles were deposited on the wire surface. They concluded that the CHF enhancement could be attributable to enhanced wettability via the deposition of nano-particles [3].

Bang et al. also investigated CHF characteristics of nano-fluids in pool boiling. They found that CHFs of nano-fluids containing alumina, zirconia, and silica nano-particles dispersed in water were enhanced. They concluded that nano-particles are deposited on the heater surface, forming a porous layer during nucleate boiling. This porous layer improves the wettability of the surface considerably, as measured by a marked reduction of the static contact angle [4].

Jeong et al. investigated the wettability of heated surfaces in pool boiling using surfactant solutions and nano-fluids. Contact angle measurements showed that both surfactant solutions and nano-fluids exhibited enhanced wettability. In addition, the surfactant solutions exhibited a greater decrease in contact angle, and hence further increased wettability [5].

Kim et al. conducted flow boiling CHF experiments using nano-fluids incorporating alumina, zinc-oxide, diamond. Their results showed that the CHF values of the nano-fluids were enhanced by up to 40–50% with respect to pure water at 2000–2500 kg/m2 s mass flux whereas the CHF was not enhanced at 1500 kg/m2 s mass flux. They attributed the enhancement to nano-particle deposition, and the enhancement appeared to be weakly dependent on nano-particle concentration for the alumina nano-fluids, whereas it increased more pronouncedly with nano-particle concentration for the zinc-oxide and diamond nano-fluids [6].

Many researchers have investigated the effects of time, temperature, concentration, particle type, dispersion medium and pH on the stability of nano-fluids. It has been found that pH is the most important factor affecting the dispersion stability of nano-fluids.Wäsche et al. showed that the zeta potentials of nano-fluids containing Al2O3, SiC, and Si3N4 were changed by the pH of the nano-fluids. They also showed that the zeta potentials of the nano-fluids were slightly increased with increasing time [7].

Zhu et al. showed that the zeta potential and absorbency were important bases for selecting conditions for dispersing particles. They also found that pH has a critical effect on the stability of the alumina suspension[8].

2. EXPERIMENT

2.1.-Preparation and characteristics of Hybrid nanofluid

Weight amount of required Nano particle and make samples of 2.5mgm. of Cuo and 2.5 mgm of $Al_2\ O_3$ each and mix it in 2 lits of Distilled water as per the requirement of the experiment. By adding the Nano Fluid in the water we change the concentration to 0.25%, 0.5 % and 1.0 %.

(a) (b)

Figure 1.(a&b) :-:-0.25 % & 0.5% volume concentration of (Al_20_3 – CuO/ H_2O) Hybrid Nanofluid

Figure 2 (c):- 1% volume concentration of(Al_20_3 – CuO/ H_2O) Hybrid Nanofluid,(d) Aluminum oxide nanopowder

2.1.-Experimental Set-up

The objective of this project is to investigate the enhancement in pool boiling critical heat flux (CHF) with water based CuO-Al2O3 hybrid nano fluid and effect of variation in concentration and particle size of hybrid nanao fluid on CHF.

- Glass container :Dia. 200 mm. & Height 100 mm
- Nichrome wire size :0.12 mm& 0.17 mm
- Dimmerstat :20 Amp, 230 volts.
- Voltmeter :0 to 75 v
- Ammeter :0 to 15 AMP
- Thermometer :0 to 100 °
- Nichrome wire resistance :4.97 ohms

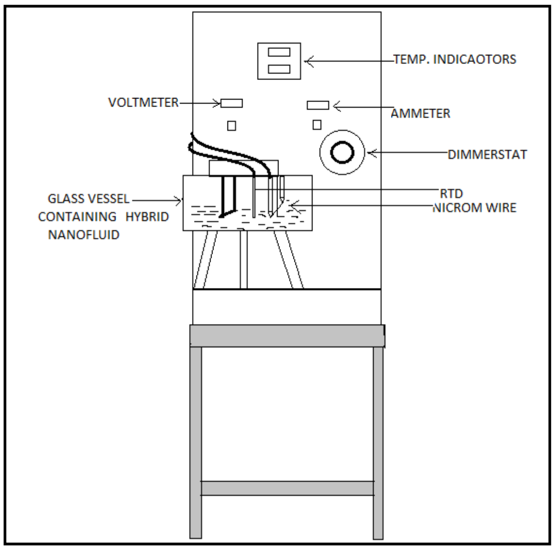


Figure 3:- Schematic diagram of Pool boiling setup

The study of CHF enhancement here we have taken number of readings for the analysis of effect of Nichrome wire size on CHF value & effect of % wt. concentration of Hybrid nanofluid on CHF value and also effect of bulk temperature on CHF value. So here we have taken no. of readings with nicrome wire size available in size of 36 gauge & 39 gauge, then no. of readings with distilled water & 0.25%,0.5% & 1.0% wt. concentration of(Al_2O_3 – CuO/H_2O) Hybrid nanofluid & First set of reading we have taken with the help of 2 liters of distilled water with nicrome wire size 36 gauge & saturation temperature.

3. DATA ANALYSIS

Experimental investigation were carried out to observe the boiling characteristics of Hybrid Nanofluid using Nichrome wire heater. The Critical heat flux is calculated from the following equation:-

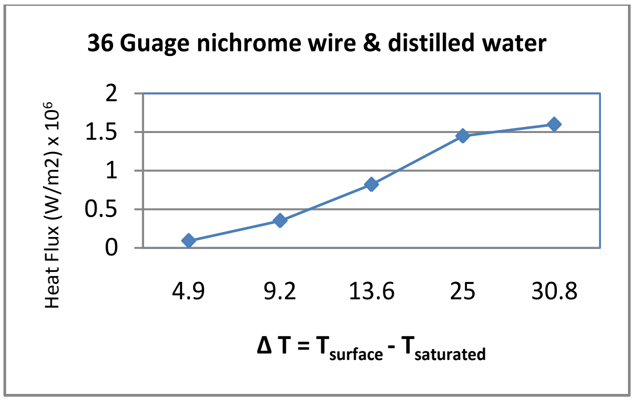
$$\text{CHF} = q = \frac{VI}{A} = \frac{VI}{\pi dL}$$

Where ,I is Current (Ampere), V is Voltage (volts) and Area of heating surface of the nicrome wire in (m2) , d is diameter of nicrome wire (m) & L is Length of the nicrome wire (m).

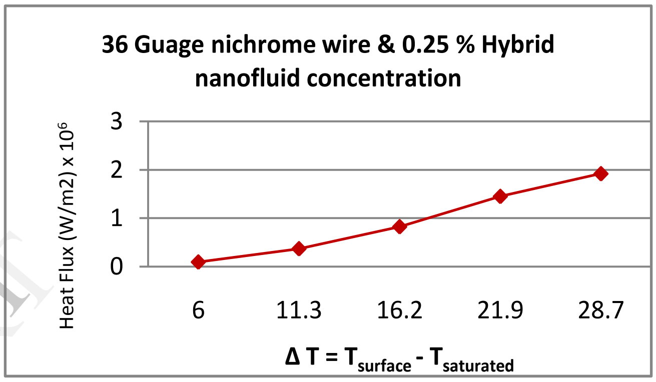
CHF is calculated by varying the volume concentration of Hybrid Nanofluid, diameter of Nichrome wire heater , variation in the volume concentration of Hybrid Nanofluid is 0.25 , 0.5 , 1.0 % by weight and Nichrome heater wire size varies from 0.17 mm and 0.12 mm

4. EXPERIMENTAL RESULTS

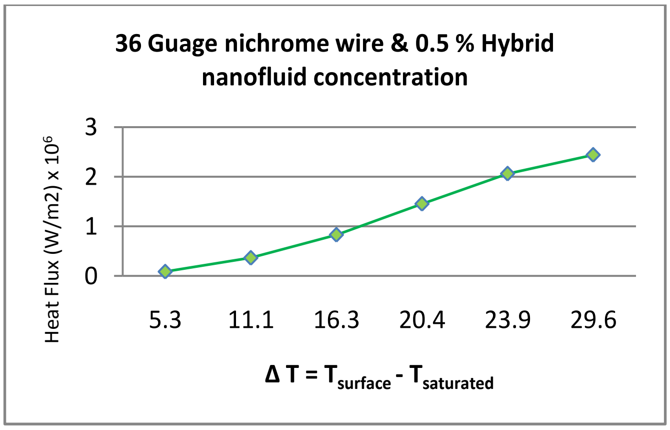
Results for Nichrome wire size is 36 gauge (0.17 mm) For Distilled Water.



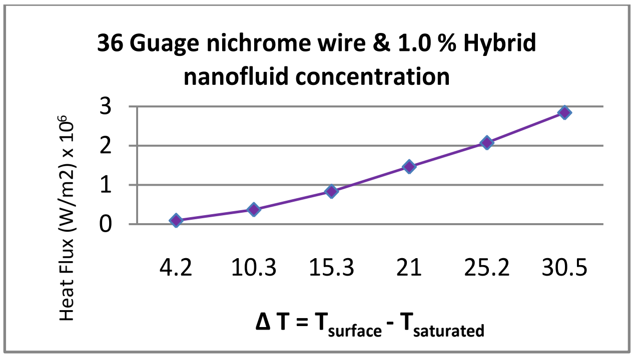
Graph No.1:-Boiling curves for Nichrome wire size 36 gauge (0.17mm)& Distilled water.



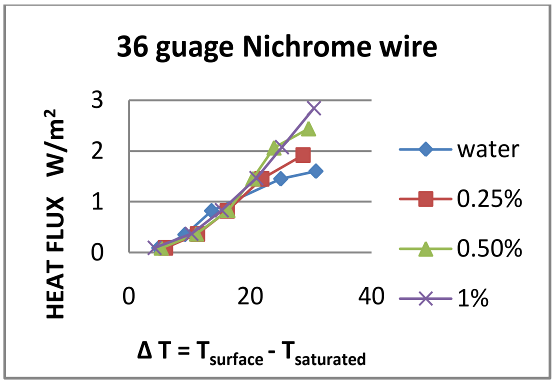
Graph No.2:-Boiling curves for Nichrome wire size 36 gauge (0.17mm),0.25%concentration of (Al_2O_3 - CuO / H_2O)Hybrid Nanofluid



Graph No.3:-Boiling curves for Nichrome wire size 36 gauge (0.17mm),0.5%concentration of (Al_2O_3 - CuO / H_2O)Hybrid Nanofluid



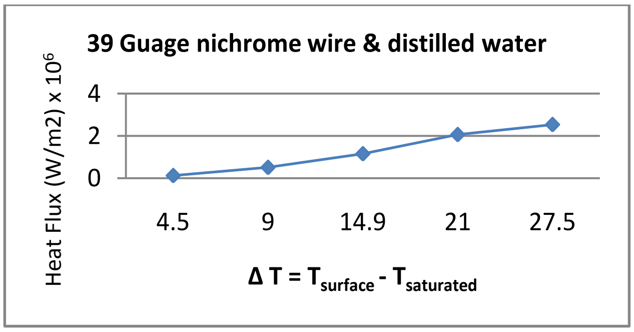
Graph No.4:-Boiling curves for Nichrome wire size 36 gauge (0.17mm),1.0%concentration of (Al_2O_3 - CuO / H_2O)Hybrid Nanofluid



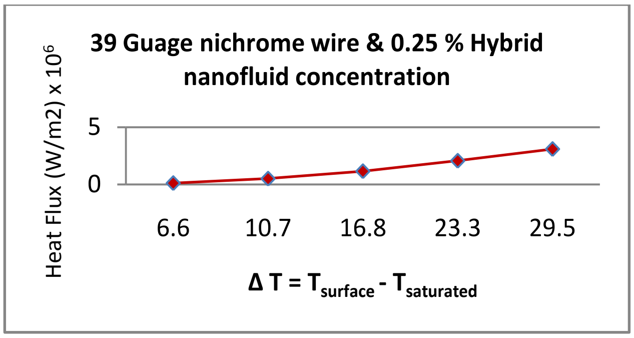
Graph No.5:-Effect of Hybrid Nanofluid concentration on critical heat flux of 36 gauge nicrome wire.

On the performance basis Distilled water attains Avg. CHF value.1% concentration of Hybrid Nanofluid attains Max. CHF value.0.25% & 0.5% concentration of Hybrid Nanofluid attains Avg. CHF value.CHF enhancement in assending order of Hybrid Nanofluid concentration.

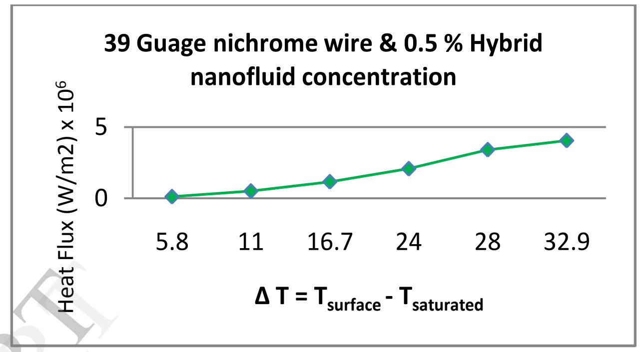
Results for Nichrome wire size is 39 gauge (0.12 mm) .



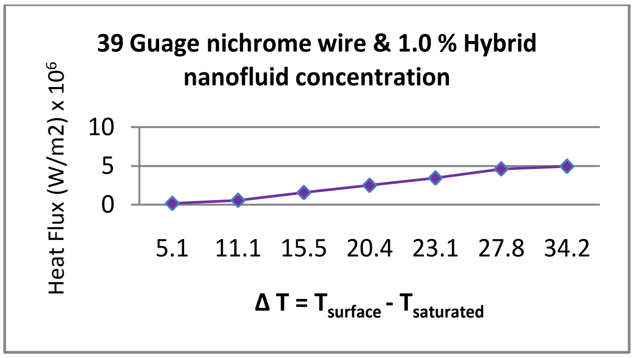
Graph No 6:-Boiling curves for Nichrome wire size 39 gauge (0.12 mm),Distilled water



Graph No7:-Boiling curves for Nichrome wire size 39 gauge (0.12 mm),0.25%concentration of (Al_2O_3 - CuO / H_2O)Hybrid Nanofluid



Graph No.8:-Boiling curves for Nichrome wire size 39 gauge (0.12 mm),0.5%concentration of (Al_2O_3 - CuO / H_2O)Hybrid Nanofluid



Graph No.9:-Boiling curves for Nichrome wire size 39 gauge (0.12 mm),1.0%concentration of (Al_2O_3 - CuO / H_2O)Hybrid Nanofluid

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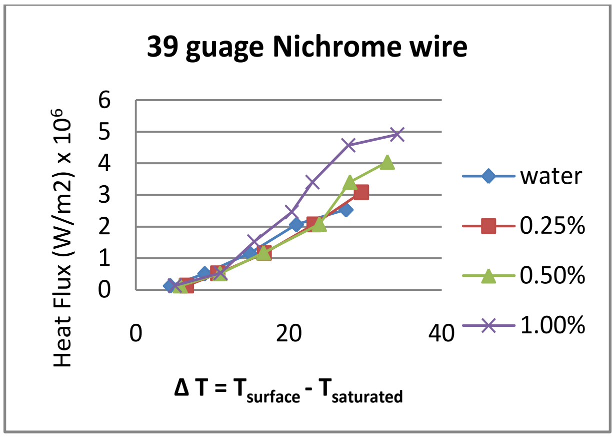

Graph No.10 Effect of Hybrid Nanofluid concentration on critical heat flux of 39 gauge nichrome wire.

On the performance basis Distilled water attains Avg. CHF value.1% concentration of Hybrid Nanofluid attains Max. CHF value. 0.25% & 0.5% concentration of Hybrid Nanofluid attains Avg. CHF value CHF enhancement in assending order of Hybrid Nanofluid concentration.

5. CONCLUSION

In pool boiling with nanofluid the following results have obtained

1. Significant increase in CHF with low concentration of aluminum oxide & copper oxide with distilled water is observed .
2. Research shows that CHF was increased by approximately 120% compared with that of pure water when nanoparticles concentration was greater than 5 g/L with nanofluid.
3. Pool boiling with Hybrid nanofluid introduces equipments in which high heat transfer in minimum area.
4. Higher departing bubble frequency & shorter delayed time is observed
5. Boiling time required to achieve the maximum CHF enhancement decreased drastically compared with pure water.

6. REFERENCES

[1] M.S. El-Genk, Immersion cooling nucleate boiling of high power computer chips, Energy conversion and management 53 (2012) 205 e 218.

[2]S.K. Das, N. Putra, W. Roetzel, Pool boiling characteristic of nanofluids, Int. J.Heat Mass Transfer 46 (2003) 851 e 862

[3] M.N. Golubovic, H.D.M. Hettiarachchi, W.M. Worek, W.J. Minkowycz, Nanofluids and critical hear flux, experimental and analytical study, Appl. Thermal Eng. 29 (2009) 1281e 1288.

[4] S.J. Kim, I.C. Bang, J. Buongiorno, L.W. Hu, Surface wet ability change during pool boiling of nanofluids and its effect on critical heat flux, Int. J. Heat Transfer 50 (2007) 4105e 4116.

[5] H.D. Kim, J. Kim, M.H. Kim, Experimental study on CHF characteristics of nanofluids at pool boiling, Int. J. Multiphase Flow 33 (2007) 691 e 706.

[6] K.J. Park, D. Jung, S.E. Shim, Nucleate boiling heat transfer in aqueous solution with carbon nanotubes up to critical heat flux, Int. J. Multiphase Flow 35(2009) 525e532.

[7] R.A. Taylor, P.E. Phelan, Pool boiling of nanofluids: comprehensive review of existing data and limited new data, Int. J. Heat Mass Transfer 52 (2009)5339e5347.

[9]Jackson, Investigation into the pool boiling characteristics of gold nanofluids .A thesis of faculty of graduate school, Univ. Missouri-Columbia, 2007.

[10] S.M. Kwark, R. Kumar, G. Moreno, J. Yoo, S.M. You, Pool boiling characteristic of low concentration nanofluids, Int. J. Heat Mass Transfer 53 (2010)972 e981.

[11] P.H.G. Allen, T.G. Karayiannis, Electro hydrodynamic enhancement of heat transfer and fluid flow, Heat Recov. Syst. CHP 15 (1995) 389 e 423.

[12] K.J. Park, D. Jung, S.E. Shim, Nucleate boiling heat transfer in aqueous solution with carbon nanotubes up to critical heat flux, Int. J. Multiphase Flow 35(2009) 525e532.

[13] R.A. Taylor, P.E. Phelan, Pool boiling of nanofluids: comprehensive review of existing data and limited new data, Int. J. Heat Mass Transfer 52 (2009)5339e5347