Heat transfer behaviour of Nanofluids

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ABSTRACT

Nanofluids are stable colloidal suspensions of nanoparticles, nanofibers, or nanocomposites in common base fluids, such as water, oil, ethylene-glycol mixtures. Study on nanofluids heat transfer is rather a very recent subject. However, it has attracted many researchers because of their promising heat transfer characteristics vis-à-vis water for applications in future nuclear and process industries. In the similar framework, the authors have investigated the pool boiling heat transfer characteristics of Al2O3 Nanofluids. Experiments were carried out to measure the heat transfer coefficient of water and Alumina nanofluid. Further, experiments were carried out to determine the critical heat flux of Alumina Nanofluids for concentrations ranging from 0.001 % to 1 % by weight. In all the experiments, enhancement in CHF was observed as compared to water. This property of nanofluids certainly highlights the potential application of nanofluids in nuclear industries.

Keywords: Nanofluids, CHF, Pool boiling

1 INTRODUCTION

Boiling phenomenon is of immense importance in nuclear reactor systems both as a means of achieving high heat-transfer rates from fuel to coolant and for generating steam in a heat exchanger. Till now many efforts have been done towards increasing the boiling heat transfer coefficients of conventional fluids by making use many additives in the base fluid. One of such method is adding suspended solid particles to increase the effective thermal conductivity of the base fluid. Although, this method has been used since long, traditionally, microscaled particles were used as dispersants. However, they were of little interest from practical point of view due to problems such as settling, erosion, fouling and increased pressure drop of the flow channel. The advent of nanotechnology gave rise to an alltogether different kind of fluids called nanofluids which overcame all the problems faced by traditinal suspensions. With very low settling rates and high stability, nanofluids have become topic of interest owing to their enhanced heat transfer characteristics as compared to base fluids[1-3]. In the present work, the authors have investigated the pool boiling heat transfer characteristics of Al_2O_3 Nanofluids. Experiments were carried out to measure the heat transfer coefficient of water and Alumina nanofluid prepared by dispersing nanoparticles inside water by ultrasonication.

In boiling reactor systems, occurrence of critical heat flux (CHF) is undesirable. Hence, for same operating conditions, increase in CHF can provide higher thermal margins. Use of nanofluids could be one such way to enhance the CHF [4-6]. To explore this, experiments were carried out to determine the critical heat flux of Alumina Nanofluids for concentrations ranging from 0.001 % to 1 % by weight.

2 POOL BOILING HEAT TRANSFER CHARACTERISTICS OF NANOFLUIDS

Experiments were carried out to measure the two phase heat transfer coefficient of water as well as nanofluid.

2.1 Experimental setup

The schematic of the experimental test facilit is given in Fig. 1

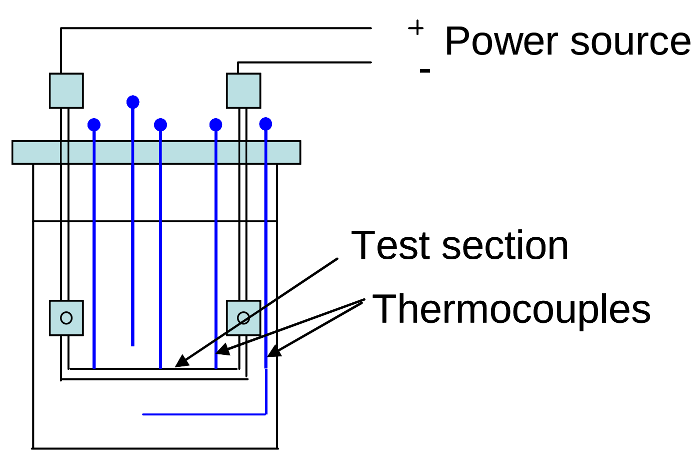

Figure 1: Schematic of test section

The experiemntal setup consists of a 10 lit capacity glass beaker in which about 8 litres of nanfluid was poured. An SS 304 tube with diameter 6 mm and thickness 0.6 mm was used as a heater. The tube was directly heated with a DC source of 400 A, 50 V power supply. Three 0.5 mm ‘K’ type Thermocouples were brazed on the surface of the tube to measure the surface temperature. Besides, the water bulk and film temperature was measured using another 2 thermocouples.

2.2 Nanofluid preparation

Nano-fluids were prepared by the two-step method, dispersing dry nanoparticles into the base liquid followed by uktrasonication. Distilled water was used as a base liquid, and Al_2O_3 (40 – 60 nm, 99.5 % purity Alfa Aesar make) nanoparticles were used. Some additives (dispersants or surfactants) could have been used to stabilize the nanoparticle suspensions, but the additives could exert a significant influence on the rheological behavior of the fluids and the boiling heat transfer. Therefore, in this work, no additive was used and ultrasonication was performed for 4-5 h just before pool boiling experiments. Nanoparticles dispersed without other additives do not change the surface tension of the base fluid. Concentration of 0.5 % by weight was used.

2.3 Experimental procedure

Experiment was first carried out with pure water. Initially sub cooled water was put in the beaker. Power was applied to the test section. The power was raised in small steps and it was kept constant for a period of 5 mins for each power level. Transient history of temperatures on the surface, in the film just next to the heater and in bulk of the fluid was recorded. Experiment was continued till nucleate boiling was substantial. Then, similar experiment was repeated with same power steps for nanofluid.

2.4 Results

Fugure 2 shows the ΔT variation of nanofluid and water.

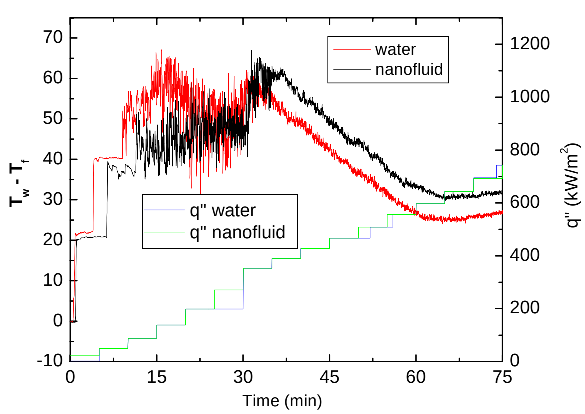

Figure 2: ΔT variation of nanofluid and water

It can be seen that, initially, the ΔT for water is higher than that of the nanofluid indicating that, the surface temperature is higher than that of fluid. But after boiling, it was seen that the ΔT of water reduced as compared to nanofluids. Figures 3 and 4 show the calculated heat transfer coefficients in single phase convective and two phase nucleate boiling region.

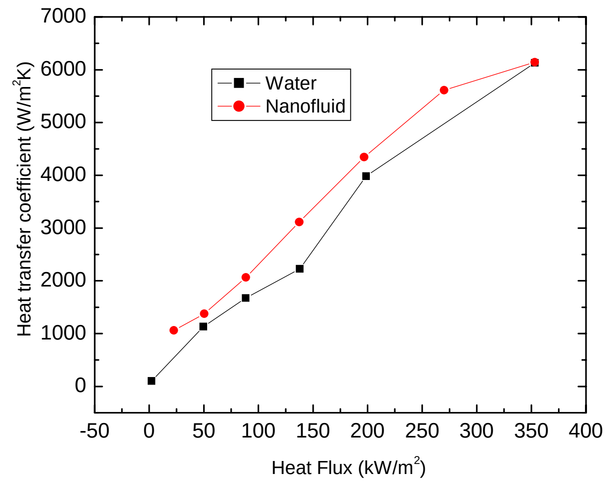

Figure 3: Heat transfer coefficient in single phase region

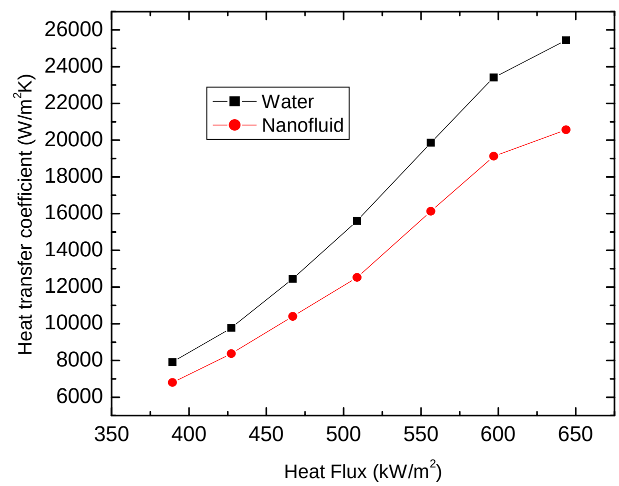

Figure 4: Heat transfer coefficient in nucleate boiling region

It is observed that, Initially, the heat transfer coefficient of nanofluid was found to be higher in single phase convection region whereas in nucleate boiling region, the heat transfer coefficient is found to higher in water.

2.5 Discussions:

By addition of nanoparticles in water, the thermal conductivity is found to be enhanced as reported by [1]. As a result of increase in thermal conductivity, the single phase convective heat transfer coefficient is found to be enhanced. On the contrary, when boiling occurs, there is a microlayer deposition of nanoparticles [7] on the heater surface which causes deterioration of heat transfer coefficient in nucleate boiling condition.

3 CHF CHARACTERISTICS OF NANOFLUIDS

experiments were carried out to determine the critical heat flux of Alumina Nanofluids for concentrations ranging from 0.001 % to 1 % by weight

3.1 Experimental setup

The experimental setup was slightly modified for the CHF experiements. The experiments were performed with a 0.2 m diameter NiChrome wire instead of SS tube. A 3 litre beaker was used in this case. The modified setup is given in Fig 5.

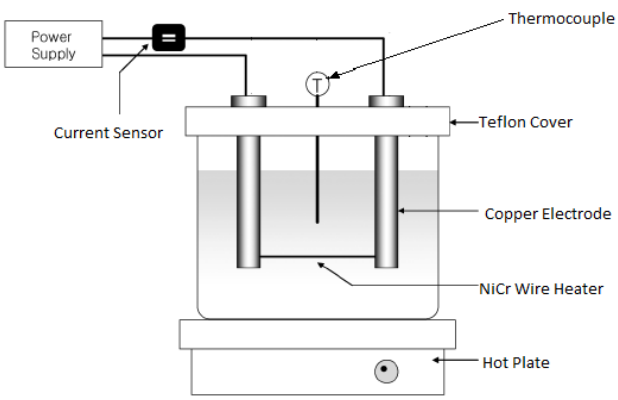

Figure 5: Experimental setup for CHF experiments

3.2 Experimental procedure

Initially, the experiment was performed with pure water. The water was heated using the heater and the temperature was brought to near saturation (95 deg C). Then power was applied to the Nichrome wire. Power was raised in very small steps. At a point when CHF occurs, a bright red spot is observed in the Nichrome wire and it gets burned which trips the electirc current. This gives accurate indication of CHF. Similar experiments were repeated for nanofluids of concentrations ranging from 0.001 % to 1 % by weight of Alumina. For each concentration, experiment was repeated 3-4 times to get accurate results.

3.3 Results

Table 1 shows the experimentally measured values of CHF for different nanofluids.

Table 1: measured CHF values

Nanofluid concentration	CHF (MW/m^2)	% increment over water
0 % (water)	1.07	0
0.001 %	1.56	46.07
0.005	1.5593	45.73
0.01	1.648	54.02
0.1	1.97	83.7
0.5	1.853	73.19
1	1.85	73.36

Figure 6 shows the variation of CHF with increase in nanofluid concentration. It is seen that, even low concentration like 0.001 % enhances the CHF by 45 %. CHF first increases with increase in concentration and then it is found to be decreased. But as compared to water, all the concentrations tested had enhancement in CHF.

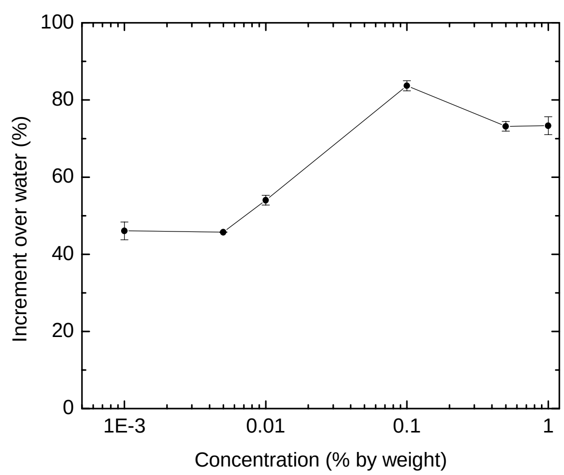

Figure 6: Enhancement of CHF over water in case of nanofluids

3.4 Discussion

It has been observed from Fig 6 that, there is a particular trend in enhancement of CHF with increase in nanoparticle concentration. The main increase in CHF is because of change in surface properties of wire. In case of low concentration of nanoparticles, there could be a fine deposition of nanoparticles on the wire which increases the surface roughness increasing the nucleation sites. This causes enhancement in the CHF. But as the concentration of nanoparticles increases, the deposition layer thickness increases, hence now the number of nucleation sites are less as comparted to those in case of nanoparticles with low concentration but more than that of bare wire. As a result, the CHF decreases but is more than that in case of pure water.

4 CONCLUSION

In this paper, we have studied the heat transfer bahaviour of nanofluids. The heat transfer coefficient of nanofluids was determined experimentally. It was observed that, single phase convection heat transfer of nanofluids was found to be higher than that of water whereas, the nucleate boiling heat trasnfer coefficient is found to be higher in water. Critical heat flux of nanofluids was also measure experimentally. It was observed that, at even low concentration of 0.001 % by weight also, there was substantial enhancement in CHF (45 %). In case of nanofluieds, CHF first increased with increase in weight percentage and then decreased, but remained always higher than that of water. The reason for enhancement in CHF can be attributed to change in surface properties of wire.

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