

Investigation of Heat Transfer In Pool Boiling on Vertical Cylindrical Brass Surface With Silica and Tungsten Oxide Nanofluids

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Abstract

Investigation of heat transfer during pool boiling of two nanofluids i.e. water-silica and water-tungsten oxide has been carried out. Nanoparticles were tested at the different concentration of 0.01g/l to 1.0g/l. The vertical cylindrical brass specimen having 12mm diameter and 17mm length formed test heater. The experiments have been performed to establish the influence of nanofluids concentration as well as surface material on heat transfer coefficient at atmospheric pressure. The results indicate that independent of concentration nanoparticle material (silica and tungsten oxide) has influence on heat transfer coefficient while boiling of water –silica or water- tungsten oxide on vertical surface of brass specimen. It seems that heater material did not affect the boiling heat transfer in 1.0 g/l water-silica or water-tungsten oxide nanofluid.

Keywords: silica nanofluid and tungsten oxide nanofluid, Pool boiling, vertical cylindrical surface of brass specimen.

Introduction

In nanotechnology field have allowed development of a new category of liquids termed nanofluids, which was first used by a group in Argonne National Laboratory USA to describe liquid suspensions containing nanoparticles with thermal conductivities, orders of magnitudes higher than the base liquids, and with sizes significantly smaller than 100 nm. The augment of thermal conductivity could provide a basis for an enormous innovation for heat transfer intensification, which is pertinent to a number of industrial sectors including transportation, power generation, micro-manufacturing, chemical and metallurgical industries, as well as heating, cooling, ventilation, and air-conditioning industry.

The intensification of heat transfer processes and the reduction of energy losses are hence important tasks, particularly with regard to the prevailing energy crisis. In this regard, the heat transfer boiling has been used extensively to acquire good heat transfer performance. In terms of boiling regimes, nucleate boiling is an efficient heat transfer mechanism however, for the incorporation of nucleate boiling in most practical applications. For decades, researchers have been trying to develop more efficient heat transfer fluids. This would, in turn, improve process efficiency and reduce operational costs. This is where nanofluids could play a key role, nanofluids could potentially revolutionise heat transfer.

Accordingly, various techniques for enhancement of the boiling heat transfer have been proposed and studied. Typical approaches that have been considered to enhance pool boiling heat transfer in particular include oxidation or selective fouling of a heater surface to increase the wettability of the liquid, vibration of heaters to promote the departure of bubbles from a heater surface and extended heater surface to increase the heat transfer area. An interesting advantage of using nanofluids for heat transfer applications is the ability to alter their properties. That is the thermal conductivity and surface wettability, for example, can be adjusted by varying the particle concentration in the base fluid, and hence allowing nanofluids to be used for a variety of different applications. However, it is also important to note that addition of nanoparticles to a base fluid also changes the viscosity, density and even the effective specific heat these properties also have a direct effect on the heat transfer effectiveness.

With the modern technology available it is quite possible to produce ultra fine nanosized metallic non-metallic particles which will revolutionize heat transfer enhancement methods (Zeinali et al.2007). Considering very small particle size and their small volume fraction problems such as clogging and increased pressure drop become insignificant if these particles are used along with base fluids. The relative large surface area of nanoparticles increases the stability and reduces the sedimentation in addition to dramatic improvement in heat transfer efficiency. This is possible due to decreased particle size in a suspension and increased surface area of the particles.

In this regard improving the thermal properties of energy transmission fluids may become an effective means of augmenting heat transfer. Conventional heat transfer fluids such as water, ethylene glycol and oil have inherently low thermal conductivity relative to metals and even metal oxides. Therefore fluids with these suspended solid particles can offer better heat transfer properties compared to conventional heat transfer fluids.

Pool Boiling Experiments:

Figure shows the schematic diagram of the experimental set up. It consists of a boiling vessel of 80 mm diameter and 200 mm long made up of stainless steel 316 fitted with flanges at top and bottom.

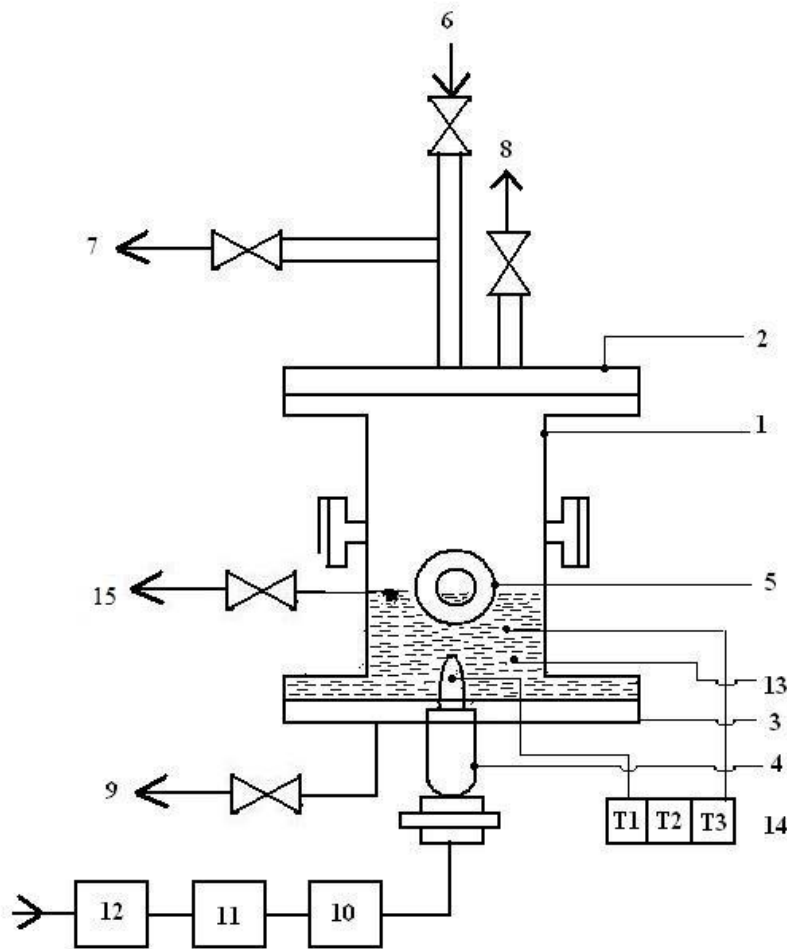


Figure 1: Schematic Diagram of Experimental Setup

1. Boiling vessel 10 Wattmeter
2. Top flange 11 Dimmer stat
3. Bottom flange 12 Stabiliser
4. Heater 13 Nanofluid
5. Watch glass 14 Temperature indicator
6. Liquid inlet (surface and liquid temperature)
7. To vaccum 15 Make up water
8. Pressure relief valve
9. Drain

Due provisions are made in these flanges for liquid charging inlet and outlet, vacuum pump lines, thermocouples, test heater section and drain. The vessel is heavily insulated by asbestos rope and woollen ropes covered by packing material to reduce any heat transfer to surroundings. The test section is a cylindrical vertical surface of 12mm diameter and 17 mm length with two thermocouples fixed to the surface at

opposite sides around at a depth of 1mm on the periphery. The test section is heated by an electrical heating element of 1000 w capacity. The heating element is connected to a wattmeter through a dimmer stat to vary the heat input during the experimentation.

Preparation of Nanofluids:

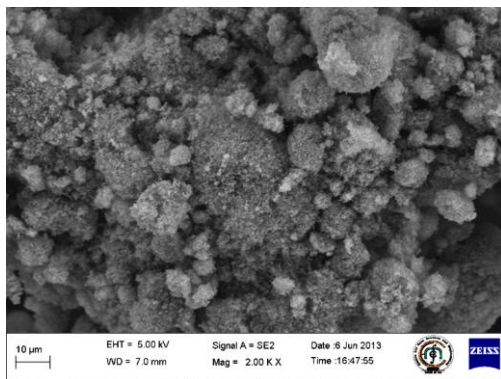
In this work to prepare the nanofluids with desired concentration, nanoparticles were homogeneously dispersed into pure water. The characteristics of nanofluids are governed by not only the kind and size of the nanoparticles but also their dispersion status in the pure water. Due care was taken to ensure complete dispersion. After weighing equivalent weight of the solid nanoparticles were mixed with pure water in a flask, and then each time, vibrating machine was used to mix the nanoparticles uniformly for about 3 – 4 hrs. No considerable sedimentation was observed for the range of concentrations.



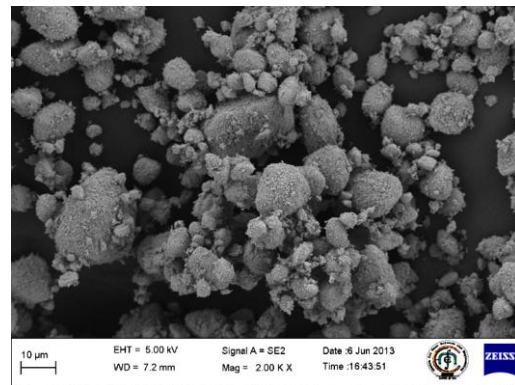
WO₃ Nanofluid



Silica Nanofluid



SEM image of silica nanoparticles



SEM Image of WO₃ Nanoparticles

Figure 2: Silica and WO₃ Nanofluids and SEM Image of Nanoparticles

Experimental Procedure and Data Collection

Before starting the experiments the boiling chamber was cleaned to remove any dirt or other particles and evacuated by using a vacuum pump. The boiling vessel was filled with distilled water up to the mark in the vessel such that heating surface is completely immersed in the liquid. The vessel is closed. The auxiliary heater was switched on and it will give more heat . The system is run for 2 to 3 hours so as to ensure thermal steady state conditions. The liquid temperature were noted down the heating is continued till the liquid reached about 95⁰C and the test section was given heat input through variac slowly and in steps the test heater power is increased to observe bubble formation and detachment. The make up water is expected to keep the concentration uniform. In every steps half an hour was allowed to get satisfactory steady state conditions the readings are noted down. The experiment is repeated for higher heat inputs. The readings are tabulated. The procedure is repeated till the last desired value of heat input (1kW).

The above procedure is followed with nanofluids.

The heat flux q is calculated using the following relation.

$$q = Q/A \text{ W/m}^2 \text{ or kW/m}^2 \dots\dots\dots 1$$

Where Q is the heat input in W or kW

A is the surface area in mm² or m²

Heat transfer coefficient h between the surface and the liquid is calculated by applying Newton’s law of cooling.

$$h = q / T_s - T_l \text{ W/m}^2 \text{ K or kW/m}^2 \text{ K} \dots\dots\dots 2$$

Where Ts is the average of surface temperatures recorded by thermocouples

T_l is the liquid temperature recorded by thermocouple

Results and Discussion

Results of water and different concentrations of silica nanofluids on brass surface is shown fig 3. At the same heat flux the heat transfer coefficient at higher concentration of nanofluid is higher than that at lower concentrations across the range of heat flux, because the particles are increased.

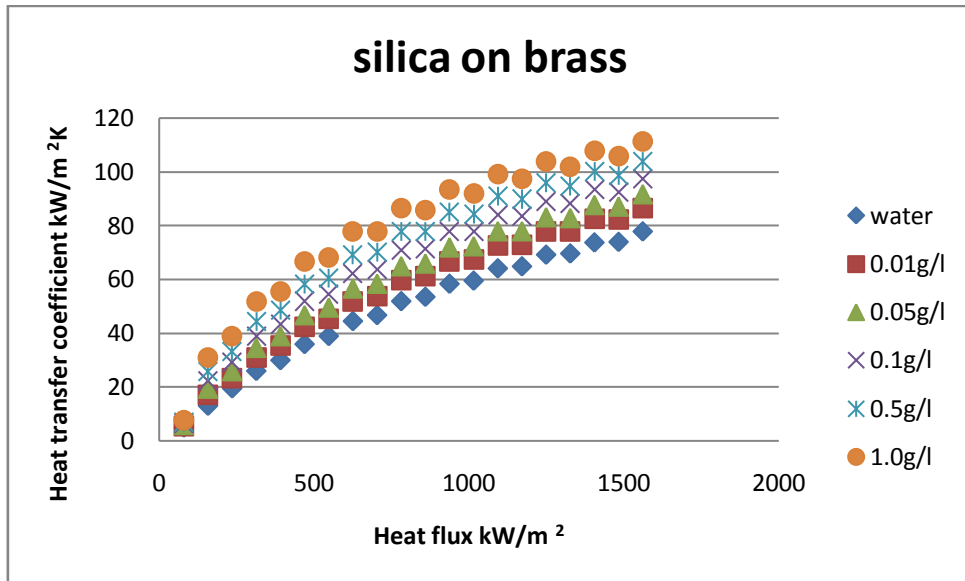


Figure 3: Comparison of Heat Transfer Coefficients For Silica Nanofluid Different Concentrations on Brass Vertical Surface

Heat transfer coefficient enhancement is about 11.10% with 0.01g/l, 17.64% with 0.05g/l, 24.99% with 0.1g/l, 33.33% with 0.5g/l, 42.85% with 1.0g/l of silica nanofluids compared with those of pure water.

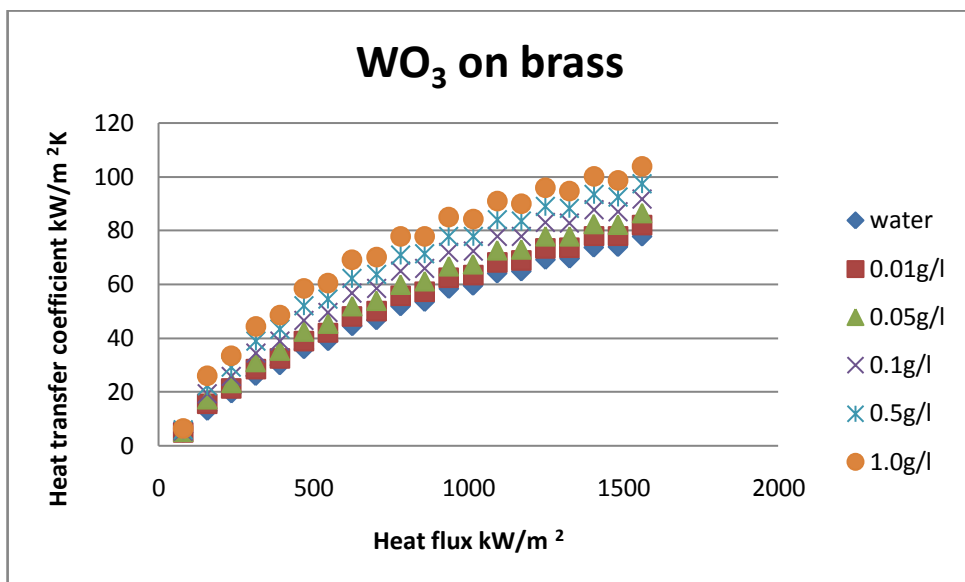


Figure 4: Comparison of Heat Transfer Coefficients For WO₃ Nanofluid Different Concentrations on Brass Vertical Surface

Showing results of water and different concentrations of wo3 nanofluids on brass surface is shown fig 4. At the same heat flux the heat transfer coefficient at higher

concentration of nanofluid is higher than that at lower concentrations across the range of heat flux. The heat transfer coefficient is increased from about 200kW/m² upto higher level.

Heat transfer coefficient enhancement is about 5.26% with 0.01g/l, 11.11% with 0.05g/l, 17.64% with 0.1g/l, 24.99% with 0.5g/l, 33.33% with 1.0g/l of tungsten oxide nanofluids compared with those of pure water.

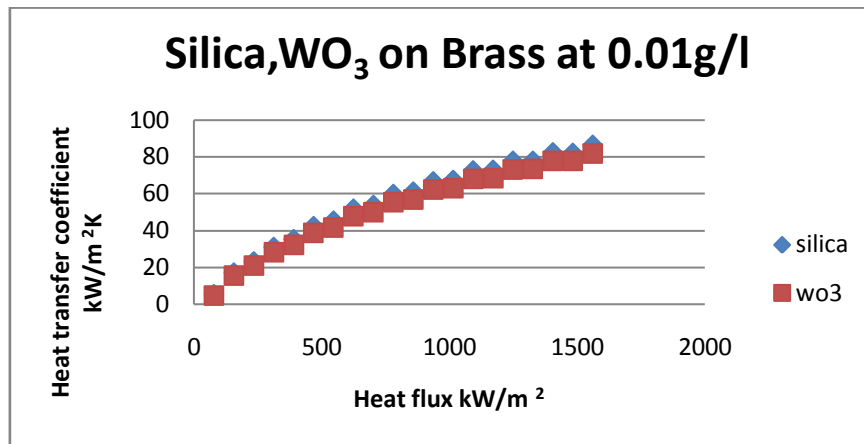


Figure 5: Comparison Of Silica And WO₃ Nanofluids On Brass Surface At 0.01g/L

Fig 5. shows that the results of silica and tungsten oxide nanofluids on brass vertical surface at 0.01g/l . Heat transfer coefficient for silica nanofluid higher than those of tungsten oxide nanofluid.

At lower range both fluids are similar up to 300kW/m² and then silica nanofluid is slightly increased than tungsten oxide nanofluid.

Heat transfer coefficient enhancement is about 5.55% is increased with 0.01g/l compare with tungsten oxide nanofluid.

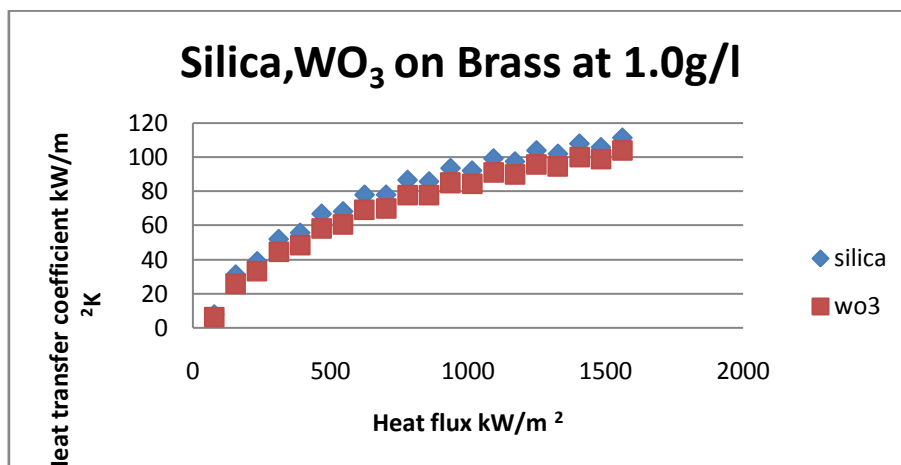


Figure 6: Comparison Of Silica And WO₃ Nanofluids On Brass Surface At 1.0g/L

Fig 6. shows that the results of silica and tungsten oxide nanofluids on brass vertical surface at 1.0g/l. Heat transfer coefficient for silica nanofluid higher than those of tungsten oxide nanofluid.

From the graph the heat transfer coefficient of both fluids are goes on increased at lower level to higher level because of only increase the concentrations of nanoparticles.

Heat transfer coefficient enhancement is about 7.14% is increased with 1.0g/l compare with tungsten oxide nanofluid

Conclusions

In Pool boiling heat transfer has been conducted on brass cylindrical specimen for different concentrations of silica and tungsten oxide nanofluids. For brass cylindrical specimen, the presence of nanoparticles significantly enhanced the pool boiling heat transfer coefficient. Furthermore based on the experimental results it is recommended to use nanofluids for enhancing the heat transfer coefficient around the brass cylindrical surfaces.

The experiments on boiling of nanofluids on brass surface with varying concentrations gave (i) with silica nanofluid the heat transfer enhancement is found gradually increasing with concentration of the silica from about 11.10% for 0.01g/l concentration to about 42.85% with 1.0g/l concentration when compared with heat transfer coefficient values for pure water.

(ii) With tungsten oxide nanofluids the heat transfer coefficient is found gradually increasing with concentration of tungsten oxide from about 5.26% for 0.01g/l concentration to about 33.33% with 1.0g/l concentration when compared with heat transfer coefficient values for pure water.

Heat transfer coefficient enhancement is about 5.55% is increased with 0.01g/l compare with tungsten oxide nanofluids and other heat transfer coefficient enhancement is about 7.14% is increased with 1.0g/l compare with tungsten oxide nanofluid.

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