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Experimental Investigation on Pool Boiling Heat Transfer With Ammonium Dodecyl Sulfate

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Abstract

We have so many applications related to Pool Boiling. The Pool Boiling is mostly useful in arid areas to produce drinking water from impure water like sea water by distillation process. It is very difficult to distill the only water which having high surface tension. The surface tension is important factor to affect heat transfer enhancement in pool boiling. By reducing the surface tension we can increase the heat transfer rate in pool boiling. From so many years we are using surfactants domestically. It is proven previously by experiments that the addition of little amount of surfactant reduces the surface tension and increase the rate of heat transfer. There are different groups of surfactants. From those I'm conducting experimentation with anionic surfactant Ammonium Dodecyl Sulfate (ADS), which is most human friendly and three times best soluble than Sodium Dodecyl Sulfate, to test the heat transfer enhancement.

Key words— Pool Boiling, Heat Flux, Ammonium Dodecyl Sulfate, Surfactant.

I. INTRODUCTION

The mechanism of pool boiling heat transfer has been studied for a long time since it is closely related with the designs of more efficient heat exchanger and heat removal systems. Recently, it has been widely investigated in nuclear power plants for application to the design of new passive heat removal systems employed in the advanced light water reactors (ALWRs) designs. The passive heat exchangers can transfer the decay heat from the Reactor Coolant System (RCS) to the water tank even though the electric power becomes unavailable for heat removal.

Among the different enhancement techniques investigated, the use of additives for liquids appears to be quite viable and attracted some research. Small amount of certain surfactant additives are known to drastically change the boiling phenomena of water. The surfactant effect has generated a lot of interest for many years. It is most desirable that employing surfactant additives in liquids can develop and mature into an enhancement technique for boiling heat transfer. Generally, it is believed that small amount of surfactant can increase boiling heat transfer. The extent of enhancement has been found to be dependent on additive concentrations, its type and chemistry, wall heat flux, and the heater geometry. Surfactant is a generic term for a surface-active agent, which literally means active at surface. It is fundamentally characterized by its tendency to adsorb at surfaces and interfaces when added in low concentrations to aqueous system.

II. NOMENCLATURE SURFACTANT

Ammonium lauryl sulfate (ALS) is the common name for ammonium dodecyl sulfate is an organic compound with the formula (CH3(CH2)10CH2OSO3NH4). Like many surfactants, ammonium lauryl sulfate makes a good base for surface tension reduction agent because of the way it disrupts hydrogen bonding in water. (It is hydrogen bonding that is the primary contributor to the high surface tension of water.) In aqueous (water based) solutions, the lauryl sulfate anions and the ammonium cations dissociate from each other. Above the critical micelle concentration, the anions then align themselves into a micelle, in which they form a sphere with the polar, hydrophilic heads of the sulfate portion on the outside (surface) of the sphere and the non-polar, hydrophobic tails pointing inwards towards the center. The water molecules around the micelle in turn arrange themselves around the polar heads, which disrupts their ability to hydrogen bond with other nearby water molecules. The overall effect of these micelles is a reduction in surface tension of the solution, which affords a greater ability to penetrate or "wet out" various surfaces, including porous structures like cloth, fibers, and hair. Accordingly, this allows the solution to more readily dissolve soils, greases, etc. in and on such substrates. It is an anionic surfactant used in many cleaning and hygiene products. The salt is of an organo-sulfate consisting of a 12-carbon tail attached to a sulfate group, giving the material the amphiphilic properties required to reduce the surface tension.

Production:

ADS is produced by reaction of n-dodecyl alcohol with chlorosulfonic acid followed by neutralization with ammonia. The industrially practiced method typically uses sulfur trioxide gas. The resulting product is then neutralized through the addition of sodium hydroxide or sodium carbonate. Lauryl alcohol is in turn usually derived from either coconut or palm kernel oil by hydrolysis, which liberates their fatty acids, followed by hydrogenation. Due to this synthesis method, commercial samples of ADS are often a mixture of other alkyl sulfates, dodecyl sulfate being the main component.

Role of ADS in This Experimentation:

With so many surfactants are tested in boiling heat transfer enhancement. In this I'm testing heat transfer enhancement with addition of ADS to water. The surfactant ADS molecules surrounds and enclose the water molecules due to effect of water loving part in the SDS as in below figure. Every water molecule having inter molecular attraction force with surrounding water molecules which is known as 'cohesion' and water molecules at solid surface (Heater surface) also having attraction force with solid surface which is known as 'adhesion', that is also called as surface tension.

The surface tension is high in pure water. Which means the attraction forces between water molecules and water molecules to solid surface is high. Therefore in pool boiling the nearest water molecules to heater surface absorbs heat and forms bubbles. The bubbles are energy movers in pool boiling. These transfers heat from heater surface to cold liquid by carrying in the form of vapor. But in case of pure water due to high surface tension un-wetted bubbles will forms, those having very low vapor content inside the bubble. By adding ADS, its molecules disturbs the bonding due to cohesion and adhesive forces between water molecules and with solid surface. So bubbles forms at low temperature difference also and that to forms wetted bubbles, those contains high vapor content inside the bubbles. And due low adhesive force these bubbles detaches easily from heater surface and flows upwards due to buoyancy effect. The detached bubbles collapse after a certain flow depending on surrounding pressure and shares the heat in the vapor content to surrounding water. Thus the hydrophilic mechanism of ADS causes to enhancement in pool boiling heat transfer.

III. LITERATURE REVIEW

The study of the saturated pool boiling of a surfactant solution shows a significant enhancement of heat transfer. Generally, it is believed that small amount of surfactant can increase boiling heat transfer. The extent of enhancement has been found to be dependent on additive concentrations, its type and chemistry, wall heat flux, heater geometry as reviewed recently by Wasker and Manglik (2000).

Wu and Yang (1995) reported experimental data on the effect of surfactants on nucleate boiling in water with nine different additives.The enhancement of heat transfer was related to depression of the static surface tension. Small concentrations of surfactant additives reduces the surface tension reduces considerably and its level of reduction depends on the amount and type of surfactant presented in the solution. The activation of nucleation sites, bubble growth and bubble dynamics influence the boiling heat transfer coefficient by Wen DS (2000). Frost and Kippenhan (1997) investigated boiling of water with various concentrations of surfactant ''Ultra wet 60L''. They observed that the increase of heat transfer being related to the reduction in the surface tension. The effect of surfactants and polymeric additives on the physical properties of aqueous surfactant and polymeric solutions as reviewed recently by Cheng L (2007).

The measurement results of surface tensions and viscosities by aqueous surfactant and polymeric solutions show the variation of physical properties and interfacial properties affected by concentrations of surfactant and polymeric solutions. Hetsroni G (2000) studied experimentally the saturated nucleate pool boiling of aqueous Habon G solutions on the surface of electrically heated constantan plate. They have concluded that the heat transfer coefficient can be enhanced by the addition of Habon G, depending upon its concentration.

Zhang N, Li L said by experimentation, that Three non-sodium-based dodecyl sulfate surfactants, ammonium dodecyl sulfate (ADS), hydrogen dodecyl sulfate, and tris(hydroxymethyl) aminomethane dodecyl sulfate were investigated. Of the three surfactants tested, it is found that ADS gives the best performance in MALDI. For proteins with moderate molecular masses (i.e., up to approximately 25 kDa), the presence of ADS in a protein sample does not result in significant degradation in mass resolution and accuracy, and the protonated molecular ion peak is the dominant peak in the MALDI spectrum. The ammonium adduct ions dominate the MALDI spectra when the protein mass exceeds approximately 25 kDa; however, ADS still gives better results than SDS. The behavior of ADS in gel electrophoresis was also investigated. It is shown that cell extracts dissolved in ADS can be separated by normal SDSpolyacrylamide gel electrophoresis by simply mixing them with the SDS sample buffer. The application of ADS as the surfactant for protein solubilization with improved performance in MALDI analysis is demonstrated in the study of a detergent insoluble fraction from a Raji/CD9 B-cell lymphocyte lysate.

The heat transfer increases with increasing the solution concentration and reaches a maximum value at a certain solution concentration, and then decreases with further increasing the solution concentration. The effect of both the surface tension and the kinematic viscosity of aqueous Habon G solutions can explain the features of boiling heat transfer of the solutions. In this investigation, The Pool Boiling heat transfer is studied with Ammonium Dodecyl Sulfate at different concentrations. For the results obtained, graphs were drawn.

IV. EXPERIMENTAL SETUP

Experimental Setup

The experimental setup consists of a

- Power Supply Equipment,
- Pool Heater,
- Beaker,
- Thermocouples.

Power Supply Equipment:

The power supply equipment consists of a Voltmeter, Ammeter and Temperature Indicator. The Voltmeter is of maximum 240 Volts, and Ammeter is of maximum 4.05 Amperes. The voltmeter and ammeter are used to set the constant power supply.

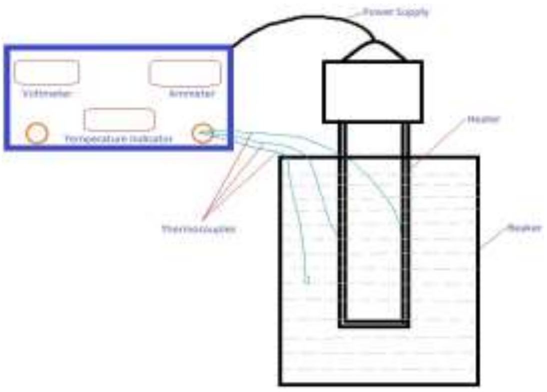

Fig:1. Experimental Setup line diagram.

The temperature indicator is used to show the temperature measurement by required number of temperatures marked reader. And thermocouples also connected to this power supply which converts the temperature measurement to digital form and shows the reading.

Fig:2. Experimental Setup Practical diagram.

Pool Heater:

The pool Heater of polished stainless steel of length 600mm and 3.75mm diameter is used. The heater is connected to the power supply equipment to regulate the amount of power supply.

Thermocouples:

Thermocouple is used to measure the temperature of matter and transfers it to the digital reader. A thermocouple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots, where a temperature differential is experienced by the different conductors (or semiconductors). It produces a voltage when the temperature of one of the spots differs from the reference temperature at other parts of the circuit. Thermocouples are a widely used type of temperature sensor for measurement and control, and can also convert a temperature gradient into electricity.

Any junction of dissimilar metals will produce an electric potential related to temperature. Thermocouples for practical measurement of temperature are junctions of specific alloys which have a predictable and repeatable relationship between temperature and voltage. Different alloys are used for different temperature ranges. Properties such as resistance to corrosion may also be important when choosing a type of thermocouple. Where the measurement point is far from the measuring instrument, the intermediate connection can be made by extension wires which are less costly than the materials used to make the sensor. Thermocouples are usually standardized against a reference temperature of 0 degrees Celsius; practical instruments use electronic methods of cold-junction compensation to adjust for varying temperature at the instrument terminals. Electronic instruments can also compensate for the varying characteristics of the thermocouple, and so improve the precision and accuracy of measurements.

V. EXPERIMENT PROCEDURE

A beaker of one liter volume is taken and filled with pure water. A heater is dipped into the water which is connected to power supply equipment. Two thermocouples are attached to heater surface to measure the temperature of the heater surface. The power supply is switched on to the heater. The supplying heat is set to constant at voltmeter reading(V) is set to 120 volts and ammeter reading(I) is adjusted to 2.05 amperes.

After reaching the saturation temperature bubble formation is started on heater surface. Then the values of temperatures of heater surface is noted and tabulated. After a certain interval time again the temperature readings are noted and tabulated. This process is continued for up to the end of nucleate boiling. The process is repeated for every 10 ppm concentration up to 100ppm and from that process is repeated for every 100ppm concentration up to 1000ppm and further the concentration is increased by 500ppm up to 3000ppm. Tabulated all those readings and calculated the Heat flux(q_s) and Coefficient of Heat Transfer (h). The Heat flux is calculated by using Roshenow Nucleate Boiling correlation.

$$q_s = \mu_l h_{fg}\left(\frac{g(\rho_l - \rho_v)}{\sigma}\right)^{0.5}\left(\frac{c_{pl}(T_s - T_{sat})}{C_{sf} h_{fg} \rho r_l^n}\right)^3$$

V. EXPERIMENTAL RESULTS

Heat Flux and Time Variation by Concentration:

The below 3D plot shows that the heat flux is increasing with increase in concentration of ADS and time of boiling is decreasing with increasing concentration of ADS. Here we can observe that the addition of ADS causes enhancement in Heat Flux.

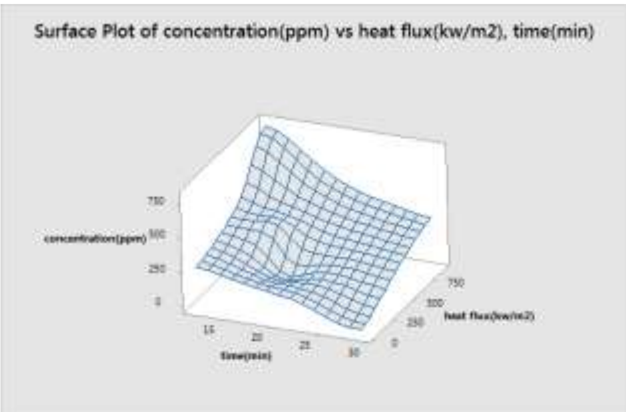

Fig.3. Heat Flux and Time Variation by Concentration.

Change in Temperature and Time Variation by Concentration:

The below 3D plot shows that the change in temperature increasing with increase in concentration of ADS and we can observe that the time of boiling decreasing by concentration of ADS.

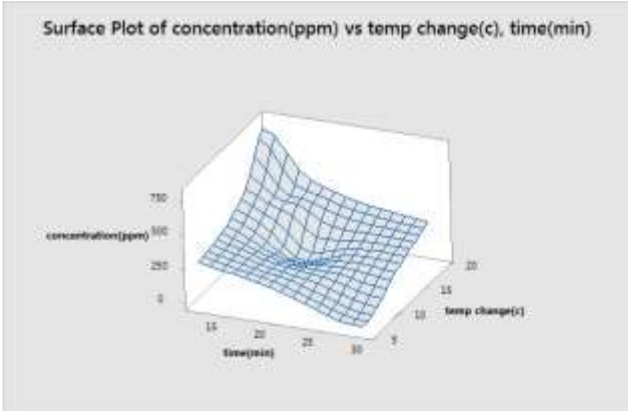

Fig.4.Temp Change and Time Variation by Concentration.

Heat Flux Variation by different Concentrations:

The graph shows that the Heat Flux is increasing with increase in concentration of ADS.

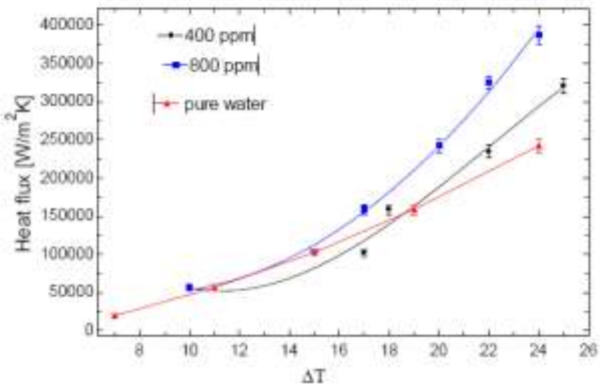

Fig.5.Heat Flux Variation by different Concentrations

Experimental Images:

The below figure shows the increase in bubble size and detachment frequency. Image 1 shows the bubbles in 100ppm, image 2 shows the bubbles in 1000ppm,images 3 is 1500ppm and image 4 is 2500ppm.

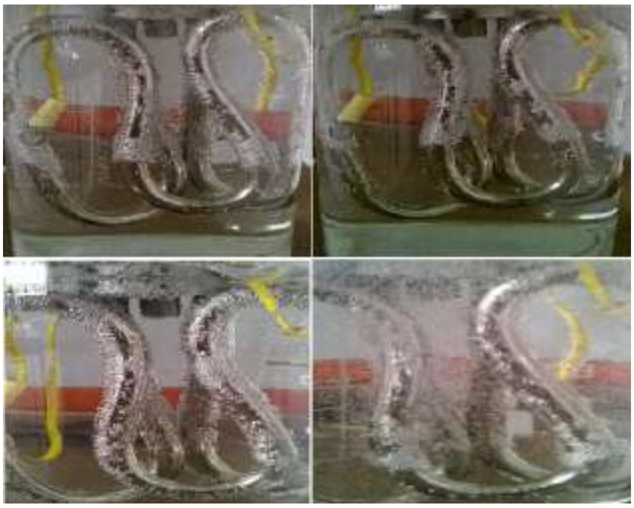

Fig.6.Bubble Variation

VII. CONCLUSION

Experimentation is conducted on Pool Boiling heat transfer with Ammonium Dodecyl Sulfate(ADS).From the results the maximum Heat Flux obtained for pure water is 27.62 KW/m^2 and maximum Heat Flux for 2500ppm is 3628 KW/m^2, which means little amount 2.5 grams of ADS increases the Heat Flux nearly hundred times. Therefore rate of heat transfer increased drastically by using ADS in pool boiling. By using ADS in power plants we may get best rate of steam generation. And in sea water desalination and polluted water desalination we may get best heat transfer rates and can produce large quantity of drinking water in minimum time. And we can said that the ADS is alternative for Sodium Dodecyl Sulfate(SDS).

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