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Experimental Analysis of Boiling and Measurement of Contact Angle of Drop on Surface

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Abstract - *The heat transfer in boiling can be enhanced by adding small amount of additive in pure water. Addition of small amount of additive in the pure water changes the physical behavior of the boiling phenomenon. The motive behind this study is to find the effects of optimum concentration of surfactant on the heat transfer rate of pure water without any abnormalities. Here Sodium Dodecyl Sulphate (SDS) is used as surfactant in pure water. The kinetics of boiling (bubble nucleation, growth and departure) was recorded by video camera. The boiling curves q Vs. (Tw-Tsat) for different concentrations of surfactant in pure water was obtained. Also from the current data, the heat transfer coefficient for pure water with and without surfactants were calculated and compared with pure water.*

The results showed that the addition of surfactant (SDS) in water can enhance the boiling heat transfer. Also the bubble behavior and the heat transfer mechanism for the surfactant solution are quite different from those of pure water. In order to study the effect of wettability, it is essential to measure the contact angle. If the contact angle becomes lower this will be increase the wettability and result in enhancement of heat transfer. Also if the contact angle is greater than 90^0 results shows the less wettability, And reduces heat transfer. When the contact angle is less than 90^0 it gives better wettability. The best heat transfer coefficient is obtained with the surface which had a water contact angle close to either 0^0 to 90^0. Hence it promotes the heat transfer.

Key Words: Contact angle, Surfactant, Heat Transfer and Boiling.

1. INTRODUCTION

The pool boiling techniques are using in various industries like processing, thermal, refrigeration, etc. The interest is in enhanced heat transfer is closely related with energy prices. Due to increase in demand, there is now an incentive to save energy, and enhanced heat transfer can be exploited to do so. Due to the energy crisis problem, the aim is to reduce the energy required for phase change during the pool boiling. For increasing heat transfer rate the boiling curve must shift to left. [3]

Generally, it is believed that small amount of surfactant can increase the boiling heat transfer. The extent of enhancement has been found to be dependent on additive concentrations. The Sodium Dodecyl Sulphate (SDS) is used as surfactant in pure water at various concentrations to increase heat transfer. Addition of small amount of surfactant in water reduces the surface tension considerably, and its level of reduction depends on the amount and type of surfactant presented in the solution. The activation of nucleate sites, bubble growth and dynamics influence the boiling heat transfer. The measurement of contact angle of water drop on surface is more important parameter in heat transfer. If the contact angle is less then wettability on surface is good, that means more heat transfer. This can be achievable by adding different surfactants in pure water.[1]

1.1 Wetting Phenomenon

First contact is defined geometrically as the angle formed by a liquid at the three phase boundary where a liquid, gas and solid intersect as shown in Figure below. The better wettability means lower is the contact angle values <90°, whereas bad wetting liquids have high contact angle values >90°. A zero contact angle represents complete wetting.[4]

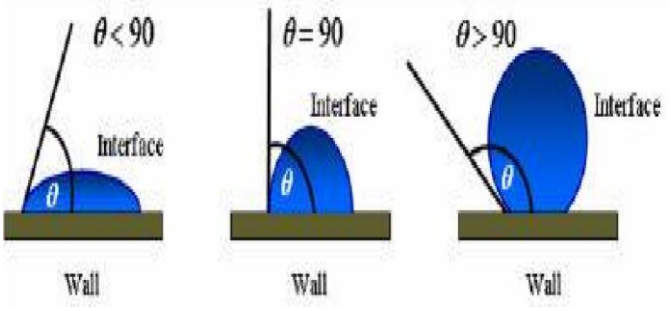

Fig-1: Different Contact Angle [ref. 4]

2. EXPERIMENTAL SETUP

This work was useful to study the phenomenon of the pool boiling, also to measure contact angle of liquid drop made on nichrome wire. For this purpose the experimental setup was constructed as shown in Fig 2.

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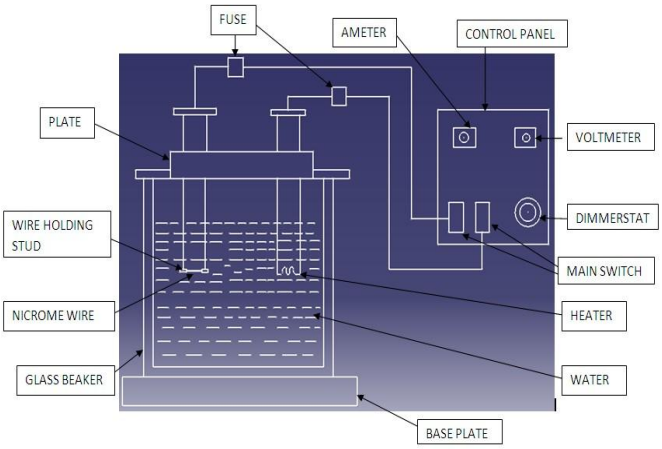


Fig -2: Block Diagram of Experimental Set up

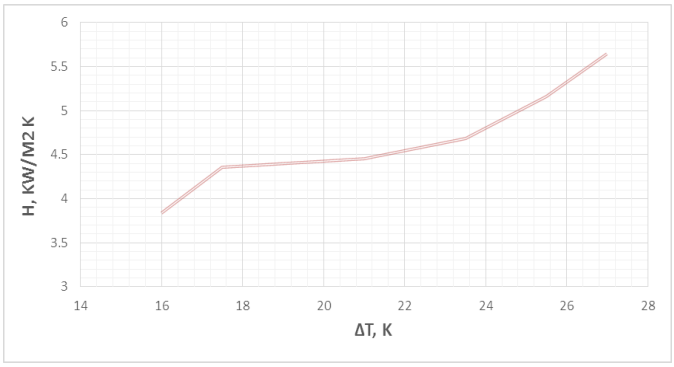
It consists of cylindrical glass container housing, the test heater and the heating coil for the initial heating of the water. The heater coil is directly connected to the mains (Auxiliary Heater) and the test heater (Nichrome wire) is connected also to mains via a dimmer stat. An ammeter (range 0-10A) is connected in series while the voltmeter across it to read the current and voltage. Voltage selector switch is used to select the voltage range 0-20V.These controls were placed inside the control panel.

The temperature of bulk water i.e. saturation temperature of water is measured by S-S sensor. The temperature nichrome wire heater is measured by using a Cr-Al k-type thermocouple which is connected to the wire using digital temperature indicator having least count 0.1^0C.

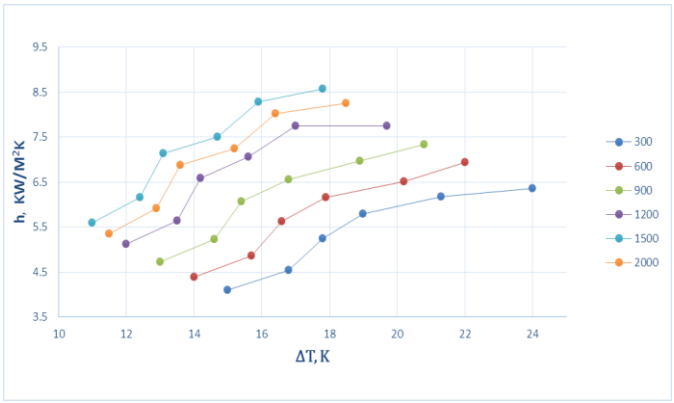
For measurement of contact angle and to study the kinetics of vapor bubble in pool boiling phenomena for pure water with and without surfactant start the main heater and heat the solution up to 40^0C to 50^0C. After that switch off the main heater supply and start the nichrome wire heater. Increase the voltage from 2V to 10V and noted respective current required to heat nichrome wire. Calculated power, heat flux, and heat transfer coefficient. A camera is fixed near to apparatus in such a way that boiling phenomenon can be recorded by camera(Canon EOS 6D) to make observations in terms of bubble nucleation, growth and its departure. Using adobe photo shop software measured the contact angle. Electronic balance was used for the measurement of the mass of SDS powder has least count of 1mg.

3. RESULTS AND DISCUSSION

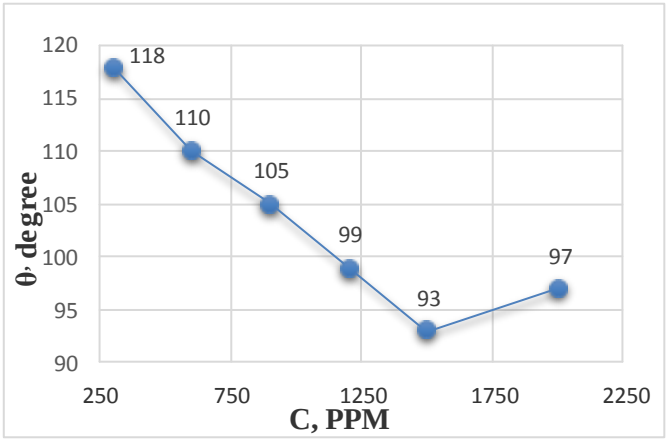
The extensive experimentation of pool boiling was carried for pure water with and without surfactant for varying concentrations of SDS and heat flux. From the obtained experimental data, results are plotted in terms of boiling curve as a heat transfer coefficient vs. heater excess temperature. Also the some images of contact angles of bubbles are measured with different concentrations of SDS in pure water.



Graph-1: Effect of excess temp. ΔT on heat transfer coeff. H for pure water



Graph-2: Effect of excess temp. ΔT on heat transfer coeff. H for SDS in pure water at 300 ppm to 2000 ppm



Graph-3: Effect of concentration C on contact angle θ for SDS in pure water at 300 ppm to 2000 ppm

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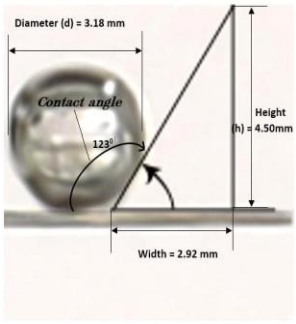

Fig- 3: Contact angle for pure water

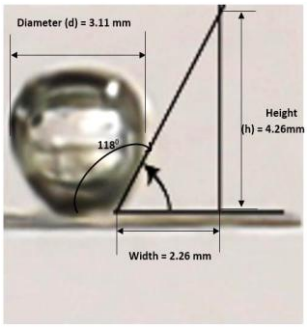

Fig- 4: Contact angle for SDS at 300 ppm

Table-1: Behavior of SDS at different parameters

Sr. No.	Concentration C (ppm)	Contact Angle (θ^0)	Surface Tension σ (N/M)	Heat Transfer Coeff. h (%)
1	300	118	0.065	4.13
2	600	110	0.042	11.46
3	900	105	0.035	19.96
4	1200	99	0.030	29.59
5	1500	93	0.027	41.29
6	2000	97	0.027	35.78

The graph is plotted in between excess temp. ΔT against heat transfer coefficient h for pure water as well as for SDS in water at different concentrations. Also concentration verses contact angle graph is plotted. The measurement of contact angle is done using Adobe Photoshop software. As shown in fig. 3 and fig. 4, for water the contact angle is 123^0 and for SDS at 300 ppm in water is 118^0. The different parameters are plotted in table no.1 as concentration of SDS increases in pure water.

3. CONCLUSIONS

1) The bubbles formed in water with surfactant solutions are much smaller than pure water and they covered the surface of wire faster.
2) The contact angle measured with surfactants has less contact angle compared with pure water on nichrome wire as concentration of SDS increases, which shows that the increased wettability. Hence more heat transfer takes place.
3) As heat flux increases, the heat transfer coefficient also increases and surface tension and contact angle decreases for SDS up to 1500 ppm, after that it is increases.

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BIOGRAPHIES

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