Reducing Wall Superheat by Using Alcohol Ethoxylate Surfactant in Pool Boiling

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ABSTRACT

In boiling heat transfer, it is usually desirable to transfer the largest possible amount of heat with the smallest possible temperature difference between the heating surface and the boiling liquid, and to maximize the critical heat flux. Study of the enhancement of boiling heat transfer has become one of the fastest growing research areas of recent years. In our experiment we have performed the trial on alcohol ethoxylate ecofridley surfactant. A considerable reduction in wall superheat is observed in the solution of water and surfactant of 2000ppm. A wall superheat is decrease by 48 percent.

Keywords*: alcohol ethoxylate* , *wall superheat, pool boiling*

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1. Introduction

When the temperature of a liquid at a specified pressure rises to its saturation temperature Tsat at that pressure, boiling occurs. A precise definition of boiling is presented by Hewitt , and Collier and Thome . Boiling is the process of addition of heat to a liquid in such a way that vapor generation occurs. There are two basic types of boiling: *pool boiling* and *forced convection boiling*. Boiling on a heating surface submerged in an initially quiescent liquid is termed as pool boiling. In contrast, when the boiling occurs under forced-flow condition it is termed as flow boiling or forced convection boiling. Pool boiling and flow boiling are further classified as *subcooled boiling* and *saturated boiling*. When the temperature of the liquid is below the saturation temperature Tsat, it is said to be subcooled boiling or local boiling. If the liquid is at the saturation temperature then it is called saturated boiling or bulk boiling. The phenomenon of boiling heat transfer is much more complex than that of convection heat transfer without phase change. This is because in addition to all the variables associated with convection heat transfer, other variables associated with phase change are also relevant for boiling heat transfer. As a large number of variables are involved in boiling heat transfer neither general equation describing the boiling process nor the general Correlation of boiling heat transfer data is available. [2]

In boiling heat transfer, it is usually desirable to transfer the largest possible amount of heat with the smallest possible temperature difference between the heating surface and the boiling liquid, and to maximize the critical heat flux. Study of the enhancement of boiling heat transfer has become one of the fastest growing research areas of recent years . This growth has been driven by the need to improve boiling heat transfer in high heat-flux devices (for example, in electronic component cooling) and in reducing the size and cost of equipment in chemical, refrigeration, and other types of plants. Various enhancement techniques have been developed over the past decades to fulfill these criteria.

Addition of small amount of surfactant to liquid, as an enhancement technique, shows a significant enhancement in pool boiling heat transfer. Enhancement of nucleate pool boiling heat transfer with surfactant can lead to a significant increase in power level of boilers and boiling water nuclear reactors without increasing their size and operating temperature. One interesting field of application of surfactant enhanced heat transfer is in desalination of seawater, which is becoming essential in some arid regions. Sephton in 1974 showed that addition of small amounts of surfactants to seawater can substantially enhance the boiling process, and reduce the price of the desalinated water to an acceptable level. As the environmental impact of surfactants was not known at that time, the research was discontinued.

Boiling is a mode of heat transfer that is widely used in many industrial processes, including electricity generation, chemical production, and refrigeration. It is a change of phase heat transfer mechanism, which allows for a high heat transfer from a relatively small temperature gradient because of the latent heat of vaporization. This is beneficial from a practical standpoint especially regarding material selection in boiling equipment. The fundamental physical process of boiling consists of the interaction between buoyant forces and surface forces of a vapor bubble at a nucleation site. As soon as the buoyancy force overcomes the surface tension force, the bubble departs and escapes, allowing for a new vapor bubble to form anew in its place. Therefore, the rate of bubble growth and departure, as well as the number of available nucleation sites there are for bubbles to form, are what determine the heat transfer rate. Increasing any of these will enhance the boiling process. Common ways of enhancing heat transfer in boiling is roughening the surface **,** which increases number of nucleation sites, or using hydrophilic surfaces [2]. Surfactants, the focus of this study, are known to lower the surface tension forces, thereby making it easier for bubbles to depart and increase the bubble departure frequency. Surfactants also tend to increase the number of nucleation sites, thereby increasing heat transfer **by** having more bubble growth locations. Previous works have investigated boiling with surfactants, mostly in the context of liquid-vapor surface tension, viscosity, and surfactant concentration. The effect of surface adsorption is the main enhancement mechanism to be explored in this work.[1]

2 Experimental Works and Test Procedure

2.1 Experimental Work

The apparatus for experimental studies on pool boiling is shown in Figure 1. 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 R1) and the test heater (Nichrome wire) is connected also to mains via a dimmerstat. 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 50/100V. These controls are placed inside the control panel.

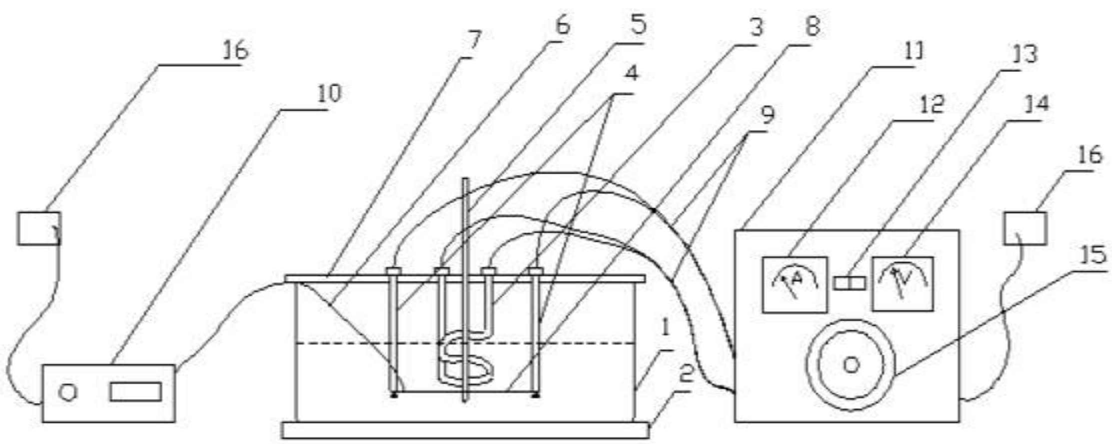

Fig-1: Experimental setup

1.Glass Container 2.Wooden Platform 3.Auxilary Heater (R1) 4.Test Heater (R2) 5.Thermometer 6.Thermocouple 7.Clay Lid 8.Nichrome Wire 9.Heater Connecting Cable 10.Digital Temperature Indicator11.Control Panel 12.Ammeter13.Voltage Range Selector Switch 14.Voltmeter 15.Dimmerstat 16.Electric Power Switch

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Test Procedure

The glass container was filled with 4 liters of pure water and it kept on a stand, which is fixed on a wooden platform. The temperature of bulk water i.e. saturation temperature of water was measured using mercury thermometer with least count of 0.5oC. A Cr-Al k-type thermocouple is connected to nichrome heater wire to measure the temperature of wire using digital temperature scanner having least count 0.10C. The kinetics of boiling (bubble nucleation, growth and departure) i.e. bubble behavior with and without surfactants in water was recorded by Handy camera (800X) video recording. Experiments were carried with and without surfactant alcohol ethoxylate in pure water (i.e. deionised water) by varying heat flux. Concentration of alcohol ethoxylate was varied from 0-3000 ppm in pure water. Each experiment was repeated three times to maintain the repeatability.

Result and discussion

The extensive experimentation of pool boiling was carried for pure water with and without surfactant of varying Concentrations of alcohol ethoxylate and heat flux. From the obtained experimental data, results are plotted in terms of boiling Curve as a heat flux vs. heater excess temperature. The saturated nucleate pool boiling data for water and water with different concentrations of alcohol ethoxylate are plotted in Fig. Boiling data of surfactant solutions lie to the left of the boiling curve of pure water, which is an indication of heat transfer enhancement. For increasing and decreasing heat fluxes same measurements of excess temperature are observed. As the concentration of surfactant solution increases wall superheat decreases. At higher concentration wall superheat is less. One can observed the effect of higher surfactant concentration in pool boiling .

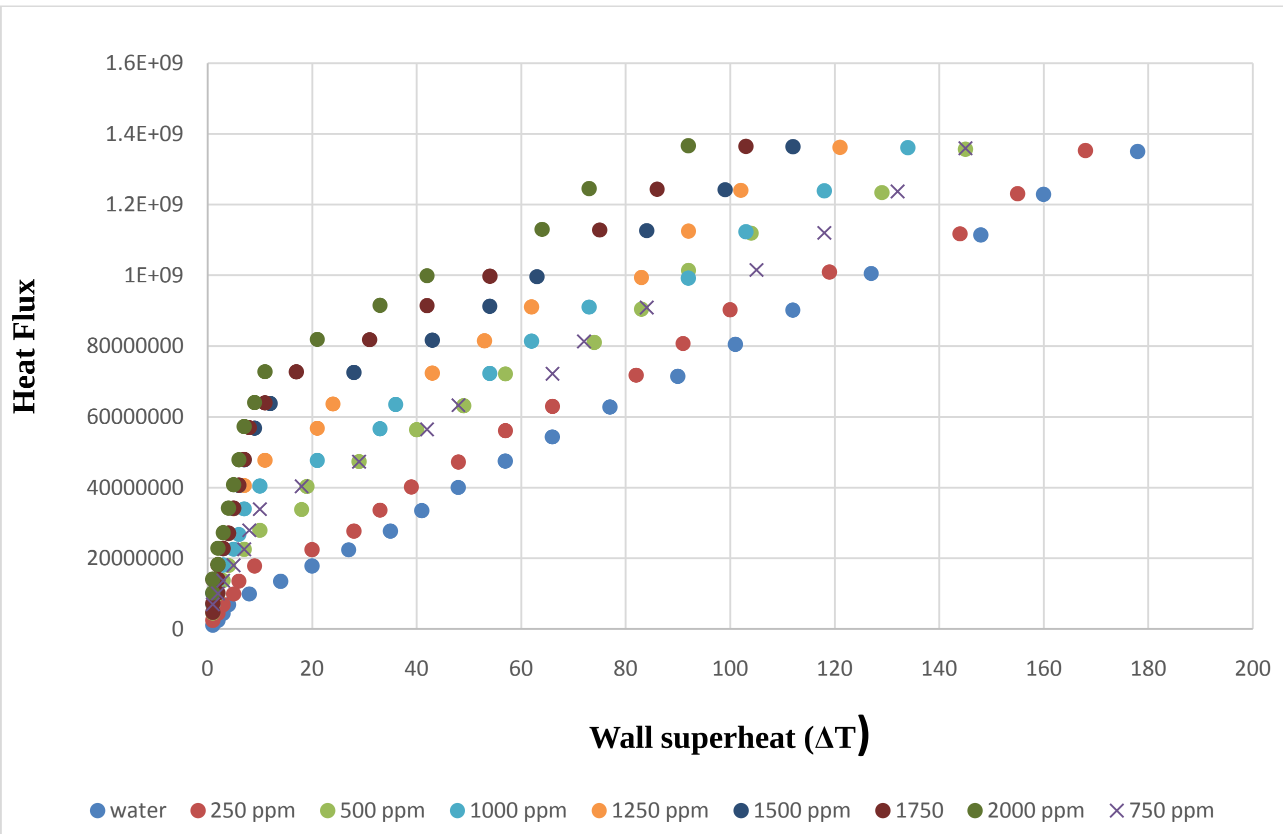

Figure: Pool boiling curves of pure water with alcohol ethoxylate

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4. CONCLUSION

Bubble action is seen to be extremely chaotic, with extensive coalescence during the rise for pure water. The boiling excess temperature ∆Texcess becomes smaller and the vapor bubbles are formed more easily. It might be due to presence of surfactant in water promotes activation of nucleation sites in a clustered mode.

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