Experimental Study of Pool Boiling Heat Transfer Enhancement Using Natural Surfactants

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Abstract- *Boiling is an efficient mode of heat transfer and having numerous applications in distillation, desalination, chemical process, refrigeration system. The use of surfactant is simple and cost effective way for heat transfer enhancement. In this study, natural surfactants (Shikakai & Reetha) are added to water as additive & due to its features like ecofriendly, biodegradable Therefore in this dissertation work, heat transfer enhancement is studied by use of natural surfactants at different concentrations with varying heat fluxes. For this study, test solutions were prepared by using natural surfactants viz Shikakai & Reetha at different concentrations of 100ppm, 300ppm and 500ppm. The entire experimental study was carried out at values of heat fluxes ranging from 5 to 50 kW/m2 and ambient conditions. The results show that with increase in concentration of surfactant, boiling curve shifts to left side to that of water and also increase in heat transfer coefficient. The reason behind this is due to reduced surface tension which causes smaller vapor bubble with increased nucleation sites. This work can be extended further for binary mixtures of two surfactants (synthetic and natural), study effect of concentrations of surfactant on critical heat flux, single bubble dynamics.*

Keywords- Heat transfer enhancement, Pool boiling, Natural Surfactants

I. INTRODUCTION

Boiling is two phase convection process; also one of the efficient modes of heat transfer. Boiling heat transfer may be enhanced due to reduce energy losses. For enhancement, active and passive techniques can be used [1].Passive techniques don't use external energy. Some techniques are use of surfactant & Nano-fluids as additives, use of rough surfaces. It is found that small surfactant additives enhance heat transfer considerably. Extensive research is done on boiling with surfactant additive. Some researchers studied effect of SDS, Triton X-100 surfactant on fluid properties, bubble dynamics, nucleate boiling phenomenon, steam carrying phenomenon [2-3]Some researchers compared SDS with non-ionic surfactants for improvement in heat transfer coefficient and critical heat flux[4-6].Investigation of effect of anionic, nonionic surfactants and binary mixtures of ethanol-water on pool boiling was carried out using heated tube and wire[7-8].Researchers also used the environment friendly surfactants Boiling enhancement using Alkyl Glycoside on horizontal tube was also studied[9].Very few researchers had done experiments on pool boiling using natural surfactant the objective of present study is to verify whether natural surfactants can be used or not.

II. EXPERIMENTAL METHOD

A. Experimental Setup

The experimental setup is fabricated with all the necessary system components for the current dissertation work. Schematic diagram of experimental setup is shown in Figure 1. It contains calibrated glass beaker, immersion test heater, Thermocouples for measuring temperature, Temperature indicator, Dimmerstat, voltmeter and ammeter. The heater is of 1500W capacity. It is having cross sectional diameter 8 mm and length 610 mm. Heater is connected to Dimmerstat to control voltage. Heater surface material is Stainless Steel. The type of thermocouple used is K-type (Cr-Al). There are three thermocouple were used to measure temperature. One thermocouple is attached to heater surface using epoxy resin adhesive. Other two thermocouples are suspended in water. Temperature indicator with 12 channels along with thermocouple is used for temperature measurement. Voltmeter is used to measure voltage across Dimmerstat. Voltmeter is connected in parallel to Dimmerstat. Ammeter is used to measure current across load. Ammeter is connected in series to Dimmerstat and load. Dimmerstat have maximum load of 8 Amp, input of 230 Volts, output of 0 to 270 Volts. Dimmerstat is connected to Voltmeter and Ammeter to measure Voltage and Current respectively. Dimmerstat supplies controlled power to water heater. The glass beaker is used for water storage. The glass beaker is made up of Borosilicate material for high temperature resistance. The glass beaker has capacity of 2000 mL.

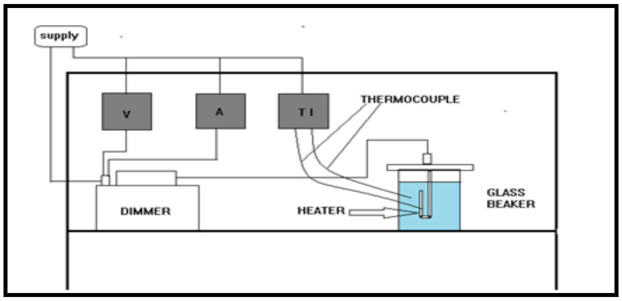

Figure 1.Schematic diagram of Experimental Setup

Following table describes the specifications of the experimental setup followed by the system component and details of the measuring instrument mounted on the setup.

Table 4.1 Specifications of Experimental Setup

Sr No.	Component Name	Range/Capacity	Least Count
1	Test Heater	1500 W, 230 V	
2	Temperature Indicator	12 channel, 0 ^{0}C to 1200 ^{0}C	1^{0}C
3	Thermocouple (K type)	0 ^{0}C to 1200 ^{0}C	
4	Dimmerstat	270 V, 8 Amp	
5	Voltmeter	0-500 V	LC=0.1 V
6	Ammeter	0-20 Amp	LC=0.001Amp
7	Glass Beaker	2000 mL	

B. Experimental Procedure

For this dissertation work, test solutions were prepared by using natural surfactants viz Shikakai & Reetha at different concentrations of 100ppm, 300ppm and 500ppm. The entire experimental study was carried out at values of heat fluxes ranging from 5 to 50 kW/m2 and ambient conditions.

Test Procedure:

- After checking the experimental setup, glass beaker is cleaned and filled with 2Litre pure water.
- Extracted surfactants with 100ppm, 300ppm, 500ppm concentrations are mixed with water.
- Water Heater is submerged in glass beaker.
- Water heater is connected to Dimmerstat. Heater is switched ON to heat water in glass beaker.
- Various heat fluxes ranging from 5 kW/m^2 to 50 kW/m^2 are supplied to heater via Dimmerstat by changing voltages.
- All necessary readings of Temperatures, Voltages and Current are noted down.

III. RESULTS AND DISCUSSION

The various system affected parameters are analyzed through the graphical representation. Each system affecting parameter is discussed based on the analysis of results obtained from the measured and estimated parameters. Boiling parameters are tested at different concentrations of surfactant. The heat transfer enhancement analysis includes study of boiling curves as well as heat transfer coefficient for different concentrations of surfactant.

A. Results for Shikakai Surfactant

It can be seen from Figure 2 that boiling curve is shifted towards left side to that of the water. Also Figure 3 shows that average heat transfer coefficient is increased by 22.10% as compared to water.

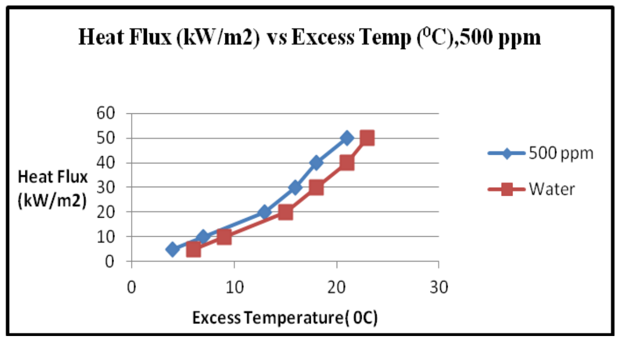

Figure 2.Effect of 500 ppm surfactant concentration on boiling curve

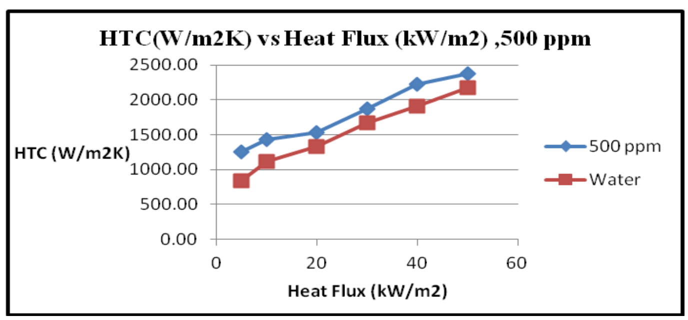

Figure 3.Effect of 500 ppm surfactant concentration on heat transfer coefficient

B. Results for Reetha Surfactant

It can be seen from Figure 4 that boiling curve is shifted towards left side to that of the water. Also Figure 5 shows that average heat transfer coefficient is increased by 30.03% as compared to water.

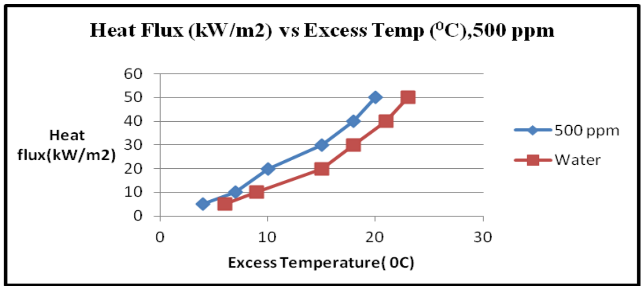

Figure 4.Effect of 500 ppm surfactant concentration on boiling curve

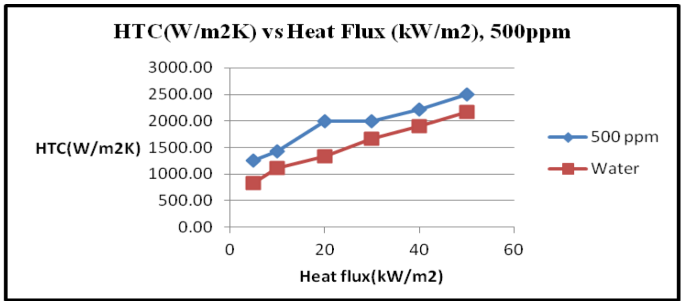

Figure 5.Effect of 500 ppm surfactant concentration on heat transfer coefficient

IV. CONCLUSION

From experimental investigations, following conclusions are made.

i. Addition of surfactant to water causes shifting of boiling curve to the left side to that of water.
ii. Increase in concentration of surfactant increases heat transfer coefficient. Maximum increase in heat transfer coefficient is found to be 22.10 % and 30.03 % at 500ppm concentration for Shikakai and Reetha respectively.
iii. The reason for enhancement is due to decrease in surface tension, less force required to bubble, smaller bubbles with large nucleation site.
iv. Enhancement in heat transfer for Reetha is greater than to that of Shikkai.

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