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EXPERIMENTAL ANALYSIS OF CONVECTIVE HEAT TRANSFER COEFFICIENT FOR POOL BOILING OF MILK AND WATER

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ABSTRACT

When a liquid is in contact with a surface maintained at a temperature above the saturation temperature of the liquid, boiling will eventually occur at that liquid-solid interface. Conventionally, based on the relative bulk motion of the body of a liquid to the heating surface, the boiling is divided into two categories; pool boiling and convective boiling. Boiling is a very effective and efficient mode of heat transfer, and it is encountered in various engineering applications. Khoa making is one of the important applications which involve boiling of milk with an aim of evaporating the large quantity of water present in it. Khoa is a heat dissipated milk product which forms an important base for the preparation of variety of milk sweets. The main objective of the project is to analyze heat transfer during pool boiling of milk and water in an aluminum pan of diameter 21.5 cm and thickness 1.2mm under closed condition for different heat inputs varying from 220 to 340 W. During heating of milk the evaporated water was condensed at the inner surface of the condensing cover which is separated through a pump system and analysis of heat transfer characteristics of the water and milk through pool boiling over a flat heater is carried. The Convective heat transfer coefficient for pool boiling of milk & water is investigated.

INTRODUCTION

Pool boiling is an efficient method for dissipating heat in industry settings due to the ability of the boiling fluid to achieve high heat fluxes while maintaining low wall superheat temperatures (ie. the temperature difference between the heated surface and the working fluid). This is critical in applications where thermal stresses must remain low such as integrated circuit cooling. However, continued heat dissipation will be required as computing power increases. Current means by forced convection of air will no longer be an efficient means for circuit cooling. This makes nucleate pool boiling by circuit immersion an attractive solution with the following advantages: heat transfer during boiling is very effective, boiling is an isothermal process, mass flow required for boiling is lower than single phase cooling due to the phase change (latent heat), and direct immersion eliminates thermal resistance between source and sink. The immersing nature of pool boiling cooling does also pose difficulties such as thermal hysteresis of the surface, surface temperature gradients due to non uniform heat sources, variations in the distribution of activation sites and the decrease in heat transfer as the critical heat flux (CHF) is approached. These obstacles must be overcome in order to design robust and reliable cooling methods for circuits. Fluids are conventionally driven by applying macroscopic net asymmetric potentials such as pressure gradient by a pump or compressor, and electric motor. However, these methods either require an external power source for driving a motion or have a limitation in the displacement. On the other hand, spatially periodic systems with localized asymmetric structures (ratchets) can induce directed transport of liquid/ particles in the absence of net force. The rectification and enhanced liquid motion can enhance pool boiling heat transfer by altering the surface boundary layer and passively remove the insulative vapour layer which forms during pool boiling and inhibits heat transfer as superheat temperature increases. Boiling is the process by which evaporation occurs at a solid-liquid interface. Boiling occur, when the surface temperature Ts must exceed the saturation temperature of the liquid T_{sat}at a given pressure. Boiling is characterized by bubble formation at the surface, these bubbles nucleate, grow and detach from the surface in a complex manner depending upon on many variables such as superheat temperature, surface tensions,

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surface geometries, etc. Newton's Law of cooling describes the process in the form of

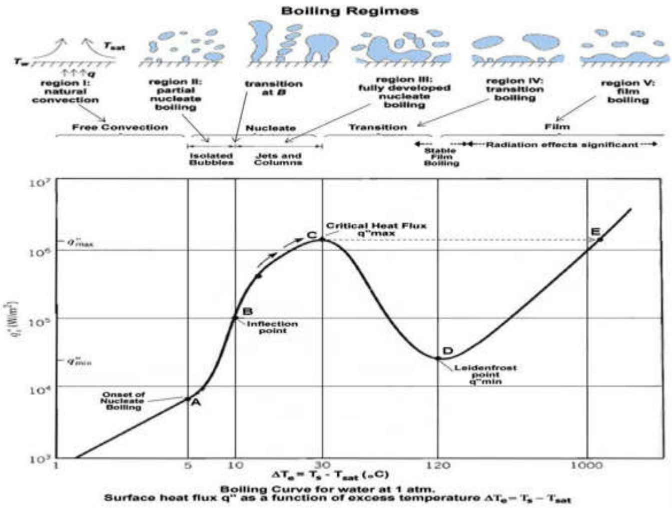
$$\frac{Q}{A} = q" = h(T_s - T_{sat}) = h\Delta T \qquad (2.1)$$

Where Q is the total heat transfer, A is the surface area over which the heat is transferred, q” is the heat flux (heat transfer per unit area), *h* is the heat transfer coefficient and is defined as the superheat temperature. Nukiyama [1] was the first to indentify the different regimes of pool boiling, as plotted on the boiling curve, using a heated Nicrome wire (due to its high melting temperature) in saturated water. However, the transition boiling region of the curve was not fully characterized until Drew and Mueller [2], but it was predicted by Nukiyama. The pool boiling curve, as shown in Figure, is a standard graphical method for characterizing pool boiling phenomena and the performance of surface and/or liquid treatments. Pool boiling is divided into four regimes which are determined by the nature of the vapour formation: natural convection (I), nucleate boiling (II), transition boiling (III) and film boiling (IV). If a saturated liquid is considered, the heated surface temperature is raised slightly above the saturation temperature, then no vapour forms and heat is transferred by means of the convection of superheated liquid which rises to the free surface to evaporate via buoyancy forces. This is regime I of the pool boiling curve. Nucleate boiling begins when the temperature of the heated surface rises high enough above the saturation temperature (wall superheat temperature) and bubbles begin to form on the surface which detach and float upward to the free surface. Nucleate boiling, regime II, is characterized by a sharp increase in slope on the pool boiling curve. As vapour formation becomes more regular, bubbles forming on the surface begin to coalesce vertically and horizontally which reduces heat transfer due to the vapour layer which is formed.

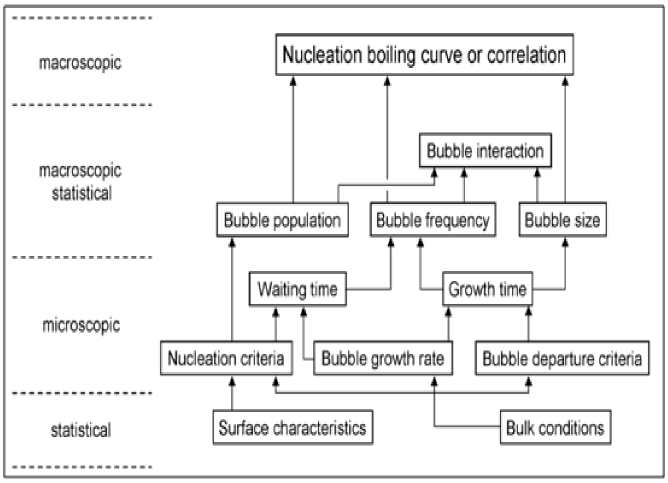
As the surface temperature increases further, a maximum heat flux is reached, point C, which is typically referred to as the critical heat flux (CHF). Care must be taken when operating near the CHF of a system, if the heat flux is increased further in order to maintain equilibrium the surface temperature “jumps” to temperatures on the order of thousands of degrees (point E) in which film boiling occurs (regime IV). This region is also known as the Leiden frost regime. This leads to a “burnout” condition since this jump in temperature is typically well above the melting point of most metals. If the surface temperature is decreased, the minimum heat flux, or Leidenfrost temperature, can be reached at point D and in this regime the vapor film is no longer stable. If the heat flux is controlled, then surface temperature can fall suddenly and if the surface temperature is controlled then transition boiling, regime III, is reached.

Nucleate Boiling Mechanisms

Nucleate pool boiling provides high heat transfer while maintaining low surface superheats and is widely used in industrial processes such as heat exchangers. Nucleate boiling involves many processes by which heat is transferred which makes the modelling the process very difficult. Typically, these correlations involve characterizing bubble formation, growth, departure and coalescence along with surface to liquid and bubble to liquid interactions. An overview of these relationships can be viewed in Figure



Boiling Curve for water at 1 atm.
Surface heat flux q'' as a function of excess temperature $\Delta T_e = T_s - T_{sat}$

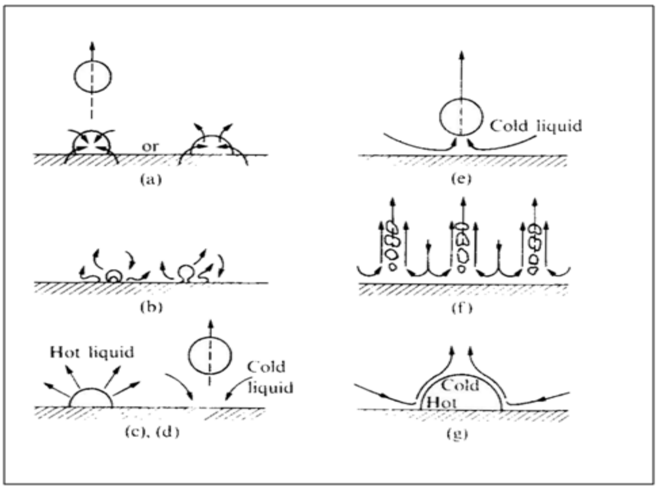


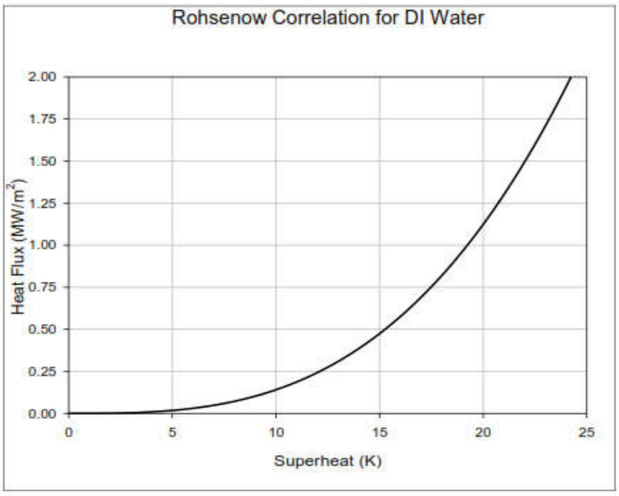
Nucleate Pool Boiling Correlations

Since the maximum heat transfer with minimal wall superheat occurs in the nucleate boiling regime this has been the area of the most rigorous research. The first and most widely used accepted correlation describing heat transfer in the nucleate regime was proposed by Rohensow. Rohsenow suggested that heat transfer under pool boiling conditions is the result of local liquid circulation in the region near the heated surface, which is enhanced by bubble detachment. This correlation has been plotted for saturated water at atmospheric pressure and can be viewed below in Figures.

Critical Heat Flux Correlations

Over the years, many researchers have attempted to predict CHF with various models and equations. Many of these models have been shown to be deficient in fully encompassing the nature of CHF and therefore a unified theory and governing equation has yet to be formulated. This is an indication of the complexity of the driving mechanisms behind pool boiling phenomena. Kutateladze [11] postulated that critical heat flux was a hydrodynamic instability that resulted from the vapor phase velocity reaching a critical value.





After performing dimensional analysis he proposed the following correlation.

$$q''_{CHF} = K h_{fg} \rho_v^{1/2} [\sigma g(\rho_l - \rho_v)]^{1/4} \qquad (2.3)$$

Where q"$_{CHF}$ is the heat flux at CHF and the value K is a constant determined experimentally which is equal to 0.16. Borishanskii [8] offered a modification to the value K modelling the system by considering the phase boundary instability caused by the coaxial flow of the liquid stream and vapour. The equation also takes viscosity (μ_l) into account, but it does not play a significant role.

$$K = 0.13 + 4\left\{\frac{\rho_l \sigma^{3/2}}{\mu_l^2 [g(\rho_l - \rho_v)]^{1/2}}\right\}^{-0.4} \qquad (2.4)$$

Rohsenow and Griffith [9] postulated that the increased number of bubbles that occur at high heat fluxes inhibits the flow of liquid to the heated surface. They proposed the following correlation for CHF.

$$q''_{CHF} = C h_{fg} \rho_v \left(\frac{g}{g_s}\right)^{1/4} \left[\frac{\rho_l - \rho_v}{\rho_v}\right]^{0.6} \qquad (2.5)$$

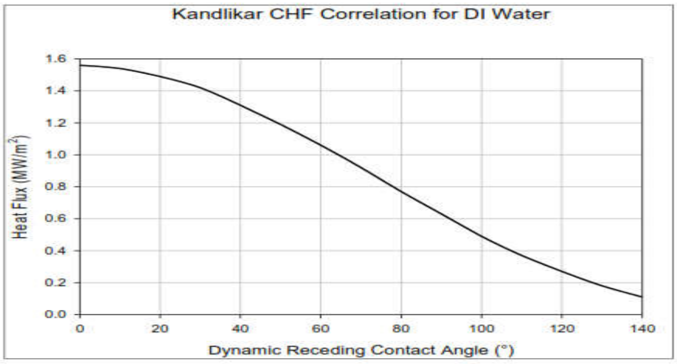
Where the coefficient C = 0.012 m/s, g is the local gravitational acceleration and gs is the standard gravitational acceleration 9.81 m/s^2. Zuber [10] postulated that instability is created between the vapour flow leaving the heated surface and the liquid toward the surface as CHF is approached. He further suggested that vapour patches form and collapse on the heater surface and Taylor and Helmholtz instabilities are the cause of CHF. He formulated an equation similar to Kutatelazde [11], but K = 0.131. Very few investigators have studied the effects of the liquid surface contact angle on CHF even though it is considered to be a very crucial parameter. Kirishenko and Cherniakov [12] developed a model based on dynamic receding contact angle. Dynamic receding contact angle (β) is chosen because as the bubble grows along the surface the contact angle between the surface and the receding liquid/ vapour interface characterizes the wettability of the surface.

$$q''_{CHF} = 0.171 h_{fg} \rho_v^{1/2} [\sigma g(\rho_l - \rho_v)]^{1/4} \frac{(1+.000324\beta^2)^{1/4}}{(0.018\beta)^{1/2}} \qquad (2.6)$$

Diesselhorst [13] found that this model overestimates CHF for large contact angles and found it to overestimate CHF values for water, but the trend on increasing CHF with decreased contact angle was correct. Kandlikar [14] developed a model considering a force balance on a bubble and the presence of a thin liquid micro layer under the bubble. It was proposed that near CHF the momentum created by the evaporation on the sides of the bubble exceeded gravity and the surface tension forces causing the bubble to grow along the heated surface. He expanded this model by considering the critical wavelength for the onset of vapour layer instability.

$$q''_{CHF} = h_{fg} \rho_v^{1/2} \left(\frac{1+\cos\beta}{16}\right) \left[\frac{2}{\pi} + \frac{\pi}{4}(1+\cos\beta)\cos\varphi\right]^{1/2} [\sigma g(\rho_l - \rho_v)]^{1/4} \qquad (2.7)$$

Where β is again defined as the dynamic receding contact angle and φ is the angle of the surface relative to the horizontal. This model was tested experimentally and compared to previous models and has been shown to be quite accurate for predicting CHF for various fluids. Equation 2.6 has been plotted in Figure 2-5 for DI water using dynamic receding contact angles found by Kandlikar [15] by dropping liquid droplets at various surface temperatures, roughness and materials (typical values were found to be in the range of 45 - 80°).



Experimental Set Up

Background Information and Apparatus

When a liquid is in contact with a submerged surface maintained at a higher temperature than the saturation temperature of the liquid, boiling occurs. Heat is transferred from the solid surface according to the following equation

$Q=h\,(T_s-T_f)$

Where $T_s - T_f = \Delta Te$ is known as excess temperature

T_s= Surface temperature

T_{sat} = Saturation temperature

$q= Q/A$, heat flux, $A=\Pi D^2/4$

h= convection coefficient in boiling

There are various distinct regimes of pool boiling in which the heat transfer mechanism and heat transfer coefficient differ radically. The boiling curve shows the different regimes of pool boiling like free convection, nucleate boiling and film boiling. A typical boiling heat transfer apparatus as shown in figure. It consists of glass cylinder fitted with a liquid holding aluminium bowl, a drain valve, and a heater at the bottom. The liquid used here is water and milk.

A copper condensing coil is placed inside the glass cylinder through which water is circulated by means of a pump through a gate valve. A bypass valve is also provided in the waterline neat the sump. The water flow rate is measured with a rota meter. A safety valve and a feed valve are fitted at the top of the cylinder. The power to the heater is adjusted with a dimmer stat and measured in terms of VI with the help of voltmeter and an ammeter. Individual Thermocouples are provided to measure the temperature of the heating pad, the liquid temperature. Vapour temperature. The various instruments (Voltmeter, ammeter, temperature indicator, thermocouple selector switch. Etc.) Are mounted on a wooden panel.

Components of experimental set up

Figure: voltmeter, ammeter, temperature indicator, dimmer stat, glass cylinder, pump, heater with aluminium bowl, control panel.

Experimental Procedure

Pool boiling of Water

- Fill the copper bowl with about 1000 ml of Water through the feed valve provided on the top of the glass column after ensuring that the drain valve at the bottom of the container is closed. Close the feed valve after filling.
- Start the pump with bypass valve and gate valve fully open and observe the water falling into the sump
- Slowly close the bypass valve partially and set the water flow rate at any desired valve indicated by the rota meter.
- Set the power input to the heater at the minimum valve by observing V and I readings.
- Record the temperature T1, T2, T3.
- Increase the power input to the heater slowly till the sample starts boiling and record all the temperature.
- After the experiment is over, switch off all the equipments and drain the liquid out.

Pool boiling of Milk

- After that fill the aluminium bowl with about 1000ml of milk through the feed valve provided on the top of the glass column after ensuring that the drain valve at the bottom of the container is closed. Close the feed valve after filling.
- Start the pump with bypass valve and gate valve fully open and observe the water falling into the sump
- Slowly close the bypass valve partially and set the water flow rate at any desired valve indicated by the rota meter.
- Set the power input to the heater at the minimum valve by observing V and I readings.
- Record the temperature T1, T2, T3.
- Increase the power input to the heater slowly till the sample starts boiling and record all the temperature.

- After the experiment is over, switch off all the equipments and drain the liquid out.

RESULTS AND DISSCUSIONS

Case (1): Calculation of Heat Transfer Coefficient of Water

From the above observations and calculations the convective coefficient of pool boiling of Water and Milk at different heat inputs are shown bellow. From the above experimental data Pool boiling of Water and milk on the flat heater at various heat fluxes is observed. The free convective heat transfer is observed.

Fig: 1: Shows the effect of time on heat transfer coefficient of water for different heat inputs. It is observed from the graph that heat transfer coefficient initially increases with time reaches a minimum and increases again from there after for all considered heat inputs. The heat transfer coefficient increases with increase of heat input. The heat transfer coefficient differs drastically at starting up to 25min, whereas there after the heat transfer coefficient is closer for all considered heat input of range 220W to 340W. The minimum heat transfer coefficient observed is 605.26, 660.77, 714.71, 856.59, 829.14, and 1038.26. for respective 220, 240, 260, 280, 300, 320, and 340 heat inputs and is obtained at time range of 30min to 45min.

Table 1. Calculation convective heat transfer coefficient of pool boiling of water at 220W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^{O}C)	T_2 (^{O}C)	T_3 (^{O}C)	ΔTe (^{O}C)	h (W/m^2 K)
1	10	127	1.73	94	86	33	8	756.57
2	20	127	1.73	96	87	34	9	672.51
3	30	127	1.73	98	88	33	10	605.26
4	40	127	1.73	99	90	34	9	672.51
5	50	127	1.73	100	92	34	8	756.57
6	60	127	1.73	102	94	33	8	756.57

Table 2. Calculation convective heat transfer coefficient of pool boiling of water at 240W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^{O}C)	T_2 (^{O}C)	T_3 (^{O}C)	ΔTe (^{O}C)	h (W/m^2 K)
1	10	134	1.79	96	87	32	9	734.19
2	20	134	1.79	99	89	33	10	660.77
3	30	134	1.79	102	92	33	10	660.77
4	40	134	1.79	104	95	34	9	734.19
5	50	134	1.79	106	98	34	8	825.96
6	60	134	1.79	110	99	34	11	600.70

Table 3. Calculation convective heat transfer coefficient of pool boiling of water at 260W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^{O}C)	T_2 (^{O}C)	T_3 (^{O}C)	ΔTe (^{O}C)	h(W/m^2 K)
1	10	138	1.88	97	89	32	8	893.38
2	20	138	1.88	100	92	33	8	893.38
3	30	138	1.88	105	95	32	10	714.71
4	40	138	1.88	107	98	32	9	794.12
5	50	138	1.88	109	101	33	8	893.38
6	60	138	1.88	111	104	32	7	1021.01

Table 4. Calculation convective heat transfer coefficient of pool boiling of water at 280W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^{O}C)	T_2 (^{O}C)	T_3 (^{O}C)	ΔTe (^{O}C)	h(W/m^2 K)
1	10	145	1.93	92	86	34	6	1284.89
2	20	145	1.93	94	87	33	7	1101.33
3	30	145	1.93	97	88	32	9	856.59
4	40	145	1.93	102	94	33	8	963.67
5	50	145	1.93	107	99	33	8	963.67
6	60	145	1.93	109	100	34	9	856.59

Table 5. Calculation convective heat transfer coefficient of pool boiling of water at 300W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^{O}C)	T_2 (^{O}C)	T_3 (^{O}C)	ΔTe (^{O}C)	h(W/m^2 K)
1	10	149	2.02	93	86	32	7	1184.49
2	20	149	2.02	96	87	33	9	921.27
3	30	149	2.02	98	88	33	10	829.14
4	40	149	2.02	100	91	33	9	921.27
5	50	149	2.02	105	97	34	8	1036.43
6	60	149	2.02	108	100	34	8	1036.43

Table 6. Calculation convective heat transfer coefficient of pool boiling of water at 320W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^OC)	T_2 (^OC)	T_3 (^OC)	ΔTe (^OC)	h (W/m^2 K)
1	10	154	2.08	96	91	33	5	1764.84
2	20	154	2.08	98	92	34	6	1470.70
3	30	154	2.08	101	93	33	8	1103.03
4	40	154	2.08	109	99	34	10	882.42
5	50	154	2.08	112	103	34	9	980.47
6	60	154	2.08	116	108	32	8	1103.03

Table 7. Calculation convective heat transfer coefficient of pool boiling of water at 340W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^OC)	T_2 (^OC)	T_3 (^OC)	ΔTe (^OC)	h (W/m^2 K)
1	10	160	2.12	98	92	33	6	1557.39
2	20	160	2.12	102	95	33	7	1334.90
3	30	160	2.12	106	97	34	9	1038.26
4	40	160	2.12	108	100	33	8	1170.79
5	50	160	2.12	110	103	33	7	1334.90
6	60	160	2.12	114	108	33	6	1557.39

Case 2. Calculation of Heat Transfer Coefficient of Milk

Table 8. Calculation convective heat transfer coefficient of pool boiling of milk at 220W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^OC)	T_2 (^OC)	T_3 (^OC)	ΔTe (^OC)	h W/m^2 K)
1	10	127	1.73	95	85.5	33	10.5	576.43
2	20	127	1.73	97	86	34	11	550.23
3	30	127	1.73	99	88	33	11	550.23
4	40	127	1.73	100	90	33	10	605.26
5	50	127	1.73	101	91	34	10	605.26
6	60	127	1.73	104	95	33	9	672.51

Table 9. Calculation convective heat transfer coefficient of pool boiling of milk at 240W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^OC)	T_2 (^OC)	T_3 (^OC)	ΔTe (^OC)	h (W/m^2 K)
1	10	134	1.79	96	86	33	10	660.70
2	20	134	1.79	99	88	34	11	660.70
3	30	134	1.79	102	90	34	12	550.64
4	40	134	1.79	103	94	33	9	734.19
5	50	134	1.79	105	98	33	7	943.95
6	60	134	1.79	106	100	33	6	1101.28

Table 10. Calculation convective heat transfer coefficient of pool boiling of milk at 260W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^OC)	T_2 (^OC)	T_3 (^OC)	ΔTe (^OC)	h (W/m^2 K)
1	10	138	1.88	93	83	34	10	714.71
2	20	138	1.88	94	84	34	10	714.71
3	30	138	1.88	96	85	34	11	649.73
4	40	138	1.88	97	87	33	10	714.71
5	50	138	1.88	99	89	33	10	714.71
6	60	138	1.88	102	93	33	9	794.12

Table 11. Calculation convective heat transfer coefficient of pool boiling of milk at 280W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^OC)	T_2 (^OC)	T_3 (^OC)	ΔTe (^OC)	h (W/m^2 K)
1	10	145	1.93	91	83	32	8	963.67
2	20	145	1.93	94	85	32	9	856.59
3	30	145	1.93	96	86	33	10	770.93
4	40	145	1.93	97	87	33	10	770.93
5	50	145	1.93	101	91	33	10	770.93
6	60	145	1.93	106	97	33	9	856.59

Table 12. Calculation convective heat transfer coefficient of pool boiling of milk at 300W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^{O}C)	T_2 (^{O}C)	T_3 (^{O}C)	ΔTe (^{O}C)	h (W/m^2 K)
1	10	149	2.02	94	85	32	9	921.27
2	20	149	2.02	96	86	33	10	829.14
3	30	149	2.02	99	87	33	11	690.95
4	40	149	2.02	103	93	34	10	829.14
5	50	149	2.02	105	96	34	9	921.27
6	60	149	2.02	107	98	34	9	921.27

Table 13. Calculation convective heat transfer coefficient of pool boiling of milk at 320W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^{O}C)	T_2 (^{O}C)	T_3 (^{O}C)	ΔTe (^{O}C)	h(W/m^2 K)
1	10	154	2.08	93	83	33	10	882.42
2	20	154	2.08	96	85	33	11	802.20
3	30	154	2.08	102	90	33	12	735.35
4	40	154	2.08	103	94	34	9	980.47
5	50	154	2.08	106	97	33	9	980.47
6	60	154	2.08	109	101	33	8	1103.03

Table 14. Calculation convective heat transfer coefficient of pool boiling of milk at 340W

S.NO	Time (min)	Voltage V	Current I(amps)	T_1 (^{O}C)	T_2 (^{O}C)	T_3 (^{O}C)	ΔTe (^{O}C)	h(W/m^2 K)
1	10	160	2.12	96	86	34	10	936.63
2	20	160	2.12	99	87	34	12	778.69
3	30	160	2.12	100	89	34	11	849.48
4	40	160	2.12	103	93	33	10	936.63
5	50	160	2.12	106	98	34	8	1170.79
6	60	160	2.12	111	104	32	7	1334.90

Q in Watts	h (Water) in W/m^2 K	h(Milk) in W/m^2 K
220	756.57	605.26
240	660.77	550.64
260	893.38	794.12
280	963.67	770.93
300	921.27	829.14
320	1103.03	735.35
340	1334.90	849.48

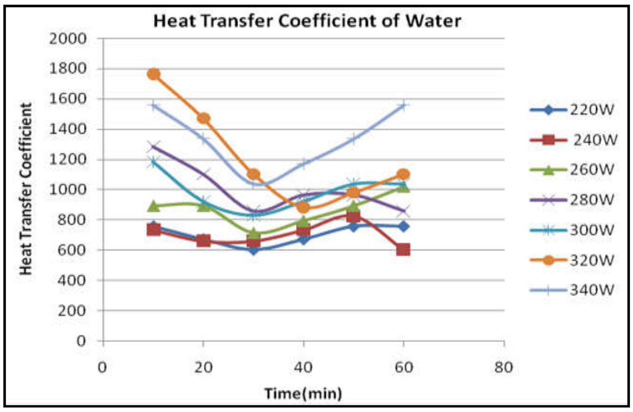


Figure 1. Graphical representation of heat transfer coefficient of water for different heat inputs

The trend seen at moderate time corresponding to minimum heat transfer coefficient gives slight decrease of heat transfer coefficient with time which shows that again the heat present in the water internally supports the boiling so further supplying with slight decrement in heat input can be enough the process to continue, whereas the constant supply of heat input again results in wastage of some heat. It clearly shows that initially with supply of higher heat input, the heat is utilized completely in heating the fluid. Where as after 45 min the heat transfer increases between particles of the fluid as it rearrange themselves. So from there again the heat transfer coefficient increases with increase of space between particles. So higher heat input is the best in getting best heat transfer coefficient that supports the boiling of water without wastage of input heat. Higher heat input boost up the process where as at lower heat input though the process of heating continues simultaneously the heat dissipates to out surrounding. Fig: 2: Shows the effect of time on heat transfer coefficient of milk for different input heats. It is observed that the trend is same as that of in water decreases initially with time reaches a minimum and increases again. Initially during starting there is slight decrease in heat coefficient with time up to 25min reaches a minimum and increases there from. The minimum heat transfer coefficient is 550.23, 550.64, 94.73, 770.93, 690.95, 735.35, and 778.69 for 220, 240, 260, 280, 300, 320, 340 heat inputs after 25 min. The trend of heat transfer variation during starting is same as that of in water but with slight variation that heat transfer is different drastically with heat input for water where as that variation is low in the case of milk (can be seen in the graph with closer lines initially up to 25min till reaches the minimum).

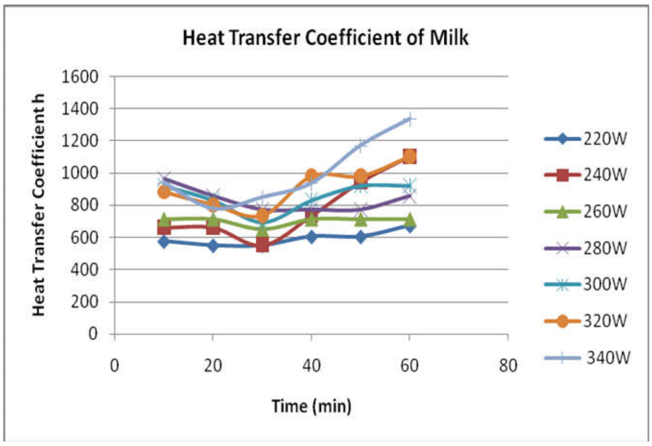


Figure 2. Graphical representation of heat transfer coefficient of milk for different heat inputs

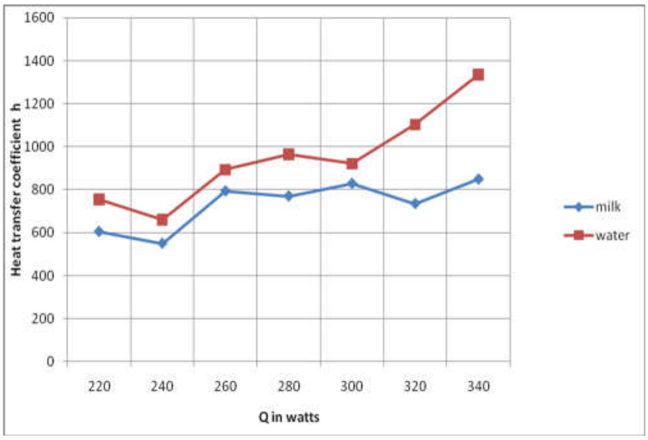


Figure 3. Graphical representation of heat transfer coefficient of milk and water

After crossing minimum value again as time proceeds there is observed the drastic variation in heat transfer coefficient with heat input. This is due to that the heat transfer at micro level is reaches the better level because of the property of milk particles with rise of bubbles at that time period. Fig: 3: shows the effect of heat input on heat transfer coefficient for both water and milk separately.

The fig shows that the heat transfer coefficient increases with increase of heat input. The heat transfer coefficient is 605.26, 550.64, 794.12, 770.93, 829.14, 735.35, 849.48 for milk whereas the same is 756.57, 660.77, 893.38, 963.67, 921.27, 1103.03, and 1334.90 for water at respective 220,240,260,280,300,320,340 heat inputs. The heat transfer increases by 40.34 % with increase of heat input from 220W to 340W for milk whereas the same is 76.44% for water with the same increase of heat input. So it shows that increase of heat transfer coefficient is higher in case of water than in milk. Finally 340W heat input is the best in utilizing input heat properly for heating the fluid for both in case of water and in milk. The heat transfer coefficient for water is higher than that of water shows that water boils faster than milk.

Conclusions

The pool boiling experiment of water and milk over a flat plate heater is conducted and the following has been concluded. The Convective heat transfer coefficients under pool boiling mode have been determined for milk and the water. The values of the convective heat transfer coefficients are found to increase for the heat inputs ranging from 220W to 360W. This can be ascribed to a higher heating surface temperature which results in the formation of more active nucleation sites and rapid formation of the vapour bubbles at the pan-liquid surface. The variation of the heat flux with excess temperature of milk also predicted since it is found to vary exponentially with increasing excess temperature as well as heat input. Finally it is found that heat transfer coefficient is higher for water compared to milk and that to increase by 18.93% to 42.85% by variation of input heat from 220W to 340W.

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