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Effect of operating variables on the heat transfer coefficient during film and drop wise condensation

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Abstract
Condensation is one of the important phenomenon in Chemical Engineering. It is the crucial component of distillation. It is often use for the production of water for human use and crucial process in the forming of cloud chamber. DNA condensation also plays an essential role for functioning process of Gene Regulation and one of the important process in surface condensing and Phase Transition processes. Due to condensation importance in Chemical Industry this review study is done. The aim of this Research is to study the effect of flow rate and temperature difference on the heat transfer coefficient during film and Dropwise condensation. For this purpose the experiment is performed in a Film and Dropwise Condensation Unit and the effect of flow rate and temperature difference on heat transfer coefficient is studied. To analyze our experimental data graphical method is used and the results show that low temperature difference and high flow rate favors the both Dropwise Condensation as well as Filmwise Condensation.

Keywords: Condensation, Distillation, Cloud Chamber, DNA Condensation, Surface Condensing, Phase Transition

Introduction

Condensation is the change of physical state of matter from vapor phase to liquid phase and is the reverse of evaporation. Condensation is a crucial part of distillation as a condenser is connected with a source of cold flow for the cooling of vapor which are separated by distillation and collected at the top of the column.

Cloud Chamber formation and operation also based upon condensation phenomenon. Methanol vapor saturates the chamber. The alcohol falls as it cools down and the cold condenser provides a steep temperature gradient.

Condensation of long double-helical DNAs is a sharp phase transition, which takes place within a narrow interval of condensing agent concentrations.

Surface condensation is condensation which occurs on the visible surfaces of a construction, rather than between the layers. A condensation phase transition is the transformation of a thermodynamic system from one phase or state of matter to another one by heat transfer.

Condensation is found in numerous industrial applications such as power plants and water desalination systems and more compact and more effective condensers would reduce the systems, size and weight while increasing the power. In order to create improved condensers fundamental advancements in condensation are required. [1]

Dropwise condensation heat transfer depends not only on the condensing conditions but also on the interfacial phenomenon between the condensate and condensing surfaces expressed as the free energy difference between the condensate and condensing surfaces. [2]

The heat transfer co-efficient was found to be a function of the active site density, the saturation temperature, the departing drop size and the vapor to surface temperature difference. [3] The heat transfer co-efficient was found to increase with the increasing steam velocity. [4]

Previous research shows the strong dependence of heat transfer co-efficient on vapor to surface temperature difference and vapor velocity both of which vary around the perimeter of the horizontal tube. Very small concentration in liquid phase can give rise to significantly larger heat transfer co-efficient. [5]

Experimental Setup
The experiment is carried out in a H911 Film and Dropwise Condensation Unit as shown in figure. 1.

Apparatus
H911 Film and Dropwise Condensation Unit

Fig 1: Experimental Setup

Procedure
- Ensure that the water level in the chamber is correct.
- Carry out the air separation procedure.
- Run the unit for about 5 minutes with a saturation steam temperature T_1 of 100 ^{0}C and low condenser water flow rate. His is to warm all components and to reduce condensation on glass.
- Select the steam temperature T_1 which is may be constant for the test and it is may be (50 ^{0}C-100 ^{0}C).
- Circulated water through the Dropwise condenser at low rate and adjust the heater input to maintain the selected value of T_1.
- Note the steam temperature T_1, surface temperature T_2, the cooling water inlet temperature T_3, the outlet temperature T_4 for the selected flow rate.
- Increase the water flow rate and again adjusted the heater input to bring the steam temperature T_1 to a selected value.
- Again note the T_1, T_2, T_3 and T_4 for this increased flow rate.
- Repeat at other water flow rates up to maximum.
- Repeat in the similar manner but using Film wise Condenser with appropriate water flow rates, observing T_1, T_5, T_6 and T_7 for the same flow rates as noted for the Dropwise Condenser.
- Plot the graphs to observe the behavior of the flow rate and temperature difference v/s heat flux and heat transfer co-efficient.

Observations and Calculations
Some useful data which help us in this research is given below about the apparatus.
Dimension of each Condenser
Length = L = 90×10^{-3}m
Diameter = d = 12.7mm = 12.7×10^{-3}m
Surface Area = A = $3.7\times10^{-3}m^2$ (approximately)
Internal Volume of Steam Chamber (When Empty) = 184cm^3 = $1.84\times10^{-3}m^2$
Internal Diameter of Chamber (Glass Cylinder) = 76mm = 76×10^{-3}m
Normal Water Capacity = 500cm^3
Surface Area of Heating Element = 144cm^2 = $14.4\times10^{-3}m^2$
Temperature Drop across the Shell of Condenser = 2×10^{-6}ØK
Specific Heat Capacity of Water = Cp = 4.180 KJ/Kg. K
Heat Loss by Steam Chamber (By Experiment) = 2.5WK^{-1}

Dropwise Condensation
Sample Calculations procedure is same for all.
Chamber Pressure = P = -50 (Bar) Steam Temperature = T_1 = 373.15 K Indicated Surface Temperature = T_2 = 300.25 K Correction for Thermocouple = 0.5K Corrected Surface Temperature = $T^{/}_2$ = T_2+0.5K= 300.75 K Water Inlet Temperature = T_3 = 294.15 K Water Outlet Temperature = T_4 =299.95 K Water Mass Flow Rate = m* = 10 (Kg/Sec.) Heat Transfer Rate = Q = 242.44 W Heat Transfer Area = A = πdL = 3.7×10^{-3} m^2 Heat Flux = Ø = Q/A = 67.720 (KW/m^2) Correction of Temperature Drop through Condenser Shell =0.135K Corrected Steam to Surface Temperature Difference = $\Delta T = T_1 - T^{/}_2 - 0.135K$= 72.265 K Heat Transfer Co-efficient = h = Q/ΔT = 0.93 (KW/m^{2}K)

Effect of Flow Rate

	1	2	3	4
Chamber Pressure (Bar)	-50	-50	-50	-50
Saturation or Steam Temperature T_1 (^{0}C)	373.15	373.15	373.15	373.15
Indicated Surface Temperature $T^{/}$ (^{0}C)	300.25	300.85	300.65	300.65
Correction for Thermocouple(^{0}K)	0.5	0.5	0.5	0.5
Corrected Surface Temperature $T^{/}_2$ (^{0}C)	300.75	301.35	301.15	301.15
Water Inlet TemperatureT_3 (^{0}C)	294.15	294.15	294.15	294.15
Water Outlet TemperatureT_4 (^{0}C)	299.95	300.25	300.55	300.45
Water Flow Rate (gm. /sec.)	10	15	20	25
Heat Transfer Rate Q (W)	242.44	382.47	535.04	685.35
Heat Flux Ø (KW/m^2)	67.720	106.835	149.452	183.896
Correction of Temperature Drop through Condenser Shell 2×10^{-6}ØK	0.135	0.213	0.298	0.367
Corrected Steam to Surface Temperature Difference (^{0}C)	72.265	71.587	71.702	71.633
Surface Heat Transfer Co-efficient (KW/m^{2}K)	0.93	1.49	2.08	2.56

Effect of Temperature Difference

	1	2	3	4
Chamber Pressure (Bar)	-60	-60	-60	-60
Saturation or Steam Temperature T_1 (^0C)	312.5	313.55	334.8	333.15
Indicated Surface Temperature $T^/$ (^0C)	300.65	300.05	300.65	300.65
Correction for Thermocouple(K^0)	0.5	0.5	0.5	0.5
Corrected Surface Temperature $T^/_2$ (^0C)	301.15	300.55	301.15	301.15
Water Inlet TemperatureT_3 (^0C)	294.15	294.15	294.15	294.15
Water Outlet TemperatureT_4 (^0C)	300.35	300.25	300.35	300.15
Water Flow Rate (gm. /sec.)	30	30	30	30
Heat Transfer Rate Q (W)	777.48	764.94	777.48	752.4
Heat Flux Ø (KW/m^2)	217.173	213.670	217.173	210.167
Correction of Temperature Drop through Condenser Shell 2×10^{-6}ØK	0.434	0.427	0.434	0.420
Corrected Steam to Surface Temperature Difference (^0C)	10.916	12.573	33.216	33.58
Surface Heat Transfer Co-efficient (KW/m^2K)	19.89	16.994	6.538	6.258

Filmwise Condensation
Effect of Flow Rate

	1	2	3	4
Chamber Pressure (Bar)	-50	-50	-50	-50
Saturation or Steam Temperature T_1 (^0C)	373.15	373.15	373.15	373.15
Indicated Surface Temperature $T^/$ (^0C)	300.75	300.45	300.55	301.05
Correction for Thermocouple(^0K)	0.5	0.5	0.5	0.5
Corrected Surface Temperature $T^/_2$ (^0C)	301.25	300.95	301.05	301.55
Water Inlet TemperatureT_3 (^0C)	294.15	294.15	294.15	294.15
Water Outlet TemperatureT_4 (^0C)	300.25	300.55	300.65	301.35
Water Flow Rate (gm. /sec.)	4.5	5	5.5	6
Heat Transfer Rate Q (W)	114.741	133.76	149.435	180.576
Heat Flux Ø (KW/m^2)	32.050	37.363	41.741	50.440
Correction of Temperature Drop through Condenser Shell 2×10^{-6}ØK	0.0641	0.074	0.083	0.1
Corrected Steam to Surface Temperature Difference (^0C)	71.83	72.126	71.27	71.5
Surface Heat Transfer Co-efficient (KW/m^2K)	0.44	0.51	0.58	0.70

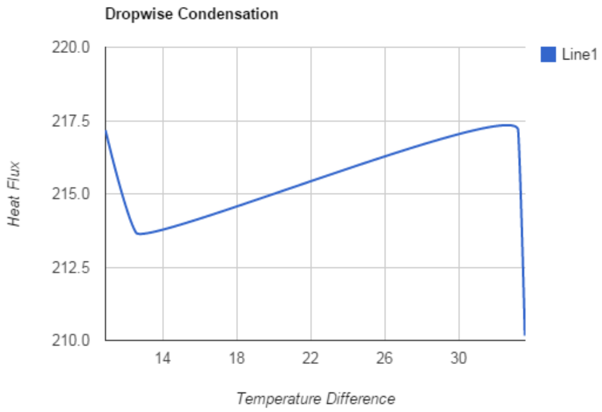
Effect of Temperature Difference

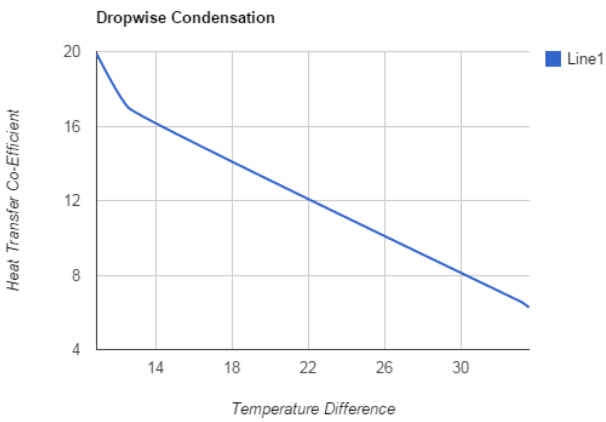
	1	2	3	4
Chamber Pressure (Bar)	-60	-60	-60	-60
Saturation or Steam Temperature T_1 (^0C)	312.5	313.55	334.8	335.15
Indicated Surface Temperature $T^/$ (^0C)	300.65	300.45	300.45	301.15
Correction for Thermocouple(^0K)	0.5	0.5	0.5	0.5
Corrected Surface Temperature $T^/_2$ (^0C)	301.15	300.95	300.95	301.65
Water Inlet TemperatureT_3 (^0C)	294.15	294.15	294.15	294.15
Water Outlet TemperatureT_4 (^0C)	300.45	300.45	304.05	298.35
Water Flow Rate (gm. /sec.)	30	30	30	30
Heat Transfer Rate Q (W)	790.02	790.02	1241.46	526.68
Heat Flux Ø (KW/m^2)	220.675	220.675	346.776	147.117
Correction of Temperature Drop through Condenser Shell 2×10^{-6}ØK	0.441	0.441	0.693	0.294
Corrected Steam to Surface Temperature Difference (^0C)	10.909	12.159	33.157	33.206
Surface Heat Transfer Co-efficient (KW/m^2K)	20.228	18.149	10.458	4.430

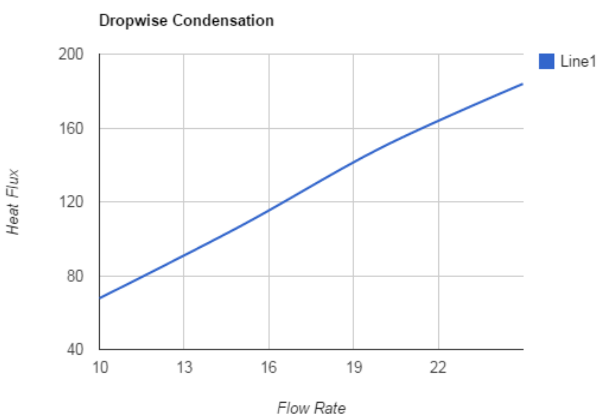
Results and Discussions

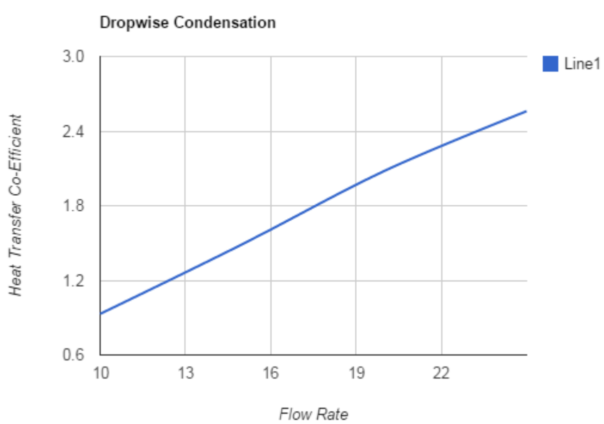
Dropwise Condensation

From this research the results are given below.





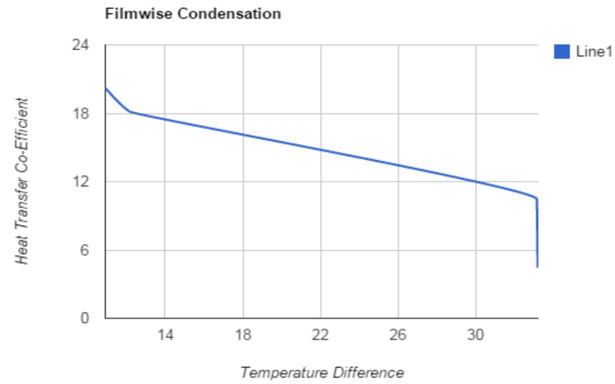


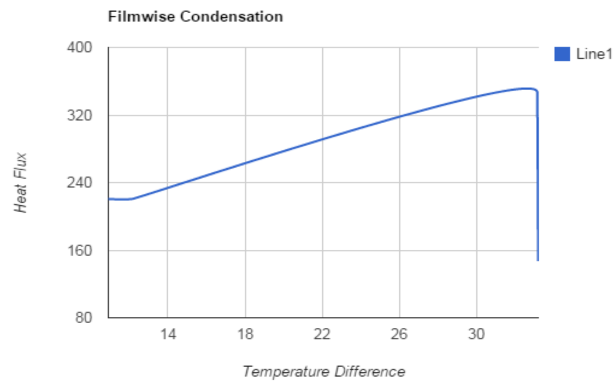


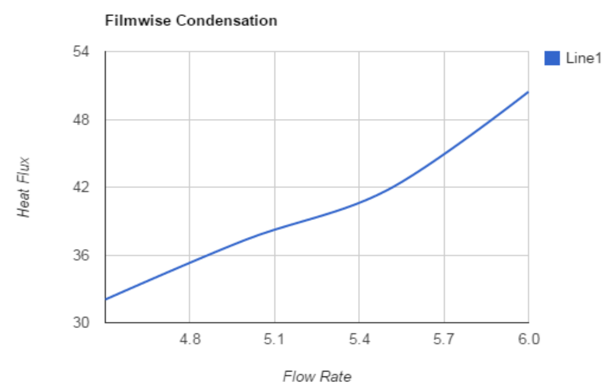
- Results show that in the Dropwise Condensation the Temperature Difference is inversely proportional to the Heat Flux and Heat Transfer Co-Efficient.
- Results show that in the Dropwise Condensation the Flow Rate is directly proportional to the Heat Flux and Heat Transfer Co-Efficient.

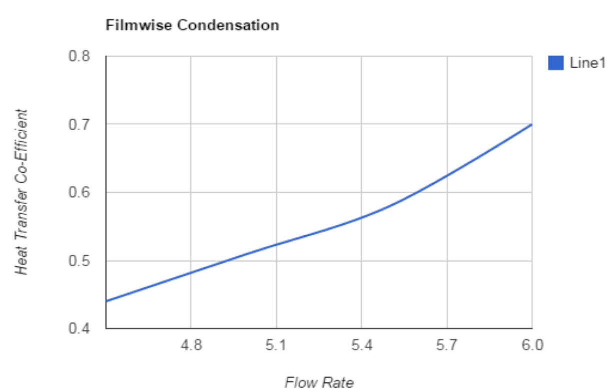
Filmwise Condensation

From this research the results are given below.









- Results show that in the Filmwise Condensation the Temperature Difference is inversely proportional to the Heat Flux and Heat Transfer Co-Efficient.
- Results show that in the Filmwise Condensation the Flow Rate is directly proportional to the Heat Flux and Heat Transfer Co-Efficient.

Conclusions

In this research finally we conclude that low temperature difference and high flow rate favors the both Dropwise Condensation as well as Filmwise Condensation.

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