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Heat Transfer Co-Efficient Through Dropwise Condensation and Filmwise Condensation Apparatus

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Abstract- This paper realise the out line of Heat transfer coefficient for circular copper tube of polished and non-polished through vapour bubbles form of filmwise or dropwise condensation and summurise the main result with its corellation application. During processes of this set up visually observe the exchange of heat during dropwise and filmwise condensation. This unit contained with an integrated steam generator boiler and steam extraction through control valve to the chamber tubes. Condensation of steam on the surface of tubes causes heat transferred from steam to tubes ,into water as heat exchange medium, at peak stage due to temperature difference may condense in to two ways-dropwise or filmwise on tube surfaces.in film -wise condensation, the heat from the vapour to the cooling medium is transferred through the film of the condensate formed on the surface ,where as in dropwise condensation process, only a part of surface is covered with condensate. Due to good contact between the vapour and surface very high heat transfer rates are reported in dropwise process. However, it has been difficult to sustain drop wise condensation commercially for long periods of time.

Index Terms- Materials: Polished copper tube and plane copper tube, Characterization: Heat transfer coefficient W/m2 K , Condensation , Pressure rate: At 3 bar, Equipment: Dropwise and film wise set up with temperature sensors and Bourdon tube pressure gauge

I. Introduction

Whenever a saturated vapour comes in contact with lower temperature surface condensation occurs , film wise in which the condensation wets the surface forming a continuous film which covers the entire surface where as drop wise in which the vapour condenses into small droplets of various sizes which falls down the surfaces in a random fashion .in filmwise condensation the heat from the vapour to the cooling medium is transferred through the film of condensate formed on the surface where as in drop-wise condensation process , only a part of surface is covered with condensate. Very high heat transfer rate are reported in dropwise processes due to the good contact between the vapour and surface .

Theory: Condensation is the change of phase from the vapour state to the liquid or solid state.

Condensation plays a major role in the heat rejection parts of the rankine power cycle and the vapour compression refrigeration cycle, which generally involve pure substances. Dehumidification in air conditioning and the production of liquefied petroleum gases, liquid nitrogen and liquid oxygen and exampled in which condensation and mixture takes place. There are mainly two mode of condensation processes known as film wise condensation and dropwise condensation. If condensate tends to wet the surface and there by forms a liquid film, then processes of condensation is known as film wise condensation. If condensate does not tends to wet the surface, the condensate forms the droplets on the surface and every time fresh surface is exposed to the vapour. Both type of condensation processes are common in practise and both may occur simultaneously in a single apparatus

FIG .1

1.1 FILMWISE CONDENSATION

FIG .2

FIG .3

in filmwise condensation, the new condensate formed joins the liquid film formed on the surface previously and this increases the film thickness . In film condensation the liquid condensate forms a continuous film, which covers the surface and takes place when the liquid wets the surface. This film flows over the surface under the action of gravity or other body ,surface tension and shear stresses due to vapour flow .Heat transfer to the solid surface takes place through the film, which forms the greatest part of thermal resistance.The heat transfered from vapour to condensate formed on the surface by the convection and it is further transferred from the condensate film to the cooling surface by the conduction .this combined mode of heat transfer by conduction and convection reduces the heat transfer rete considerably compared with drop wise condensation .this is the reason that the heat transfer rate of filmwise condensation are lower than dropwise condensation.

1.2 DROPWISE CONDENSATION

FIG .4

FIG .5

Dropwise condensation occur when saturated pure vapour comes in contact with the cold surface such has copper tube ,it condenses and may form liquid droplets on the surface of the tubes .these drop lets may not exhibit an affinity for the surface and instead of coating the tube they fall from it leaving bare metal on which successive droplets of condensate may form. When condensation occurs by this mechanism, it is called drop wise condensation . when considering surface is contaminated with substance which prevents condensate from the wetting surface ,the vapour will condense in drops instead of a continuous film. Although dropwise condensation would be preferred to filmwise condensation yet it is extremely difficult to achieve or maintain. This is because most surfaces becomes wetted after being exposed to condensing vapour over a period of time .dropwise condensation can be obtained under control conditions with the help of certain additives to the condensate and various surfaces coatings but it is commercial viability has not yet been approved .for this reason the condensing equipment in use is designed on the basis of filmwise &dropwise condensation.

The vapour starts condensing on a surface when the vapour saturation temperature is more than the surface temperature .the temperature of the condensate formed on the surface is less than its saturation temperature and it becomes sub-cooled, more vapour will condensate on the exposed surface or on the previously formed condensate as the temperature of the previous condensate is less than the saturation temperature of vapour.

II. SPECIFICATIONS

1. Condenser –two water cooled condensers fabricated from copper polished or Natural finish (ilmwise condenser) and nonpolished copper or Gold plated (Dropwise condenser)

1. Diameter of the copper tube,d=28mm
2. Length of the copper tube L=150mm
3. Diameter of the gold coated copper tube d_1=28mm
4. Length of the gold coated copper tube L_1=150mm

2. Specific heat of water C_{pw}=4186.6 J/kg-k

3. Material – gold coated nonpolished dropwise and Natural finish polished filmwise

4. Thermocouples - Fitted with 7 thermocouples to measure the mean metal temperature and 2 thermocouples to measure the inlet and outlet water temperature.

5. Heating coils with thermal protection, with 3KW power input

6. Heat extraction – by water

7. Steam chamber - diameter -90mm, Height-300mm, Thickness-5mm

8. Steam safety- pressure gauge and Pressure relief valve

2.1 TESTING REQUIREMENTS

1. Continuous water supply (Min. 10 LPM @ 2 to 3 bar),
2. Electricity 250 W,
3. Condenser : Two water-cooled condenser fabricated
4. measuring jar for outlet wate and stop watch.

III. TESTING EQUIPMENT

When dimensions of the test tubes permit inside of non condensable closed chamber ,the test tubes shell be round and arrang the 7 thermocouples to measure the mean metal temperature and 2 thermocouples to measure the inlet and outlet water temprature at setup and pressure measuring bourdon tubepressure gauge placed at boiler. The total equipment setup have been intented in fig. 6

FIG .6

3.1 PROCEDURE

- First switch on the main power
- Fill the water in boiler up to 90% of its capacity and close the all valves, Water level indicates in glass tube in front of the boiler
- Then switch on the heater button.
- Wait 15 to 20 min of getting required pressure.
- Allow the steam slowly to the chambers by opening the steam control valves with max.pressure is 2 bar .(valve is fixed on steam flow pipe)
- The chamber consists of two copper rods one is polished another one is non polished with same diameter and same length.
- The system is allowed to come to steady state.
- Located the temprature sensors at all important points for Note down the temperature T_1,T_2,T_3,T_4,T_5,T_6 AND T_7.

3.2 Tabular column:

Sl no	Heat input Q		Time taken to collect 50cc of Water in Sec.		Thermocouple readings						
	V volts	I amps	From non-polished	From polished	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1	100	0.56	2.5	2.5	32	33	33	37	36	34	35

T_1=Water inlet temperature in ˚c
T_2=surface temperature in plane copper tube in ˚c
T_3=vapor temperature between plane copper tube and glass column in ˚c
T_4=vapor temperature between gold plated copper tube and glass column in ˚c
T_5=surface temperature in polished copper tube in ˚c
T_6=water outlet temperature of polished copper tube in ˚c
T_7=water outlet temperature of plane copper tube in ˚c

Specimen calculation:

Heat input to boiler=Q=V×I xcos Φ in watts
Here cos Φ = 0.96

DROP WISE CONDENSATION

1. Mass flow rate of water for film condensation M_{dw}= $V_{dw} \times 10^{-3}$ in kg/sec

$M_{dw} = \frac{50}{1000 X2.5}$ = $2x10^{-3}$ kg/sec

2.Heat carried away by water in formation of drop wise condensation (at gold plated copper tube)

$M_{dw} \times C_{pw} \times (T_6 - T_1)$ in watt
= $2x10^{-3}$ x 4186.6 x (33-32)
= 8.3725 W

3.LMTD(dropwise) $= \frac{(T4-T2)-(T4-T7)}{In\left(\frac{T4-T2}{T4-T7}\right)}$

$= \frac{(37-33)-(37-35)}{In\left(\frac{37-33}{37-35}\right)}$

= 2.885

4.Drop wise condensation heat transfer co-efficient h_{dw}

$$\frac{Qdw}{\pi dl(LMTDdw)} \text{ in W/m}^2\text{K}$$

$= \frac{8.3725}{\pi x0.028x0.15x2.885}$

= 220.0085 W/m^{2}K

FILM WISE CONDENSATION

Mass flow rate of water for film condensation M_{fw}= $V_{fw} \times 10^{-3}$ IN kg/sec

$M_{dw} = \frac{50}{1000 X2.5}$ = $2x10^{-3}$ kg/sec

Heat carried away by water in formation of film wise condensation (at gold plated copper tube)

$Q_{fw} = M_{fw} \times C_{pw} \times (T_7 - T_1)$ in watt
= $2x10^{-3}$ x 4186.6 x (33-32)
= 8.3725 W

LMTD(film wise)= $\frac{(T5-T3)-(T5-T6)}{In\left(\frac{T5-T3}{T5-T6}\right)}$

$= \frac{(36-33)-(36-34)}{In\left(\frac{36-33}{36-34}\right)}$

=2.4666

Film wise condensation heat transfer co-efficient h_{fw}

$= \frac{Qfw}{\pi dl(LMTDfw)}$ in W/m^{2}K

$= \frac{8.372}{\pi x0.028x0.15x2.466}$ = 75.782 W/m^{2}K

IV. CONCLUSION

In this paper through modal calculation finally observed that the heat transfer coefficient (h W/m^{2}K) associated with dropwise condensation is quite large compare with film wise condensation. The drop wise condensation of steam has heat transfer co-efficient 2 to 10 times as large as film condensation. However, it has been difficult to sustain drop wise condensation commercially for long periods of time. This can be achieved in this prototype in terms how the condensation form on the vertically non polished copper tube and vertically plane polished copper tube with same dimensions when these are inside of non condensable closed chamber shown in fig 1, and also can be observed the continuous formation of vapour drops (condensation) on the copper tubes when the continuous steam pressure released for spatial time (min 30 seconds) through operating pressure control valve from the boiler. From this stage have been observed that when pressure of vapour increase the rate of heat transfer increases in indicates that the rise of pressure of vapour is directly proportional rate of heat transfer.

This model setup allows the additional model calculation of heat transfer , heat flux and also a future improvement of the model is expected with extensions that account for another effect on the heat transfer such as drainage limitations , the vapour shear or pressure effects. And also this paper suggest that when ever the requirement of condensation is more ,the surface should be non polished.

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