Experimental Investigation of Heat Transfer Coefficient and Pressure Drop inside Horizontal Mini Channels

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Abstract: *This study examines the pressure drop and heat transfer characteristics of annular condensation in triangular mini-channel with two-sided cooling walls. The present paper is to determine the condensation heat transfer coefficient in single channel. The test were conducted for two mass flow rates of 3×10^{-4}Kg/s and 4×10^{-4}Kg/s and four vapour qualities of 0.2, 0.4, 0.6 and 0.8 in horizontal triangular channel having 1.5mm hydraulic diameter. The experiments were conducted using steam as a working fluid and water as a coolant. In addition to this, project aims to investigate the factors affecting condensation heat transfer. The conclusion of the test will be with increase in the vapour quality and mass flux there is an increase in the heat transfer coefficient*

Keywords: *condensation, Heat transfer coefficient, pressure drop, small triangular channel, vertical down flow, mass flow rates, and vapour qualities*

1 INTRODUCTION

Lightweight and compact condensers for vapor compression cycles have a variety of applications from electronics' cooling to transportation. However, as reported in the literature, uncertainties in measured condensation heat transfer coefficients can be as high as ±20% to ±40% due to the challenges of measuring condensation heat fluxes and wall temperatures at the micro- and mini-scales.

Channel Geometry					
Type	**Angle**	**Width**	**Depth**	**Hydraulic Diameter**	**Length**
V	90	2.25mm	1.125mm	1.5mm	96mm

Table 1: Channel geometry

The present study concerns the design of a relatively new class of condensers that employ a series of mini -channels to meet the stringent size and weight requirements of defence electronics. Another goal is to maintain mostly annular flow along the mini-channels to capitalize upon the large condensation heat transfer coefficients associated with thin films. With superheated or saturated inlet conditions, a very thin film is initiated in the upstream region of the channel, which is driven along the channel by the shear stresses exerted by the core vapor flow. Mini-channels greatly increase vapor velocity and therefore the shear stress exerted upon the film interface. This greatly decreases the film thickness, resulting in very high condensation heat transfer coefficients. While mini-channels do enhance heat transfer performance, they also increase pressure drop. Therefore, the design of mini-channel condensers requires predictive tools for both pressure drop and condensation heat transfer coefficient

2. . EXPERIMENTATION OF THE SYSTEM

2.1 Fabrication of small triangular channel

Aluminium bar of cross section 150*80 mm is fabricated for square small channel of hydraulic diameter 2.5mm, 1.5mm and length 96mm with having single channel cut on the top and bottom of the triangular block shown in fig. the top and bottom of the mini channel is covered with cover plate made up of acrylic glass .Two cover plates are provide with two drilled holes for the inlet and outlet for the working fluid and coolant. The test specimen was fabricated by CNC milling machine.

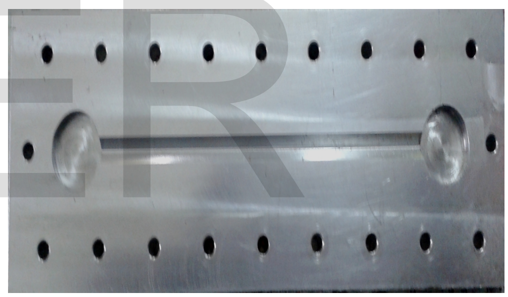


Fig 1:Fabricated test specimen

2.2 Location of thermocouple

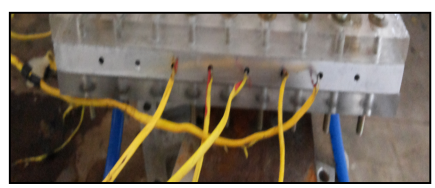


Fig -2: Location of thermocouple

Five thermocouples are inserted in between steam side and the coolant side. They were placed at a distance as shown in figure 2 along the channel length

2.3 Experimental Setup

The experimentation was conducted using steam as a refrigerant and water as a coolant in the condenser. The preheater is completely insulated with the glasswool.fig shows the test line assembled for the experimental investigation of flow condensation in minichannel. Two booster pumps are used to circulate the refrigerant and coolant through the test line. The generated vapour is condensed in the test section. The five thermocouples are inserted between the refrigerant and the coolant side as shown in figure. The intensive and extensive properties like temperature, pressure and flow rate are measured at various points during testing; the condensate water from the condenser was measured.

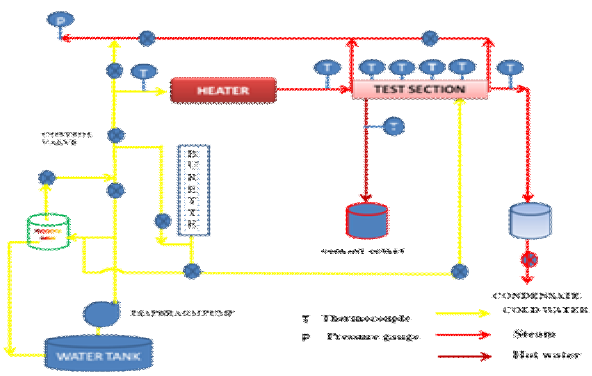


Fig -3: Flow diagram.

2.4 Data reduction

The inlet vapour quality of the test section (x_i) is determined by energy balance in heat sink.

$$m_s h_f + Q_a = m_s (h_f + x_o h_{fg}) \quad (1)$$

Where,

h_f the enthalpy of the water into sink, Q_a=I*V is the heat added into the sink and h_{fg} is the latent heat of vaporization.

Heat transfer coefficient (h)

$$h = Q_c / (T_s - T_w)\, A \quad (2)$$

Where,
Qc= heat removed by refrigerant in W
A= area of the surface in m^2=(L*b)*2
b= depth of the channel in m
L= length of the channel in m

Heat absorbed by cooling water (Q_c)

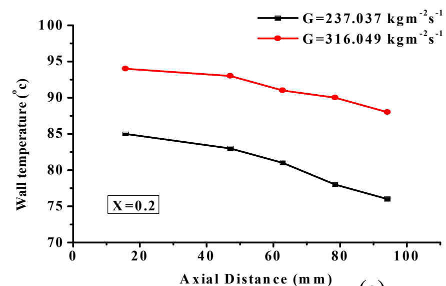
$$Q_c = m_c\, c_p\, (T_{co} - T_{ci}) \quad (3)$$

Where,
m_c= mass flow rate of coolant in Kg/sec
C_p= specific heat of coolant in KJ/Kg ˚C
T_{co}= outlet temperature of coolant in ˚C
T_{ci}= inlet temperature of coolant in ˚C
I= current in amp
V= voltage in volts

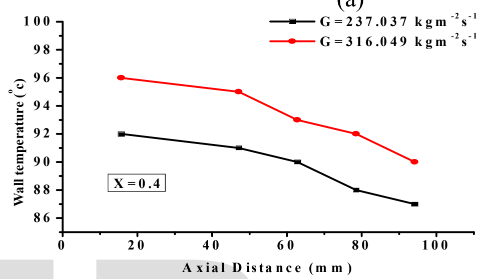
3. RESULT AND DISCUSSION

3.1Effect of wall temperature along the channel length for horizontal single triangular channel

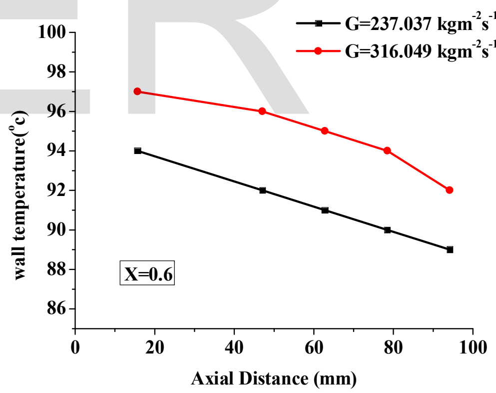
Fig 4 a, b, c and d shows wall temperature along the channel length for horizontal single triangular channel. From the initial observation of the result it is clearly indicates there is a decrease in trend of wall temperature along the length. In addition to that, it is evident from the trends the highest wall temperature for highest mass flux of 316.049Kgm^{-2}s^{-1}.this trend was observed for all vapour quality. This is due to low temperature gradient on the cooling side.



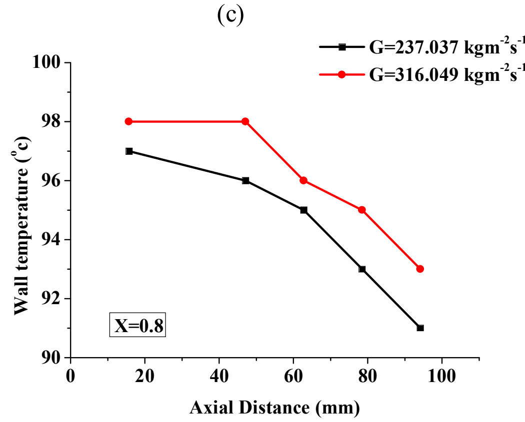
(a)



(b)



(c)



(d)

Fig 4 a, b, c, d: wall temperature along channel length for horizontal single triangular channel.

3.2 Effect of heat transfer coefficient along the channel length for horizontal single triangular channel

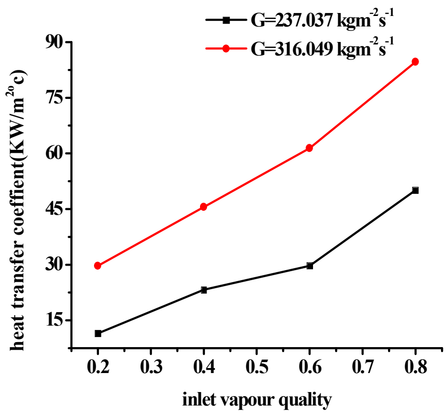
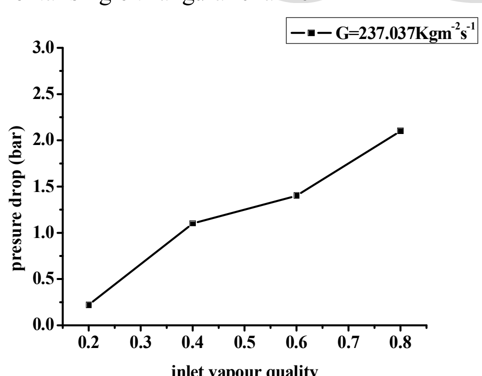


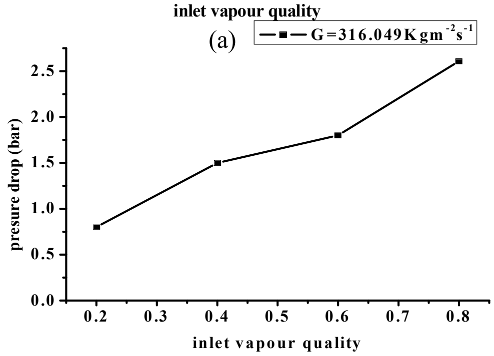
Fig 5: condensation heat transfer coefficient versus vapour quality for horizontal single triangular channel

Fig 5 shows the variation in heat transfer coefficient with vapour quality for horizontal single triangular channel. It is observed from the trend, as a quality increases there is an increase in heat transfer coefficient .In addition to that, the result shows for higher mass flux there is an increase in heat transfer coefficient. This occurrence is due to the formation of thin film layer around the channel.

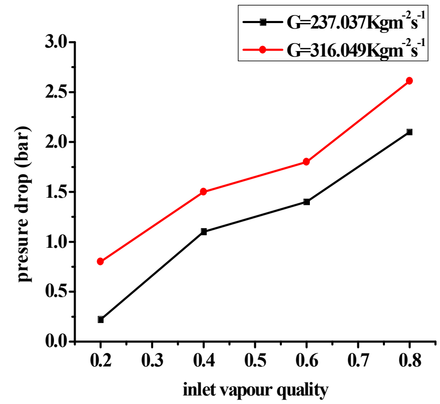
3.3 Effect of pressure drop along the channel length for horizontal single triangular channel



(a)



(b)



(c)

Fig.6.a, b, c: Pressure drop versus vapour quality with mass flow rate for horizontal single triangular channel

Fig 6 a, b, c and d shows the variation in pressure drop with vapour quality and mass flow rates for horizontal single triangular channel. It is observed from the trend, as quality increases there is an increase in pressure drop. In addition to that, the result also shows for higher mass flux of 316.049Kg/m^{2}s there is an increase in pressure drop. This occurrence is due to the formation of thin film layer around the channel.

4. APPLICATION OF MINI CHANNEL

1. High coefficient of heat exchange.
2. Reduced refrigerant charge
3. Very high level solution flexibility
4. Higher performance(High volumetric heat flux, modest pressure drop)
5. Can be serviced and repaired on site

5. CONCLUSION

The triangular test section with a hydraulic diameter of 1.5mm channel was tested. The experiment was carried by varying mass flux of 237.037 to 316.049Kg/m^{2}s and vapour quality ranges from 20% to 80% at a fixed saturation temperature of 100˚C.The obtain experimental result shows flow condensation heat transfer coefficient and pressure drop increases with increasing mass flux and vapour quality this may be due to flow which occur in annular regime.

6. REFERENCES

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