University of Thi-Qar Journal for Engineering Sciences
http://www.doi.org/10.31663/tqujes.12.1.416(2022)
Vol 12.1(April 2022)

ISSN :2664- 5572 (online)
ISSN:2664-5564 (print)
Available at http://jeng.utq.edu.iq
utjeng@ utq.edu.iq

Investigate the Flow of Boiling Heat Transfer in a Complex Geometry Flat Channel

R.SHAKIR*

Petroleum and Gas Engineering Department, College of Engineering, University of Thi-Qar, IRAQ
*Corresponding author E-mail: raed-sh@utq.edu.iq ; shraed904@gmail.com

Abstract

This investigation has been studied to a complex geometry of flat channels. A piece of copper plate by dimensions (25 mm) width by (25 mm) length and (5 mm) depth was, therefore, developed for copper plate, it was a square shape. The heat was applied on range (50-600) watts (3) mass of flow rate had employed. The ranges of heat had applied for each flow of mass was employed. The square copper of flat geometry with a channel height (3 mm) and a channel length (25 mm) is heated via an electric heater. It has been researched and reported that the characteristics of a geometrical structure and on metal contribute to test piece to guess of coefficient of single-phase on heat transfer and to guess of coefficient of two-phase on heat transfer.An iteration process via excel software was utilized to get properties of flow heat such as; a coefficient single-phase and a coefficient two-phase of heat transfer was clearly been laminar also a fully developed on this flow, a guess on wall of temperature, a prediction on fluid of temperature at guess tests. A possibility mechanism of heat transfer was reported for flat-channel of complex geometry. So results on the main of this article to acquire an inlet and an outlet a guess of heat flow, a fluid temperature, as well as get coefficient of single-phase and a coefficient of two-phase on heat transfer in addition to mention a some of numerical results such as the liquid of temperature for inlet location had been between (20.84 -32.63) Celsius also liquid of temperature for outlet location had been between (21.40-45.26) Celsius; a temperature of wall had been between (40.70-48.60) Celsius.. Ultimately, so I have no experimental data had obtained of empirical set-up so that R113 data had obtained on guess analysis was only employed by equations of heat transfer at guess set-up very similar to real lab tests under to steady-state conditions.

Keywords: Flat-channel, Boiling, Coefficient of heat transfer, Heat sink.

1. Introduction

The substantial goal of this study has to explain how to remove unwanted heat are generated by electrical devices such as x-rays had equipment for microprocessors that are electronics and other to high-power of electrical devices and so forth still wanted to be effective in heat dissipation at high-performance of technologies. So; fluids such as water and an R113 are two coolant forms that was supported the complex geometry of channel sinks. For flows of multi-phase or single-phase of fluid or air streamed into them **[1–5]**; Several researchers had reported to flow of boiling phenomena Kandlikar et al**,[6]** and **[7]** ; Kuznetsov and Vitovsky;**[8]**. Cuta et al; **[9]**.Ibtisam A. Hasan; Iman S. Kareem; Duha Adil Attar **[10**] had studied an array of pin fins heat sinks in order to build a cooling system for PV panels. So 1-D analysis condition was employed to transfer an excess heat by the PV panel with the heat sink by existing to guess an operation temperature of the PV panel by Theoretical and panel performance has been studied empirically. Hayder Mohammed Hasan **[11]** was numerically investigated to micro-channel of heat exchanger SIMPLE algorithm by finite volume method also employed FORTRAN code to get the distribution of temperature for their project.The purposes to present on this study are: (1) to obtain of new heat transfer data for R113 on single-phase and on two-phase to flat-channel, (2) to obtain a significant parametric trend and an explore the possibility of a mechanism on coefficient of heat transfer, (3) to guess on the accuracy of previous to correlations of flat-channel at guessing the new data, and (4) to develop a new method for heat transfer correlation for R113 on boiling tests of flat-channel to complex geometry.

2. Theory

An estimation of heat transfer coefficient on single-phase and on two-phase to the R113 is existed according to the liquid of wall temperatures at the system pressure as an indication to temperature; As seen in Fig.1, a description for a point to that only a one heat flux distribution can exist on the solid-fluid interface.A dominant influence on the conduction of wall , as indicated on Fig.1, the 2-D array; first-D array was perpendicular to the second-D array was fluid flow R113 parallel to the R113 fluid flow, a thermal conductivity for the following equation, was not observed eventually **[12]&[13]**.

$$\delta^2 T/\delta y^2 + \delta^2\, T/\delta z^2 = 0 \qquad (1)$$

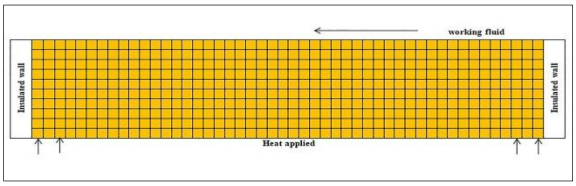

Fig.1 Wall Conduction of copper test Piece **[12]&[13]**

Where (y) is perpendicular to flow axis; (T) is a temperature in a copper wall. Heat conduction on eq.(1) was discovered via the partition to the square cell zone has (0.5 mm) square.An energy balance to be achieved via each cell, as seen in Fig.1. **[12]&[13]**

$$T_{i,j} = \delta y^2\left(T_{i+1,j} + T_{i-1,j}\right) + \delta z^2\left(T_{i,j+1} + T_{i,j_1}\right)/2\,(\delta y^2 + \delta z^2) \qquad (2)$$

Where (δz) and (δy) are the cell size .So eq.(2) was meant to vary from boundary conditions that are iteratively solved to the point where the temperature at each cell is the same as previously predetermined a guess error of (0.002) via the iteration method.

The value for (T_w) at mini-scale can be obtained as**[14]**:

$$T_W = T_{th} - \frac{q_h\, L_{th}}{K_C} \qquad (3)$$

The value of (T_L) at mini-scale is obtained by**[14]**:-

$$T_L = T_{in} + \frac{q_h\, W\, Z}{M_L C_p} \qquad (4)$$

The guess of single-phase to coefficient of heat transfer to flat -channel can be found by**[14]**:-

$$q_h = A_h h_{sp}(T_w - T_L) \qquad (5)$$

The exit quality can be obtained by employing**[14]**,

$$x = 1/h_{Lg}[q_h/m - C_P(T_{sat} - T_{in})] \qquad (6)$$

The calculation of heat transfer on two-phase to flow boiling is obtained by**[14]**:-

$$q_h = A_h h_{tp}(T_w - T_{sat}) \qquad (7)$$

The calculation of Nussle number can be obtained by:-

$$NU_{x,3} = NU_{x,4}\frac{NU_{fd,3}}{NU_{fd,4}} \qquad (8)$$

Where prandtls (Pr); number as follows **[14]:**

$$P_r = \frac{C_p\, \mu_L}{k_L} \qquad (9)$$

The Reynolds number can be obtained by**[14]**-

$$R_e = \rho_L V D_h/\mu_L \qquad (10)$$

In where (D_h), seen by

$$D_h = A_{hc}/P_{hc} \qquad (11)$$

The Reynolds number for single-phase & two-phase regions are found respectively by.

$$Re_L = (G(1 - x)D_h)\,/\,\mu_L \qquad (12)$$

$$Re_v = (G\, x\, D_h)/\mu_v \qquad (13)$$

In where "(NUx_4), ($NUfd_3$),"and ($NUfd_4$), " are given to be gained by liquid properties respectively"."As defined all single-phase set to coefficient of heat transfer can be obtained**[14]**:-

$$h_{sp} = \frac{N_u k_L}{D_h} \qquad (14)$$

In addition to all two-phase set to coefficient of heat transfer should be gained by**[14]**:-

$$h_{tp} = \frac{q_h/A_h}{T_w - T_{sat}} \qquad (15)$$

3. The Set-up

The set-up has (3) main sections; a flow loops, a copper of test section; a flat-channel of complex geometry In addition to a test piece of copper.

3.1 Flow loop

On consideration that the set-up has a new technology of development plan .So before the boiling test in Fig.2.In the sequence of test, the running liquid R113 has been degassed for roughly (2-4) hours in the higher thermal test in order to remove any a dissolved gas was derived to the atmosphere from the set-up. The valve at the top of a the preheater was occasionally opened to permit the dissolved gas to fly to the atmosphere. In addition, any test pressure was closed to ambient pressure. After extracting the gas from the R113 working liquid, remove the liquid R113 by the accumulation of the pump. The key goal of the coarse filter is to prevent main debris. A finer filter was employed during boiling tests .So, the optimal R113 was calculated relied on a mass flow and an inlet temperature (M_L; T_{in}). So, during the inspection, a coarse filter is employed to block large particles. The mass speed was balanced by a flow meter and a by-pass valve was located in front of the flat-channel of complex geometry. The heat adjusted controller for liquid R113 was transported to pre-heater to get the appropriate for temperature inlets to transfer to a complex geometry of flat-channels of copper housing .A pre-heater was joined to the controller unit. Before of conditions of steady-state essentialed to be maintained. A working liquid R113 has crossed through to flow loop to the equipment. A procedure involves around (2-3) hours to steady state to situation. The temperature of a heater and a copper housing can continuously drives the movement. In this state, the heating duration was roughly (40 to 90 minutes), and the heating time employed was reset by an iterative process via the boiling test in order to continue a device pressure be similar to the environment for all guess of boiling tests.

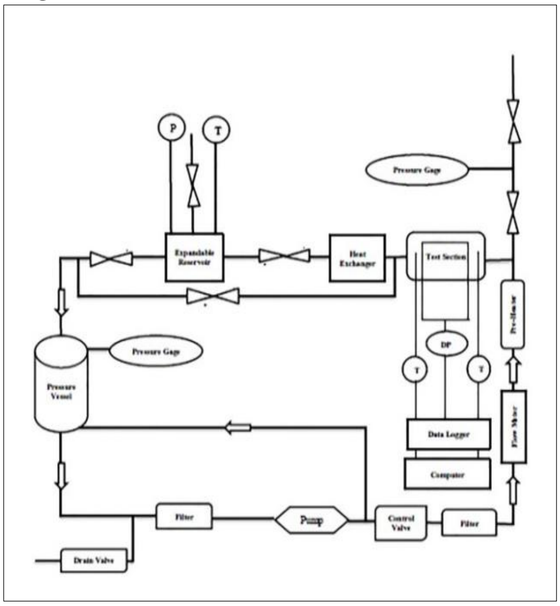

Fig.2. The Flow Loop[12]

3.2 Test section

Figs. (3 & 4**)** are seen a copper on test section had composed of (3) parts: a copper housing, a top cover, a complex geometry of flat-channel. The top bodies, a bottom box and so all the foundations are prepared of copper, a copper box was employed. So; Figs. (3 & 4) are seen the copper of the test portion of this investigation is seen on analytical analysis. So, top housing contains a complicated to flat-channel of complex geometry. It was fitted with an inlet plenum; an outlet plenum was equipped by pressure; a temperature port for receiving at similar sensors was presented.

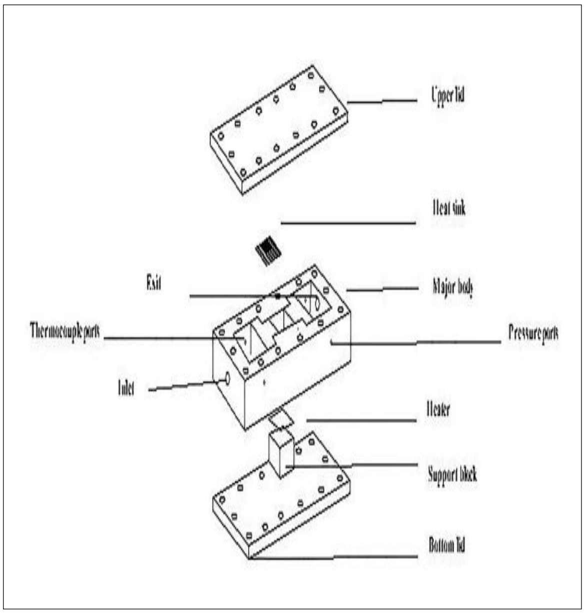

Fig.3. Test housing [13]

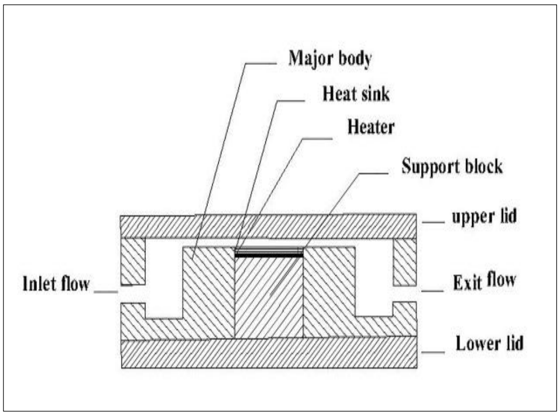

Fig. 4. Test section [13]

3.3 Test piece

Fig.(5) is seen the parts that had been gained on the copper to flat-channel of complex geometry; So, (6) thermo-couple posts, (1) each on inlet plenum, an outlet plenum, and (4) underneath on flat-channel of complex geometry zone .So all thermo-couples are employed to gain an inlet temperature and an outlet temperature.A wall temperature of thermocouples with a sample diameter of (0.5 mm) was pushed through (2) holes for an inlet location and (2) holes for an outlet location, drilled both of them (4 mm) below the channel surface with a drilled (10 mm) and (20 mm) in a test piece from the inlet end respectively. Thermocouples had empolyed to measure the heat sink's stream on temperature distribution . These holes allowable (4) sheathed k-type thermocouples and all thermocouples had calibrated in an exceedingly water bath and had accurate to (±0. 55 ºC) roughly.A groove is cut out on the surface of the top housing to line an O-ring.A copper to a flat-channel of complex geometry so channel had an altitudinous footprint on the surface to the housing of copper was (25 mm by 25 mm) was presented total width by total length

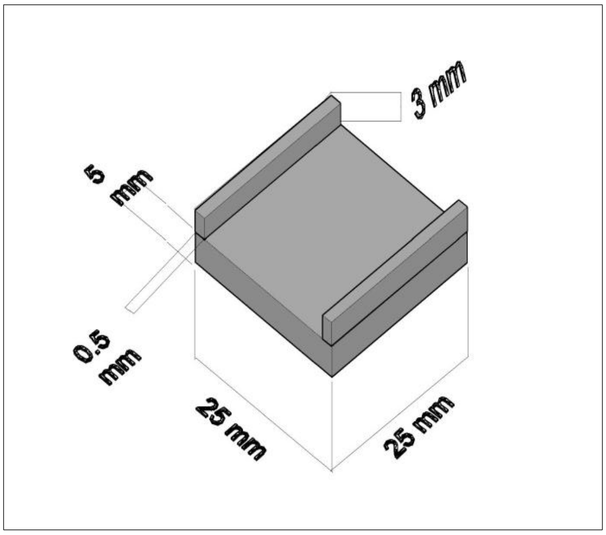

Fig.5. Test piece of flat-channel

3. Results and discussion

Figure .6 shows an overview to the predictive data on the coefficient of heat transfer versus exit equality for boiling tests. An initial objective to the project was to identify data on single-phase of coefficient and coefficient of two-phase. There are 2-zones in the Figure. 6, a zone of single-phase also a zone of two-phase, a single-phase was laminar and was developing flow. At outlet position low mass flow has a higher value was been compared with others; so this prediction was detected more evidence for boiling on a flat-channel of heat sink. So these factors may explain the relatively of good correlation between the coefficient of heat transfer and an exit equality.

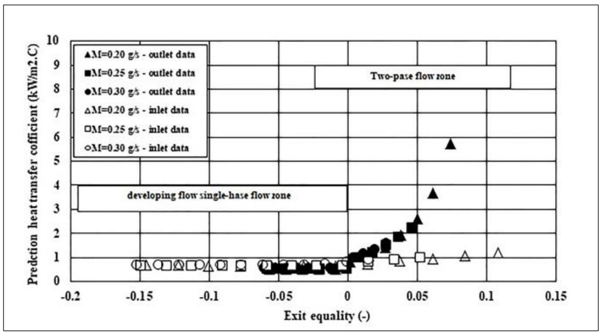

Fig.6. Coefficient of heat transfer versus exit quality

Figure .7 is presented the results obtained by the final analysis of prediction tests, for an inlet data and an outlet data to a coefficient of heat transfer on single-phase and on a coefficient of heat transfer on two-phase against a temperature for inlet fluid .In Figure .7 the data started approximately constant after that there is a clear trend of increasing to the end. As seen in Figure.7, the data outlet at outlet location higher than data inlet at inlet location. So a present study was designed to get the effect to the coefficient of heat transfer for a flat-scale of heat sink. This study set out with the key of assessing an importance to the coefficient of heat transfer on boiling tests.

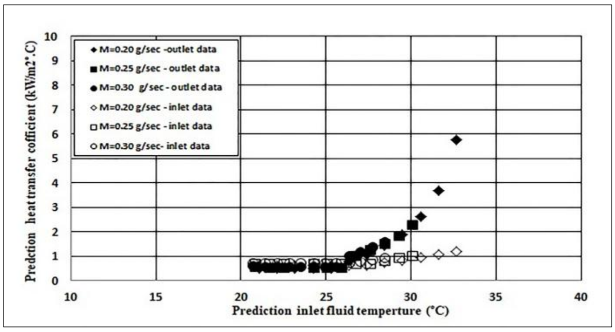

Fig.7. Coefficient of heat transfer versus inlet temperature

Figure .8 provides to the prediction data on the coefficient of heat transfer against of outlet on fluid temperature of prediction tests, for an inlet and an outlet data to single-phase and on two-phase heat transfer. In Figure.8 the data had started approximately constant data after that got there is a clear trend of rising to the end. As seen in Figure .8, the data outlet at the outlet location higher than the data inlet at the inlet location; so, a present investigation was designed to find the influence to the coefficient of heat transfer for a flat-scale of heat sink. As can be seen from Figure .8 the flow on single-phase was laminar also was developing. This investigation set out with the goal of assessing to the significance to the coefficient of heat transfer on boiling tests.

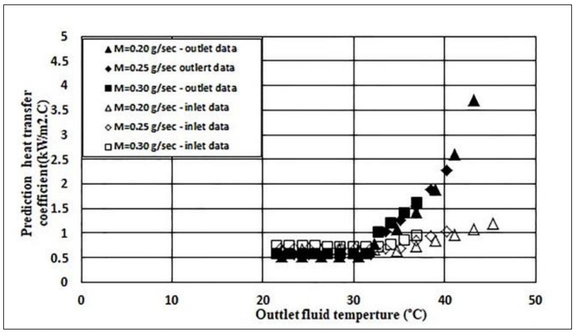

Fig.8. Coefficient of heat transfer versus outlet temperature

Figure .9 is seen the prediction data on the coefficient of heat transfer against of wall temperature of prediction tests, for single-phase and on two-phase of heat transfer.A coefficient of heat transfer for single-phase flow remains relatively constant and approximately the same after that data there is a clear trend of rising to power relationship to the end. Thus, there was a significant positive on correlation between on wall temperature and single-phase and on-two-phase heat transfer.As seen in Figure .9, the data outlet higher than the data inlet as well as the low mass flow has bigger data at inlet data and outlet data. Therefore a present study was designed to calculate the influence of wall temperature on the coefficient of heat transfer for flat-channel of heat sink. The flow on single-phase was laminar also developing at all mass flow. So, This search was set out with the goal of estimating for significance to the wall temperature with a coefficient of heat transfer on both phases, single-phase and on two-phase for boiling tests.

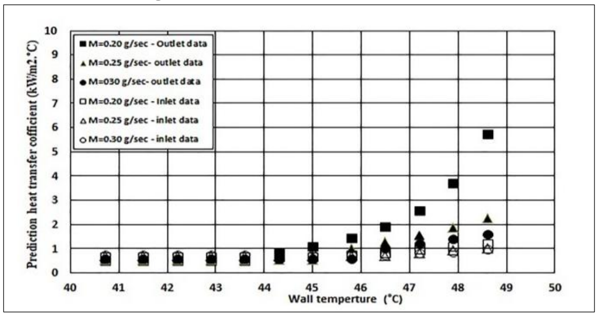

Fig.9. Coefficient of heat transfer versus wall temperature

Conclusions

The conclusions are dependent on transmitted relied on iteration process and equations of Heat transfer executed in the present study.

1. Guess study has demonstrated better than or similar to conventional test to flat-channel of heat sink.

2. The topical of this present work was to get a coefficient of heat transfer on single-phase and a coefficient of heat transfer for two-phase in a flat-channel of heat sink using R113 as coolant liquid. To achieve this objective, an appropriate guessable facilities had been designed and invented both for the synthesis of copper on heat sink and for convective and for conduction heat transfer conditions for boiling tests.
3. The boiling of coefficient of heat transfer had been divided into a single-phase zone as well as two-phase zone. Many correlations had been employed to predict for coefficient of heat transfer for both single-phase and for two-phase.
4. The two-phase to coefficient of heat transfer depends substantially on liquid temperature; as well as increases almost polynomial by increasing exit quality at different for rate of mass flow.
5. The flow of coefficient of heat transfer on single-phase, as well as two-phase had been laminar and had been developing flow for all at mass rates.

NoMenclature

A_h = area of heat temperature
A_{hc} = area of channel heat temperature
C_p = specific heat, kJ / kg.K
D_h = hydraulic diameter, m
h_{sp} = "single-phase of heat transfer coefficient", $W/m^2.k$
h_{tp} = "two-phase of heat transfer coefficient", $W/m^2.k$
K_C = "Thermal conductivity", W / m .K
L = length of flat-channel, mm
N_U = Nussle number
q_h = Heat apply, watts
R_e = Reynolds number
P_r = prandtls number
T = temperature, ^oC
T_{in} = inlet temperature, ^oC
T_L = liquid temperature, ^oC
T_{sat} = salutation temperature, ^oC
T_W = wall temperature, ^oC
V = liquid velocity, m/s
W = width of flat-channel ,mm
Z = Flow direction, mm

Greek symbols

ρ_L = Density of a liquid , kg/m^3
μ_L = Dynamic viscosity $N.s/m^2$

References

[1] Tuckerman, David B., and Roger Fabian W. Pease. High-performance heat sinking for VLSI. *IEEE .Electron device letters* ,1981, 2.5, 126.
[2] P.-S. Lee, S.V. Garimella, Saturated flow boiling heat transfer and pressure drop in silicon microchannel arrays, *Int. J. Heat Mass Transfer* ,2008, 51, 789.
[3] Celata GP, Cumo M, Zummo G. Thermal–hydraulic characteristics of single-phase flow in capillary pipes. *Exp Therm Fluid Sci* ,2004,28,87.
[4] Steinke ME, Kandlikar SG. Single-phase liquid friction factors in microchannels. *ASME 3rd Int. Conf. Microchannels Minichannels, American Society of Mechanical Engineers Digital Collection*,2005, 291.
[5] Zunaid M, Jindal A (6). ri., Gakhar D, Sinha A. Numerical study of pressure drop and heat transfer in a straight rectangular and semi cylindrical projections microchannel heat sink. *J. Therm Eng* ,2017,3, 65.
[6] Cornwell K, Kew PA. Boiling in small parallel channels. Energy Effic. *Process Technol., Springer*,1993,38.
[7] Kandlikar SG. Spiesman,"Effect of Surface Characteristics on Flow Boiling Heat Transfer,." *Eng. Found. Conf. Convect. Pool Boil. Irsee, Ger. May*, 1997,18.
[8] Kandlikar SG. A theoretical model to predict pool boiling CHF incorporating effects of contact angle and orientation. *J. Heat Transfer* ,2001,123, 9.
[9] Kuznetsov V V, Vitovsky O V. Flow pattern of two-phase flow in vertical annuli and rectangular channel with narrow gap. Two-Phase Flow Model Exp.,1995.
[10] Hasan IA, Attar DA. Improved Photovoltaic Panel Performance Using a Cylindrical Pin Fins as a Heat Sink. *Univ Thi-Qar J. Eng. Sci.* ,2019,10,84.
[11] H.Hasan. Effect of the Axial Heat Conduction in Parallel Flow Rectangular Microchannel Heat Exchanger. *Univ Thi-Qar J. Eng. Sci.* ,2013,4, 37.
[12] Shakir R. Boiling Heat Transfer in a Micro-Channel Complex Geometry. *IOP Conf. Ser. Mater. Sci. Eng.,. 928, IOP Publishing*,2020, 22129.
[13] Shakir R. Investigation of Single-Phase Flow Characteristics in an Inline Pin-Fins Complex Geometry. *J. Phys. Conf. Ser., IOP Publishing,* 2021, 1879, 32118.
[14] Holman, J.P.Heat Transfer. 10th Edition, McGraw-Hill, New York, 2009.