Faculty of Mechanical Engineering

SINGLE PHASE AND TWO PHASE FLOW FOR HEAT TRANSFER
IN MICRO CHANNEL HEAT SINK

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SINGLE PHASE AND TWO PHASE FLOW FOR HEAT TRANSFER IN MICRO CHANNEL HEAT SINK

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A thesis submitted
in fulfillment of the requirements for the degree of Doctor of Philosophy
in Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016
DECLARATION

I declare that this thesis entitled “Single Phase and Two Phase Flow for Heat Transfer in Micro Channel Heat Sink” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ...........................................

Name : ...........................................

Date: .............................................
I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy of Mechanical Engineering.

Signature : ........................................

Supervisor Name : ........................................

Date : ........................................
DEDICATION

To a man who tasted the bittersweet to make me sip from his love. To the one who has made of my academic journey possible; To my father, May God Bless His Soul.

To my source of patience and inspiration. To the one and only one after God and His Prophet; my mother. To my soul twin and best companion

To the one I was blessed to be with; Who has always been beside me from the beginning of my life; and who assisted and stood by me during moments of loneliness

Who withstood everything for the sake of me; my wife Sabah. To the one who opened new life horizons for us, Who has shown us the real life. To the second father if he is not the first; The big brother if he is not a twin. To the most faithful friend Dr. Mustafa Mouchanan. To my source of inspiration and strength after God the Almighty

To those who sacrificed precious things for the sake of me. For them and because of them, I have steadily walked all my way; My brothers and my sisters. To a man with dedication, distinction and generosity Hassan Qassim. To those who lit my way by their erudition and knowledge Dr. Yussoff and Prof. Razali
ABSTRACT

Advancements in microprocessors and other high power electronics have resulted in increased heat dissipation from those devices. In addition, to reduce cost, the functionality of microprocessor per unit area had been increasing. The increase in functionality accompanied by reduction in chip size had caused its thermal management to be challenging. In order to dissipate the increase in heat generation, the size of conventional microchannel heat sinks had to be increased. As a result, the performance of these high heat flux generating electronics was often limited by the available cooling technology and space to accommodate the larger conventional microchannel heat sink. One way to enhance heat transfer from electronics without sacrificing their performance was the use of heat sink with many microchannels and liquid passing through it recently, the microchannel heat sink have been widely used to transfer heat from the microprocessors in the computer industry. As the heat flux increases, the thin film evaporation occurring in the evaporator plays a key role in a heat transfer. It had been shown that most of the heat input to the evaporator of the microchannel heat sink was transferred through the evaporating thin film region. A better understanding of heat transfer characteristics in the evaporating thin film region will lead to develop new equation in the thin film region and enhancing the evaporating heat transfer in the heat pipe. An analytical model describing thin film evaporation was developed including the thin film interface and disjoining pressure. A mathematical equation was then developed to investigate the effect of heat flux on film thickness in the thin film evaporation region. Results are provided for liquid film thickness, total heat flux, and evaporating heat flux distribution. In addition to the sample calculations that were used to illustrate the transport characteristics. The calculated results from the current model match closely with those of analytical results of Wang et al. (2008) and Wayner jr. et al. (1976). This work will lead to a better understanding of heat transfer and fluid flow occurring in the evaporating film region and develop an analytical equation for evaporating liquid film thickness. numerical analysis and experimental tests to predict the heat transfer and chf are the focus of this work. The experimental test section had three microchannels with having of 30 mm x 25.4 mm x 53.34 mm in size. The effect of flow instabilities in microchannels was investigated of each microchannel to stabilize the water flow boiling process. Water flow boiling was investigated in this study using degassed, deionized water in an aluminum, copper and a graphene rectangular microchannel with a hydraulic diameter of 540 µm and 426 µm for Re 650-3000. The power input was adjusted for constant heat flux (630-520) kw/m² for each flow rate. High speed images were taken periodically for water flow boiling. The change in regime timing revealed the effect of deposition on the onset of nucleate boiling (ONB) cycle duration and bubble frequencies are reported for different flow boiling durations. The addition bubble formation was found to stabilize bubble nucleation and growth and limit the recession rate of the upstream and downstream interfaces, mitigating the spreading of dry spots and elongating the thin film regions to increase thin film evaporation.
ABSTRAK

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my sincere acknowledgement to my supervisors Dr. Mohd Yusoff Bin Sulaiman and Professor Dr. Md Razali Bin Ayob from the Faculty of Mechanical Engineering Universiti Teknikal Malaysia Melaka (UTeM) for their essential supervision, support and encouragement towards the completion of this thesis.
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\( A \) - Total surface area of micro-channel \((m^2)\)

\( A_c \) - Area of cross-section of micro-channel \((m^2)\)

\( C_p \) - Specific heat capacity \((J/kg \, K)\)

\( D \) - Diameter \((m)\)

\( D_h \) - Hydraulic diameter \((m)\)

\( H \) - Height of channel \((m)\)

\( h \) - Convective heat transfer coefficient

\( K \) - Thermal conductivity \((W/m \, K)\)

\( L \) - Heat sink length \((m)\)

\( P \) - Total pressure \((Pa)\)

\( q^* \) - Heat flux \((W/cm^2)\)

\( Q \) - Volumetric flow rate \((cm^3/s)\)

\( R_{th} \) - Thermal resistance \((K/W)\)

\( T \) - Temperature \((K)\)

\( t \) - Wall thickness at bottom \((m)\)

\( u \) - Fluid x-component velocity \((m/s)\)

\( v \) - Fluid y-component velocity \((m/s)\)

\( w_c \) - Channel width \((m)\)

\( w_w \) - Wall thickness at bottom \((m)\)

\( w \) - Fluid z-component velocity \((m/s)\)
x - Axial coordinate
y - Vertical coordinate
z - Horizontal coordinate
ΔP - Pressure drop (Pa)
P - Pressure
ρ - Density (kg/m³)
μ - Dynamic viscosity (m²/s)
A - Dispersion constant (J)
h_{fg} - Heat of vaporization (J/kg)
k - Conductivity (W/mK)
\dot{m}_e - Interface net evaporative mass transfer (kg/(m² s))
\dot{m}_x - Mass flow rate (kg/ms)
p_c - Capillary pressure (N/m²)
p_l - Liquid pressure (N/m²)
p_v - Vapor pressure (N/m²)
p_d - Disjoining pressure (N/m²)
Δp - \( p_1 - p_2 \) (N/m)
q'' - Heat flux (w/m²)
q''_o - Characteristic heat flux (w/m²)
ϕ - Dimensionless heat flux