UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

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

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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: : ....

APPROVAL

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/m^2 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

Kemajuan mikropemproses dan alat elektronik berkuasa tinggi telah meningkan pembebasan haba daripada peranti-peranti yang menggunakannya. Disamping itu, fungsi mikropemproses bagi setiap keluasan unit juga bertambah demi mengurangkan kos. Peningkatan yang berlaku disebabkan oleh pengurangan saiz cip ini memberi cabaran untuk menguruskan haba yang dilepaskan. Saiz sinki haba saluran mikro konvensional perlu diperbesarkan untuk membebaskan pertambahan haba yang dijana. Fluks haba tinggi yang dijana oleh alatan elektronik ini memberi kesan terhadap prestasi disebabkan oleh teknologi penyejukan dan ruang untuk memuatkan sinki haba saluran mikro konvensional sedia ada yang terlalu terhad. Satu kaedah untuk memperbaiki pemindahan haba daripada alatan elektronik tanpa perlu mengorbankan prestasinya adalah dengan penggunaan sinki haba yang mempunyai banyak saluran mikro serta mengalirkan cecair padanya. Sejak itu, sinki haba saluran mikro digunakan secara meluas untuk memindahkan haba mikropemproses dalam industri komputer. Disebabkan oleh fluks haba meningkat, pengewapan lapisan nipis yang berlaku di dalam penyejatan memainkan peranan penting dalam pemindahan haba. Ini telah dibuktikan bahawa kebanyakan input haba sejatan yang berlaku pada sinki haba saluran mikro dipindahkan ke kawasan lapisan nipis penyejatan. Memahami tentang ciri pemindahan haba yang lebih baik dalam kawasan lapisan nipis sejatan dapat menghasilkan persamaan baru untuknya dan meningkatkan sejatan haba yang dipindahkan di dalam paip haba. Model analisis yang menerangkan tentang lapisan nipis sejatan telah dibangunkan dan permukaan lapisan nipis serta tekanan tak searas turut dihuraikan. Satu persamaan matematik dilakukan untuk menyiasat tentang kesan fluks haba pada ketebalan lapisan dalam kawasan lapisan nipis sejatan. Hasilnya adalah termasuk ketebalan lapisan cecair, jumlah fluks haba, dan penyebaran fluks haba yang tersejat. Ini adalah tambahan kepada contoh pengiraan yang digunakan untuk menggambarkan ciri pengangkutannya. Hasil kiraan daripada model terbaru hampir sama dengan keputusan analisis oleh Wang et al. (2008) dan Wayner jr. et al. (1976). Usaha ini memberi pemahaman yang lebih baik tentang pemindahan haba dan aliran cecair yang berlaku dalam kawasan lapisan sejatan serta menghasilkan persamaan analisis ketebalan lapisan cecair yang tersejat. Analisis berangka dan ujian eksperimen pada pemindahan haba dan chf adalah fokus kerja ini. Bahagian ujian eksperimen mengandungi tiga saluran mikro dengan saiz 30 mm x 25.4 mm x 53.34 mm. Kesan aliran yang tidak stabil dalam saluran mikro diselidik untuk mengesan proses didihan aliran air yang stabil. Dalam ujikaji ini, didihan aliran air dikaji dengan menggunakan air terion dan dinyahgas di dalam saluran mikro bersegi empat daripada aluminum, tembaga dan grafen berserta hidraulik berdiameter 540 µm dan 426 µm untuk Re 650-3000. Input tenaga diselaraskan untuk fluks haba yang sama (630-520) kw/m^2 bagi setiap kadar aliran. Imej berkelajuan tinggi diambil dari semasa ke semasa untuk didihan aliran air. Perubahan terhadap masa menerangkan kesan pemendapan pada permulaan tempoh kitaran nukleat didihan (ONB) dan frekuensi gelembung bagi tempoh didihan aliran yang berbeza juga

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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/m^3)

μ - Dynamic viscosity (m^2/s)

A - Dispersion constant (J)

h_{fg} - Heat of vaporization (J/kg)

k - Conductivity (W/mK)

$\dot{m}_e$ - Interface net evaporative mass transfer ($kg/(m^2 s)$)

$\dot{m}_x$ - Mass flow rate (kg/ms)

p_c - Capillary pressure (N/m^2)

p_l - Liquid pressure (N/m^2)

p_v - Vapor pressure (N/m^2)

p_d - Disjoining pressure (N/m^2)

Δp - $p_1 - p_2$ (N/m)

q'' - Heat flux (w/m^2)

q_o'' - Characteristic heat flux (w/m^2)

ϕ - Dimensionless heat flux