UNIVERSITI PUTRA MALAYSIA

THERMAL DIFFUSIVITY Of SMALL VOLUME LIQUIDS USING A CONVERGING THERMAL WAVE TECHNIQUE

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By

SEPIDEH SOLTANINEJAD

Thesis submitted to the School of Graduates Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

May 2013

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DEDICATION

Dedicated to:

Specially Dedicated to My Beloved Parents

And to My Beloved Sisters

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

THERMAL DIFFUSIVITY OF SMALL VOLUME LIQUIDS USING A CONVERGING THERMAL WAVE TECHNIQUE

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May 2013

Chairman: Mohd Maarof H.A. Moksin, PhD

Faculty: Science

Thermal diffusivity of transparent and large volume liquids has been measured accurately by using pump-probe techniques like thermal lens and hot wire. Therefore, this technique would be rendered useless in the case of opaque and small volume liquids. The probe beam would have very weak transmission in the opaque liquids while small volume liquids would not give an appreciable beam deflection to measure. Since there is always a limited amount of precious liquids for evaluation, it is crucial to have a measuring technique dedicated for small volume transparent and opaque liquids.

Such a technique was designed and developed based on a conventional photoflash technique but with an elaborate sample container, which was a small crucible with a thin copper foil base of diameter 10 mm. The liquid filled up about 1 mm height in the crucible during measurement. Thermal waves were induced into the liquid by irradiating the bottom of the container with a camera flash. The heat was generated at the copper base bottom surface subsequent to the radiation absorption before being defused through the base and liquid sample. The temporal temperature of the sample was measured by placing a thermocouple at an appropriate distance in the liquid. The thermal diffusivity was determined by fitting the theoretical temperature to the experimental data.

The theoretical temperature was developed based on the hypothesis that the temperature at the point of detection is a product of heat diffusion in the axial and radial directions that depends on the thickness and thermal properties of the bilayer of solid and liquid as well as on the method of heat generation and detection.

The whole set up was calibrated by using distilled water. The thermal diffusivity of the distilled water was $1.442 \times 10^{-7}\ \mathrm{m^2 s^{-1}}$ which was obtained by fitting the theoretical temperature to the experimental data with R-square value of greater than 0.99. Other work has reported values in the range of $(1.440 - 1.447) \times 10^{-7}\ \mathrm{m^2 s^{-1}}$.

The technique has been used to measure thermal diffusivity of nano-fluids of zinc sulfide, silver, gold and copper nanoparticles suspension in water, and palm oil biodiesel blends. The metal nano-fluids were prepared by using laser ablation while ZnS nano fluid was prepared by using microwave method.

The thermal diffusivity of the silver nano-fluids at room temperature increased in the range of $(1.68 - 1.87) \times 10^{-7}\ \mathrm{m^2 s^{-1}}$ with volume fraction concentration in the range of $0.10\ \mathrm{mg/L}$ to $4.168\ \mathrm{mg/L}$ closely matching the results obtained by using thermal lens. The same trend of thermal diffusivity increase with concentration of nanoparticles was also found in the other nano-fluids.

The thermal diffusivity of palm-oil-biodiesel blends of B10, B20, B30, B70, and B80 was found in the range of $(1.32 - 0.8) \times 10^{-7}\ \mathrm{m^2 s^{-1}}$. Addition of more than 20% biodiesel had no drastic effect in lowering the thermal diffusivity that might help in reducing the fuel volatility due to the increase of the blend flash point.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGUKURAN KEMERESAPAN TERMA BAGI CECAIR ISIPADU KECIL DENGAN MENGGUNAKAN TEKNIK BARU GELOMBANG TERMA MENUMPU

Oleh

SEPIDEH SOLTANINEJAD

Mei 2013

Pengerusi: Prof. Mohd Maarof H.A Moksin, PhD

Fakulti: Sains

Tahap kemeresapan terma bagi cecair telus dan berkapasiti besar telah diukur dengan tepat menggunakan teknik ‘pump-probe’ seperti kanta terma dan dawai panas. Oleh yang sedemikian, teknik ini tidak memberikan apa-apa kesan dalam kes cecair berkapasiti kecil dan legap. Sinaran alat penguji akan menghasilkan transmisi yang sangat lemah dalam cecair legap manakala cecair berkapasiti kecil tidak akan memberikan pesongan sinaran yang cukup untuk diukur. Oleh kerana hanya ada jumlah terhad bagi cecair berharga untuk penilaian, adalah amat penting untuk mempunyai satu teknik pengukuran yang didedikasikan hanya untuk cecair berkapasiti kecil dan legap.

Teknik ini telah direka dan dibangunkan berdasarkan kepada teknik konvensional photoflash tetapi dengan bekas sampel yang teliti iaitu satu pijar kecil dilengkapi dengan tapak kerajang tembaga nipis berdiameter 10 mm. Cecair berkenaan akan diisi sebanyak 1 mm tinggi dalam pijar tersebut semasa proses pengukuran. Gelombang terma diresapkan kepada cecair berkenaan dengan mendedahkan bahagian bawah bekas kepada flash kamera. Haba dijanakan pada tapak tembaga bahagian bawah selepas penyerapan radiasi sebelum disebarluaskan menerusi tapak dan cecair sampel. Suhu semasa sampel telah diukur dengan meletakkan thermocouple pada jarak yang bersesuaian di dalam cecair tersebut. Tahap kemerasapan terma telah ditentukan dengan membandingkan suhu teori kepada data eksperimen.

Suhu teori telah dibangunkan berdasarkan kepada hipotesis dimana suhu pada titik pengesanan adalah satu produk penyebaran haba dalam arah paksi dan jejari yang bergantung kepada ketebalan dan sifat haba dua lapisan pepejal dan cecair serta ke atas kaedah pengesanan dan penjanaan haba.

Seluruh system pengukuran ini telah ditentukur dengan menggunakan air suling. Tahap pemerasapan terma bagi air suling adalah $1.442 \times 10^{-7}\ \mathrm{m^2 s^{-1}}$, yang mana telah diperolehi dengan memadankan suhu teori kepada data eksperimen dengan nilai R-square lebih besar daripada 0.99. Kajian-kajian lain telah melaporkan nilai-nilai di antara julat $(1.440 - 1.447) \times 10^{-7}\ \mathrm{m^2 s^{-1}}$.

Teknik ini telah digunakan untuk mengukur tahap pemerasapan terma bagi nanofluids daripada zink sulfida, perak, emas, dan nanopartikel tembaga terapung dalam air dan juga campuran biodiesel minyak sawit. Nanofluid-nanofluid daripada logam telah disediakan dengan menggunakan proses ablasi laser manakala ZnS nanofluids disediakan dengan menggunakan kaedah gelombang mikro.

Tahap pemerasapan terma bagi nanofluid-nanofluid perak pada suhu bilik telah meningkat dalam julat $(1.68 - 1.87) \times 10^{-7}\ \mathrm{m^2 s^{-1}}$ dengan jumlah kepekatan dalam julat antara $0.10\ \mathrm{mg/L}$ kepada $4.168\ \mathrm{mg/L}$ menghampiri hasil yang telah diperolehi dengan menggunakan kanta terma. Trend peningkatan yang sama bagi tahap pemerasapan haba dengan pecahan nanopartikel juga telah ditemui dalam nanofluid-nanofluid yang lain.

Tahap pemerasapan terma bagi campuran biodiesel minyak sawit B10, B20, B30, B70, dan B80 telah ditemui dalam julat $(1.32 - 0.8) \times 10^{-7}\mathrm{m^2 s^{-1}}$. Penambahan lebih daripada 20% biodiesel tidak memberikan kesan yang drastik dalam menurunkan tahap pemerasapan terma yang mungkin dapat menolong dalam mengurangkan tahap kemeruapan minyak yang disebabkan kepada peningkatan titik flash campuran .

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I certify that a Thesis Examination Committee has met on 27 Mei 2013 to conduct the final examination of Sepideh Soltaninejad on her thesis entitled "Thermal Diffusivity of Small Volume Liquids Using a Converging Thermal Wave Technique" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Member of the Examination committee were as follows

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of Supervisory committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

SEPIDEH SOLTANINEJAD

Date: 27 May 2013

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