บันทึกข้อความ

ส่วนราชการ ภาควิชาวิศวกรรมเครื่องกล คณะวิศวกรรมศาสตร์ มหาวิทยาลัยอุบลราชธานี โทร ๓๓๐๙

ที่ ศธ ๐๕๒๙.๘.๔/๑๖๖ **วันที่** ๑๓ กุมภาพันธ์ ๒๕๕๕

เรื่อง ขออนุมัติเงินสนับสนุนเพื่อนำเสนอบทความทางวิชาการในระดับนานาชาติ

เรียน รองคณบดีฝ่ายวิจัยและบริการ ผ่านหัวหน้าภาควิชาวิศวกรรมเครื่องกล

ด้วยข้าพเจ้า นายอนิรุตต์ มัทธุจักร์ ตำแหน่ง ผู้ช่วยศาสตราจารย์ สังกัดภาควิชาวิศวกรรมเครื่องกล คณะวิศวกรรมศาสตร์ มีความประสงค์ขออนุมัติเงินสนับสนุนเพื่อนำเสนอบทความทางวิชาการในระดับนานาชาติ เป็นจำนวนเงิน ๔๐,๐๐๐.- บาท (สี่หมื่นบาทถ้วน) ในการประชุมวิชาการระดับนานาชาติ "3rd International Conference on Mechanical, Industrial, and Manufacturing Technologies (MIMT 2012)" โดยจะนำเสนอบทความวิชาการจำนวน ๒ บทความ โดยมีชื่อ "Visualization of ignition over high speed liquid fuel jet" และ "Visualization of supersonic non-Newtonian liquid jets" ซึ่งได้รับการตอบรับให้เข้าร่วมการนำเสนอแล้วตามเอกสารที่แนบมานี้

ทั้งนี้การนำเสนอผลงานจะมีขึ้นในระหว่างวันที่ ๒๔ – ๒๕ มีนาคม ๒๕๕๔ ณ ประเทศจีน พร้อมนี้ได้แนบชุดโครงการเพื่อขอรับการสนับสนุน เอกสารการตอบรับ รายการชื่อบทความที่ตอบรับซึ่งปรากฏชื่อบทความและผู้นำเสนอแล้ว รวมถึงต้นฉบับบทความที่จะไปนำเสนอ

จึงเรียนมาเพื่อโปรดพิจารณา

(ดร.อนิรุตต์ มัทธุจักร์)
ผู้ช่วยศาสตราจารย์ ภาควิชาวิศวกรรมเครื่องกล

เรียน รองคณบดีฝ่ายวิจัยและบริการ
เพื่อโปรดพิจารณา

ดร. [illegible]
13 ก.พ. 2555

โครงการประชุมวิชาการระดับนานาชาติเพื่อเสนอผลงานวิจัย

1. ชื่องานประชุม: 3rd International Conference on Mechanical, Industrial, and Manufacturing Technologies (MIMT 2012)

2. สถานที่: ประเทศจีน

3. ผู้ขอรับทุน: ผศ.ดร.อนิรุตต์ มัทรุจักร์ สังกัดภาควิชาวิศวกรรมเครื่องกล

4. หลักการและเหตุผล

การศึกษาวิจัยในด้านการทดลองทางวิศวกรรมเครื่องกลนั้น มีความสำคัญต่อการพัฒนาองค์ความรู้ทางด้านวิศวกรรมเป็นอย่างยิ่ง ทั้งนี้เนื่องจากเป็นการศึกษาเพื่อยืนยันผลการคำนวณ และพัฒนาทฤษฎี ตลอดจนหลักการก่อนจะนำออกมาใช้งานในภาคการผลิตจริง ดังนั้นนักวิจัยในแวดวงการศึกษาด้านนี้จึงได้จัดการประชุมวิชาการระดับนานาชาติ ภายใต้ชื่อ 3rd International Conference on Mechanical, Industrial, and Manufacturing Technologies (MIMT 2012) ขึ้นอย่างต่อเนื่อง โดยในปีนี้กำหนดจัดขึ้นที่ประเทศจีน โดยในการประชุมครั้งนี้มีบทความที่เสนอเข้าร่วมงานจำนวนมากจากทั่วโลก โดยบทความของข้าพเจ้าเป็นหนึ่งในบทความที่ได้รับการตอบรับให้เข้าร่วมการนำเสนอด้วย จึงเป็นโอกาสดีที่จะได้พบปะนักวิจัยที่เกี่ยวข้องจากทั่วโลก และได้แลกเปลี่ยนความรู้ ประสบการณ์ และยังถือเป็นการยกระดับมาตรฐานทางวิชาการของคณะวิศวกรรมศาสตร์ มหาวิทยาลัยอุบลราชธานี อีกด้วย

5. วัตถุประสงค์ของโครงการ

1. เพื่อนำเสนอผลงานวิจัยในการประชุมวิชาการระดับนานาชาติ
2. เพื่อเผยแพร่ความรู้งานวิจัยและส่งเสริมงานวิจัยให้มีการตีพิมพ์ในการประชุมระดับนานาชาติ
3. เพื่อเป็นการแลกเปลี่ยนองค์ความรู้ใหม่และประสบการณ์ในงานประชุมวิชาการกับนักวิจัยจากทั่วโลก
4. เพื่อสร้างชื่อเสียงให้กับสถาบัน และประเทศไทยให้เป็นที่รู้จักในระดับสากล
5. เพื่อเป็นการส่งเสริมความร่วมมือทางวิชาการกับผู้เชี่ยวชาญที่มีชื่อเสียงในสาขาที่วิจัย

6. ลักษณะการปฏิบัติงาน

เดินทางไปยัง ประเทศจีน ในระหว่างวันที่ 22 มีนาคม 2555 – 27 มีนาคม 2555 เพื่อนำเสนอผลงานจำนวน 2 บทความ ซึ่งมีชื่อว่า "Visualization of ignition over high-speed liquid fuel jet" และ "Visualization of supersonic non-Newtonian liquid jets" ซึ่งเป็นบทความที่เกิดจากโครงการวิจัยที่ได้รับการสนับสนุนงบประมาณจากสำนักงานคณะกรรมการวิจัยแห่งชาติ นอกจากนี้ยังจะได้เข้าร่วมรับฟังการบรรยายและแลกเปลี่ยนความคิดในงานวิจัยใหม่ๆ กับนักวิจัยท่านอื่นๆ จากนานาประเทศ

7. ระยะเวลาในการดำเนินงาน

ช่วงวันที่ 22 มีนาคม 2555 – 27 มีนาคม 2555 รวมทั้งสิ้น 6 วัน รวมวันเดินทาง มีรายละเอียดดังนี้

1. เดินทางจาก จ.อุบลฯ - กรุงเทพฯ ในวันที่ 22 มีนาคม พ.ศ. 2555
2. เดินทางจาก กรุงเทพฯ – ประเทศจีน ในวันที่ 23 มีนาคม พ.ศ. 2555
3. เข้าร่วมกิจกรรมการประชุมและนำเสนอผลงานทางวิชาการในระหว่าง 24 - 25 กุมภาพันธ์ 2554
4. เดินทางจาก ประเทศจีน – กรุงเทพฯ - จ.อุบลฯ ในวันที่ 26 มีนาคม 2554
5. เดินทางจาก กรุงเทพฯ - จ.อุบลฯ ในวันที่ 27 มีนาคม 2554

8. ประโยชน์ที่จะได้รับ

1. สร้างชื่อเสียงให้กับมหาวิทยาลัยอุบลราชธานี และประเทศไทยในระดับนานาชาติ

2. ได้รับความรู้และเทคโนโลยีใหม่ที่เป็นประโยชน์ในด้านวิชาการและงานวิจัย

3. มีโอกาสในการพบปะ แลกเปลี่ยนความคิด ความรู้ และทัศนคติกับนักวิจัยจากต่างประเทศซึ่งจะเป็นประโยชน์ต่อการพัฒนางานวิจัยให้ทัดเทียมกับต่างประเทศ และเรียนการสอนในสถาบัน

4. มีโอกาสในการประสานความร่วมมืองานวิจัย ระหว่างผู้เข้าร่วมงานประชุมกับผู้เชี่ยวชาญระดับนานาชาติ

9. งบประมาณ (ขอถัวเฉลี่ยจ่ายทุกรายการ)

งบประมาณที่คาดว่าจะใช้ในการนำเสนอผลงานทางวิชาการในครั้งนี้ มีรายละเอียดดังนี้

รายการ	งบประมาณที่คาดว่าจะต้องใช้ (บาท)
1. ค่าลงทะเบียน	
1.1 ค่าลงทะเบียน 460 USD + Additional page fee 60 USD	16,177
1.2 ค่าลงทะเบียน สำหรับบทความที่ 2 (Additional paper) 300 USD	9,955
2. ค่าพาหนะเดินทาง	
2.1 ค่ารถโดยสาร สนามบินอุบล ที่พัก จำนวนเงิน 300 บาท ไป-กลับ	600
2.2 ค่าเครื่องบินโดยสาร อุบลฯ - กทม ไปกลับ	5,000
2.3 ค่าเครื่องบินโดยสารระหว่าง กทม – ประเทศจีน ไป-กลับ	10,000
2.4 ค่ารถโดยสาร สนามบินประเทศจีน – ที่พัก 40 USD ไป-กลับ	1,244
3. ค่าที่พัก	
3.1 ในประเทศ อัตราคืนละ 1,250 บาท จำนวน 2 คืน	2,500
3.2 ในประเทศจีนอัตราคืนละ 160 USD จำนวน 3 คืน	14,933
4. ค่าเบี้ยเลี้ยง	
4.1 ในประเทศไทย 240 บาท/วัน จำนวน 2 วัน	480
4.2 ในประเทศ Singapore 2,100 บาท/วัน จำนวน 3 วัน	6,300
5. ค่าใช้จ่ายอื่นๆ	
รวมงบประมาณทั้งสิ้น (หกหมื่นเจ็ดพันหนึ่งร้อยเก้าสิบบาทถ้วน)	**67,190**

หมายเหตุ คำนวณที่อัตราแลกเปลี่ยน 1 USD เท่ากับ 31.11 บาท ณ วันที่ 12 กุมภาพันธ์ 2555

ทั้งนี้ขอรับการสนับสนุนในวงเงิน 40,000.- บาท (สี่หมื่นบาทถ้วน)

ลงชื่อ...ผู้เสนอโครงการ

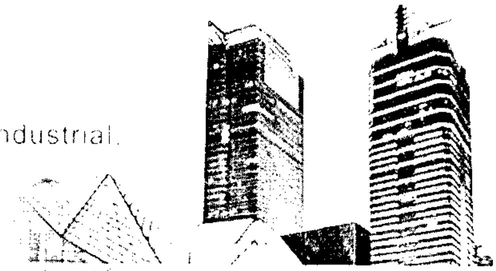
(ดร.อนิรุตต์ มัทธุจักร์)

ผู้ช่วยศาสตราจารย์ ภาควิชาวิศวกรรมเครื่องกล

MIMT 2012

2012 3rd International Conference on Mechanical, Industrial, and Manufacturing Technologies

Shenzhen, China   March 2012



Welcome to MIMT 2012

MIMT 2010 was held in Sanya, China during January 22-24, 2010
MIMT 2011 was held in Singapore during February 26-28, 2011

2012 3rd International Conference on Mechanical, Industrial, and Manufacturing Technologies (MIMT 2012) will be held in Shenzhen, China during March 24-25, 2012. As a conference co-sponsored by IACSIT, MIMT 2012 has been listed in the IACSIT Conference Calendar. MIMT 2012 is co-sponsored by International Association of Computer Science and Information Technology (IACSIT) and Singapore Institute of Electronics (SIE). MIMT 2011 aims at bringing together the researchers, scientists, engineers, and scholar students in all areas of Mechanical, Industrial, and Manufacturing Technologies, and provides an international forum for the dissemination of original research results, new ideas and practical development experiences which concentrate on both theory and practices. The conference focuses on the frontier topics in the Mechanical, Industrial, and Manufacturing Technologies subjects.

All accepted papers of MIMT 2012 will be published in the Applied Mechanics and Materials Journal (ISSN: 1660-9336).

Applied Mechanics and Materials (ISSN: 1660-9336) is Indexed by Elsevier SCOPUS and Ei Compendex (CPX), Cambridge Scientific Abstracts (CSA), Chemical Abstracts (CA), Google and Google Scholar google.com, ISI (ISTP, CPCI, Web of Science), Institution of Electrical Engineers (IEE), etc.

All papers of MIMT 2010 have been indexed by Ei Compendex.

MIMT 2011 has been held successfully, and the conference summary and photos is available. (Click)

- Last Date of Paper Submission: 25th January, 2012
- MIMT 2012 will be published in the Applied Mechanics and Materials Journal (ISSN: 1660-9336)
- The MIMT 2012 will be held in Shenzhen, China during Mar 24-25, 2012
- 2012 4th International Conference on Computer Modeling and Simulation
- 2012 4th International Conference on Computer and Automation Engineering
- 2012 4th International Conference on Digital Image Processing
- 2012 4th International Conference on Computer Engineering and Applications

Indexed by

Engineering Village

Important Dates

- Registration   Before February 25, 2012
- Camera Ready   Before February 25, 2012
- MIMT 2012 Conference   March 24-25, 2012

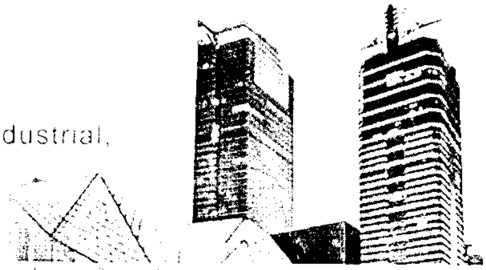
Paper Submission (Choose One)

- E-mail:

MIMT 2012

2012 3rd International Conference on Mechanical, Industrial, and Manufacturing Technologies

Shenzhen, China March 2012



IACSIT

UniSA

REGISTRATION FEE*** (by US Dollar)

	Registration Fee
Authors (IACSIT Member)*:	400 USD / 2400 人民币
Authors (Full-time Student)*	400 USD / 2400 人民币
Authors (Non Member)*	460 USD / 2700 人民币
Listeners:	200 USD / 1300 人民币
Invited Speaker	Free
Additional Paper(s)**	320 USD / 2000 人民币
Additional Page	60 USD / 400 人民币 / One Page
Extra Proceeding	50 USD / 300 人民币

* One regular registration can cover a paper within 5 pages, including all figures, tables, and references.

** One regular registration with one or more additional papers has only one proceeding book.

*** The Accommodations are not included.

AUTHORS REGISTRATION FEE INCLUDES:

- participation in the technical program
- lunch
- Dinner
- badge
- conference bag and/or conference accessories
- conference document (proceedings on book)
- coffee breaks
- welcome reception
- One Day Tour of Shenzhen

LISTENERS REGISTRATION FEE INCLUDES:

- participation in the technical program
- lunch
- Dinner
- badge
- conference bag and/or conference accessories
- coffee breaks

- Last Date of Paper Submission
- MIMT 2012 will be published in the Applied Mechanics and Materials Journal (ISSN 1660-9336)
- The MIMT 2012 will be held in Shenzhen, China during Mar 24-25, 2012
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- 2012 4th International Conference on Digital Image Processing
- 2012 4th International Conference on Computer Engineering and Applications

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2012 3rd International Conference on Mechanical, Industrial, and Manufacturing Technologies
MIMT 2012

Notification of Acceptance of the MIMT 2012

March 24-25, 2012, Shenzhen, China

http://www.iacsit.org/mimt/

Dear Amrut Matthujak, Kulachate Pianthong, Kazuyoshi Takayama and B.E. Milton,

Paper ID : M114

Paper Title : Visualization of ignition over high-speed liquid fuel jet

Congratulations! The review processes for 2012 3rd International Conference on Mechanical, Industrial, and Manufacturing Technologies (MIMT 2012) has been completed. The conference received submissions from nearly 30 different countries and regions, which were reviewed by international experts, and [illegible] have been selected for presentation and publication. Based on the recommendations of the reviewers and the Technical Program Committees, we are pleased to inform you that your paper identified above has been accepted for publication and oral presentation. You are cordially invited to present the paper [illegible] at MIMT 2012 to be held during March 24-25, 2012, in Shenzhen.

The MIMT 2012 is co-sponsored by International Association of Computer Science and Information Technology (IACSIT) and Singapore Institute of Electronics (SIE).

(Important) So in order to the register the conference and have your paper included in the proceeding successfully, you must finish following FIVE steps.

1. Revise your paper according to the Review Comments in the attachment carefully.

2. Format your paper according to the Template carefully.
[illegible] (DOC Format)

3. Download and complete the Registration Form
http://www.iacsit.org/mimt/reg.doc English
[illegible]

4. Finish the payment of Registration fee by Credit Card (The detailed information can be found in the Registration form)

[illegible] (English)

http://www.iacsit.org/mimt/CNreg.doc (Chinese) [illegible]

5. Finish the TTP Copyright Form

[illegible]

6. Send your final papers (both .doc and .pdf format), copyright form (.jpg format) and filled registration form (.doc format) to us at [illegible] (Before February 25, 2012).

If the above requirements are met by the set deadlines, all registered papers will be published by Applied Mechanics and Materials Journal (ISSN: 1660-9336), which will be Indexed by Elsevier: SCOPUS www.scopus.com and Ei Compendex (CPX) www.ei.org/. Cambridge Scientific Abstracts (CSA) www.csa.com, Chemical Abstracts (CA) www.cas.org, Google and Google Scholar google.com, ISI (ISTP, CPCI, Web of Science) www.isinet.com, Institution of Electrical Engineers (IEE) www.iee.org, etc.

Maybe some unforeseeable events could prevent a few authors not to attend the event to present their papers, so **if you and your co-author(s) could not attend MIMT 2012 to present your paper for some reasons, please inform us. And we will send you the official receipt of registration fee and proceedings after MIMT 2012 free of charge.**

Please strictly adhere to the format specified in the conference template while preparing [illegible]. If you have any problem in preparing the final paper, please feel free to contact us [illegible] updated information on the conference, please check the conference website at [illegible]. The Conference Program will be available at the website in March, 2012.

Finally, we would like to further extend our congratulations to you and we are looking forward to [illegible] Shenzhen, China!

Yours sincerely,

MIMT 2012 Organizing Committees

[illegible]

Shenzhen, China

ງຸພຣະຣາຊ

Visualization of ignition over high-speed liquid fuel jet

Anirut Matthujak[1,a], Kulachate Pianthong[1,b], Kazuyoshi Takayama[2,c] and B.E. Milton[3,d]

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[3]School of Mechanical and Manufacturing Engineering, The University of New South Wales (UNSW), Sydney, AUSTRALIA

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Keywords: Ignition, high speed fuel jet, heat column, CO_2 laser, shadowgraph.

Abstract. This study investigates the mechanism on the ignition of the high speed liquid fuel jet by the visualization. N-Hexadecane having the cetane number of 100 was used as liquid for the jet in order to enhance the ignition potential of the liquid fuel jet. Moreover, the heat column and the high intensity CO_2 laser were applied to initiate the ignition. The ignition over the liquid fuel jet was visualized by a high speed digital video camera with shadowgraph system. From shadowgraph images, the auto-ignition or ignition of the high speed liquid fuel jet, velocity of 1.186 km/s, did not take place. The ignition still did not occur, even though the heat column or the high intensity CO_2 laser was alone applied. The attempt to initiate the ignition over the liquid fuel jet was achieved by applying both the heat column and the high intensity CO_2 laser. Observing the signs of luminous spots or flames in the shadowgraph would readily indicate the presence of ignitions. The mechanism of the ignition and combustion over the liquid fuel jet was clearly clarified. Moreover, it was found that the ignition over the high speed liquid fuel jet in this study was rather the force ignition than being the auto-ignition induced by shock wave heating.

Introduction

Recently, it is known well that increasing the jet speed into supersonic range may be beneficial in improving auto-ignition and combustion in combustion applications such as SCRAM (Supersonic Combustion RAM) jet and direct injection (DI) diesel engines due to enhanced atomization and mixing, and jet-induced shock wave [1,2].

In 1994, there was a study of auto-ignition over high speed fuel jet by Shi's study [3]. In this study, the auto-ignition were investigated using visualization by double exposure holographic interferometry technique. From holographic images, auto-ignition of the diesel fuel jet at the jet velocity of 2 km/s in normal ambient condition was claimed to be occured. It was supposed that the heat generated by the leading edge shock was able to ignite the liquid diesel fuel jets based upon gas dynamics theory.

Subsequently, more detail studies on the auto-ignition feasibilty over the high speed liquid fuel jet have been carried out by Pianthong's study [4]. Using shadowgraph optical system visualization, the auto-gnition of supersonic diesel fuel jet at the jet velocity of around 2 km/s was not found at normal ambient conditions, even though the air in test chamber was heated up to be around 110 °C using a 600 w electric heater. This conflicts with Shi's study.

In 2007, the argument of auto-ignition over high speed fuel jets was concluded by Matthujak's study [5]. The auto-ignition over the fuel jets in the atmospheric air was carefully re-examined using double exposure holographic interferometry and shadowgraph technique. In this study, it was also found that no auto-ignition took place on all liquid fuel jets injected into ambient air even though the estimated temperature and pressure at the jet tip across the shock wave to induce auto-ignition was sufficiently high. This study concluded that in high-speed liquid fuel jets experiments the jet speed alone is not sufficient to initiate the auto-ignition of the high speed liquid fuel jet. The discrepancy between the experiments and the estimation is attributable to the unsuitability of the high temperature distribution around the jet, the mixing condition, the air-fuel ratio, and the ignition delay time.

Although, the auto-ignition over the high speed liquid fuel jet has been concluded that it does not occur at the ambient condition by Pianthong's and Mutthujak's study , no study has presented, visualized, and described the ignition over the liquid fuel jet so far. Hence, this study aims to initiate the ignition of the high speed liquid fuel jet in order to obtain the initial condition of the ignition. Also, it aims to present, visualize, and describe the mechanism of the ignition over the fuel jet which has never been achieved in the previous studies. In order to enhance the ignition, the n-Hexadecane jet having a cetane number of 100 were used as liquid jets and impinged against the hot column at temperature of 650 °C K for enhancing the vaporization process and heating up the air in the test chamber. Moreover, the high intensity CO2 laser was also applied to initiate the ignition.

Experimental apparatus

In this study, high speed fuel jet is generated by a technique known as the projectile impact driven method [6]. The liquid fuel retained in the nozzle cavity is impacted by a high velocity projectile. The liquid fuel, absorbing the momentum and energy transmitted from the projectile, are injected from the nozzle orifice. The high speed projectile needed in this technique has been launched by the vertical two stage light gas gun (VTSLGG), shown in Fig 1a. The VTSLGG consists of a 50 mm diameter and 1.50 m long high pressure reservoir, and a 50 mm diameter pump tube (2 m in length).The launch tube has a diameter of 15 mm and length of 1 m. The pressure relief section has a length of 53 cm, which is designed to diminish the blast wave in front of the projectile. The pressure relief section has 3 columns of the relief holes, each hole having a diameter of 8 mm. The total height of the VTSLSS is around 6 m. The projectile velocity of around 323.5 m/s was used to generate all jet in this study. The component detail and the operation procedure of the VTSLGG have been described in Matthujak's study [5].

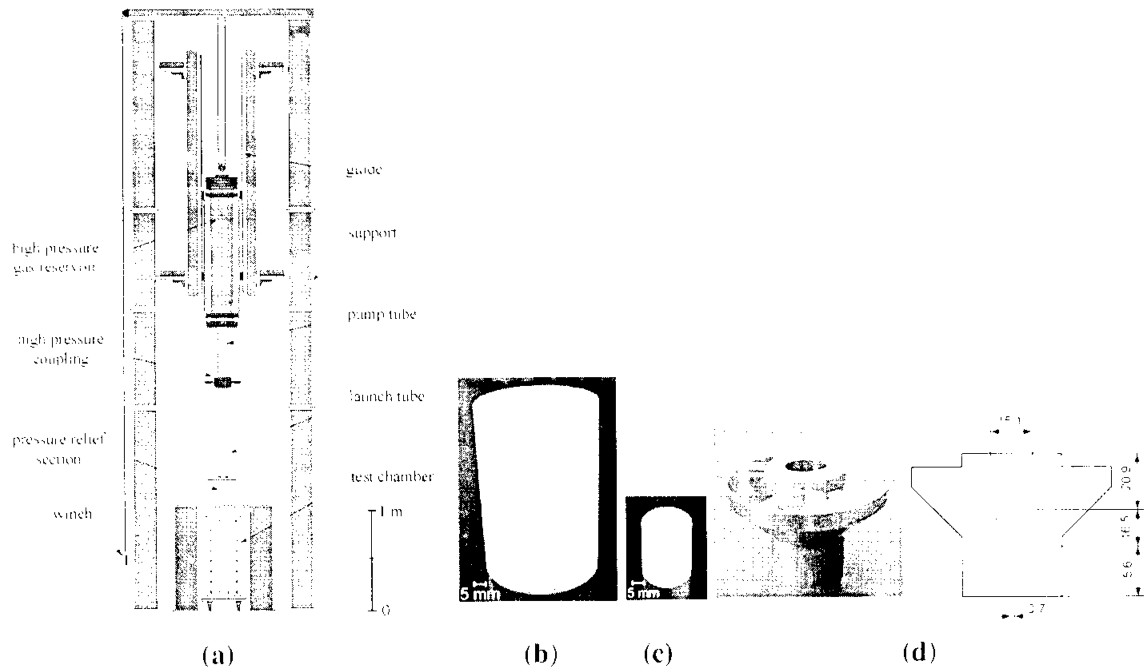

Figure 1 (a) Vertical two-stage light gas gun (b) Piston (c) projectile (d) nozzle geometry

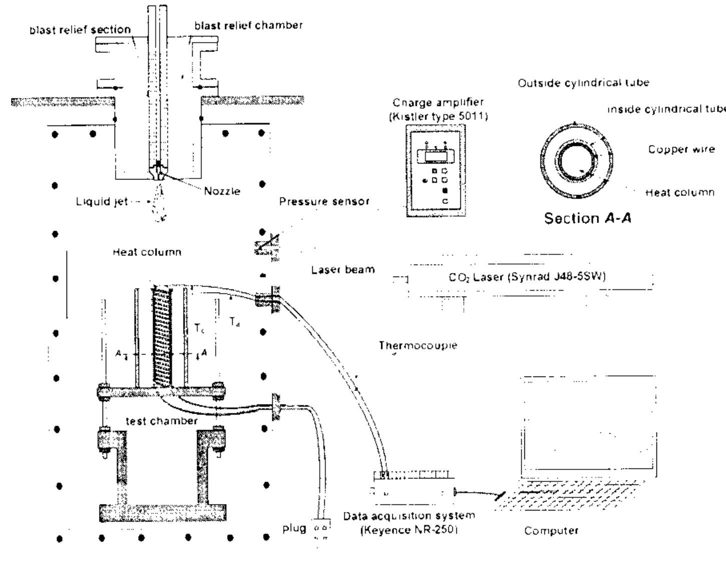

Figure 2 Ignition system of high speed liquid fuel jet with ignition detection system

Figures 1b-d show the piston, the projectile and the nozzle used in this study. The projectile, 20 mm long and 15 mm in diameter, is made of polycarbonate and weights 4.2 g. The piston used in the pump tube is made of high density polyethylene (HDPE), has a diameter of 50 mm and length of 75 mm (weight of 130 g). The nozzle that is connected to launch tube is made of mid-steel, and its dimension is shown in Fig. 1c.

In order to enhance the ignition over high speed fuel jets, n-Hexadecane having a cetane number of 100 was used instead of diesel fuel (cetane number of 52) as liquid jets. The copper metal column having a diameter of 25 mm and 180 mm long was used as a heat column. The column surface at temperature of 650 °C was heated up by the electric wire being spiraled around the column as shown in Fig 2. Heat from the column made the air temperature in the test chamber to be 450 °C. The heat column was inserted in two metal cylindrical tubes for heat insulation. Moreover, the high intensity CO_2 laser (Synrad, type j48-5SW), which the output energy is 50 watts, was applied to initiate the ignition. In order to precisely detect the ignition, not only the high-speed video digital with shadowgraph optical system, but also pressure sensor (Kistler type 5011) was used in this experiment.

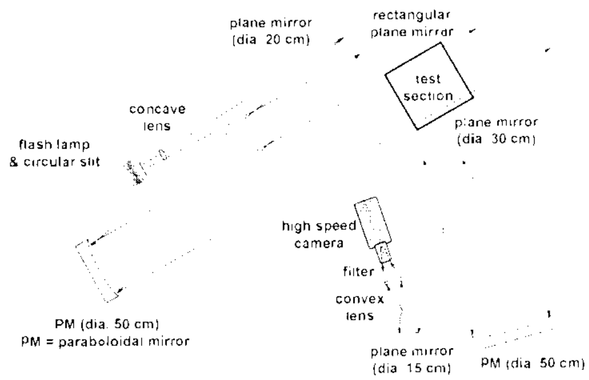

Figure 3 Arrangement of shadowgraph optical and high-speed digital video system

Visualization

Figure 3 shows a high speed digital video camera with shadowgraph optical arrangement used for visualization in this study. A flash lamp is used as light source. The source light is collimated passing through a circular slit and a concave lens. The flash light interval is 2 ms and rise time of 250 μs. The laboratory space is so limited that plane mirrors of diameter 150 mm, 200 mm, and 300 mm and a rectangular plane mirror of 240 mm x 600 mm were combined. Two paraboloidal schlieren mirrors of diameter 500 mm were used for collimating source light beam passing the test section area. A convex lens was used to focus the object image on the camera screen. The high speed digital video camera is a Shimadzu HPV-1 at frame rate of 1,000,000 f/s, exposure time of 1/4 of inter-frame time, and the total number of images of 104. The test section has 20 mm thick acrylic windows and its view field is 150 mm x 650 mm.

Results and discussion

In this study, n-Hexadecane was used as a liquid jet. Its fire and explosion properties are shown in Table 1. Four experimental conditions were conducted and investigated are shown in Table 2. Using a high speed digital video camera, it could record shadowgraph images with frame rate of 10^6 fps with 102 frames in series. Therefore, it is possible to visualize the whole jetting process from its emergence from the nozzle orifice until it passes from the test scene. Since not all frames can be displayed in the paper, six sequential ones are selected to represent the stages in jet development, as shown in Fig. 4. The physical width of each frame is always 150 mm, the width of the test window, which provides a scale in the vertical direction as well.

Table 1 Fire and explosion properties of n-Hexadecane used in the experiment

Cetane no.	Boiling point (°C)	Flash point (°C)	Auto-ignition point (°C)
100	286	>100	205

Table 2 Experimental conditions

Condition	A	B	C	D
CO_2 Laser	*OFF*	*ON*	*OFF*	*ON*
Heat column	*OFF*	*OFF*	*ON*	*ON*

Figure 4a shows various stages of high speed n-Hexadecane jet for condition A. The n-Hexadecane jet shows the slimmest width and looks more elongated to be over 350 mm at 295 μs. Its averaged speed at 295 μs is 1.186 km/s with Mach number of 3.41 in room temperature air. The jet motion is supersonic so that oblique shock waves are created over its top part and also the jet's nodes. The multiple jet pulse (described the detail in the previous study [5]) is more obviously seen before the emerging time of 234 μs.

Base upon gas dynamic theory, temperature across the shock waves over supersonic n-Hexadecane jet tips at its velocity of 1.186 km/s is estimated to be 588.5 °C, which is much higher than the auto-ignition point of n-Hexadecane fuel at 205 °C as shown in Table 1. However, no sign of ignition took place even though the estimated temperature at the jet tip behind the shock wave was sufficiently high enough to induce ignition. Hence, it can be concluded that the jet velocity alone can not be a sufficient condition of ignition or auto-ignition. The discrepancy between the experiments and the estimation is attributable to the unsuitability of the high temperature distribution around the jet, the atomization condition, the vaporization condition, the mixing condition, the air-fuel ratio and the delay time.

Therefore, a high intensity CO_2 laser was shot continuously on the jet at 125 mm below from the nozzle tip to initiate ignition over the jet for condition B. Still no sign of ignition took place as shown in Fig 4b. The jet development in Fig 4b was similar to that in Fig 4a even though the jet received the heat energy from CO_2 laser. It can be implied that the high intensity CO_2 laser alone could not initial any ignition over the jet.

Further ignition enhancement over the jet was conducted by installing a heat column inside the test chamber. For condition C, the jet was injected and impinged against the heat column as shown in Fig 4c. In order to extensively investigate the ignition after the jet being heated up from the heat column, the duration time of visualization was extended by changing the interval time of the high speed digital video camera from 4 μs to 4 ms (millisecond). From the images, there was no ignition over the jet even though the temperature of heat column and air being 650 °C and 350 °C, respectively, was much higher than the auto-ignition point of n-Hexadecane at 205 °C. It can be implied that the heat column alone could not initial any ignition over the jet.

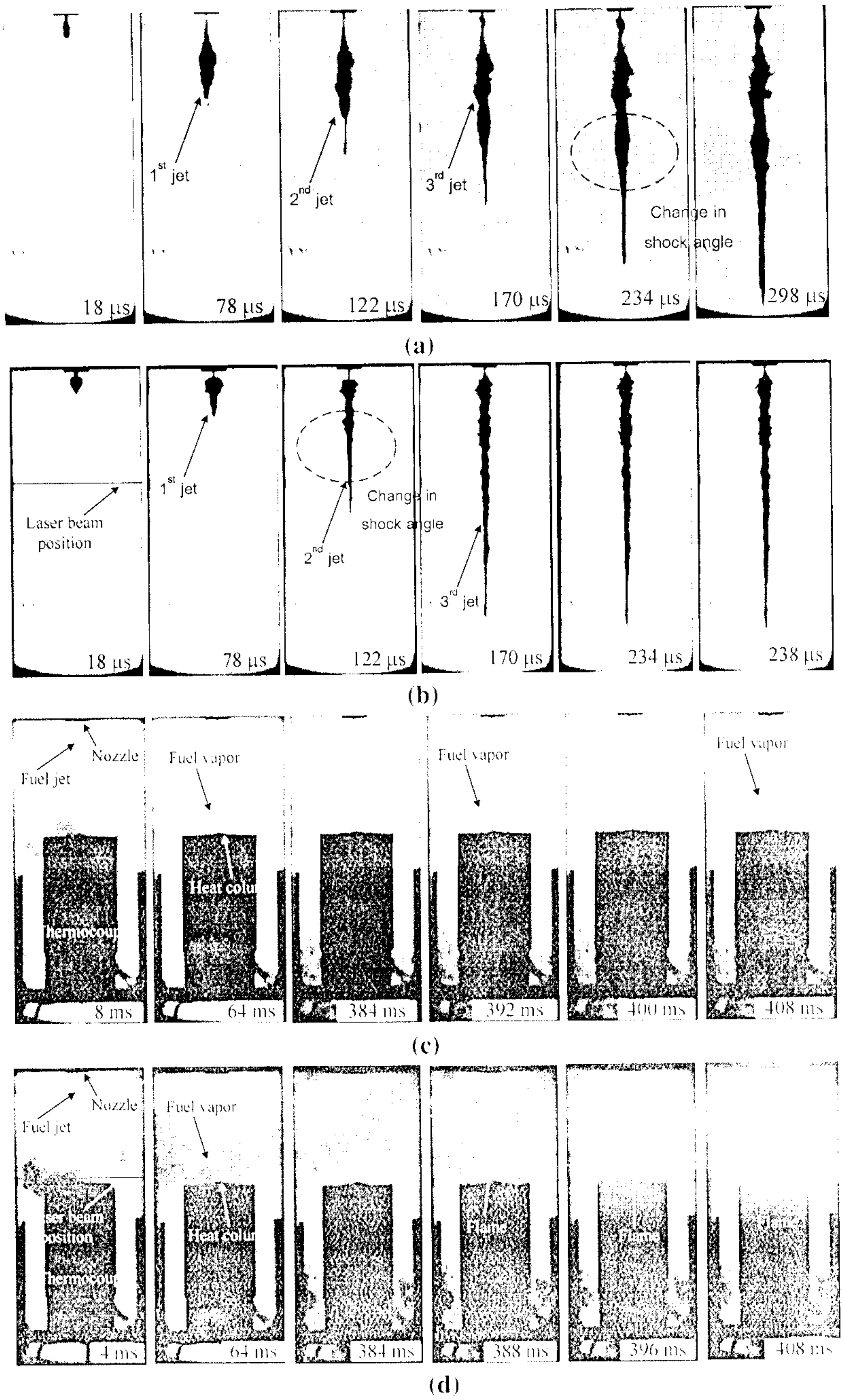

Figure 4 Various stages of high speed n-Hexadecane jet for conditions (a) A, (b) B, (c) C and (d) D

From the previous experiments for conditions B and C, the CO_2 laser or the heat column alone could not initiate the ignition over the fuel jet. Hence, in condition D, both of the CO_2 laser and the heat column were applied to enhance the ignition as shown in Fig 4d. The ignition over the jet was successfully achieved in this condition. Signs of luminous spots or flames, readily indicated the presence of ignitions, was started observing from the elapsed time of 388 ms. Even though the ignition took place, its pressure being built up due to the ignition or the combustion was not high enough for being sensed by the pressure sensor. It was found that this ignition is force ignition, not auto-ignition, because the ignition was initialed at the passage position of the laser beam.

Therefore, base upon combustion theory for liquid fuel and four experiment conditions, the mechanisms of the ignition over the high-speed fuel jet for this study can be described as follows. After the fuel was injected from the nozzle, it was broken up from 4 ms to 64 ms in Fig 4d, being atomization process. Then, the liquid fuel was enhanced to be fuel vapor by heat from the heat column until 384 ms, being vaporization process. During such process, the fuel vapor mixed with the hot air to appropriate air/fuel ratio , being mixing process. Finally, the air-fuel vapor was ignited by CO_2 laser beam at 392 ms, being ignition process. The combustion process continuously took place, which it can be observed the flame propagation from 388 ms to 488 ms, until the fuel vapor was completely burned.

Concluding remarks

The ignition over high speed n-Hexadecane jet was examined using a high speed digital video camera with shadowgraph system. Results obtained are summarized as follows:

(1) The temperature behind the shock waves over supersonic n-Hexadecane jet tips could not initial the ignition over the jet even though it was much higher than the auto-ignition point.

(2) The heat column or the high intensity CO_2 laser alone cannot initial the ignition over the jet.

(3) The ignition over the fuel jet was achieved using both the heat column and the high intensity CO_2 laser, which the heat column enhanced the vaporization process while the CO_2 laser initialed the ignition process.

(4) The occurance of the ignition over the fuel jet was confirmed by signs of luminous spots or flames, these indicate the presence of ignitions obviously observed in the shadowgraph images.

(5) The ignition over the jet in this study is the force ignition, not the auto-ignition.

Acknowledgments

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Dear Amrut Matthujak, Chandet Kasammmitporn, Wattichai Sittiwong and Kulachate Pianthong,

Paper ID : M128

Paper Title : Visualization of supersonic non-Newtonian liquid jets

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Visualization of supersonic non-Newtonian liquid jets

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Keywords: supersonic jet, non-Newtonian liquid, impact driven method, shadowgraph.

Abstract. This paper describes the study of supersonic non-Newtonian liquid jets injected in ambient air from an orifice. The main focus is to visualize three types of time-independent non-Newtonian liquid jet and to describe their characteristics. Moreover, the comparison between their dynamic behaviors with Newtonian liquid jet was reported. The supersonic liquid jets are generated by impact driven method in a horizontal single-stage power gun. The jets have been visualized by the high speed digital video camera and shadowgraph method. The effects of different liquid types on the jet penetration distance, average jet velocity and other characteristics have been examined. From the shadowgraph images, the unique dynamic behaviors of each non-Newtonian liquid jets were obviously observed, which were different from that of Newtonian liquid jet. The maximum average jet velocity of 1,802.18 m/s (Mach no. 5.30) has been obtained. The jet penetration distance and average velocity are significantly varied when the liquid types are different.

Introduction

Recently, high speed liquid jets are well known in extensive engineering applications such as the cleaning and cutting technologies, mining, and tunneling, SCRAM (Supersonic Combustion RAM) jets, direct injection (DI) diesel, drug injection, the tissue cutting, and the removing of a cerebral thrombus [1-4]. Hence, their characteristics or dynamic behaviors have been intensively gained attention and continuously studied by many researcheres [5-9].

However, most of the previous studies have been interested at only high speed Newtonian liquid jets such as water, diesel fuel, gasoline, kerosene, and alcohol jets while there have been few studies about high speed non-Newtonian liquid jet [7]. Therefore, dynamic behaviors of high speed non-Newtonian liquid jet at its speed in supersonic range is still needed to clearly understand. In this study, supersonic non-Newtonian fluid jets were generated by impact driven method and visualized by shadowgraph technique. Three types of time-independent non-Newtonian fluid jets, which are pseudo plastic, dilatant, and bingham plastic fluids, are clarified. Effect of verious jet types on jet penetration distance and average jet velocity are also analyzed. Moveover, the distinction of charateristics between newtonian and non-Newtonian fluid jets are described.

Experimental apparatus

In this study, supersonic liquid jets are generated by impact driven method [5]. Using this technique, the liquid retained inside the nozzle cavity is impacted by a high velocity projectile. The liquid obtains the momentum transfer from the projectile and is injected from the nozzle. The high velocity projectile in this technique has been generated by the Horizontal Single Stage Powder Gun (HSSPG) as shown in Fig. 1a. The HSSPG consists of launcher, launch tube, pressure relief section, and test chamber. The launch tube has a diameter of 8 mm and length of 1.5 m. The pressure relief section has a length of 40 cm, which is designed to diminish the blast wave in front of the projectile. The pressure relief section has 3 slots, which each slot has a diameter of 4 mm and a length of 36 cm. The test chamber has a diameter of 48 cm. It is enclosed by polymethyl methacrylate (PMMA) windows on two sides for visualization. The projectile is made of polymethyl methacrylate (PMMA), is cylindrical shape with diameter of 15 mm and length of 8 mm (weight of 0.92 g) as shown in Fig. 1b. This HSSPG has been employed to generate the high speed liquid jet velocity ranged from 550 to 2,290 m/s injected into air in each gunpowder weight. The nozzle being connected to pressure relief section is made of mid-steel, and its dimension is shown in Fig. 1c. Gunpowder of 5 g is used in this study, which can launch the projectile speed of about 952 ± 32 m/s.

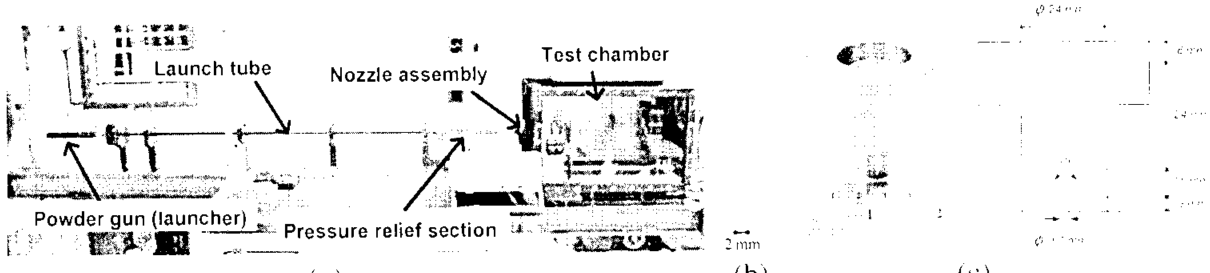


Figure 1 (a) Horizontal Single-Stage Powder Gun, (b) projectile, and (c) Nozzle geometry

Visualization method

In this study, a high speed digital video camera and shadowgraph optical arrangement was used for visualization as shown in Figure 2. The dynamic formation of supersonic jets is quantitatively measured by sequential observations. A Xenon lamp is used as a light source. Thereafter, the source light is passed through a concave lens and a circular slit. The laboratory space is limited so that two plane mirrors of diameter 190 mm are combined in this arrangement. Two paraboloidal schlieren mirrors of diameter 300 mm were used for collimating source light beam passing the test section area. A Nikon 60 mm Macro lens was used to focus the object image on the camera screen. The high speed digital video camera is a Photron SA5 at frame rate of 30,000 f/s, minimum shutter speed of 1 μs, and 5.46 seconds record time at full resolution.

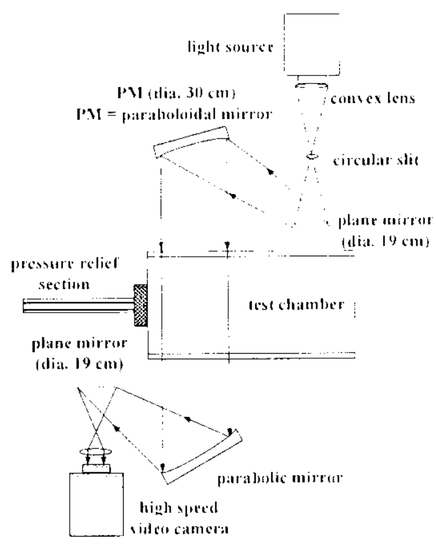


Figure 2 Arrangement of shadowgraph optical system and high speed digital video camera

Results and discussion

Using a high speed digital video camera, Photron SA5 could record shadowgraph images at frame rate of 30,000 f/s and shutter speed of 1 μs. Such a sequential recording is very useful to observe the jet formation. Four liquids, which are water, milk, salad dressing, and toothpaste being classified as newtonian, pseudo plastic, dilatant, and bingham plastic fluids, respectively, are investigated in this study. Since not all frames from the camera can be displayed in the paper, only twelve sequential ones are selected to represent the stages in jet development, as shown in Fig. 3.

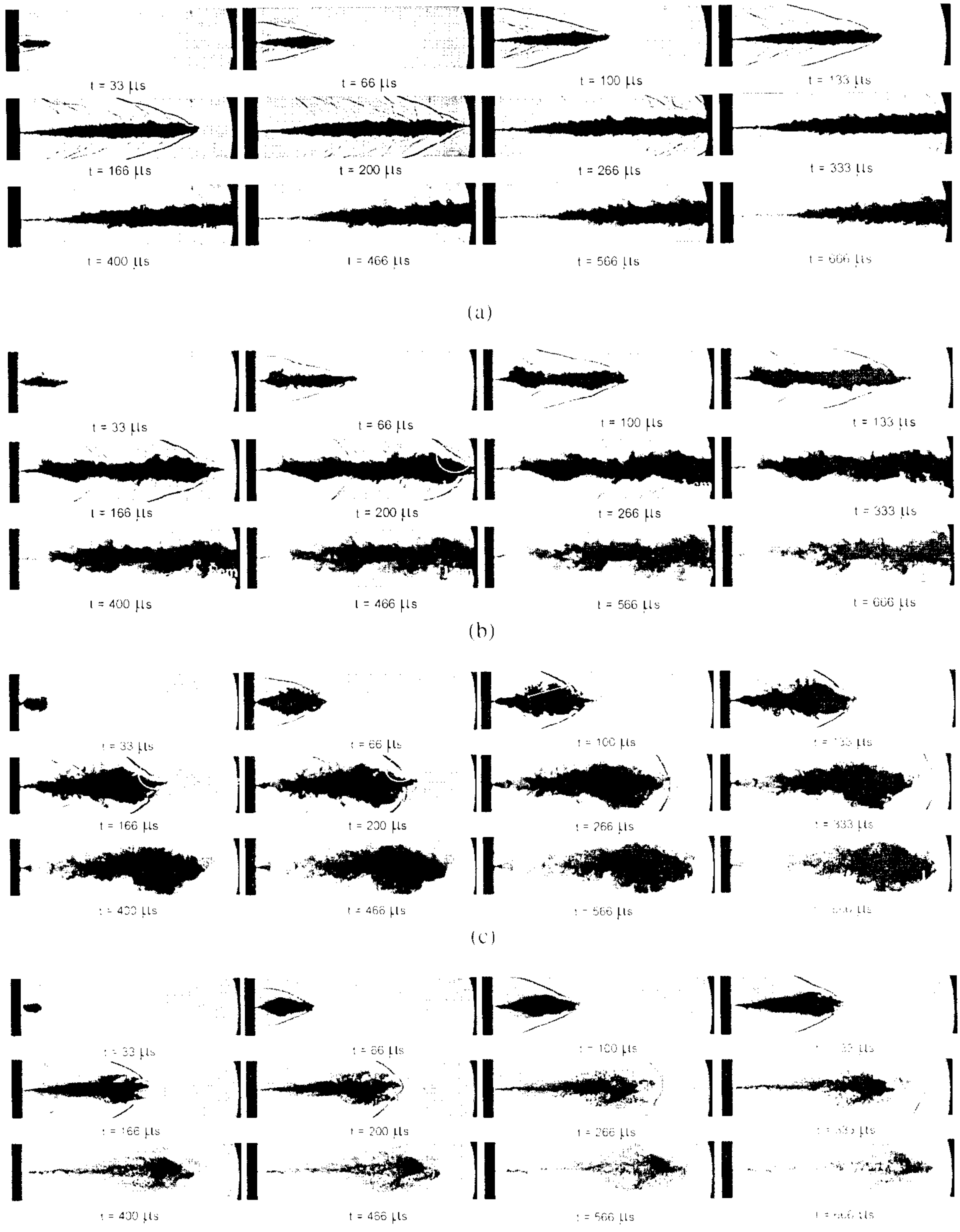


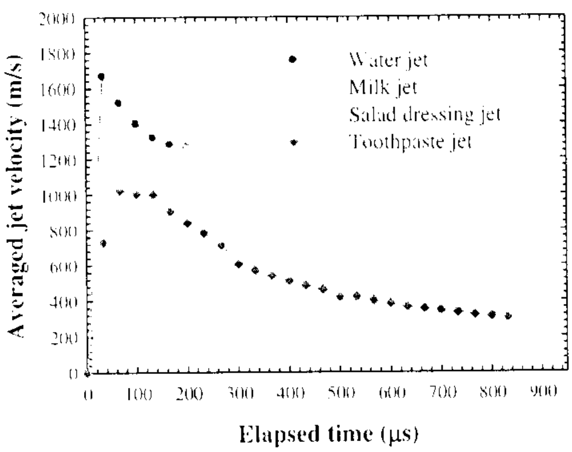
Figure 3 Jet formation (a) water jet (b) milk jet (c) salad dressing jet (d) toothpatse jet

In order to compare with non-Newtonian liquid jet, a water jet formation being classified as newtonian liquid jet is shown in Fig 3a. Its dynamic behaviors have been clearly described in Anirut's study [10]. The water jet shows the slim width and looks more elongated to be over 213 mm at 166 µs. Its averaged speed at 166 µs is 1,282 m/s and Ms = 3.77 in room temperature air. The jet motion is supersonic so that oblique shock waves are created over its top part and also the jet's nodes as shown in the figure.

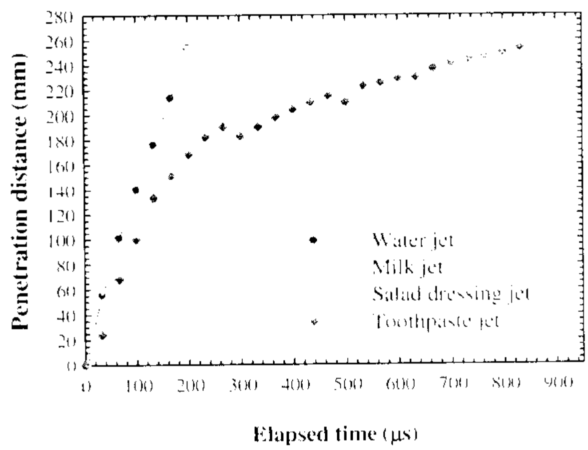
Figure 3b shows a milk jet formation, which milk is classified as pseudo plastic fluid. The milk jet is similar to the water jet at the earlier stage, being the elasped time (t) of 33 to 133 µs. The second shock wave and the change in shock angle was obviously observed at t = 66–133 µs and t = 200 µs, respectively. Such both behaviors were implied that the second jet took place from a single impact of the projectile (this behavior has been described in Kulachate's and Anirut's study [8, 9]). Base upon rheology of pseudo plastic fluid, which its dynamic viscosity decreases as the rate of shear increases, therefore, the nodes created over the milk jet look more bulkier than those in water jet at t = 166–333 µs and the atomization of milk jet look more stronger than that of water jet at t = 400–666 µs.

Figure 3c shows a salad dressing jet formation, which salad dressing is classified as dilatant fluid. The general trend is much different from water and milk jets. The jet was quickly and strongly atomized once it was injected from the orific while the strong atomization of the water and the milk jets took place at the later stage. It may be because of the rheology of dilatants fluid, which its dynamic viscosity increases as the rate of shear increases. From the images, the second shock wave and the change in shock angle was obviously observed at t = 100–200 µs and t = 166-266 µs, respectively. Such both behaviors were implied that the second jet took place being similar to the milk jet. After 333 µs, the jet boundary on images looks blurred. A shock wave is attached at the jet's leading edge but after 333 µs it becomes a detached shock wave because the jet penetration is slower than the shock motion. The atomization mechanism of the salad dressing jet was seemingly quicker than that of water and milk jets since that of the salad dressing jet was nearly finished at t = 400–666 µs while that of water and milk jets was not at those times.

Figure 3d shows toothpaste jet formation, which toothpaste is classified as bingham plastic fluid. Its general trend is not much different from water and milk jets at the earlier stage, being the elasped time of 33–133 µs. After t = 166 µs, a shear layer occurring around the toothpaste jet is similarly strongest, which is implied that its atomization are strongest. It may be due to rheology of bingham plastic fluid, which the shear stress must reach a certain minimum value before flow commences. Thereafter, dynamic viscosity decreases as the rate of shear increases, being similar to pseudo plastic fluid. After t = 266 µs, a shock wave was detached at the jet's leading edge due to the slow jet penetration and such shock was still undulated far from the jet tip even though the jet did not penetrate. A strong atomization of the jet was clearly seen at t = 333–666 µs.



(a)



(b)

Figure 4 Effect of difference liquids on (a) average jet velocity (b) jet penetration distance

Fig. 4a shows the effect of different liquid jets on the average jet velocity. During the maximum velocity point at the emerging time of around 33 μs, the velocity of all liquid jets drops gradually as obviously seen in the figure. The maximum averag velocity of milk jet is fastest, being estimated to be 1,802.18 m/s. The next one is water, salad dressing, and toothpatse jets, respectively, which are estimated to be 1,669.03 m/s, 1,262.38 m/s, and 1,024.35 m/s, respectively. That effects on the penetration distance. In Fig. 4b, it is found that the faster the average jet velocity is, the longer the jet penetrates. Hence, the penetration distance of the milk jet is the longest at the same elapsed time as shown in the figure. The second one is water and salad dressing jets, respectively. The shortest penetration distance is toothpatse jet. It can be noticed that at the later stage the average velocity of the salad dressing jet and the toothpaste jet is quite equivalent at the same elasped time.

Concluding remarks

This study reports the formation of supersonic water, milk, salad dressing and toothpaste jets injected in air, being defined as newtonian, pseudo plastic, dilatant, and bingham plastic fluids. Using a high speed digital video camera with shadowgraph optical arrangement, the dynamic behaviors of all jets have been clearly revealed. From the visualization results, the shock wave around the jet is clean and smooth. The milk jet is similar to the water jet at the earlier stage, being narrow and long. The salad dressing jet was quickly and strongly atomized once it was injected from the orific. However, a shear layer of the toothpaste jet occurring around the jet or the atomization was seemingly strongest. The jet penetration distance and average jet velocity are significantly varied when the liquid types are different. The maximum average jet velocity of 1,802.18 m/s (Mach no. 5.30) has been obtained being occurred at the milk jet. That effects on the milk jet having the longest penetration distance at the same elasped time.

Acknowledgement

We would like to acknowledge the National Research Council of Thailand (NRCT) through Ubon Ratchathani University Research grant 2011, Thailand Research Fund (RTF) contract MRG5180046, Thailand Toray Science Foundation 2011, and Department of Mechanical Engineering, Faculty of Engineering, Ubon Ratchathani University for the financial support

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