

ผลกระทบของสัดส่วนเชิงปริมาตรและความดันการขีดต่ออันตรกิริยาระหว่างไนโตรเจนเหลวกับน้ำ



นายอูริช อັซซโคสิต

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรดุษฎีบัณฑิต

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EFFECT OF VOLUMETRIC RATIO AND INJECTION PRESSURE
ON LIQUID NITROGEN-WATER INTERACTION



Mr. Urith Archakositt

ศูนย์วิทยทรัพยากร

จุฬาลงกรณ์มหาวิทยาลัย

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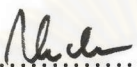
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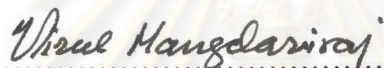
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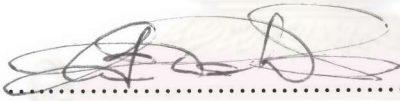
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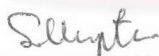

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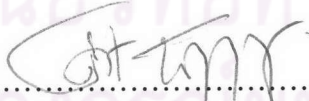
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วิทยานิพนธ์นี้เป็นการศึกษาอันตรกิริยาระหว่างเชื้อเพลิงและสารหล่อเย็นที่อุณหภูมิต่ำ โดยมีน้ำที่อุณหภูมิห้องเป็นเชื้อเพลิงและไนโตรเจนเหลวที่สภาวะอิ่มตัวภายใต้ความดันบรรยากาศเป็นสารหล่อเย็น การทดลองกระทำโดยการฉีดน้ำผ่านท่อขนาดเส้นผ่านศูนย์กลาง ๑.๕ เซนติเมตร ลงไปในท่อทดลองขนาดเส้นผ่านศูนย์กลาง ๑๐ เซนติเมตร ความสูง ๑ เมตร ที่มีไนโตรเจนเหลวบรรจุอยู่ในจำนวน ๒๐๐๐ ลูกบาศก์เซนติเมตร โดยทำการศึกษาผลกระทบจากพารามิเตอร์ที่สำคัญ ๒ ค่าคือ สัดส่วนเชิงปริมาตรของน้ำต่อไนโตรเจนเหลวและความดันการฉีด สัดส่วนเชิงปริมาตรที่ใช้มีค่า ๐.๐๕ ๐.๑๐ ๐.๑๕ และ ๐.๒๐ และความดันการฉีดมีขนาด ๒ บาร์เกจ ๓ บาร์เกจ และ ๔ บาร์เกจ

ผลการทดลองพบว่า ความดันที่บันทึกได้ระหว่างการทดลองภายใต้เงื่อนไขต่างๆมีทั้งลักษณะที่เป็นคลื่นยอดแหลมปรากฏชัดเจนและที่ไม่ปรากฏให้เห็นเป็นยอดแหลม ความดันที่เป็นคลื่นยอดแหลมมีอัตราการเพิ่มขึ้นสูงถึง ๒๕ บาร์ต่อวินาที ตรงกันข้าม ความดันที่ไม่ปรากฏให้เห็นเป็นยอดแหลมมีอัตราการเพิ่มขึ้นเพียง ๐.๒ บาร์ต่อวินาที ชากน้ำแข็งที่สังเกตได้หลังการทดลองกับลักษณะความดันที่เป็นคลื่นยอดแหลมแสดงถึงการเกิดอันตรกิริยาอย่างรุนแรงระหว่างน้ำและไนโตรเจน เมื่อเปรียบเทียบเวลาที่แตกต่างกันระหว่างทรานสดีวเซอร์ความดันที่ด้านล่างและด้านบนของระบบสำหรับยอดความดันเดียวกันพบว่า ความดันที่เป็นคลื่นยอดแหลมแผ่ออกไปและมีอัตราเร็วเทียบกันได้กับอัตราเร็วเสียงในทางทฤษฎีของของผสมเอกพันธ์ระหว่างของเหลวและก๊าซ ซึ่งมีค่าตั้งแต่ 26 ถึง 50 เมตรต่อวินาที ภายใต้เศษส่วนที่ว่างระหว่าง 0.1 ถึง 0.9 การเกิดขึ้นของความดันที่เป็นคลื่นยอดแหลมมีอัตราเร็วเข้าใกล้อัตราเร็วเสียงนี้ยืนยันว่ายอดความดันที่ได้เป็นคลื่นกระแทกเนื่องจากการระเบิดเป็นไอของไนโตรเจนเหลว

ผลที่ได้นี้แสดงว่าการระเบิดเป็นไอมีความเป็นไปได้จากอันตรกิริยาระหว่างน้ำกับไนโตรเจน และมีคุณลักษณะคล้ายคลึงกับที่เกิดขึ้นในอันตรกิริยาระหว่างเชื้อเพลิงนิวเคลียร์หลอมละลายที่อุณหภูมิสูงกับสารหล่อเย็น อาศัยแบบจำลองคณิตศาสตร์ที่พัฒนาขึ้นสำหรับอันตรกิริยาที่อุณหภูมิสูง (TEXAS) ซึ่งปรับและประยุกต์เพื่อใช้จำลองปรากฏการณ์ผสมกันระหว่างน้ำและไนโตรเจนเหลว พบว่ามีความสอดคล้องกันกับช่วงการผสมกันของน้ำและไนโตรเจนที่สังเกตได้จากการทดลอง แต่ไม่พบที่เกิดความดันที่เป็นคลื่นยอดแหลม ซึ่งชี้ว่าลักษณะการเกิดความดันที่เป็นคลื่นยอดแหลมจากการทดลองดังกล่าวมิได้เป็นผลจากปรากฏการณ์ผสมกันแต่น่าจะเป็นผลจากอันตรกิริยาที่รุนแรงกว่า

จากผลการศึกษาี้ แผนผังแสดงแนวโน้มการเกิดอันตรกิริยาอย่างรุนแรงเช่นการระเบิดเป็นไอระหว่างน้ำและไนโตรเจนเหลวจึงถูกจัดสร้างขึ้น เพื่อใช้ทำนายผลกระทบจากสัดส่วนเชิงปริมาตรของน้ำและไนโตรเจนเหลวและค่าความดันการฉีดน้ำต่ออันตรกิริยาระหว่างน้ำและไนโตรเจนเหลว

ภาควิชา นิวเคลียร์เทคโนโลยี

ลายมือชื่อนิสิต.....

สาขาวิชา วิศวกรรมนิวเคลียร์

ลายมือชื่ออาจารย์ที่ปรึกษา.....

ปีการศึกษา ๒๕๔๖

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....

C1827621 : MAJOR NUCLEAR ENGINEERING

KEY WORD: VAPOR EXPLOSION / FUEL COOLANT INTERACTION /
CRYOGENIC / SEVERE ACCIDENT / NUCLEAR SAFETY

URITH ARCHAKOSITT : EFFECT OF VOLUMETRI RATIO AND
INJECTION PRESSURE ON LIQUID NITROGEN-WATER
INTERACTION. THESIS ADVISOR : ASSC. PROF. TATCHAI SUMITRA,
THESIS COADVISOR : ASST. PROF. SUNCHAI NILSUWANKOSITT,
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To study the fuel-coolant interaction (FCI) at the low temperature, the water and the liquid nitrogen were used respectively as the molten fuel and the coolant. To initiate the interaction, the water at room temperature in a storage was injected via a 1.5-cm diameter guide tube into the 10-cm diameter and 1-m height cylindrical chamber to come into contact with the 2000-cc liquid nitrogen at atmospheric saturation. The experiments were conducted with two key parameters, the water/liquid nitrogen volumetric ratio and the water injection pressure, to study their effects on the interaction. The volumetric ratios were 0.05, 0.10, 0.15 and 0.20 with the injection pressure of 2, 3, and 4 bar (g).

The pressure recorded during the experiments showed the profiles with the observable pressure spikes and without. The maximum pressurization rate of the spike was up to 25 bar/s. On the other hand, it was 0.2 bar/s without the spike. Ice debris collected post experiments and the pressure profiles with spikes suggested the strong interaction between the water and the liquid nitrogen. The occurrence of the spikes and their inceptions recorded by two pressure transducers at different heights also indicated the pressure wave propagation. The propagation velocities due to the observed strong interactions were comparable with the theoretical sound speed of the liquid/vapor nitrogen mixture, which ranged from 26 to 50 m/s with the void fraction of 0.1 to 0.9. Such velocities confirmed that the pressure spikes were the shock wave caused by the vapor explosion of liquid nitrogen.

These results suggested the possibility of the vapor explosion-liked interaction between the water and the liquid nitrogen like that observed in the FCI at the high temperature. The experiments also were simulated by an available FCI code, TEXAS, modified for the mixing phase of water and liquid nitrogen. The simulations agreed with the mixing experiments and did not exhibit any pressure spike. It indicated that the spike was not the result from the mixing process but from the more violent process.

Finally, the interaction zone of the vapor explosion-liked interaction was created to predict the effect of the volumetric ratio and the injection pressure on the liquid nitrogen-water interaction.

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