

#### Convection-driven melting in an n-octane pool fire bounded by an ice wall

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#### Convection-driven melting in an noctane pool fire bounded by an ice wall

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Presentation by Hamed Farmahini Farahani



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> APS Fall Meeting November 19-21, 2017 Denver, CO

#### Background

In Situ Burning in Marine Environment

In situ burning after Deepwater Horizon spill 2010

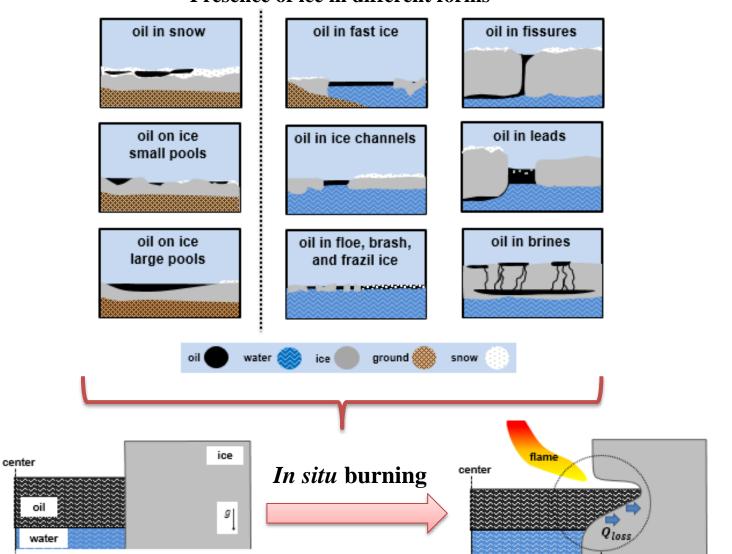




https://www.marinelink.com/news/worst-spill-fire411277

#### Background

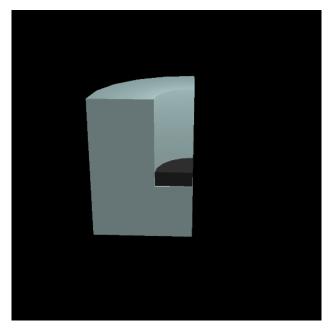
In Situ Burning in Ice-infested Waters



#### Presence of ice in different forms

## **Problem Definition**

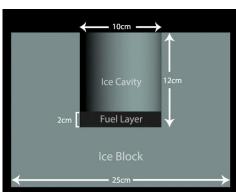
**Geometry Change of Ice and Its Effects** 



- 1. Expansion of the pool area
  - → Thinning the fuel layer
  - ➔ Faster extinction
  - Joining melt pools (multiple small pools adjacent to each other)
  - → Higher burning rates
  - ➔ Deposit of oil residue

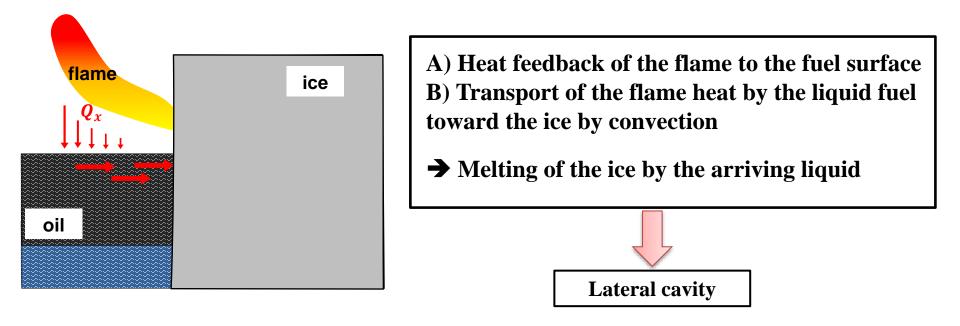
Lateral cavity formation

- 2. Melt-water accumulation
  - → Change in the level of the fuel
  - ➔ Overflow from the top
  - ➔ Faster extinction





#### **Objective** Lateral Cavity Formation



#### **Objectives**

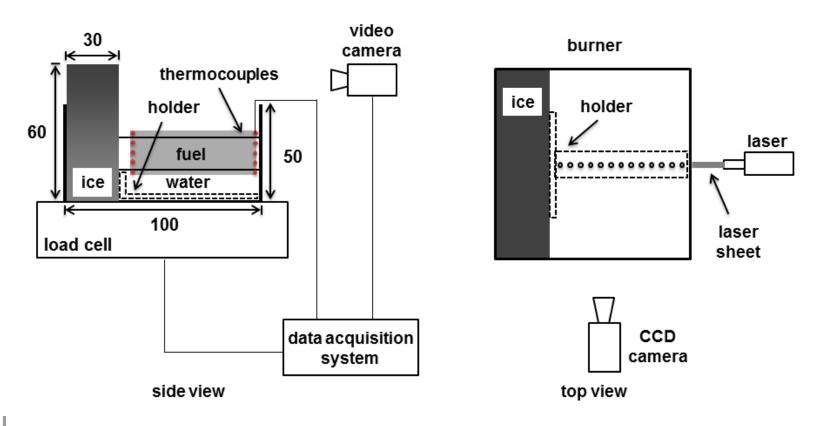
- <u>Visualize</u> the flow field in liquid fuel and cavity formation
- **Evaluate** the role of convective mechanisms in the melting process



## **Experimental Setup**

Burning of n-octane adjacent to an ice wall

- Burning behavior by a load-cell (balance)
- Temperature field by thermocouples
- Flow field by PIV

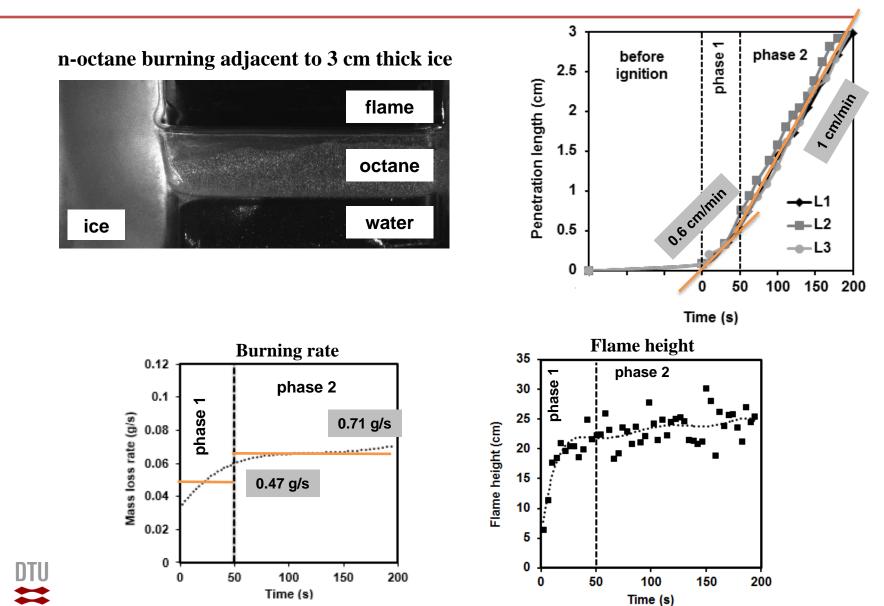




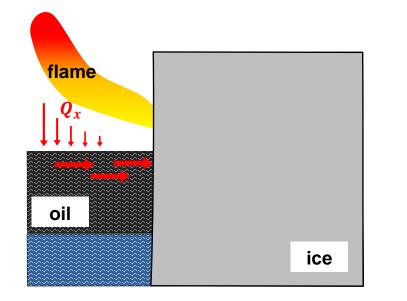
## **Experimental Results**

Investigating the effect of heat feedback and convection within the fuel layer on ice melting

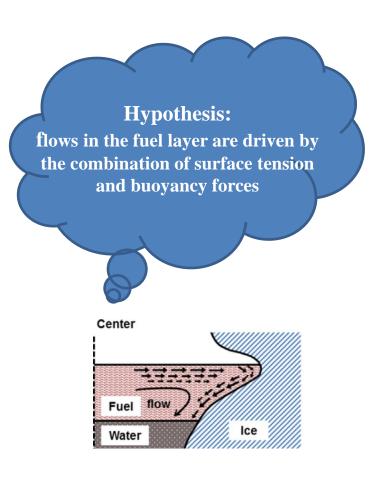
## **Flame Feedback and Melting**



## **Convection in the Fuel Layer**



Transport of the flame heat by the liquid fuel toward the ice by convection to provide the required heat for the melting



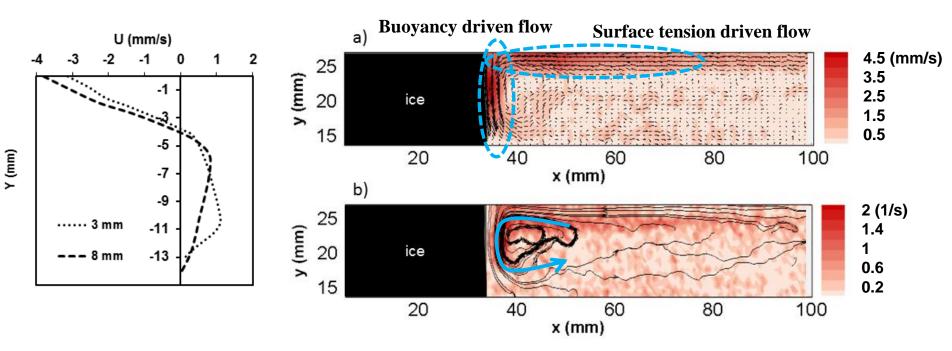


## **Convection in the Fuel Layer**

#### **PIV Results - Before Ignition**

- n-octane temperature is 10-12 °C.
- Ice temperature is below 0 °C.

**Before ignition** 



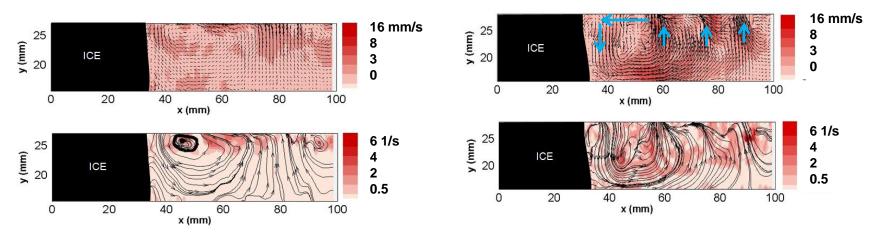
**Combined one roll structure** 



#### **Convection in the Fuel Layer** PIV Results - After Ignition (Phase 1)

•

40 seconds After ignition



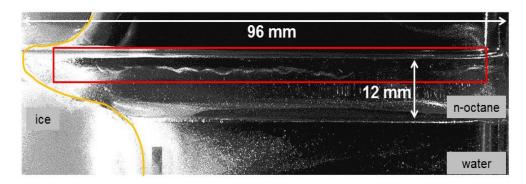
#### • 10 seconds After ignition

- Increase in the magnitude of velocity and vorticity over time
- Transition from one roll to multi-roll structure
- Quality of PIV measurements after phase 1 became low



#### **Convection in the Fuel Layer** PIV Results - After Ignition (Phase 2)

- The PIV images lost quality due to the out of plane motions, high temperature differences causing refractive index variation, loss of tracer particles near the surface
- The top layer without particles indicate the presence of small recirculation zones known as multi-roll structure



$$Ma = \frac{\partial \sigma}{\partial T} \frac{\Delta T_h R}{\mu \alpha}$$

$$Grashof$$

$$Grashof$$

$$Marangoni$$

$$Grashof$$

$$Marangoni$$

$$Gr_{0} \sim 2.6 \times 10^{5}$$

$$Ma_{0} \sim 3.2 \times 10^{5}$$

$$Gr_{0} \sim 2.6 \times 10^{5}$$

$$Ma_{0} \sim 3.2 \times 10^{5}$$

$$Gr_{1} \sim 1.7 \times 10^{6}$$

$$Ma_{1} \sim 5.3 \times 10^{6}$$

$$Ma_{1} \sim 5.3 \times 10^{6}$$

$$Ma_{2} \sim 1.2 \times 10^{7}$$



## Conclusions

- Two burning phases were associated with the melting velocity
- The heat pathway from the flame to the ice wall was identified to be the cause for melting the ice
- One roll structure with relatively low velocities were observed before ignition due to the initial low temperature difference
- After the ignition (increase of the temperature difference in the fuel layer) flow field transitioned to an unsteady state with multi-roll structure
- The flow field within the liquid fuel determined the melting

Findings of this study may be applied towards the problems that are related to ice melting caused by global warming





## **Meet Our Team**

#### Project: In Situ Burning of Oil http://www.isboil.dtu.dk/





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Ali S. Rangwala



Hamed F. Farahani (Ph.D. Student)

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Laurens van Gelderen (Ph.D. Student)

# Thanks

• Questions?



## Temperature field

