Effect of Low Wall Temperature on the Flame and Fuel Layer Distribution of Pool Fires

Cong Li [1, 2], Hamed Farmahini Farahani [1], Rui Yang [2], Ali S. Rangwala [1]

[1] Department of Fire Protection Engineering, Worcester Polytechnic Institute

[2] Department of Engineering Physics, Tsinghua University

1 Background

- Spilled oil would harm the environment and affect the wildlife.
- *In-situ* burning (ISB) is a common method of cleaning oil spills on water.

Deepwater Horizon oil spill, the largest marine oil spill in the history of the petroleum industry, began on 20 April 2010, in the Gulf of Mexico on the BP-operated Ma.

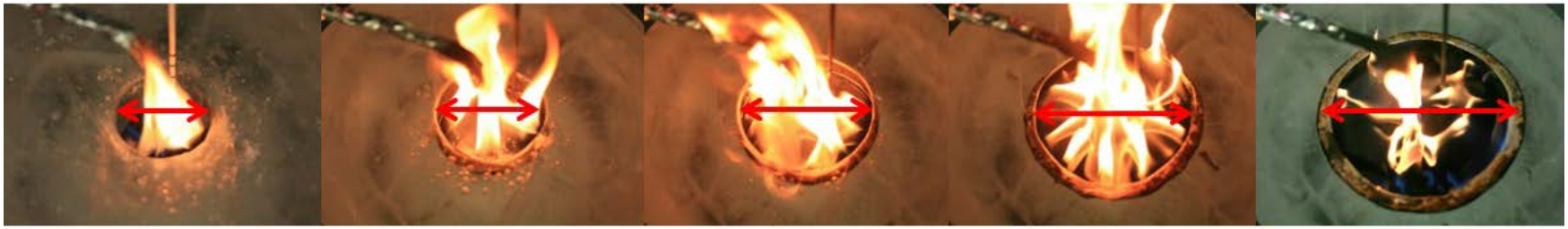
1 Background

- In remote areas with presence of ice, such as Arctic area, *In-situ* burning can be convenient and effective.
- It is important to investigate the controlling parameters to provide guidelines for *In-situ* burning in the Arctic conditions.

Large-scale field experiments carried out in the Norwegian part of the Barents Sea east of Svalbard archipelago.

Experiment with the residuals of in-situ burning to evaluate chemical composition and toxicity by Faksness *et al.* (2012).

1 Background

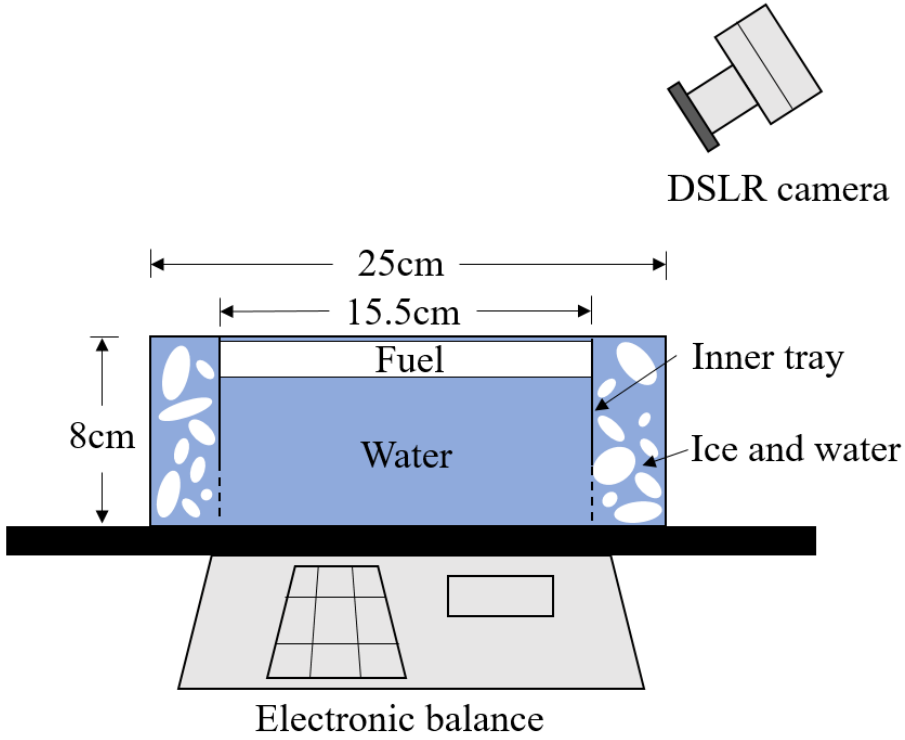


Objective: The effect of the ***wall temperature*** on the ***flame shapes and fuel layer***.

- In the presence of ice, ullage, ice melting, surface area increase, and movement of water sub-layer below the fuel alter the burning dynamics.

[1] Farmahini Farahani, H., Shi, X., Simeoni, A., Rangwala, A.S., A study on burning of crude oil in ice cavities. Proc. Combust. Inst., 2015. 35(3): p. 2699-2706.

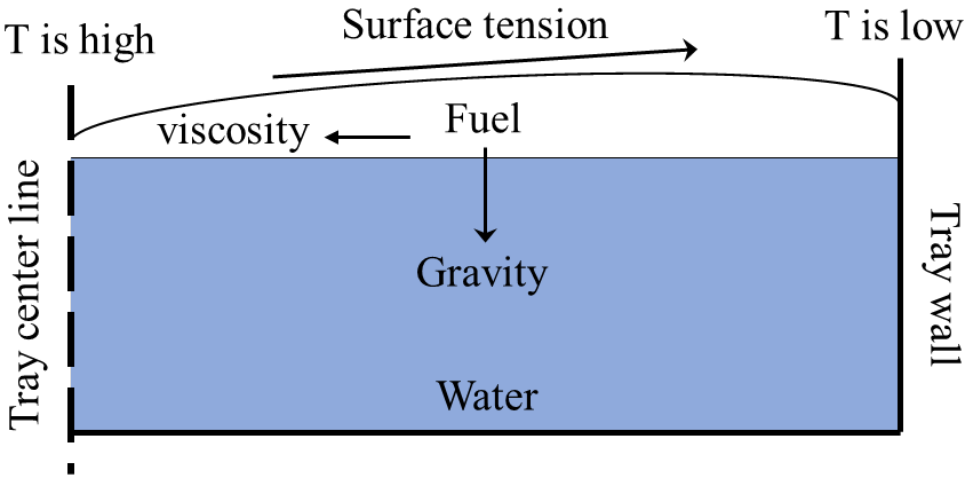
2 Mechanism



Schematic illustration of the experimental setup.

Fuel	Wall temperature	Initial thickness
m-Xylene	0 ℃, 20 ℃	1 mm, 2 mm

2 Mechanism



$$Ma = \sigma_T R \Delta T_h / \mu\alpha$$

- Marangoni effect is the mass transfer along an interface due to a gradient of the surface tension.
- The direction of the surface tension is from the tray center to the wall.

2 Mechanism

Temperature difference

⇩

Surface tension (Marangoni stress)

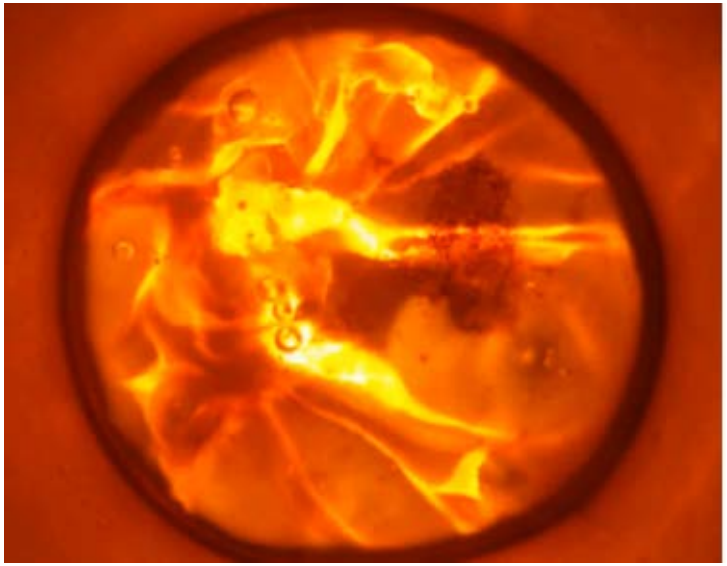
⇩

Fuel moves toward the wall

⇩

First stage: The fuel layer is distributed uniformly over the entire surface.
Second stage: The ***ring-shaped fuel*** is formed with decreasing width.

2 Mechanism



Evolution of flame and fuel layer before the fire went out from the underwater perspective.

- The flames were disappearing in the tray center and only existed at the boundary.
- The dark area in the tray center was expanding.

3 Results and analysis

3.1 Evolution of flame

(i) The fire burned uniformly on the entire surface, while the flames were merged above the tray center.

(ii) There was no burning in the tray center that created a dark area.

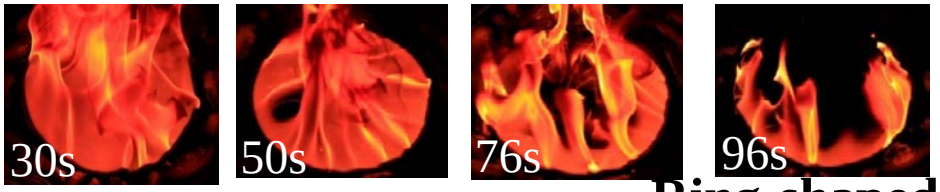
(iii) The fire only burned at the boundary in the shape of a ring.

(iv) The complete annular fire broke into some fractions until it went out.

3 Results and analysis

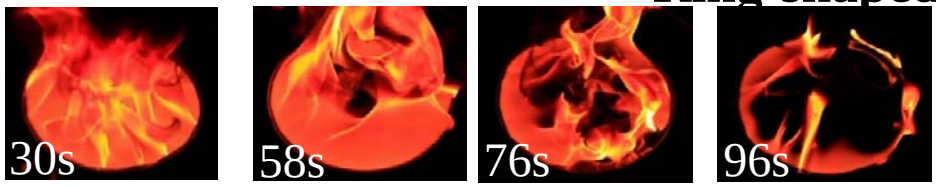
3.1 Evolution of flame

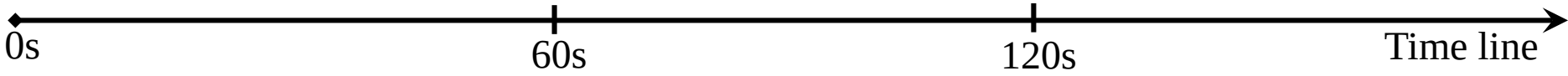
- 1mm-0°C



Ring-shaped fuel layer

- 1mm-20°C





- 2mm-0°C

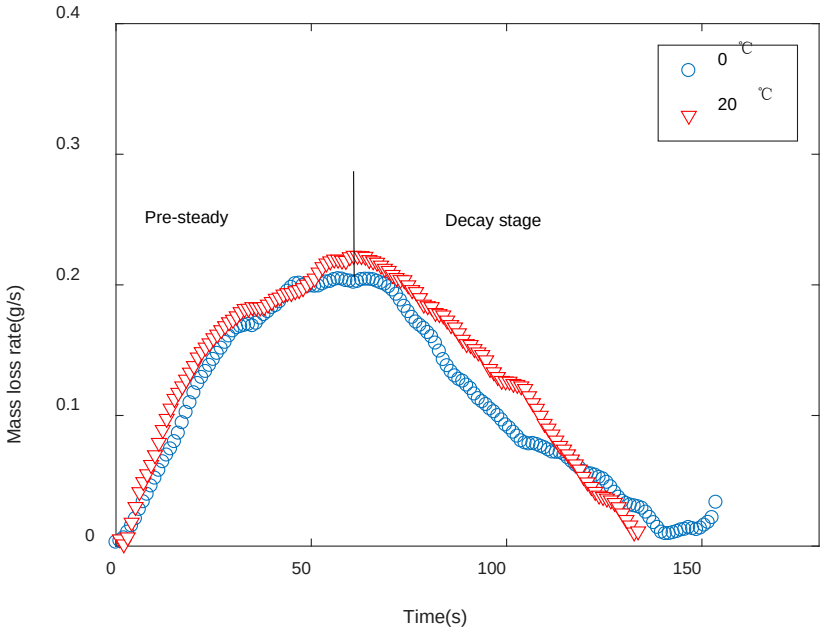
Distribution over the entire surface

- 2mm-20°C

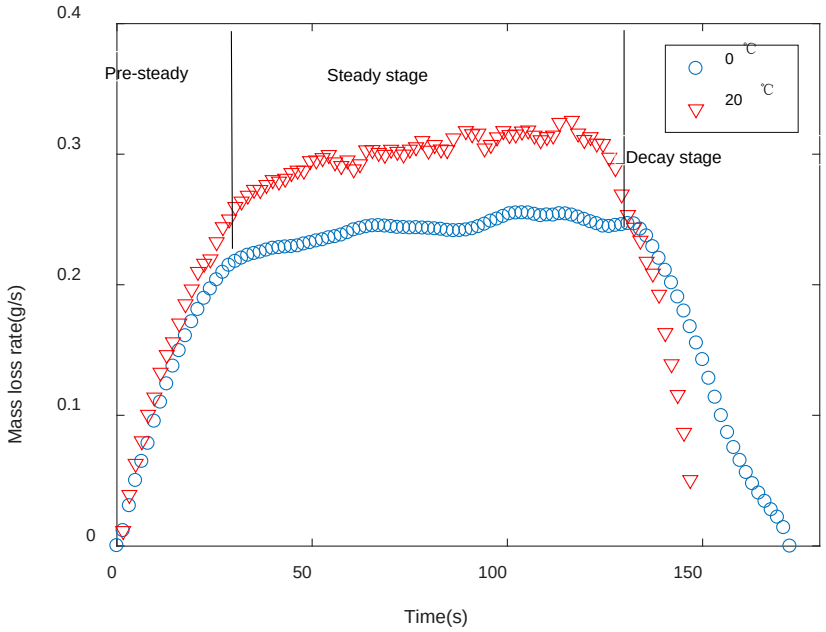
3 Results and analysis

3.3 Mass loss rate (MLR)

1mm-thickness



2mm-thickness

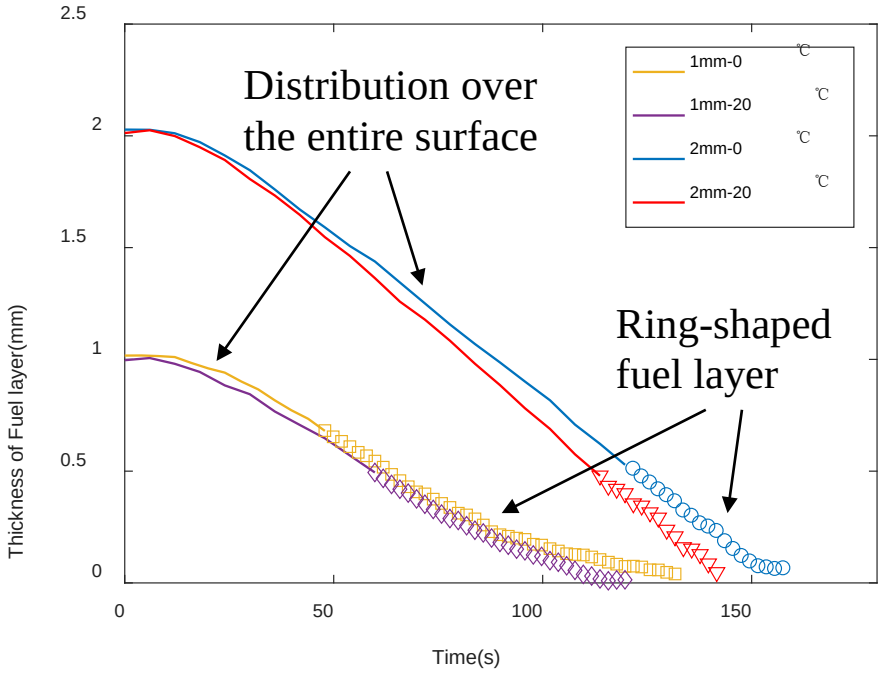


MLR of m-Xylene with various fuel thickness.

- (i) Pre-steady stage. (ii) Quasi-steady stage. (iii) Decay stage.
- Low temperature would cause ***lower MLR*** and ***longer duration*** than higher temperature because of ***more heat losses*** from the side wall.

3 Results and analysis

3.2 Fuel thickness



Variation of calculated fuel thickness.

- The thickness with low temperature was always larger than 20 ºC
- When the flame went out, the thickness of the residual fuel layer was slightly larger than zero.

4 Conclusions

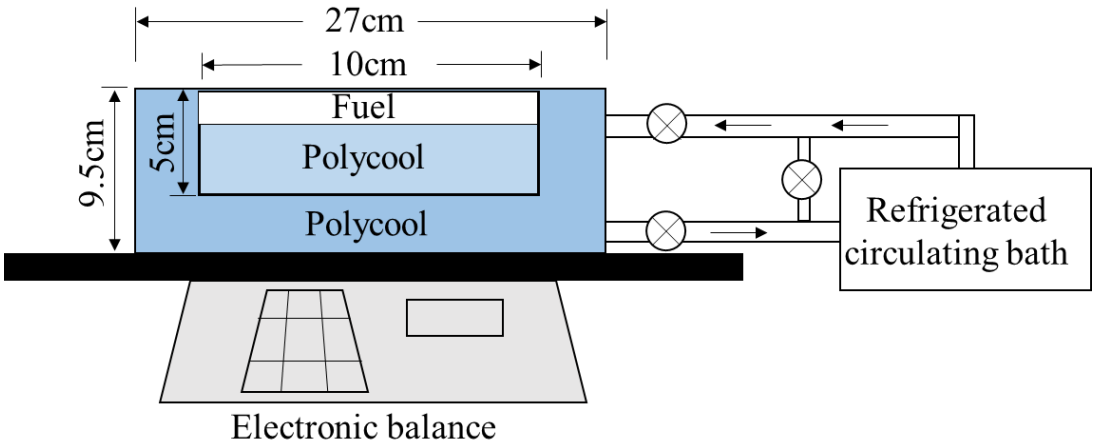
1. The temperature difference causes the ring-shaped fuel layer before the extinction.

2. The ring fire occurs with the formation of the ring-shaped fuel.

3. The ring-shaped fuel at lower temperature is thicker and lasts for a longer time because of the stronger Marangoni stress.

5 Future work

- Lower wall temperature using refrigerated circulating bath (down to -20 °C).
- Different fuel types.
- Different fuel layer thickness.
- More output terms in the experiment.



Experimental setup of refrigerated circulating bath.

Thank you!