Compression of Reactive Gas Pocket in a Water-Filled Pipe

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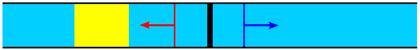
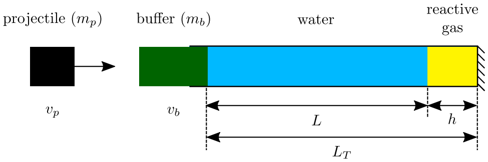
Explosions in Piping Systems in Nuclear Power Plants

- Mixture of hydrogen-oxygen-steam can be generated in piping system
  - → Core material reaction: $Zr + 2H_2O \rightarrow ZrO_2 + H_2$
  - → Radiolysis of water: $H_2O \xrightarrow{\text{rad.}} O_2 + H_2 + \ldots$
- Water-hammer type events in pipes

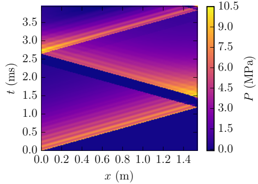
- Will pocket of reactive gas trapped in a water-filled piping system ignite?



1D Acoustics Coupled with 0D Ignition Model



h_0	v_p	v_b
2.5 mm	4.9 m/s	6.0 m/s



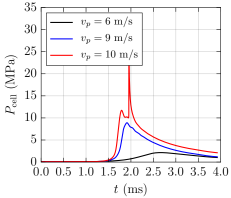
- Method of characteristics for acoustics in liquid
- Adiabatic compression of reactive gas with detailed chemistry

$$\text{Energy:}\ \ \rho c_v \frac{\partial T}{\partial t} = -\sum_i e_i \dot{\omega}_i - \frac{P}{V}\frac{\mathrm{d}V}{\mathrm{d}t}$$

$$\text{Species:}\ \ \rho \frac{\partial Y_i}{\partial t} = \omega_i \ \ \text{and}\ \ \text{Ideal gas law:}\ \ P = \rho R T$$

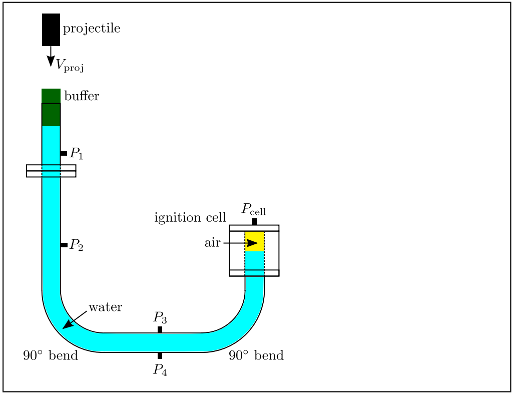
- Cavitation model (Wylie and Streeter, 1994)

H_2-air ($\Phi = 1.0$, $h_0 = 7.4$ mm)

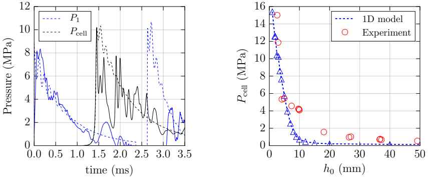


Gas Gun Experiment

- Water-filled pipe with gas pocket on one end



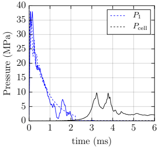
Air, $v_p = 6.0$ m/s (left: $h_0 = 2.5$ mm)

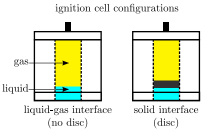


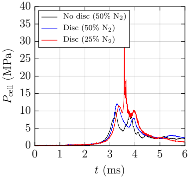
Large (37 mm) vs. small (3 mm) gap

Ignition & Conclusions

H_2-O_2–N_2
$v_p = 28$ m/s, $h_0 = 100$ mm, $X_{N_2} = 0.56$







- No ignition with gravity accelerated projectile
- Small values of h_0 lead to compressed gaps that are below quenching distance
- Large values of h_0 lead to compressed gaps that are above quenching distance
  - → Dominated by fluid instabilities
  - → Multi-phase mixture
- Model
  - → Valid for small gaps, however, under-predicts for large gaps
  - → Need better cavitation model
- Will instabilities suppress ignition?

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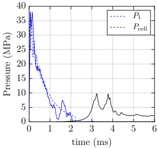

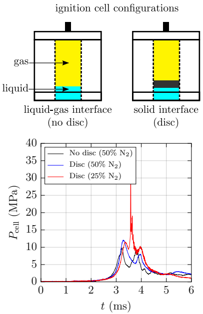

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Thank you