VTT TECHNICAL RESEARCH CENTRE OF FINLAND LTD

Ex-vessel steam explosion analysis with MC3D

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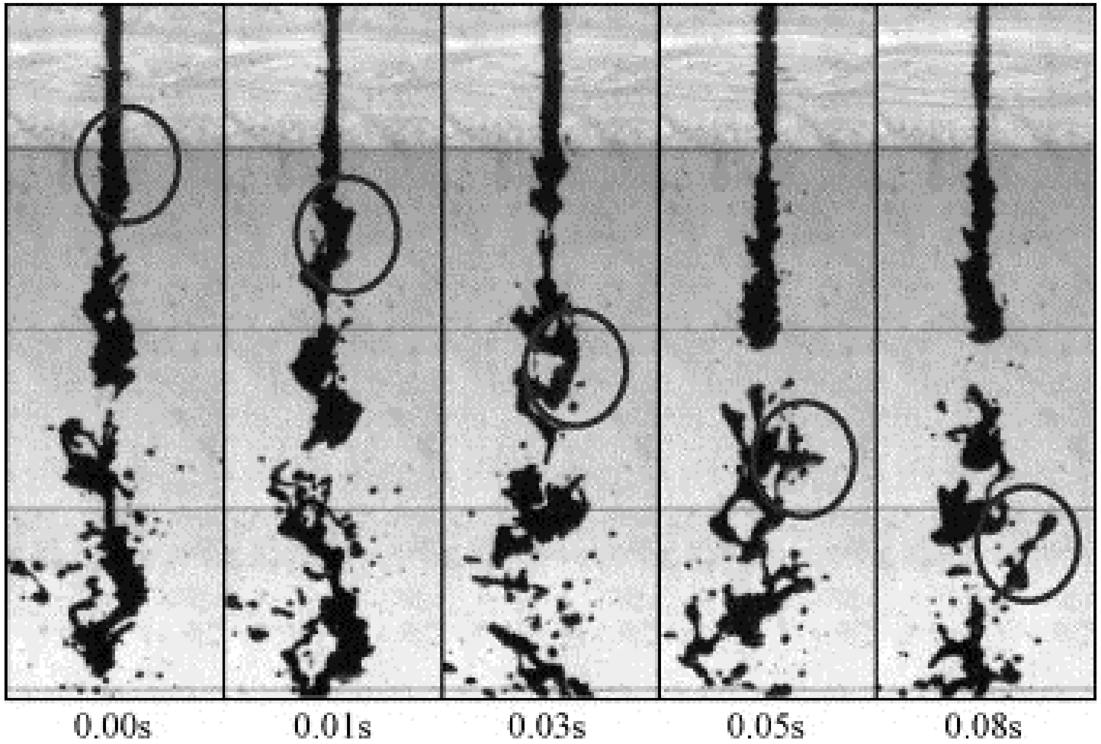
Content

- Theory of Steam explosions
- MC3D
- Simulations
- Results

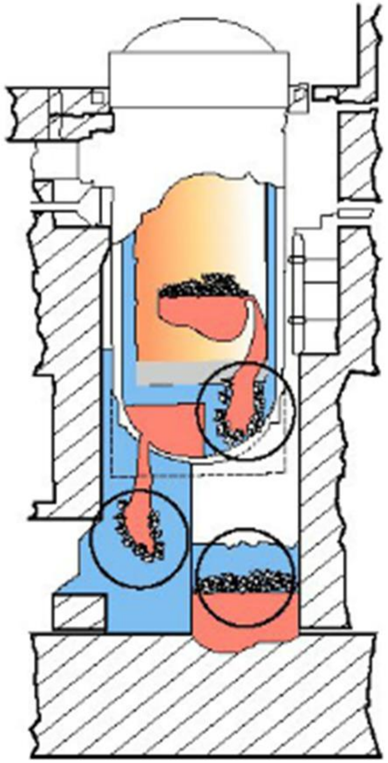
Steam explosion theory

- Premixing stage
  - Initial coarse mixing
  - Melt properties and temperature dominates
- Triggering stage
  - Highly stochastic
  - External vs internal
- Explosion stage
  - Fine fragmentation
  - Supersonic progression



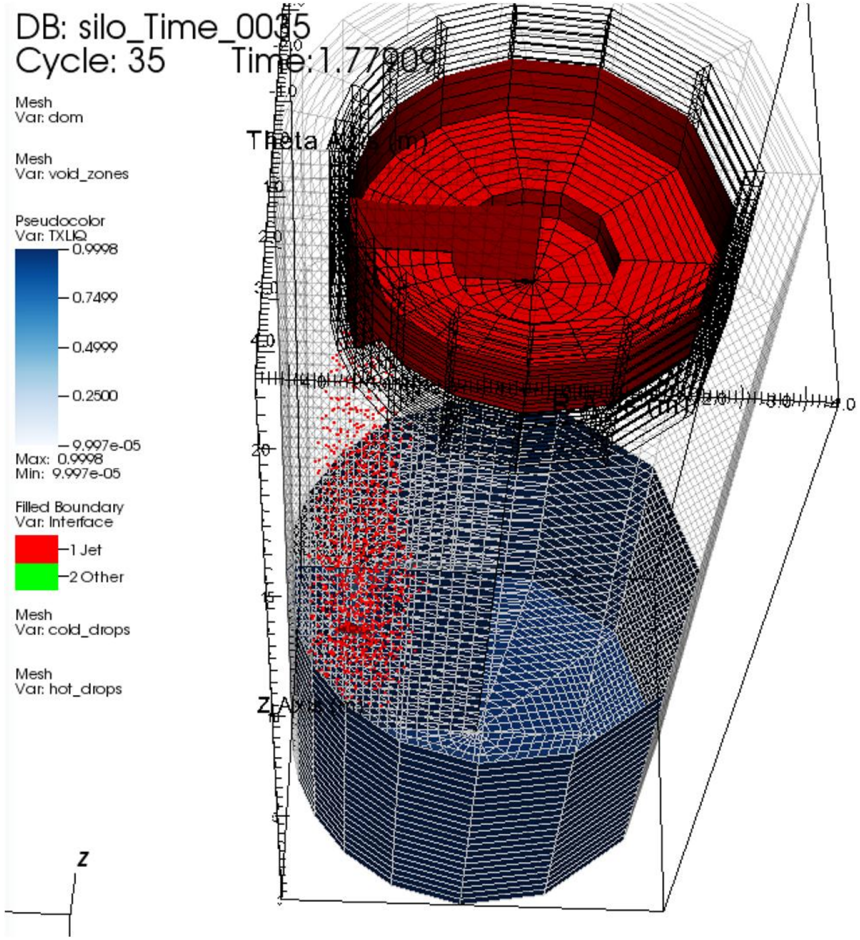
Steam explosion locations

- In-vessel steam explosion
  - Might damage the RPV and cause it to rupture prematurely
- Ex-vessel steam explosion
  - Containment damage
- In-vessel and Ex-vessel differences:
  - Coolant temperature and volume
  - Ambient pressure
- Debris bed flooding



MC3D

- Developed at IRSN & CEA in France
- Separate Premixing & Explosion stage
- Fragmentation model limitations
  - Produces drops of one size
  - Jet diameter >> drop diameter



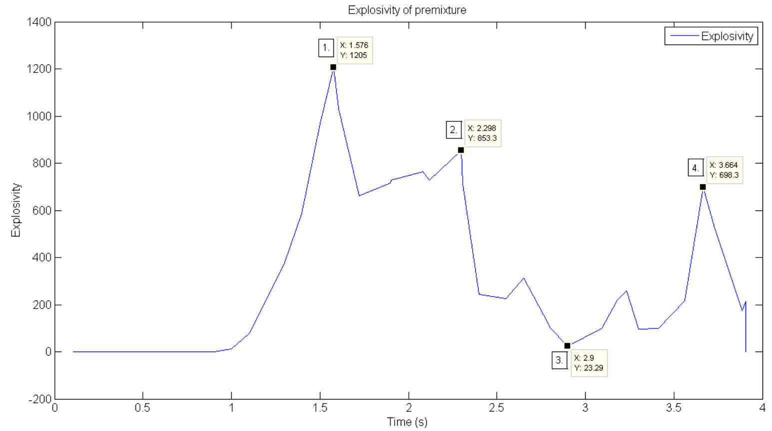
Simulation cases

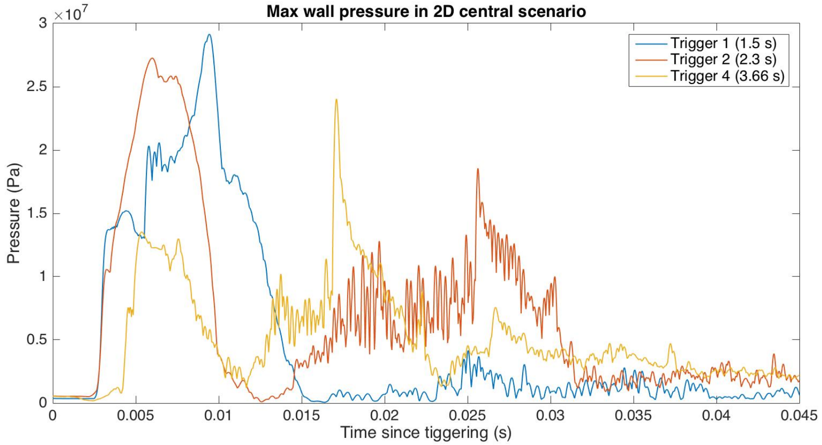
- Parameters
  - MELCOR simulations to calculate starting parameters
    - Same parameter set for LOCA and Station blackout
  - Standard Corium melt properties from MC3D
  - Melt temperature higher than in MELCOR due to differences in calculation techniques

- Test cases
  - Standard parameters central case to see effect of triggering time
  - Different side breaks (3D models)
  - Sensitivity analysis of key parameters, e.g.
    - Melt temperature
    - Water level
    - Drop size

Results - Standard case & Side breaks

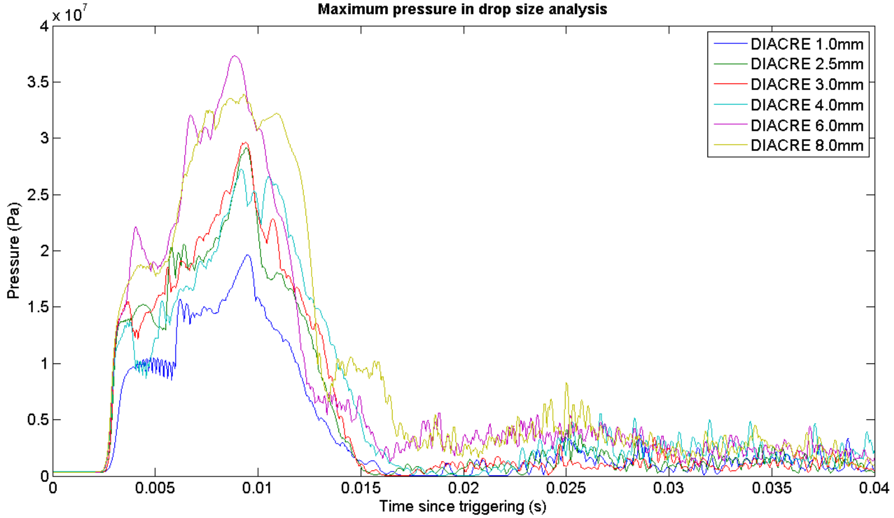
- Trigger time does not effect the explosion strength as long as explosivity is high enough for ignition.
- Side breaks failed to ignite
  - Explosivity higher than in central case
  - 3D central case also failed to ignite
  - ➢Problems with 3D model

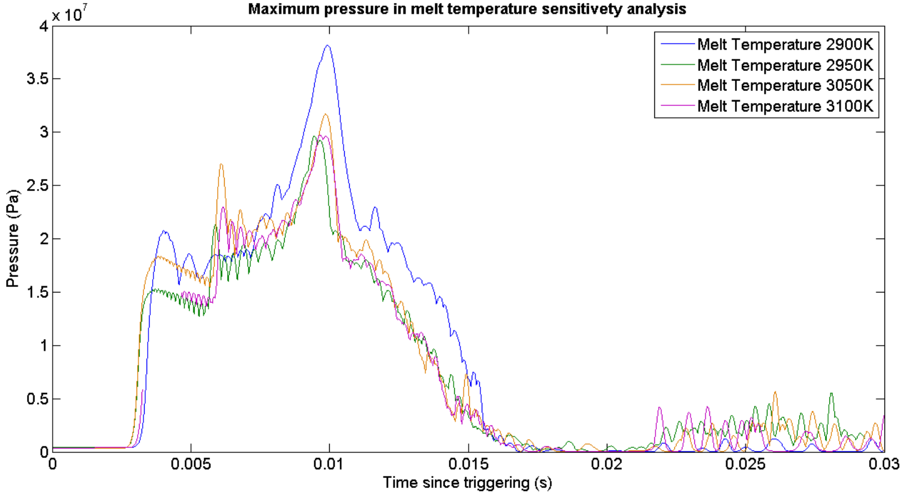




Results - Sensitivity analyses

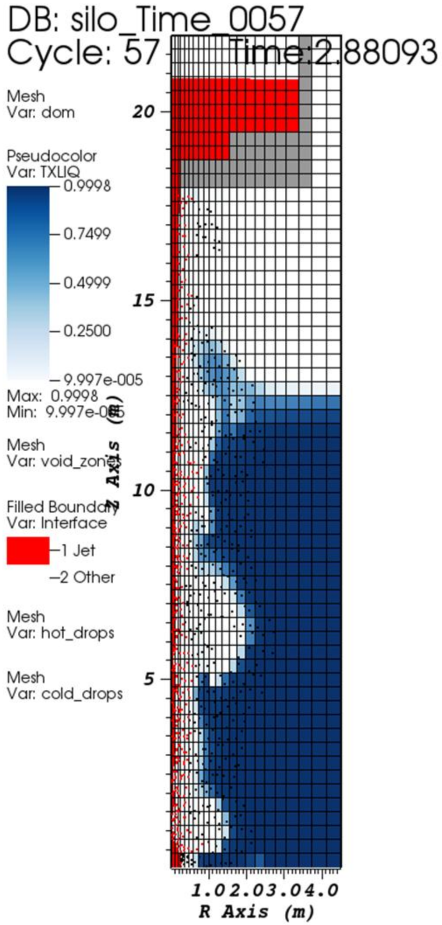
- Drop size has the most clear effect
- Small effects from melt temperature as long as melt is clearly superheated, otherwise no explosion
- Low water level produces weaker explosion.
- Water temperature has only a small effect on explosion strength





Conclusion

- Results have to be considered with all the uncertanties in mind
- The code handels 2D models fine but 3D casues problems
- Melt properties need to be defined clearly for accurate results
- Scenario that produces strongest explosions unrealistic



Snapshot of premixing configuration in standard central case

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