The Effect of Geometry and Trigger Mechanism on the Risks of Thermal Runaway: Internal Dynamics and Mass Ejection

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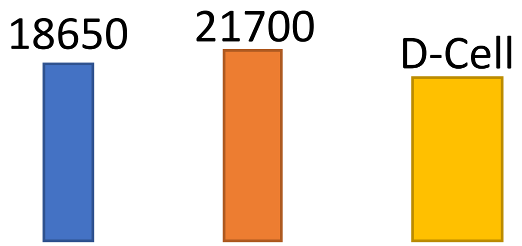
Overview

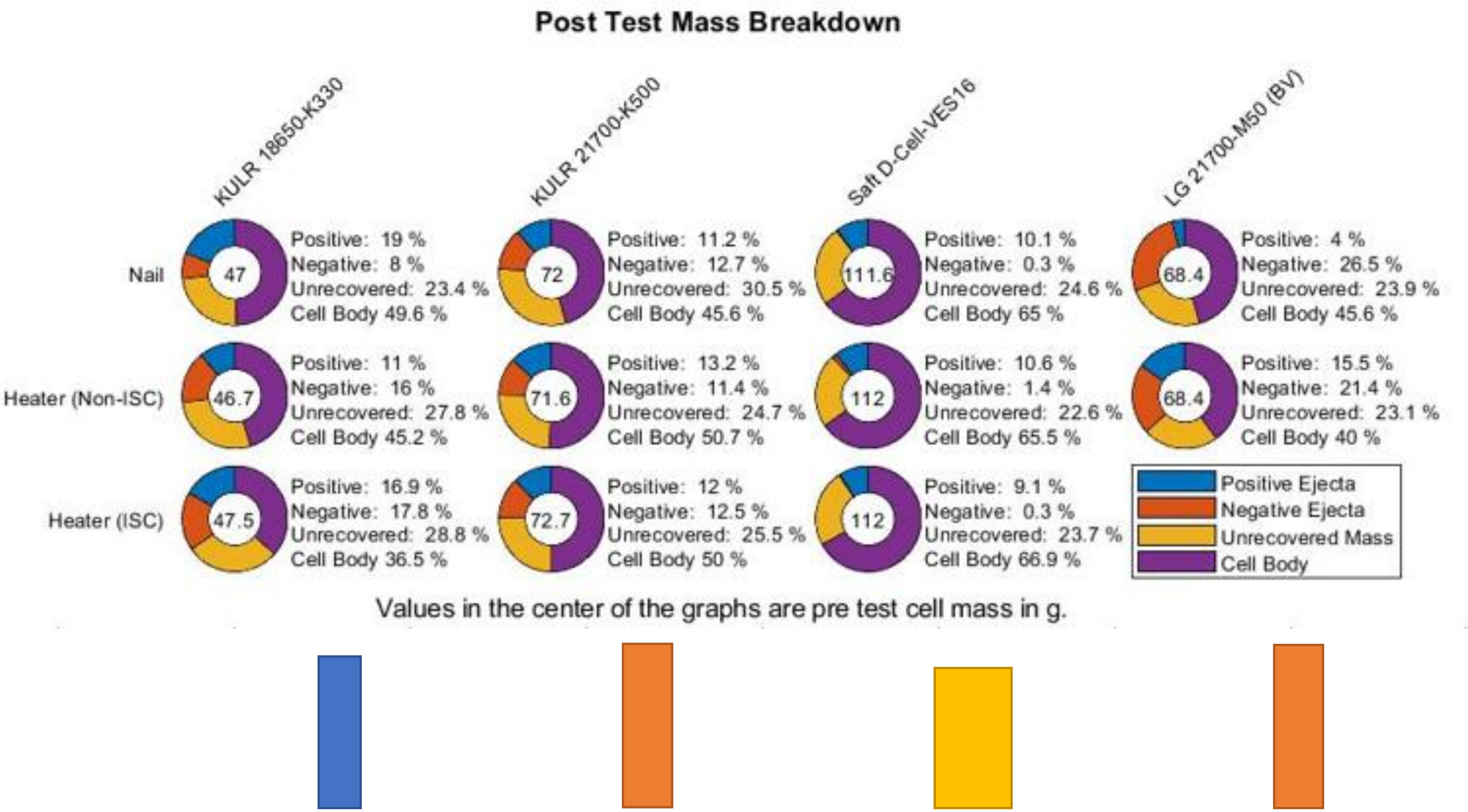
- Fractional Thermal Runaway Calorimeter (FTRC)
  - Heat, Mass and Temperature Measurements
  - Simultaneous X-Ray Radiography
  - Adaptable for Different Trigger Mechanisms
    - Heater Internal Short Circuit (ISC)
    - Heater
    - Nail Penetration
- Battery Cells
  - KULR 18650-K330
  - KULR 21700-K500
  - LG 21700-M50
  - SAFT D-Cell-VES16

Size Reference



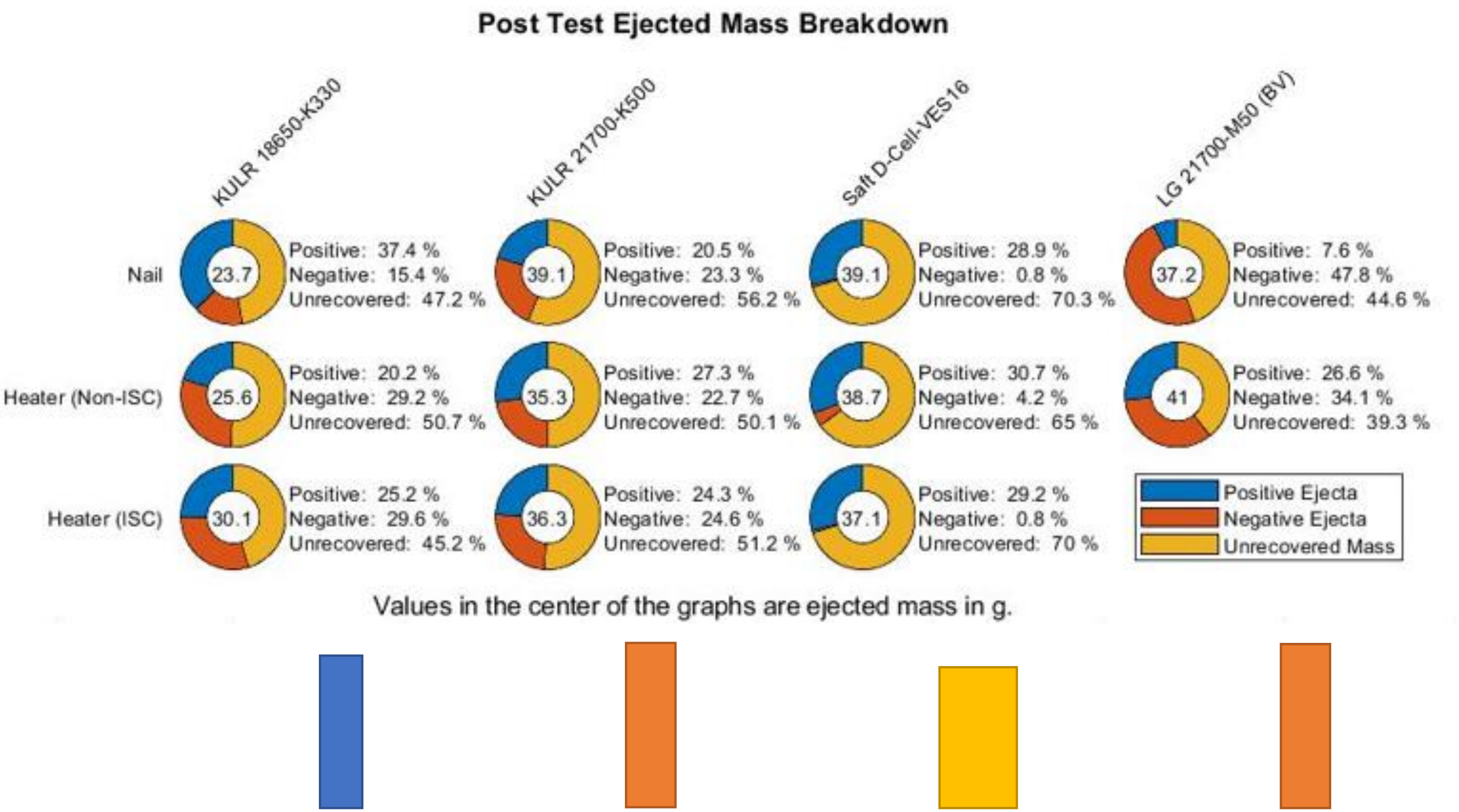
Post-Test Overall Mass Distribution

- On average, more mass remains within cell bodies with larger cell diameter
- SAFT D-Cell had largest percentage of mass remaining within cell casing
    - Speed of thermal runaway within cell plays role on mass ejection
- Very little negative vent engagement for all trigger mechanisms with SAFT D-Cell
- KULR 18650 ejected mass for Heater (ISC) trigger substantially higher than for other trigger mechanisms
    - Clogging of vents allows internal pressure to build resulting in more ejecta



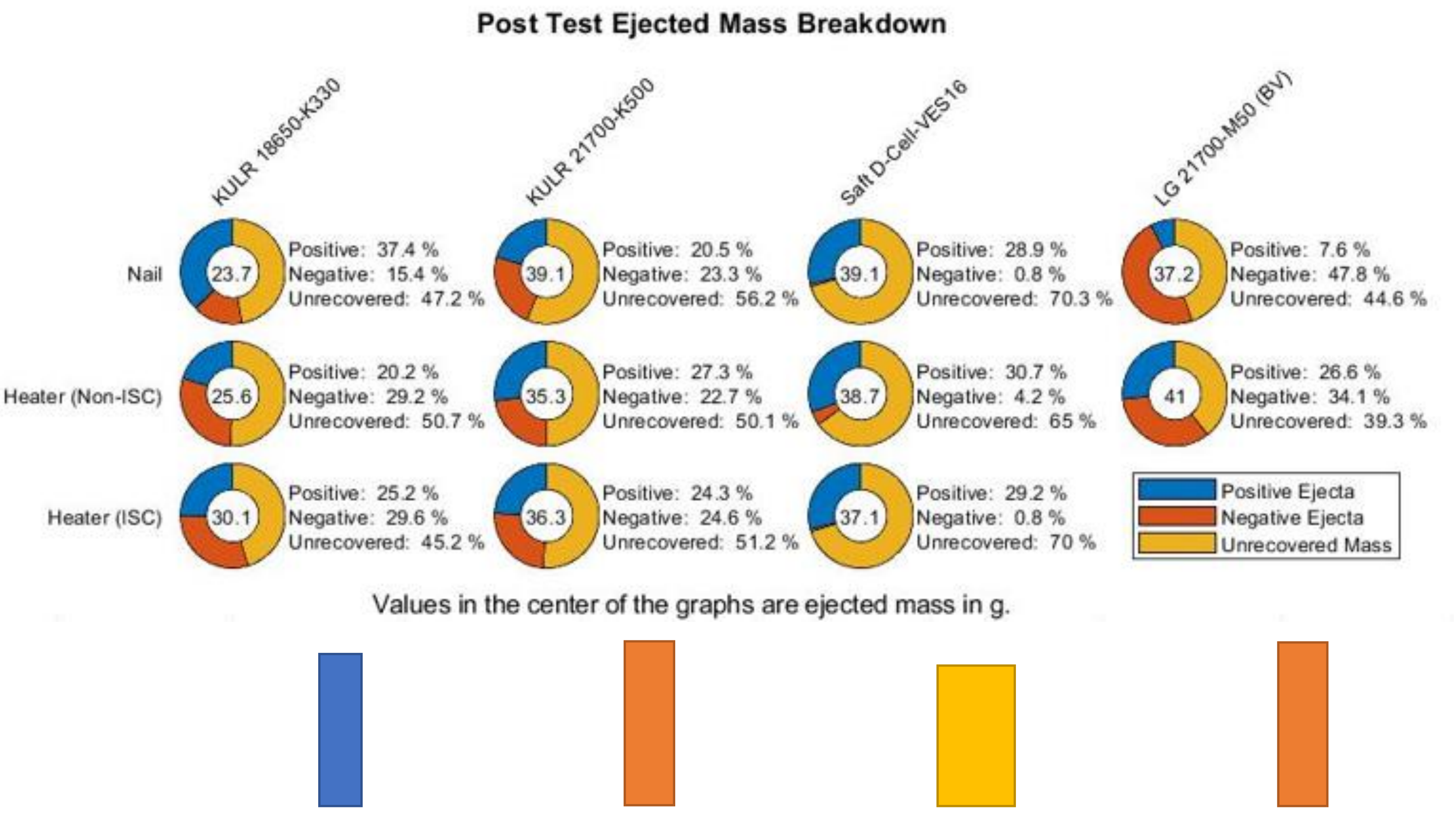
Post-Test Ejected Mass Distribution

- SAFT D-Cell shows largest percentage of ejecta as unrecovered mass
  - Higher concentration of volatile electrolyte results in more gas creation
- KULR 18650 Nail trigger shows larger percentage of mass being ejected through the positive end of the cell
  - Nail hole potentially provides additional vent for gases to escape from, relieving pressure that would otherwise have built and actuated the negative vent
- LG 21700 outputting greater percentage of negative ejecta than any other cell



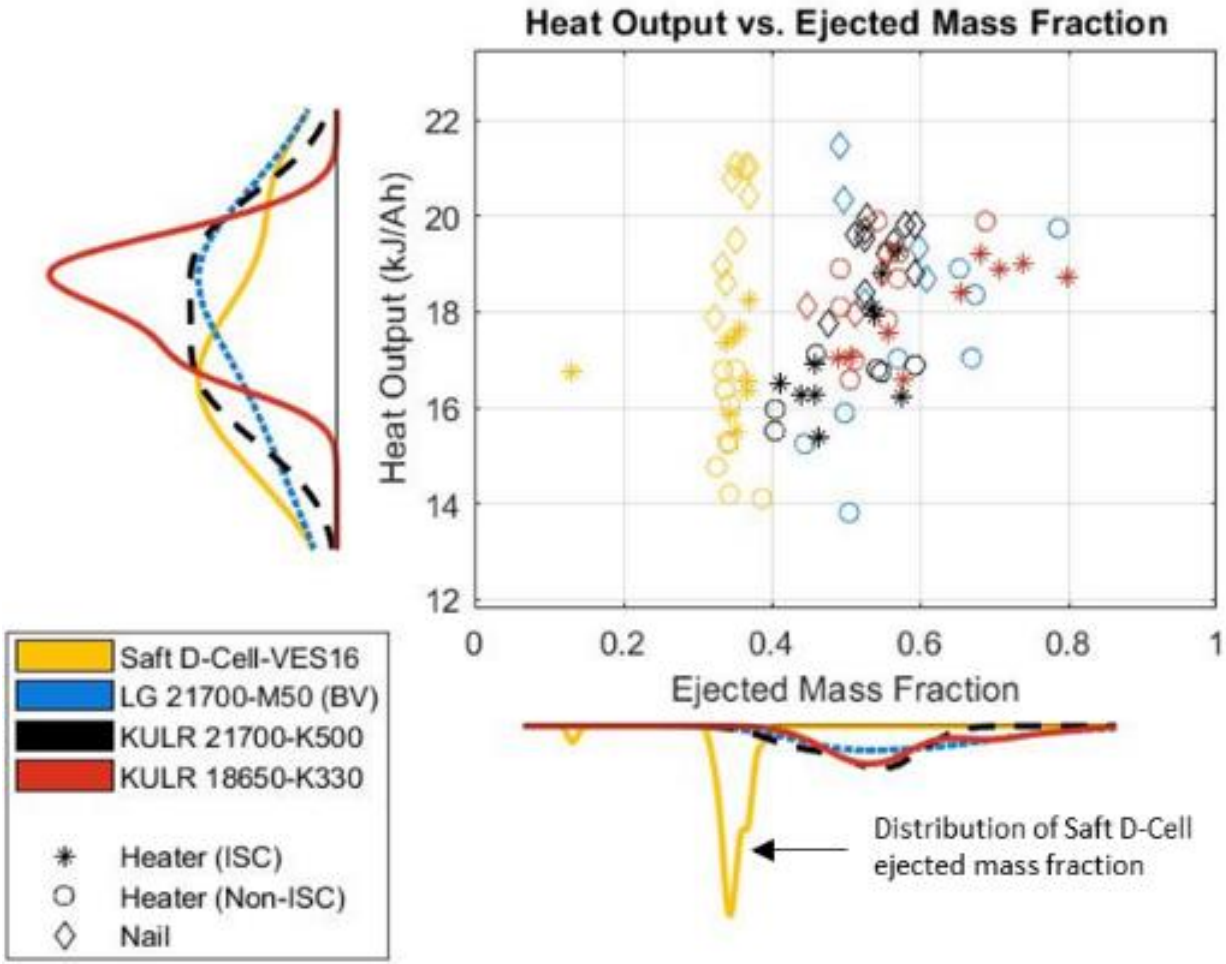
Post-Test Ejected Mass Distribution

- LG 21700 has dissimilarity between Nail trigger and Heater (non-ISC)
  - Nail initiates multiple instances of thermal runaway resulting in a higher rate of gas generation and quick pressurization of the cell
  - Positive vent engages with negative vent engaging soon after. The larger area of the negative vent allows for material to pass through with less resistance resulting in larger mass percentage leaving through negative end of cell.



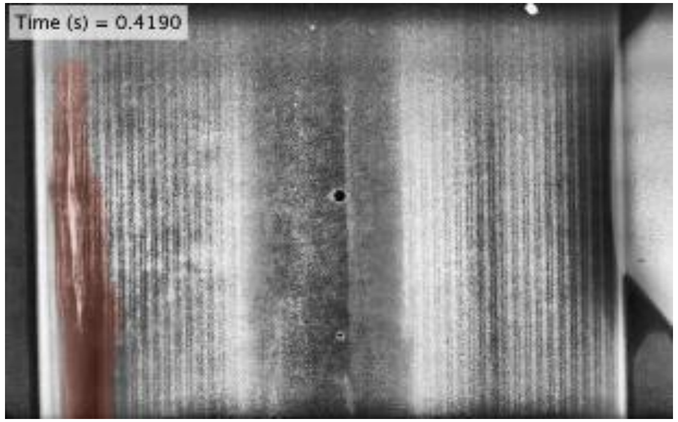
Mass Ejection

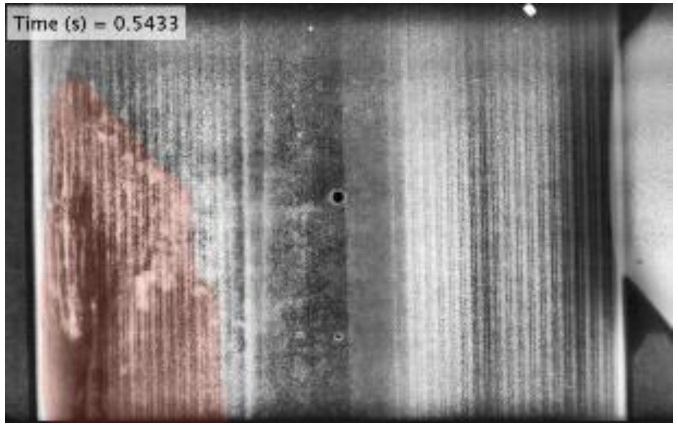
- SAFT D-Cell shows consistent ejected mass fraction value while heat output varies based on trigger mechanism
- Spread of ejected mass from each cell seems to increase as cell diameter decreases
  - Larger vent area could potentially allow for unimpeded flow of material out of cell casing
- KULR 18650 shows two groupings for Heater (ISC) trigger
  - Vent clogging allows pressure to build resulting in more ejecta and a slight bump in heat output

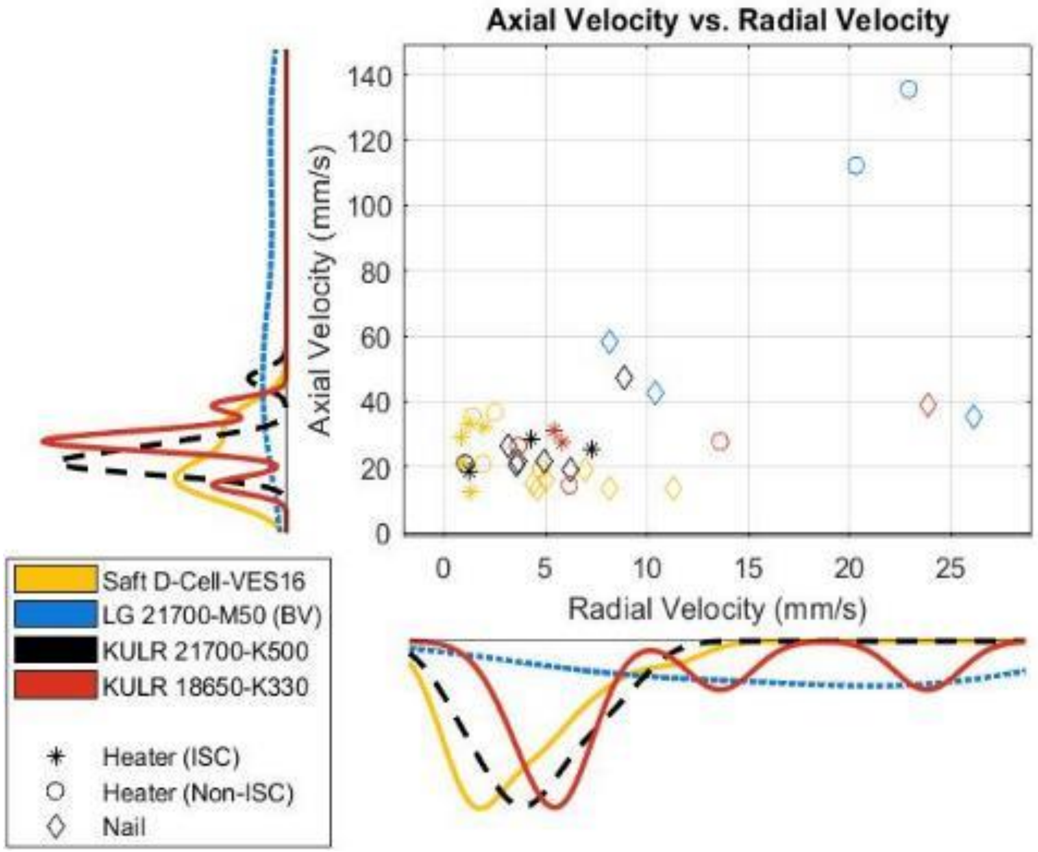


Thermal Runaway Propagation

- LG 21700 exhibited fastest thermal runaway front velocities while SAFT D-Cell showed slowest
- Potential relationship between electrolyte and speed of thermal runaway reaction
- Speed of reaction also impacts amount of ejected mass and unrecovered mass from cells
- Radial velocities for the SAFT D-Cell are noticeably quicker when the nail trigger mechanism is used as opposed to heater or ISC
    - The speed of the nail itself does not seem to have an impact on radial speed. Nail speeds average around 26 mm/s.

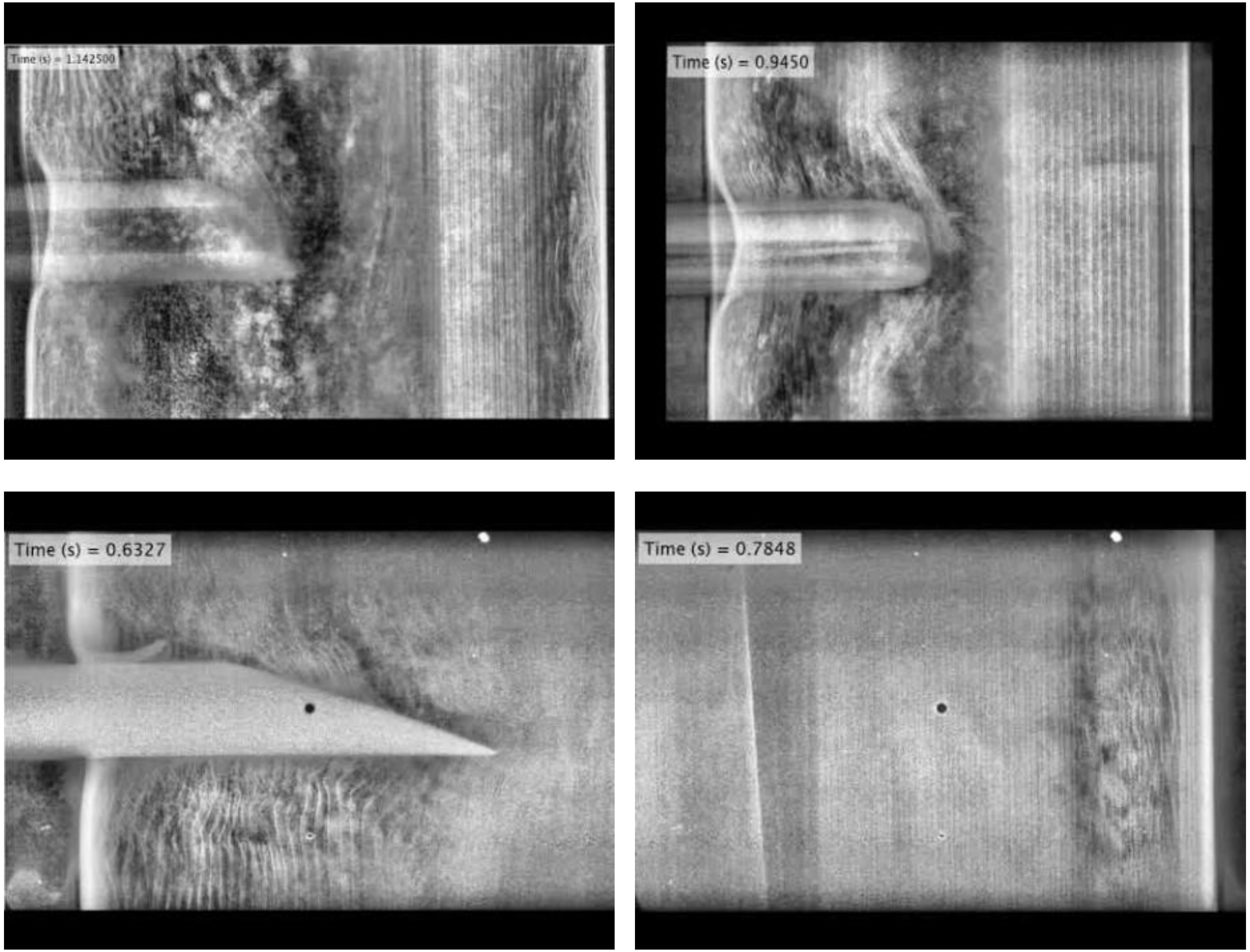






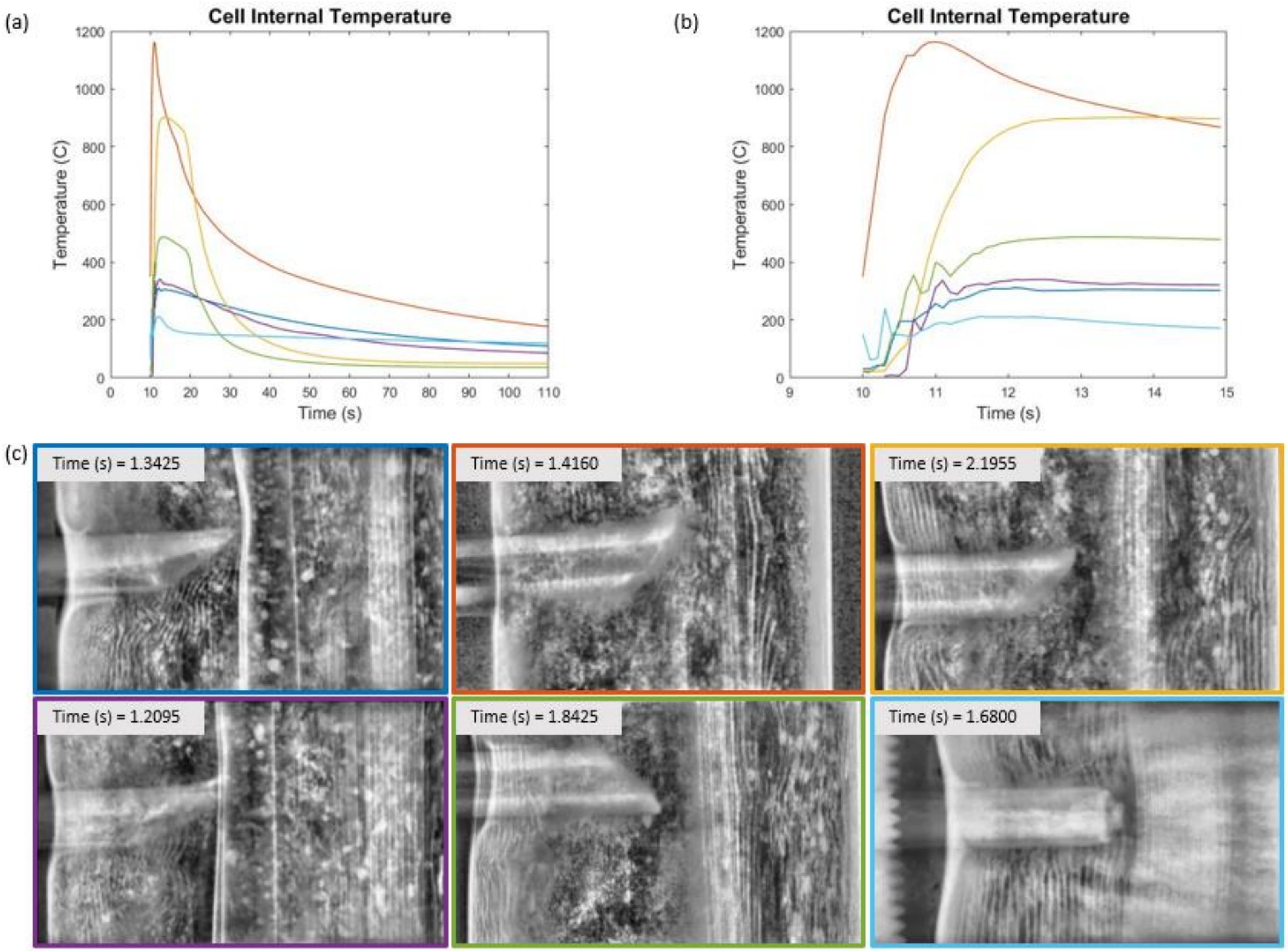
Cell/Trigger Characteristics

- Radiography of LG 21700 showed cracks forming in the jelly roll with Nail trigger
- Nail Trigger mechanism would sometimes impede the flow of material leaving the cell
    - Results in lower percentage of mass ejecta than otherwise
- Speed thermal runaway propagation between nail trigger and ISC trigger for SAFT D-Cell



Internal Temperature Estimation

- Molten copper visible in all cells except for SAFT D-Cell suggesting internal temperatures never exceed 1080 °C
  - Contributing factors for apparent lower internal temperatures: heat of vaporization of electrolyte, higher thermal mass
- Comparing radiography to temperatures obtained with thermocouple embedded nails displays inconsistencies
  - Use caution when using values obtained in this way for modelling



Thank you for listening

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