



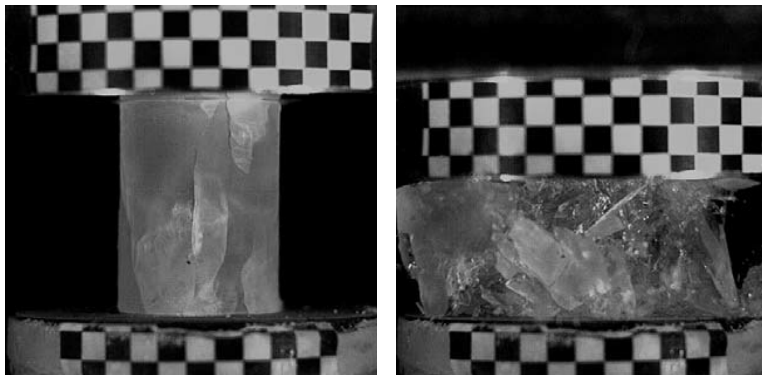
Reduced temperature effects on aerospace materials undergoing dynamic impact events

Justin Littell Ph.D.
Research Aerospace Engineer
NASA Langley Research Center
Structural Dynamics Branch (D322)

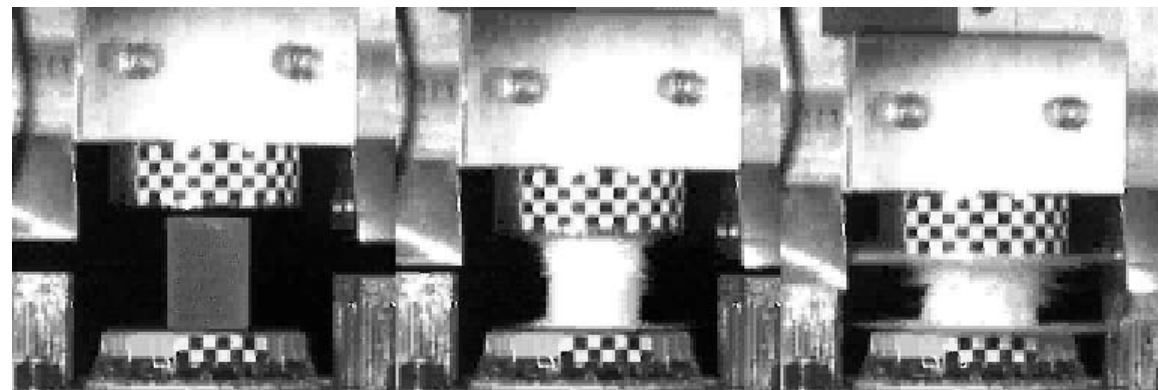
May 14, 2024

Ice Characterization

- At low velocities (up to 100 ft/s) ice depends on complex internal crystalline structure
- At high velocities (> 100 ft/s) ice behaved more like a fluid and less dependent on internal crystalline structure



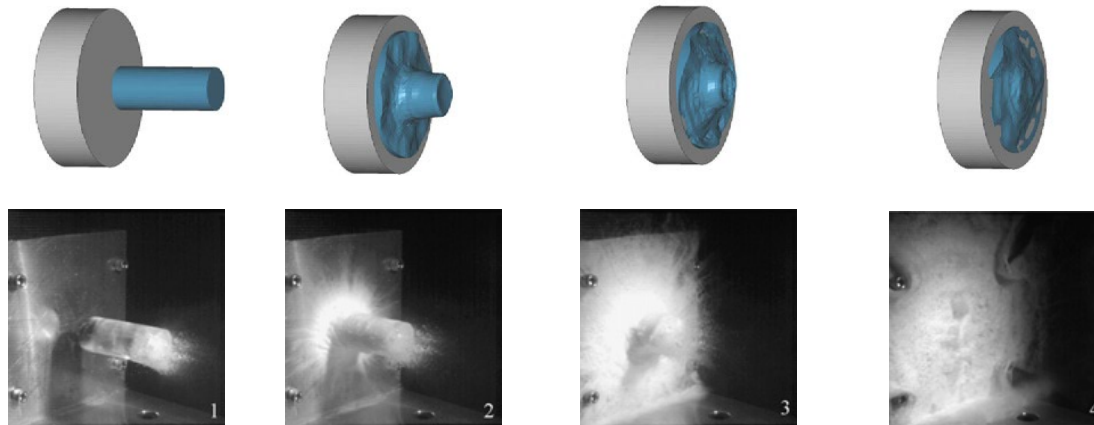
Ice deformation at 11 ft/s



Ice deformation at 100 ft/s

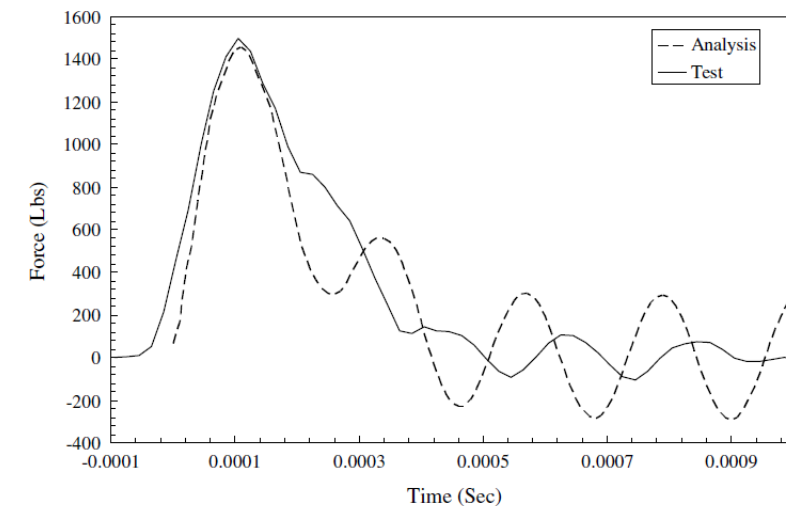
Ice Dynamic Modelling

- Ice should be regarded as a class of materials rather than a single specific material with defined properties
 - Has 13 different crystal structures and two amorphous states
- Failure in ice that does not contain flaws requires a nucleation mechanism in addition to crack propagation
- Ice modelled as a rate sensitive plasticity model with failure
 - Tabular data (collected) for flow stress
 - Scaling function based on strain rate
 - Plastic strain and pressure cut-off used as failure criteria



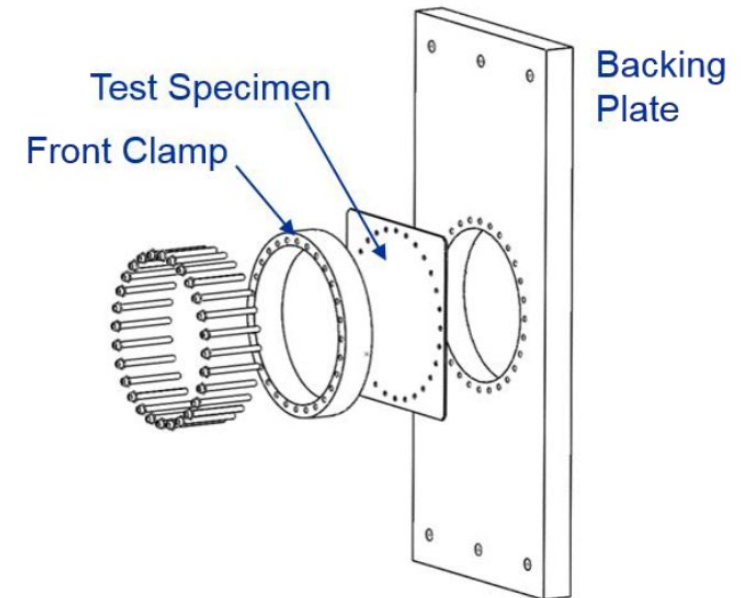
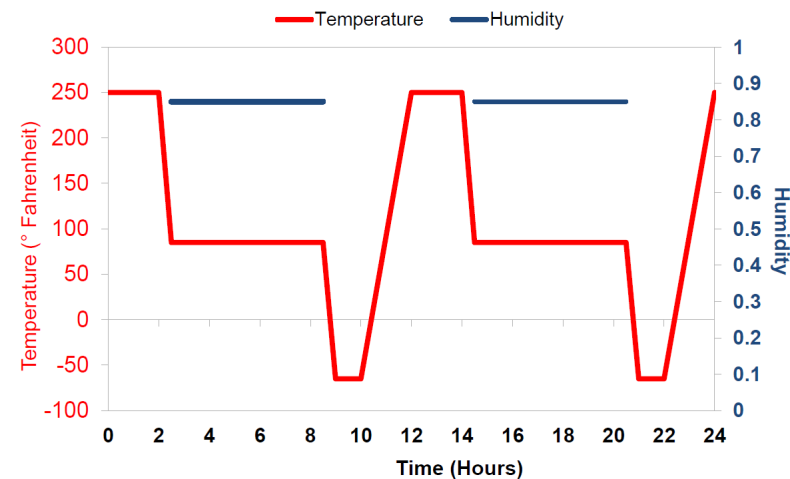
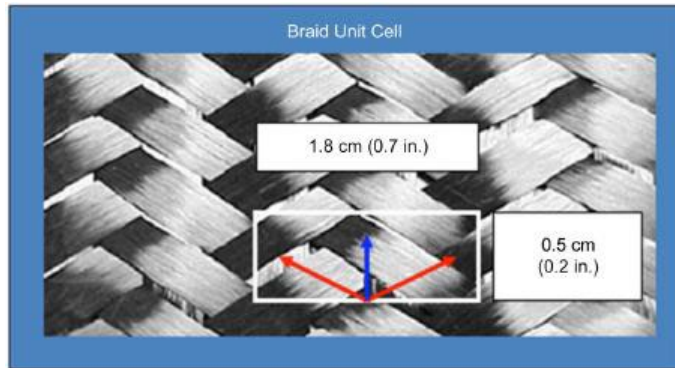
Ballistic simulations (top) and tests (bottom) of ice

Test analysis comparison at 500 ft/s



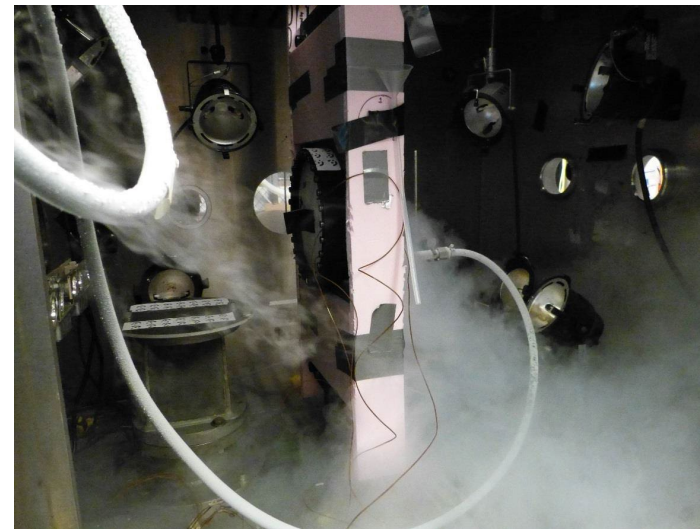
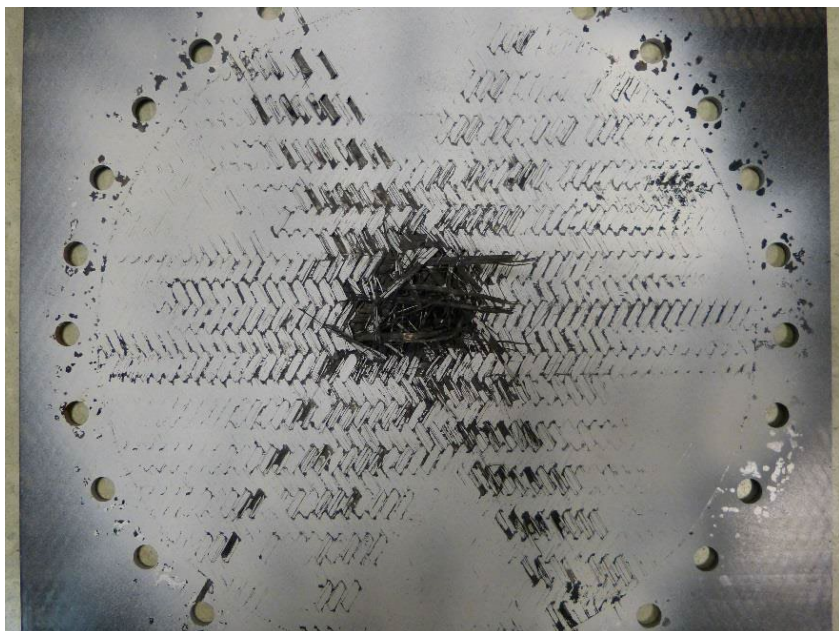
Composite ballistic Impact resistance

- Two experiments:
 - Identify and quantify any degradation in impact penetration resistance of composites under cyclic temperature and humidity conditions experienced by materials in the fan section of commercial gas turbine engines for a representative aircraft flight cycle
 - Identify change in ballistic threshold when testing at cryogenic temperatures (77K)

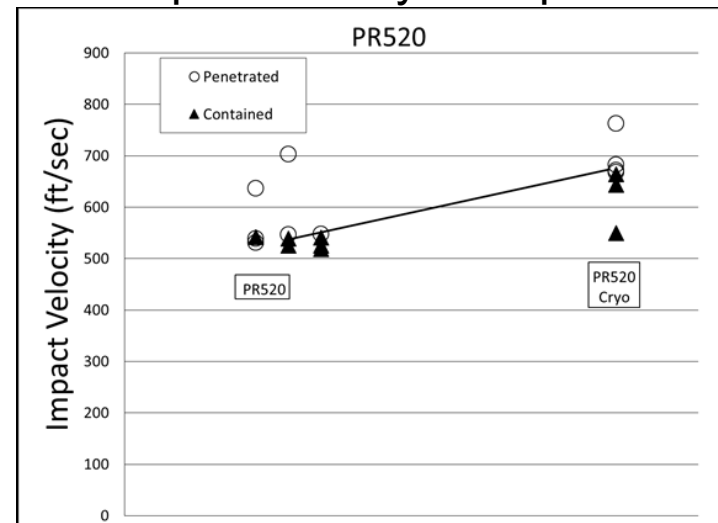


Composite ballistic impact resistance

- Cryo temperatures (77K) show some increase in ballistic resistance for panels made with resin PR520 (toughened)
- Diffused damage seen on the panel indicative of increased fiber energy absorption



PR520 panel at cryo temperatures

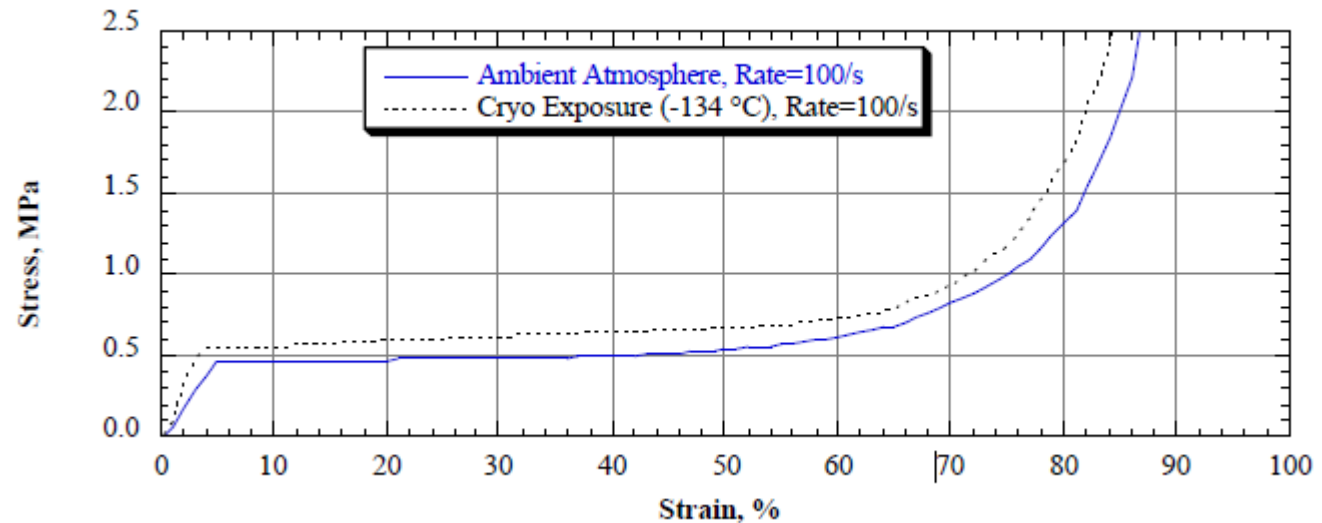


Material properties of foam

- Polymeric foams, both open and closed cell have a strong dependance on temperature
- Decreasing temperature is similar to increasing test speed
 - Both result in an increase in crush strength



Drop tower capable of 100/s strain rate



Polyisocyanurate foam crush results @ 100/s strain rate

Conclusion



- Ice is complex!
- Temperature effects must be accounted for when dealing with aerospace structures in low temperature environment
- Data collection and interpretation requires additional challenges in test setup and planning
- Low temperature environments include both off-world environments (moon, planets) but also items such as supercooled propulsion systems in rockets and other items not immediately considered