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# MECHANICAL CHARACTERIZATION OF INSULATION MATERIALS DURING THERMAL BATTERY MANUFACTURING

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# AGENDA

Motivation

Test Set-up

Material Selection

Test Results

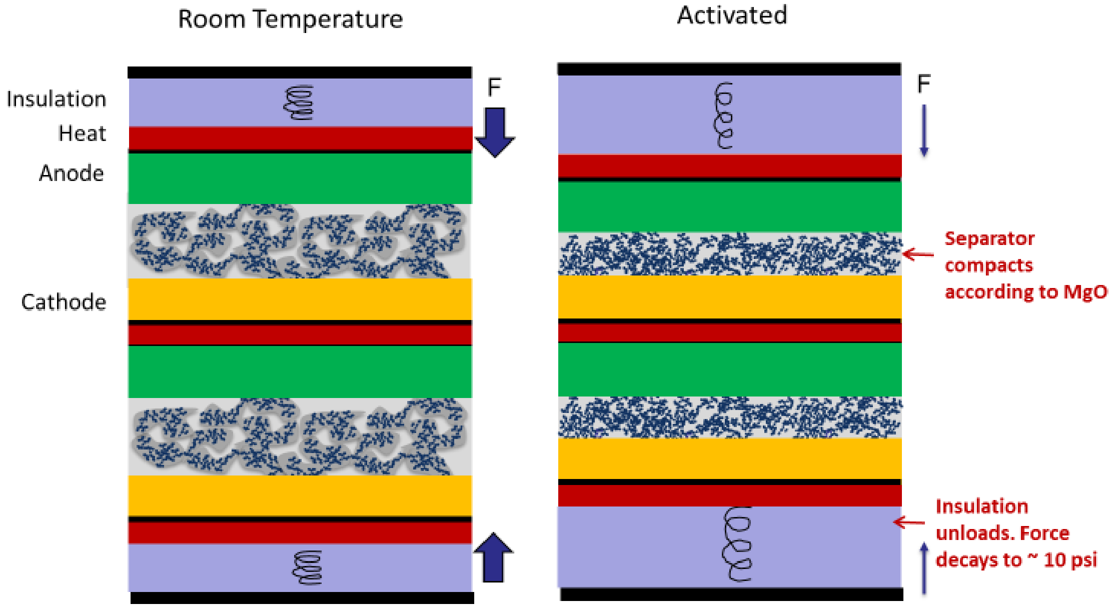
Implications to Modeling and Design

Future Work

Acknowledgements

# MOTIVATION

*Insulation acts like a spring in the battery to prevent slipping in mechanical environments.*




Three main questions for battery design:

- By how much does the stress relax in compressed axial insulation during storage?
- Does the insulation material have the ability to continue to impose force on the stack after activation?
- How does the cyclic nature of the load application during manufacturing affect those parameters?

# CHARACTERIZING CYCLIC LOAD BEHAVIOR

Goals:

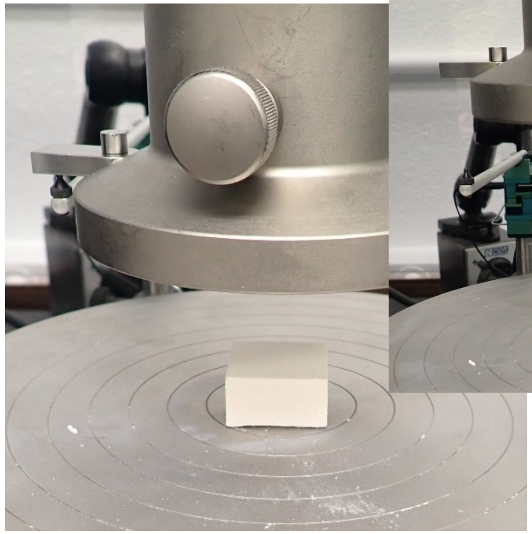
- Mimic the manufacturing process
- Collect data for each cycle on recovery elastic modulus, irrecoverable strain, and amount of creep

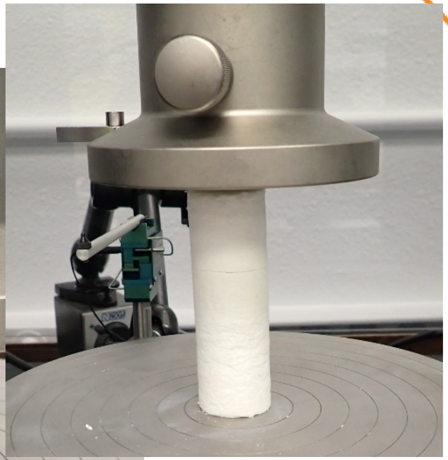
Specimens were dried at 600˚C for 2 hours

Tested in a dryroom with a maximum dewpoint of -28˚C

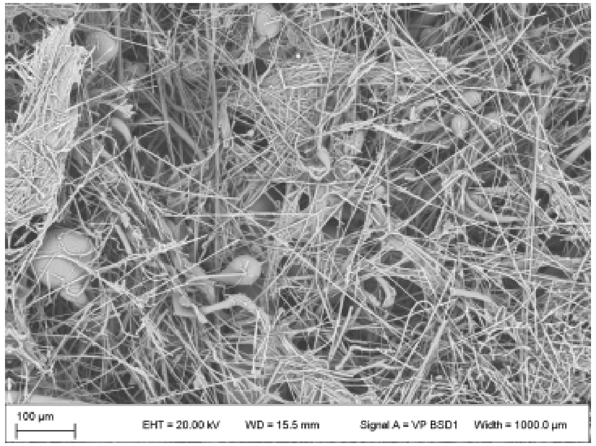
ADMET eXpert 2613 Dual Column Table Top Universal Testing System

| Material | Maximum Stress (psi) | Percent of Ultimate Stress |
|---|---|---|
| Duraboard | 250 | 28 |
| Fiberfrax | 150 | 8 |
| Microtherm | 150 | 70 |
| MinK | 150 | 97 |
| WDS Shape | 100 | 58 |
| Zircal | 400 | 27 |

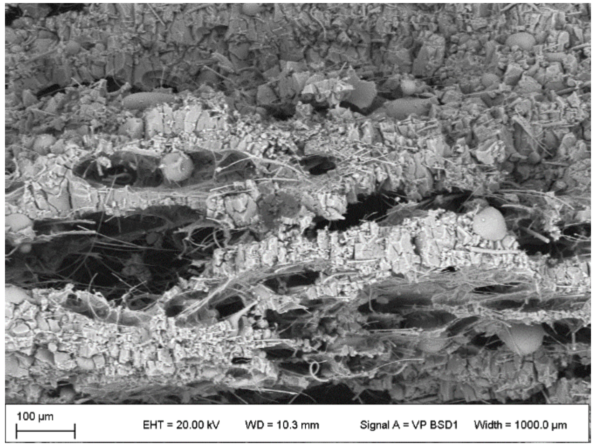




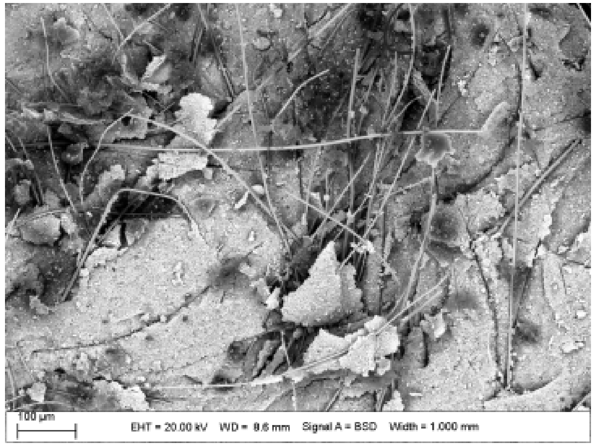
# MATERIAL SELECTION



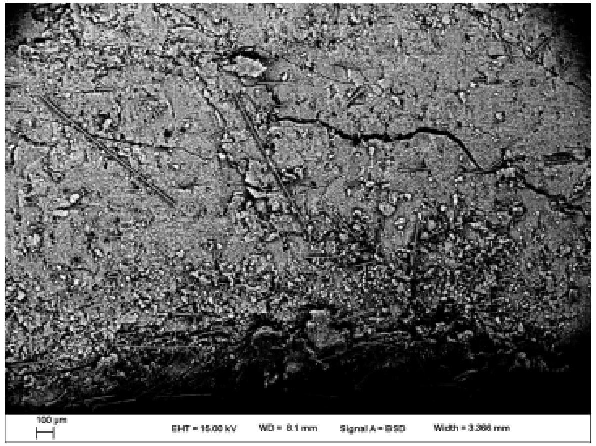

Duraboard



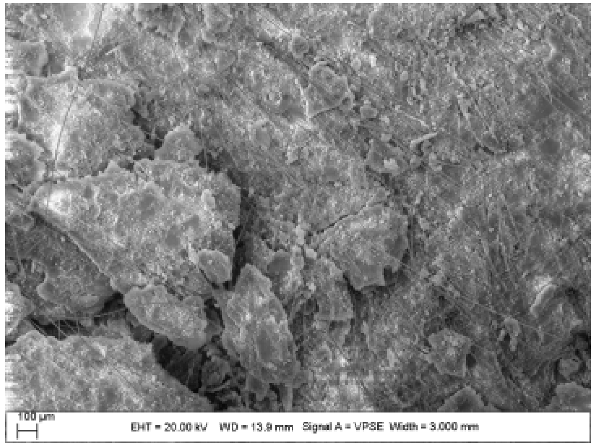

Fiberfrax



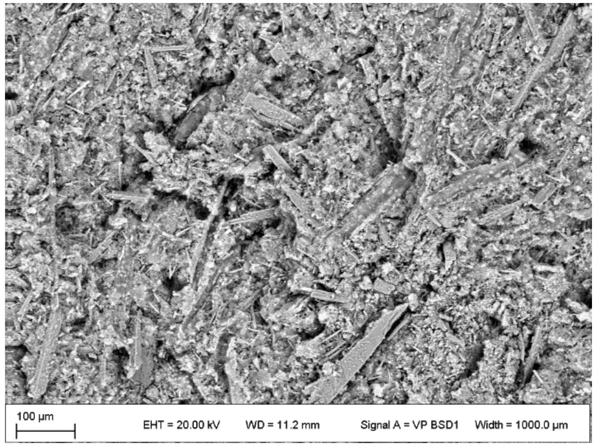

Microtherm




MinK




WDS Shape

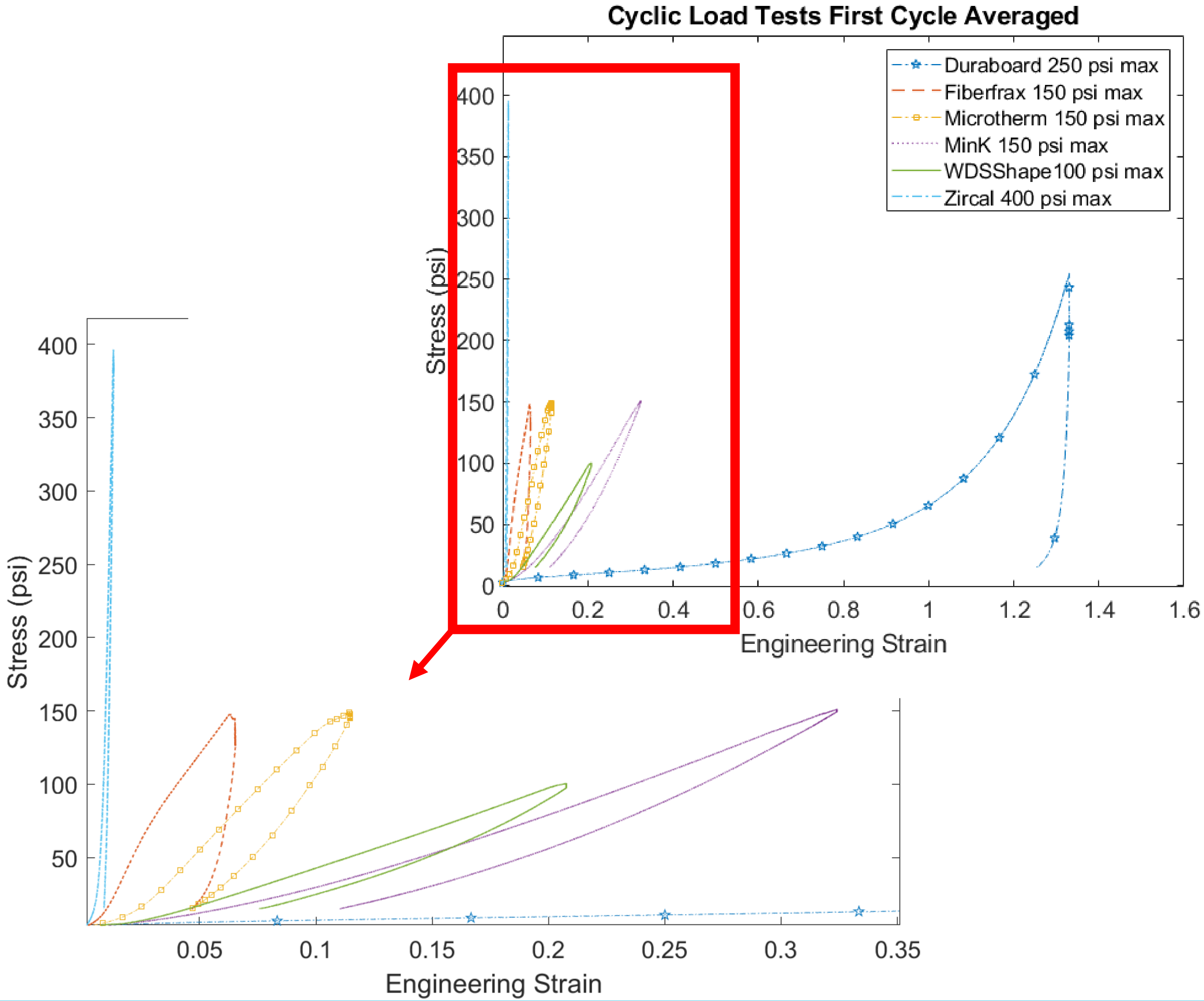



Zircal

# FIRST LOAD CYCLE

All materials exhibited irrecoverable strain, likely due to some initial crushing of the material

Durboard exhibited the most deformation and the least amount of recovery



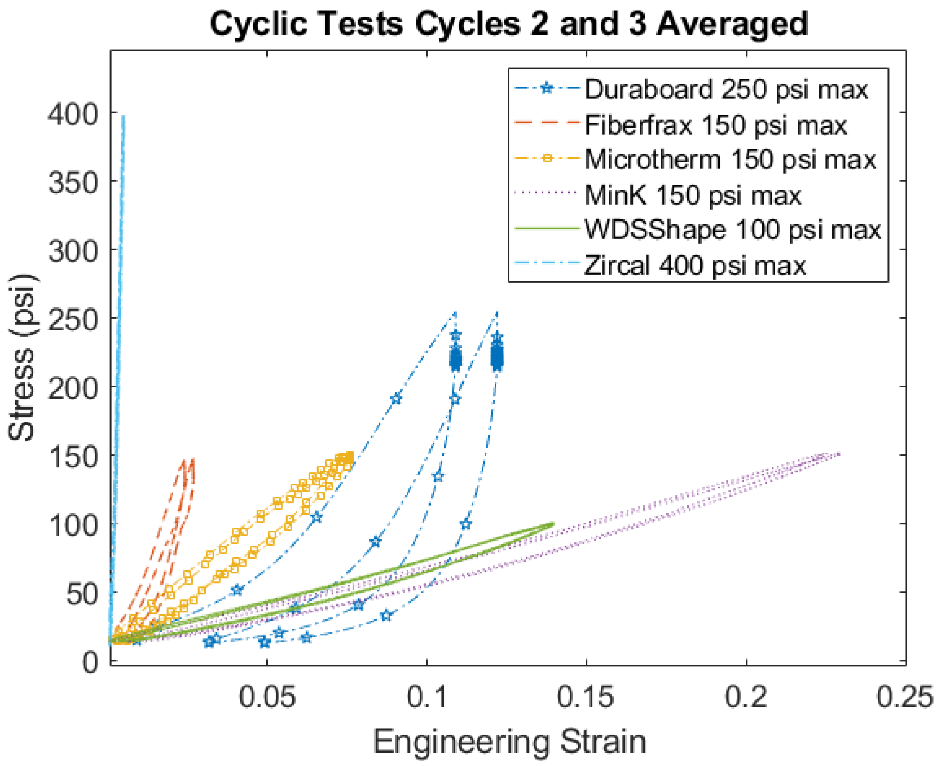
# COMPARISON OF CYCLES

The largest amount of irrecoverable strain in first cycle

Each subsequent cycle adds small amount of additional irrecoverable strain

Recovery elastic modulus different than subsequent cycles for some materials

Recovery elastic modulus consistent from cycle to cycle for others




| Material | Recovery Elastic Modulus Cycle 1 (psi) | Irrecoverable Strain Cycle 1 | Recovery Elastic Modulus Cycle 2 (psi) | Irrecoverable Strain Cycle 2 | Recovery Elastic Modulus Cycle 3 (psi) | Irrecoverable Strain Cycle 3 |
|---|---|---|---|---|---|---|
| Duraboard | 9140 | 1.256 | 9720 ↑ | 0.032 ↓ | 10300 ↑ | 0.017 ↓ |
| Fiberfrax | 9160 | 0.047 | 8810 ↓ | 0.004 ↓ | 8850 — | 0.004 — |
| Microtherm | 2020 | 0.046 | 1800 ↓ | 0.003 ↓ | 1670 ↓ | 0.003 — |
| MinK | 653 | 0.111 | 657 — | 0.006 ↓ | 658 — | 0.005 — |
| WDS Shape | 709 | 0.077 | 725 — | 0.004 ↓ | 746 — | 0.003 — |
| Zircal | 112000 | 0.009 | 109000 — | 0.0002 ↓ | 110000 — | 0.0002 — |

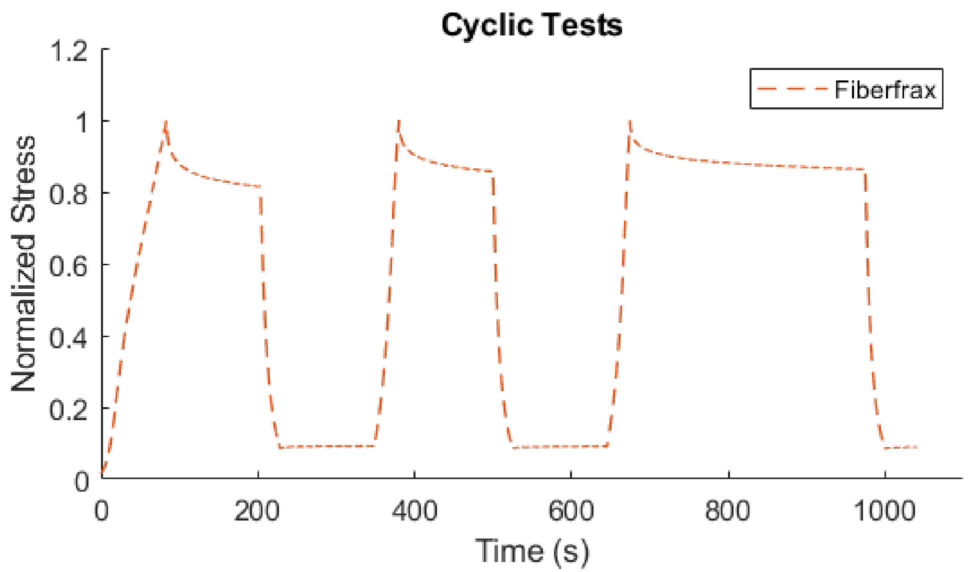
# STRESS VS TIME

All materials experienced some amount of stress relaxation

The amount of stress relaxation was greater in the first cycle than subsequent cycles

For some materials the stress relaxation continued to reduce with each cycle

Could account for variation seen in insitu closing force estimates




Percent Stress Relaxation

| Cycle | Duraboard | Fiberfrax | Microtherm | MinK | WDS Shape | Zircal |
|---|---|---|---|---|---|---|
| 1 | 20.6 | 18.7 | 4.9 | 2.5 | 4.7 | 5.3 |
| 2 | 16.6 | 15.1 | 3.5 | 1.2 | 3.0 | 3.8 |
| 3 | 16.2 | 13.6 | 3.9 | 1.5 | 2.8 | 3.0 |

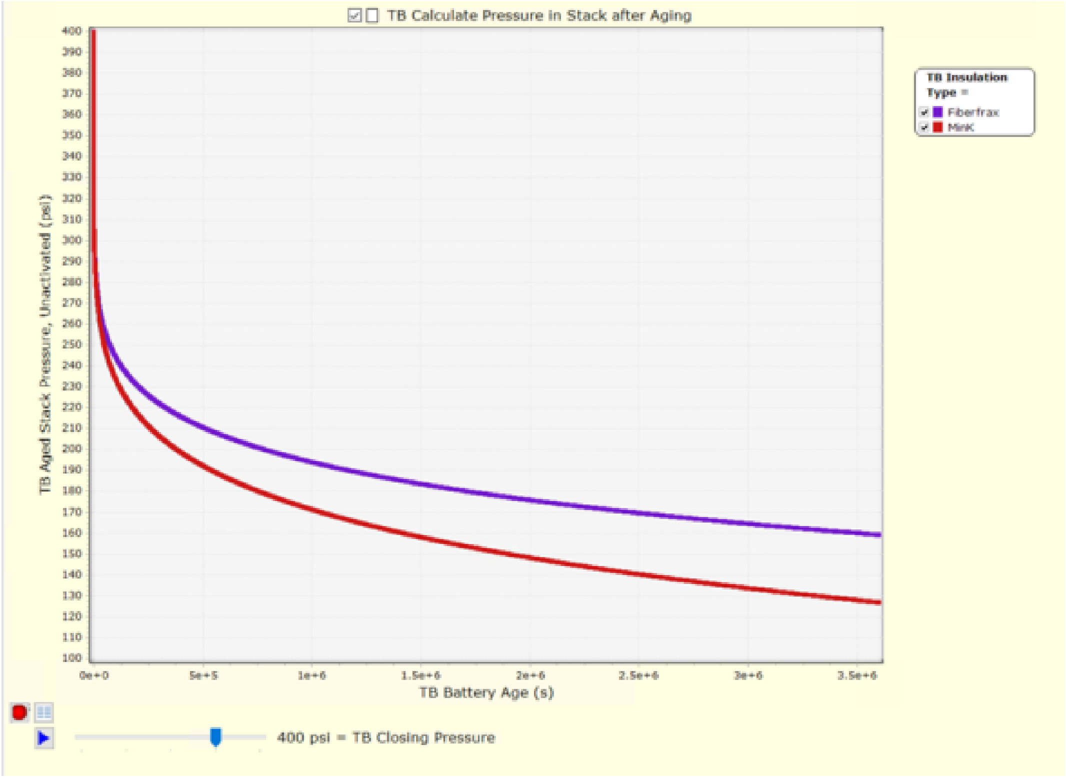
# IMPLICATIONS TO MODELING AND DESIGN

Number of cycles appears to influence amount of stress relaxation, recovery modulus, and amount of irrecoverable strain

Need to use material properties from later cycles in models

Number of cycles is variable among batteries in a build

The variation in the number of cycles can be accounted for as uncertainty within models, allowing for the designer to understand the range of closing forces expected as a battery design ages



# FUTURE WORK

Do some testing on radially confined samples to be representative of use case

Using the information gathered in this study to develop simple empirical models for aged stack pressure and pressure in stack after activation

Incorporate empirical models into set based tools for trade studies

Characterize stress relaxation over time in battery representative atmosphere

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# Questions?

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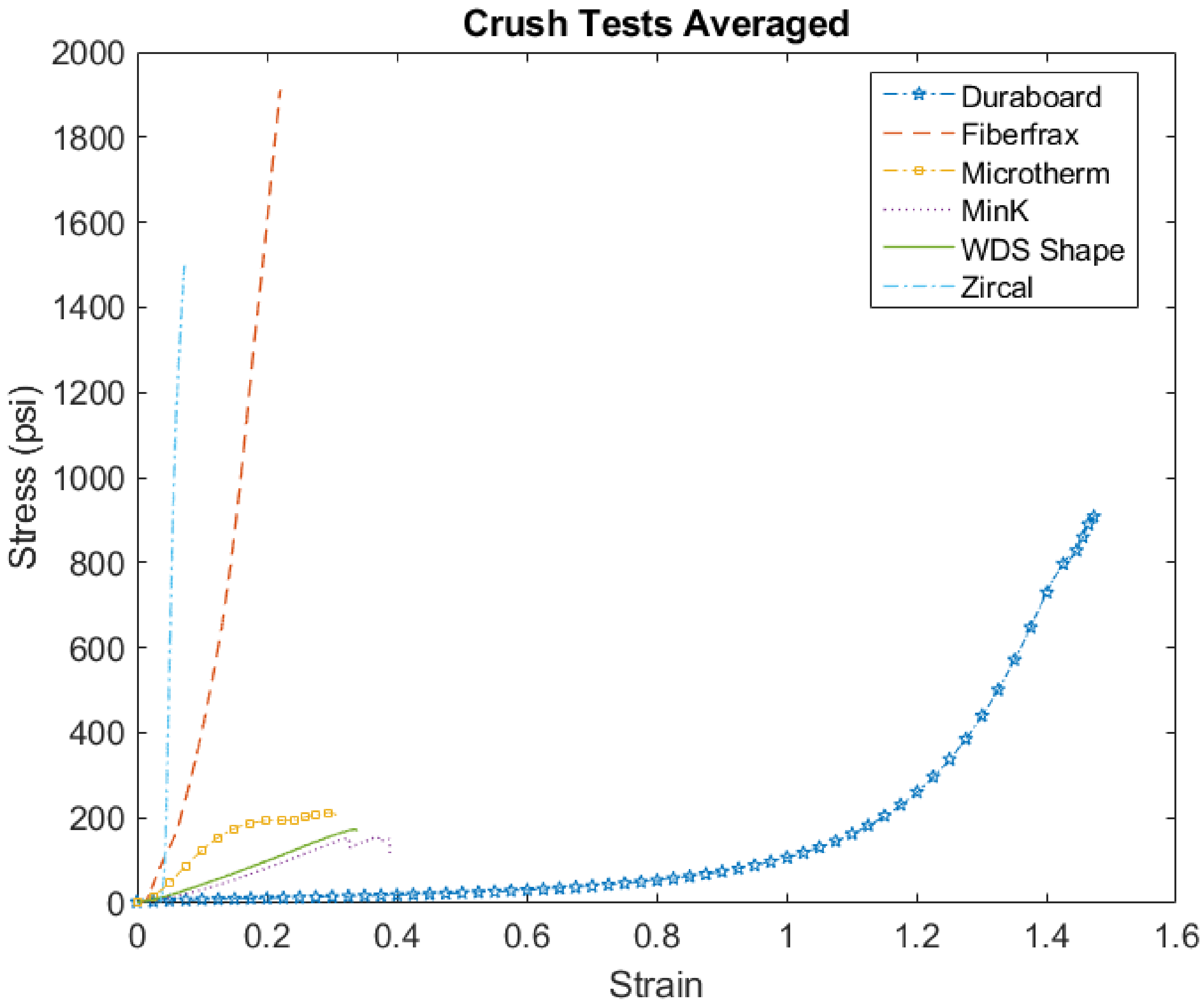
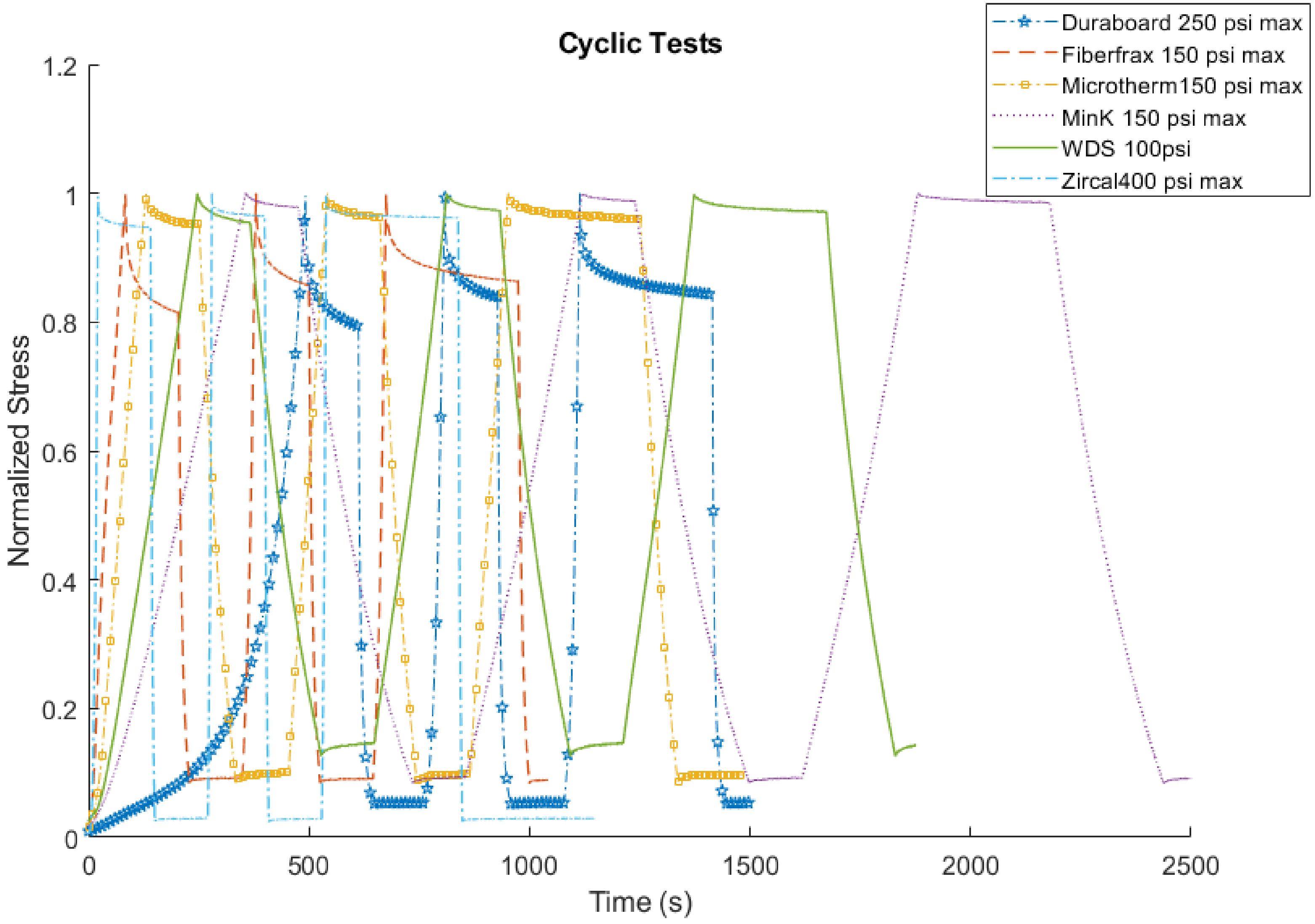
# BACKUP

# CRUSH TESTS


Crush Tests Averaged
Stress (psi)
Strain
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Duraboard
Fiberfrax
Microtherm
MinK
WDS Shape
Zircal


Cyclic Tests
Duraboard 250 psi max
Fiberfrax 150 psi max
Microtherm150 psi max
MinK 150 psi max
WDS 100psi
Zircal400 psi max
Normalized Stress
Time (s)
0
0.2
0.4
0.6
0.8
1
1.2
0
500
1000
1500
2000
2500