“Endurance” Regression Testing

Obtaining a Hydrostatic Design Basis for Fiberglass pipe

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The problem

- Lack of confidence in ASTM D2992 methods
- ISO14692, Shell DEP
  - Prescribing Regression Gradients
  - Requiring 100's of 1000 hour tests

Typical complaints of ASTM D2992-B static

1. All specimens are damaged

2. Multiple failure modes throughout the test, yet plotted as (1)

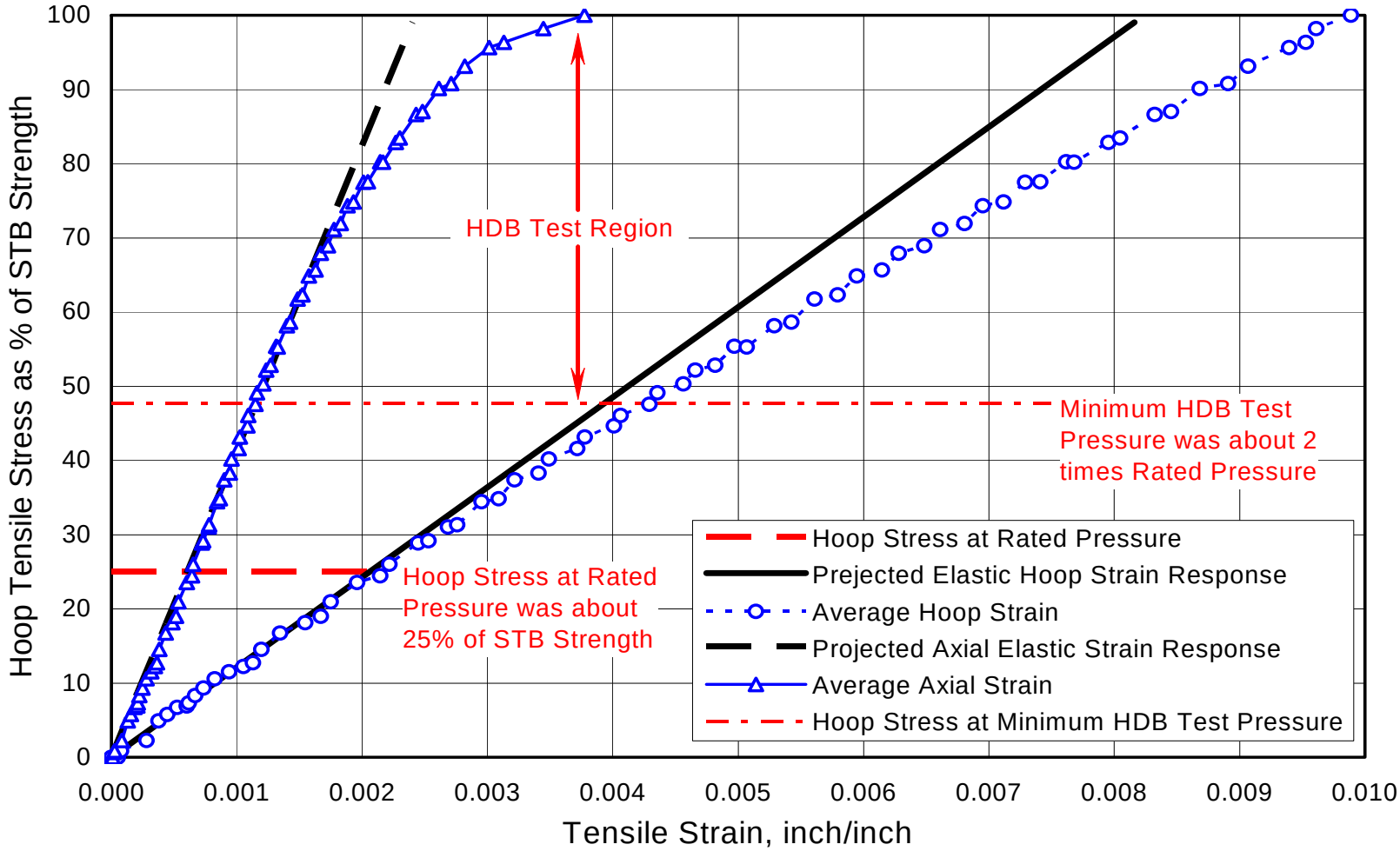
3. Extrapolating different and un-natural failure modes likely innaccurate

4. Data < 1000 hours dominates results *(most un-natural failure mode of pipe in operation)*

5. Time to failure is random, single data points at any given time
   difficult to gauge the reliability of a single failure

6. Testing near critical stress for so long, Un-avoidable to cycle (pressure /temperature)
   Cycles result in failures which otherwise would not have occurred. i.e. Power loss

ASTM D2992: (PEL) Test Damaged pipe to Predicting performance of undamaged pipe?



“Endurance” Regression Testing

- Modified ASTM D2992-B, maintaining the concept, eliminating some problems

- Endurance: The ability to withstand hardship or adversity; especially: the ability to sustain a prolonged stressful effort or activity

  – Stressful (bearable, not damaged)

Endurance Testing (concept)

- Choose aging pressure (PEL, traditional HDB, experience, other)
- Age all specimens at constant pressure
- Fail multiple specimens at known times
- Plan failure times, invite all (3rd party, end users, YOU!)

Concept continued

- On failure day: fail multiple specimens – ASTM D1599 *
  Average, standard deviation at each failure time, identify outliers

- Plot data (Aging pressure, Failure pressures Vs time)

- Extrapolate failure pressure

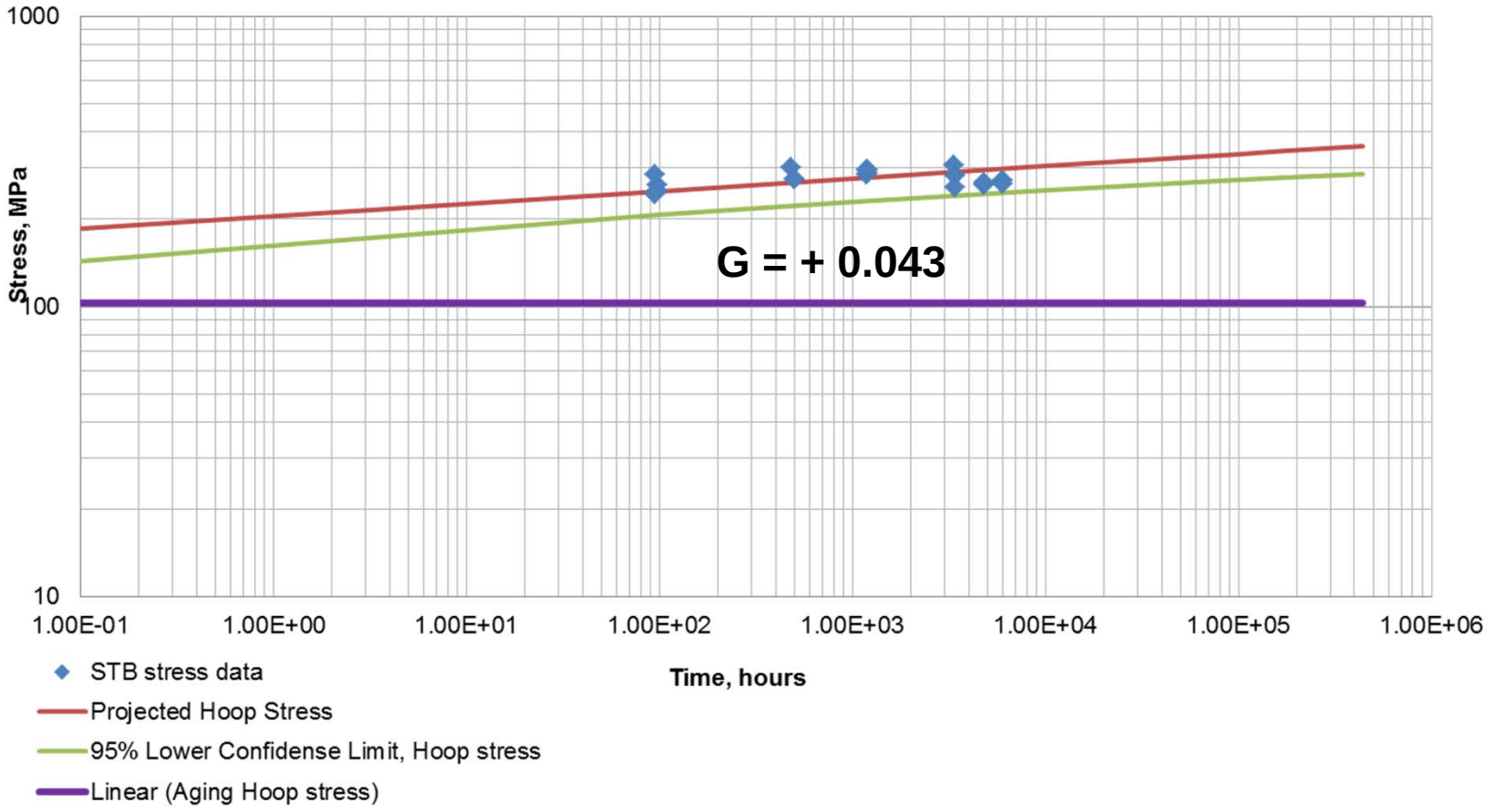
- Intersect failure/ aging pressure = life at constant age conditions

- **Specimens creep naturally / force fluids to diffuse into laminate**

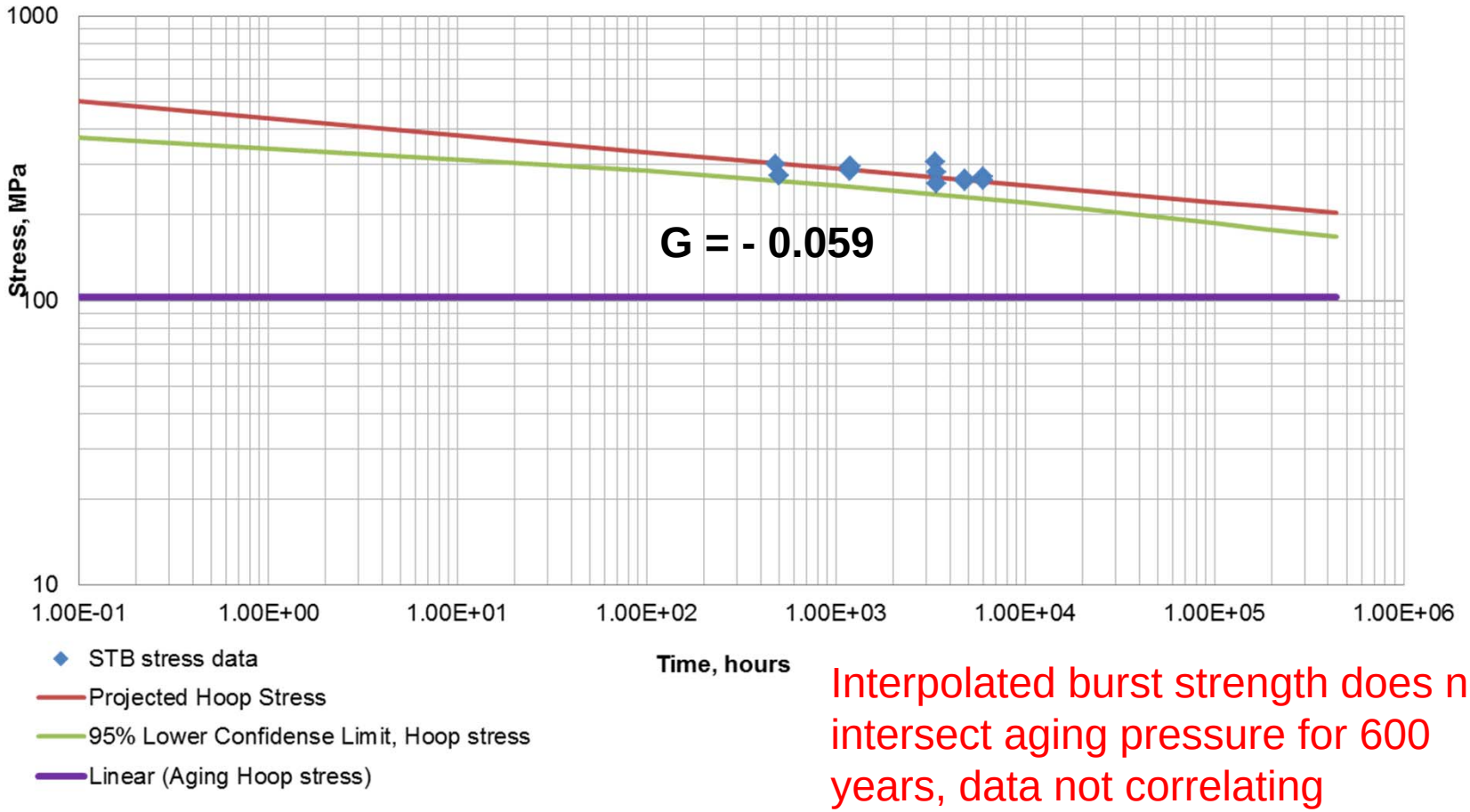
- **Degradation is natural nearer typical design conditions**

Prototype: 150F, 100 – 6000 hours

aging stress: HDB > (15KSI) > operating



Prototype: same data 500 – 6000 hours



Interpolated burst strength does not intersect aging pressure for 600 years, data not correlating

Discuss + regression slope

- Pipe gaining strength over time

- Possibilities:
  - Resin cures a bit further initial aging process?
  - Residual stress, resin shrinkage in cure, later swelling of resin with increased water saturation?
  - Plasticization of the inner resin layers, lowering Tg and modulus allowing greater strain before cracking?
  - Beneficial Creep, reinforcement aligns to suit loading conditions

Conclusion

- Fiberglass pipe rate of degradation is a function of :
  - Construction Materials
  - Strain
  - Chemical exposure
  - Temperature

- This method measures these effects in a more natural state

- Accurate fiberglass Regression Gradients
  = greater confidence in design
  = potential method evaluating remaining service life of installed pipe