Characterizing Uncertainty of Engineering Events: Deterministic Vs. Probabilistic Analysis of Mechanistic Damages and Failures

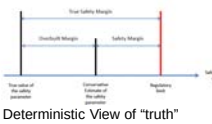
Mohammad Modarres
University of Maryland

Presented at the
29th Annual Regulatory Information Conference (RIC2017)
March 15, 2017

Topics

- Overview of deterministic and probabilistic evaluation of mechanistic failure data
- Decision making based on deterministic and probabilistic results
- Conclusions

Deterministic and Probabilistic Assessment of Integrity in Regulation



Deterministic View of "truth"

- An example of a regulatory limit in PTS: From "Alternate PTS Rule" in 10 CFR 50.61a that provides revised PTS criteria in form of an embrittlement reference temperature: $RT_{MAX\text{-}X}$ such as for $T_{wall} \leqq 9.5"$ should be $RT_{MAX\text{-}AxialWeld} \leqq 269$ °F.
- Another example of this Rule requires that number of flaws detected within the inner 1" (or 10% of the wall T_{wall}) with through-wall-extent in ranges $0.075" \leqq$ TWE $\leqq 0.475"$ be limited to 166.7 or less per 1000" of weld length.

Probabilistic View of "truth"

Probability that *True margin*, (D- δ), exceeds the *desired safety margin*,Δ, is expressed by:

$$Pr[(D-\delta) > \Delta] = \Pr[\delta < (D-\Delta)] = \int_0^{D-\Delta} f(\delta)d\delta$$

Deterministic Vs. Probabilistic Treatment of the Truth

- In deterministic analysis the "truth" is conservatively assessed--but the degree of conservatism remains unknown

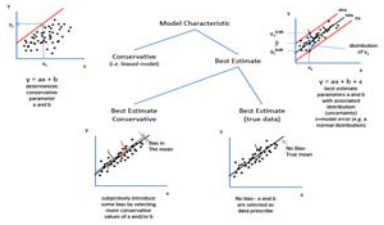
- Decision making is easy (i.e., you meet the criteria or not)
- The decision implies "right" and leads to "safe" outcome
- Reduces the burden on the decision maker
- If "right" the true margin would mostly be very large
- When "wrong" the regulator and licensee remain harmless

- In probabilistic analysis the best estimate of the "truth" is assessed in *light of the evidence available* by finding a distribution function that contains the truth - Degree of confidence is known and can be assessed

- Decision making is based on probability
- Probability of "right" decision and confidence over the decision is quantified given the evidence available
- More burden on both the regulator and licensee
- As new evidence becomes available the decision may need revision
- Results in more reasonable margins

Comparison Between Best Estimate and Conservative Models When Data Available

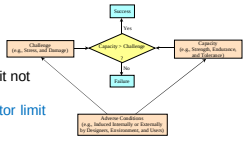
- When evidence is in form of data and assuming no uncertainty in data such as detection error and sizing errors:



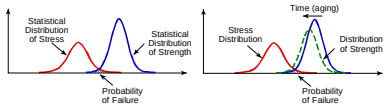
Probabilistic Framework for Mechanistic Failures and Regulatory Decision

- Failures occur when Challenge ≧Capacity
- Similarly regulatory limit not met when

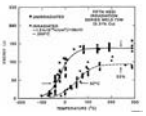
Safety Variable > Regulator limit



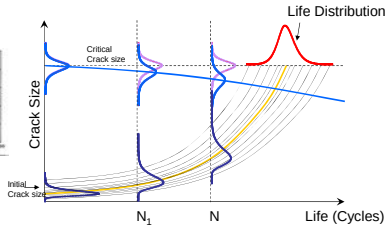
The Shock Model View of this Framework



Damage-Endurance Model



Embrittlement trend curves showing radiation-induced mean ΔT_{30} vs. neutron exposure and temperature



7

Conclusions

- "The only certainty is uncertainty"- John Allen Paulos.
- Conservative deterministic analyses also involve uncertainties, we just don't quantify them and pretend that they don't exist.
- We live in age of data and information. We have the tools, can and should bring all important pieces of information available and formally use them in decision making
- Advances in characterizing uncertainties in fracture mechanics models, input surveillance and tests data, and separating reducible and irreducible uncertainties are here and can be used effectively in regulatory decision making.
- Performing and using best estimate plus uncertainties is involved and requires training.
- Best estimate plus uncertainty results in major improvement in the quality and defense of the decision– governmental and private agencies have used them with much success (that includes NRC too).

8