Thermodynamic Treatment of Materials Damage

- If the system involves heat conduction, diffusion, chemical reaction and work of any form, the rate of total entropy per volume, \( \frac{dS}{dt} \), can be derived using the balance equation for entropy density change:

\[
\frac{dS}{dt} = \frac{dS}{dt}_{\text{Conduction}} + \frac{dS}{dt}_{\text{Diffusion}} + \frac{dS}{dt}_{\text{Diff}} + \frac{dS}{dt}_{\text{Chemical Reaction}} + \frac{dS}{dt}_{\text{Mechanical work}}
\]

where \( \frac{dS}{dt} \) is the vector of the total entropy flow per unit area across the boundary between the system and its surroundings by reversible processes, and \( \sigma \) is the entropy produced by the irreversible processes taking place inside the system.

Reliability Assessment Using Entropy as Index of Damage

- The evolution trend of the damage, \( D(t) \), is obtained from

\[
D(t) \sim \int_0^t \left( \int \left[ f(D(t)) \right] dD \right) dt
\]

where \( f(D(t)) \) is the time-to-failure distribution function, and the reliability function can be expressed as

\[
R(t) = \left[ \int g(T)dt \right] = 1 - \int_{D_f} f(D) dD
\]

The Degradation Modeling Validation

- The degradation modeling approach will be validated by modeling the corrosion-fatigue process.

- Summing the contributions of the mechanical and electrochemical processes, we can write the total entropy generation for combined effect of plastic deformation and anodic and cathodic dissolution as:

\[
\frac{dS}{dt} = \frac{\eta}{\Delta S} + \Pi \cdot \varphi + \tilde{A}_{\text{corr}}
\]

where \( \eta \) is the rate of corroded mass, \( \Delta S \) the difference between the sum of the entropies of the reactants and the products of the corrosion reaction, \( \Pi \) the deviationary part of stress, \( \varphi \) the rate of plastic strain, \( \tilde{A} \) the electrochemical plus mechanochemical potential losses, and \( \tilde{A}_{\text{corr}} \) is the corrosion rate.

Experimental Procedure

- When the specimen is exposed to corrosive environment the stress is applied with a material testing system under the action of cyclic load of constant amplitude.

- The specimens are divided into six groups, under six different conditions:
  - Dry air test, under elastic and plastic deformation conditions
  - Corrosion at open circuit potential, under elastic and plastic deformation conditions
  - Corrosion at pitting potential, under elastic and plastic deformation conditions

- Electrochemical measurement

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