AE 737: Mechanics of Damage Tolerance

Lecture 20 - Crack Retardation

Dr. Nicholas Smith

Wichita State University, Department of Aerospace Engineering

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1/18(#/)

schedule

- 16 Apr Crack Retardation
- 21 Apr Exam Review, HW8 Due
- 23 Apr Exam 2
- 28 Apr Damage Tolerance

outline

• crack growth retardation

crack growth retardation

crack growth retardation

- When an overload is applied, the plastic zone is larger
- This zone has residual compressive stresses, which slow crack growth until the crack grows beyond this over-sized plastic zone

crack growth retardation

- We will discuss three retardation models, but no model has been shown to be perfect in all cases
- The Wheeler method reduces da/dN, the Willenborg model reduces ΔK , and the Closure model increases R (increases σ_{min})

wheeler retardation

- As long as crack is within overload plastic zone, we scale da/dN by some ϕ ($a_i + r_{pi}$)= $(a_{ol} + r_{pol})$
- And ϕ is given by

$$\phi_i = \left[rac{r_{pi}}{a_{ol} + r_{pol} - a_i}
ight]^m$$

 \bullet and the constant, m is to be determined experimentally

wheeler example

- (p. 340), A wide edge-cracked panel (β = 1.22) has an initial crack length of 0.3 inches. Use p = 3.5, m_T = 32 and q = 0.6 to grow a crack for two load cases. Use the Wheeler retardation model with m = 1.43, a plane stress plastic zone, and σ_{YS} = 68 ksi.

wheeler example (cont)

• Case 2: σ_{max} = 18 ksi and σ_{min} = 3.6 ksi for 6,000 cycles, followed by one cycle of σ_{max} = 27 ksi and σ_{min} = 5.4 ksi, followed by another 6,000 cycles of σ_{max} = 18 ksi and σ_{min} = 3.6 ksi.

willenborg retardation

- Once again, we consider that retardation occurs when $(a_i + r_{pi}) = (a_{ol} + r_{pol})$
- Willenborg assumes that the residual compressive stress in the plastic zone creates an effective, $K_{max, eff}$, where $K_{max, eff} = K_{max} K_{comp}$
- The effective stress intensity factor is given by

$$K_{max,eff} = K_{max,i} - \left[K_{max,OL}\sqrt{1-rac{\Delta a_i}{r_{pol}}} - K_{max,i}
ight]$$

gallagher and hughes correction

- Galagher and Hughes observed that the Willenborg model stops cracks when they still propagate
- They proposed a correction to the model

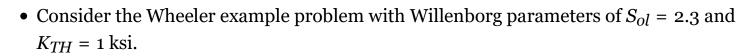
$$K_{max,eff} = K_{max,i} - \phi_i \left[K_{max,OL} \sqrt{1 - rac{\Delta a_i}{r_{pol}}} - K_{max,i}
ight]$$

gallagher and hughes correction

• And the correction factor, ϕ_i is given by

$$\phi_i rac{1-K_{TH}/K_{max,i}}{s_{ol}-1}$$

willenborg example



closure model

- ullet Once again, we consider that retardation occurs when $(a_i + r_{pi}) = (a_{ol} + r_{pol})$
- Within the overloaded plastic zone, the opening stress required can be expressed as $\sigma_{OP} = \sigma_{max}(1-(1-C_{f0})(1+0.6R)(1-R))$

closure model

ullet Commonly this is expressed using the Closure Factor, C_f

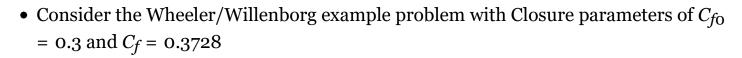
$$C_f = rac{\sigma_{OP}}{\sigma_{max}} = (1 - (1 - C_{f0})(1 + 0.6R)(1 - R))$$

• Where C_{f0} is the value of the Closure Factor at R=0

closure model

- ullet When using the closure model, we replace R with C_f
- If the model we are using is in terms of ΔK we will also need to use $\Delta K = (1 C_f)K_{max}$

closure example



under-loads

- We might expect a compressive "underload" to accelerate crack growth
- This effect is not usually modeled for a few reasons
 - 1. Compressive underloads are uncommon in airframes
 - 2. The acceleration effect is minimal
 - 3. Analysis is generally adjusted with experimental data, so acceleration can be built in to current model
 - 4. Structures with large compressive loads are not generally subject to crack propagation problems