AE 737: Mechanics of Damage Tolerance

Lecture 18 - The Boeing Method

Dr. Nicholas Smith

Wichita State University, Department of Aerospace Engineering

31 March 2022

schedule

- 31 Mar - Boeing Method, HW 6 Due
- 5 Apr - Cycle counting
- 7 Apr - Crack Retardation, HW 7 Due, HW 6 Self-grade Due
- 12 Apr - Crack retardation
- 14 Apr - Finite Elements in Fracture, HW 8 Due, HW 7 Self-grade Due
- 19 Apr - Exam Review
- 21 Apr - Exam 2

outline

- boeing method

boeing method

boeing method

- Whether integrating numerically or analytically, it is time-consuming to consider multiple repeated loads
- It is particularly difficult to consider flight loads, which can vary by "mission"
- For example, an aircraft may fly three different routes, in no particular order, but with a known percentage of time spent in each route
- Traditional methods would use a random mix of each load spectra

boeing method

- The Boeing Method combines each repeatable load spectrum into one single equivalent cycle
- Note: this is ch. 20 in the text

boeing method

- The Boeing method is derived by separating the geometry effects from load and material effects in the Boeing-Walker equation.

$$\frac{da}{dN} = \left[\frac{1}{n}\right] \frac{dL}{dN} = 10^{-4} \left[\frac{k_{max} Z}{m_T}\right]^p$$

$$\frac{dL}{dN} = n10^{-4} \left[\frac{k_{max} Z}{m_T}\right]^p$$

$$\frac{dN}{dL} = \frac{1}{n} 10^4 \left[\frac{m_T}{k_{max} Z}\right]^p$$

boeing method

$$\int_0^N dN = \frac{10^4}{n} \int_{L_0}^{L_f} \left[\frac{m_T}{k_{max} Z}\right]^p dL$$

$$N = 10^4 \left(\frac{m_t}{z\sigma_{max}}\right)^p \int_{L_0}^{L_f} \frac{dL}{\left(n\sqrt{\pi L/n}\beta\right)^p}$$

boeing method

- In this form, the term $10^4 \left(\frac{m_t}{z\sigma_{max}}\right)^p$ is strictly from the applied load and material, while $\int_{L_0}^{L_f} \frac{dL}{\left(n\sqrt{\pi L/n}\beta\right)^p}$ is from geometry
- If we now define G to account for crack geometry

$$G = \left[\int_{L_0}^{L_f} \frac{dL}{\left(n\sqrt{\pi L/n}\beta\right)^p}\right]^{-1/p}$$

boeing method

- And define $z\sigma_{max} = S$ as the equivalent load spectrum, then we have

$$N = 10^4 \left(\frac{m_t/G}{S}\right)^p$$

- Using this method, G is typically looked up from a chart (such as on p. 369)

boeing method

- To replace a repeated load spectrum with an equivalent load, we need to invert the relationship
- The previous equation gives cycles per crack growth, inverting gives crack growth per cycle

$$\text{crack growth per cycle} = 10^{-4}\left(\frac{m_t/G}{S}\right)^{-p}$$

boeing method

- If we consider a general, repeatable "block", we have

$$10^{-4}\left(m_t/G\right)^{-p}\sum_i\left(\frac{1}{z\sigma_{max}}\right)_i^{-p}N_i = 10^{-4}\left(\frac{m_t/G}{S}\right)^{-p}$$

- Which simplifies to

$$\sum_i (z\sigma_{max}) = S^p$$

boeing method example

- (from p. 366), $q = 0.6$, $p = 3.9$

boeing method example - cont.

Count cycles from the right (instead of the left)