Acoustic Emission Monitoring of Precursor Damage

John C. Duke, Jr.
Damage Science and Mechanics Lab
Virginia Tech
jcduke@vt.edu
Presentation Overview

• Background and Motivation
  – Nature of Fatigue Performance
  – Safe-life Design

• Review of 7075 AE response

• Transitions in modes of micromechanical damage development
7075 Al is an alloy used for aircraft structural applications

Understanding how it responds to sustained and cyclic loads is important.

Acoustic Emission has been used to study this alloy for more than 30 years.
Fatigue Performance of Materials varies

![Graph showing the relationship between stress amplitude and cycles to failure for 7075-T6 material.](image-url)
Damage development begins with the 1\textsuperscript{st} cycle

Life: 1.1 million cycles
(N=0 \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow failure \rightarrow )

\begin{align*}
N = 0 & \quad 10^4 & \quad 2 \times 10^4 & \quad 6 \times 10^4 & \quad 10^5 & \quad 2 \times 10^5 \\
\end{align*}

50 \mu m
Tensile Testing Configuration
Precipitate particles impede dislocation movement
AE: precipitate particles removed

- Moving dislocations
- Fracture of particles

Graph showing the relationship between True Root Mean Square Voltage (volts) and Load (kg) over time (min) for 7075 Solution Treated material.
7075 Al: dislocation movement during yielding and inclusion particles fracture during plastic deformation peaking at 3-5% strain
Dislocation mechanisms are responsible for the peak at yield and the spikes at 12.25% strain when load drops occur.
7475 Al: reduced inclusions

Precipitates impede dislocation movement

Much less emission from fractured inclusion particles
Precipitates removed

7475 Solution Treated

True Root Mean Square Voltage (volts)

Load (kg)

Time (min)
Critical transition points in the damage development process

1. Yield
2. Peak of inclusion particle fracture (not obvious in load displacement plot)
3. Discontinuous plastic deformation
4. Ultimate load/point of localized deformation (neck)

These critical points discerned during quasi-static tension are almost certainly important as regards damage development due to cyclic loading. The effects of strain rate are important and still require further study. Simply monitoring stress/strain behavior does not provide the same insight; especially for non-uniform loads such as in real structures.
Transitions in damage development
Stress-strain..... AE-strain

Loading & Acoustic Response of Specimen 2

Load [kN]  RMS (V)

Ultimate Load
AE of Solution treated 7075

~12.5% strain

necking
AE monitoring during loading of cracked specimen
Summary

• AE monitoring allows tracking of damage development in addition to crack growth.
• AE monitoring of dislocation related damage development in metal alloys offers possible insight into critical transition points in the damage development process.
• Improved instrumentation and additional testing needed to fully exploit this capability.
Questions?

Comments!

Contact Info:  John C. Duke, Jr.
Damage Science and Mechanics Lab
Virginia Tech
e-mail: jcduke@vt.edu