The Purpose of Generating Fatigue Crack Growth Threshold Data

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Overview

- NASA Applications
- Laboratory Data
- Summary
NASA Applications

- Space Shuttle Main Engine Thrust Structure
- Ti-6Al-4V Titanium
- High Cycle Fatigue
  - Launch Vibration
- Threshold used as design allowable
  - All $\Delta K$ values below $\Delta K_{th}$
High Cycle Fatigue (HCF) Components. Fracture critical components operating in a potential HCF environment...

The metallic component is acceptable if the calculated HCF stress intensity is below the stress intensity factor threshold for the metallic material.
Design Threshold Data

<table>
<thead>
<tr>
<th>Data ID</th>
<th>R</th>
<th>Thk</th>
<th>Spec Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>P3EA21AB01C3</td>
<td>0.1</td>
<td>0.25</td>
<td>C(T)</td>
</tr>
<tr>
<td>P3EA21AB01D3</td>
<td>0.1</td>
<td>0.25</td>
<td>C(T)</td>
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<td>P3EA21AB01D2</td>
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<td>C(T)</td>
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<td>C(T)</td>
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<td>C(T)</td>
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</table>

Ti-6Al-4V MA
C(T), W = 2”, B = 0.25”
Room Temp, Lab Air

Recent Threshold Testing

- Threshold testing completed on Ti-6-4 MA specimens to compare threshold values between C(T), ESE(T), M(T) & SM(T) designs
Short Middle Through Crack Specimen

SM(T)

- Crack has less tendency to turn compared to the C(T) specimen
- Specimen has high stiffness - allowing high cyclic frequency
- Requires much less material than for an M(T) specimen.

Comparison of W = 3” C(T) specimen with W = 3.4” SM(T) specimen.
SM(T) Threshold Data

Ti-6Al-4V MA
SM(T), W = 3.4”, B = 0.25”
Room Temp, Lab Air

Forman, R.G., unpublished
Effect of Specimen Geometry on $R = 0.1$ Threshold

Ti-6Al-4V MA
Room Temp, Lab Air

Forman, R.G., unpublished
Effect of Specimen Geometry on $R = 0.7$ Threshold

Ti-6Al-4V MA
Room Temp, Lab Air

Forman, R.G., unpublished
### Ti-6Al-4V MA Thresholds

<table>
<thead>
<tr>
<th>R Value</th>
<th>Specimen Type</th>
<th>$\Delta K_{th}$ (ksi in$^{1/2}$)</th>
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<tbody>
<tr>
<td>0.1</td>
<td>C(T)</td>
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<tr>
<td></td>
<td>M(T)</td>
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<tr>
<td></td>
<td>ESE(T)</td>
<td>3.9</td>
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<tr>
<td></td>
<td>SM(T)</td>
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<tr>
<td>0.7</td>
<td>C(T)</td>
<td>2.4 / 2.1</td>
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<tr>
<td></td>
<td>M(T)</td>
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<tr>
<td></td>
<td>ESE(T)</td>
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<tr>
<td></td>
<td>SM(T)</td>
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</table>
Specimen Configuration Effects

Constant $K_{\text{max}}$ Data

Specimen Configuration Effects at Threshold

Specimen Configuration Effects at Threshold

Low Carbon Steel
R = 0.1

Summary

- Test data shows that different width and thickness C(T), M(T) and ESE(T) specimens generate different thresholds.
- Structures designed for “infinite life” are being re-evaluated:
  - Threshold changes from 6 to 3 ksi in\(1/2\)
  - Computational life changes from infinite to 4 missions
- Multi-million dollar test programs required to substantiate operation
- Using ASTM E647 as standard guidance to generate threshold data is not practical

- A threshold test approach needs to be standardized that will provide positive margin for high cycle fatigue applications