Reliability for the 21st Century: Meeting Challenges of New Technologies and New Markets

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NCCAVS symposium, February 22, 2018
Smaller Features
High Complexity
Electronics everywhere

New use conditions
How to define qualification criteria to continuously meet customer’s Q&R needs when technology is rapidly changing?
Reliability response choices

Standards (Stress) Based Qualification (SBQ)
- Product is “as good” as past products
- “We did the same as the rest of the industry”

Knowledge Based Qualification (KBQ)
- Product engineered for real usage
- “We did what was necessary to protect the customer”

Qual requirements
Standards
Car Usage

Accounting for UC

Standards → Reality

Real Workload

Real Environment

Real User Behavior

Standards not capturing real use conditions

Prob. Distr. of car trips start times
<table>
<thead>
<tr>
<th>Name</th>
<th>Empirical acceleration model/equation</th>
<th>Primary stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffin-Manson 1950s</td>
<td>$\frac{N_{use}}{N_{test}} = \left( \frac{\Delta T_{use}}{\Delta T_{test}} \right)^{-n}$</td>
<td>$\Delta T$</td>
</tr>
<tr>
<td>Norris-Landzberg 1968</td>
<td>$\frac{N_{use}}{N_{test}} = \left( \frac{\Delta T_{use}}{\Delta T_{test}} \right)^{-n} \left( \frac{f_{use}}{f_{test}} \right)^{m} e^{\left[ \frac{1414}{T_{hi,use}} - \frac{1}{T_{hi,stress}} \right]}$</td>
<td>$\Delta T, T_{max}$,</td>
</tr>
<tr>
<td>Peck 1983</td>
<td>$\frac{N_{use}}{N_{test}} = \left( \frac{RH_{use}}{RH_{test}} \right)^{-n} \text{ Exp} \left( \frac{E_a}{k} \right) \left[ \frac{1}{T_{use}} - \frac{1}{T_{test}} \right]$</td>
<td>RH-relative humidity</td>
</tr>
</tbody>
</table>
ACCOUNTING FOR SYSTEM BOUNDARY CONDITIONS

Ex: FLI qualification

Reliability Risk Assessment vs. Field Risk

Qual Requirements

\[ N_{use} = N_{stress} \left( \frac{\Delta T_{use}}{\Delta T_{stress}} \right)^{-n} \]

Not impacted by brd. thickness

Use Condition Risk

Impacted by board thickness

Challenge
## Accounting for Geometry (FF)

### Example: Solder Joint T-M qualification

**Geometry A**

- Solder Joint (SJ)

**Geometry B**

### Qualification Requirement

\[
N_{use} = \left( \frac{\Delta T_{use}}{\Delta T_{test}} \right)^{-n} \left( \frac{f_{use}}{f_{test}} \right) e^{\left[ \frac{1}{4414} \left( \frac{1}{\lambda_{use}} - \frac{1}{\lambda_{test}} \right) \right]}
\]

**Use Condition Risk**

<table>
<thead>
<tr>
<th>Requirement (A)</th>
<th>Requirement (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not a function of FF</td>
<td>A function of FF</td>
</tr>
</tbody>
</table>

- SJ damage (A) >> SJ damage (B)
### ACCOUNTING FOR ACTUAL USE CONDITIONS

#### Ex. T-M FLI qual

<table>
<thead>
<tr>
<th>Use Condition</th>
<th>Empirical Acc. Model</th>
<th>Requirements ($N_{stress}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed</td>
<td>$\frac{N_{use}}{N_{stress}} = (\frac{\Delta T_{use}}{\Delta T_{stress}})^{-n}$</td>
<td>750 TCB</td>
</tr>
<tr>
<td>Measured UC</td>
<td>$\frac{N_{use}}{N_{stress}} = (\frac{\Delta T_{use}}{\Delta T_{stress}})^{-n}$</td>
<td>It depends!!</td>
</tr>
</tbody>
</table>

**It depends!!**

**Extreme sensitivity to sampling rate!**

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**CHALLENGE**
<table>
<thead>
<tr>
<th>Empirical Acc. Equations</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not account for FF (architecture, geometry, materials)</td>
<td>Defined in terms of applied stress, like $\Delta T$</td>
</tr>
<tr>
<td>Do not account for system boundary condition</td>
<td>Applied stress is often a very remote proxy for damage/failure</td>
</tr>
<tr>
<td>Have difficulties accounting for measured UC</td>
<td>$\text{Damage} = f(\text{applied stress, FF, system BC, materials...})$</td>
</tr>
</tbody>
</table>
How to get closer to **damage**?
Example: Solder Joint (SJ) qual in temp.cycling (TC)

Use Conditions

Accelerated Test

Temp. Use Conditions

Damage (D)

Test Condition

N=?

New Application of Computational Modeling: Definition of Qualification Requirements

M. Pei, et. al, “Define Electrical Packing Temperature Cycling Requirement with Field Measured User Behavior Data”, ECTC 2013, PP159-65

<table>
<thead>
<tr>
<th>Approach</th>
<th>Metric</th>
<th>Use Conditions</th>
<th>Acceleration equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBQ</td>
<td>Applied stress: $\Delta T$</td>
<td>Representative user</td>
<td>MTTF vs. $\Delta T$</td>
</tr>
<tr>
<td>KBQ</td>
<td>PoF metric (ex: ISED)</td>
<td>Field measured users</td>
<td>MTTF vs. ISED</td>
</tr>
</tbody>
</table>

**KBQ:** Based on the PoF metrics and measured use conditions. Predictive modeling/simulation are necessary to overcome the limitations of empirical reliability models.
KBQ: Realistic Account of use conditions

M. Pei, M. Vujosevic, S. Mukherjee, “Knowledge Based Requirement Calculation for Server BGAs Temperature Cycling (TC) Qualification”, ASME InterPACK2017, San Francisco, CA August 29-Sept 1, 2017
<table>
<thead>
<tr>
<th>FF</th>
<th>SBQ UC: 5cycles/day</th>
<th>KBQ UC: measured</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1135 TCT</td>
<td>375 TCT</td>
</tr>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td>1135 TCT</td>
<td>95 TCT</td>
</tr>
<tr>
<td><img src="image2.png" alt="Image" /></td>
<td>1135 TCT</td>
<td>210 TCT</td>
</tr>
</tbody>
</table>

Geometry drives requirements
KBQ: Accounting for system BC

Adhesive properties drive requirements

Conclusions
The new reliability frontier is knowledge based

Standards must evolve to meet the needs of the 21st century