BOARD, PACKAGE AND DIE THICKNESS EFFECTS UNDER THERMAL CYCLING CONDITIONS

APT2 Session: BGA Reliability
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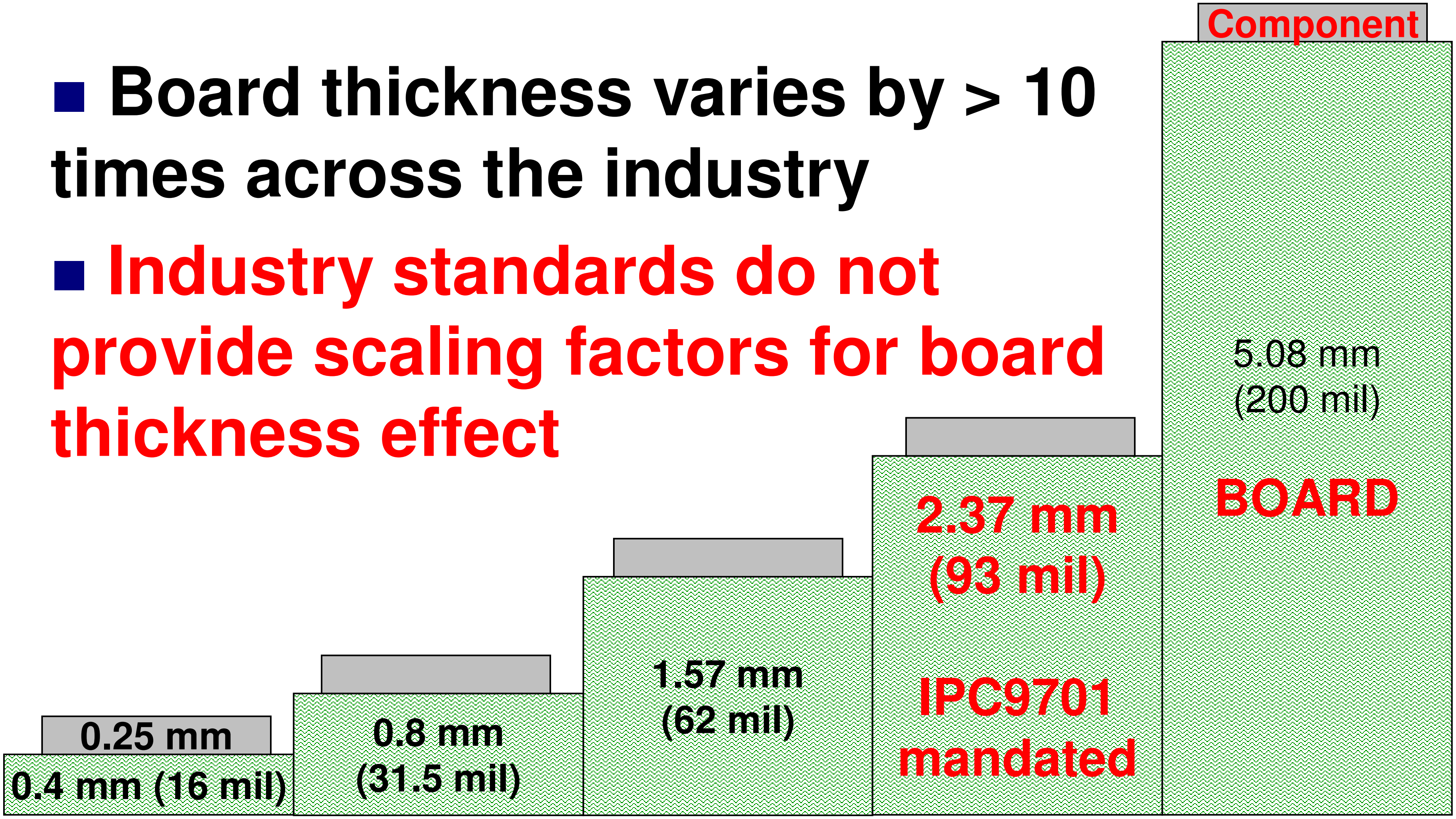
Outline

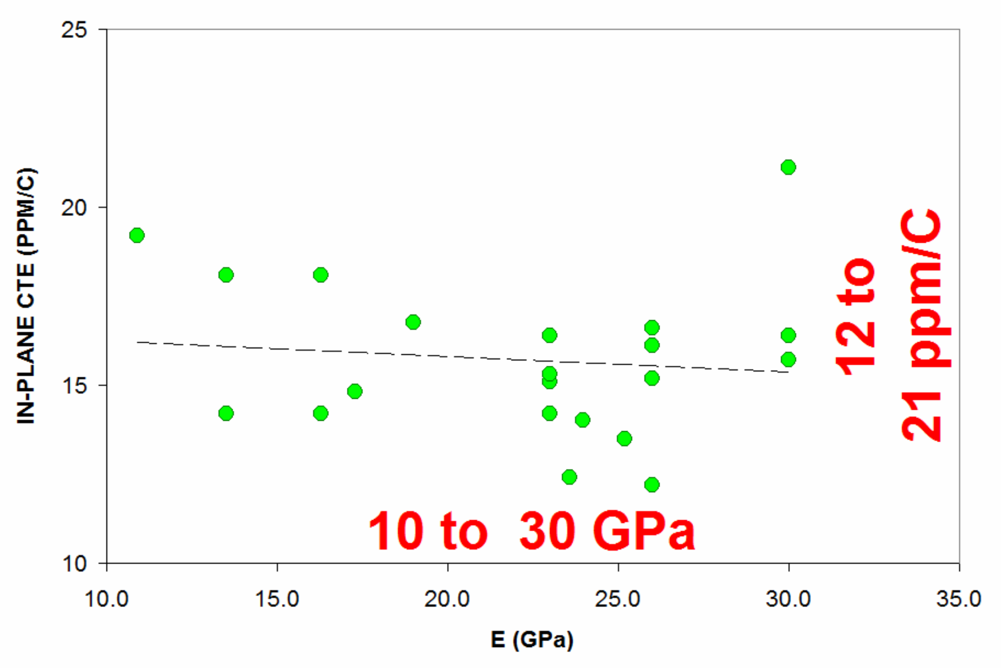
- Board thickness problem
- Model description
- Validation examples
- Conclusions
- Q & A

Board thickness problem (1)

- Board thickness varies by > 10 times across the industry
- Industry standards do not provide scaling factors for board thickness effect



Board thickness problem (2)



- Board effective CTEs and Young’s moduli change with board thickness
- Contrary to popular belief, there is no “typical properties” of FR-4 boards

Board thickness model (1)

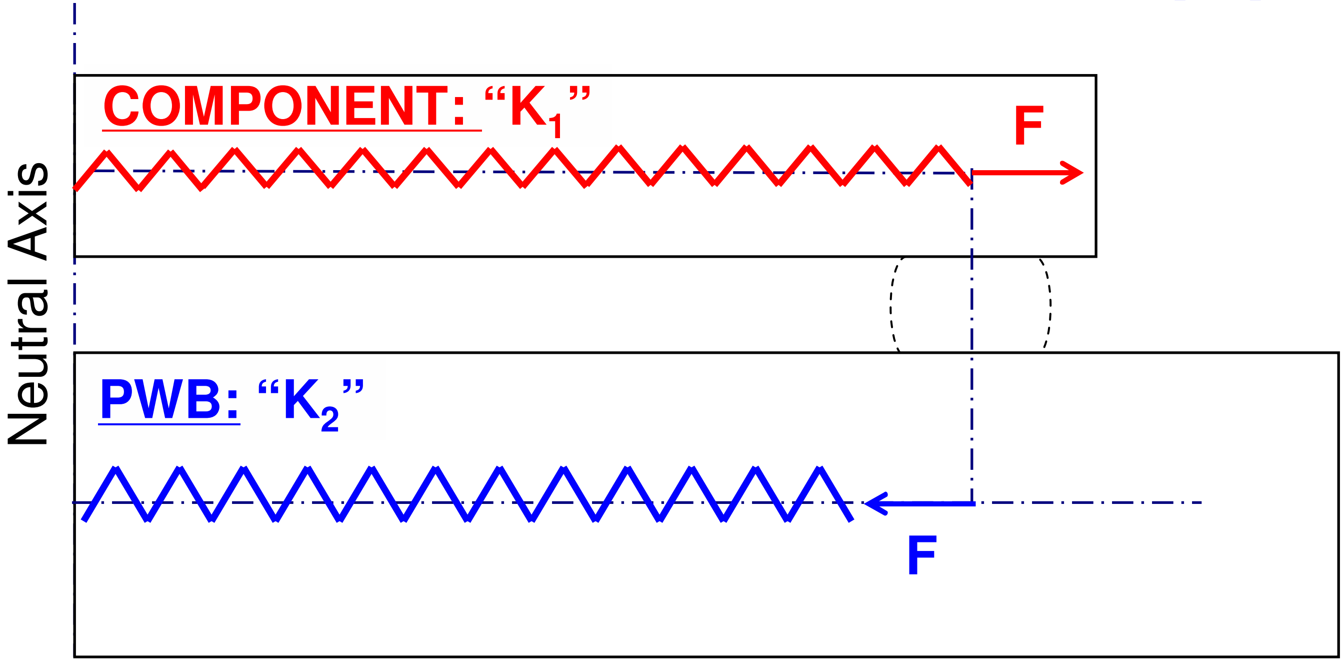
From strain energy models for SnPb and Pb-free assemblies (Clech et al., 1996, 2004, 2009), and as a first order approximation, cycles to failure N_f go as:

$$N_f \sim 1 / [K * (\Delta\alpha)^2]$$

where the parameters that control the board thickness effect are:

- K = assembly stiffness
- $\Delta\alpha$ = Board-to-component CTE mismatch

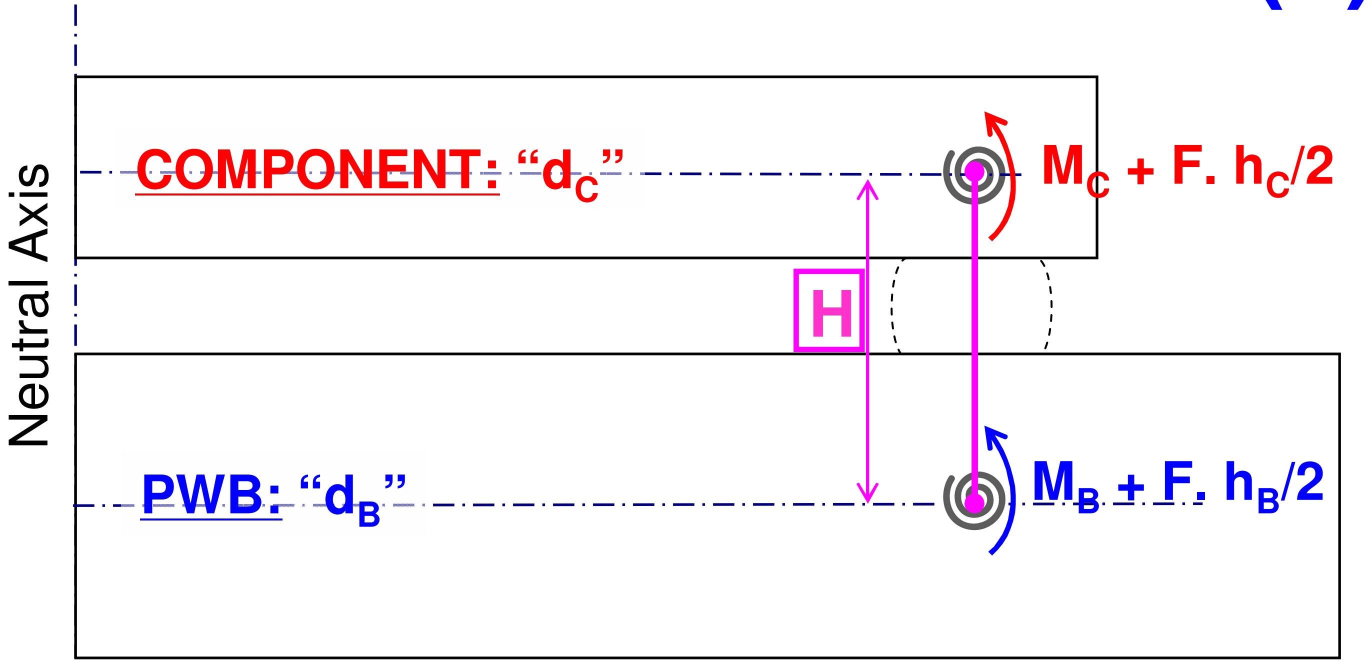
Board thickness model (2)



For single-sided assembly, K is the stiffness of three springs in series:

- K_1: component stretching stiffness
- K_2: board stretching stiffness

Board thickness model (3)



- K_3: bending stiffness of board and component bi-metallic strip
  - ☐ d_C and d_B are board and component flexural rigidity factors

Board thickness model (4)

- **For single-sided assemblies:**

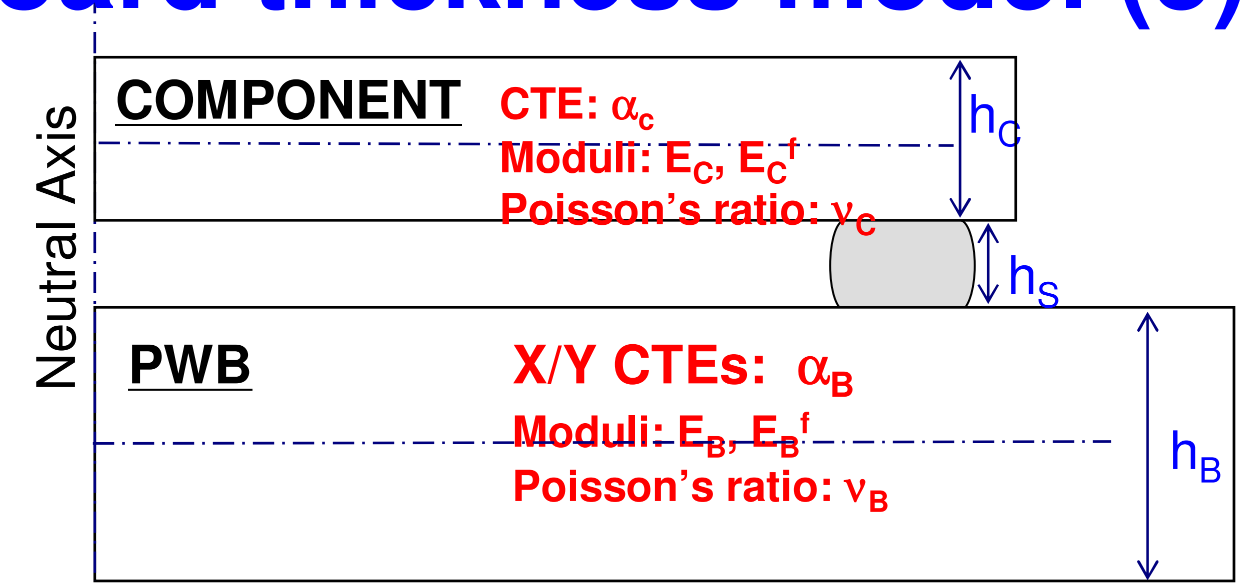
$$H = \frac{h_C}{2} + h_S + \frac{h_B}{2}$$

$$N_f = F \cdot \frac{\boxed{\frac{1-\upsilon_C}{E_C h_C}} + \boxed{\frac{1-\upsilon_B^2}{2E_B h_B}} + \boxed{\frac{H^2}{\frac{E_C^f h_C^3}{12\left(1-\upsilon_C\right)} + \frac{E_B^f h_B^3}{6\left(1-\upsilon_B^2\right)}}}}{\Delta\alpha^2}$$

N_1 from component axial compliance **+** **N_2 from board axial compliance** **+** **N_3 from assembly flexural compliance**

F = model calibration factor (for given component size and thermal cycle)

Board thickness model (5)



COMPONENT

CTE: α_C
Moduli: E_C, E_C^f
Poisson's ratio: ν_C

PWB

X/Y CTEs: α_B
Moduli: E_B, E_B^f
Poisson's ratio: ν_B

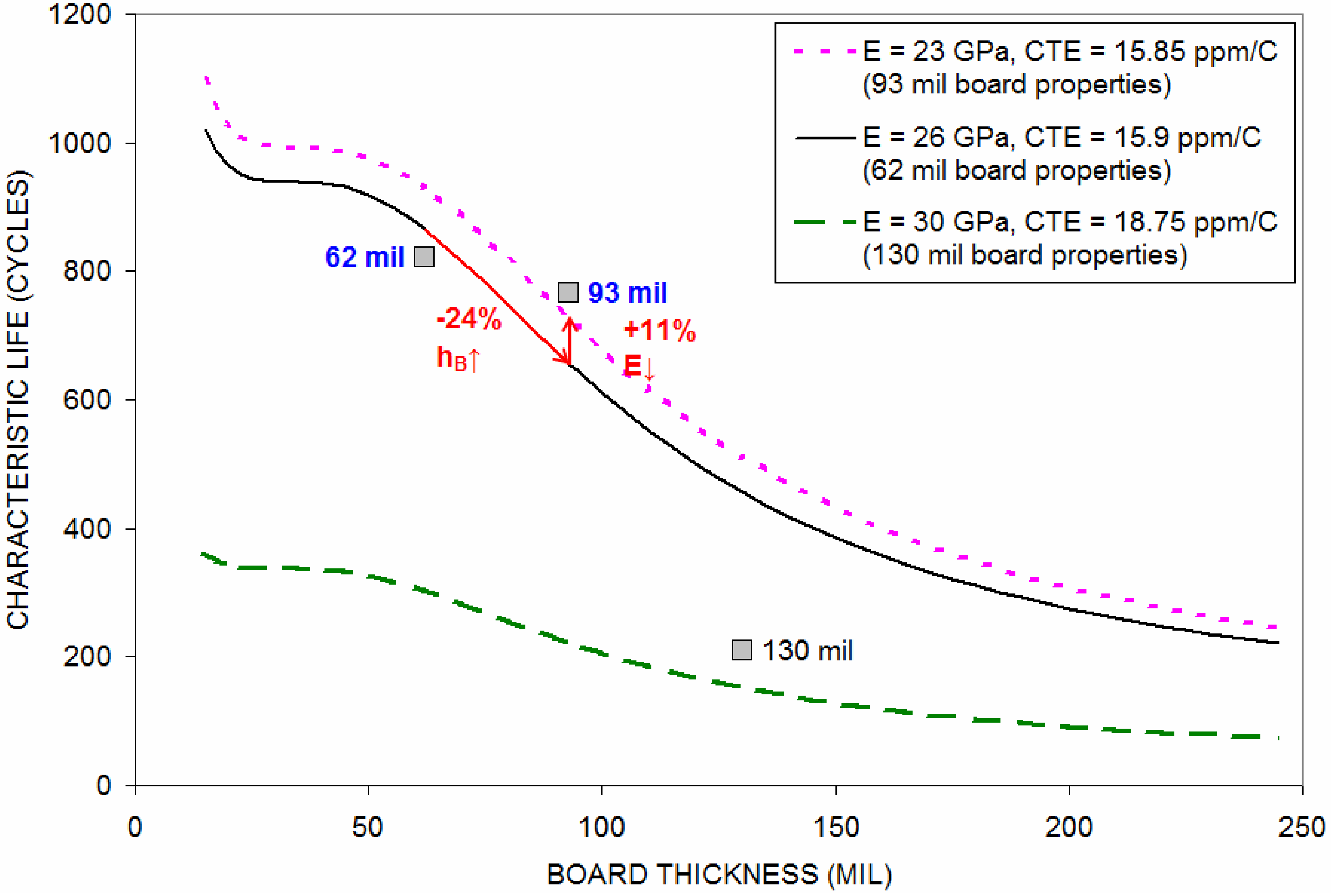
- **For double-sided assemblies:**

$$N_f = F \cdot \frac{\boxed{\frac{1-\upsilon_C}{E_C h_C}} + \boxed{\frac{1-\upsilon_B^2}{E_B h_B}}}{\Delta\alpha^2}$$

N_1 + N_2

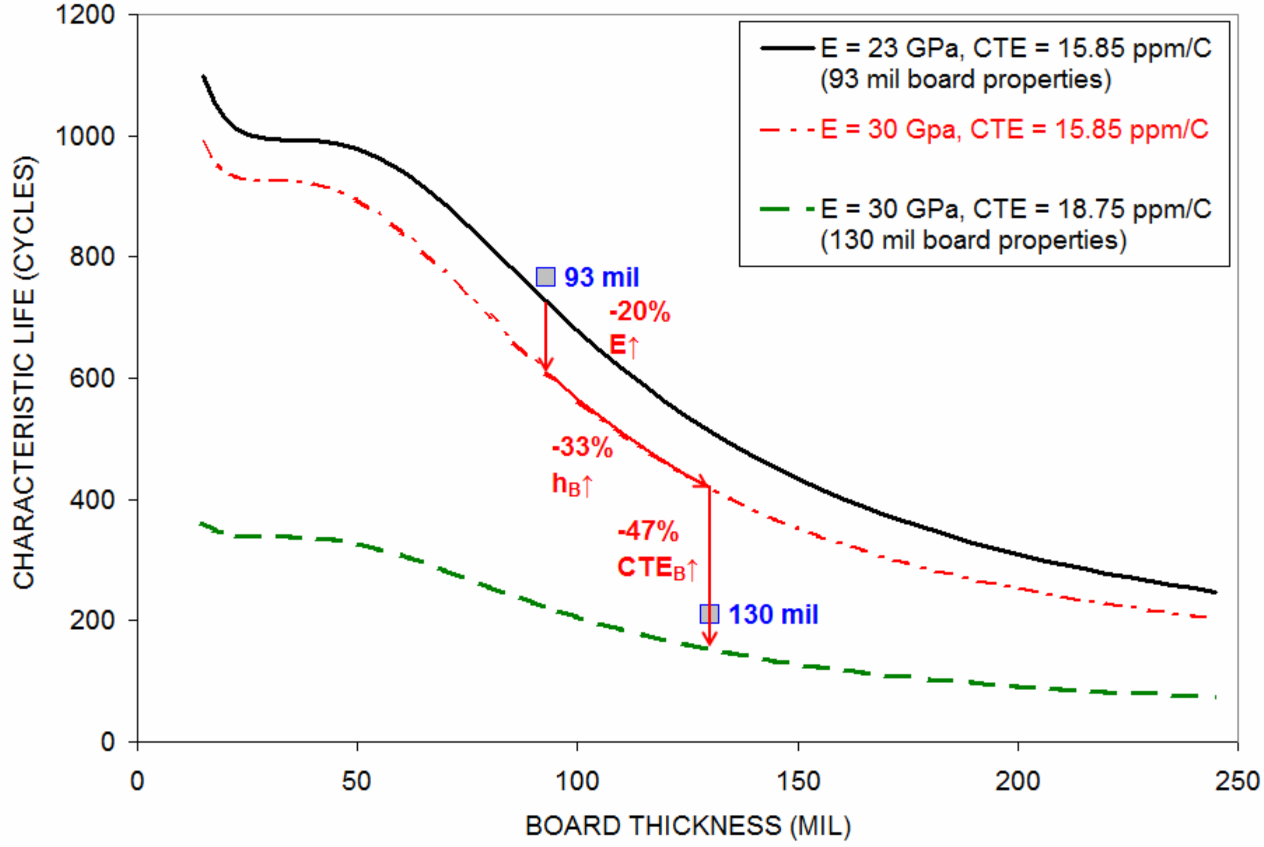
1: Single-sided HiTCE CBGA (1)

- Fit of model to board thickness data from Shih et al., 2004



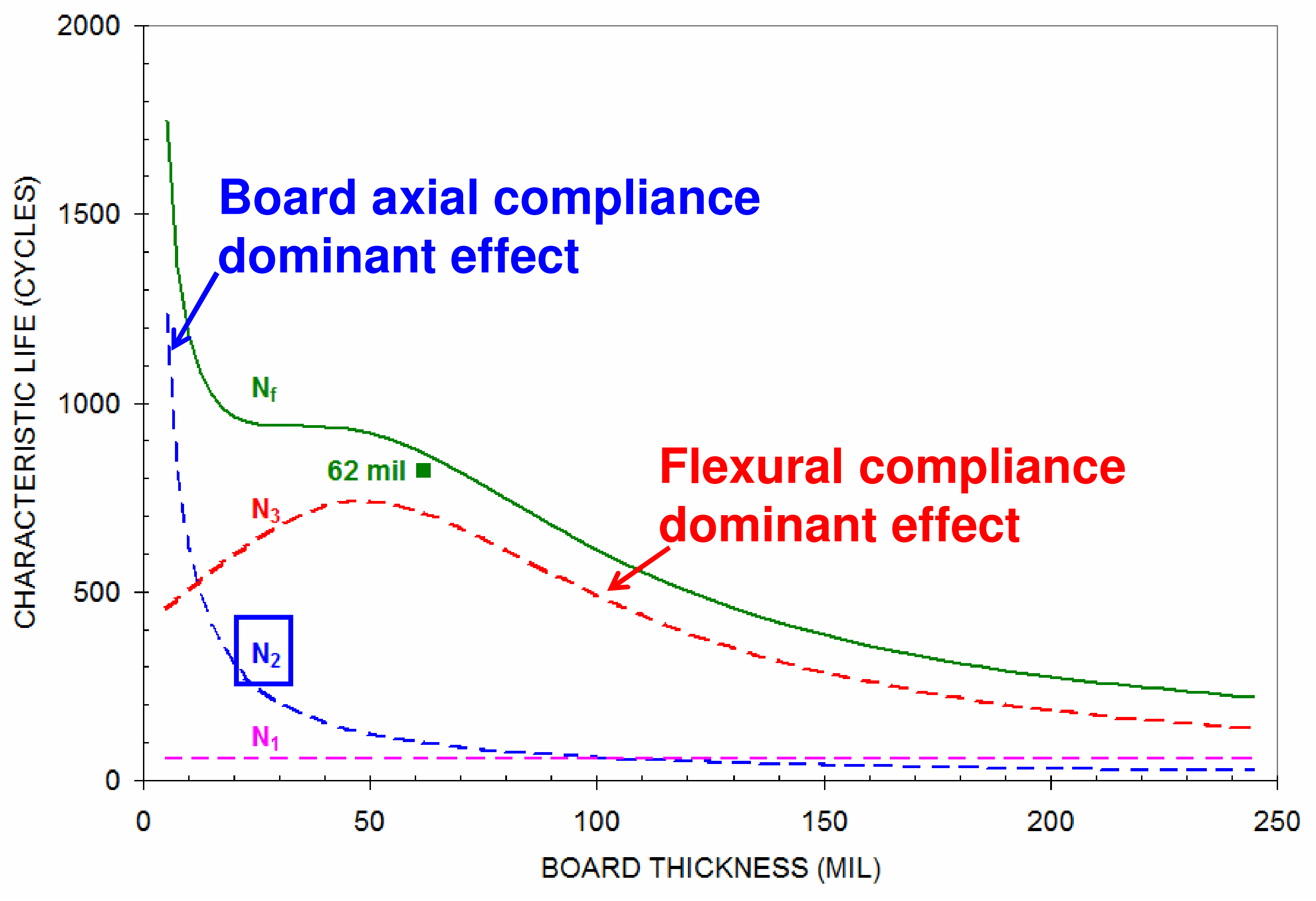
1: Single-sided HiTCE CBGA (2)

- Drop in life from 93 to 130 mil board is larger (compared to 62 vs. 93 mil) due to higher board modulus and CTE



1: Single-sided HiTCE CBGA (3)

- Board axial compliance becomes the controlling factor for very thin boards.

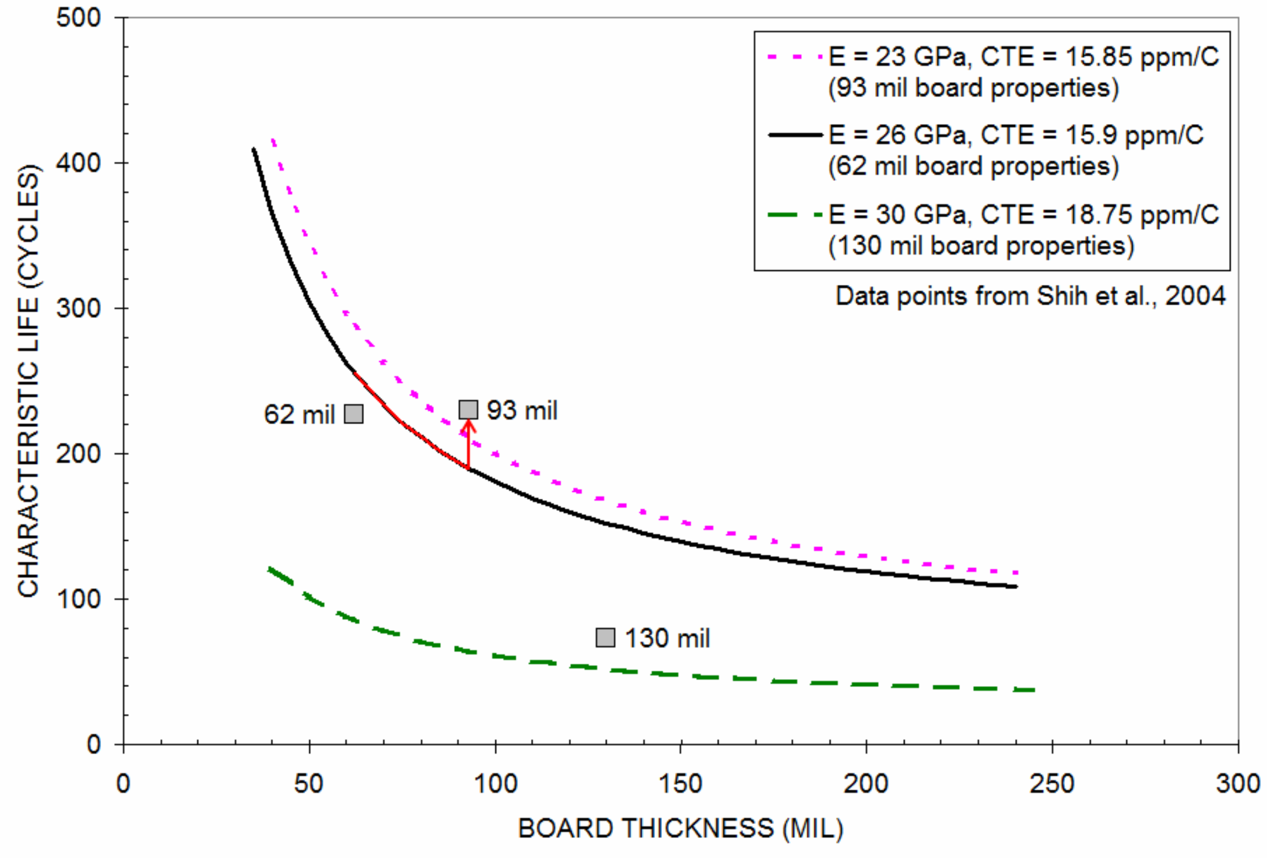


Board axial compliance dominant effect

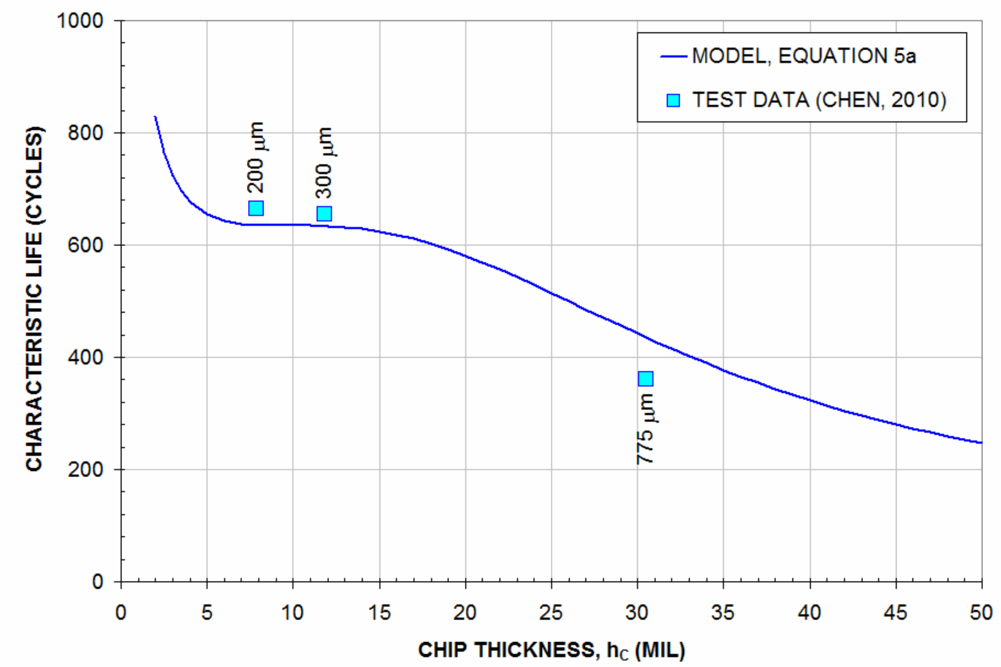
Flexural compliance dominant effect

2: Mirrored HiTCE CBGAs

- **Using the same calibration factor as for single-sided boards, the model predicts the life of mirrored assemblies**



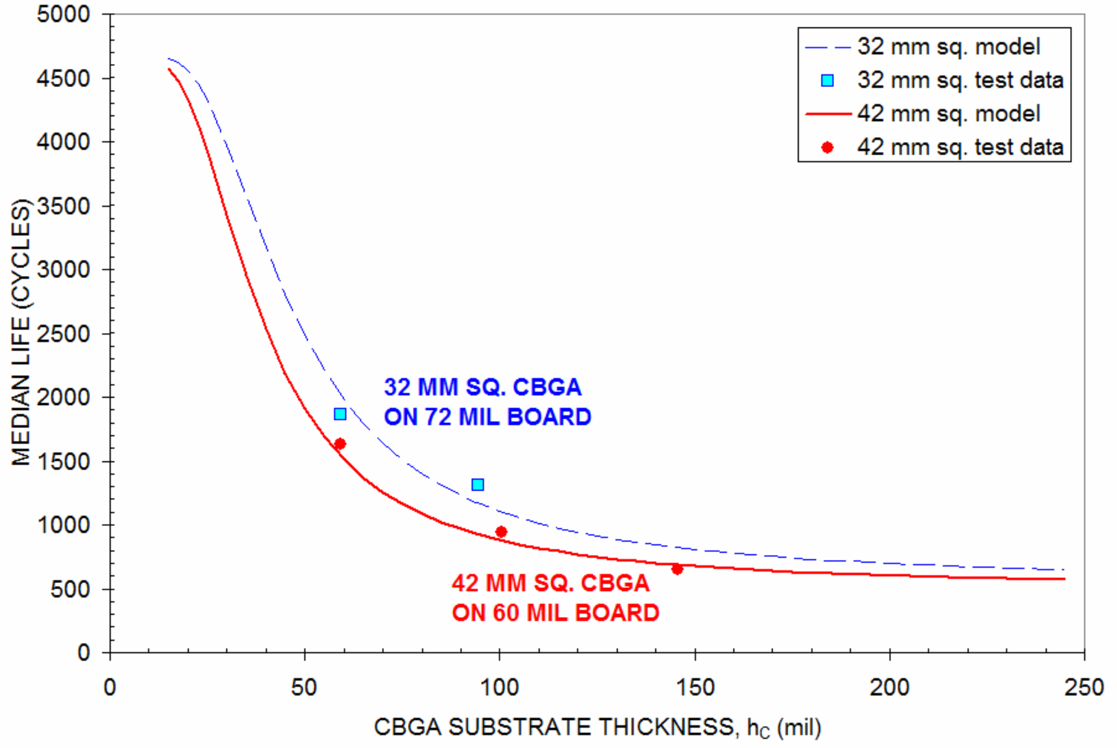
3: Die Thickness Effect



WLCSP on
1 mm (39 mil)
board

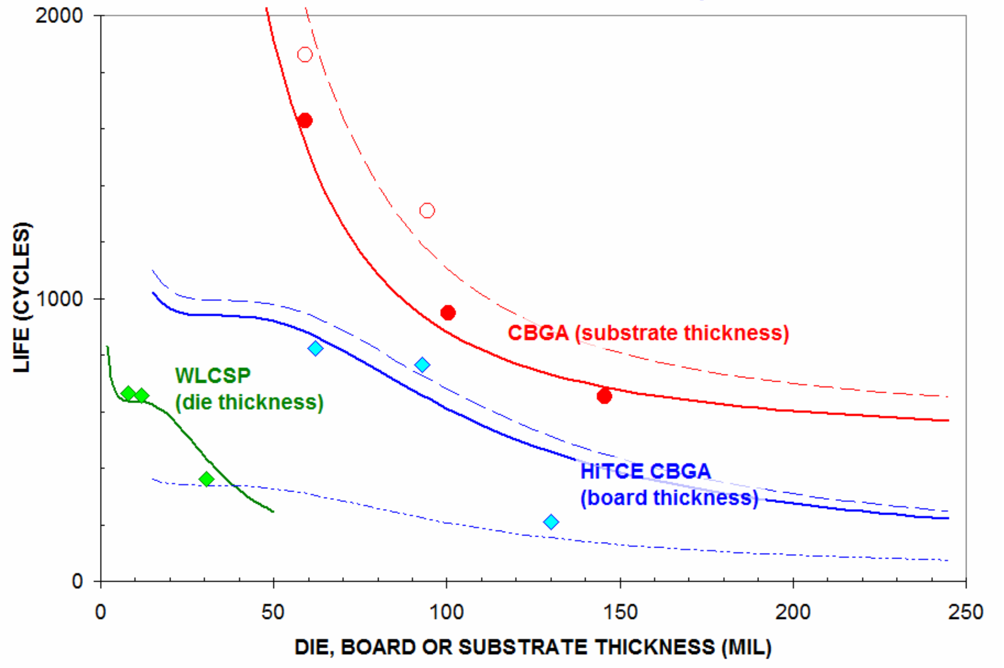
- **By symmetry, the model applies to bare die assemblies**
  - **200-300 μm die data falls in shoulder area of the curve, giving support to the shape of "single-sided" model**

4: CBGA Thickness Effect



- Single calibration factor is used to fit model to SAC data of Farooq et al., 2003.
  - Life goes as 1/DNP (not 1/DNP^2) when pitch is constant

Summary



- Model has been validated for:
  - ☐ Board thickness: 1-3.3 mm (39-130 mil)
- Single-sided and mirrored assemblies
  - ☐ Die thickness: 200 to 775 microns
  - ☐ CBGA thickness: 1.5 to 3.7 mm

Conclusions

- Strength-of-materials model captures board thickness effect for single-sided and mirrored assemblies
  - Approach can help reduce cost of product reliability assessment
- Board thickness effect is NOT just about board thickness
  - Effective board properties: CTEs AND Young’s moduli matter and change with board thickness

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Thank You!

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