

Center for Aircraft Structural Life Extension

Providing Structural Integrity Technology to the Aerospace Community



Stress Intensity Values for Finite Width, Small Cracks, and Abnormal Aspect Ratios



U.S. AIR FORCE

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Extension
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- **Available AFGROW Solutions for Corner Cracks**
 - **Finite Width Correction**
 - **The Virtual Crack Closure Technique (VCCT)**
 - **AFGROW / VCCT Stress Intensity Comparisons**
 - **Concluding Remarks**
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AFGROW Classic Solution

- **Newman-Raju***
 - **Single / Double (symmetric) Corner Crack at a Hole**
 - Angle used for “c” dimension: $\Phi = 5^{\circ**}$
 - Angle used for “a” dimension: $\Phi = 80^{\circ}$
 - **Valid Solution Space**
 - $0 < a/t \leq 1.0$
 - $0.2 \leq a/c \leq 2.0$
 - $(D+2c)/W < 0.5$

* "Stress Intensity Factor Equations for Cracks in Three-Dimensional Bodies Subjected to Tension and Bending Loads," Chapter 9, Computational Methods in the Mechanics of Fracture, Elsevier Science Publishers B.V., 1986

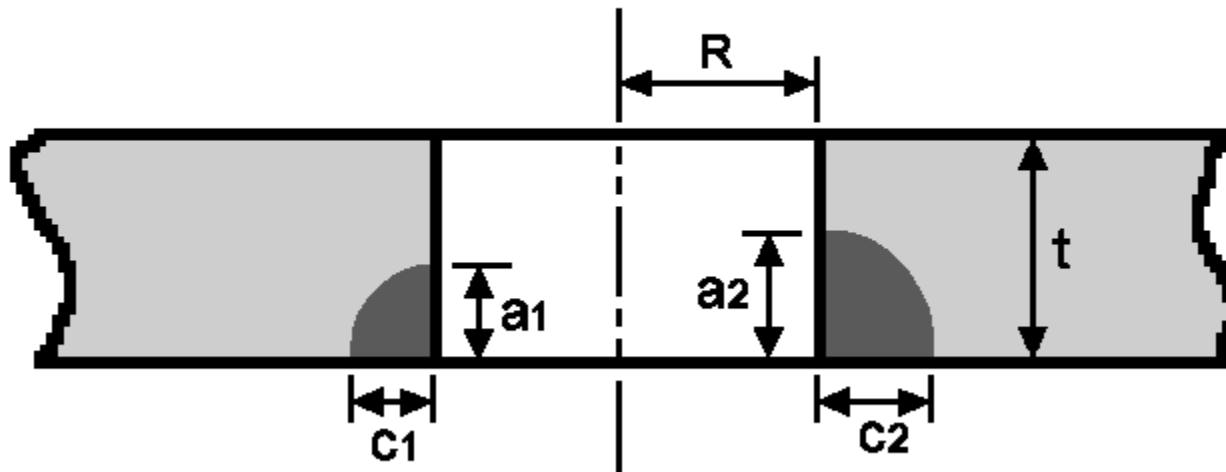
** Parametric Elliptical Angle

AFGROW Advanced Solution

R/t: 0.1, 0.111, 0.125, 0.1428, 0.1667, 0.2, 0.25, 0.333, 0.5, 0.667, 0.75, 0.8, 1.0, 1.25, 1.33, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

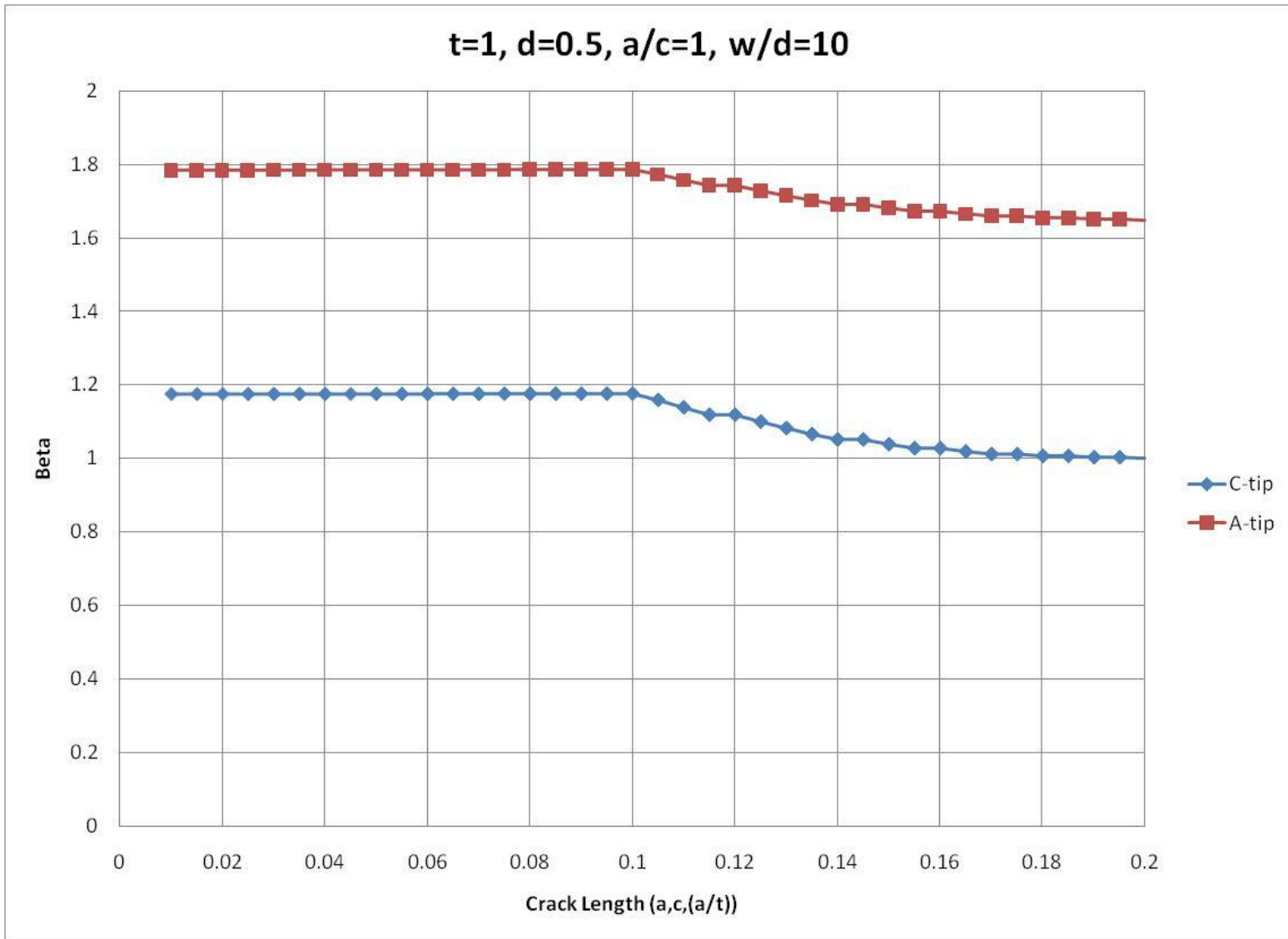
a1/c1, a2/C2: 0.1, 0.111, 0.125, 0.1428, 0.1667, 0.2, 0.25, 0.333, 0.5, 0.667, 0.75, 0.8, 1.0, 1.25, 1.33, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

a1/t, a2/t: 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 0.95, 0.99

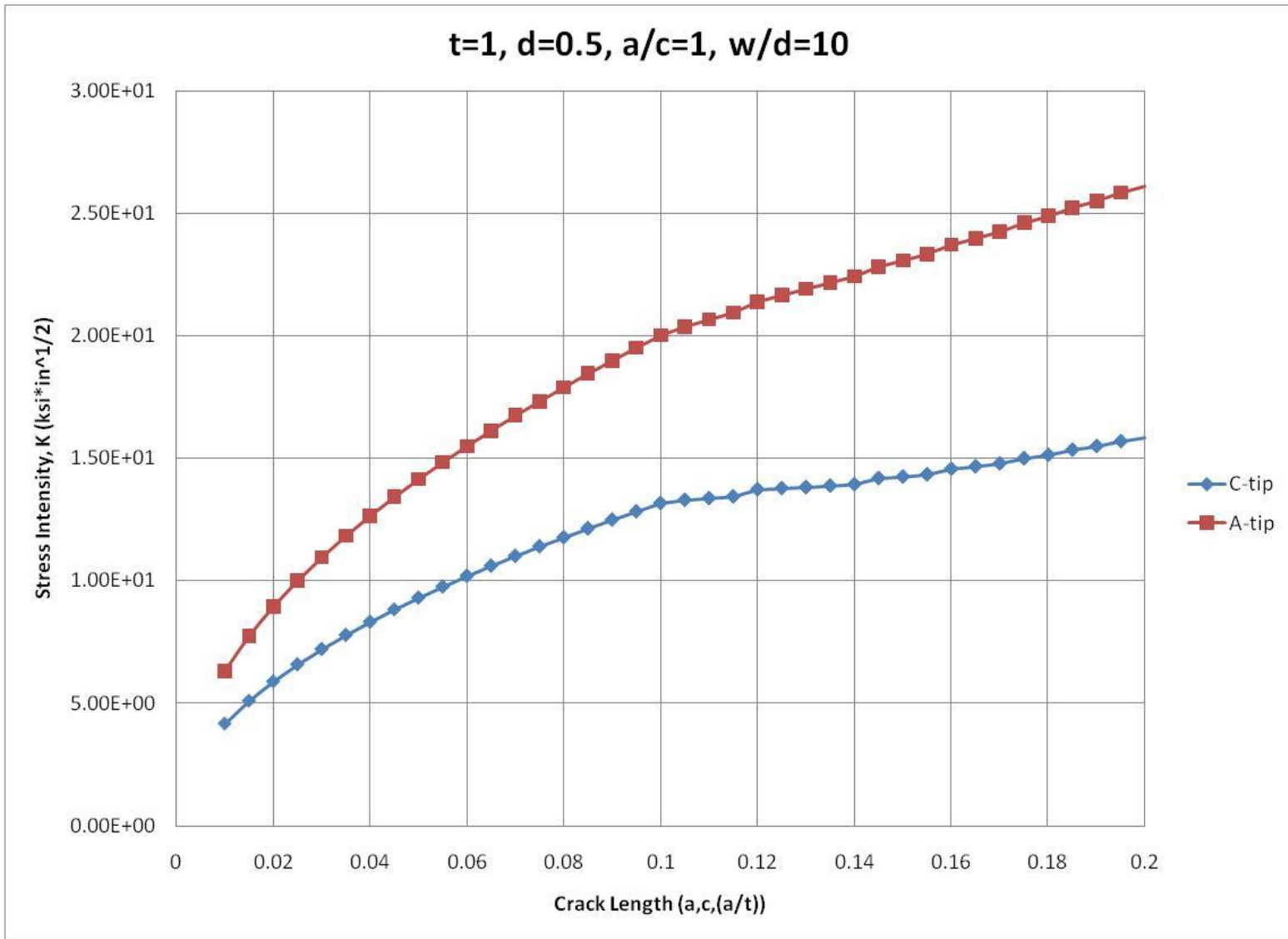


* Fawaz / Andersson Solutions

AFGROW Advanced Solution

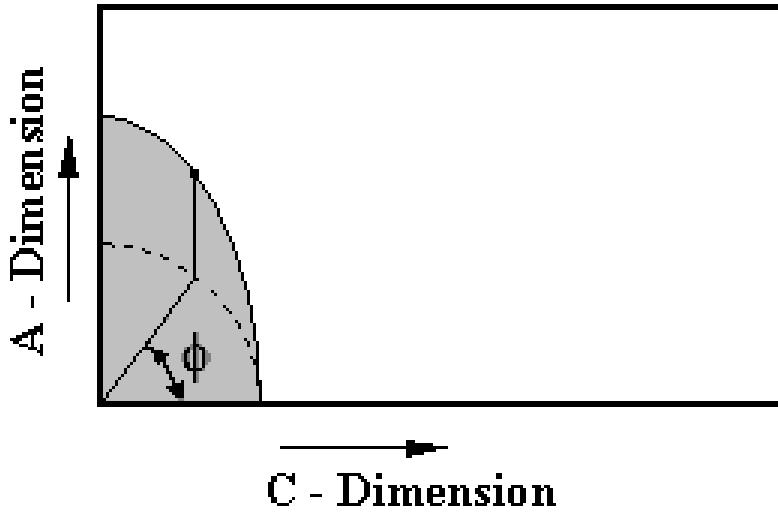


AFGROW Advanced Solution

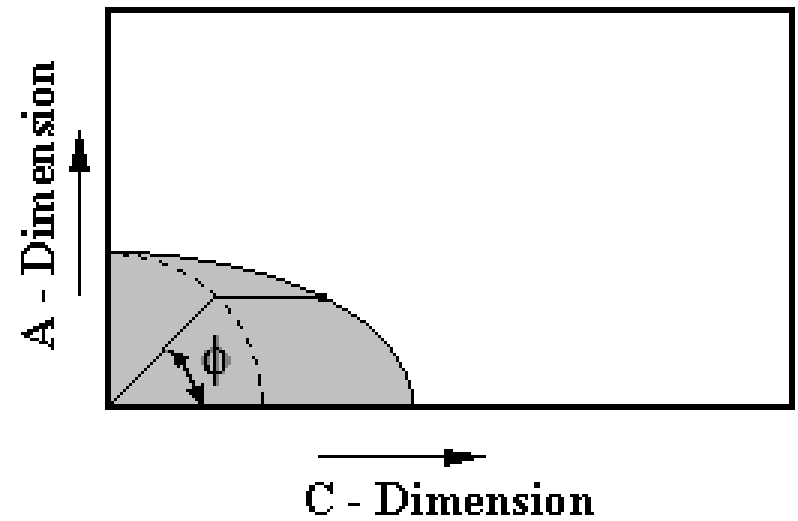


Parametric Angles

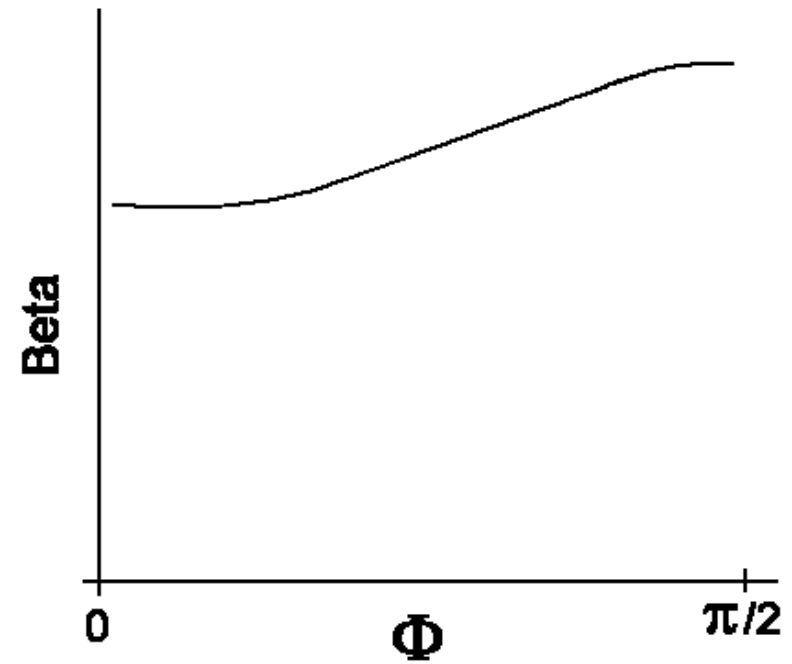
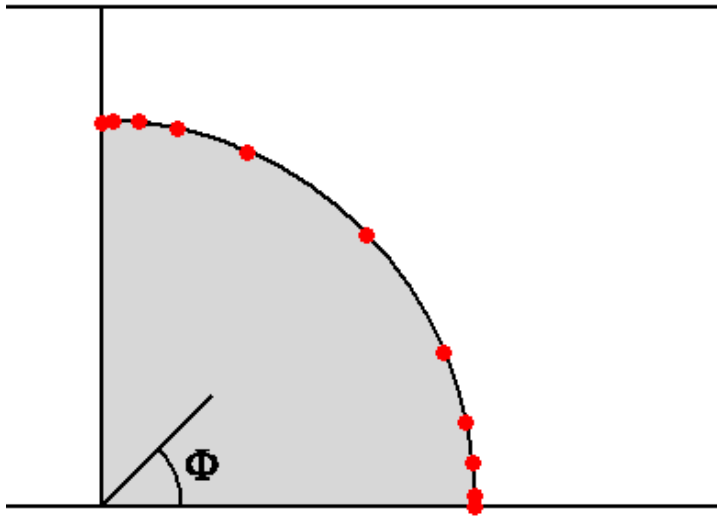
$$A \geq C$$



$$A \leq C$$



Solution Locations



Finite Width Correction

■ Single Corner Crack

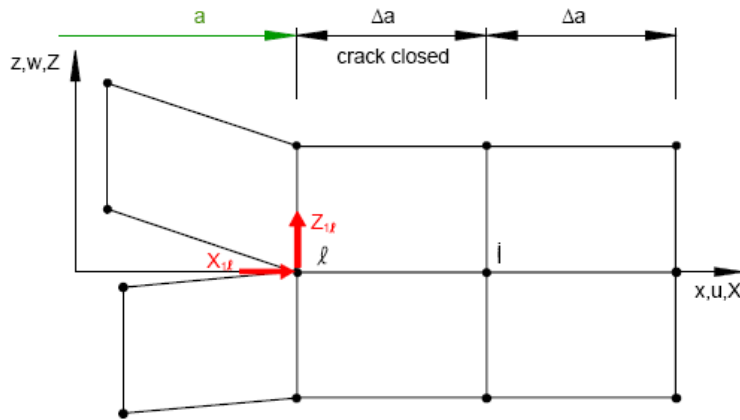
$$F_{ww} = 1 - \left(\left(2.65 - 0.24 \left(2.75 - \frac{W}{D} \right)^2 \right)^{-\frac{W}{D}} \right) \left(\frac{2C}{W - D} \right)^{\frac{W}{D} + 0.5}$$

■ Double Corner Crack

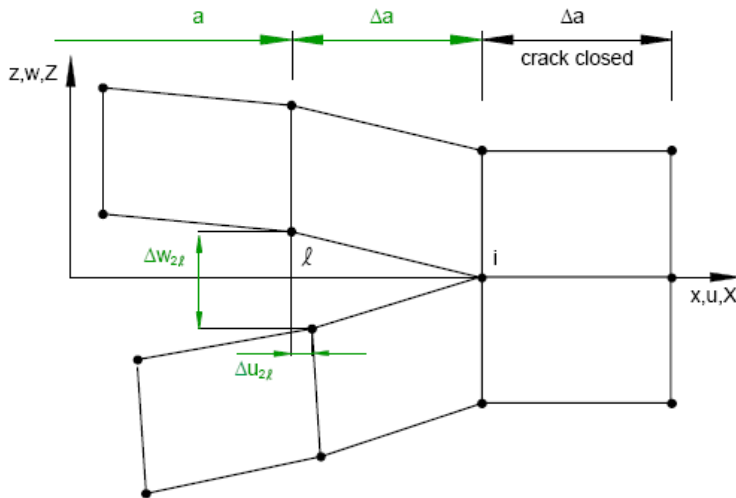
$$F_{ww} = 1 - \left(\left(1.32 \frac{W}{D} - 0.14 \right)^{-\left(0.98 + \left(0.1 \frac{W}{D} \right)^{0.1} \right)} - 0.02 \right) \left(\frac{2C}{W - D} \right)^{\frac{W}{D} + 2.5}$$

* These corrections are calculated for Through Cracks and used as both “a” and “c” tip correction factors for part-through cracks.

Two Step VCCT



(a). First Step - Crack closed



(b). Second Step - Crack extended

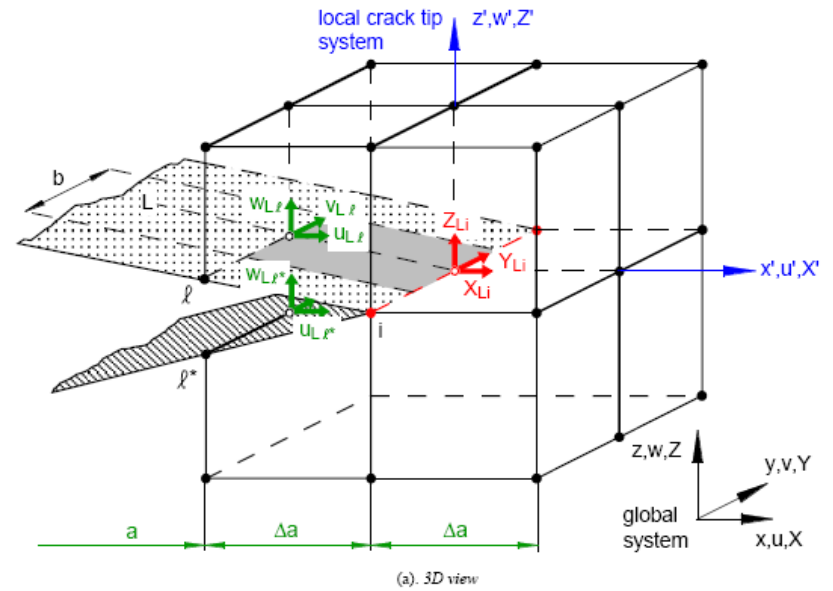
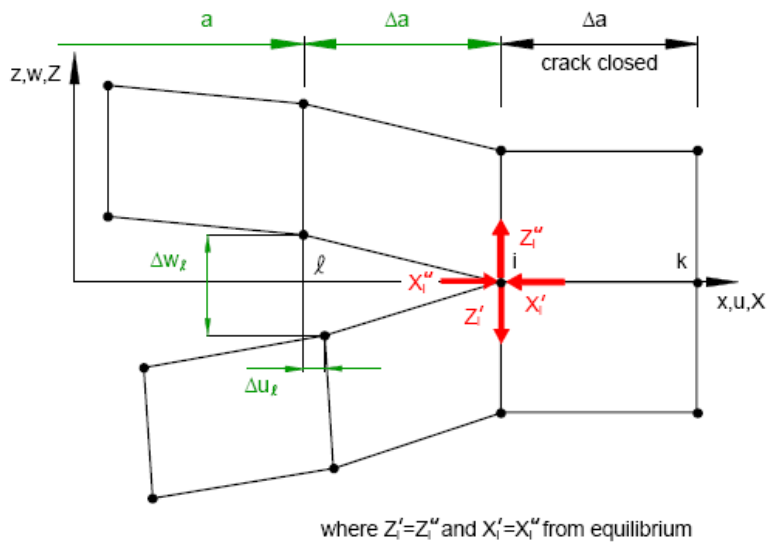
■ Crack Closure
Technique

-or-

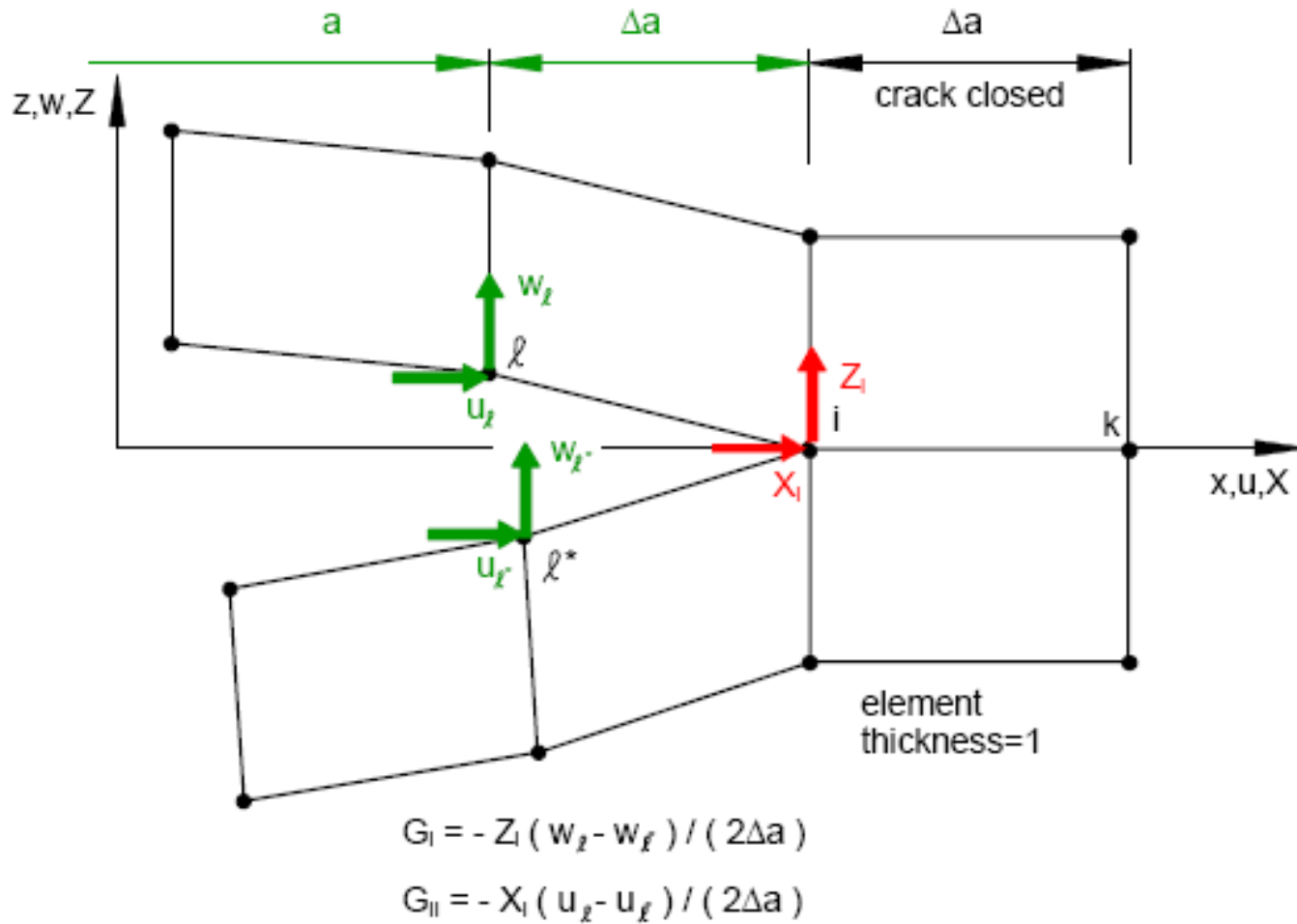
■ Two Step VCCT

*Krueger, "The virtual Crack Closure
Technique: History, Approach and
Applications", ICASE Report No.
2002-10, NASA/CR-2002-211628

Single Step VCCT



VCCT Calculation



VCCT Assumptions

- The amount of crack wake displacement is nearly equal to the “forward” growth’s new crack wake displacement.
- The amount of crack front load is nearly equal to the “backward” growth’s old crack front load.
- Therefore, the crack front/wake elements should be significantly smaller than the crack length.

$$\Delta c \ll c$$

Strain Energy / Stress Intensity

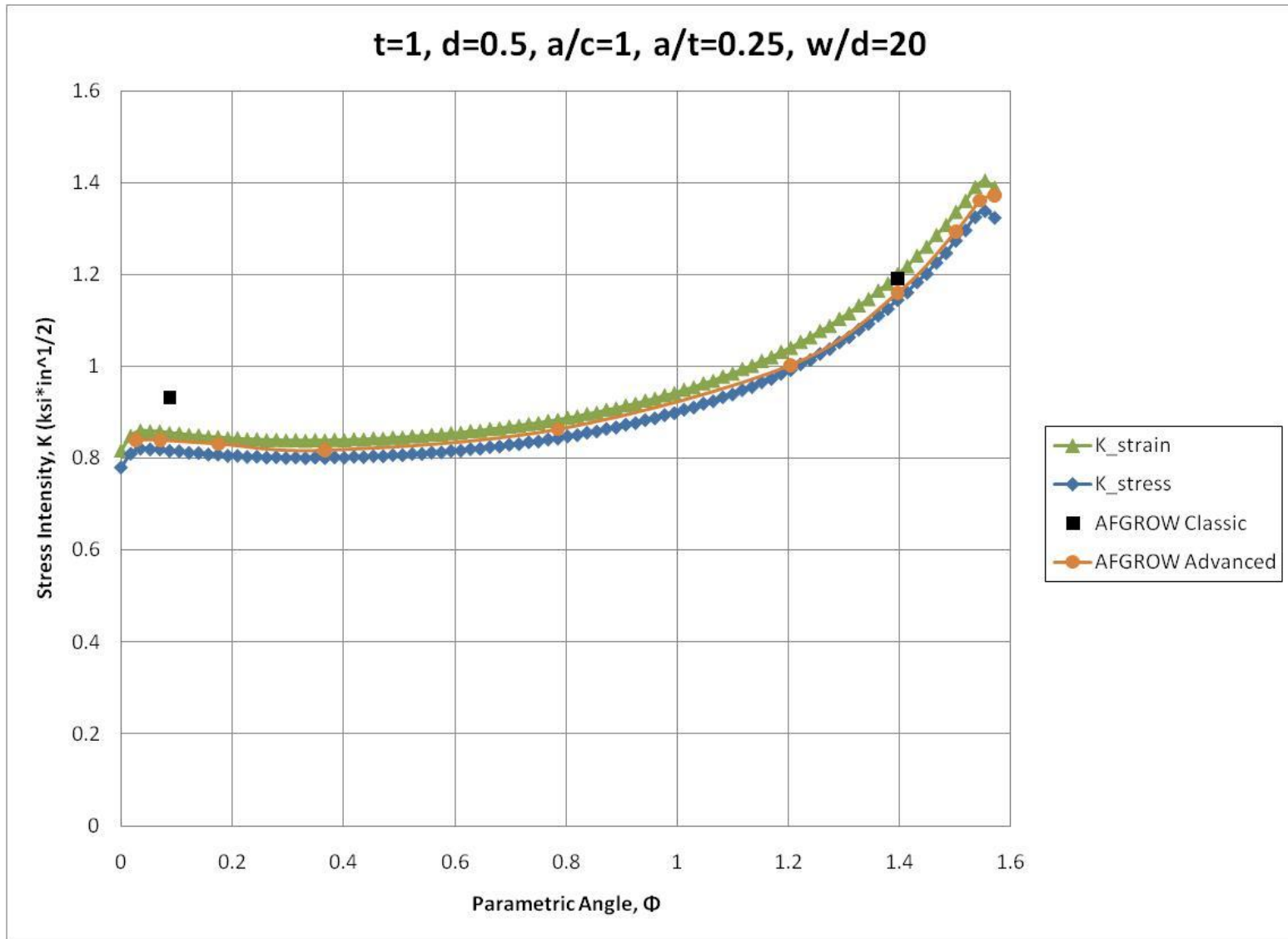
■ Plane Stress

$$K_I = \sqrt{G_I E}$$

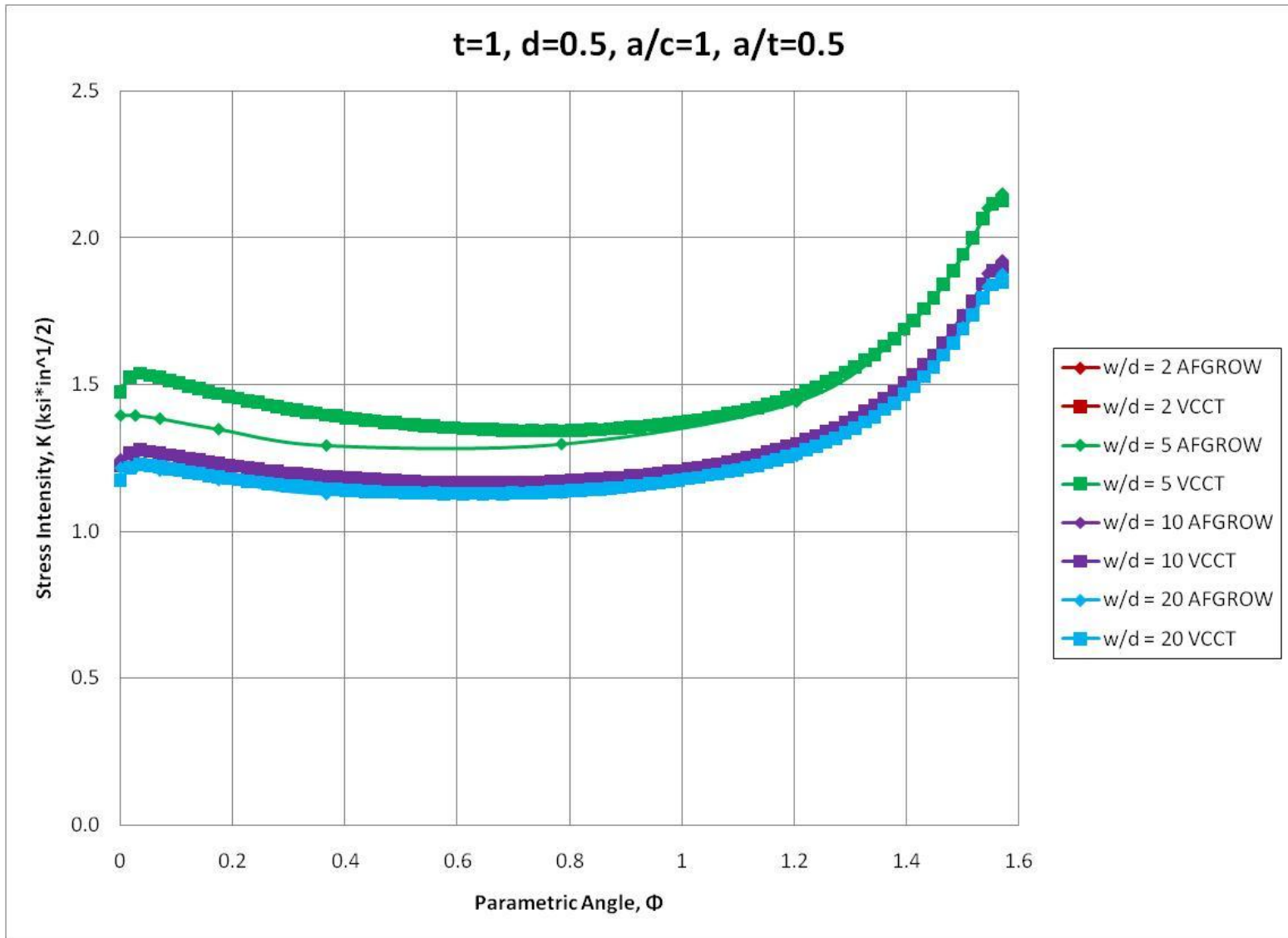
■ Plane Strain

$$K_I = \sqrt{\frac{G_I E}{1-\nu}}$$

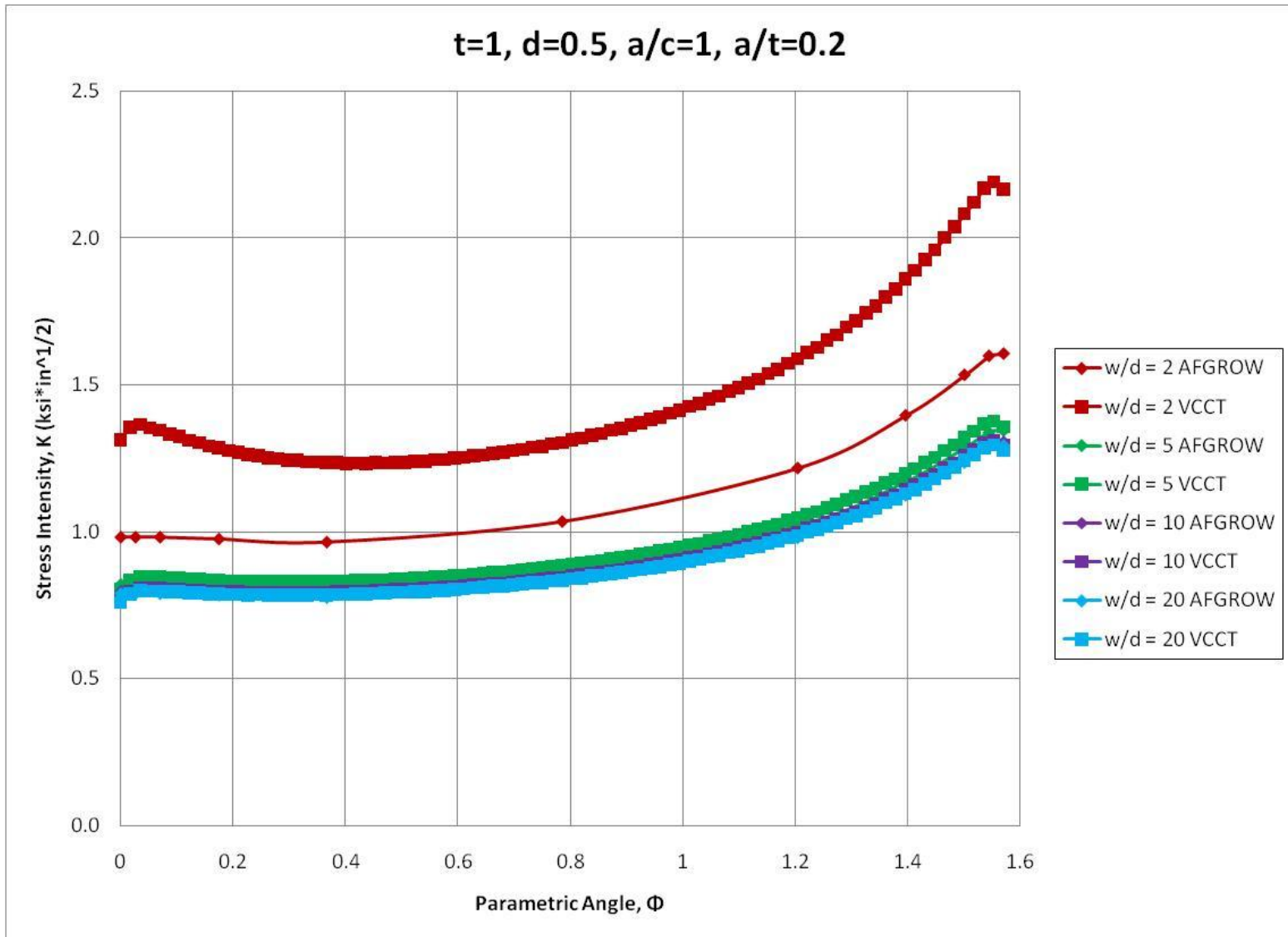
Double Sym. Corner Crack



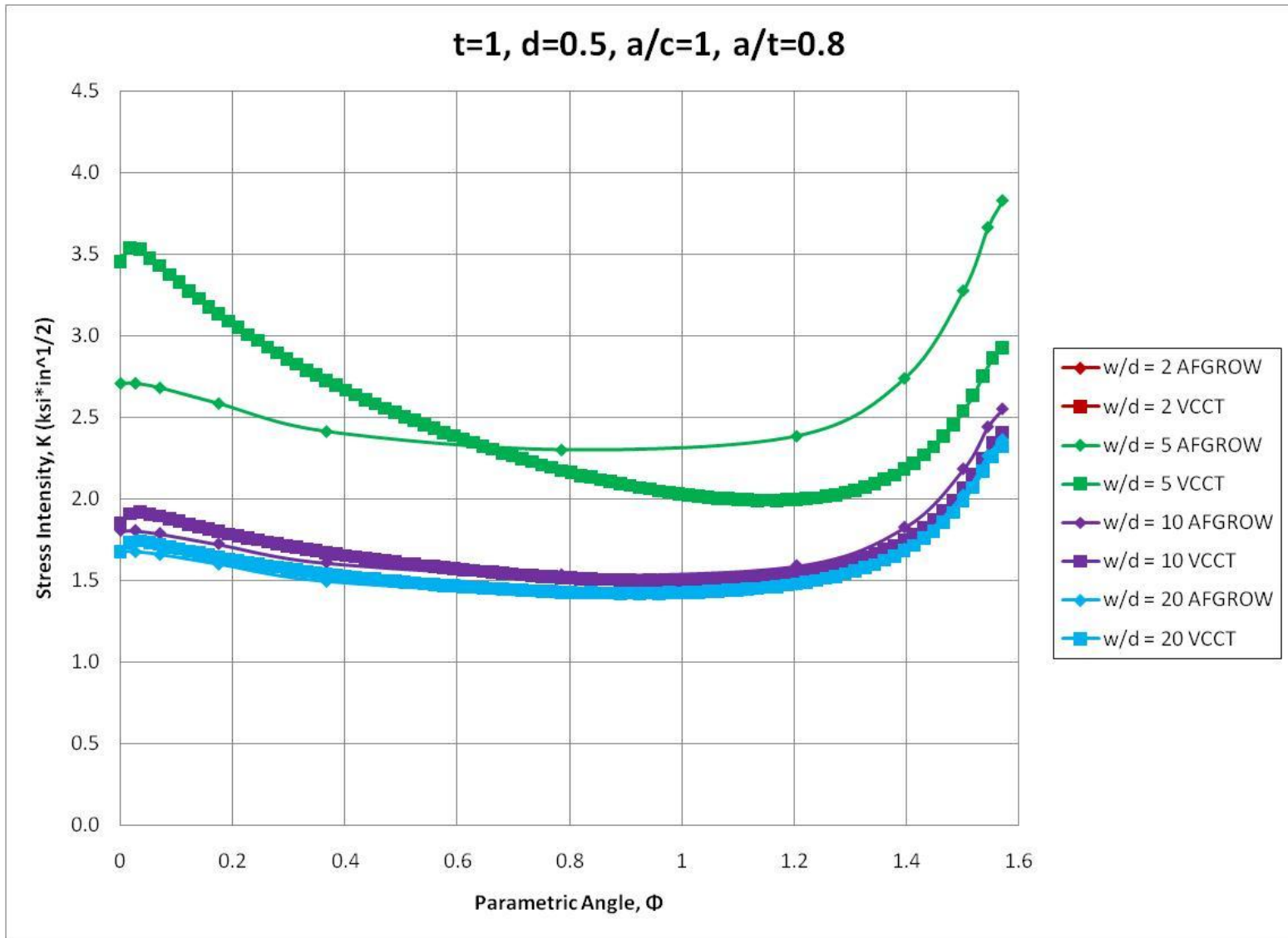
Double Sym. Corner Crack



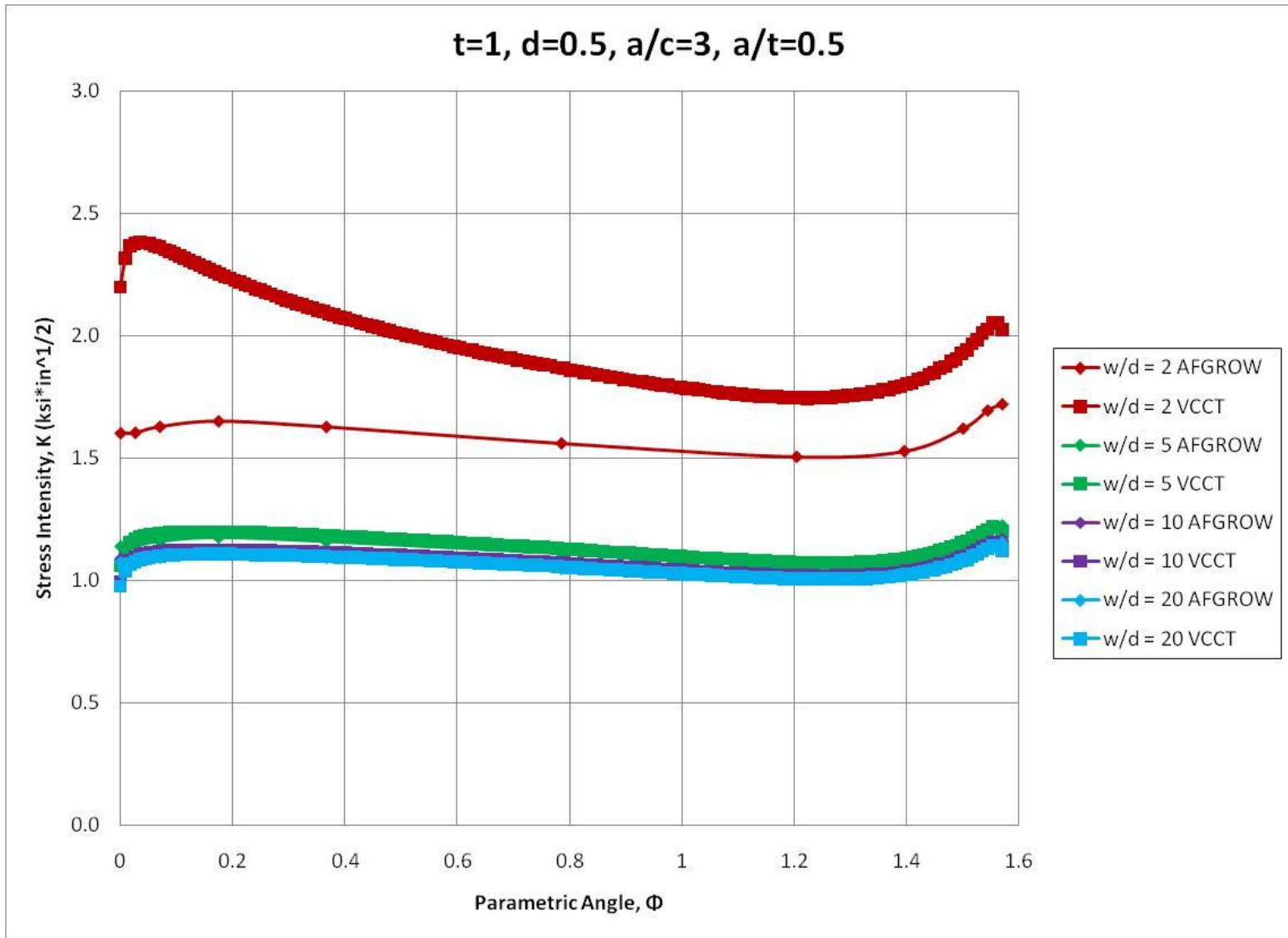
Double Sym. Corner Crack



Double Sym. Corner Crack

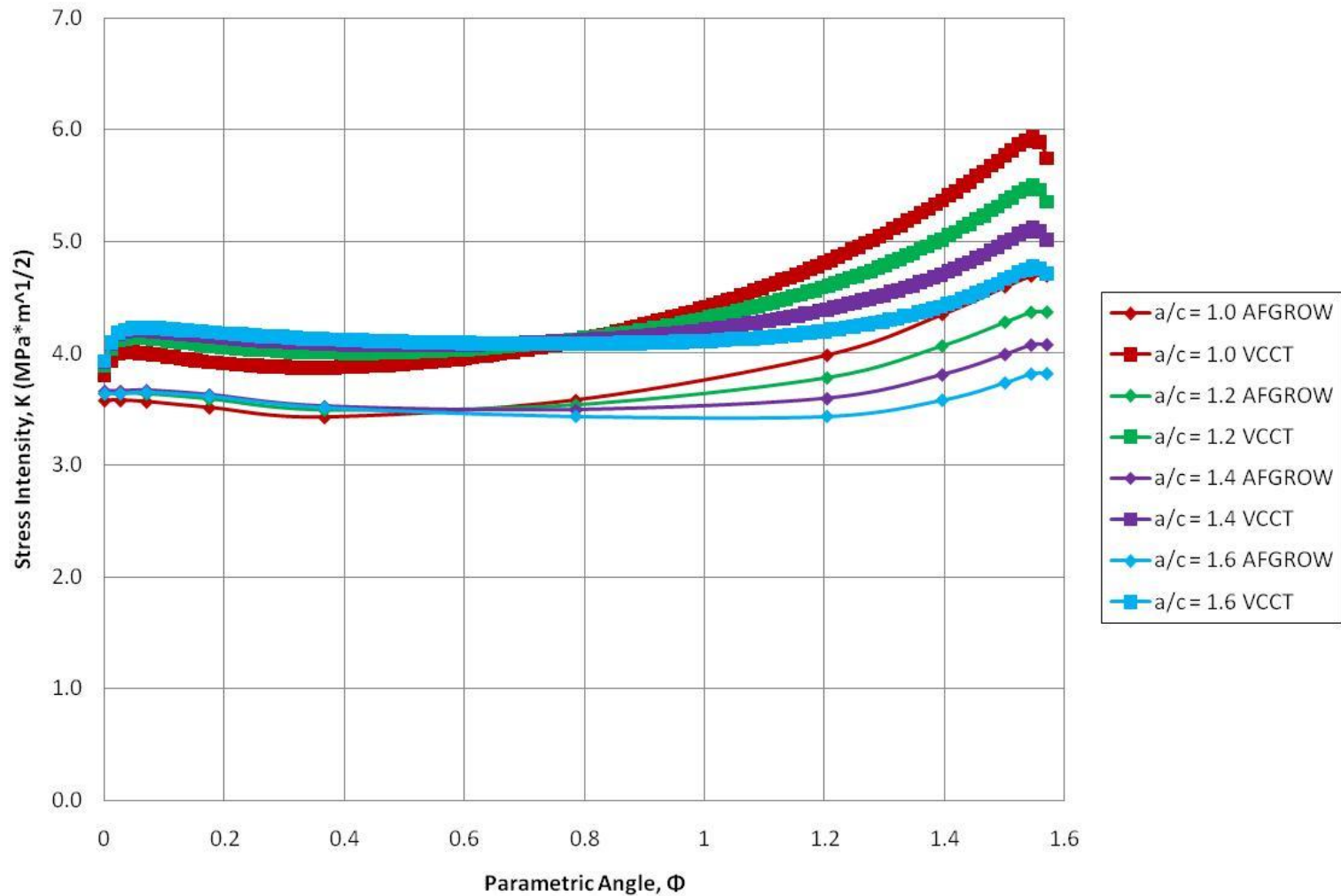


Double Sym. Corner Crack



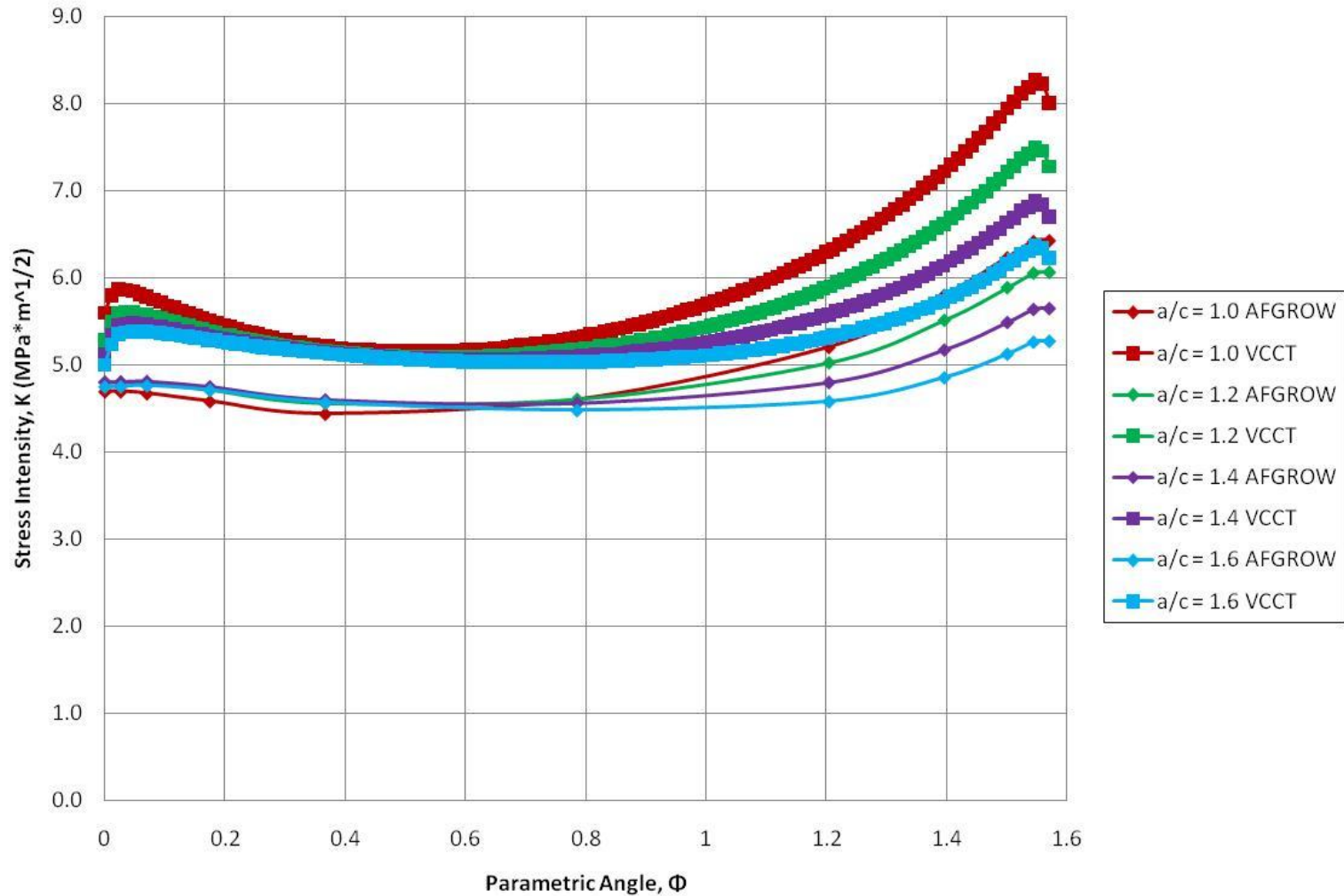
Single Corner Crack

$t=3.2, d=6, a/t=0.281, w/d=1.67$



Single Corner Crack

$t=3.2, d=6, a/t=0.469, w/d=1.67$



Conclusions

- **The Finite Width corrections currently implemented in AFGROW may not be accurate for small width panels.**

 - **The Finite Width corrections for both the “a” and “c” tip may not be the same.**
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Questions?

