

# 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**

**Matthew Hammond, PE**  
**Center for Aircraft Structural Life**  
**Extension**  
**USAF Academy**



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

# 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

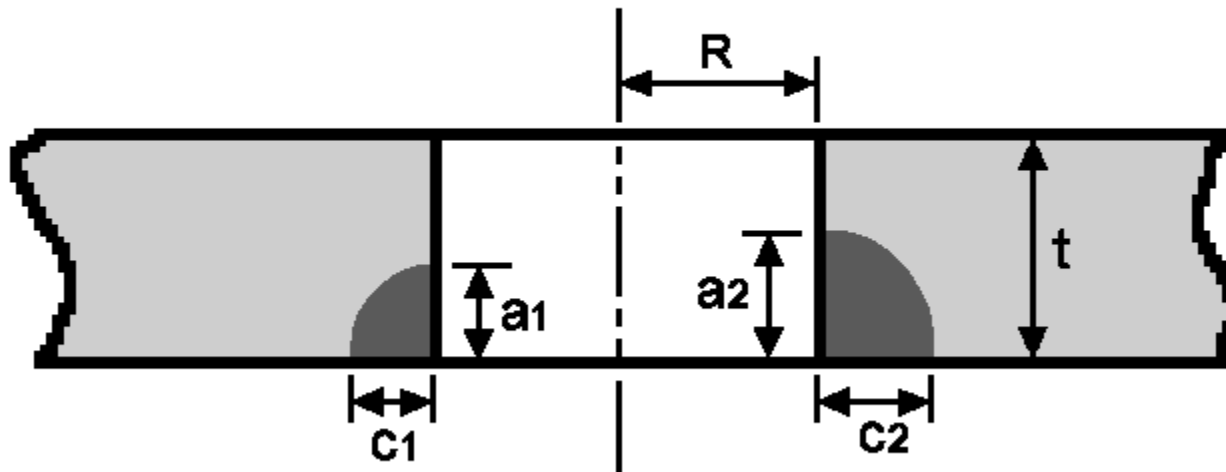
---

# 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

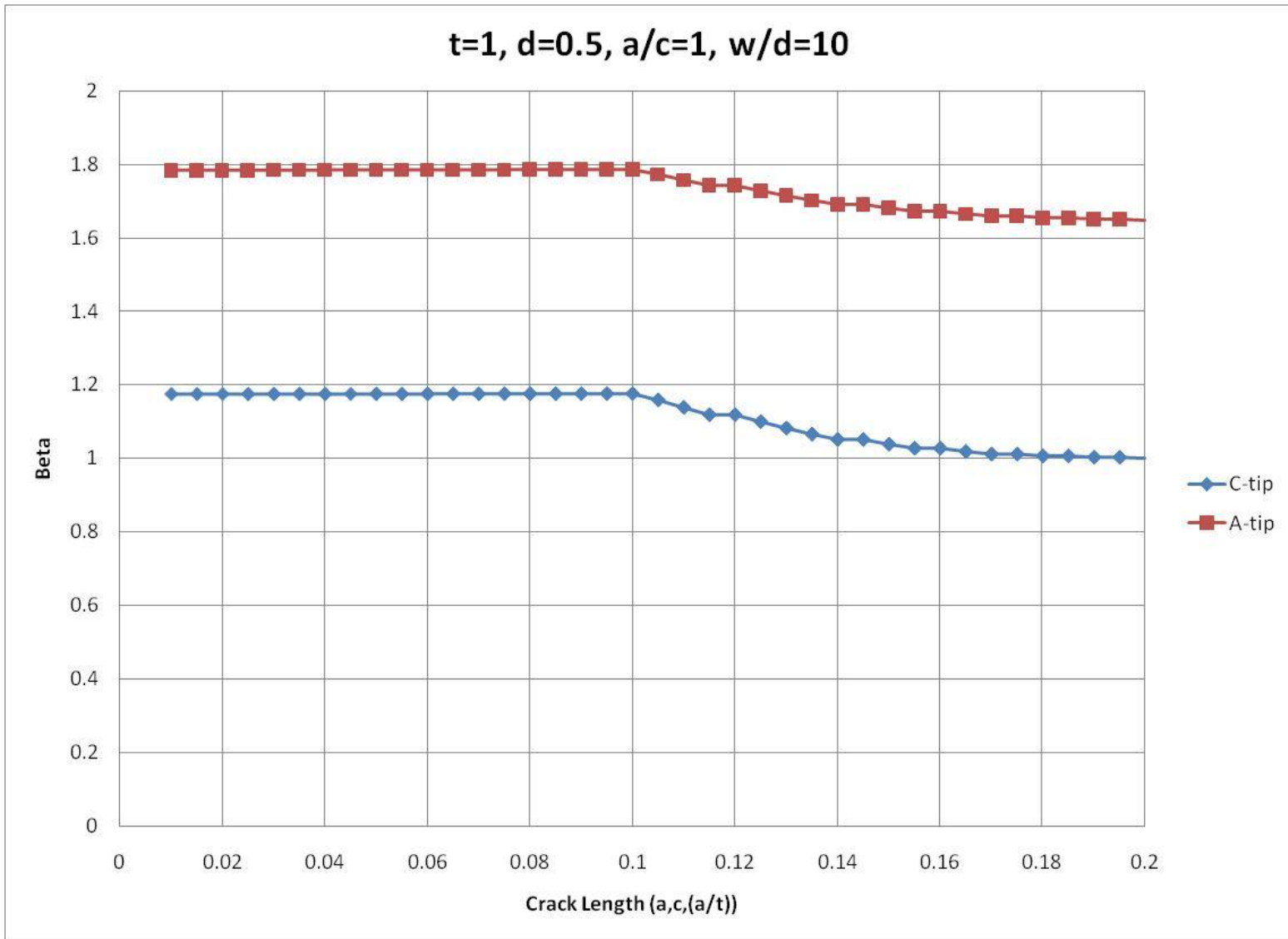
**a1/c1, a2/C2:** 0.1, 0.111, 0.125, 0.1428, 0.1667, 0.2, 0.25, 0.333, 0.5, 0.667, 0.75, 0.8, 1.0, 1.25, 1.33, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

**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

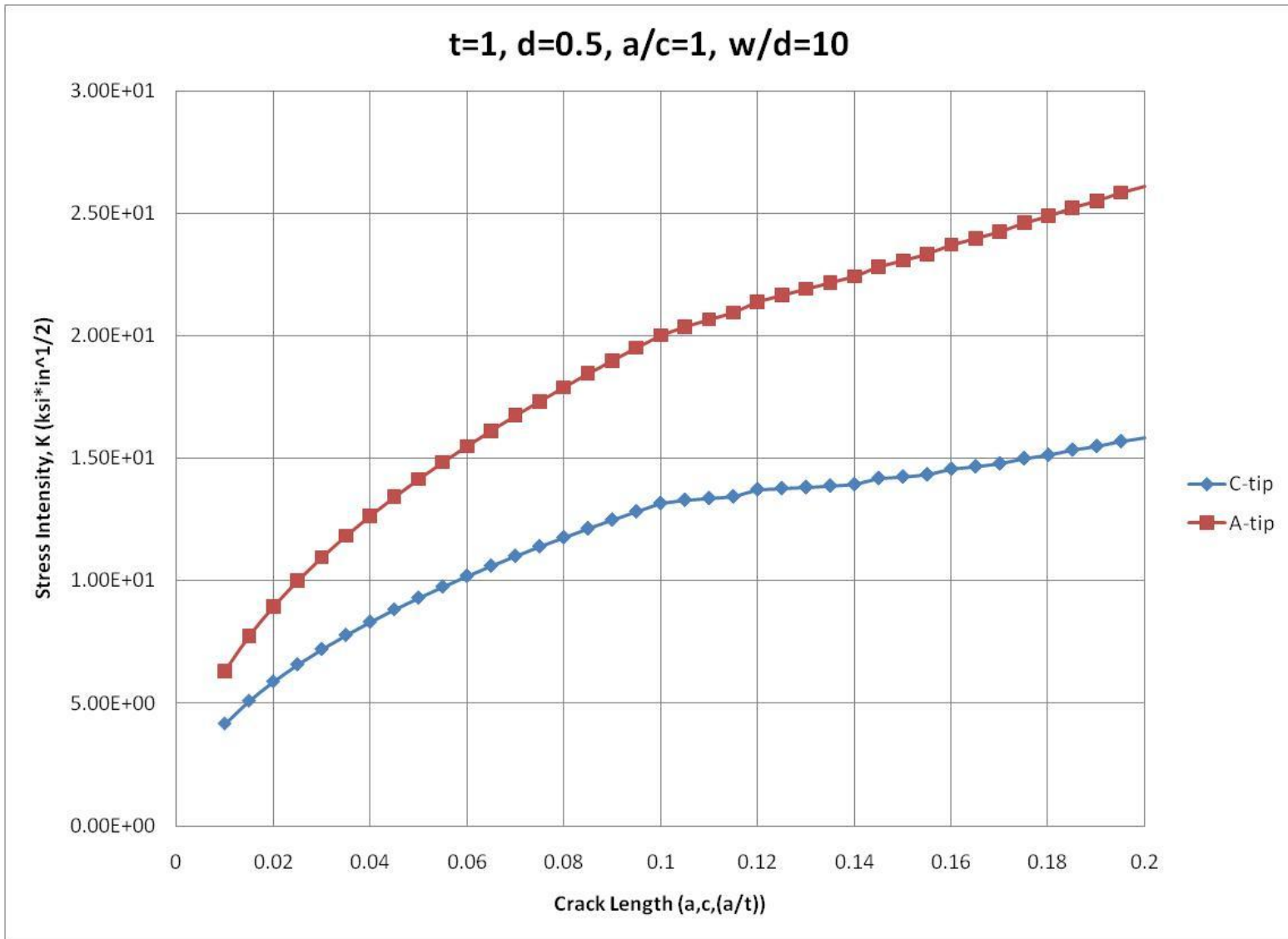


\* Fawaz / Andersson Solutions

# AFGROW Advanced Solution

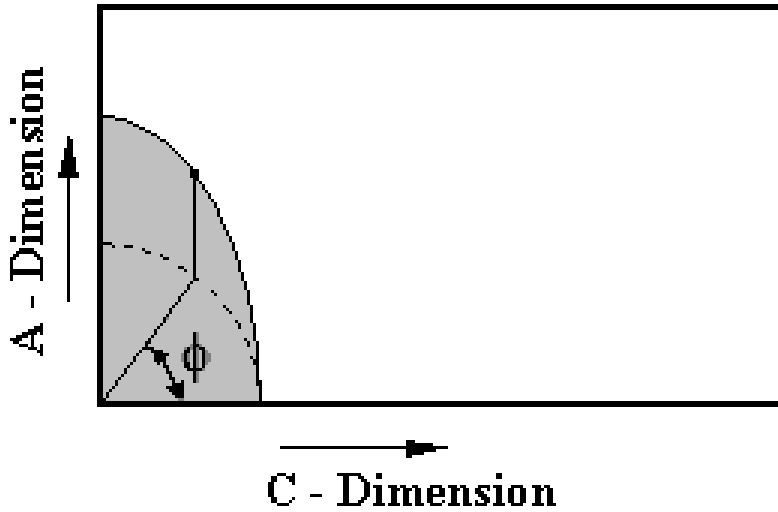


# AFGROW Advanced Solution

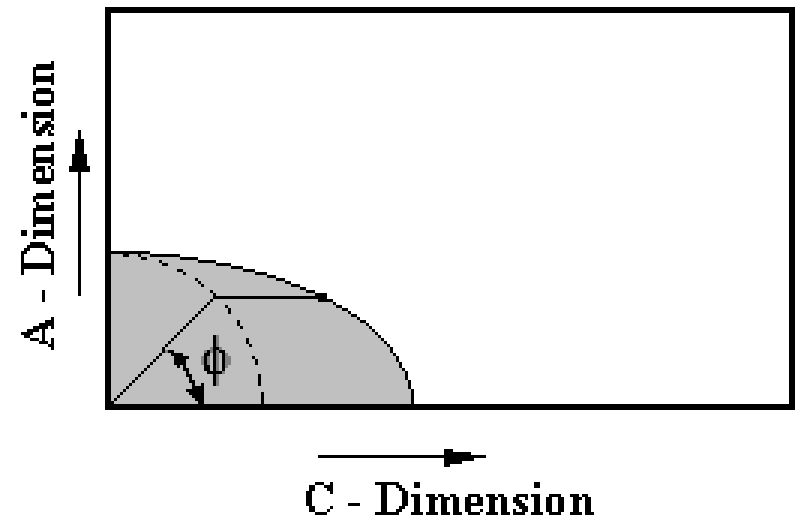


# Parametric Angles

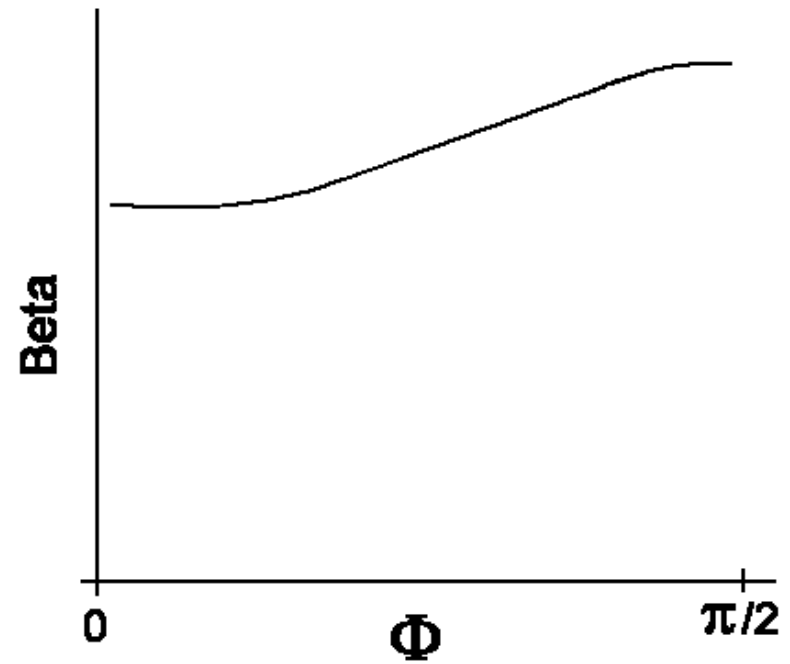
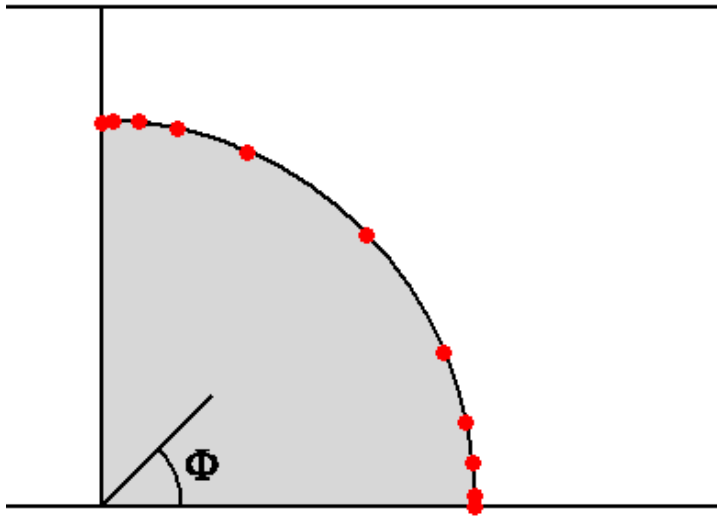
$$A \geq C$$



$$A \leq C$$



# Solution Locations



# Finite Width Correction

## ■ Single Corner Crack

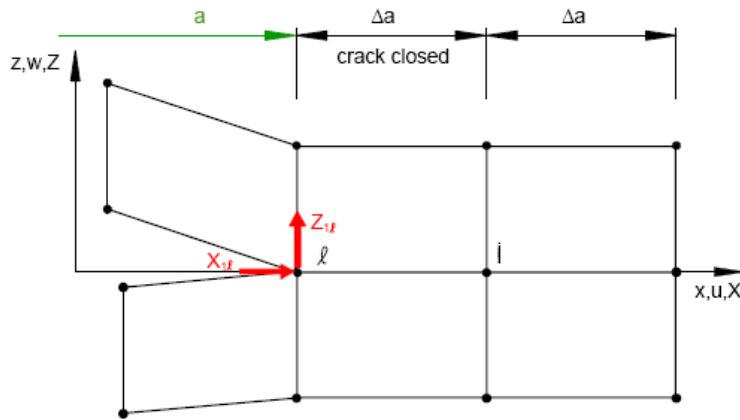
$$F_{ww} = 1 - \left( \left( 2.65 - 0.24 \left( 2.75 - \frac{W}{D} \right)^2 \right)^{-\frac{W}{D}} \right) \left( \frac{2C}{W - D} \right)^{\frac{W}{D} + 0.5}$$

## ■ Double Corner Crack

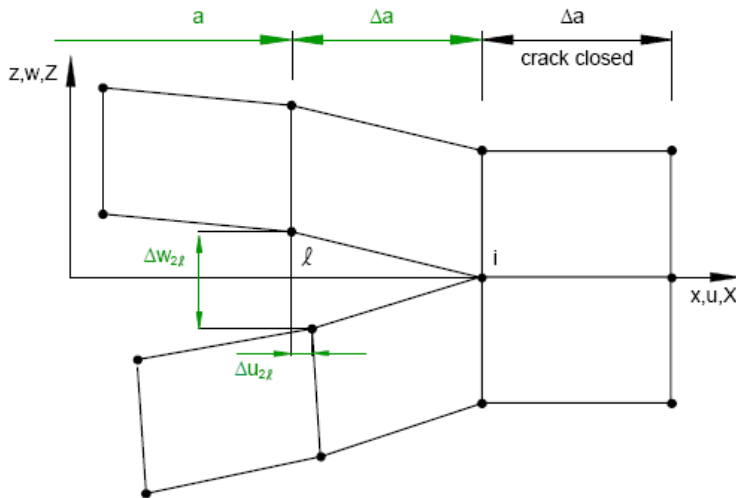
$$F_{ww} = 1 - \left( \left( 1.32 \frac{W}{D} - 0.14 \right)^{-\left( 0.98 + \left( 0.1 \frac{W}{D} \right)^{0.1} \right)} - 0.02 \right) \left( \frac{2C}{W - D} \right)^{\frac{W}{D} + 2.5}$$

\* 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

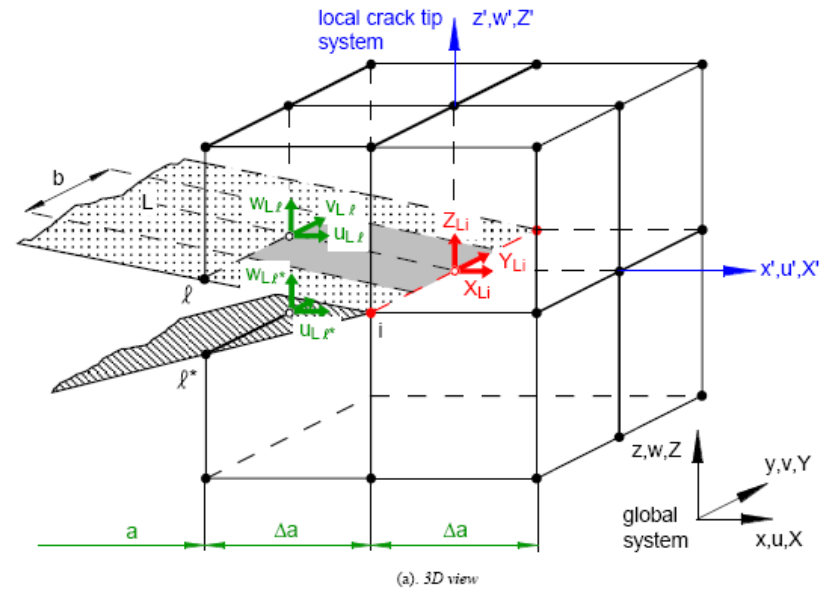
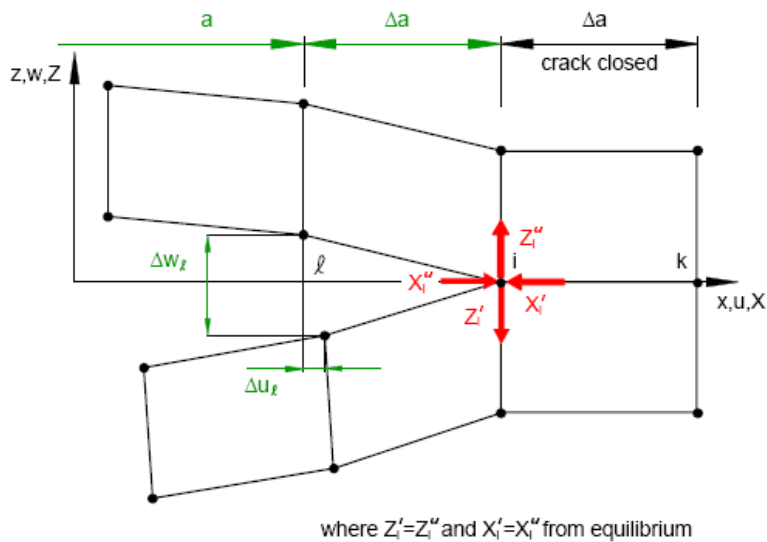
■ Crack Closure  
Technique

-or-

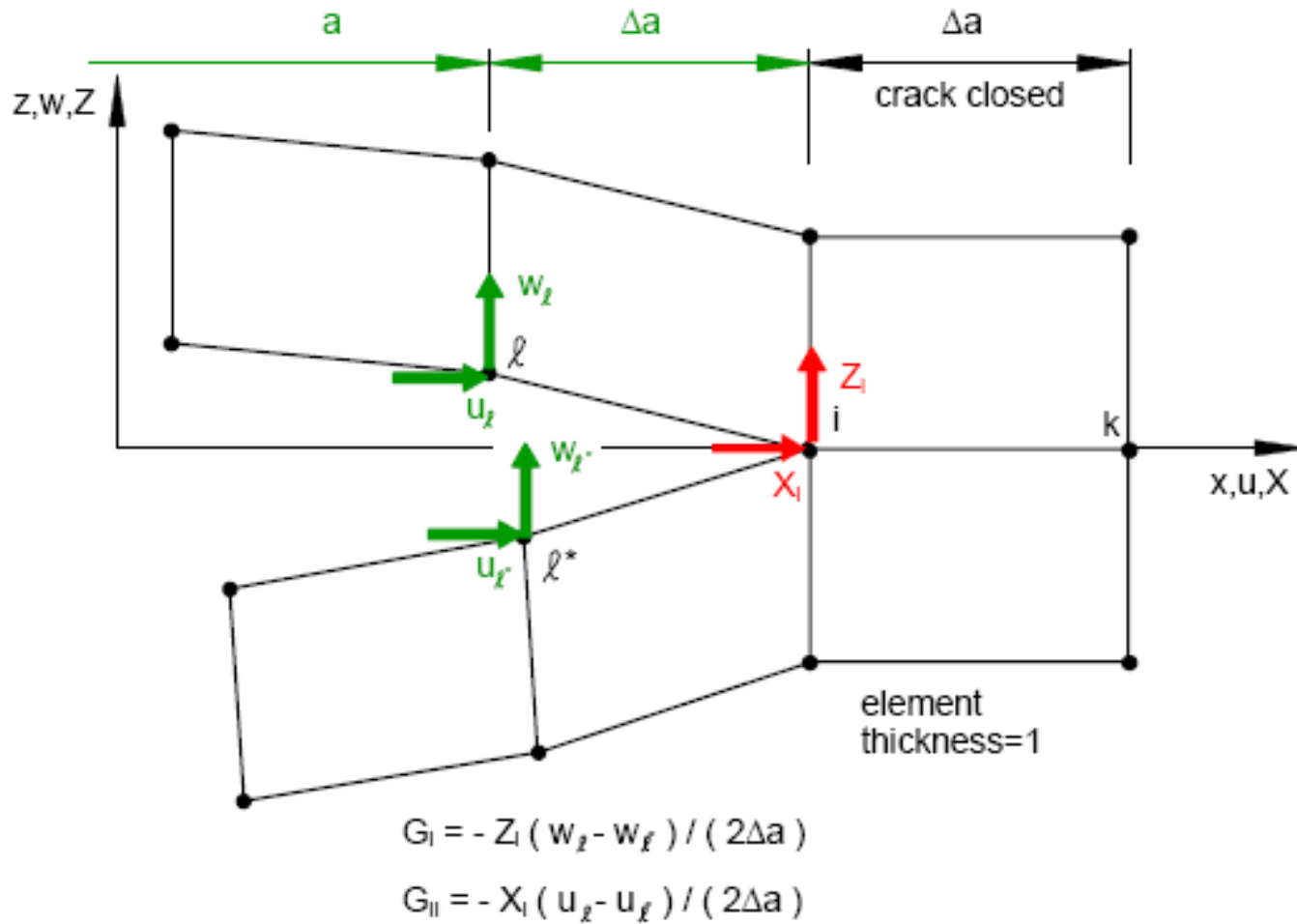
■ Two Step VCCT

\*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

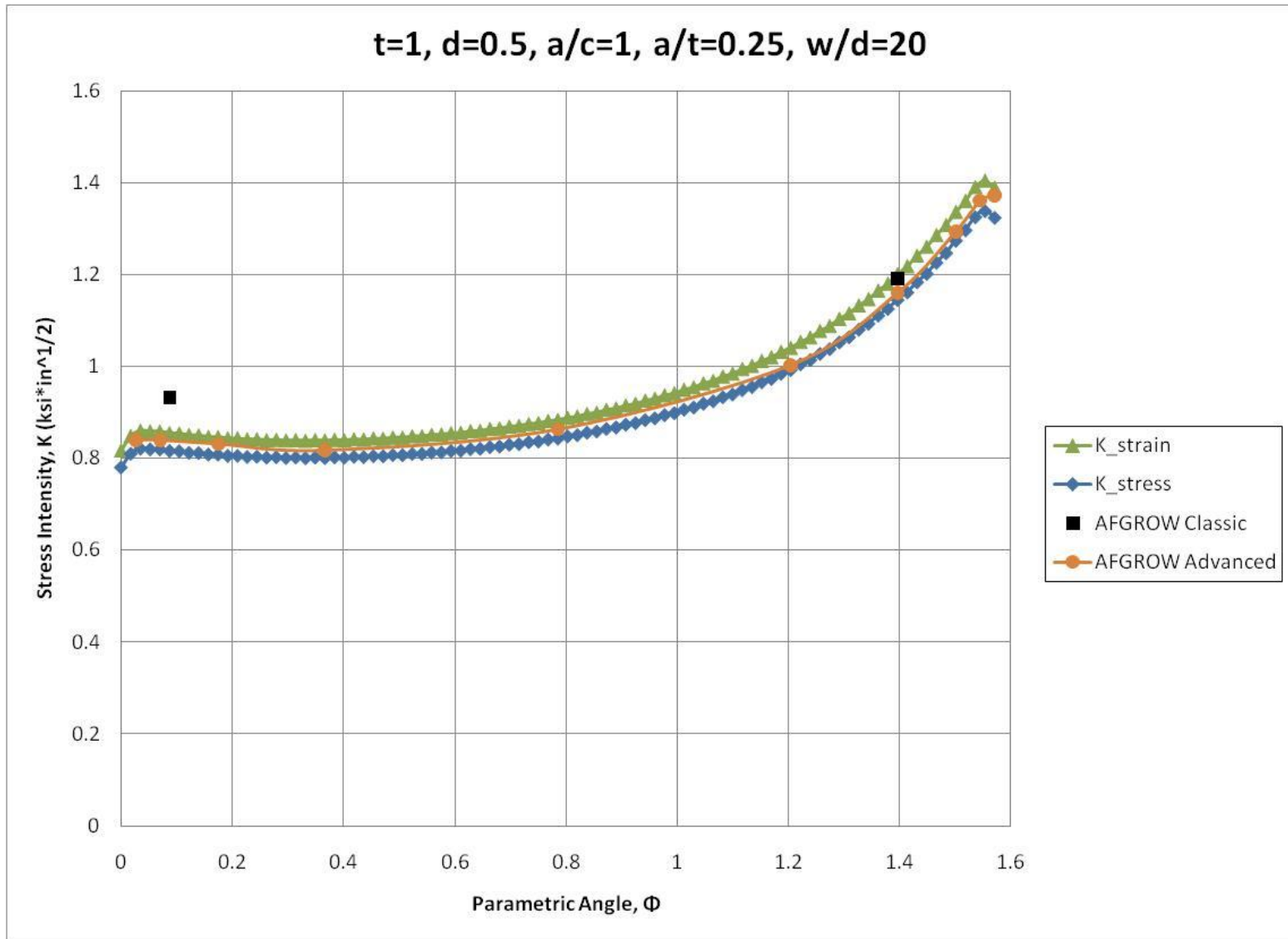
$$K_I = \sqrt{G_I E}$$

- Plane Strain

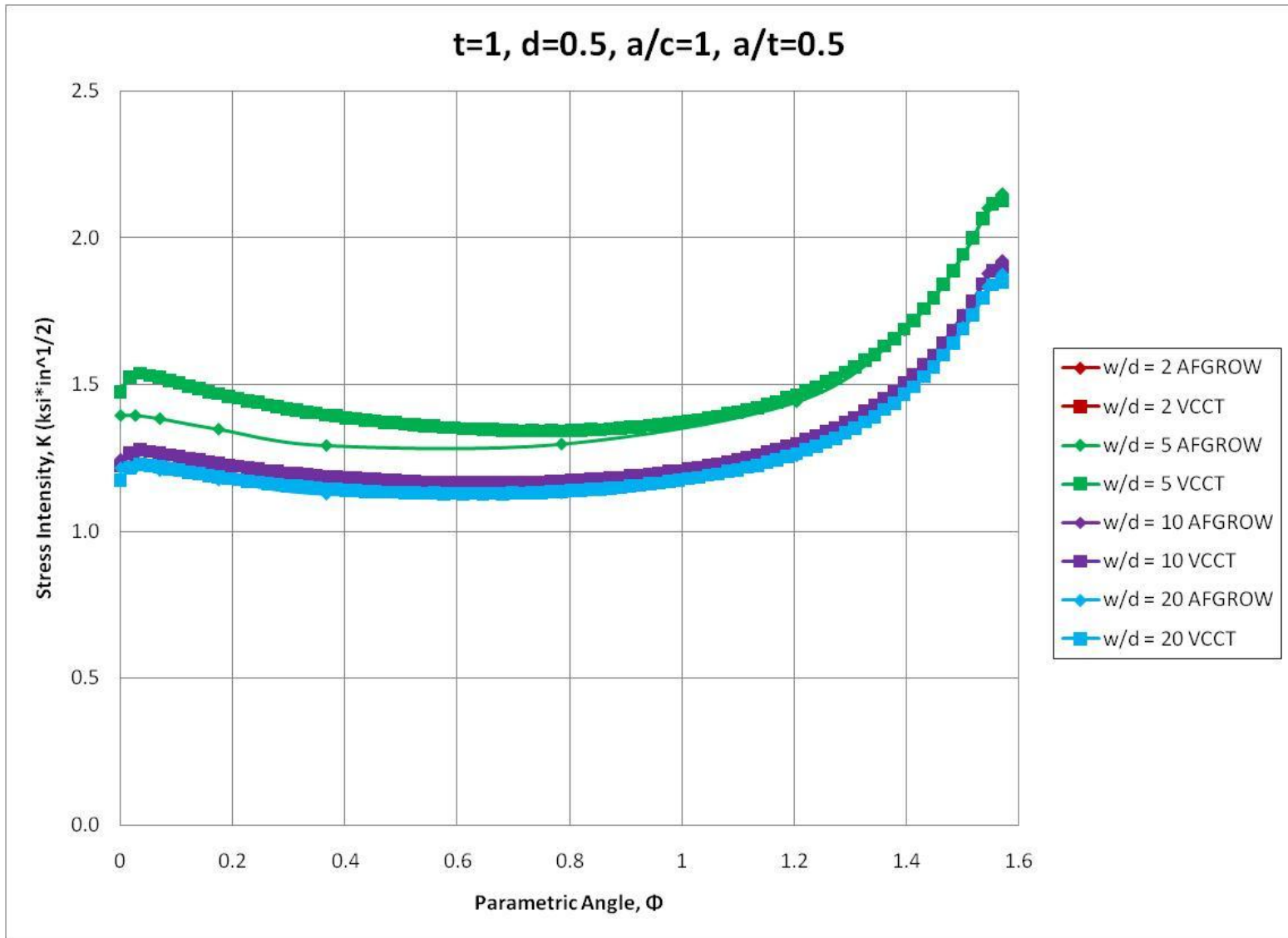
$$K_I = \sqrt{\frac{G_I E}{1-\nu}}$$

---

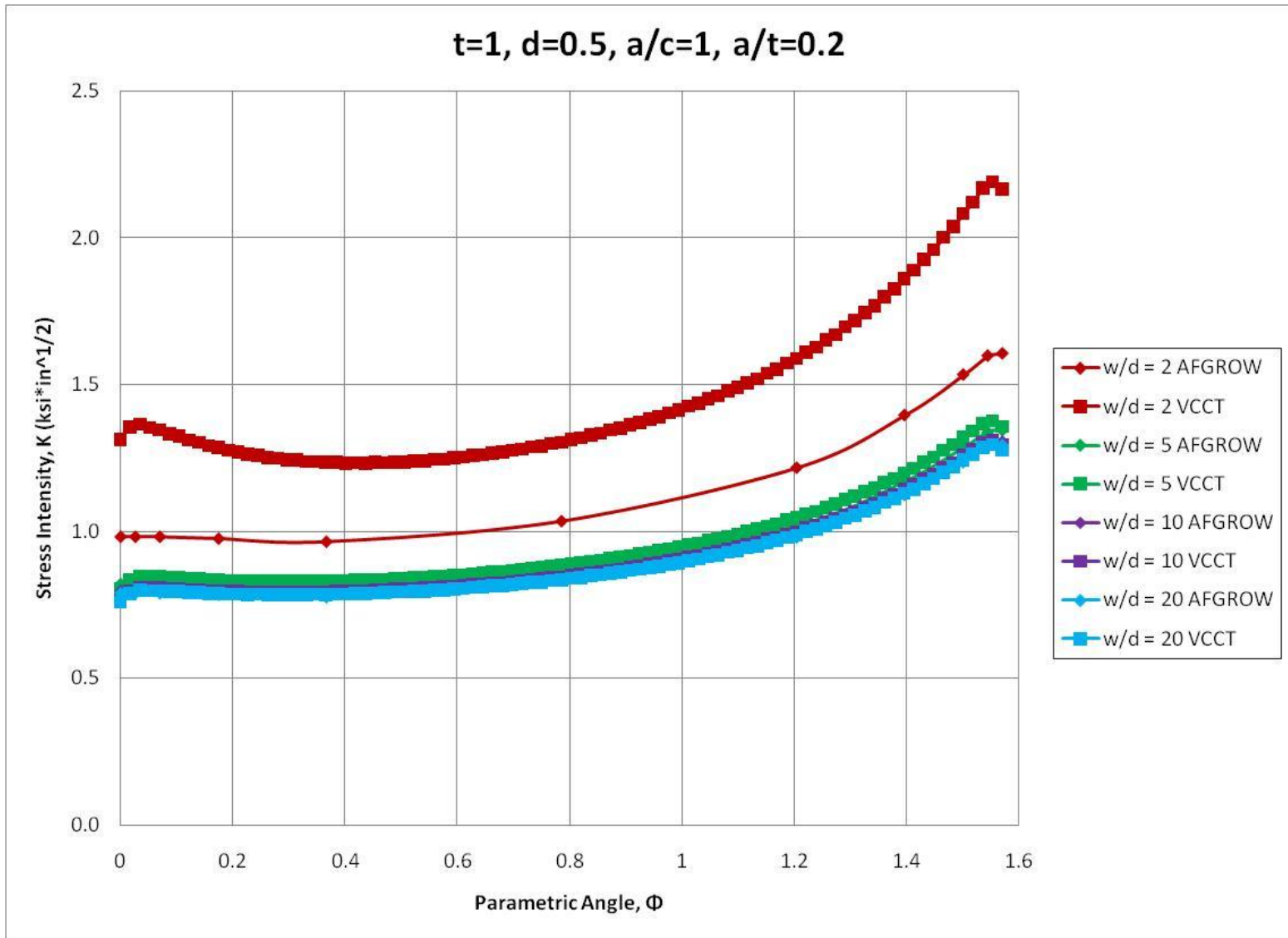
# Double Sym. Corner Crack



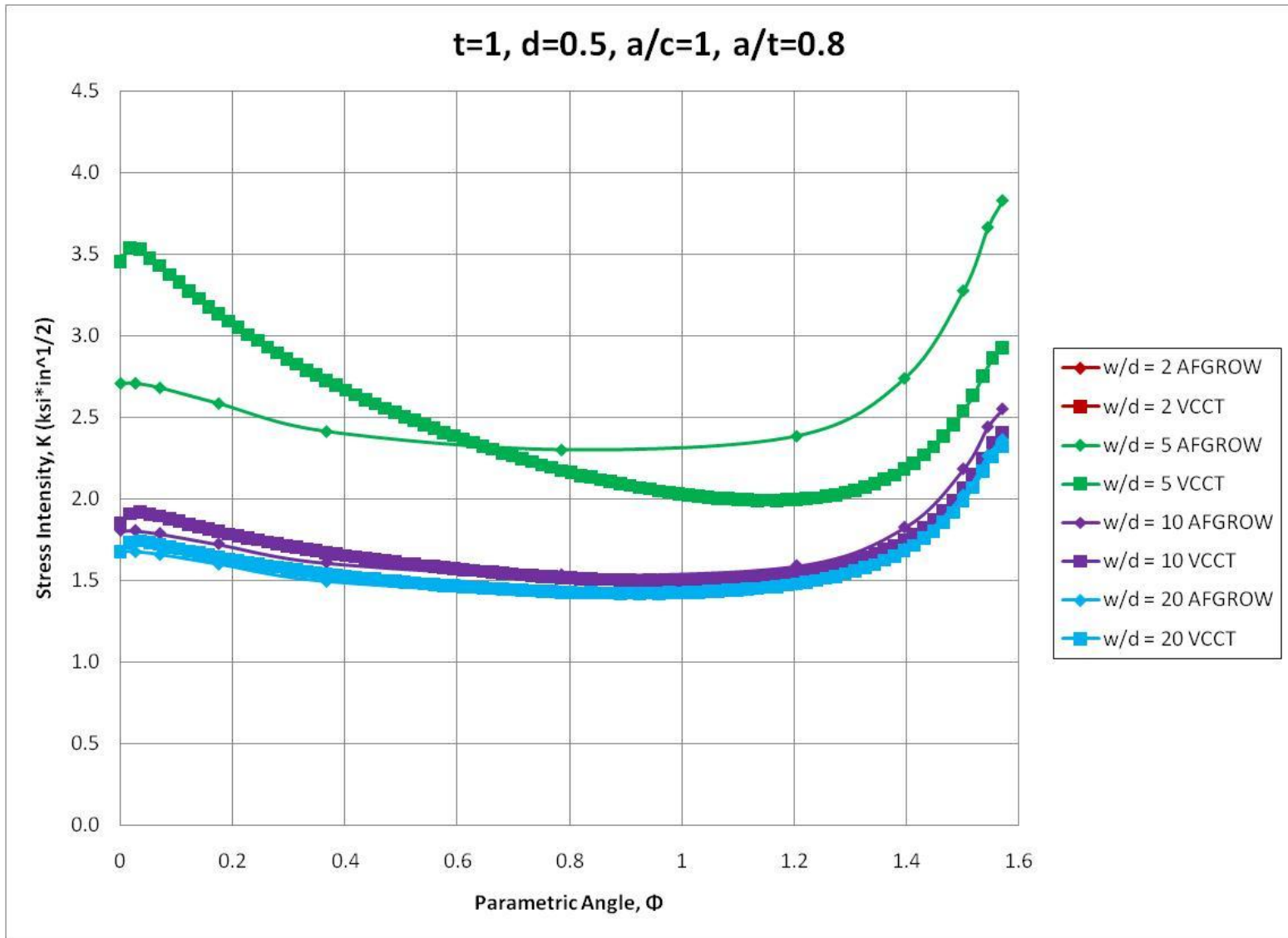
# Double Sym. Corner Crack



# Double Sym. Corner Crack

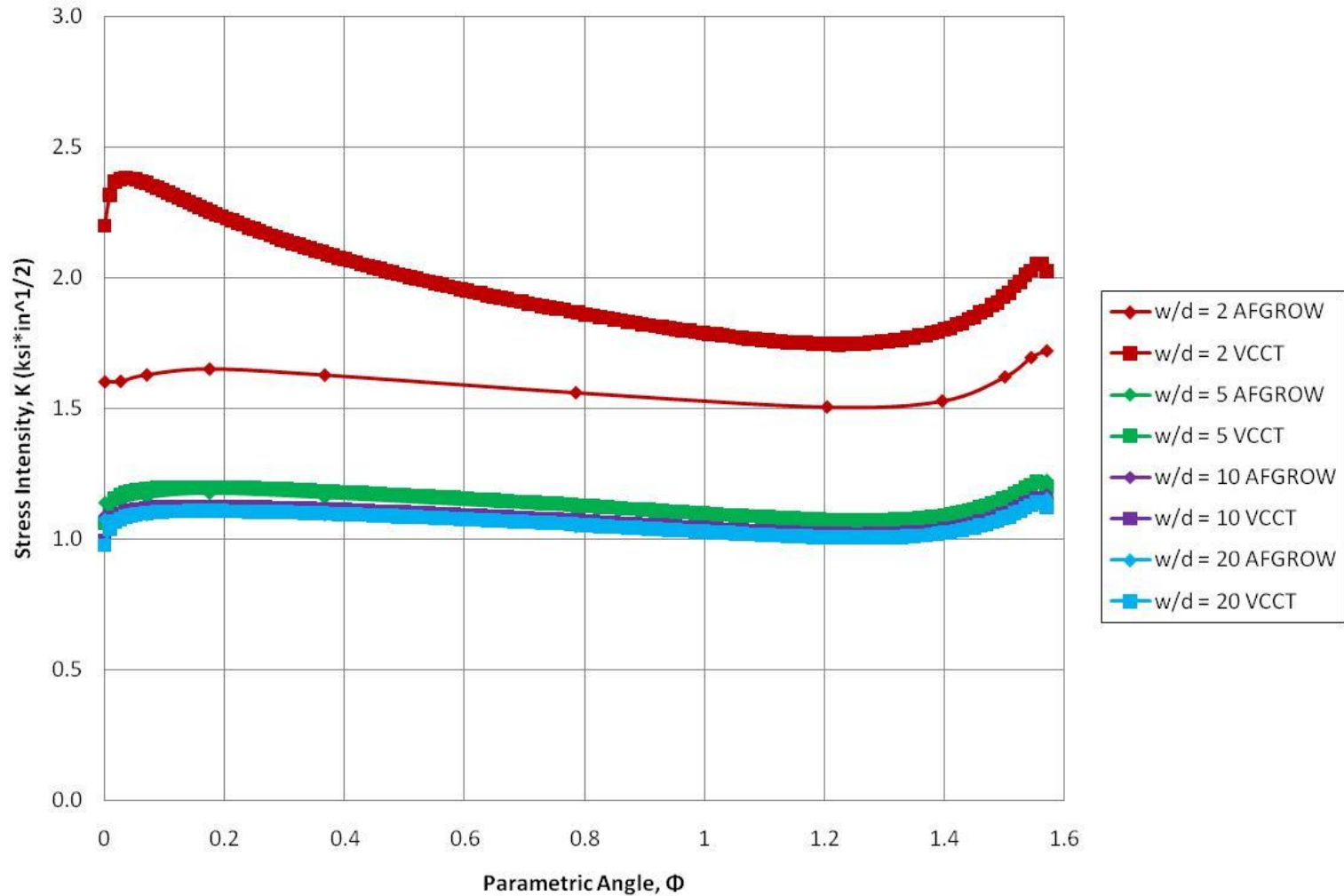


# Double Sym. Corner Crack



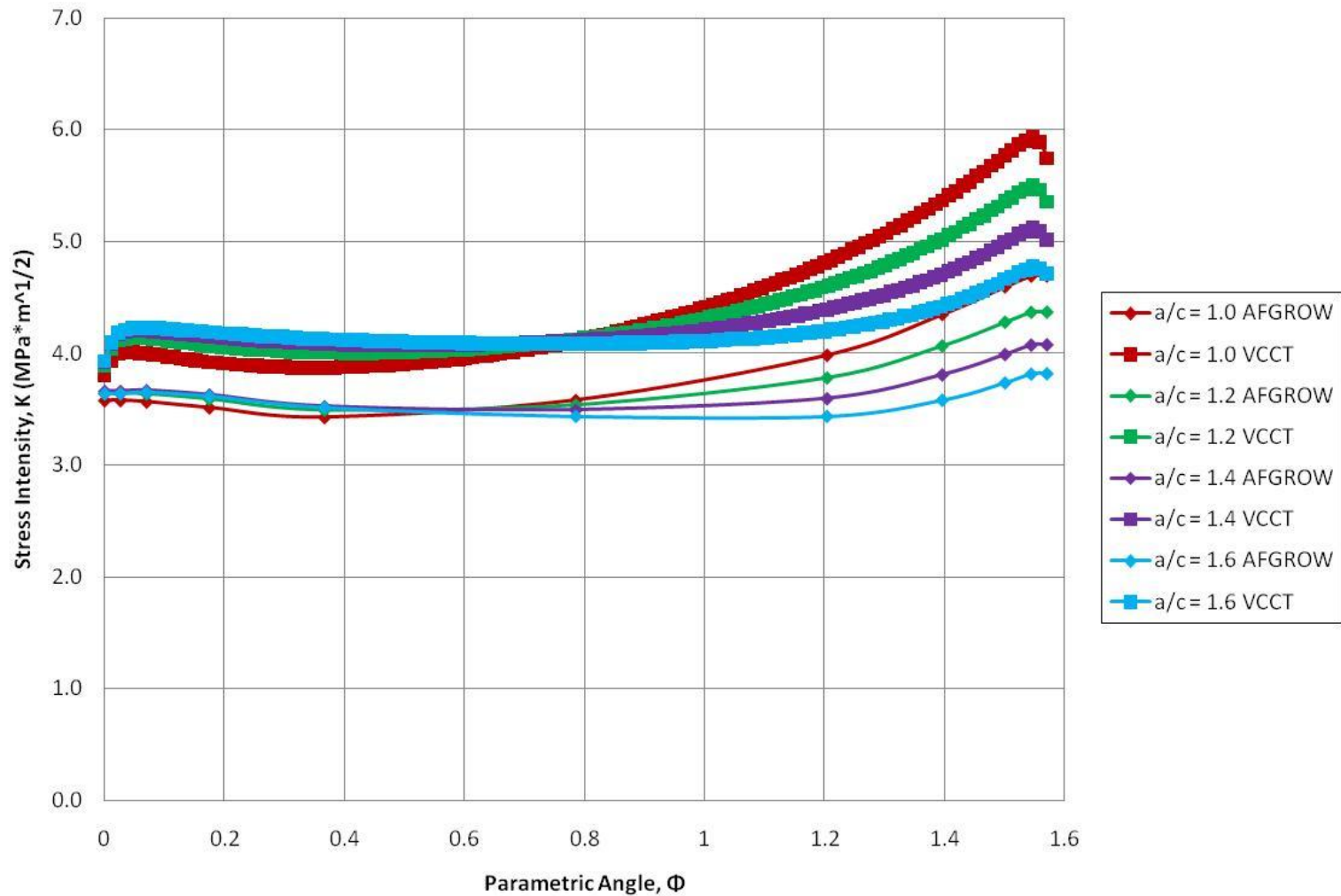
# Double Sym. Corner Crack

$t=1, d=0.5, a/c=3, a/t=0.5$



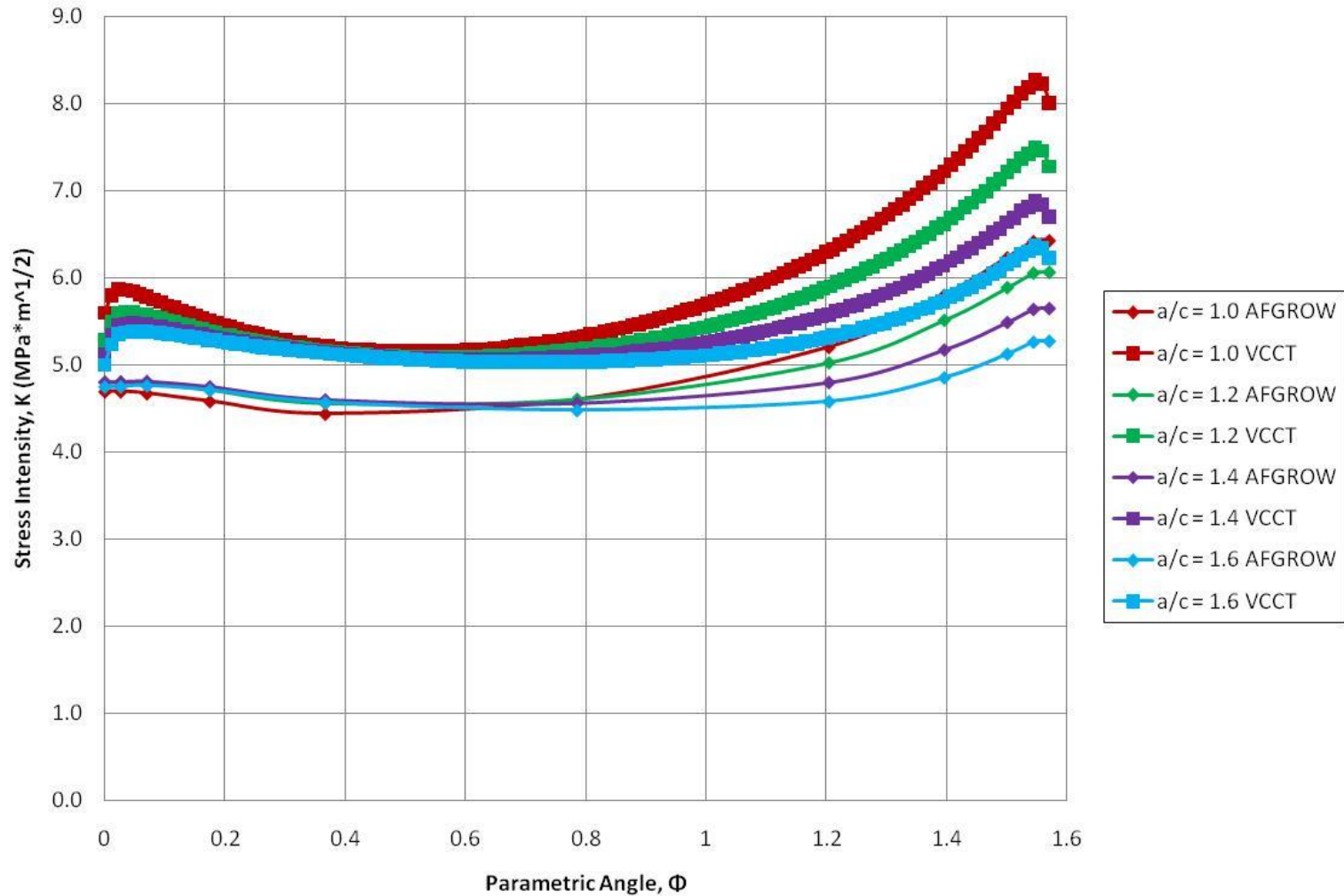
# Single Corner Crack

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



# 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.**
-

**Questions?**

---

