LexTech

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AFGROW Workshop 2021

Finite Width Correction for Part-Through Cracked Holes

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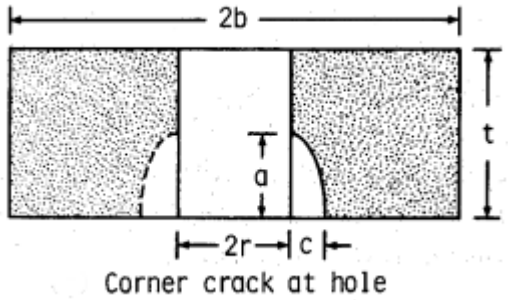
Finite Width Correction

Current Closed-Form Finite Width Correction

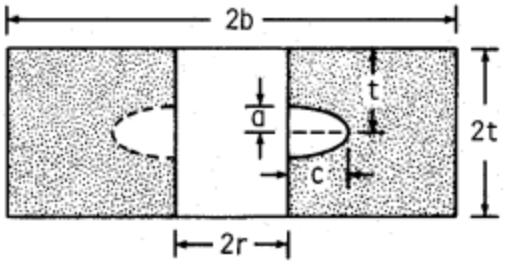
$$F_w = \left[\sec\left(\frac{\pi\, r}{2\, b}\right)\sec\left(\frac{\pi(2r+nc)}{4(b-c)+2nc}\sqrt{\frac{a}{t}}\right)\right]^{1/2} \quad *$$

n = 1 for a single crack
n = 2 for two, symmetric cracks
W = $2b$
D = $2r$

This correction is applied to all points on a given crack front for a given a and c dimension.



Corner crack at hole

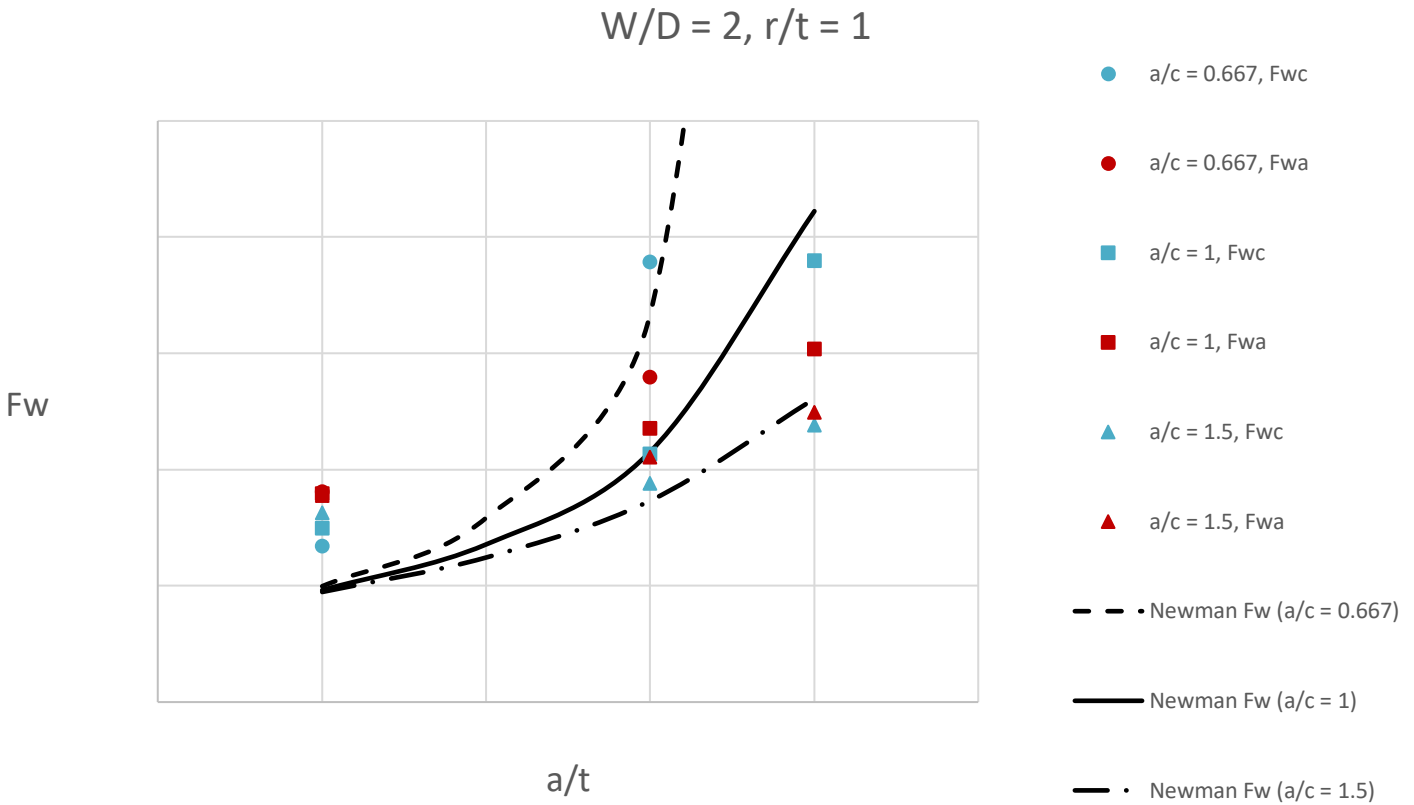


Surface crack at hole

* Newman, J.C., and Raju, I.S., "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, Elsvier Science Publishers B.V., 1986, Equation 62.

Finite Element Model Results *

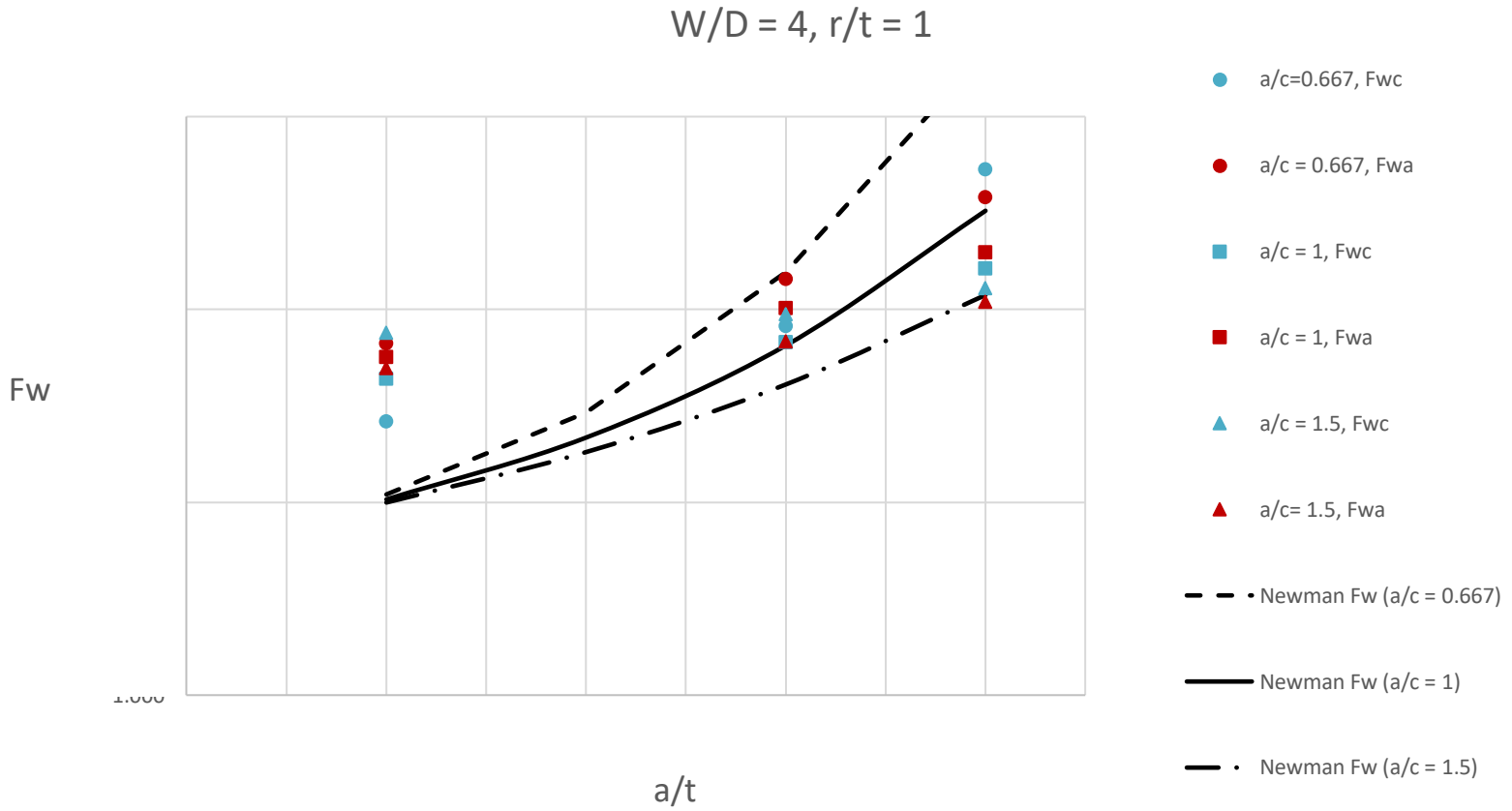
Single Corner Cracked Hole



* SimModeler (Dr. Adrian Loghin)

Finite Element Model Results *

Single Corner Cracked Hole



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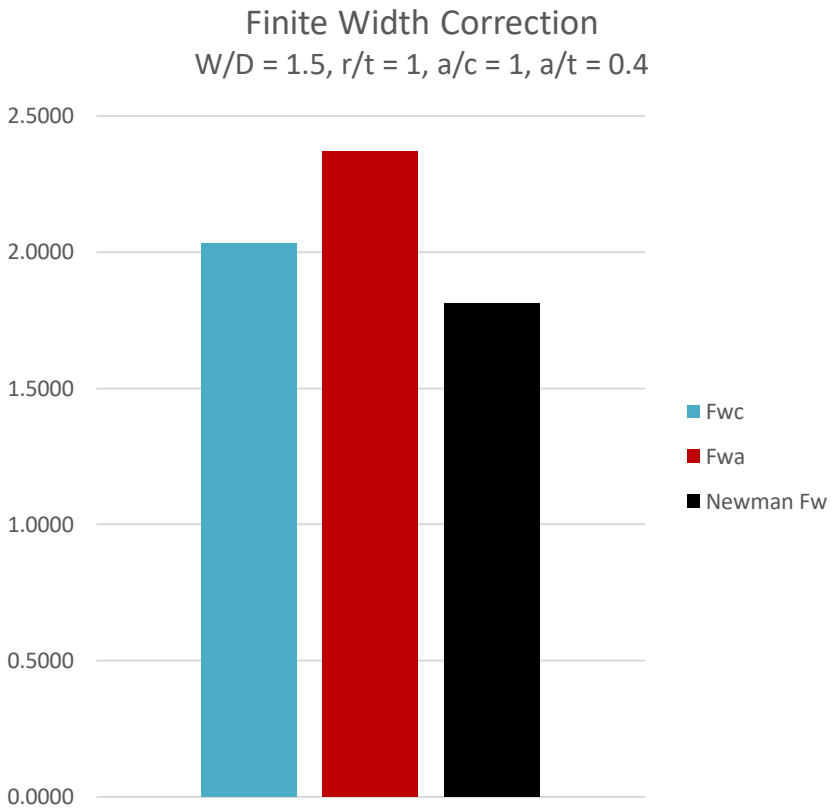
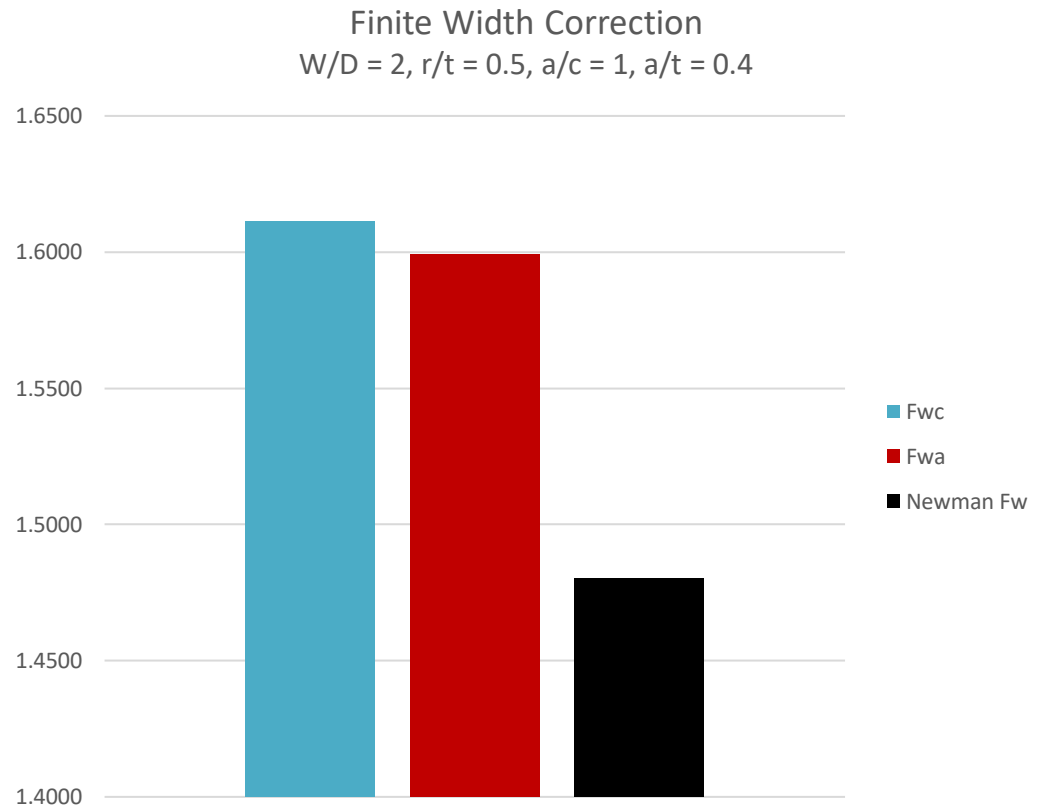
Finite Element Model Results *

Single Corner Cracked Hole





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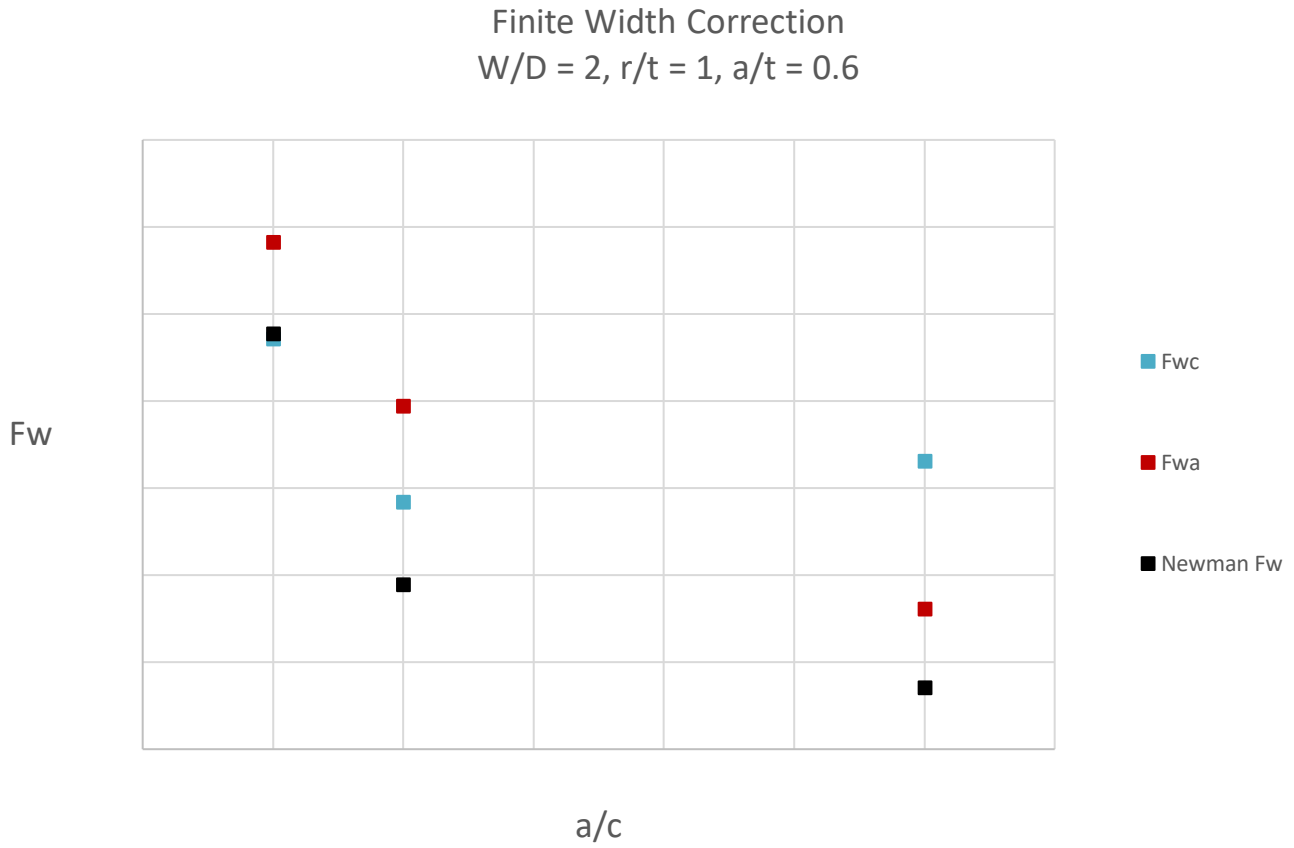
Finite Element Model Results *

Effect of Crack Aspect Ratio



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What Do We Know?

The 1986 Newman Fw correction is low when a/t < 0.6

The 1986 Newman Fw correction is high when a/t > 0.6

The actual Fw is not the same for each crack dimension

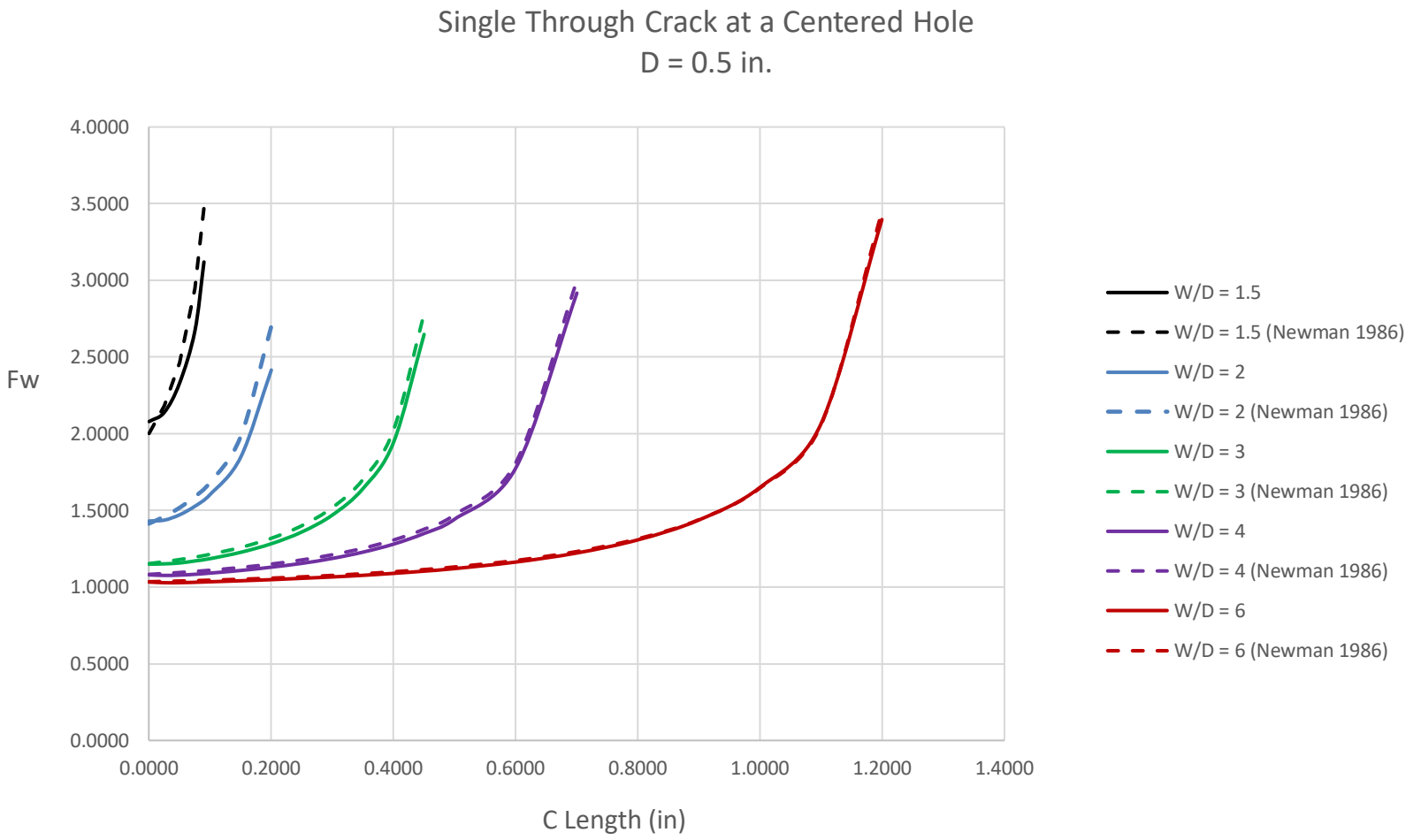
Fw is a function of W/D, r/t, a/c, and a/t

We have a problem

What is the Plan Moving Forward?

- Review/Modify the Current AFGROW Finite Width Solution for the Through Crack (2-D) Case - Completed
- Develop an Initial FEM Solution Matrix for a Single Corner Cracked Hole – Completed
- Obtain FE Solutions for the Initial Matrix – Completed by Dr. Scott Prost-Domasky (APES, Inc.)
- Develop a New Closed-Form Finite Width Correction for the Corner Cracked Hole Geometry – In Progress
- Verify and Validate the Solution – Not Started
- Apply to Double Corner Cracks and Surface Cracks – Not Started
- Make Changes as Required – Not Started
- Determine How to Apply the Solution Along the Crack Front – Really Not Started

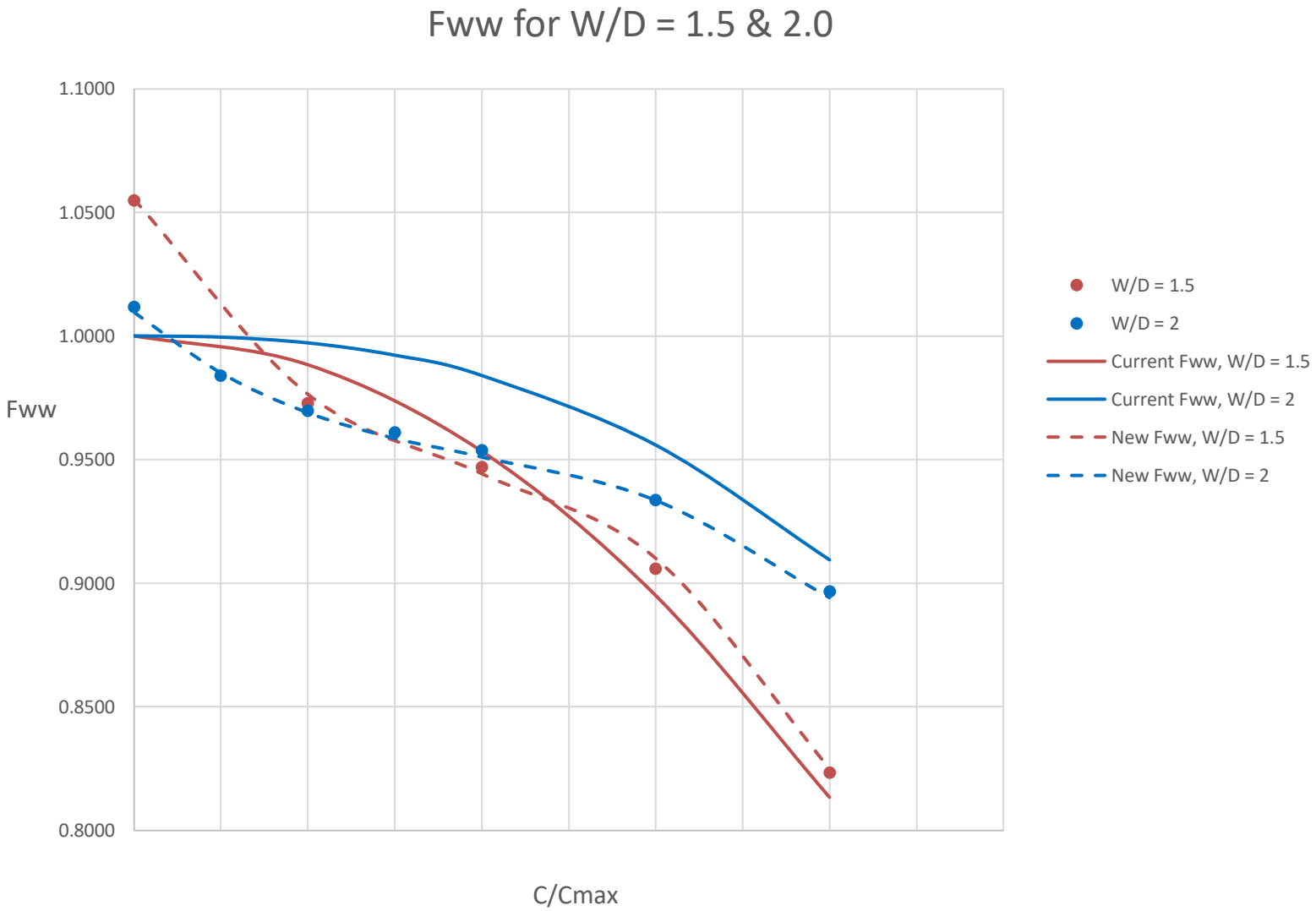
Through Cracked Hole Finite Width Correction



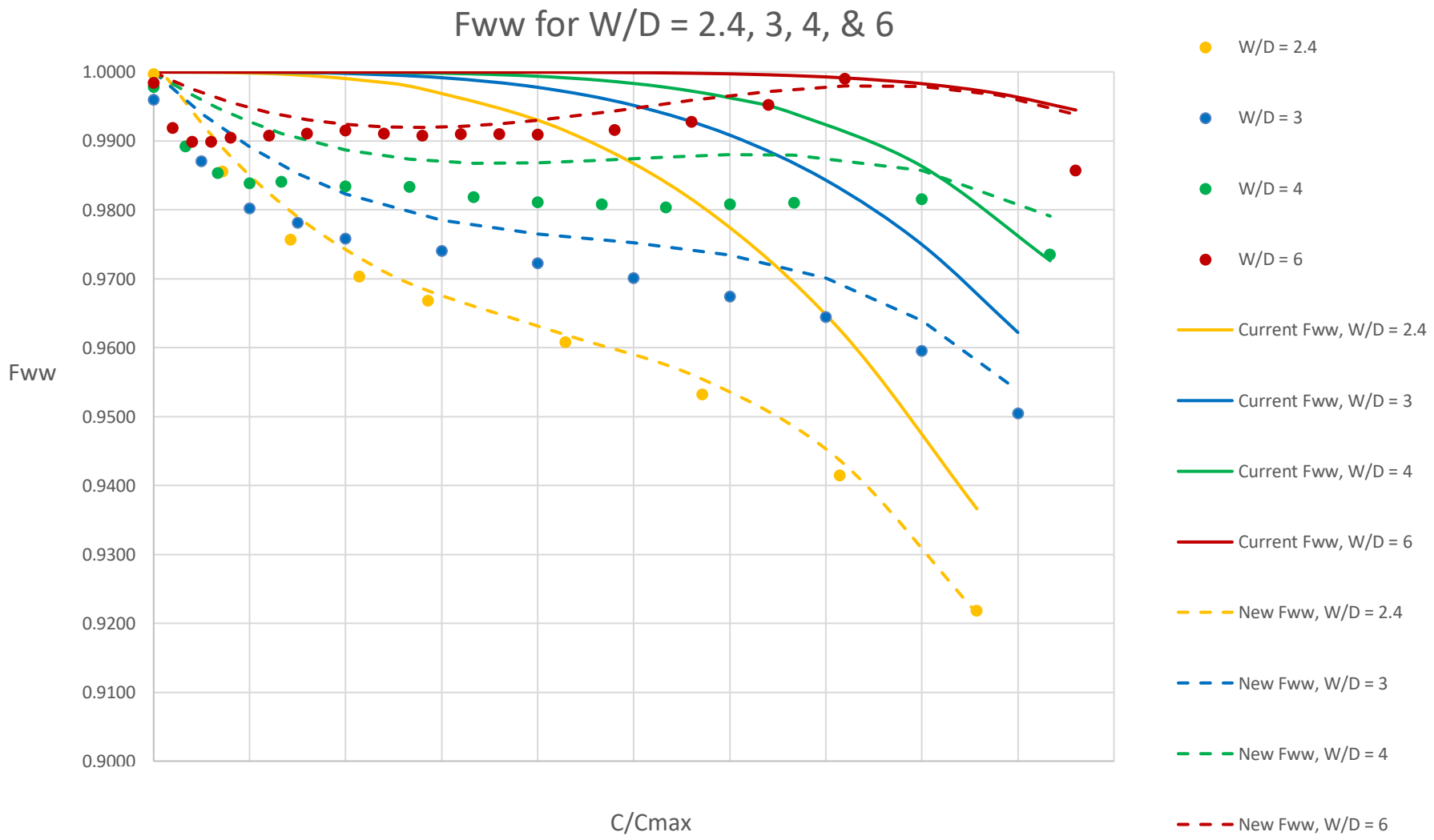
Through Cracked Hole Finite Width Correction

- The through crack finite width correction is used as the baseline solution for all 3-D finite width corrections
- The 3-D width correction must converge to the 2-D correction as (a/t, a, & c) → 0 (both directions) and a/t → 1 (c-direction only)
- The Width Correction for a=c=0 is the unflawed Kt value for any W/D divided by 3
- AFGROW currently uses the 1986 Newman/Raju width correction (F_w) with a/t = 1 and a modification (F_{ww}) to correct it for W/D <= 6
- This has recently been reviewed, and a new correction has been developed
- We would like the correction to apply for W/D >= 1.5

Through Cracked Hole Finite Width Correction



Through Cracked Hole Finite Width Correction



Through Cracked Hole Finite Width Correction Summary

- The new Fww correction for a single through crack at a hole is much better than the current correction for (W/D <= 2) and is within << 1% of FE solutions
- The new Fww correction is also better than the current correction for (2 < W/D < 6) and is conservative within 1% of FE models
- For W/D > 6, Fww > 0.99, converges to 1.0 as W/D → 50 and is within <<1% of the required width correction
- The applicability of the new Fww correction still needs to be validated for the double, symmetric through crack case

Part-Through Finite Width Correction

- The through crack finite width correction $(F_w * F_{ww})$ is used as the baseline solution for all 3-D finite width corrections
- The part-through crack correction is defined for any point (x) as $\left(\frac{K}{K_\infty}\right) / (F_w F_{ww}) = F_x$
- Dr. Scott Prost-Domasky provided the StressCheck results for the initial 3-D solution matrix for a single corner cracked hole
- Wide plate K_∞ values for the a and c-dimensions were obtained from the Fawaz-Andersson single corner cracked hole solutions in AFGROW
- Required parameter coverage for compatibility with the Fawaz-Andersson solution database are (0.1 < r/t < 10), (0.1 < a/c < 10), (0 < a/t < 1)

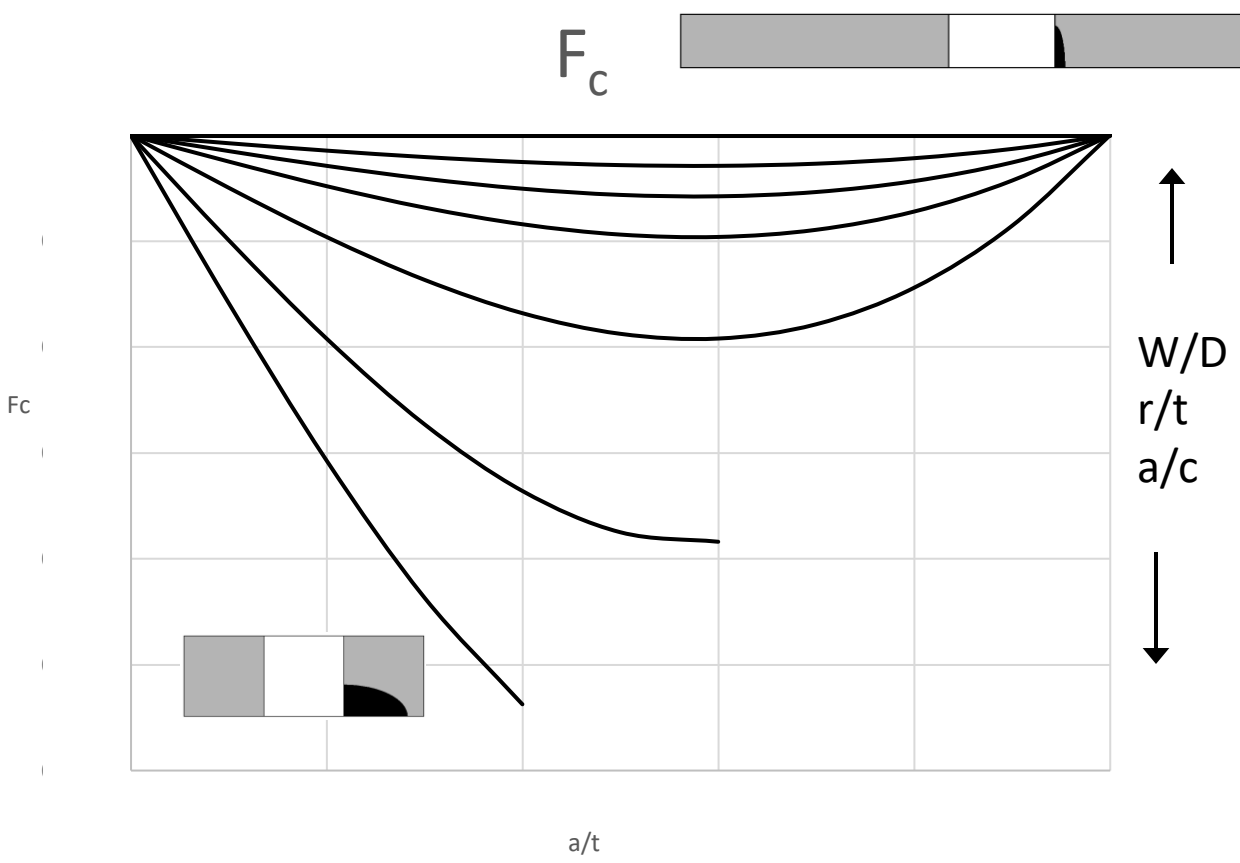
Initial Single Corner Cracked Hole Solution Matrix

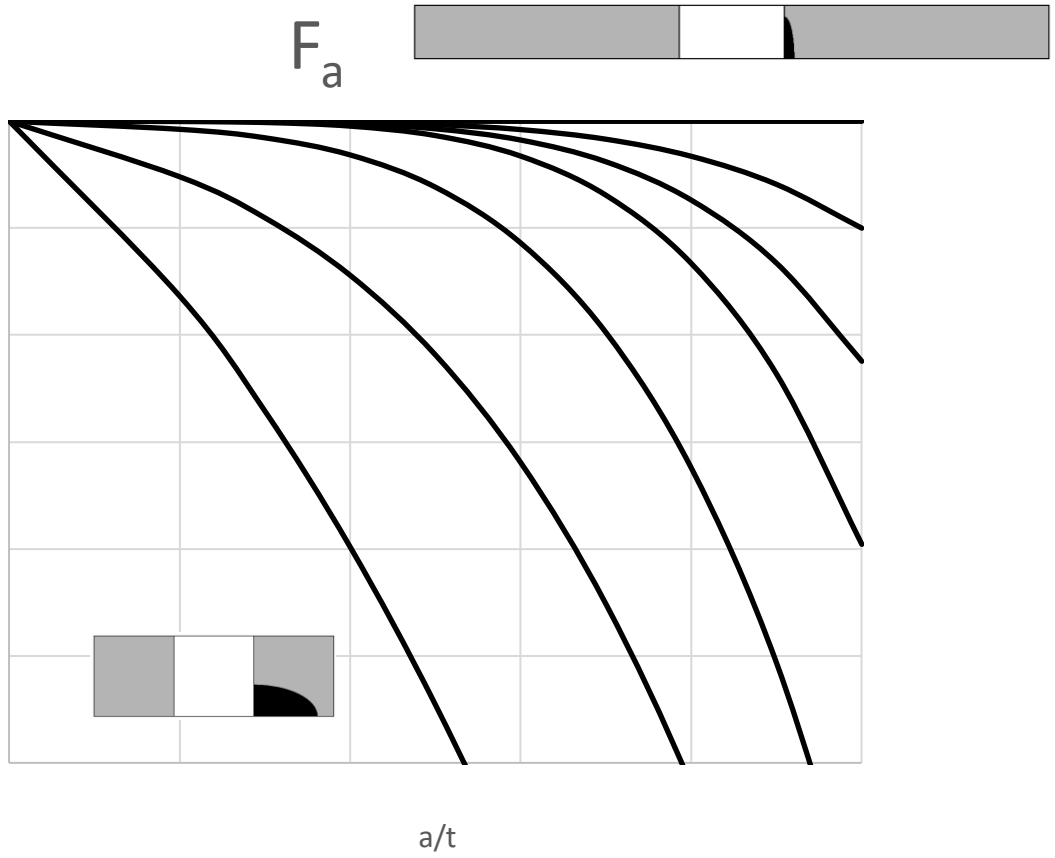
Prost-Domasky (APES)

W/D	r/t	a/c	a/t
1.5	0.5	0.5	0.2
2.0	1.0	1.0	0.4
4.0	2.0	1.5	0.6
6.0	4.0	2.0	0.8
10.0		4.0	0.9
		6.0	

Note: The full matrix was not used for all W/D values, but was concentrated between W/D = 2 and 4. A smaller subset of the matrix was used for W/D = 1.5, 6, and 10. Also, some combinations of these parameters are not physically possible.

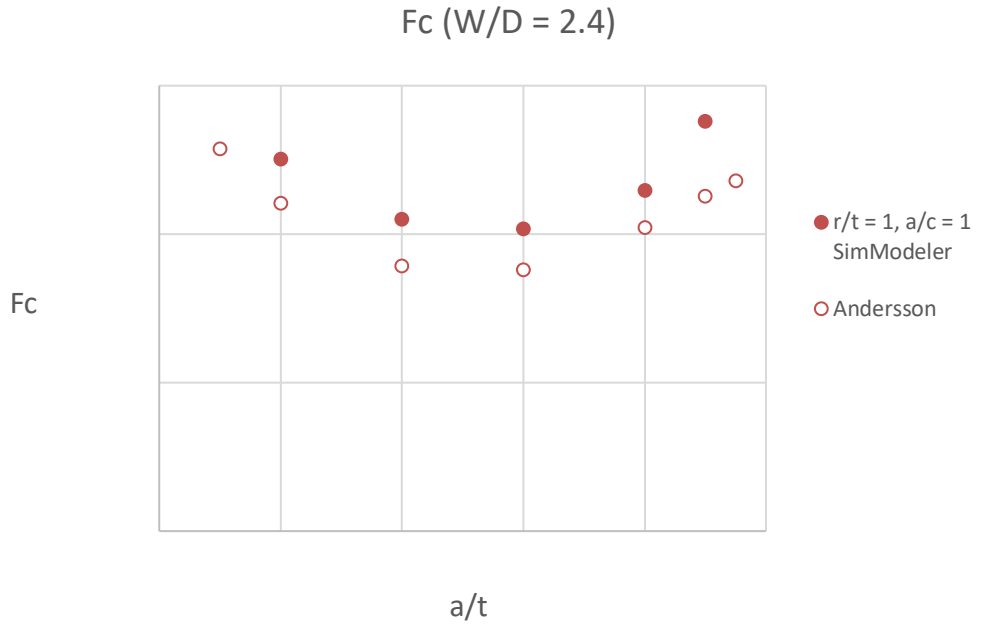
Part-Through Finite Width Correction Trends

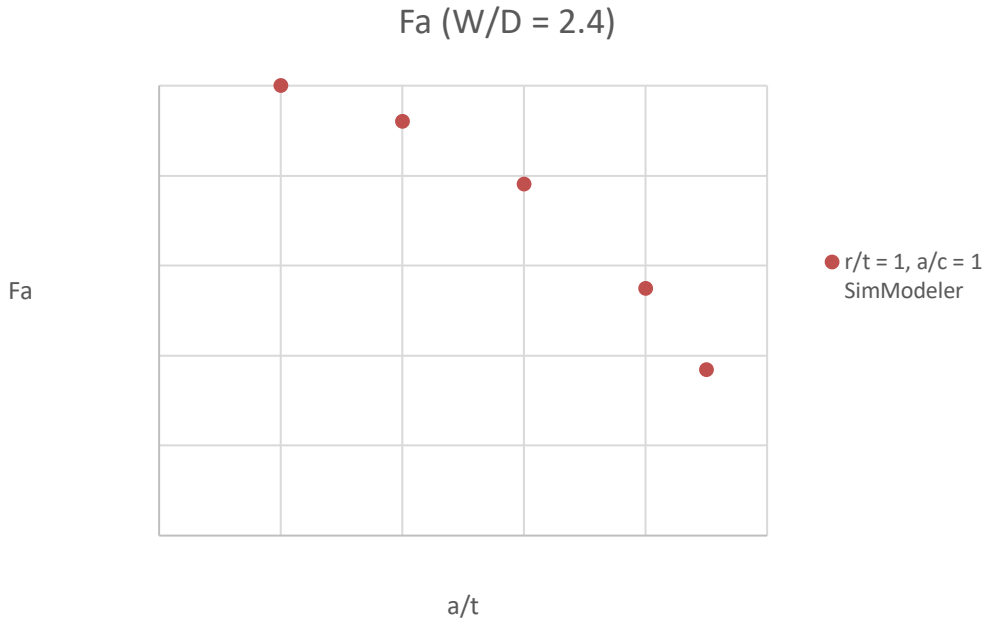




Part-Through Finite Width Correction Examples

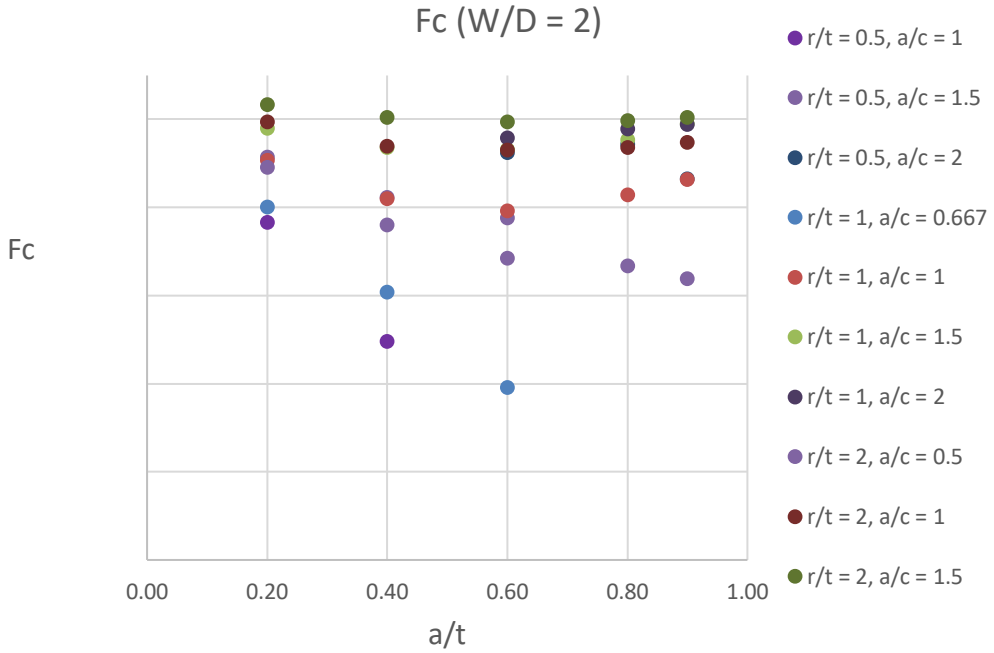
ERSI RR Narrow Plate Case

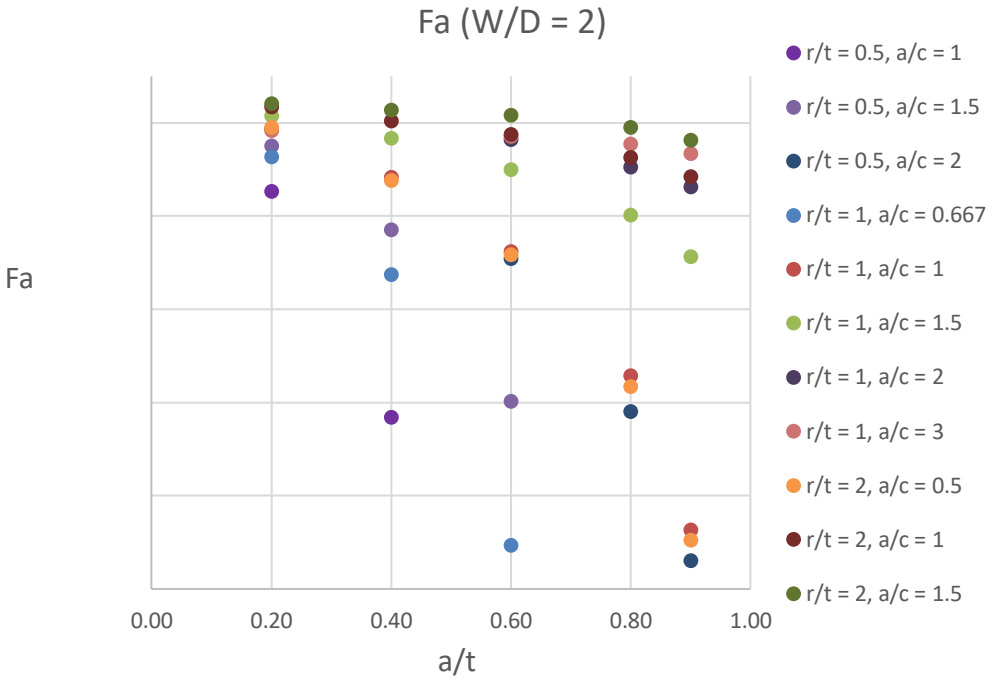




Part-Through Finite Width Correction Examples

Prost-Domasky (APES) Solutions





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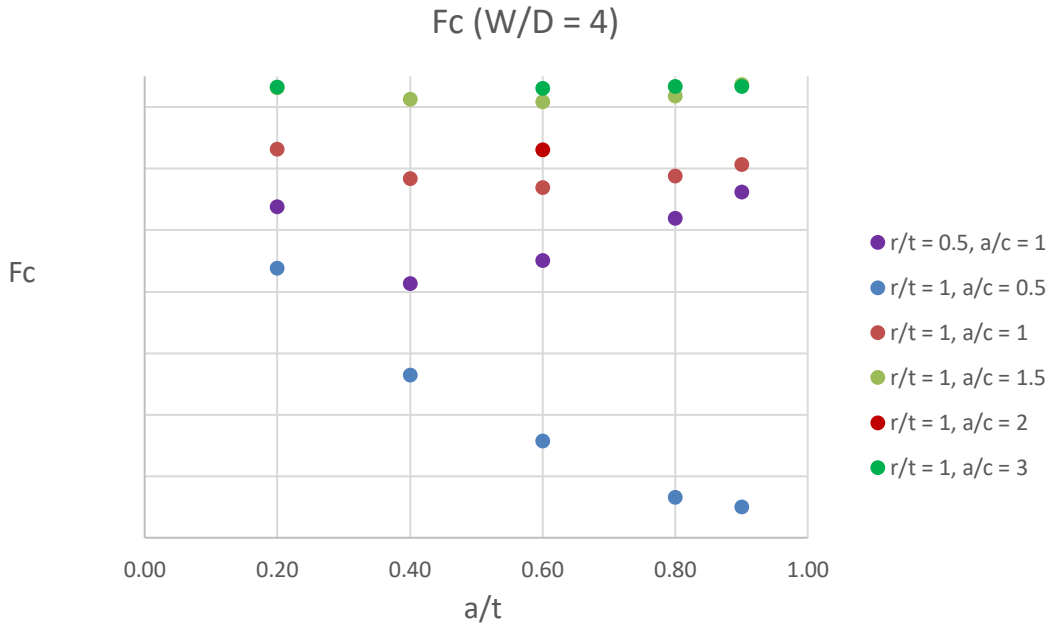

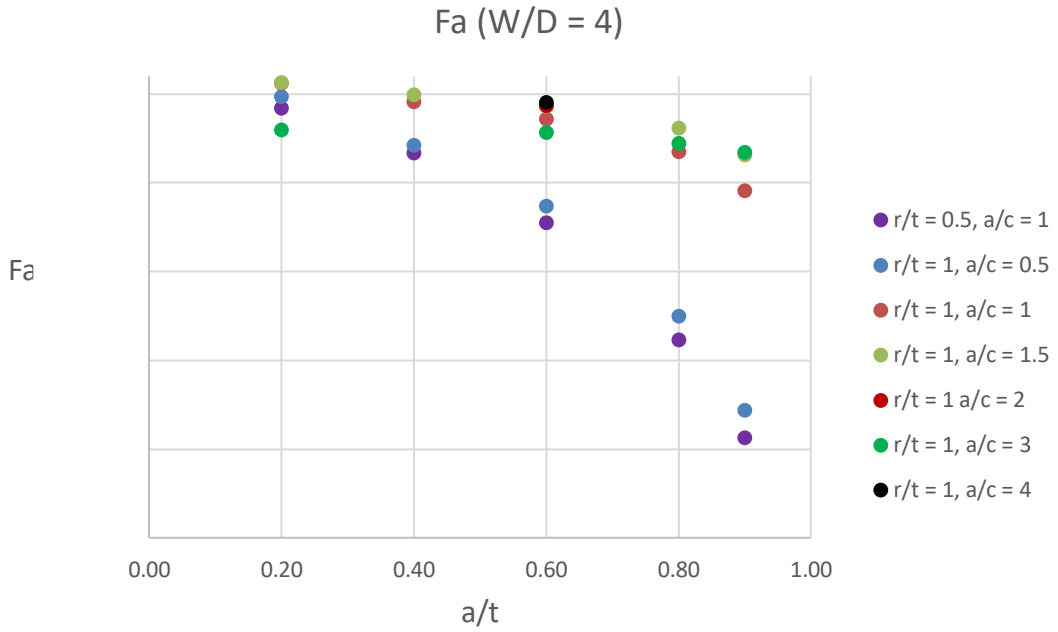

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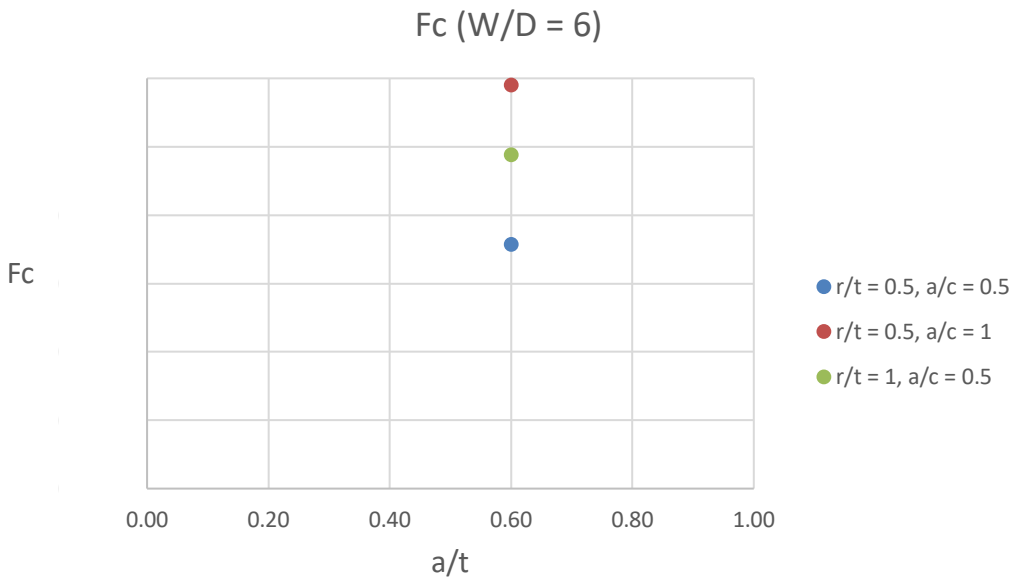
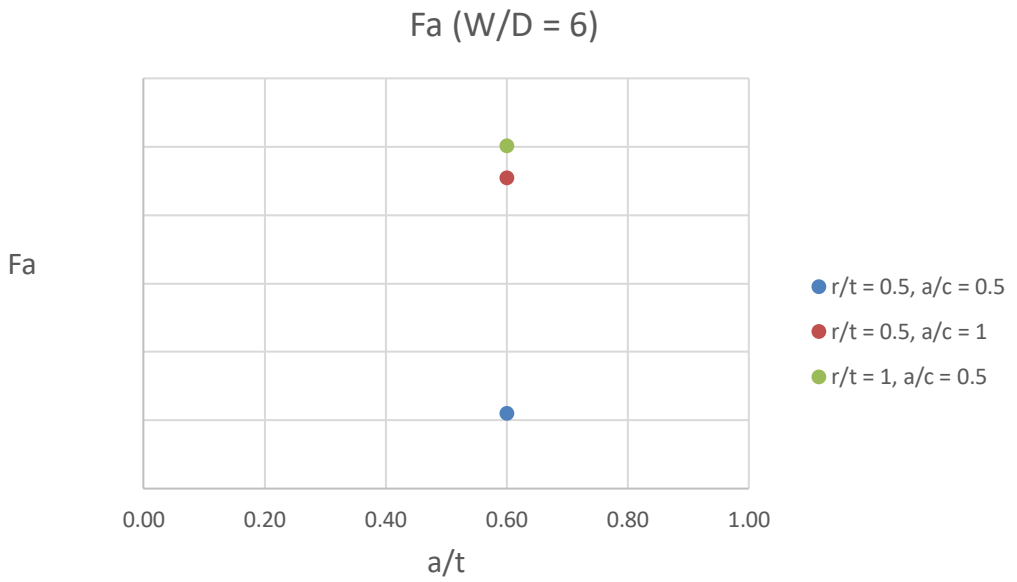
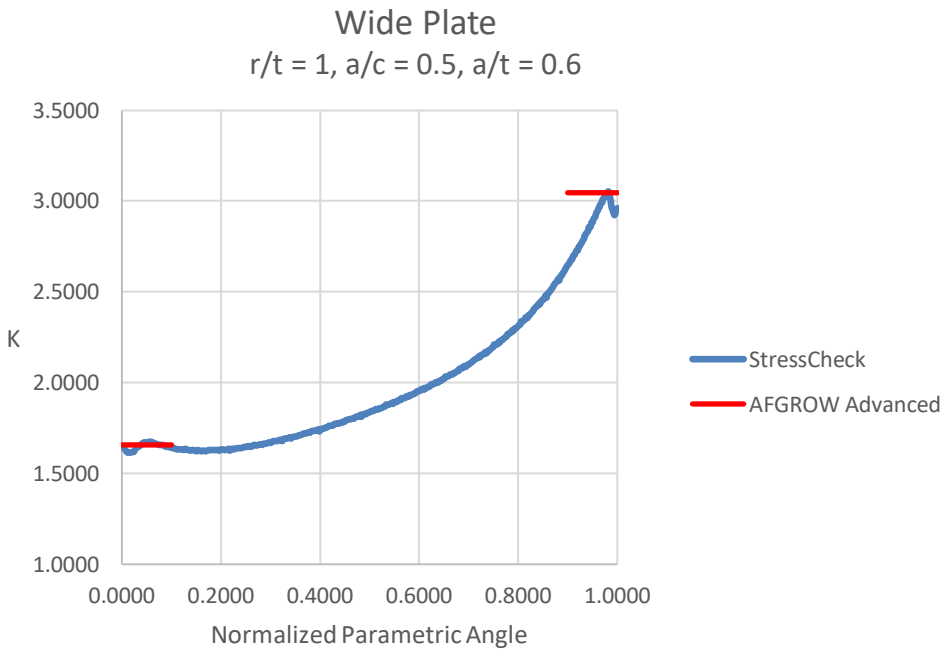
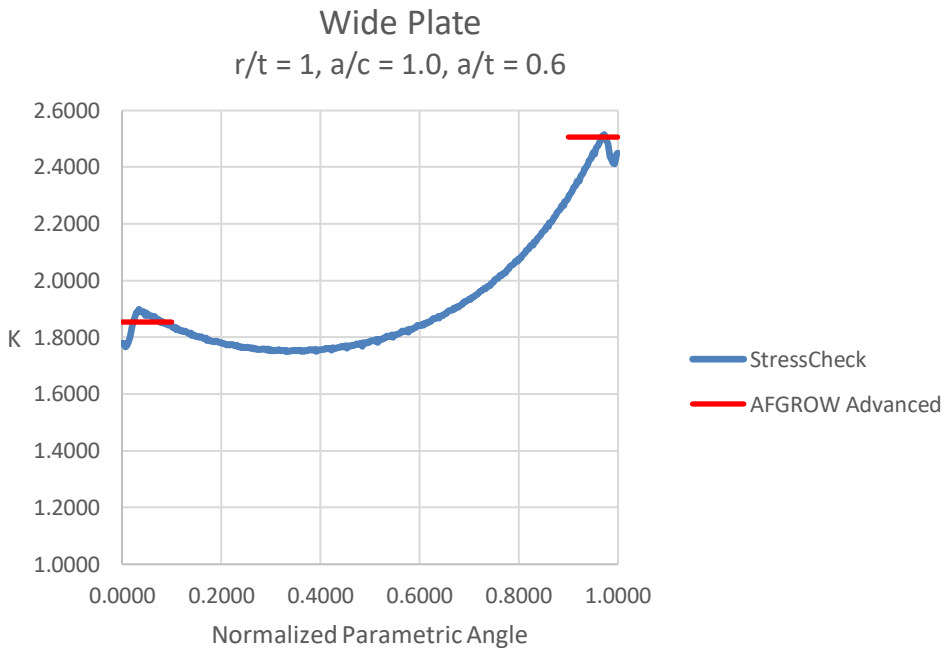




K-Solutions at the Vertices





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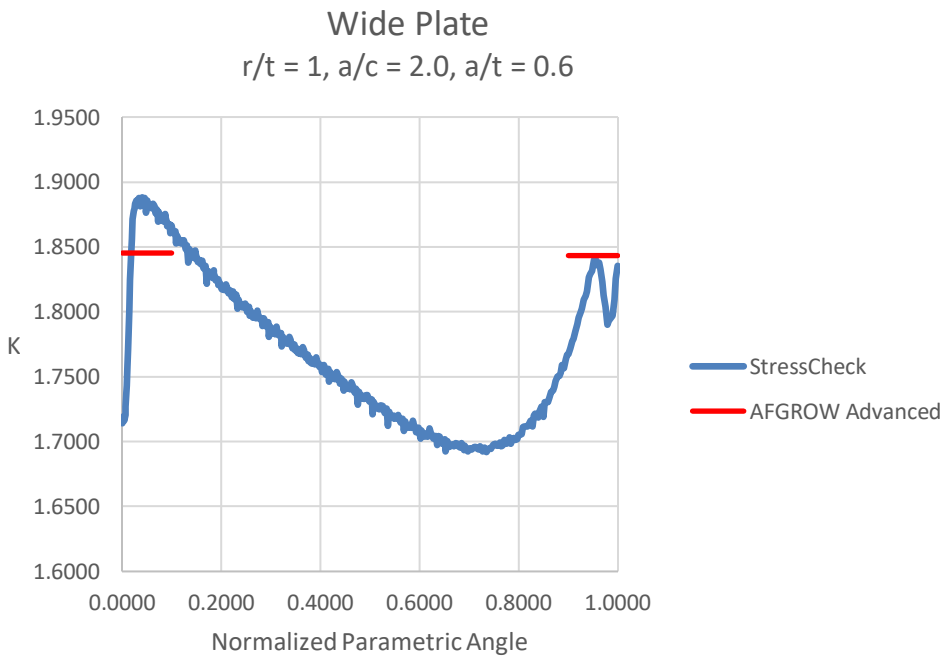

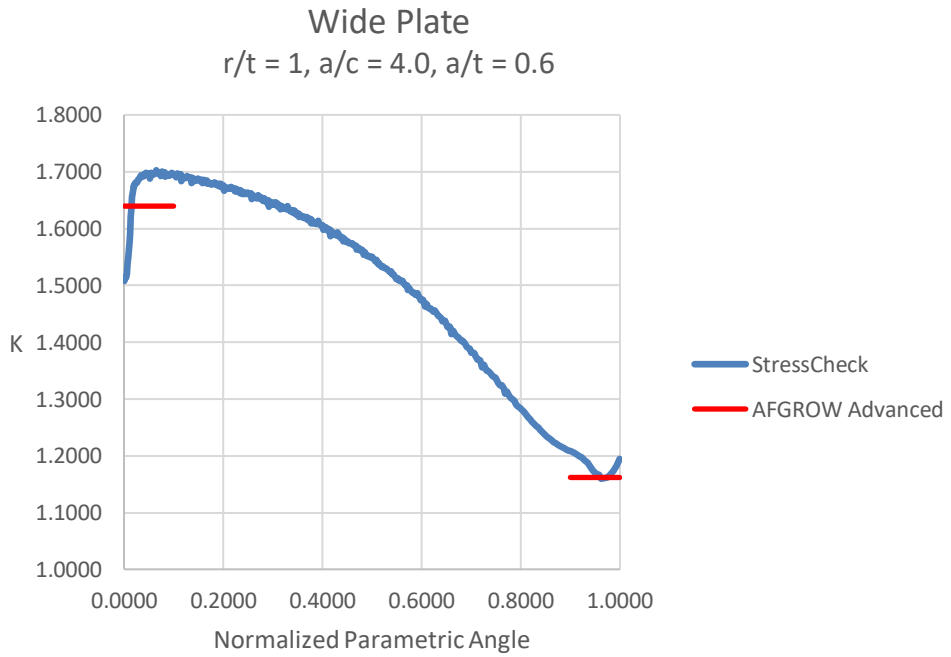

Summary and Conclusions

- The current closed-form finite width correction for a single corner crack at an open hole needs to be corrected as soon as possible
- It is now clear that the finite width correction is not the same for all points on the crack front
- It is reasonable to assume that the current correction is also incorrect for double symmetric corner cracks as well as embedded cracks at an open hole
- Work is well underway to develop a new closed-form finite width solution for the single crack case (a and c-directions)
- Scott Prost-Domasky is currently working to resolve the solution noise issue (~2-3%)
- A solution is also needed for multiple point life predictions
- It is important that this issue be resolved before moving forward with any RR efforts for cracks at centered, narrow plates (W/D <= 6) or offset holes (e/D <= 3)

Thank You

A special thanks to Dr. Adrian Loghin and Dr. Scott Prost-Domasky for all of their help running the 3-D FEMs used for this presentation