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AFGROW Workshop 2020

K-Solutions for a Corner Cracked Hole

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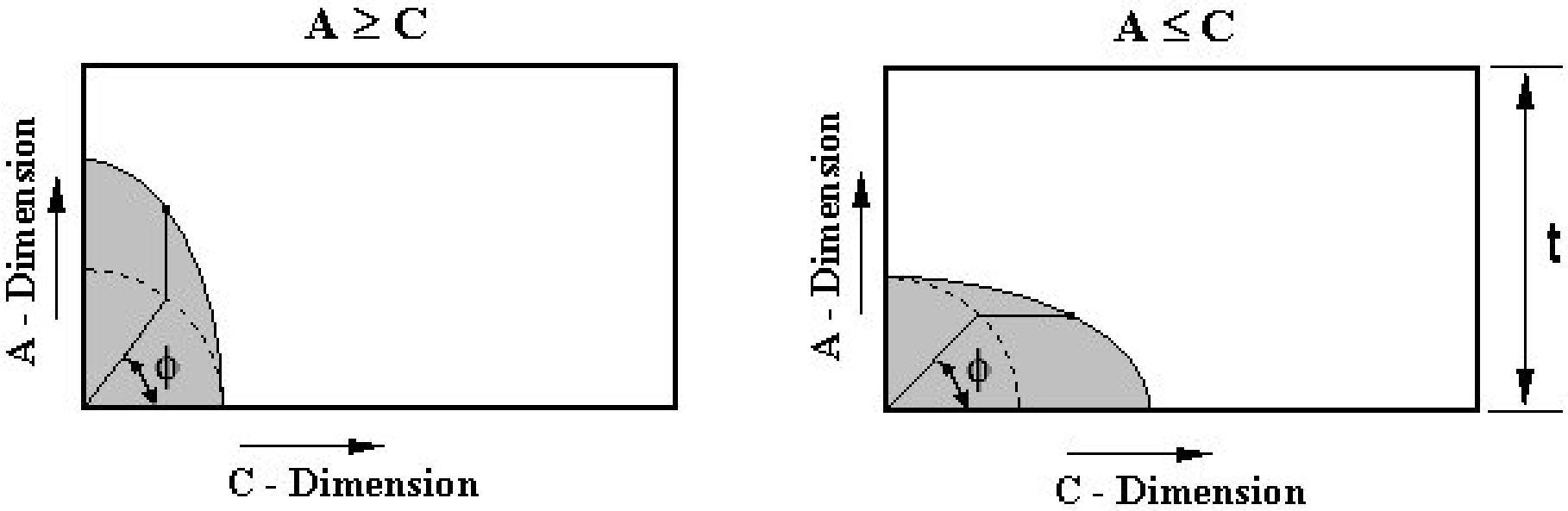
Purpose

There have been some discussion recently about the similarities and differences between the 1986 Newman/Raju curve fit solution, what is used in AFGROW, and the Fawaz/Andersson solutions from 2000.

An issue was raised at the 2019 ASIP Conference that there may be a “typo” in the 1986 Newman/Raju curve fit solution implementation in AFGROW

The purpose of this presentation is to show a comparison between these solutions and recently updated solutions for the purpose of discussion and clarification.

Crack Length/Parametric Angle Definitions



Corner Cracked Hole Solutions

1986 Newman/Raju Curve Fit Solution

- Two-Point “Classic” Model in AFGROW
- Parametric Angles (5, 80 degrees) for the C and A-dimensions by Default
- Angles May be Changed in Registry

2000 Fawaz/Andersson Tabular Solution Database

- Two-Point and Multi-Point “Advanced” Model Options in AFGROW
- Local Maxima Used for the C and A-dimensions *

2018 Newman/Raju Curve Fit Solution

- Modified Solution using the 2000 Fawaz/Andersson Double Corner Crack Results

2018 Updated Fawaz/Andersson Tabular Solution Database

- High Resolution Database
- Local Maxima Used for the C and A-dimensions

* For some cases with no local maximum, a set offset angle is used

Solution Limits

1986 Newman/Raju Curve Fit Solution

- 0.5 <= r/t <= 2.0
- 0.2 <= a/c <= 2.0
- a/t < 1
- (r + c)/W < 0.5

2000 Fawaz/Andersson Tabular Solution Database

- 0.1 <= r/t <= 10
- 0.1 <= a/c <= 10
- 0.1 <= a/t <= 0.99
- W = 100t

2018 Newman/Raju Curve Fit Solution

- 0.125 <= r/t <= 8.0
- 0.125 <= a/c <= 8.0
- a/t < 1
- (r + c)/W < 0.5

2018 Updated Fawaz/Andersson Tabular Solution Database

- Same as 2000 Fawaz/Andersson (except 0.1 <= a/t <= 0.95)

Load Cases

Axial, Bending, and Bearing *

For this discussion, only the single crack, axial load case will be presented

* The bearing load case is not part of the Newman/Raju solution set

Range of Parameters Considered

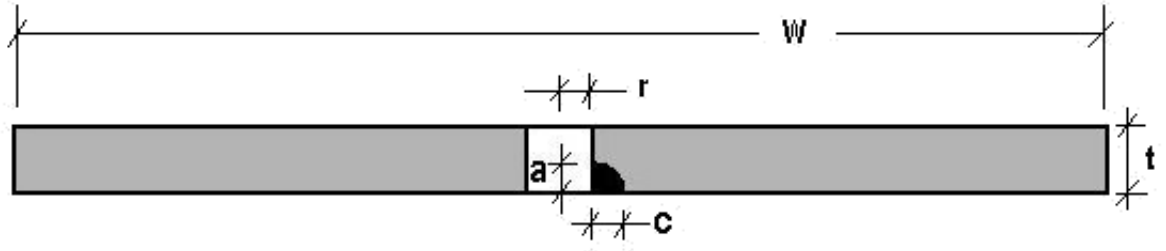
W = 100 t *

r = 0.393701 in *

r/t = 0.5, 1.0, and 2.0 **

a/t = 0.1, 0.5, and 0.9 **

a/c = 0.5, 1.0, and 2.0 **

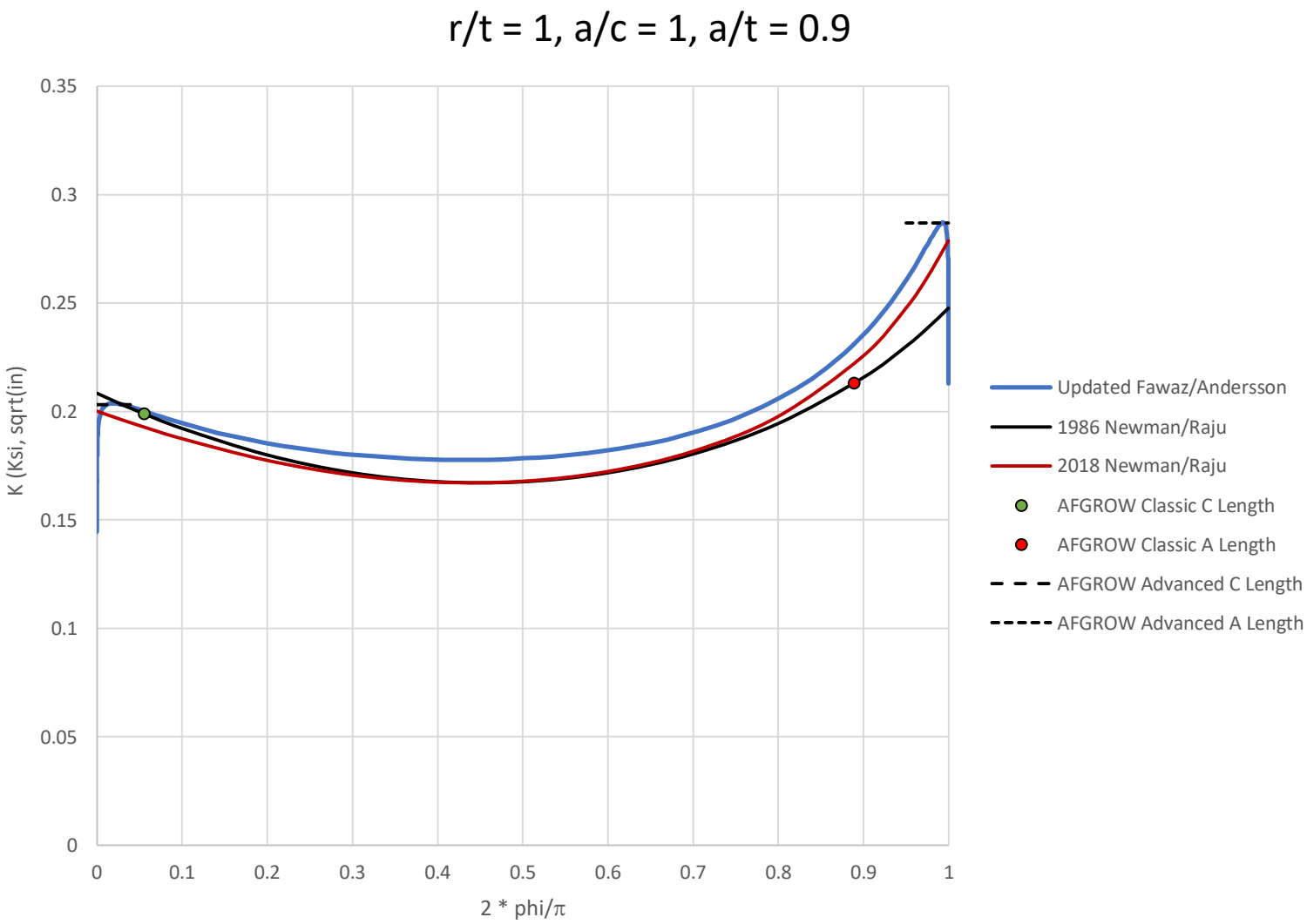


Remote Traction = 0.145038 Ksi

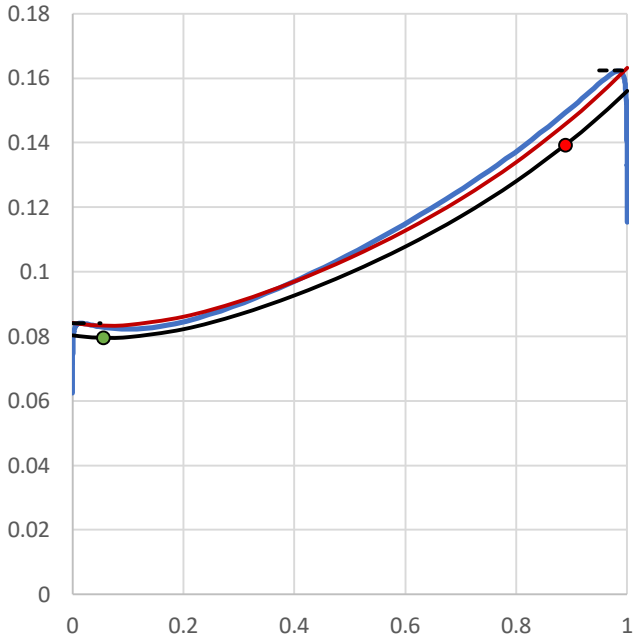
* Set for compatibility with Fawaz/Andersson database

** Set for compatibility with Newman/Raju 1986 curve fit (a/t = 0.9 shows difference for deep cracks)

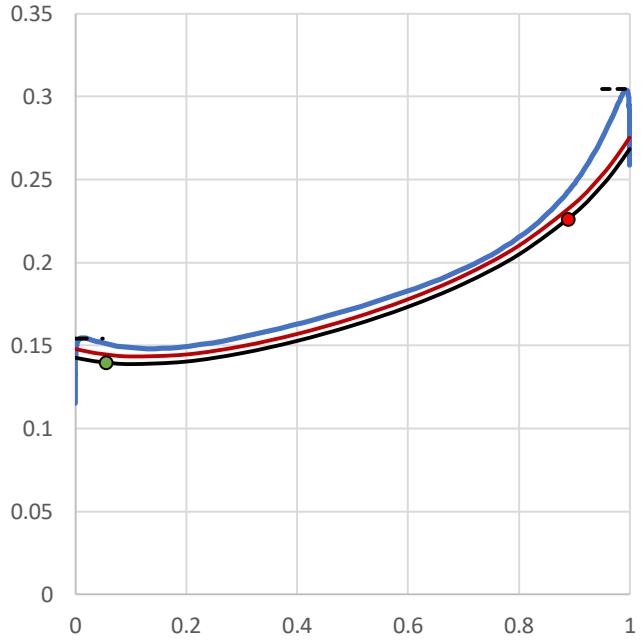
Example Case



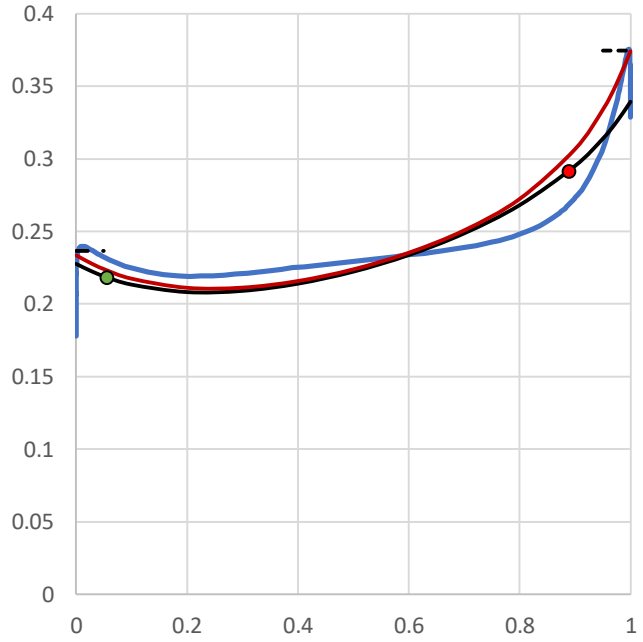
Solution Comparison (r/t = 0.5, a/c = 0.5)



a/t = 0.1

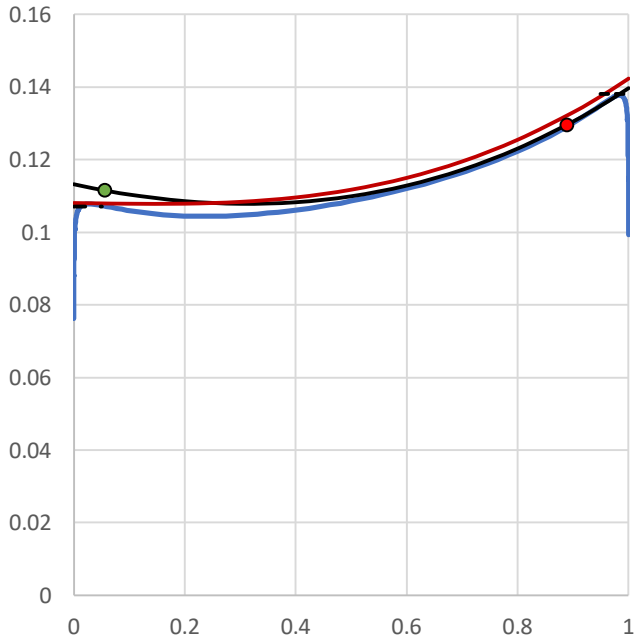


a/t = 0.5

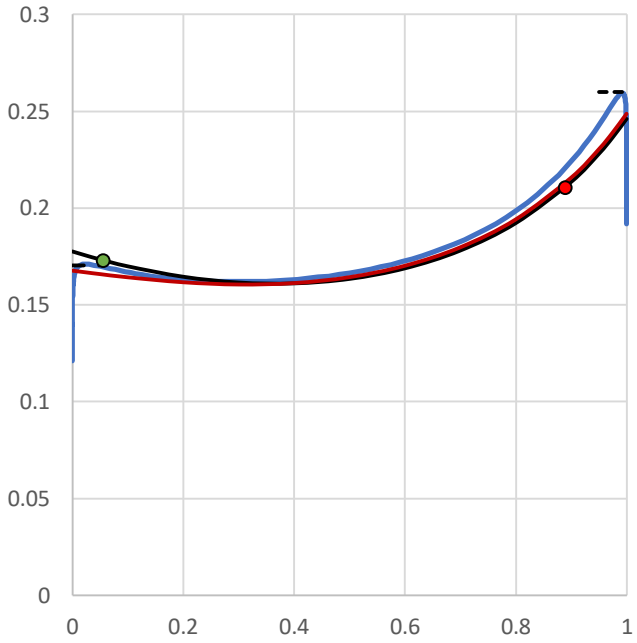


a/t = 0.9

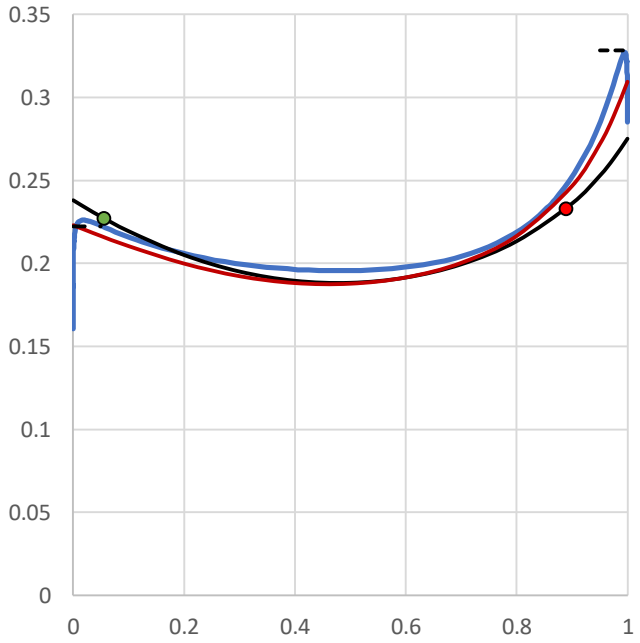
Solution Comparison (r/t = 0.5, a/c = 1.0)



a/t = 0.1



a/t = 0.5



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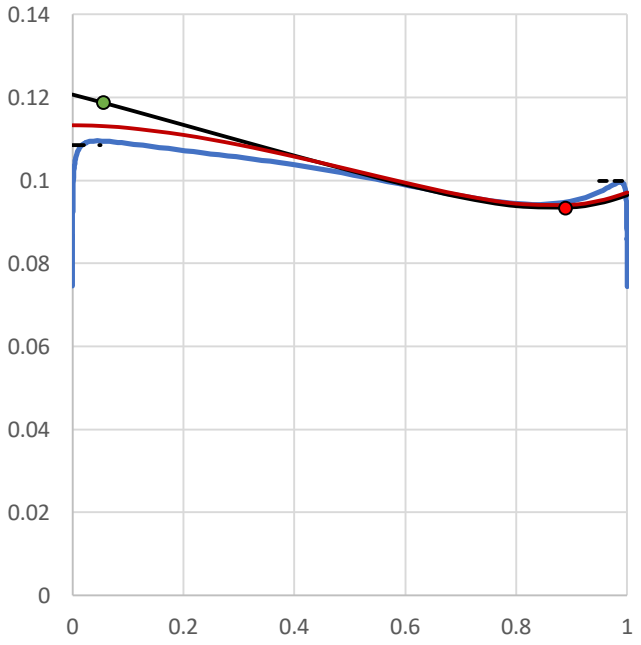
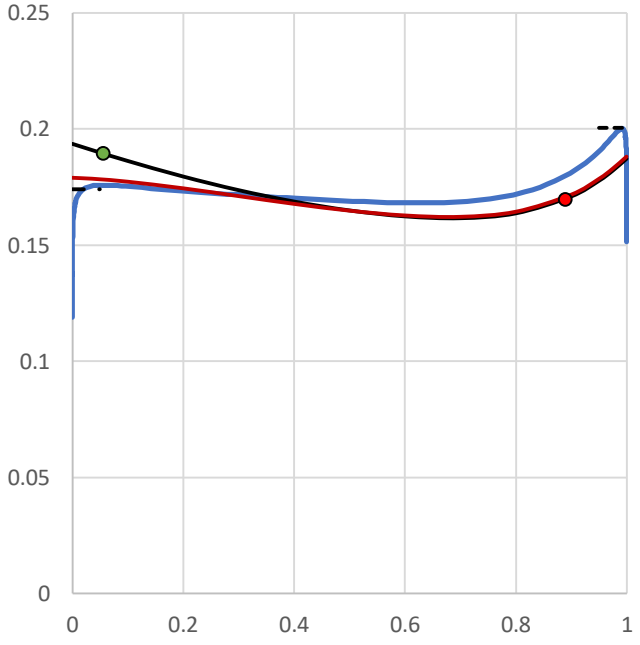
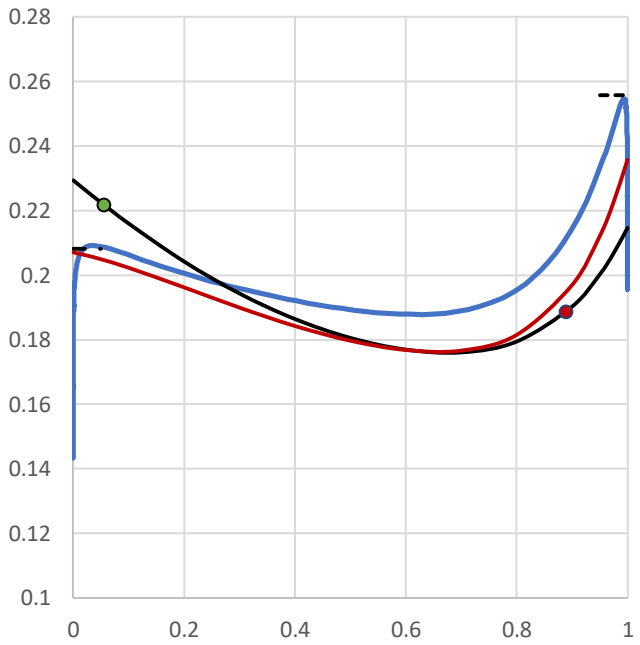
Solution Comparison (r/t = 0.5, a/c = 2.0)



a/t = 0.1

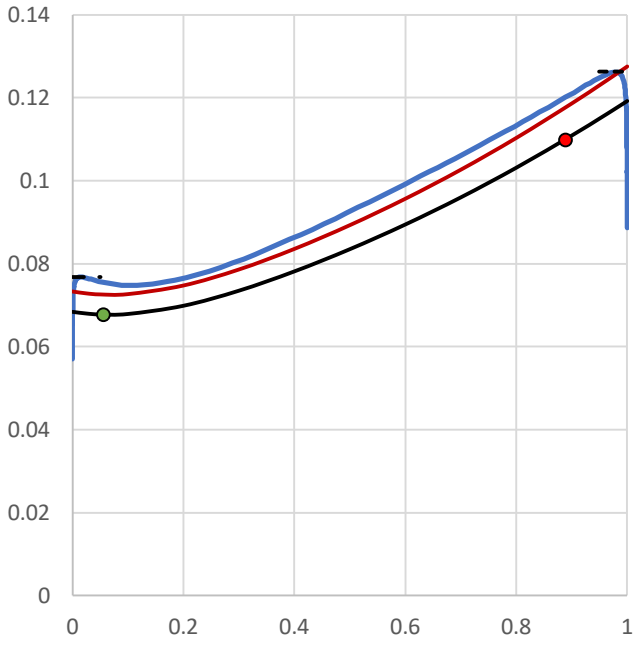


a/t = 0.5

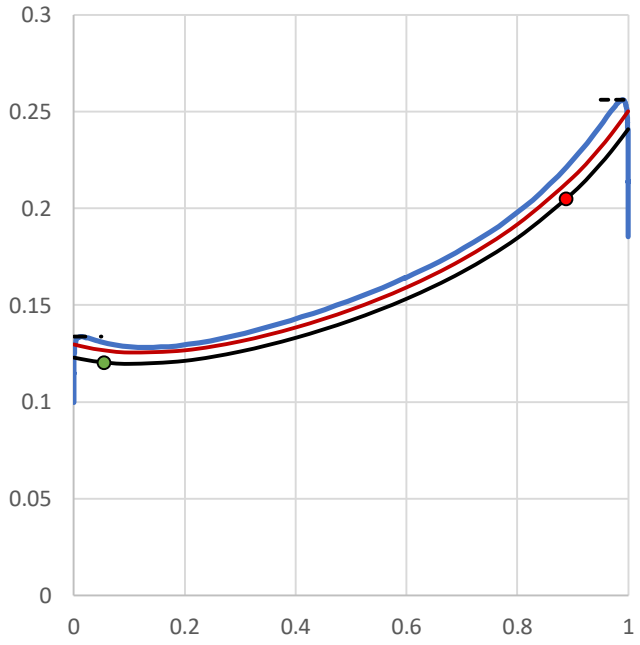


a/t = 0.9

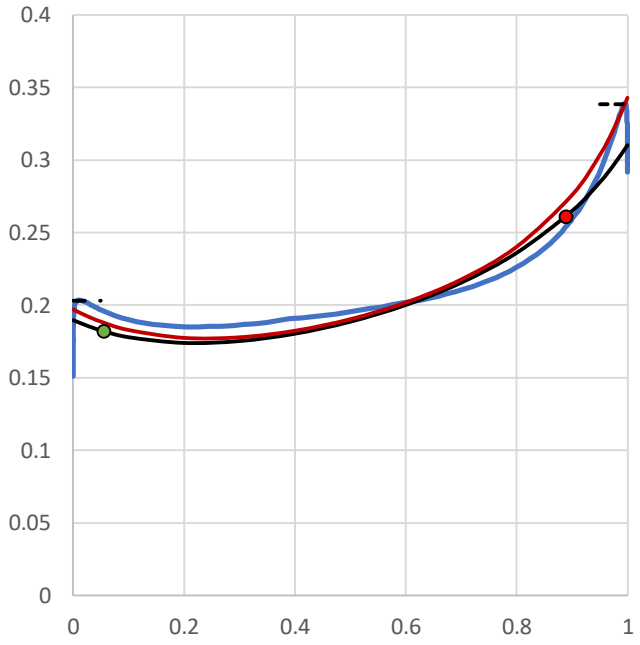
Solution Comparison (r/t = 1.0, a/c = 0.5)



a/t = 0.1

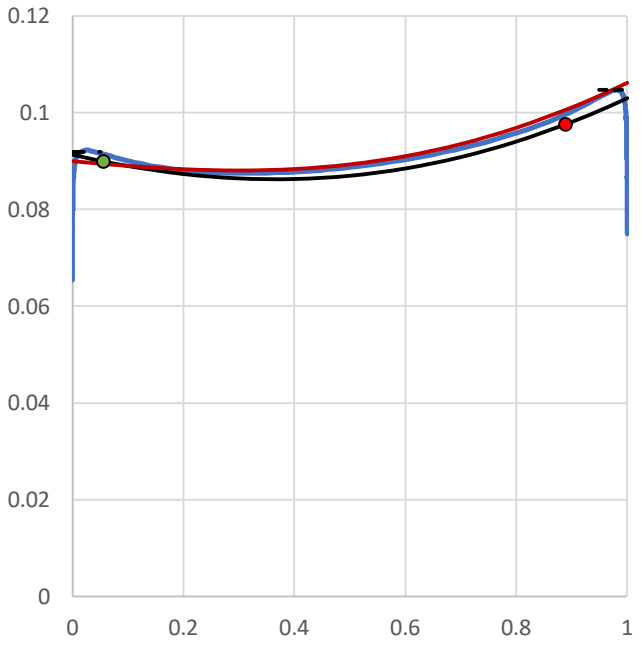


a/t = 0.5

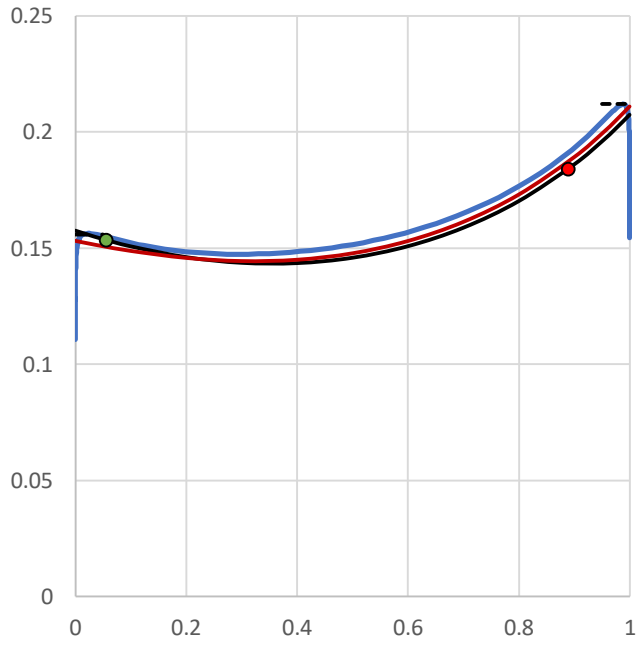


a/t = 0.9

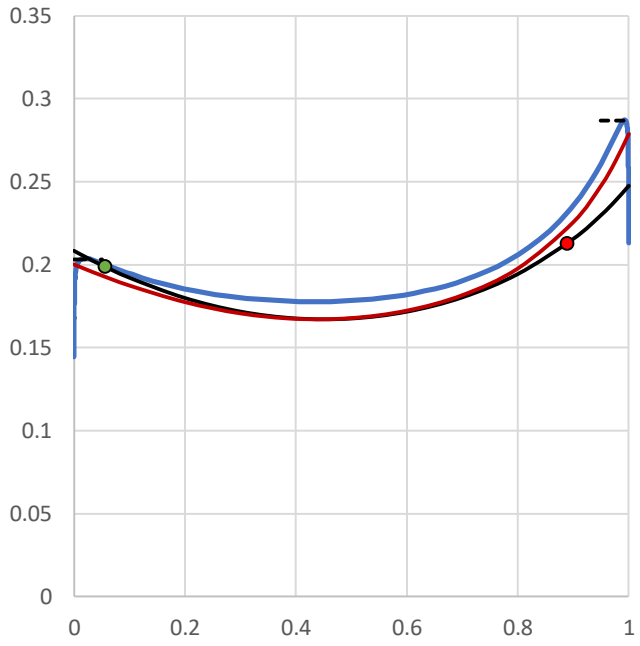
Solution Comparison (r/t = 1.0, a/c = 1.0)



a/t = 0.1



a/t = 0.5



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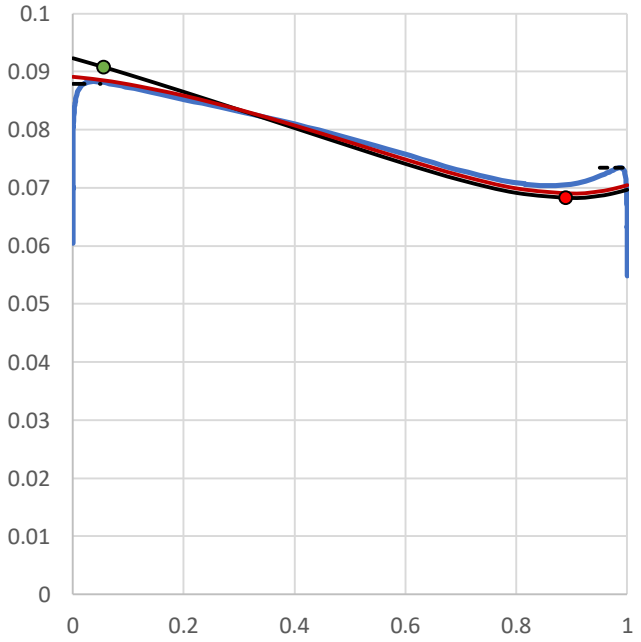
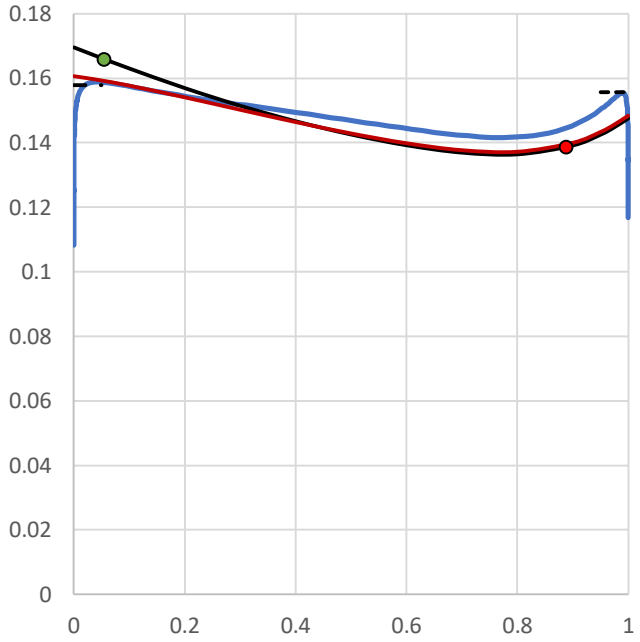
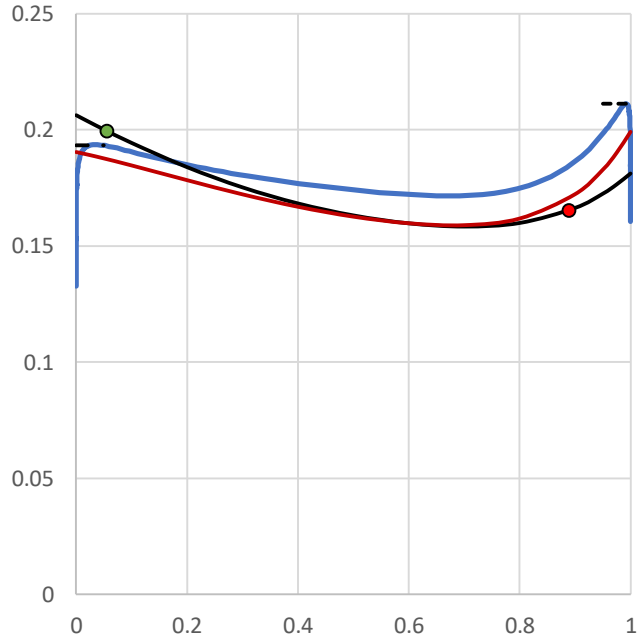
Solution Comparison (r/t = 1.0, a/c = 2.0)



a/t = 0.1

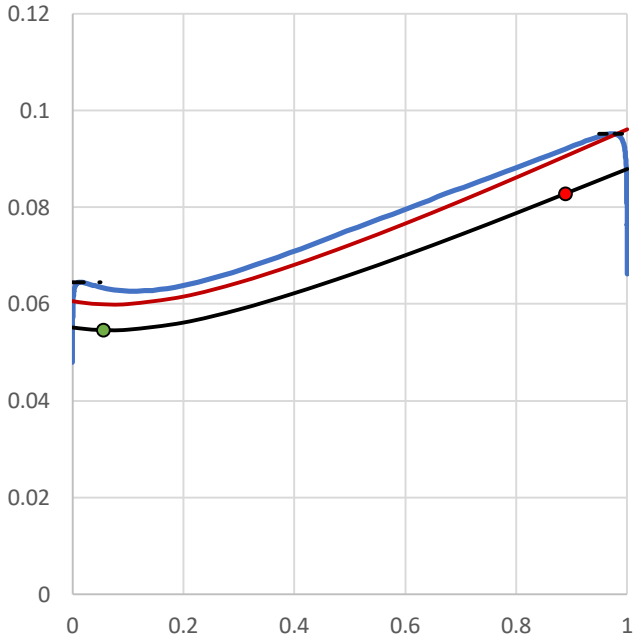


a/t = 0.5

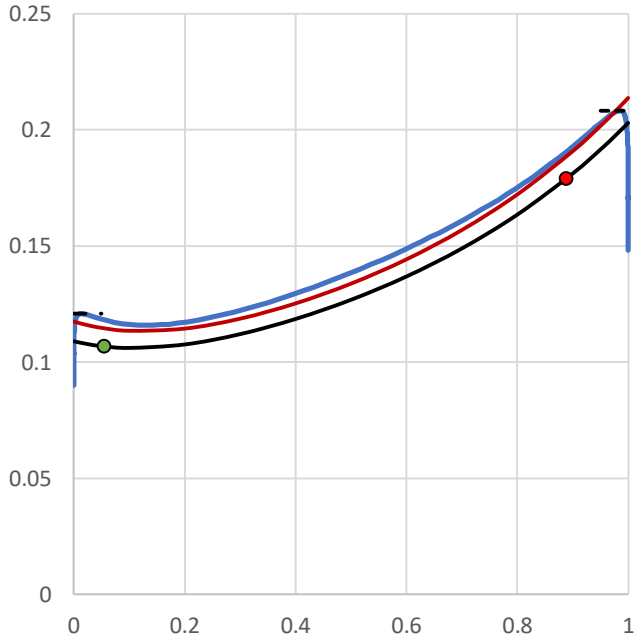


a/t = 0.9

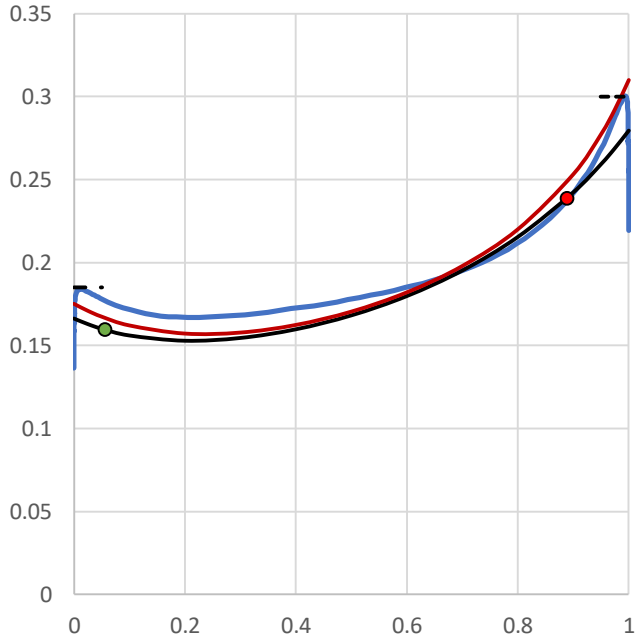
Solution Comparison (r/t = 2.0, a/c = 0.5)



a/t = 0.1



a/t = 0.5



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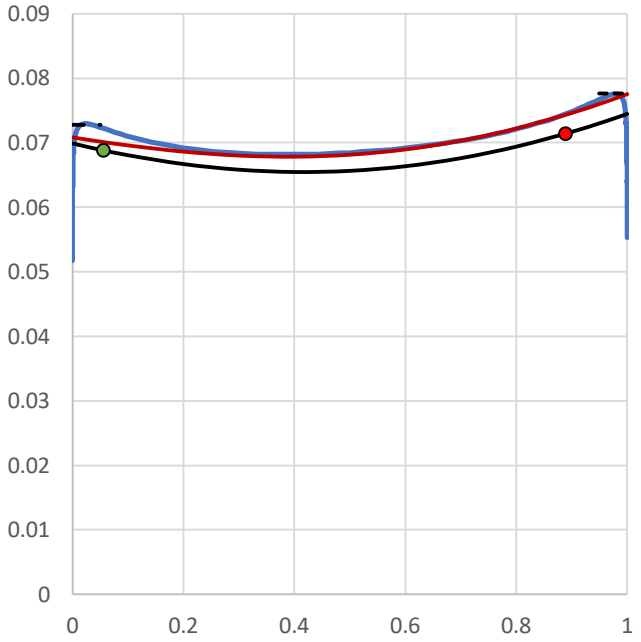
Solution Comparison (r/t = 2.0, a/c = 1.0)



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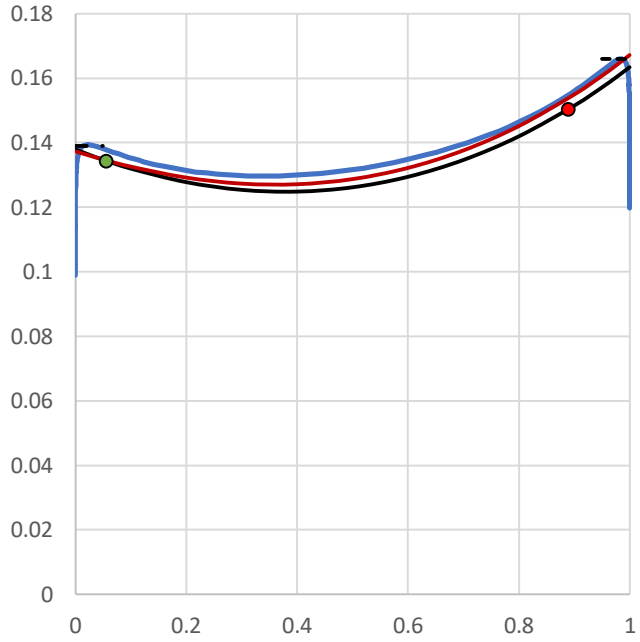
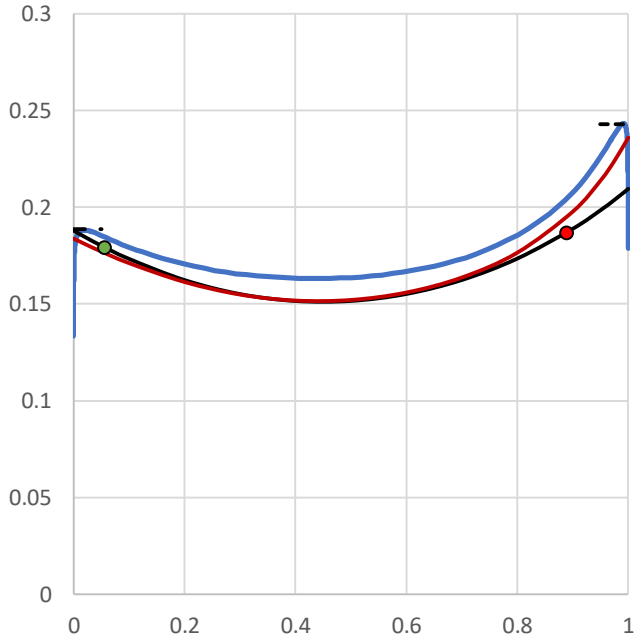


a/t = 0.5



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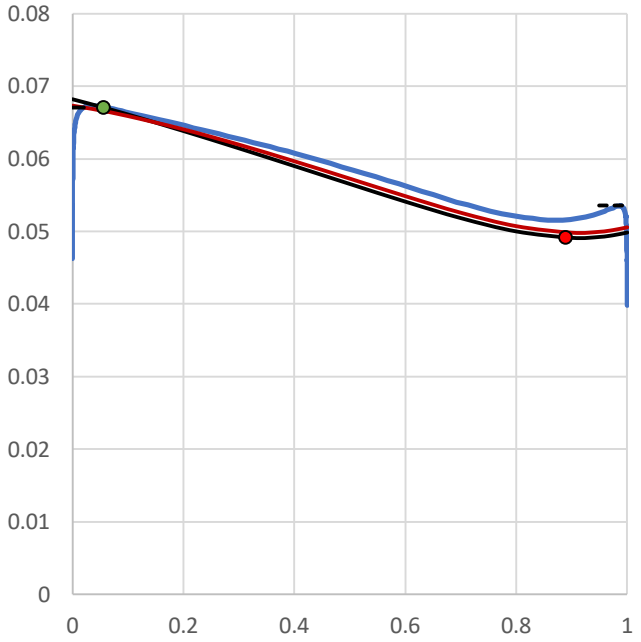
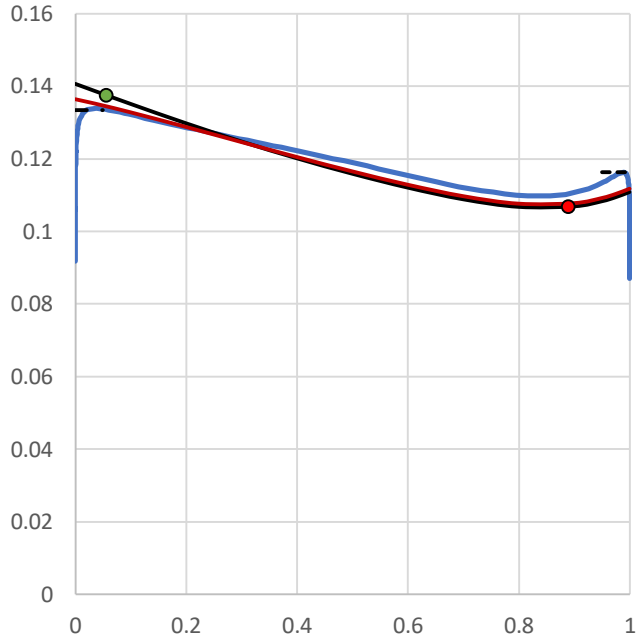
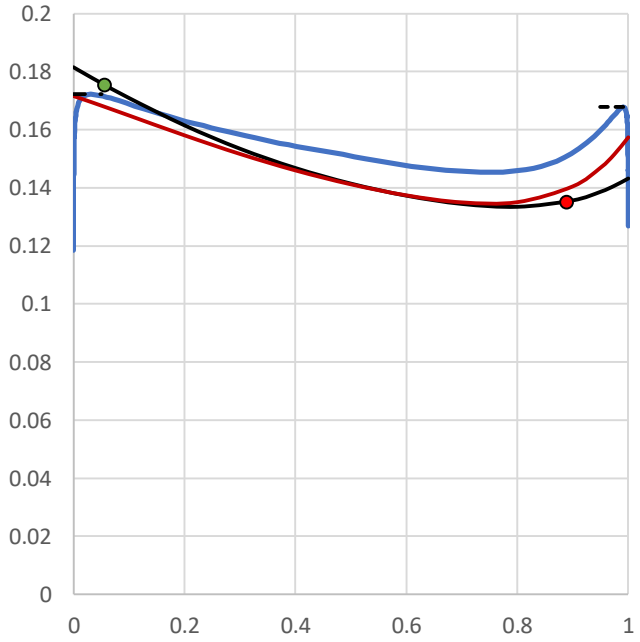
Solution Comparison (r/t = 2.0, a/c = 2.0)



a/t = 0.1



a/t = 0.5



a/t = 0.9

Parametric Angle Issue

The Classic Model in AFGROW uses 5 and 80 degrees for the c and a-dimensions respectively

- It was a common practice in the late ’80s and early 90’s to use some offset angle for each growth dimension because it is not possible to obtain FEM solutions at a free surface, and it seemed reasonable to pick two points that would best represent the solution near each free surface (normally, at local maximum points from the FEM)

Some advocate using the Newman-Raju curve fit at 0 and 90 degrees along with a closure correction factor (β_r) at each free surface

- This assumes that a correction (~0.9) to the free surface estimate gives a reasonable estimate of the “net” K that acts at each growth dimension. In the a-direction, this method results in nearly the same K that comes from using the 80-degree parametric angle and the resulting K in the c-direction is approximately 10% lower than the local maximum calculated by the FEM

Discussion/Conclusions

- No “typos” in AFGROW as related to the Single Corner Cracked Hole Axial Solutions (Classic or Advanced).
- The 2018 N/R curve fit is a significant improvement over the 1986 curve fit wrt the F/A database.
- There are still some significant differences between the N/R and F/A single crack solutions.
- It should be noted that the 2018 N/R curve fit was based on the double, symmetric crack geometry. The double/single crack Shah correction used for the N/R single crack case contributes to the larger differences between the solutions.

Discussion/Conclusions

- The updated 2018 F/A database provides very high resolution at each free surface. This allows the local maximum values to be determined more accurately for each crack tip location.
- While the 2018 N/R curve fit solution for the single corner crack geometry does a better job matching the F/A crack tip solutions, the curve fits don't always agree with the tabular F/A solution along the entire crack front.
- The 2000 F/A solution for the single corner crack geometry is in very good agreement with the 2018 updated F/A solution, as a function of ϕ, with some minor differences at each crack tip.

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Comments/Questions?