

AFGROW Workshop 2020

AFGROW Release 5.4 Overview

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Outline

- List of user issues and suggestions for enhancement from Workshop 2019 and progress to completion
- Interim release 5.3.5.24 details
- AFMAT updates
- Upcoming release 5.4 details

List of User Issues and Suggestions for Enhancement

User issues and suggestions from the 2019 AFGROW Users Workshop are listed below (asterisks mark priority issues and the number represents the level of difficulty from 1 {very easy} to 10 {very difficult}):

Task/Issue	Completion	Release
*K-Solutions for corner/through crack combinations (10+)	50%	5.4.1.25
*Add notifications from plugin to notification view in GUI (1)	50%	5.4.1.25
*Continue to pursue MSD (5)	60%	5.4.1.25
*Ability to open lkp/lkpx and sp3/spx files without switching file type in the Open file dialog (1)	100%	5.4.1.25
*COM access to plugin data (5)	40%	5.4.1.25
Bearing solution for corner crack(s) at a countersunk hole (3)		
Make changes to allow the use of spectra with three load channels (5)		
Add a stiffened panel solution? (4)		
Investigate/Fix small crack combination ($a/t < 0.1$) for advanced corner cracks at hole (also Kevin's bug fix) (6)	70%	5.4.1.25
Investigate a 3-D integration method for beta correction (7)		
Include a log file with the Spectrum Manager (list of what was done) it would need to be dated and maintained each time the spectrum is opened. Maybe a separate log file? Like a log used to track changes for software development. (3)		
Integrate Cycle Counter into Spectrum Manager (10)		
Ability to read uncounted data in the Spectrum Manager (10)		
Ability to use beta correction with a weight function solution (5)		
Incorporate Effective width in the bearing beat calculation (5)		
Solution for filled hole/interference (?)		
Change the "Initiation" menu item to "Strain-Life" initiation (1)		
Make sure that material name in the material dialogs does not loose information (1)	100%	5.3.5.24
Develop examples of AFGROW scripting in Python programming language (1)	100%	
Investigate an ability to use exceedance curve of separate maneuvers/gust to generate spectra (9)	50%	

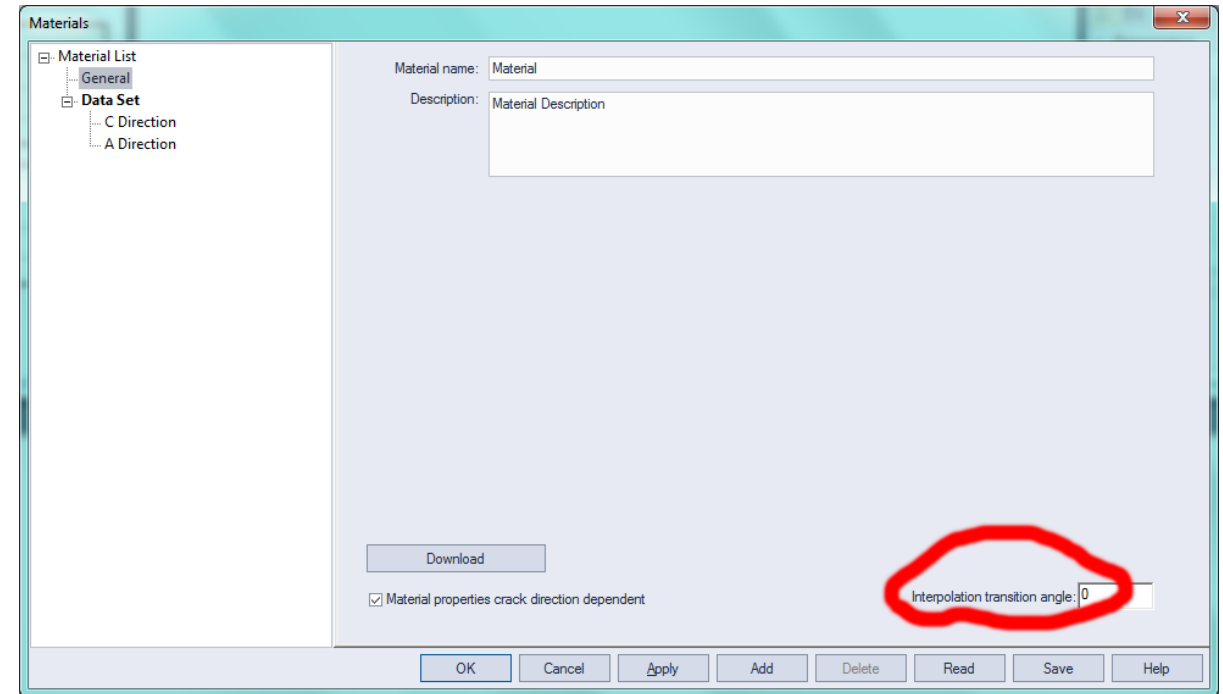
Minor Release 5.03.05.24

- Enhancement: Users may now copy data and delete selected curves in the Crack Growth Rate Data and Crack Length vs. Life plot views
- Enhancement: New plug-in interface capability to enter a table of K vs. Stress for each crack growth increment. AFGROW will linearly interpolate K from the table based on input spectrum max and min values.
- Enhancement: Transverse bending is now accounted for in net section yield calculation for all classic models without a hole. AFGROW had a warning about this limitation in the previous GUI interface.
- Enhancement: Added three new models for Axial Crack in Pipe Models: Internal, External Part-Through Cracks, and Through Crack
- Enhancement: Incorporate multi-directional crack growth rate properties for use in BAMF
- Enhancement: Added transverse bending load case for the Single Edge Corner Crack Classic Model
- Enhancement: AFGROW GUI improvements for Hi Resolution Monitors
- Enhancement: Added a new Constant K/s Specimen

Multi-Directional Material Properties for Tabular Lookup Material Data Model

When the option for direction dependent material properties is selected, the general dialog box will include an option to control how crack growth rate data are interpolated between the two orthogonal directions.

The capability to interpolate crack growth rate data along a crack front is currently only available for use with plug-in models. We plan to add this functionality to our Advanced Model interface in a future AFGROW release.

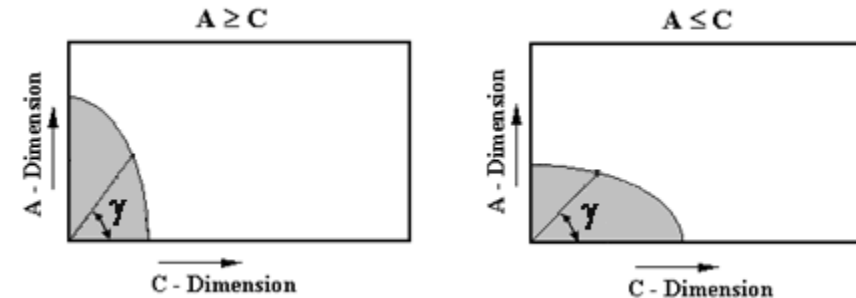


Material Orientation Angle

For crack models with multiple points along the crack front, linear interpolation is performed from the c-direction (0 degrees) toward the a-direction (90 degrees). The transition to the a-direction data will be complete at the user-defined interpolation transition angle (0 – 90 degrees).




The linear interpolation between the crack growth rate data for the c-direction and a-direction will be applied as a function of the material orientation angle (γ) between zero degrees and the interpolation transition angle.

The orientation angle should not be confused with the parametric angle (ϕ) that is used in the Newman/Raju Classic Models to identify the crack tip location around the crack front. The material orientation angle provides a reference for possible differences in crack growth rate data as the position around the crack front moves between grain orientations (e.g.: L-T to L-S).




Therefore, crack growth rate data entered for the a-direction will be used for all points beyond the user-specified interpolation transition angle.

Thick Pipe Models: Internal and External Axial Crack in Thick Pipe, Axial Through Crack in Thick Pipe

Model	Description of the Configurations	Beta Solution	
<input type="checkbox"/> 	Internal Axial Crack in Thick Pipe	Application Defined	
<input type="checkbox"/> 	External Axial Crack in Thick Pipe	Application Defined	
<input type="checkbox"/> 	Axial Through Crack in Thick Pipe	Application Defined	

Constant K/σ Specimen

Model	Description of the Configurations	Beta Solution
<input type="checkbox"/> 	Constant K Specimen	Application Defined

- The solution is based on the tapered cantilever beam test specimen geometry that was developed by , Dr. Sheldon Mostovoy in the 1970's.
- It can be used to assess the severity of a spectrum

Make sure that AFGROW GUI works on Hi Resolution Monitors

Number of da/dn Sets: 27 Number of R Sets: 2

		R1	R1 21
da/dN11	1.00e-009	2.1	0.6
da/dN12	3.00e-009	2.6	1.38
da/dN13	1.00e-008	2.6	1.5
da/dN14	2.00e-008	2.6	1.66
da/dN15	4.00e-008	2.7	1.8
da/dN16	6.00e-008	2.7	2.0
da/dN17	1.00e-007	2.9	2.3
da/dN18	2.00e-007	3.3	2.8
da/dN19	3.00e-007	3.6	3.1
da/dN101	4.00e-007	3.8	3.3
da/dN111	6.00e-007	4.2	3.7
da/dN121	1.00e-006	4.7	4.3
da/dN131	2.00e-006	5.6	5.2
da/dN141	4.00e-006	6.8	6.2
da/dN151	1.00e-005	8.8	8.0
da/dN161	2.00e-005	10	9.61
da/dN171	4.00e-005	12	11
da/dN181	1.00e-004	16	14
da/dN191	2.00e-004	19	16
da/dN201	4.00e-004	23	18
da/dN211	6.00e-004	25	20
da/dN221	8.00e-004	27	21
da/dN231	2.00e-003	34	23
da/dN241	4.00e-003	39	24
da/dN251	1.00e-002	46	25
da/dN261	3.00e-002	52	26
da/dN271	1.00e-001	56	26

Model Geometry and Dimensions

Geometry | Dimension Load

For some models AFGROW allows to combine multiple load case solutions. The ratio of the axial, bending or bearing stress to the reference stress must be input for each load case.

Axial

Stress Fraction:

Bending

Stress Fraction:

Bearing

Equivalent width:

Stress Fraction:

Filter Compression

Calculator

OK Cancel Apply Help

Exfoliation Material Loss

Material loss (damage) is modeled as a change in thickness (or equivalent dimensions for models without a thickness). This is quantified as shown below as a function of time (seconds) using the user-defined parameters: A', B and Humidity.

Enter

damage = $A' \cdot \exp(B \cdot RH) \cdot t$

Note: the units for A' are length/seconds, and Humidity is expressed in decimal format.

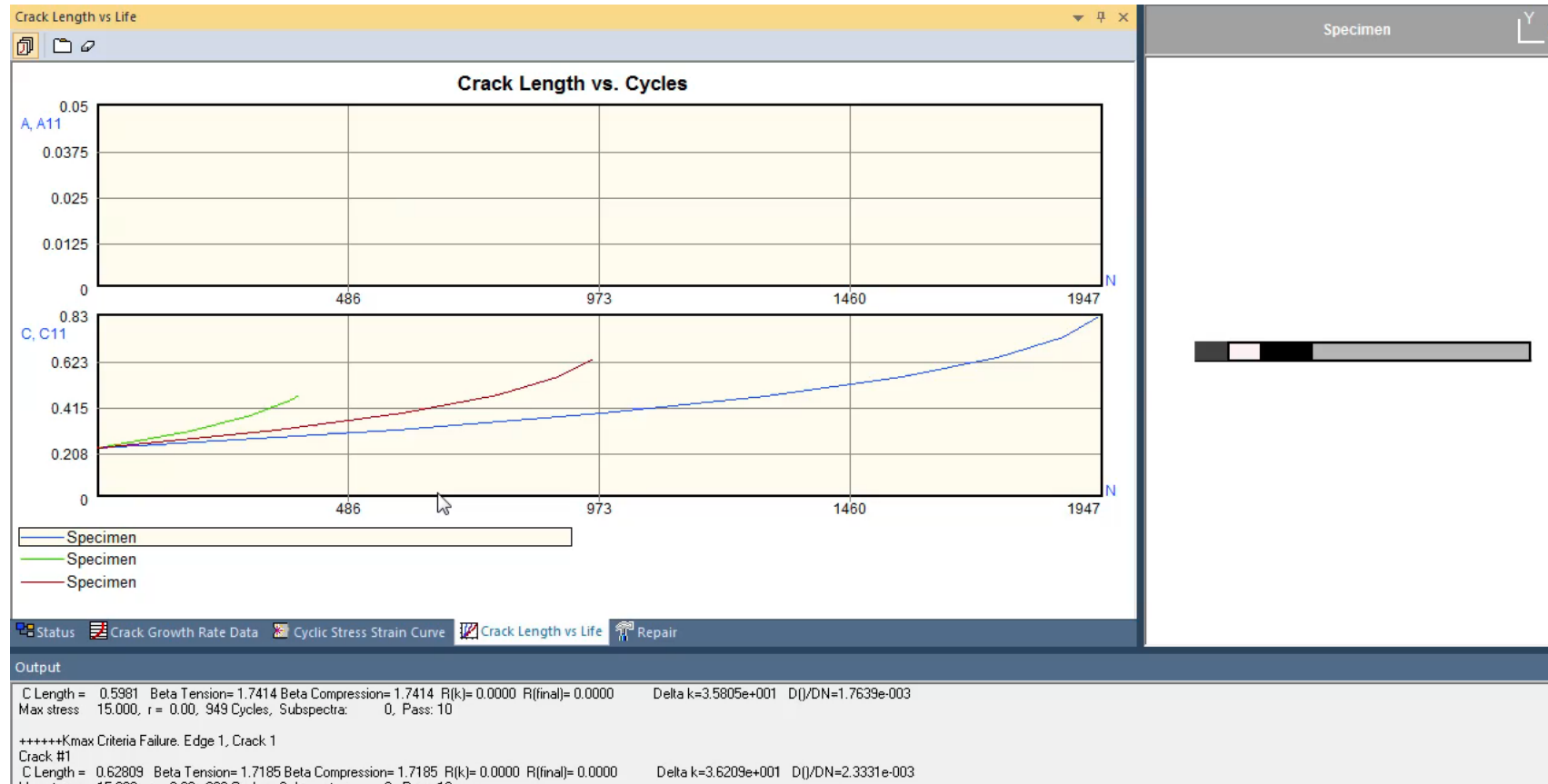
Coefficient (A'):

Coefficient (B):

Humidity % (RH):

OK Cancel

Added Ability to Delete a Curve and Copy Curve Data



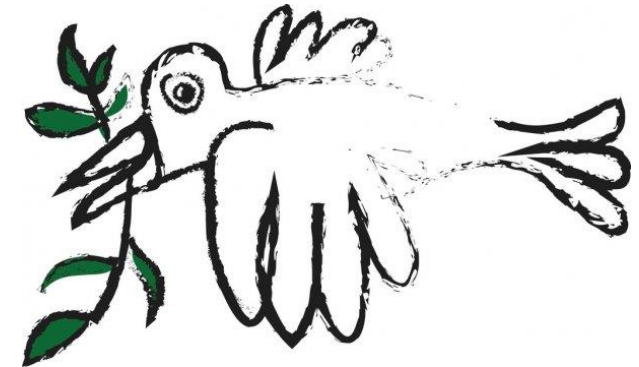
Release 5.04.01.25

- New/Enhanced Advanced Crack At Hole Solutions
- Add MSD models
- Add local material database in tabular-lookup format
- Add more crack initiation data
- Add option to open material data file through COM
- Investigate/Fix small crack combination ($a/t < 0.1$) for advanced corner cracks at hole.
- Option to use plugin from COM
- Better handling life in hours output. Output intervals printed in "hours" if the option to display life in hours is selected in the Output Intervals tab, the crack length plots also should be converted to hours
- Print NASGRO material name in the output
- Fix JavaScript Engine
- Add correction for filled unloaded hole to advanced models
- Access retardation metadata via COM



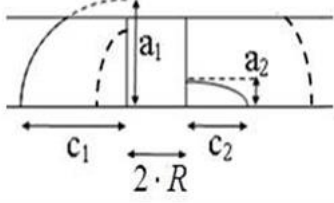
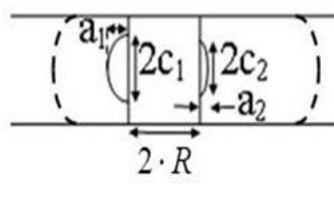
The Olive Tree

The olive tree held an extremely important place for ancient Greeks. It provided nutrition, medicine, cosmetics, perfumes, fuel, first place award and peace offering. It was gift of the Gods. Greece and the world would not exist as we know it without the olive tree.



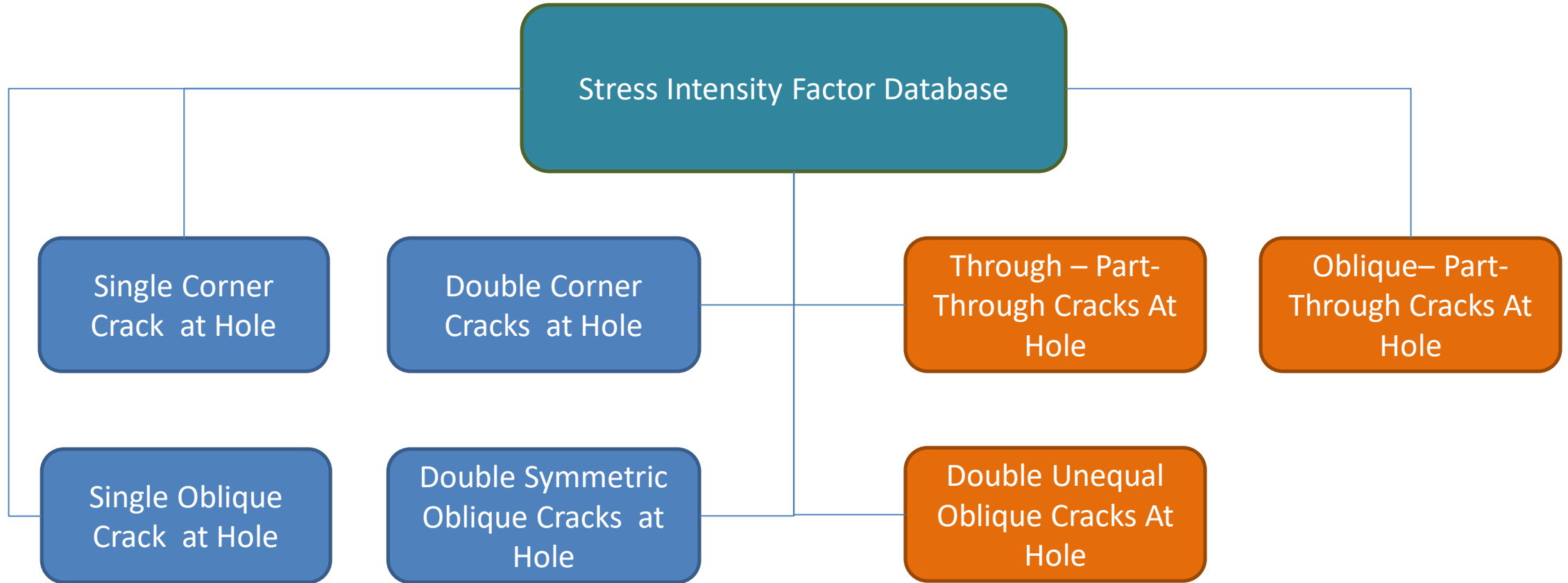
Advanced Crack At Hole Solutions in AFGROW

- The world's largest stress intensity factor database
- Created by Börje Andersson and sponsored by CASTLE
- 3 Years of super-computer number crunching
- Improved the Fawaz – Andersson unequal double corner crack at hole tabular data solution from 2003
- The 2017 release adds more solutions:
 - Corner crack – oblique crack at hole
 - Two unequal semi-elliptical crack at hole
 - Semi-elliptical crack - oblique crack at hole
 - Two unequal oblique crack at hole
 - Single corner crack, semi-elliptical crack and oblique crack at hole

Joint Type Analysed	Parameter Values				Total Number of Scenario
	c/a	a/t	R/t	b/t	
	25	23	30	1	4.32 M
	25	23	30	1	4.32 M

Parameter	Values
c/a	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, 1.333, 1.50, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0
a/t	0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 0.95, 0.975, 0.99, 1.05, 1.15, 1.50, 1.75, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0
R/t	0.075, 0.1, 0.111, 0.125, 0.1428, 0.1667, 0.2, 0.25, 0.333, 0.4, 0.4444, 0.5, 0.5714, 0.667, 0.75, 0.8, 1.0, 1.25, 1.333, 1.50, 1.75, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

Advanced Crack at a Hole Solution Database



Verification vs. Validation

- Verification - the process of establishing the truth, accuracy.
- Validation - the action of making or declaring something legally or officially acceptable

Tabular K Solution Implementation Process

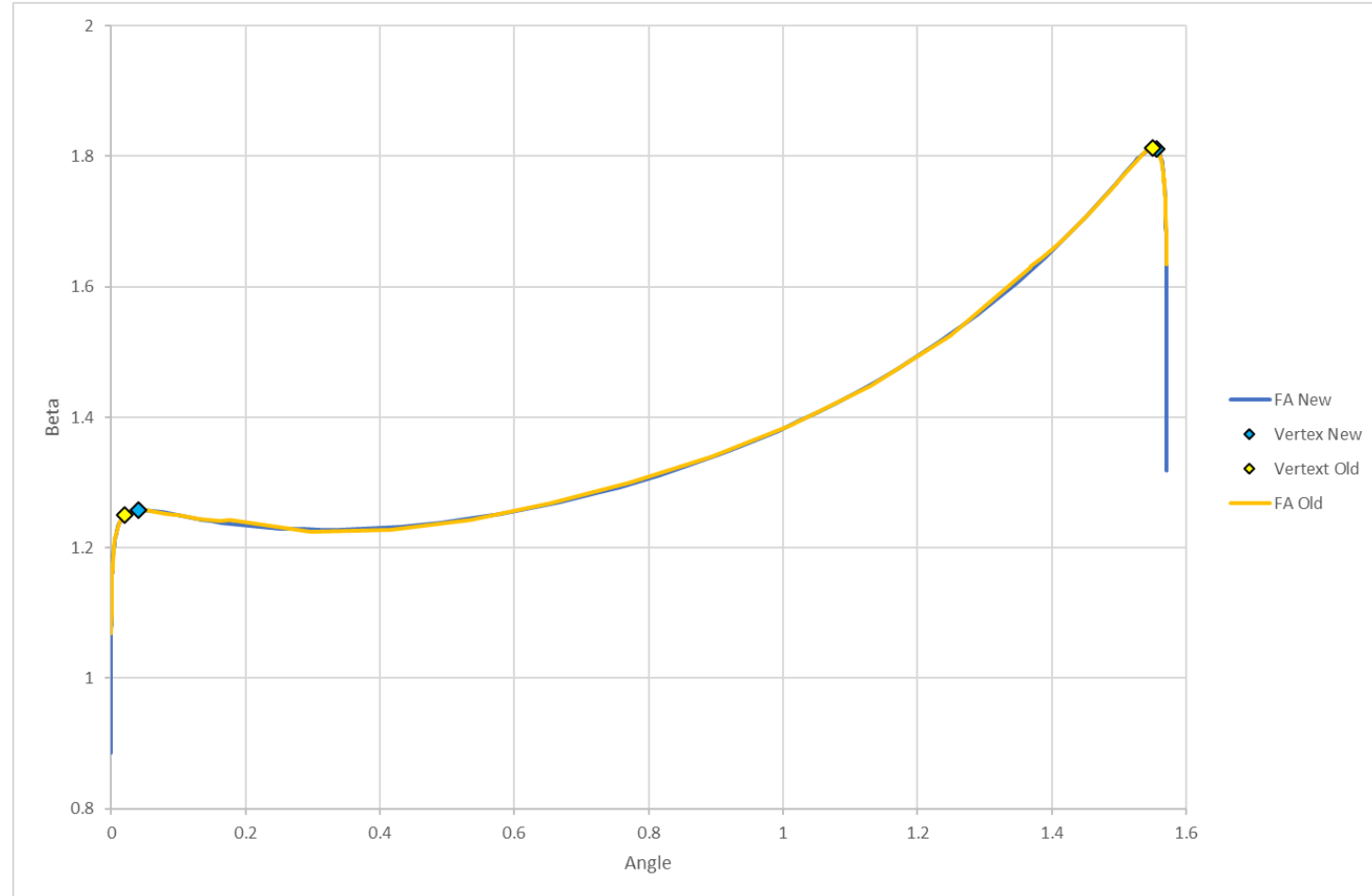
- Verify the raw data – make sure that there are no missing data and that the data are inside the acceptance bounds, and visual inspection of the data plots.
- Validate the raw data, when possible – compare data to known analytical/data solutions.
- Generate data necessary for the tabular K solution set.
- Verify the tabular K solution – visual inspection, test data using penalized regression splines (cubic spline fitting).
- Validate the tabular K solution – compare to known solutions and FEA.

Single Crack At a Hole

Axial
 r/t a/c a/t
 0.5 1 0.2

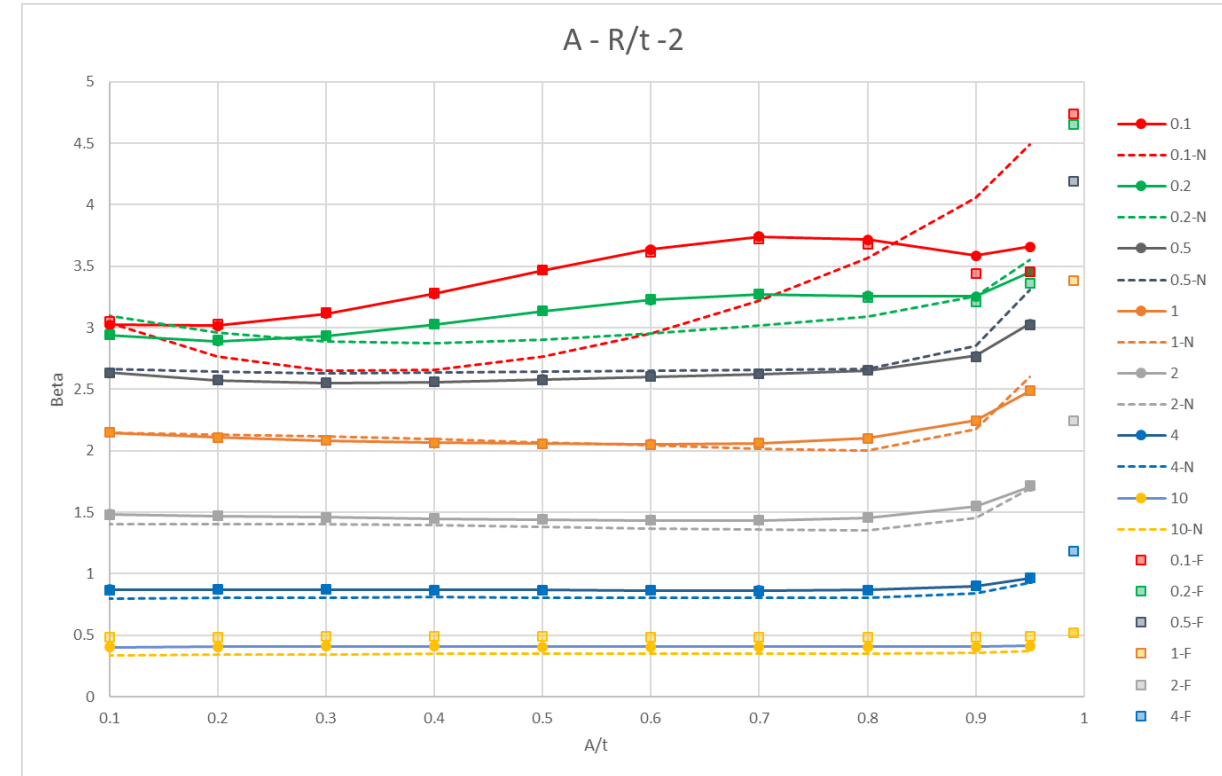
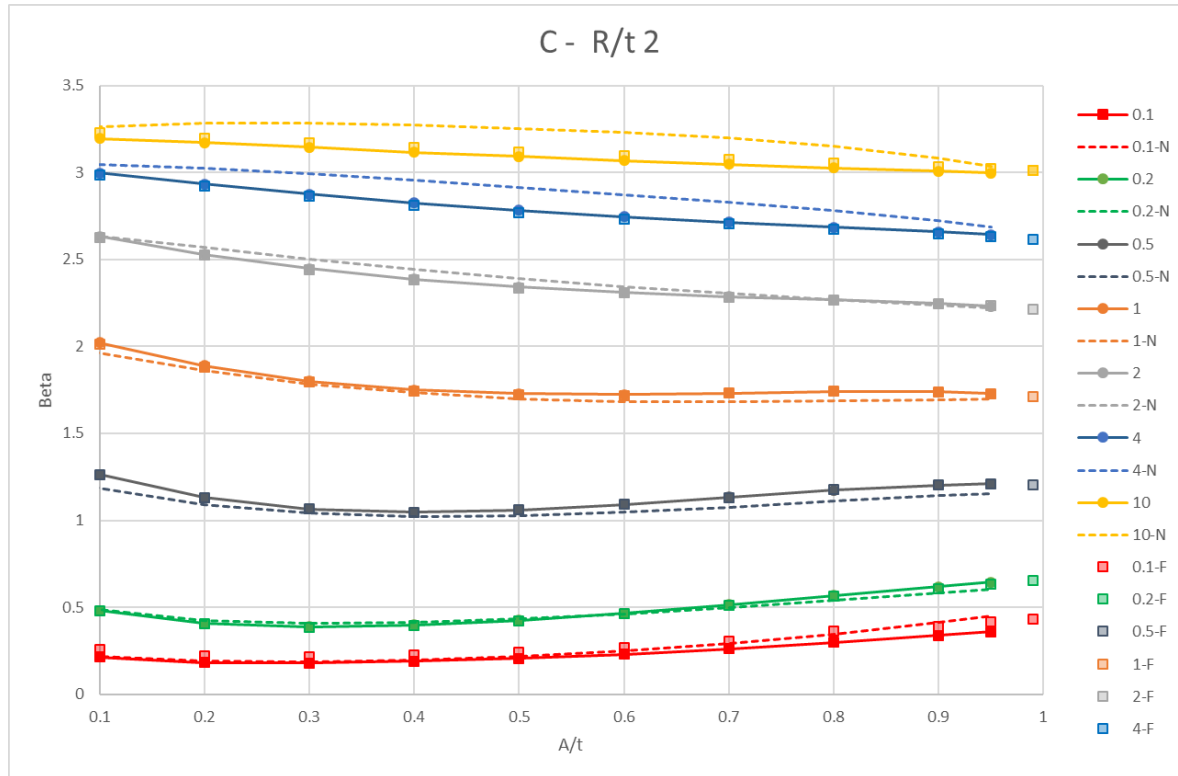
500 cases plotted and reviewed

Beta Distribution Along Crack Front



Single Crack At Hole – R/T 2, Axial

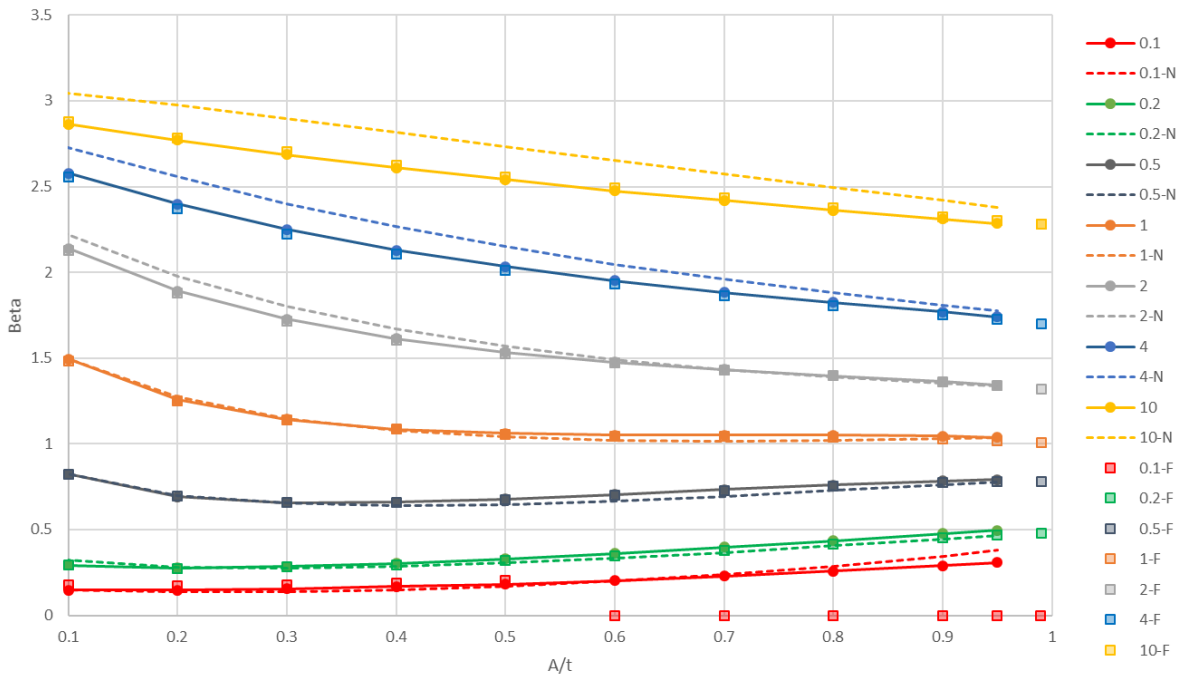
Fawaz/Andersson, Updated Fawaz/Andersson, Updated Newman solution



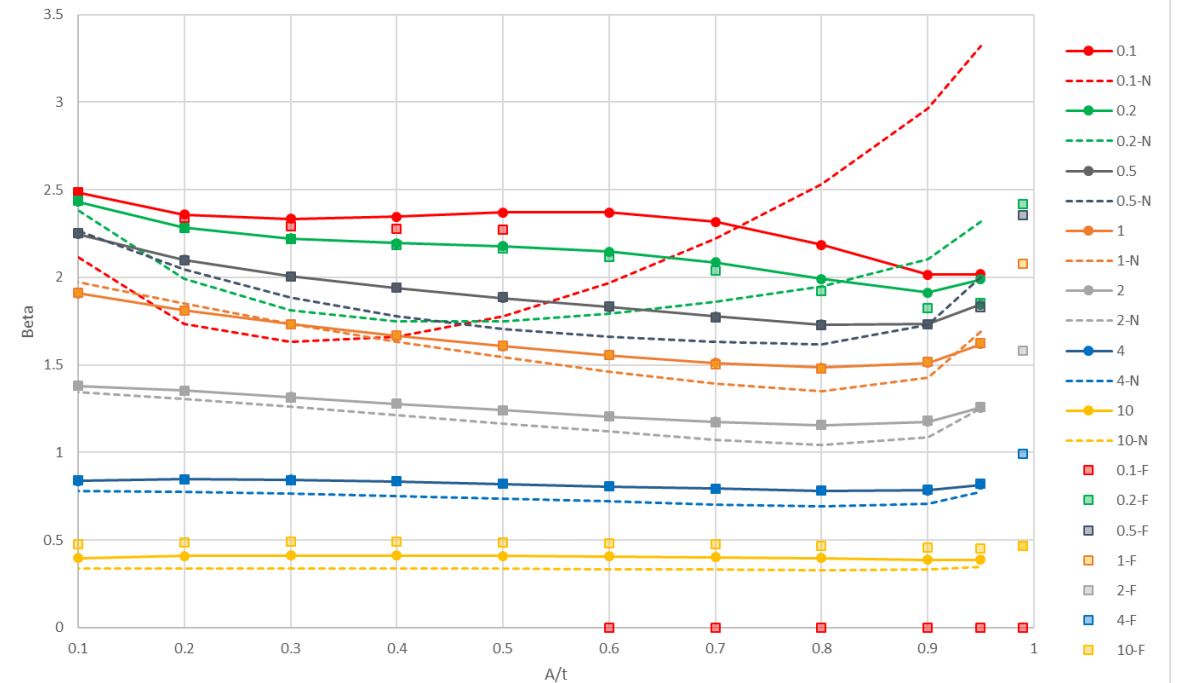
Single Crack At Hole – R/T 0.5, Axial

Fawaz/Andersson, Updated Fawaz/Andersson, Updated Newman solution

C - R/t 1

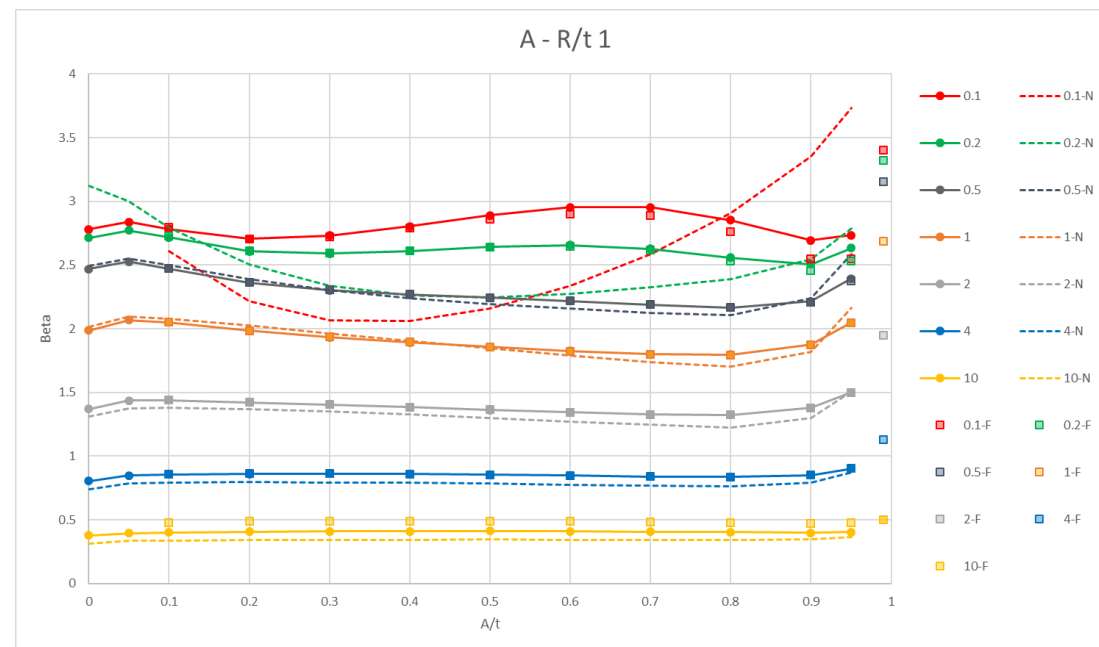
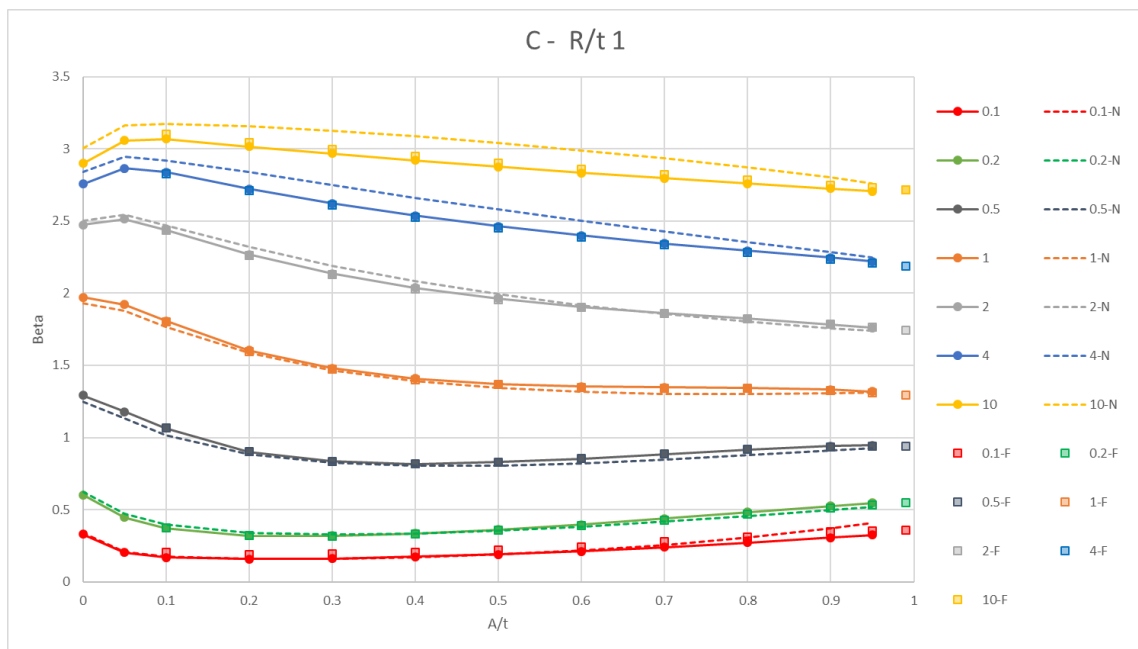


A - R/t 1



Single Crack At Hole – R/T 1, Axial

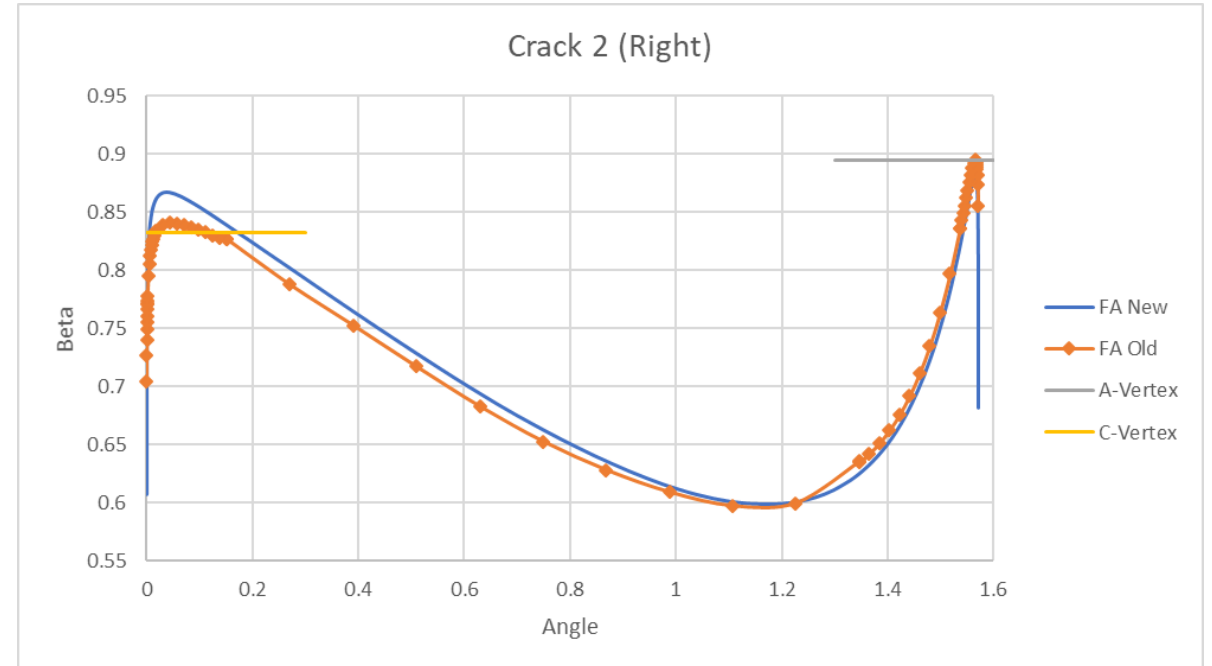
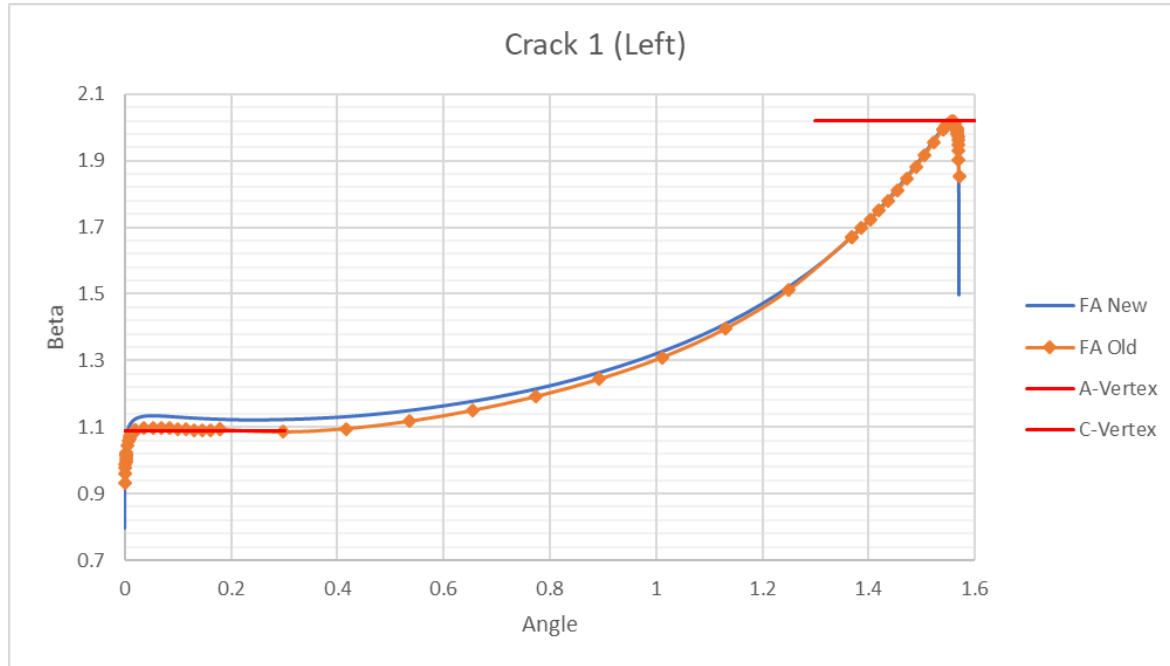
- Fawaz/Andersson, Updated Fawaz/Andersson, Updated Newman solution
- A/T extended to 0



Double Crack at Hole Data Validation

Tension

a1/c1	a1/t	r/t	a2/c2	a2/t
1	0.1	0.1	1.5	0.5

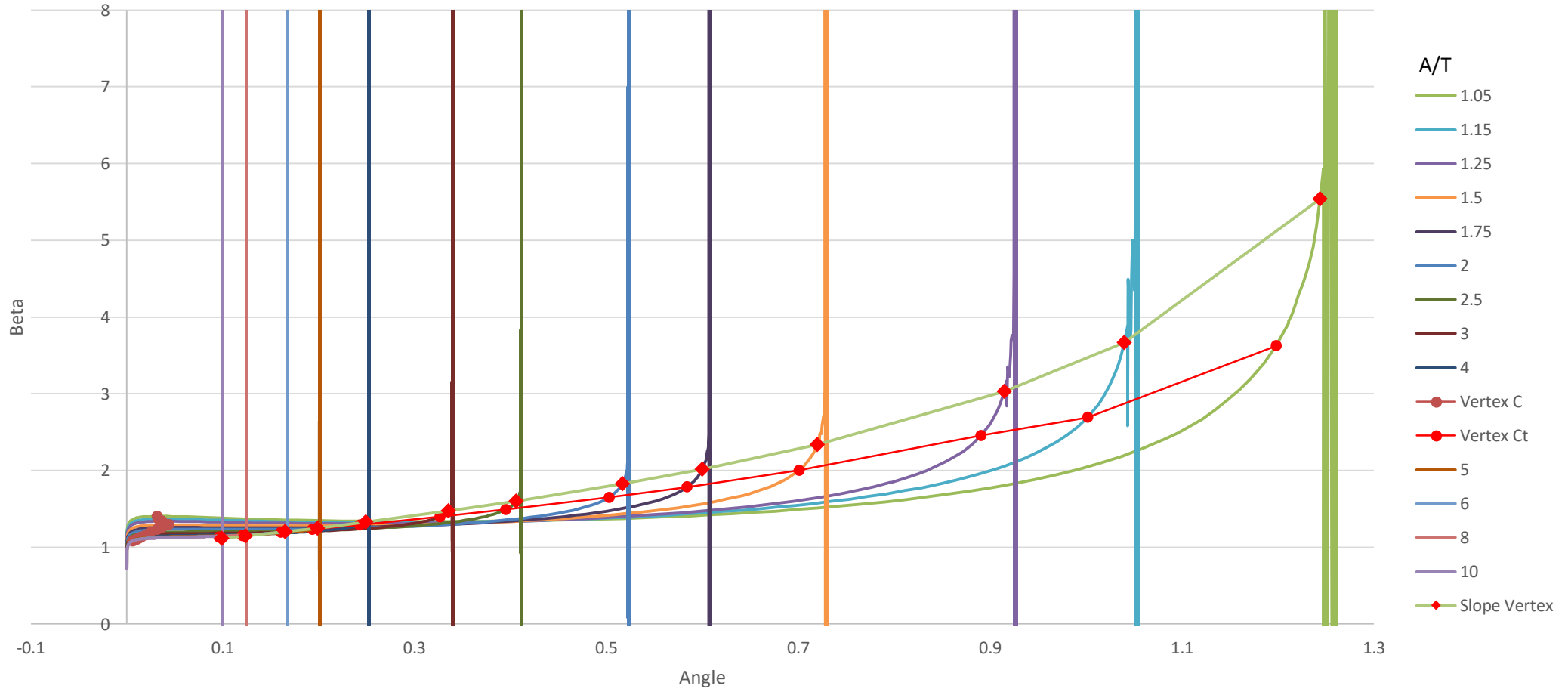


About 500 different cases plotted and reviewed

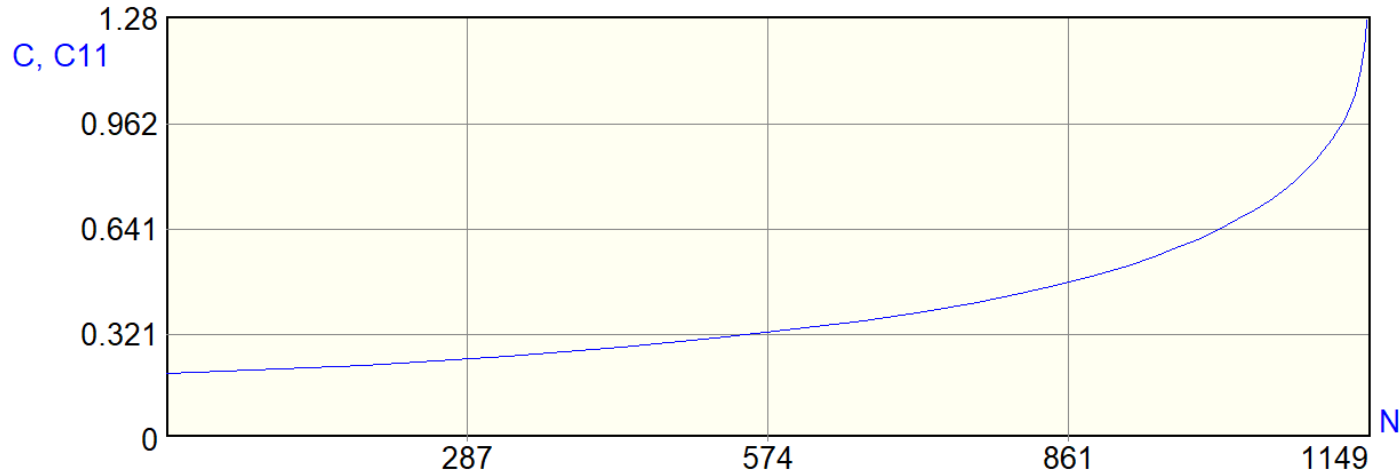
Oblique Crack Validation

Symmetric Double Oblique Crack

AoC 1, RoT 1



New Life in Hours Output Options



← The crack length plots converted to hours if the option to display life in hours is selected

Internal Through Crack - Standard Solution

Output intervals printed in "hours" if the option to display life in hours is selected



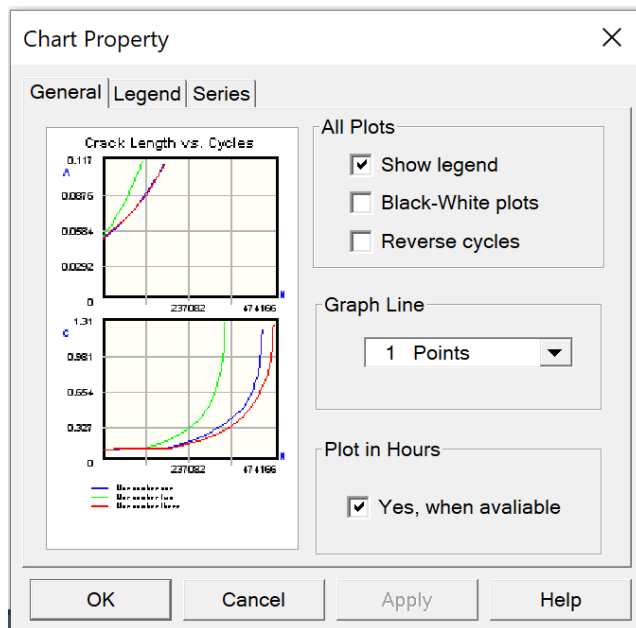
Output						
Max stress =	14.000	r = 0.00	57000 Cycles	Subspectra: 0	Pass: 571	Hours: 1140
C Crack size=	1.089	Beta Tension= 1.2170	Beta Compression= 1.2170	R(k)= 0.0000	R(final)= 0.0000	Delta k=3.1513e+01 D()/DN=3.0626e-04
Max stress =	14.000	r = 0.00	57100 Cycles	Subspectra: 0	Pass: 572	Hours: 1142
C Crack size=	1.1196	Beta Tension= 1.2498	Beta Compression= 1.2498	R(k)= 0.0000	R(final)= 0.0000	Delta k=3.2816e+01 D()/DN=4.4571e-04
Max stress =	14.000	r = 0.00	57200 Cycles	Subspectra: 0	Pass: 573	Hours: 1144
C Crack size=	1.1642	Beta Tension= 1.2498	Beta Compression= 1.2498	R(k)= 0.0000	R(final)= 0.0000	Delta k=3.3463e+01 D()/DN=5.5443e-04
Max stress =	14.000	r = 0.00	57300 Cycles	Subspectra: 0	Pass: 574	Hours: 1146
C Crack size=	1.2196	Beta Tension= 1.3171	Beta Compression= 1.3171	R(k)= 0.0000	R(final)= 0.0000	Delta k=3.6095e+01 D()/DN=2.1559e-03
Max stress =	14.000	r = 0.00	57400 Cycles	Subspectra: 0	Pass: 575	Hours: 1148
*****Fracture based on 'Kmax' Criteria (current maximum stress)						
C Crack size=	1.2821	Beta Tension= 1.3677	Beta Compression= 1.3677	R(k)= 0.0000	R(final)= 0.0000	Delta k=3.8429e+01 D()/DN=1.0000e-02
Max stress =	14.000	r = 0.00	57429 Cycles	Subspectra: 0	Pass: 575	Hours: 1148.58
Stress State in the 'C' direction (PSC): 2						
Fracture has occurred- run time: 0 hour(s) 0 minute(s) 1 second(s)						
1148.5800 hours have passed						

Life in Hours Output – What Do We Do with a Time Dependent Spectrum?

Print hours and cycles

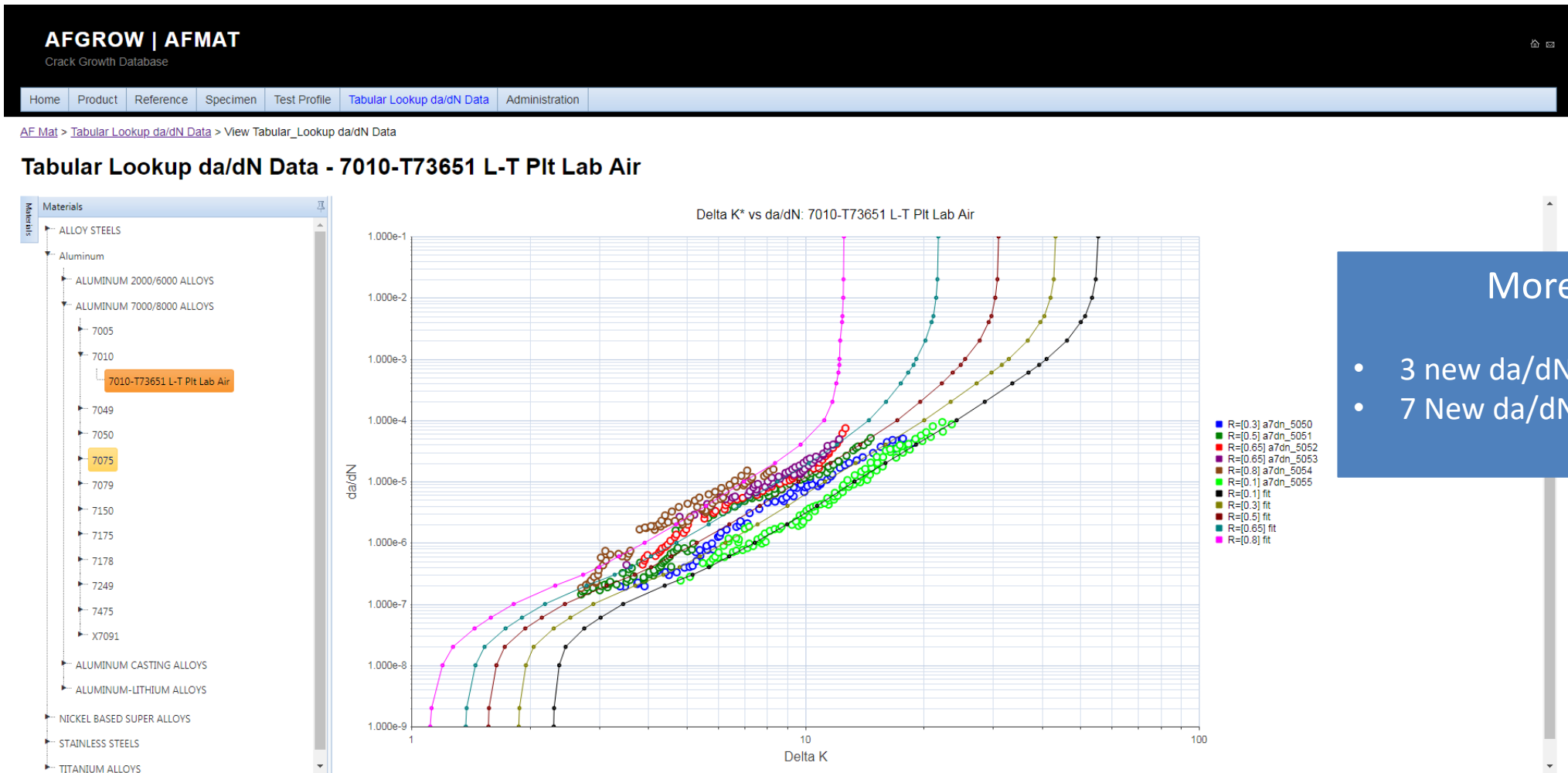


C Crack size= 1.089 Beta Tension= 1.2170 Beta Compression= 1.2170 R(k)= 0.0000 R(final)= 0.0000 Max stress = 14.000 r = 0.00 57100 Cycles Subspectra: 0 Pass: 572 Hours: 1142	Delta k=3.1513e+01 D()/DN=3.0626e-04
C Crack size= 1.1196 Beta Tension= 1.2498 Beta Compression= 1.2498 R(k)= 0.0000 R(final)= 0.0000 Max stress = 14.000 r = 0.00 57200 Cycles Subspectra: 0 Pass: 573 Hours: 1144	Delta k=3.2816e+01 D()/DN=4.4571e-04
C Crack size= 1.1642 Beta Tension= 1.2498 Beta Compression= 1.2498 R(k)= 0.0000 R(final)= 0.0000 Max stress = 14.000 r = 0.00 57300 Cycles Subspectra: 0 Pass: 574 Hours: 1146	Delta k=3.3463e+01 D()/DN=5.5443e-04
C Crack size= 1.2196 Beta Tension= 1.3171 Beta Compression= 1.3171 R(k)= 0.0000 R(final)= 0.0000 Max stress = 14.000 r = 0.00 57400 Cycles Subspectra: 0 Pass: 575 Hours: 1148	Delta k=3.6095e+01 D()/DN=2.1559e-03



- Let user decide what to see in the plot view.
- “Crack Length vs. Cycles” graph will be in hours only if “Yes” button is checked in and plots are covetable to hours

AFMAT updates since September 2019



More data

- 3 new da/dN test data sets
- 7 New da/dN curve fits

Acknowledgements

- A-10 and T-38 Structural Integrity and Analysis Group
- ASIMIS
- AFGROW Customers and Consortium Members

Questions