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AFGROW .NET

AFGROW Workshop 2019

Current AFGROW Release Overview

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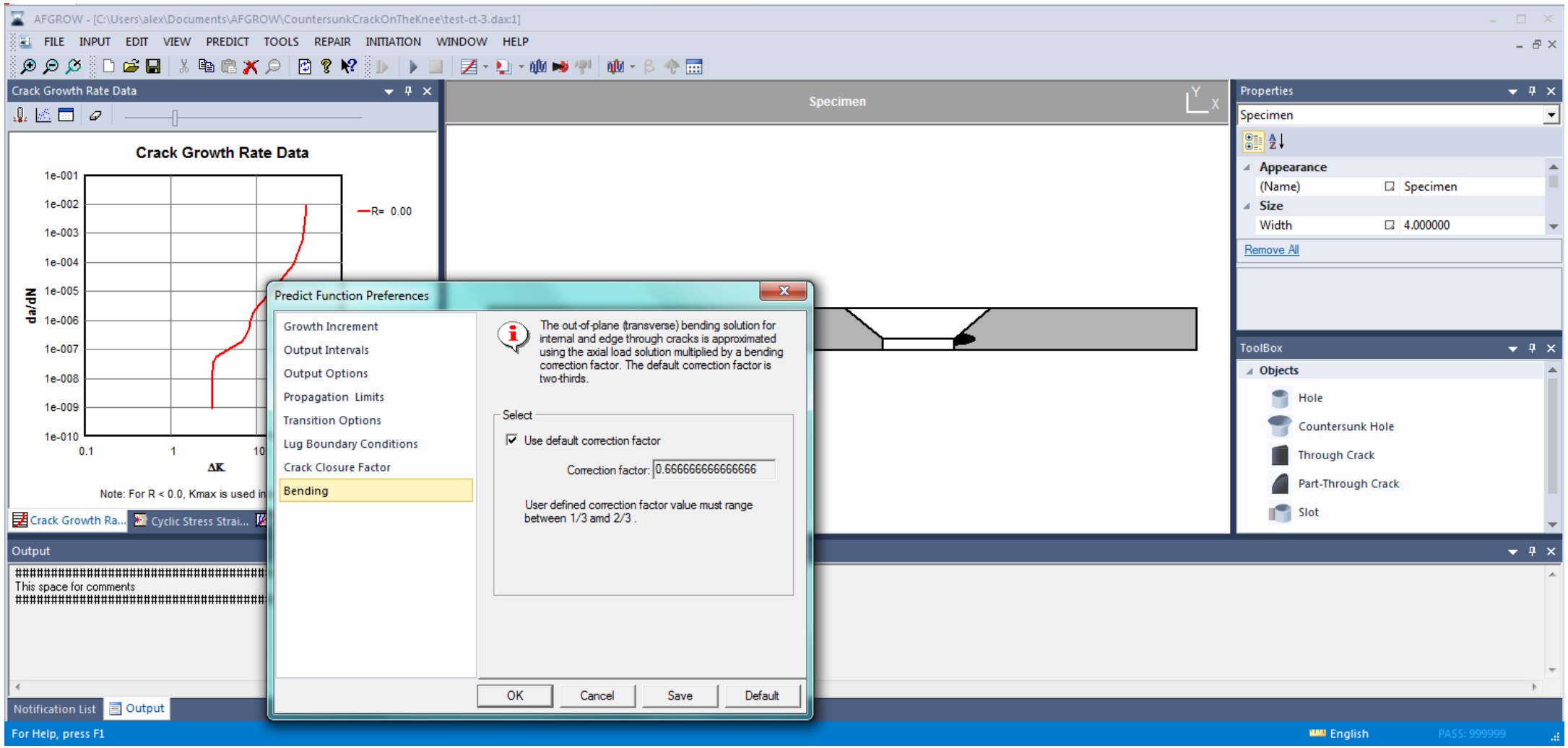
Outline

- Brief overview of release 5.3
- Changes in interim release 5.3.3.23
- Changes in interim release 5.3. 4.23
- Changes in upcoming interim release 5.3.5.24
- AFMAT updates

AFGROW Release 5.3



AFGROW Current Release 5.3 – Highlights

- 64 bit version
- Multilingual support
- Material Database redesign and outgoing data update – 6,652 da/dN material test data sets.
- 70 downloadable material data fits in tabular lookup format are available online
- Spectrum Manager Tool to create, edit and transform spectra included in the release
- Numerous K-solution changes/enhancements
- Ability to use different material data as a function of spectrum level
- Ability to apply different material data to different crack directions
- Corrosion Effects
- Ability to open read only material data from the network or online folder. System administrator managed feature

AFGROW Release 5.3 – New K-Solution Functionality

- Option to control the % of the axial load solution that is used to approximate the out-of-plane bending solution for straight through-the-thickness cracks:
  - Classic edge crack
  - Classic double edge crack
  - Classic through crack
  - All advanced cracks where bending was not available with the exception of crack at slot
- New solution for a corner crack at the countersink knuckle
- Bearing solution for advanced through crack(s) at a hole
- Capability to use the current 2-D User-Defined Beta Model for 2, inter-dependent through cracks that can be assigned different plate thickness values = 100%
- Single edge crack model with the finite height – provided by SAFE
- Added global “Constrained” property for advanced model in-plane bending - only applicable for notch solutions.

Minor Release 5.03.03.23 - October 19, 2018

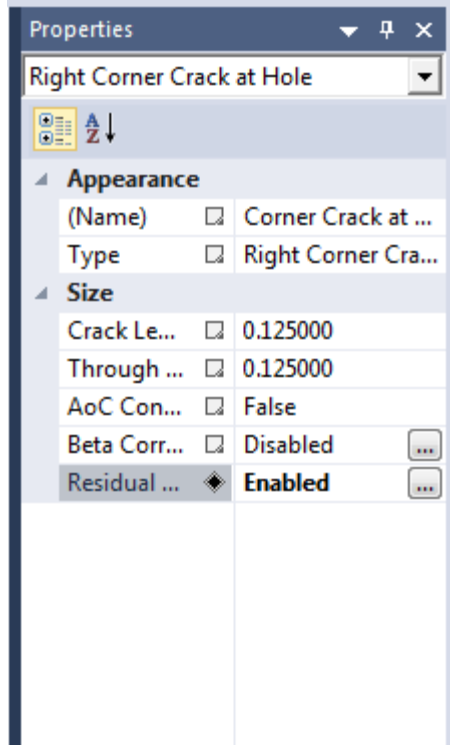
- Added the ability to use residual stresses for advanced models with crack(s) at a hole
- Made significant improvements to the residual stress Gaussian integration routine
- Added the ability for AFGROW to provide COM interface information at runtime

Improvements to Residual Stresses calculation routine

- The Gaussian integration routine did not include a part-through correction to the handbook solution for a point load on a through crack.
- The integration is now performed twice – part-through case, and through crack case. This solves the crack transition issue with the slope change limitation.
- Improved the interpolation method in the routine.

Ability to Use Residual Stresses for Advanced Models with Crack(s) at Hole

- The Advanced Solution is more accurate than the Classic Solution
- Residual stresses are applied to the one or both cracks independently
- Results look much better based on the ERSI RR test results



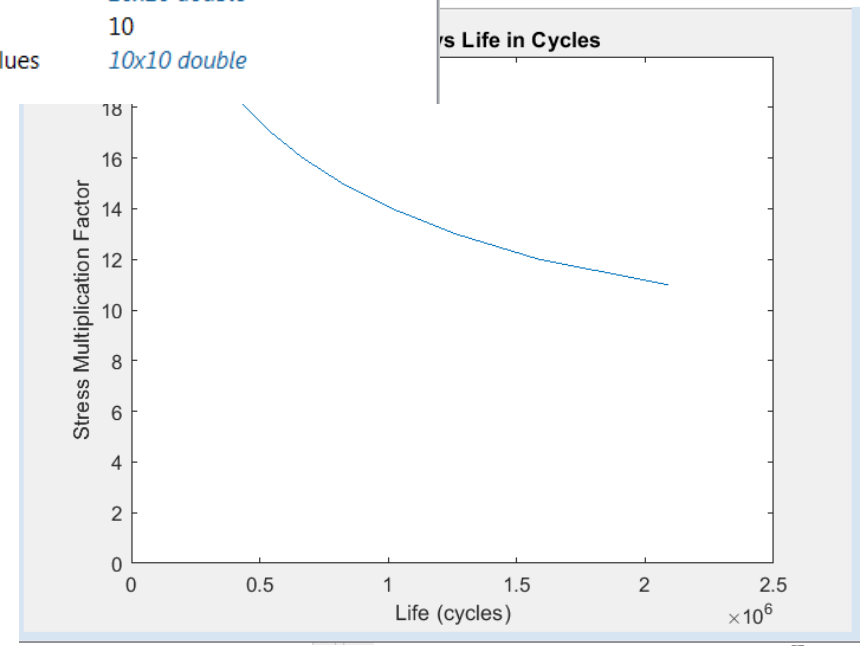
AFGROW modified to provide COM Interface Information at Runtime (Late binding)

- Binding is a process of matching function calls to the actual code that implements the function.
- Late-binding, where the target method is looked up at run time, mostly by function name
- Late binding is exclusively used by Matlab.

```
1 -  clear;
2 -  afgrow = actxserver('Afgrow.Application');
3 -  afgrow.Model = 'aSingleEdgeCorner';
4 -  afgrow.SpecimenWidth = 6;
5 -  afgrow.SpecimenThickness = 1;
6 -  afgrow.CrackLengthA = .05;
7 -  afgrow.CrackLengthC = .05;
8 -  afgrow.ConstAmplitudeSpectrum(0.0);
9
10 -  count = 10;
11
12 -  cycles = zeros(count);
13 -  smfValues = zeros(count);
14 -  for i = 1:count
15 -      afgrow.SMF = 10 + i;
16 -      [~, cycles(i), ~, ~, ~, ~, ~] = afgrow.RunFrozPredict();
17 -      smfValues(i) = afgrow.SMF;
18 -  end
19
20 -  plot(cycles, smfValues);
21 -  title('SMF Values vs Life in Cycles');
22 -  xlabel('Life (cycles)');
23 -  ylabel('Stress Multiplication Factor');
24
```

Workspace

Name	Value
afgrow	*1x1 Afgrow_Application*
ans	1
count	10
cycles	*10x10 double*
i	10
smfValues	*10x10 double*



Minor Release 5.03.04.23 - March 19, 2019

- Added a new bearing and bending load case solutions for a through crack at a hole with a slot on the other side (continuing damage model)
- Added a new bearing load case solution for a corner crack at a hole with a slot on the other site (continuing damage model)
- Added an ability to report the amount of crack growth (percentage) caused by tagged spectrum levels as well as each sub-spectrum

Bearing Load Case Solution for a Corner and Through Crack at a Hole with a Slot on the Other Site (Continuing Damage Model)

The continuing damage solution for the through-the-thickness crack geometry is valid for all combinations of crack length, plate width, hole offset and diameter for notch depths less than one half the total plate width as indicated below. Errors greater than 10% may occur when the notch depth exceeds this limit. The corner crack solution demonstrated more variability but generally remained within 5% for all cases that were tested.

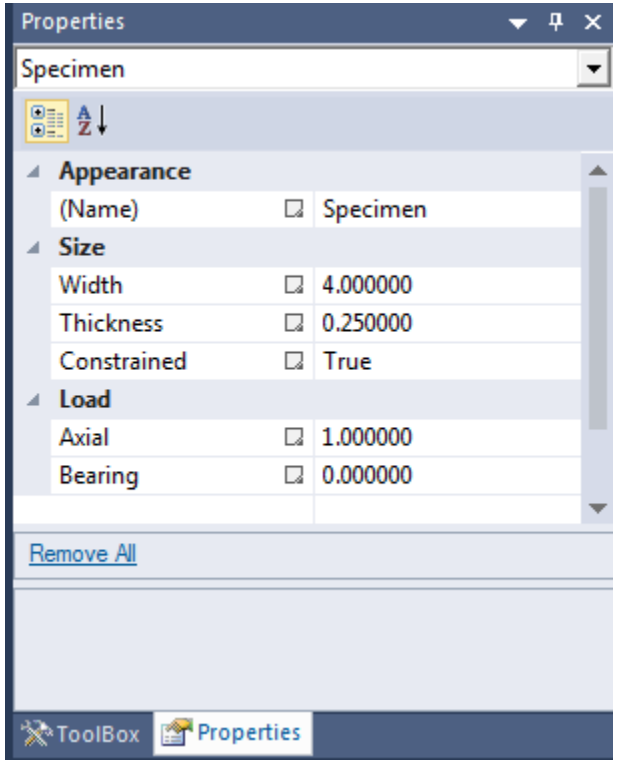
Suggested Limits:

0.5 <= a/c <= 3.0

0 < a/t < 0.95

0.25 <= r/t <= 2.0

e/W < 0.5



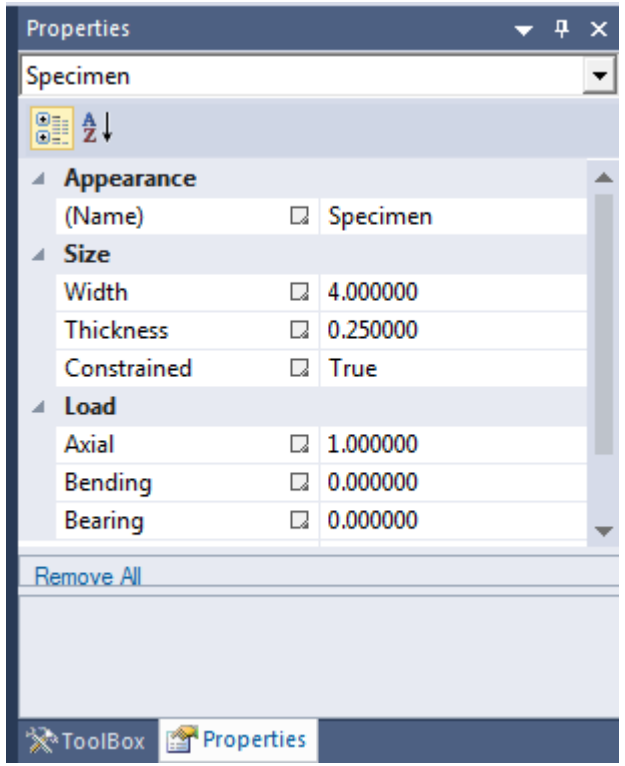
Bending Load Case Solution for a Through Crack at a Hole with a Slot on the Other Side (Continuing Damage Model)

Using option to control the % of the axial load solution that is used to approximate the out-of-plane bending solution for straight through-the-thickness cracks.

The continuing damage solution for the through-the-thickness crack geometry is valid for all combinations of crack length, plate width, hole offset and diameter for notch depths less than one half the total plate width as indicated below. Errors greater than 10% may occur when the notch depth exceeds this limit. The corner crack solution demonstrated more variability but generally remained within 5% for all cases that were tested.

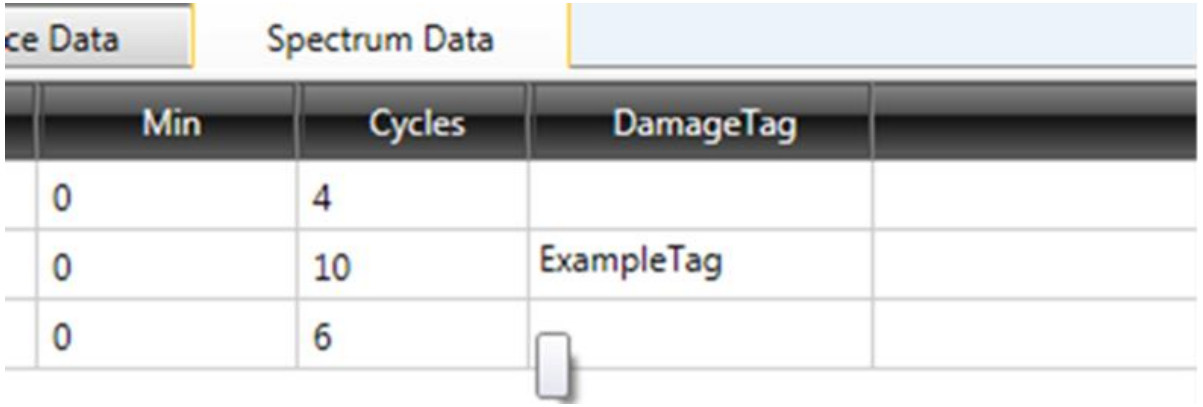
Suggested Limits:

0.25 <= r/t <= 2.0



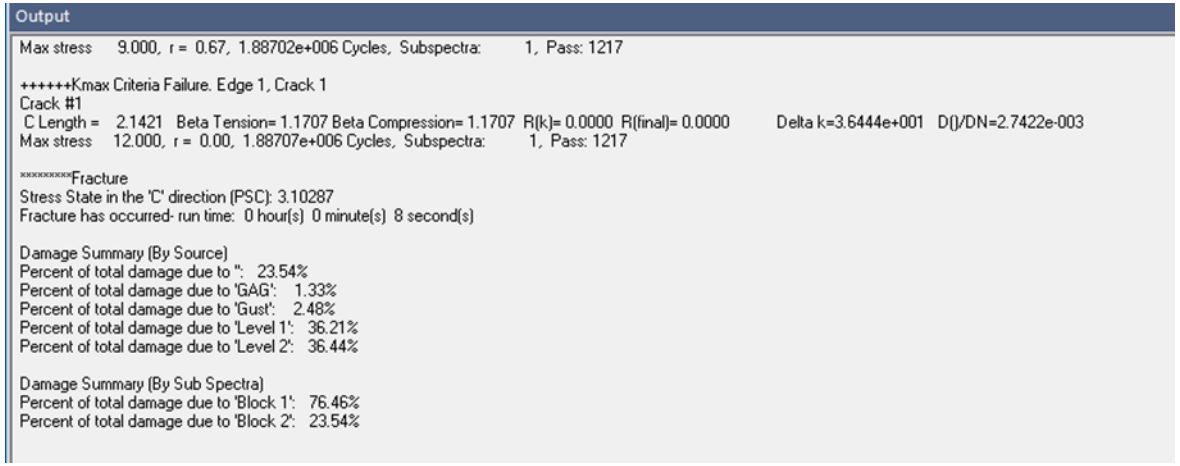
Spectrum Damage Tags

- Damage tags may be assigned to individual levels in a sub-spectrum using the AFGROW Spectrum Manager
- These tags are alpha-numeric so they can include any combination of text and numeric information
- Maximum Damage tag size is 10 characters
- Damage tags are used to track the amount of crack growth resulting from tagged spectrum levels



Report the Amount of Crack Growth (Percentage) Caused by Tagged Spectrum Levels as Well as Each Sub-Spectrum

- During a life prediction, AFGROW keeps a running total of the amount of crack growth for each tagged level in the input spectrum.
- A damage summary is provided at the end of the analysis showing the percentage of total crack growth for each damage tag.
- Damage accumulated by spectrum levels without tags are reported as the remaining percentage of the total crack growth.
- When damage tags are used, AFGROW also prints out the percentage of crack growth for each sub-spectrum.



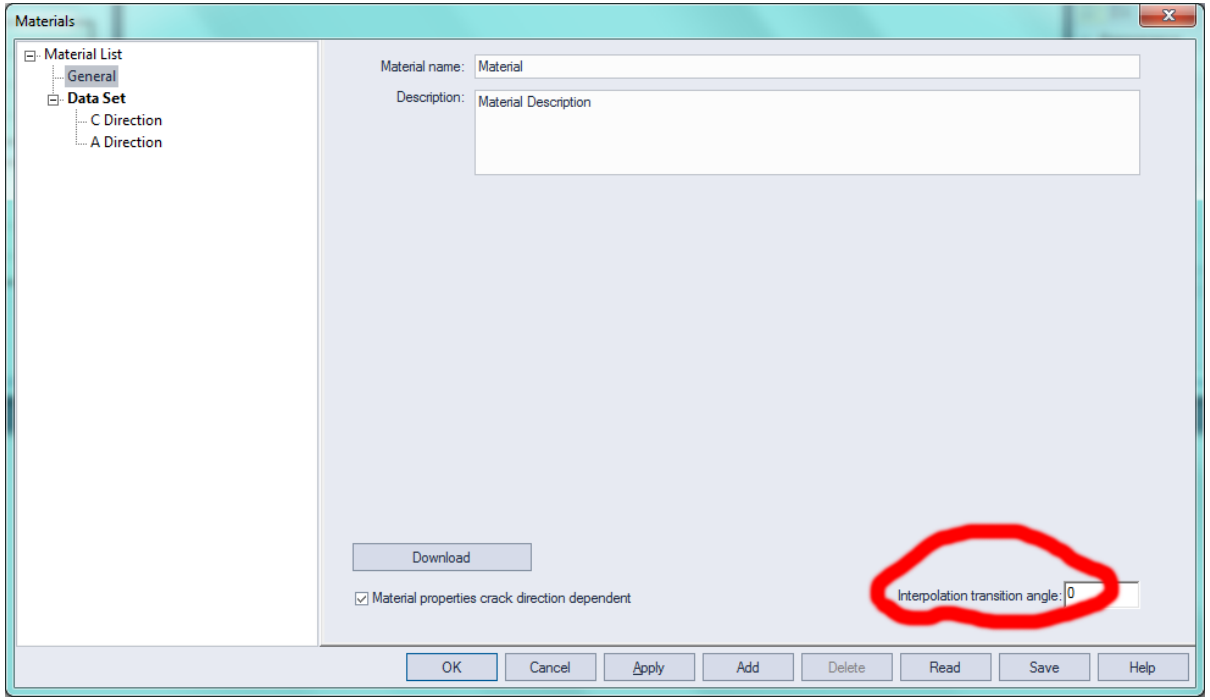
Upcoming Minor Release 5.03.05.24 - Fall 2019

- Enhancement: Add bending load for single edge corner crack
- Enhancement: Incorporated multi-directional material properties for the tabular lookup material data model
- Enhancement: Make sure that the AFGROW GUI works on Hi Resolution Monitors
- Enhancement: Added Thick Pipe Models: internal and external axial crack in thick pipe, axial through crack in thick pipe
- Enhancement: Constant K Specimen
- Bug: Walker and Forman dialogs saved only first letter of the material name
- Bug: AFGROW crashed during prediction if oblique crack at hole prediction is active
- Bug: Possible error during oblique through crack beta calculation
- Bug: AFGROW did not read the oblique option correctly for a double crack at hole
- Bug and Enhancement: It was impossible to copy data, delete curve for the material data and crack vs. life plot views
- Bug: It was impossible to set bending load using COM Interface for single and double edge through crack

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.

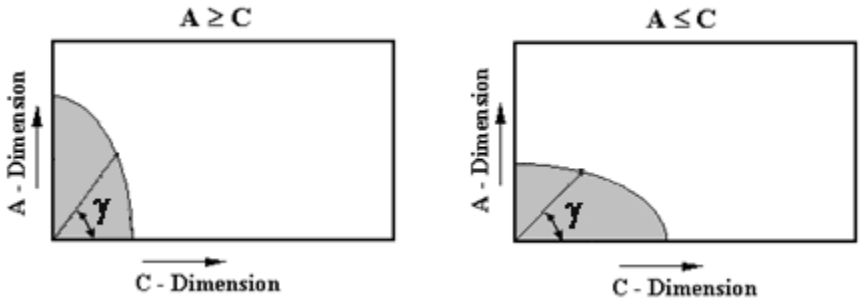


Material Orientation Angle

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 (ϒ) 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

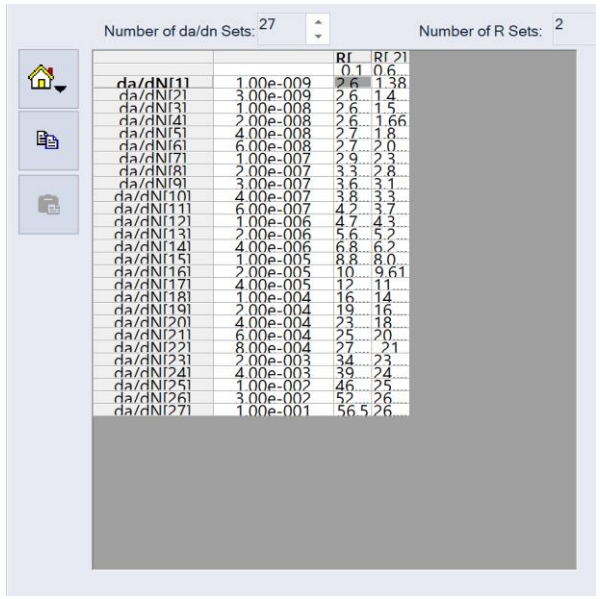
Model	Description of the Configurations	Beta Solution
	Internal Axial Crack in Thick Pipe	Application Defined
	External Axial Crack in Thick Pipe	Application Defined
	Axial Through Crack in Thick Pipe	Application Defined

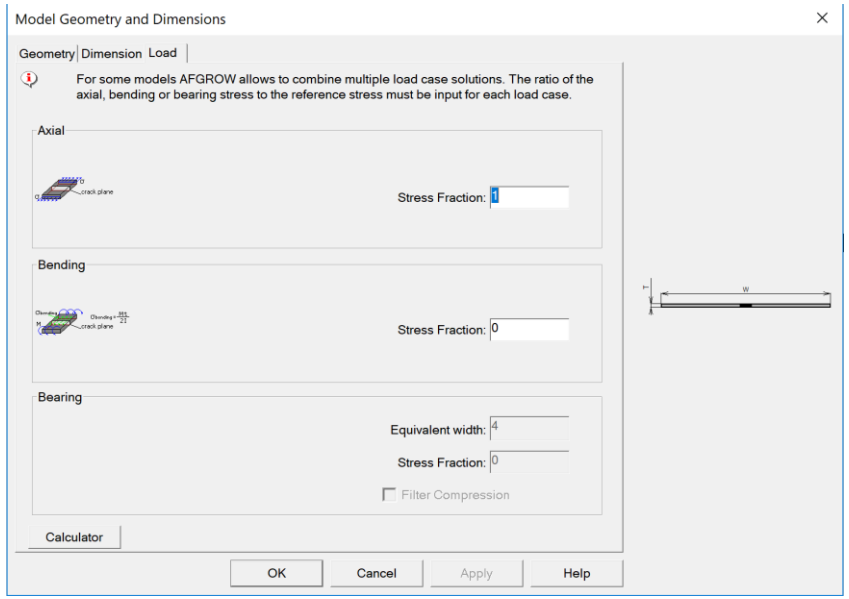
Constant K/σ Specimen

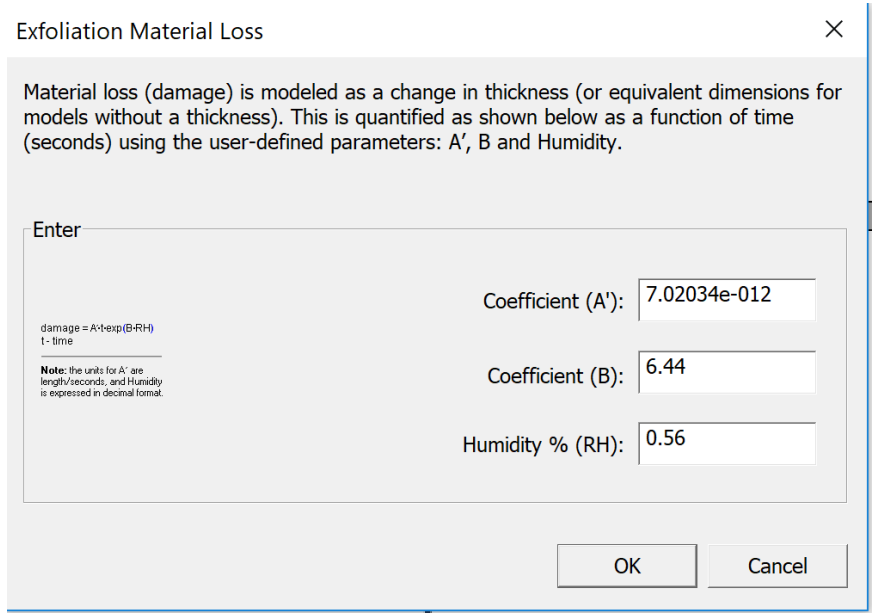
Model	Description of the Configurations	Beta Solution
	Constant K Specimen	Application Defined

- 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

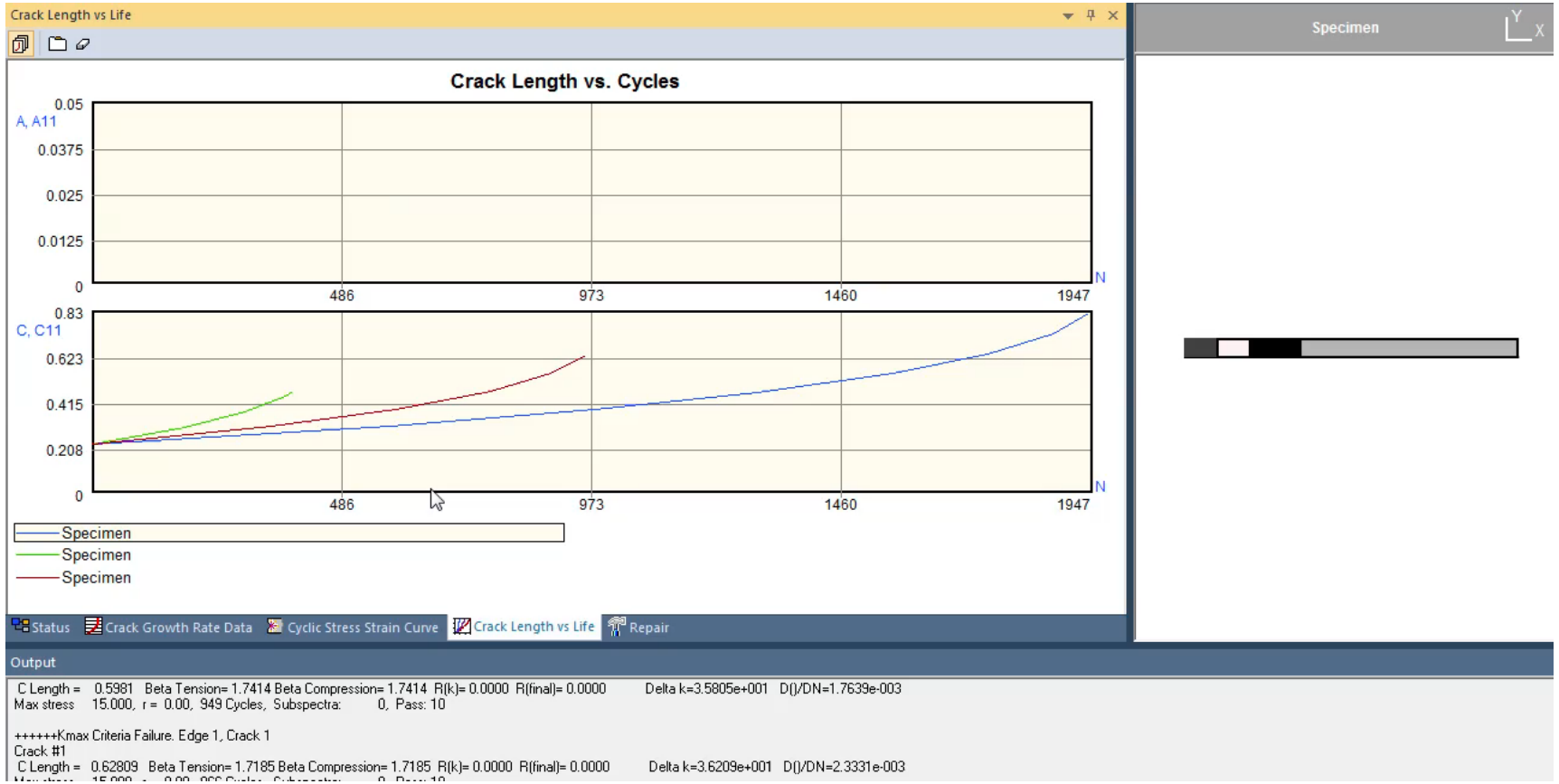
Make sure that AFGROW GUI works on Hi Resolution Monitors



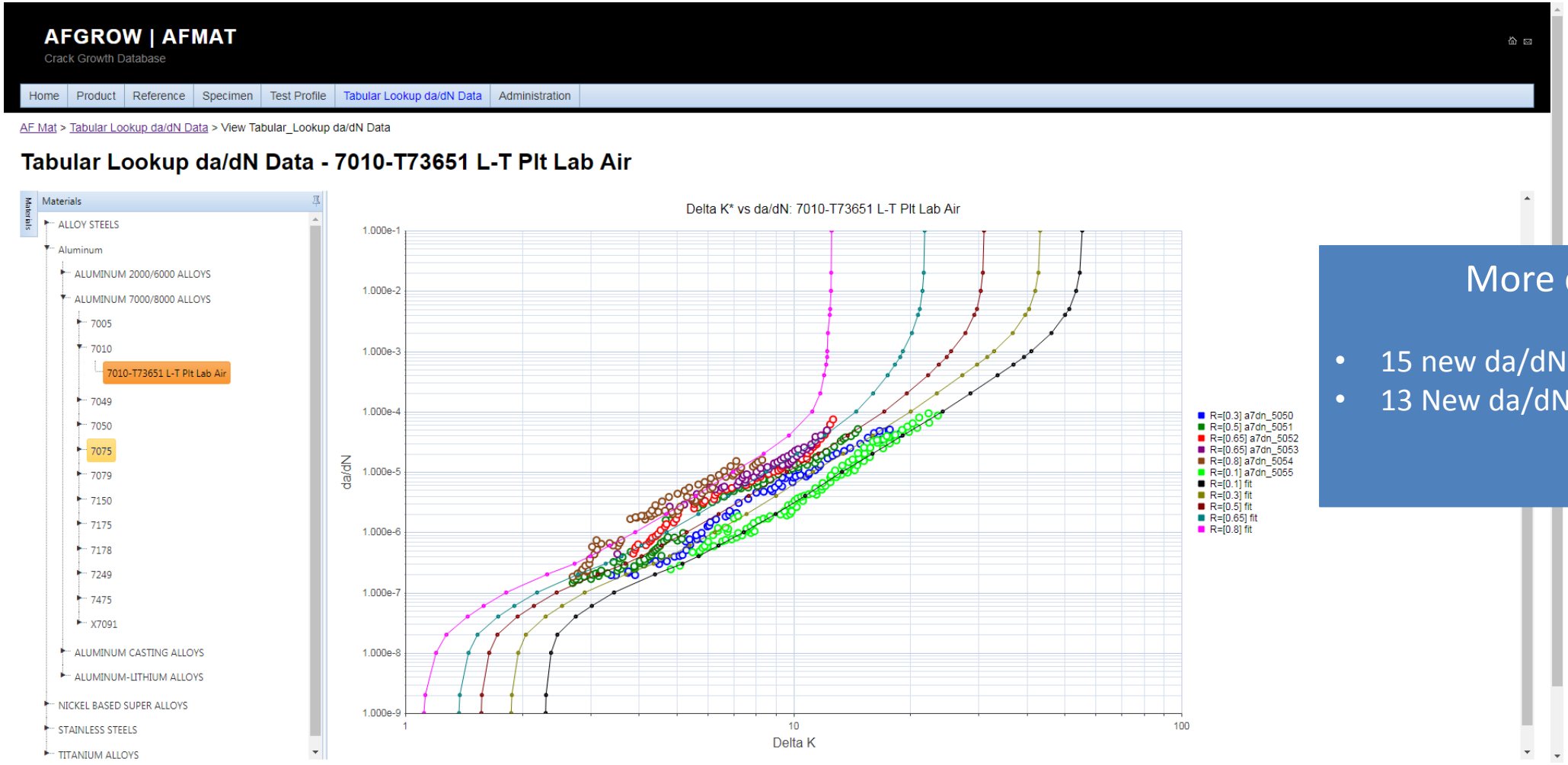




Added Ability to Delete a Curve and Copy Curve Data



AFMAT updates since September 2019



More data

- 15 new da/dN test data sets
- 13 New da/dN data sets

New da/dN data added to AF Mat

15-5PH H1025 L-T Forging	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=a12b4ddc-40da-4fca-87ca-9083fdec3f92
17-4PH H1025 T-L Round bar	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=983c292a-bf9c-45f6-8e17-dd6e42e6b2a1
7475-T761 L-T DIST H2O SHEET	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=17a67305-27c2-445d-9a21-48ba80af4b5e
7475-T761 L-T Lab Air Sheet	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=82dcc1f0-5e36-42c4-b142-9aacdb55b58a
H-11 AUST;T L-T ROUND BAR	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=92cc87be-a244-42e0-878c-1b28fe23c7b7
300M L-T Lab Air Forging	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=2d86ac11-eb0a-40e1-8f9b-3e039d81cad7
4340 180 Ksi L-T HHA	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=0726725b-e8b5-4a66-8c32-9407fca3f3c8
7050-T7651 L-T Lab Air Plate	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=1bc3bbd1-5058-4981-b8dc-2f68770f03c1
8090-T8771 L-T Lab Air Plate	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=c9338d5e-49ea-4047-a1dc-d5738ee032be
INCONEL 718 C-R LAB AIR DISC	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=c1969ead-b0d4-4207-8a35-749fa7259fae
INCONEL X-750 LAB AIR (600-1000 Degrees F) PLATE	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=ea728f99-4dbf-460b-be72-7b3a42cbfd44
Ti-5AL-2.5SN(ELI)	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=7dd2b6e5-f0b7-47c9-ae3c-1fed39b8c365
Ti-6-4 (ELI) RA L-T Lab Air	https://www.afgrow.net/afmat/ViewTabular_Lookup.aspx?refid=1d98429e-d440-48de-98d0-0d7438425407

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New da/dN test data added to AF Mat since September 2019

Id	Alloy	Data Source	Condition Heat Treatment	Property Type	Orientation	Specimen Type	Specimen Thickness	Product Form	Environment	Temperature
21556	7076	Online Literature	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	L-C	Compact Tension (CT)	0.375	Forging	LAB AIR	
21555	AZ91C	Online Literature	T6	Fatigue Crack Growth Rate (da/dN vs delta K)		Compact Tension (CT)	0	Casting	AIR	70
21554	AZ91C	Online Literature	T6	Fatigue Crack Growth Rate (da/dN vs delta K)		Compact Tension (CT)	0	Casting	AIR	70
21553	ZE41A	Online Literature	T5	Fatigue Crack Growth Rate (da/dN vs delta K)		Compact Tension (CT)	0	Casting	AIR	70
21552	ZE41A	Online Literature	T5	Fatigue Crack Growth Rate (da/dN vs delta K)	UNKNOWN	Compact Tension (CT)		Casting	AIR	70
21551	2195(WELD)	Online Literature	T8X	Fatigue Crack Growth Rate (da/dN vs delta K)	T-L	Middle Tension (MT)	0.197	Unknown	Unknown	70
21550	316(16-8-2)	Online Literature	Unknown	Fatigue Crack Growth Rate (da/dN vs delta K)		Compact Tension (CT)	0.5	Weldment	AIR	1200
21549	316(16-8-2)	Online Literature	Unknown	Fatigue Crack Growth Rate (da/dN vs delta K)		Compact Tension (CT)	0.5	Weldment	AIR	800
21548	2195(HAZ)	Online Literature	T8X	Fatigue Crack Growth Rate (da/dN vs delta K)	T-L	Middle Tension (MT)	0.197	Unknown	Unknown	70
21547	316(16-8-2)	Online Literature		Fatigue Crack Growth Rate (da/dN vs delta K)		Compact Tension (CT)	0.5	Weldment	AIR	75
21546	2195	Online Literature	T8X	Fatigue Crack Growth Rate (da/dN vs delta K)	T-L	Middle Tension (MT)	0.197	Unknown	Unknown	70
21545	PWA 1480	Online Literature		Fatigue Crack Growth Rate (da/dN vs delta K)		Compact Tension (CT)	0	Unknown	LAB AIR	70
21544	PWA 1202	Online Literature		Fatigue Crack Growth Rate (da/dN vs delta K)	L-R	Compact Tension (CT)	0.5	Bar	Unknown	500
21543	PWA 1202	Online Literature		Fatigue Crack Growth Rate (da/dN vs delta K)	L-R	Compact Tension (CT)	0.5	Bar	Unknown	81
21535	Ni-Al Bronze Casting	Additional NASA Data	SW	Fatigue Crack Growth Rate (da/dN vs delta K)	UNKNOWN	Specimen Unknown (UNK)		Casting	SEA H2O	73

Acknowledgements

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

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Questions