

## AFGROW Workshop 2015

# AFGROW Current release update, Release 5.3 and beyond

Alex Litvinov, James Harter,  
LexTech, Inc

# Release 5.2.4.19, Released: May 20, 2015

- Enhancement: Added the bending load case to the advanced countersunk hole with corner crack(s) model.
- Enhancement: When advanced corner crack(s) at a hole transitions to become a through crack or a slot, the stress fraction changes to 1 for the Axial, and 0 for Bearing and Bending load cases. This is necessary because AFGROW does not currently have the Bending and Bearing solutions for the advanced through crack or slot geometries.
- Added two new functions to the plug-in interface (requested by A-10 and Gulfstream)
- Multiple bug fixes

More information available at: <http://www.afgrow.net/about/currentver.aspx>

# Countersunk Hole with Symmetric Corner Cracks

Countersunk solution  
bending beta comparison  
with APES report

Crack Ratio	a/t	r/t	b/t	% Difference	
a/c	b/2t			Beta c	Beta a
0.5	0.025	0.5	0.05	0.405917	-0.76915
0.5	0.025	1	0.05	0	-2.71261
0.5	0.025	2	0.05	0.752097	-3.25145
0.5	0.125	0.5	0.25	-1.33026	3.446658
0.5	0.125	1	0.25	-2.33	-0.80411
0.5	0.125	2	0.25	-3.82395	-4.90247
0.5	0.25	0.5	0.5	3.604173	2.86036
0.5	0.25	1	0.5	4.419986	-0.22782
0.5	0.25	2	0.5	1.699906	-1.52487
1	0.025	0.5	0.5	-0.39471	0.00543
1	0.025	1	0.5	0.121632	-1.78971
1	0.025	2	0.5	0.290266	-2.15671
1	0.125	0.5	0.5	-2.82091	3.872626
1	0.125	1	0.5	-3.96382	-0.63312
1	0.125	2	0.5	-6.11364	-5.25029
1	0.25	0.5	0.5	0.920069	5.939642
1	0.25	1	0.5	0.994178	3.125
1	0.25	2	0.5	0.546868	0.474898
2	0.025	0.5	0.5	1.560005	2.271561
2	0.025	1	0.5	-0.79342	0.531176
2	0.025	2	0.5	0.819545	0.91003
2	0.125	0.5	0.5	-0.59682	6.703167
2	0.125	1	0.5	-2.75196	1.194639
2	0.125	2	0.5	-4.99909	-4.57402
2	0.25	0.5	0.5	2.139	11.77102
2	0.25	1	0.5	2.035623	7.886203
2	0.25	2	0.5	0.393185	3.067438
0.2	0.25	0.5	0.5	-29.9036	141.3751
0.2	0.025	1	0.05	-56.0882	11.8347
0.2	0.025	2	0.05	-54.3535	12.21823
0.2	0.125	0.5	0.25	-61.3411	16.44286
0.2	0.125	1	0.25	-58.5211	14.0781
0.2	0.125	2	0.25	-57.7612	13.17296
0.2	0.25	0.5	0.5	-54.7653	21.43401
0.2	0.25	1	0.5	-55.6617	18.75017
0.2	0.25	2	0.5	-55.8603	19.14563

# Offset Countersunk Hole with a Single Corner Crack

Countersunk hole solution bending beta comparison with APES report

Crack Ratio	a/t	r/t	Thickness Ratio	% Difference	Beta a	Beta c
a/c	b/2t		b/t			
0.5	0.025	0.5	0.05	2.906546	-0.97098	
0.5	0.025	1	0.05	2.585303	0.680531	
0.5	0.025	2	0.05	-1.29177	3.992778	
0.5	0.125	0.5	0.25	-7.21871	-8.02209	
0.5	0.125	1	0.25	-10.0708	-5.15964	
0.5	0.125	2	0.25	-1.04998	-5.14258	
0.5	0.25	0.5	0.5	0.804466	-6.82135	
0.5	0.25	1	0.5	0.138122	-4.86753	
0.5	0.25	2	0.5	-3.28122	-4.33925	
1	0.025	0.5	0.05	2.291918	-1.96016	
1	0.025	1	0.05	1.007821	0.873265	
1	0.025	2	0.05	-1.19355	2.692581	
1	0.125	0.5	0.25	-0.81139	-8.7438	
1	0.125	1	0.25	-1.51349	-7.86763	
1	0.125	2	0.25	-2.88991	-7.12383	
1	0.25	0.5	0.5	-1.26571	-8.45041	
1	0.25	1	0.5	-2.55952	-7.30806	
1	0.25	2	0.5	-5.57755	-6.32255	
2	0.025	0.5	0.05	3.548135	-4.46063	
2	0.025	1	0.05	-0.1016	-1.72377	
2	0.025	2	0.05	-0.72241	-1.11488	
2	0.125	1	0.25	2.842675	-12.6482	
2	0.125	2	0.25	0.660137	-11.81	
2	0.25	0.5	0.5	-9.72772	-6.05366	
2	0.25	1	0.5	1.206273	-13.2271	
2	0.25	2	0.5	-0.31431	-11.8962	
2	0.025	0.5	0.05	-4.30236	-9.87463	
0.2	0.025	1	0.05	-8.08811	-49.7857	
0.2	0.025	2	0.05	-60.1136	-11.355	
0.2	0.125	0.5	0.25	-58.0614	-10.5275	
0.2	0.125	1	0.25	-66.571	-16.6885	
0.2	0.125	2	0.25	-67.5651	-15.251	
0.2	0.25	0.5	0.5	-64.8627	-16.6345	
0.2	0.25	1	0.5	-54.6033	-18.604	
0.2	0.25	2	0.5	-61.0364	-16.6763	
0.2	0.25	2	0.5	-63.1362	-16.7139	

# Plug-In Interface changes

- Added the *PrePredictTest* function to the *AfgrowBetaPlugin* Interface. The function is intended to be used to test for errors prior to the start of a prediction. If this function returns true, AFGROW will continue the prediction. If function returns false, AFGROW will abort the prediction. The function has one parameter (string). When the function returns false, AFGROW will display the string in the error description dialog
- Print the version number of the plug-in model in the text and XML output files.

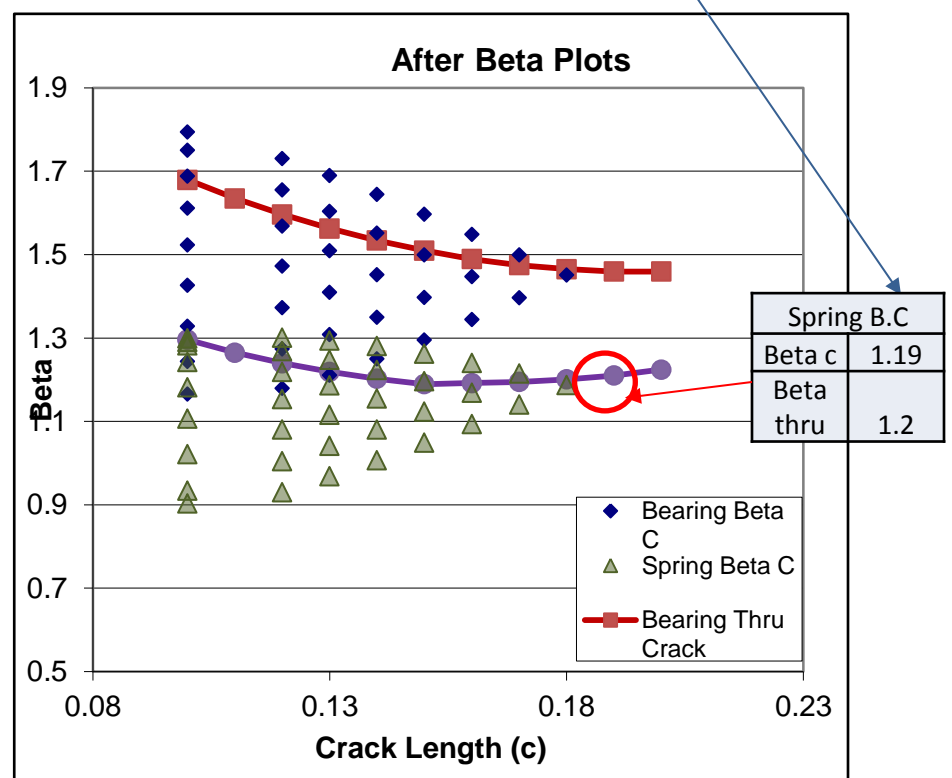
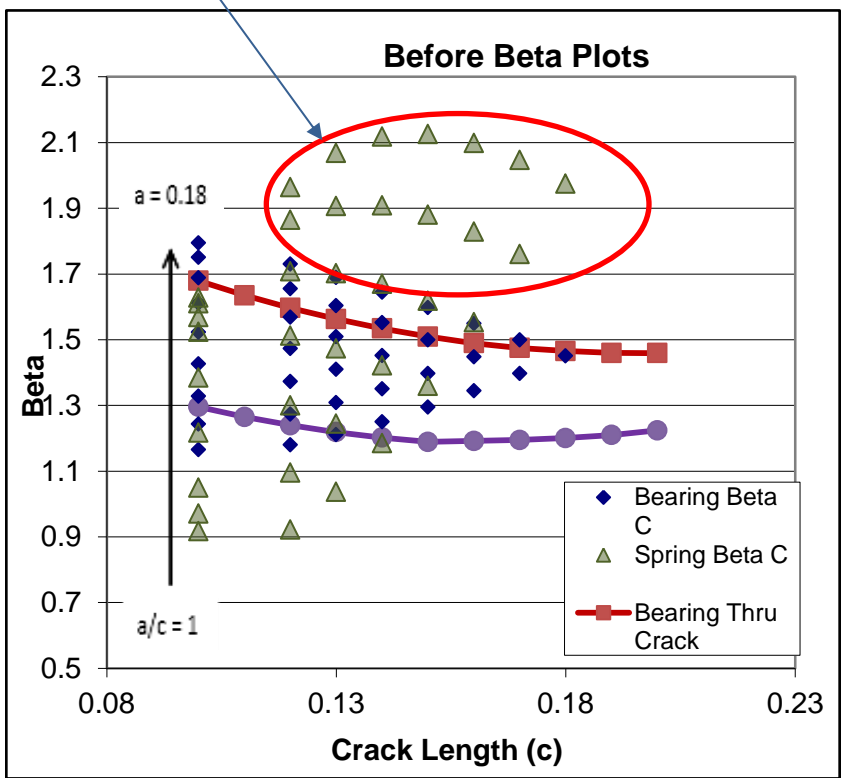
# State of the Current Release 5.2.4.19

- Bug: Model title name problem. AFGROW crashes when title string length is beyond 80 characters
- Bug: Beta Sub R is not available through COM API
- Enhancement in work: Corner crack at a lug model improvements: brought to attention Tim Allred, A-10. Data was originally generated by contractor for the Air Force. Data matrix has some “holes” and errors in some of the data.

# Improved matrix Results

Extreme Jump in beta c as the crack size

Spring corner crack Betas now match up with through crack betas



Lug geometry:  $W=1.1$ ,  $t=0.2$ ,  
 $D=0.5$



# Feature List for the release 5.3

- **64 bit version - 30%**
- **New spectrum format in AFGROW - 50%**
- **New weight functions solutions (crack at hole, stress distribution in the C-direction for part through cracks) -90%**
- **Using different material data as a function of spectrum data**
- **Applying different material data to different crack directions**
- **Ability to Replicate Results From Previous Versions (back to Version 5.01) - 20%**
- **Option to Save Input File With Retardation State Data for Later Restart – 30%**
- Undo-Redo
- **New solution for a corner crack at the countersink knuckle – 50%**
- **Server based material database – requested by Gulfstream – 50%**
- **Convert material data from AFMAT to a useable format in AFGROW**
- **Bearing solution for corner crack(s) at a countersunk hole – 15%**
- **Bearing solution for the advanced through crack(s) at hole model – 80%**
- AFGROW output post processing
- **New 2D table of the residual stress data (similar to the 2-D user defined beta) 90%**

**Bold** – Work started

**Red** – High Priority

**Blue - Finished**

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# Less Time Consuming Requests

- 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
- In the Propagation Limit tab, the option to stop at a cycle limit should be automatically switched to hours if the User has elected to display the life in hours.
- Add some type of warning in the lug dialog box to let User's know which B.C.s are being used - or at least notify them that the B.C.s are set in the Predict, Preferences dialog.
- Consider adding a failure criterion based on R-curve data
- Consider adding more warning messages to Users about input parameters than could result in poor life predictions. The concern here is for more novice Users who may be tempted to think that AFGROW's User Friendly Interface is a substitute for a good working knowledge of Fracture Mechanics.
- Add ability to open AFGROW input dialogs by clicking on items in the tree view

# Less Time Consuming Requests

- **Consider adding an 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. Need to mention Jim's research – 50%**
- **Add a notification in the weight function dialog box to explain the limitations of the stress distributions for part-thru cracks.**
- **Add the 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. This is needed to accommodate the NASGRO crack growth rate model that is a function of thickness, but would also allow the local stress state to be estimated independently for each crack. It would also be a quick and easy way to solve additional cases without developing a Plug-In module. An additional crack growth model could be added to the Classic Interface showing an image of an "L" section with a crack defined along each leg with 2 thickness parameters. – 60%**
- **Add single edge crack model with the finite height – provided by SAFE, Inc**

# Less Time Consuming Requests

- Add new width correction for an advanced single corner crack at a hole – provided by SAFE, Inc
- Add a solution for stiffened panels
- Add the ability to account for interference fit fasteners
- Increase comments capability
- Add residual strength plot
- Add plug-in model variable that can return the cycle count
- Add the block size variable for constant amplitude loading
- Add the ability to randomize load levels within a given sub-spectrum in the Spectrum Manager.
- Add the ability to normalize and de-normalize a spectrum in the spectrum manager

# Less Time Consuming Requests

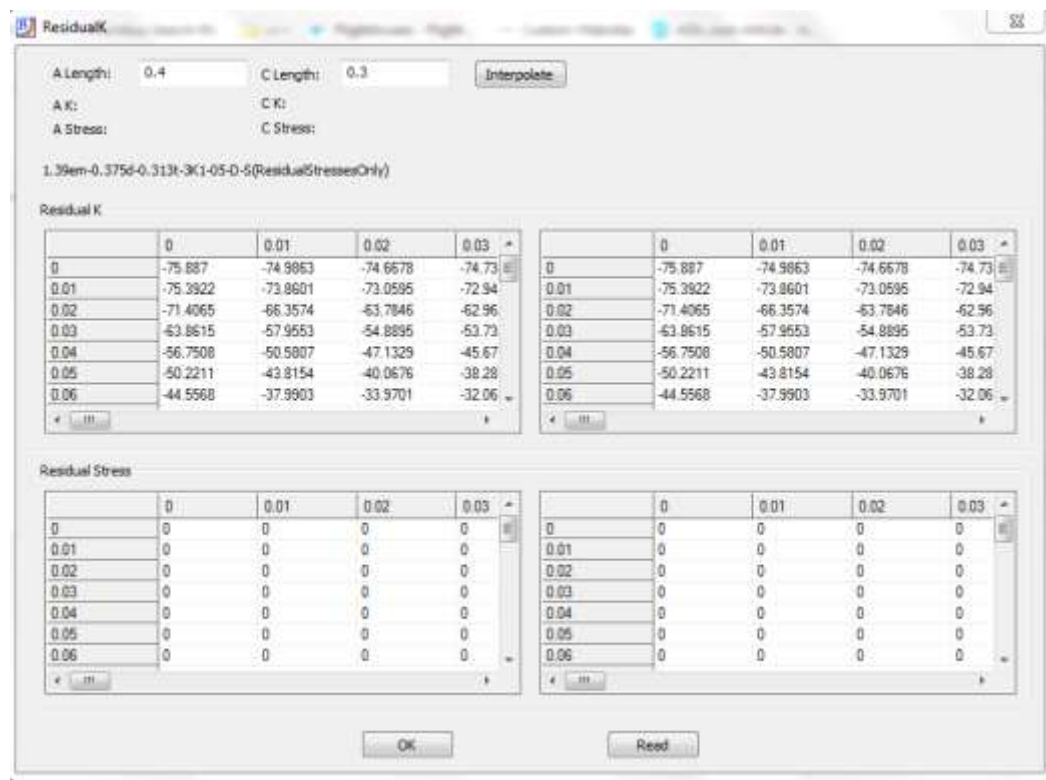
- De-couple beta calculation and prediction process (Allow plugin to use standard/advanced models)
- Add/Fix ability to manage multiple instances of AFGROW using COM API.
- Add more data to AFMAT - fracture mechanics database available online
- Add context sensitive help to AFGROW dialogs
- Access plugin models through COM

# New weight functions solutions

- Added 3 new solutions
  - Corner cracks with stress distribution along C direction
  - Single through edge crack with symmetry condition at the crack edge
  - Single through edge crack with symmetry condition at the edge away from the crack
- Status: Finished coding the solutions, coding verification is done, testing solutions accuracy and applicability, AFGROW GUI modified
- To do: finish testing the accuracy and applicability of the solutions

# New 2-D table of the residual stress data

- Status: Finished the coding, GUI development, verification, and testing.



# New solution for a corner crack at the countersink knuckle

- Based on Jody Cronenberger master thesis
- Tension loading only
- Solution Space:
  - $D/T - 0.3$  to  $2.6$ ;
  - $Cd$  (Countersunk Depth)/ $T - 0.001$  to  $0.99$  ( $0.15$ ),
  - $C/T - 0.0125(D/T) + 0.002$  to  $2.5(D/T)$
  - $A/C/T - 0.5$  to  $4$
- Status: Finished coding the solution implementation
- To do: Understand the solution boundaries and do verification runs, add COM API support, finish GUI integration

# Using different material data as a function of the spectrum

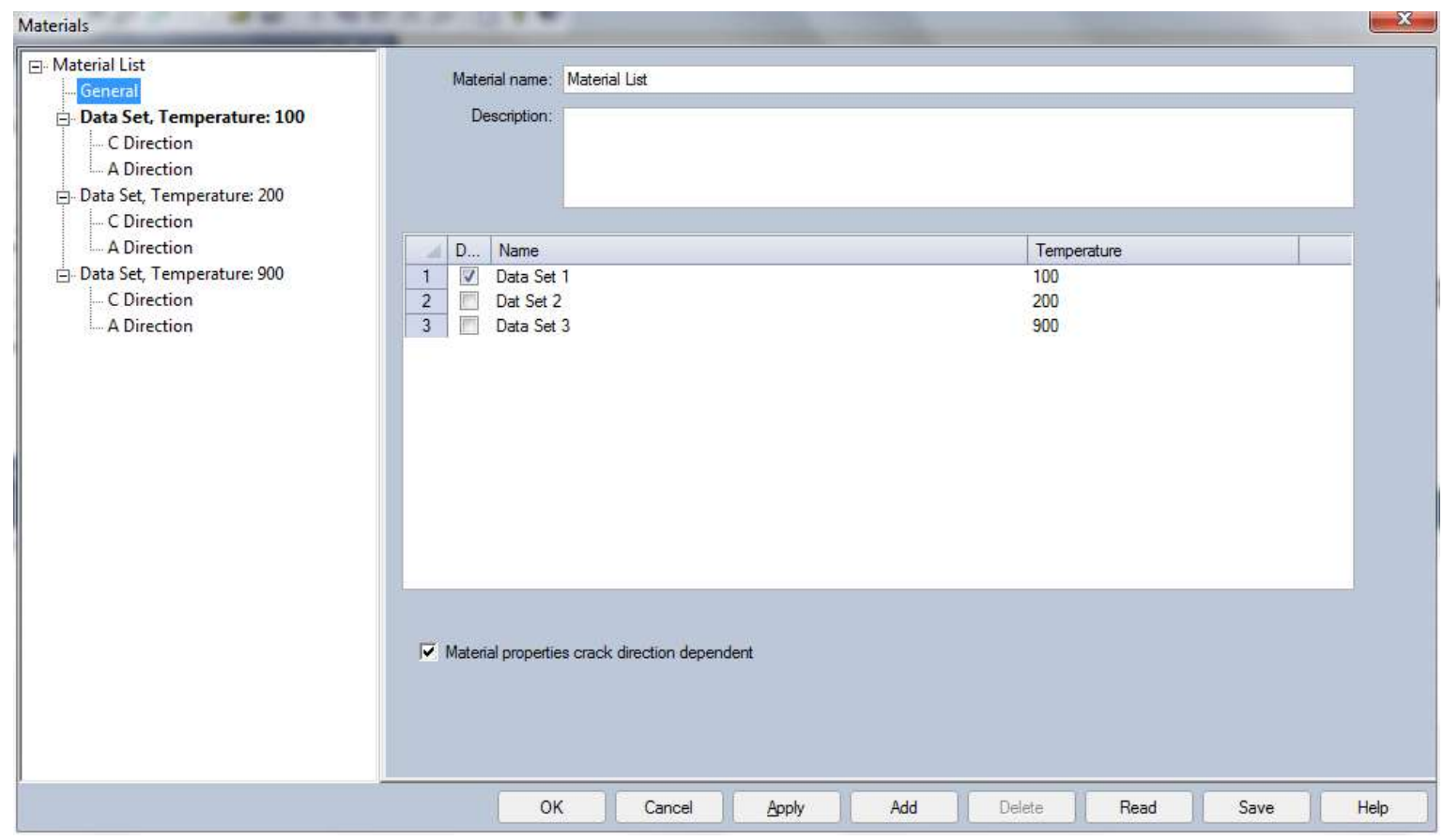
- Status: Finished the Spectrum Manager changes, finished AFGROW coding
- Material data will consist of different material “sets”
- One material “set” is always default
- Material sets can be tagged for different conditions
- Only the temperature “tag” can be used right now
- Applicable only for tabular lookup data, but code infrastructure has been changed to handle any AFGROW material model if necessary, and requires only GUI changes
- Requires spectrum with temperature “tags” applied to the sub-spectra
- Can work with the new XML spectrum format or a modified old format
- New XML tabular lookup data file
- Ability to open old tabular lookup data files
- DAX file is backward and upward compatible



# Applying different material data to the different crack directions

- Status: Finished AFGROW coding
- Works only with A and C directions (Ct and C direction will have the same material data)
- Applicable only for tabular lookup data, but code infrastructure has been changed to handle any AFGROW material model if necessary, and requires only GUI changes
- C direction is always the default direction
- Will not work with the Advanced multipoint corner crack(s) at hole model
- Can be used in conjunction with the “Using different material data as a function of spectrum” change
- DAX file is backward and upward compatible
- Plugin model needs to be changed to handle different material data to the different crack directions
- Crack initiation and repair will use the C direction default dataset (for spectrum dependent material data)

# New Material features dialog changes – General



# New Material features dialog changes - Material Set Property

Materials

Material List

- General
  - Data Set, Temperature: 100
    - C Direction
    - A Direction
  - Data Set, Temperature: 200
    - C Direction
    - A Direction
  - Data Set, Temperature: 900
    - C Direction
    - A Direction

Input values of Delta\_K for da/dN values and up to 10 different R(stress ratio) values. Matrix must have at least two R values and two da/dN values. Input Delta\_K for R >= 0, input Kmax for R < 0.0

Name: Data Set 1

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

		R[ 1]	R[ 2]
da/dN[1]	1.00e-009	2.606	1.38
da/dN[2]	3.00e-009	2.636	1.409
da/dN[3]	1.00e-008	2.673	1.503
da/dN[4]	2.00e-008	2.685	1.66
da/dN[5]	4.00e-008	2.729	1.897
da/dN[6]	6.00e-008	2.792	2.089
da/dN[7]	1.00e-007	2.954	2.355
da/dN[8]	2.00e-007	3.307	2.814
da/dN[9]	3.00e-007	3.605	3.133
da/dN[10]	4.00e-007	3.839	3.383
da/dN[11]	6.00e-007	4.209	3.744
da/dN[12]	1.00e-006	4.781	4.355
da/dN[13]	2.00e-006	5.696	5.218
da/dN[14]	4.00e-006	6.873	6.254
da/dN[15]	1.00e-005	8.825	8.014
da/dN[16]	2.00e-005	10.684	9.61

Ultimate Strength: 66

Young's Modulus: 10500

Coefficient of Thermal Expansion: 1.25e-005

Poisson's Ratio: 0.33

Upper limit on da/dN, DADNHI: 0.01

Lower limit on da/dN, DADNLO: 1e-009

Plane Stress Fracture Toughness, KC: 62.777

Plane Strain Fracture Toughness, KIC: 35

Delta K threshold value @R=0: 2.831

Yield Strength, YLD : 47










Lower limit on R shift (Max: 0): -0.3

Upper limit on R shift (0, 1): 0.63

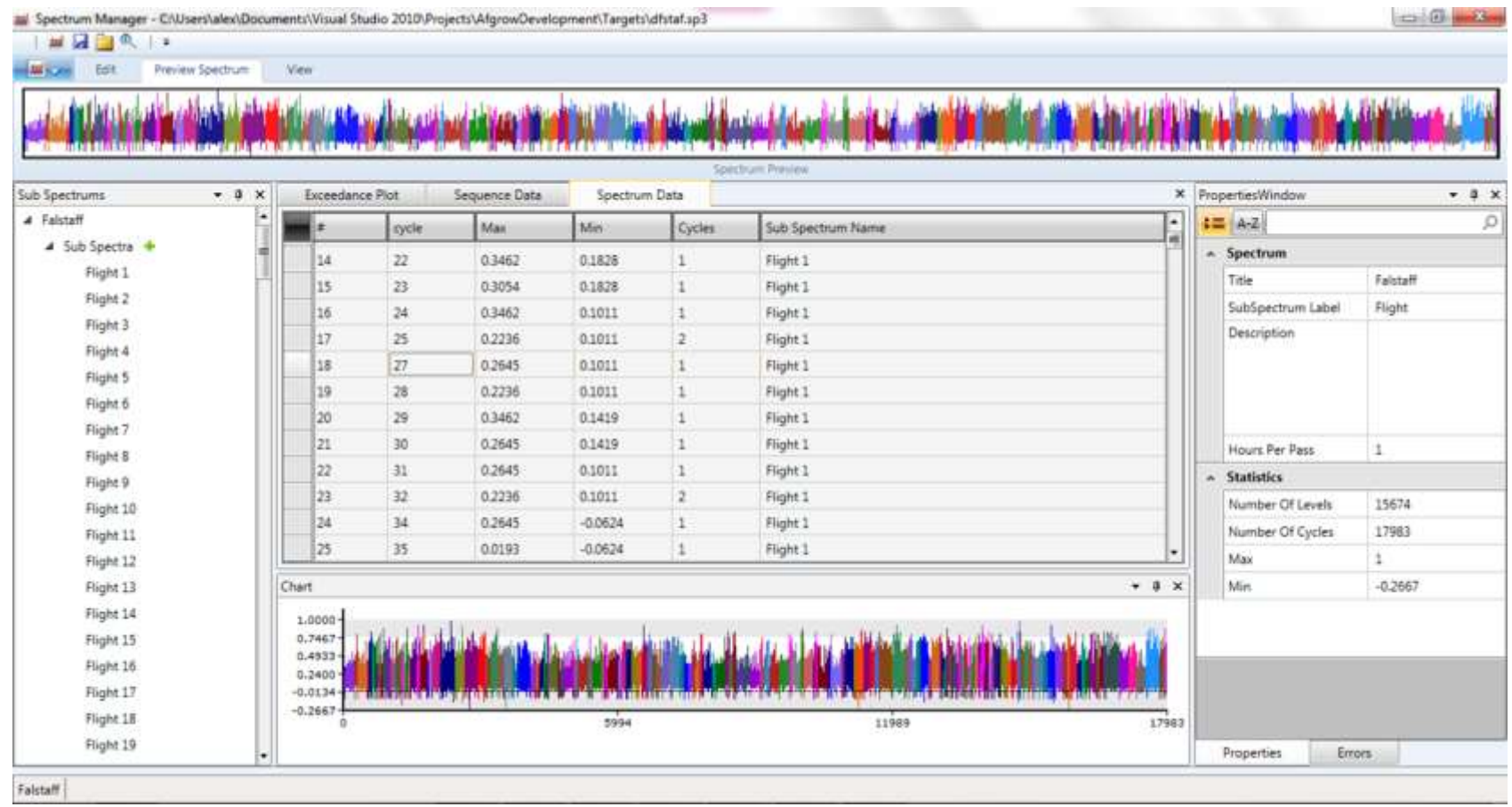
OK    Cancel    Apply    Add    Delete    Read    Save    Help

# New Classic Models

- Single corner crack model with the finite height
- 2 inter-dependent through cracks that can be assigned different plate thickness values

Model	Description of the Configurations	Beta Solution
<input type="checkbox"/>	 Part Through Crack in Pipe	Application Defined
<input type="checkbox"/>	 Through Crack	User Defined
<input type="checkbox"/>	 Interdependent Through Cracks	User Defined
<input checked="" type="checkbox"/>	 Internal Through Crack	Application Defined
<input type="checkbox"/>	 Single Through Crack at Hole	Application Defined
<input type="checkbox"/>	 Double Through Crack at Hole	Application Defined
<input type="checkbox"/>	 Single Through Crack at a Semi-circular Notch	Application Defined
<input type="checkbox"/>	 Single Edge Through Crack	Application Defined
<input type="checkbox"/>	 Single Edge Through Crack in a Finite Height ...	Application Defined

# Spectrum Manager



The screenshot displays the Spectrum Manager application window. At the top, there is a 'Spectrum Preview' section showing a multi-colored waveform. Below this, the main interface is divided into several panes:

- Sub Spectrums:** A tree view on the left showing a hierarchy starting with 'Falstaff' and 'Sub Spectra', followed by 19 individual 'Flight' items.
- Table:** A central table with columns: '#', 'cycle', 'Max', 'Min', 'Cycles', and 'Sub Spectrum Name'. It lists 11 rows of flight data.
- Chart:** A smaller spectrum plot at the bottom of the table pane, with a y-axis ranging from -0.2667 to 1.0000 and an x-axis with markers at 0, 5994, 11989, and 17983.
- PropertiesWindow:** A panel on the right showing details for the selected 'Falstaff' spectrum, including 'Title', 'SubSpectrum Label', 'Description', 'Hours Per Pass', and 'Statistics'.

#	cycle	Max	Min	Cycles	Sub Spectrum Name
14	22	0.3462	0.1828	1	Flight 1
15	23	0.3054	0.1828	1	Flight 1
16	24	0.3462	0.1011	1	Flight 1
17	25	0.2236	0.1011	2	Flight 1
18	27	0.2645	0.1011	1	Flight 1
19	28	0.2236	0.1011	1	Flight 1
20	29	0.3462	0.1419	1	Flight 1
21	30	0.2645	0.1419	1	Flight 1
22	31	0.2645	0.1011	1	Flight 1
23	32	0.2236	0.1011	2	Flight 1
24	34	0.2645	-0.0624	1	Flight 1
25	35	0.0193	-0.0624	1	Flight 1

# Spectrum Manager Overview

- Visual spectrum design
- Spectrum level reordering
- Sub-spectra organized in any user-defined sequence
- Sub-spectra may be placed in the sequence more than once
- Sub-spectra may be re-ordered in the sequence
- Spectrum statistics at a glance
- Exceedance curve
- Sub-spectra tagging for future analysis
- Synchronized data views
- Spectrum level damage tagging

PropertiesWindow

A-Z

SubSpectrum

Name	Flight 2
Description	

Statistics

Number Of Levels	160
Number Of Cycles	215
Max	0.5505
Min	-0.1033

Tags

Humidity	100
Temperature	120

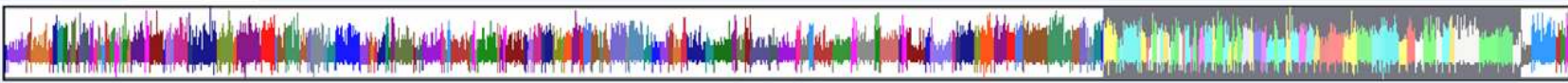
Name

Name of SubSpectrum

# Synchronized Views

Spectrum Manager - C:\Users\alex\Documents\Visual Studio 2010\Projects\AfgrowDevelopment\Targets\dfstaf.sp3

Edit Preview Spectrum View

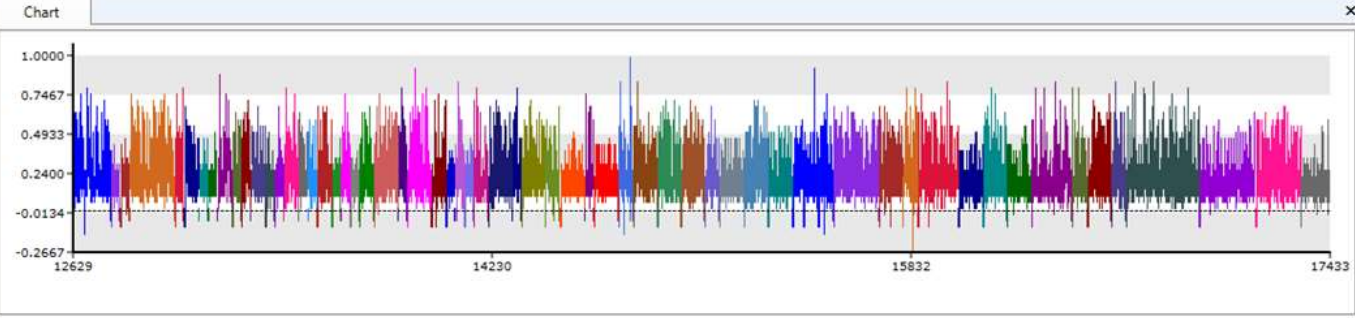


Spectrum Preview

#	cycle	Max	Min	Cycles	Sub Spectrum Name
10848	12629	0.2236	0.0193	1	Flight 136
10849	12630	0.3054	0.1419	1	Flight 136
10850	12631	0.6322	0.2645	1	Flight 136
10851	12632	0.4279	0.2236	1	Flight 136
10852	12633	0.4279	0.0602	1	Flight 136
10853	12634	0.1828	0.0602	2	Flight 136
10854	12636	0.2236	0.0602	1	Flight 136
10855	12637	0.3462	0.1828	1	Flight 136
10856	12628	0.2054	0.1011	1	Flight 136

SubSpectrums

Chart



PropertiesWindow

PropertiesWindow

^ Spectrum

Title	Falstaff
SubSpectrum Lab	Flight
Description	
Hours Per Pass	1

^ Statistics

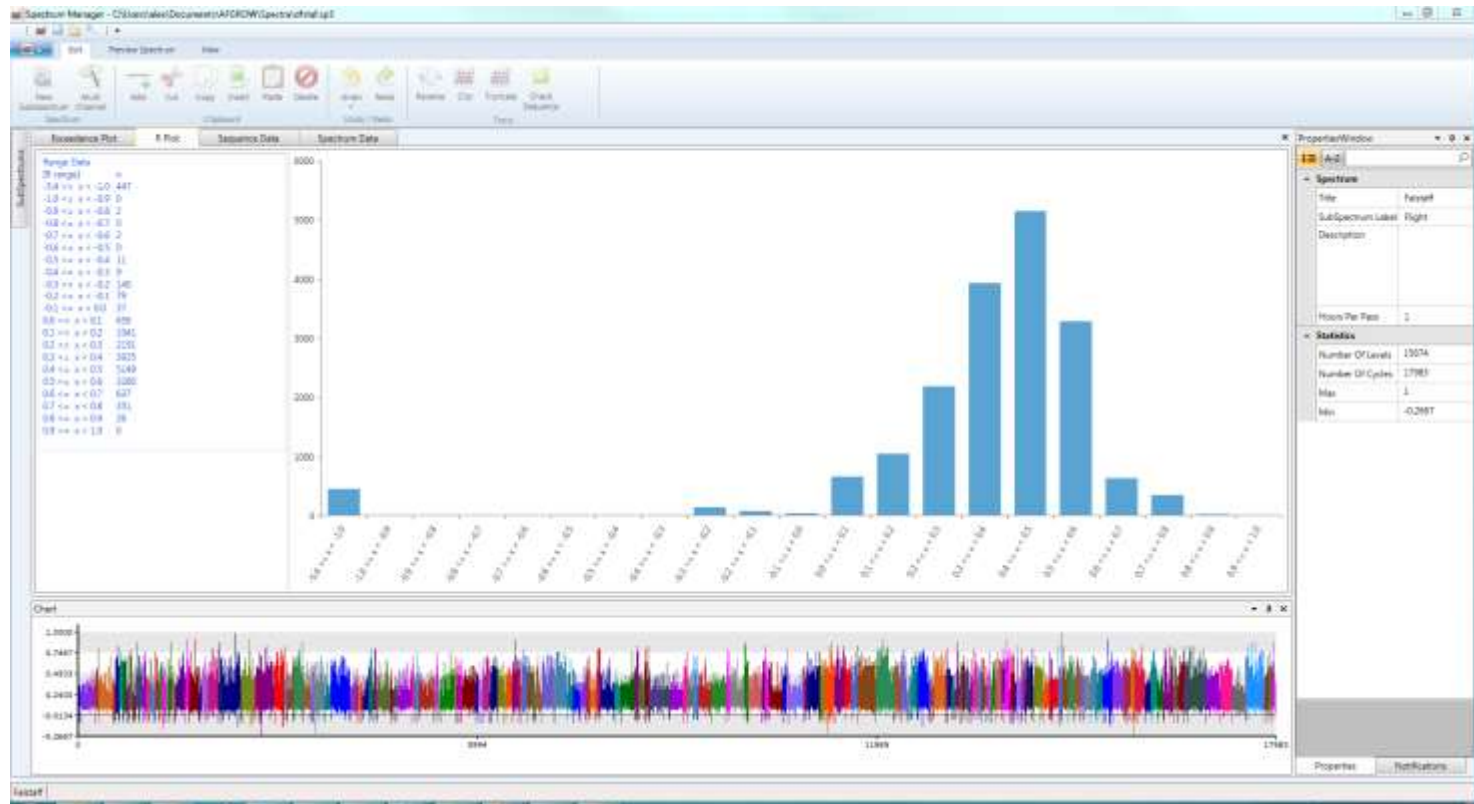
Number Of Level	15674
Number Of Cycle	17983
Max	1
Min	-0.2667

Properties Errors

Falstaff



# Stress Ratio Distribution Plot



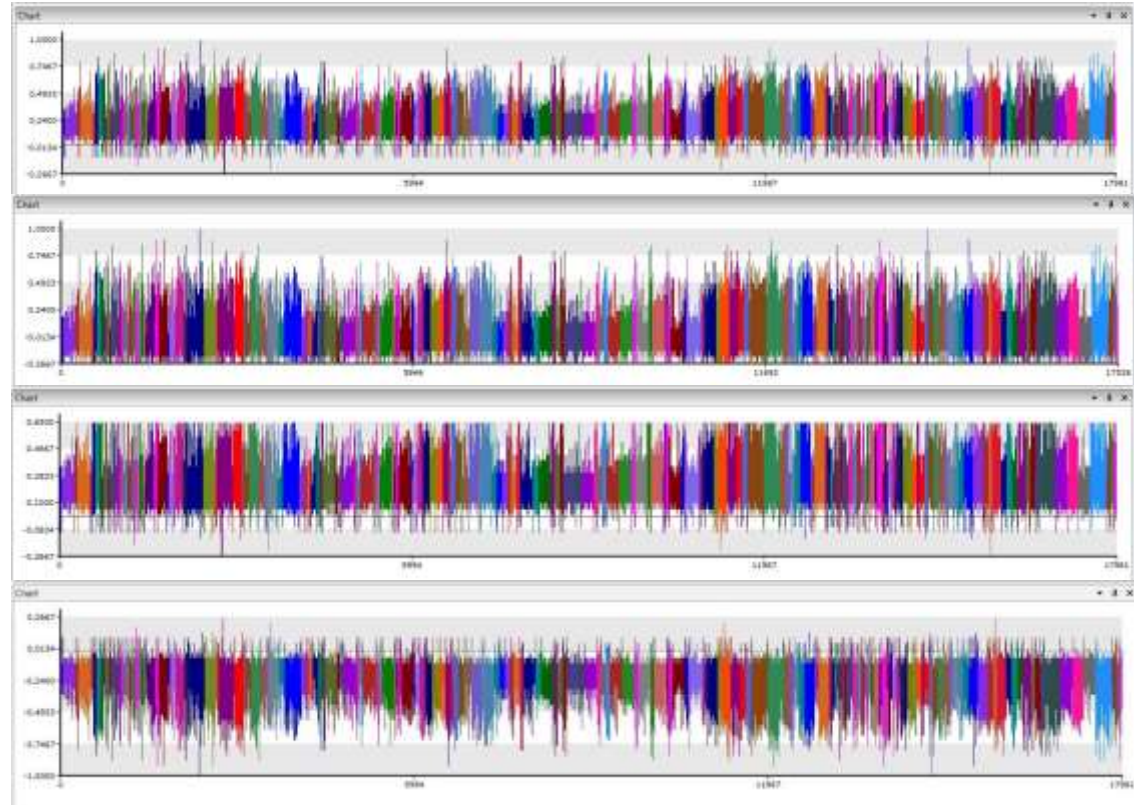


# Spectrum Manipulation

Truncation

Clipping

Reversing



# Stress Ratio Distribution Plot



# Beyond Release 5.3

- 2-D weight functions
- Corrosion effects and the  $d(\text{geometry change})/dt$  model
- MSD

# Acknowledgement

- A-10 and T-38 Structural Integrity and Analysis Group
- SAFE Inc.
- Analytical Processes / Engineered Solutions
- NRC (compounding solution for two cracks under bearing load)
- AFGROW Customers and Consortium Members