

AFGROW Workshop 2012

AFGROW Release 5.2

Alex Litvinov, James Harter,
LexTech, Inc

New Release

- Extended Advanced Model Solution for Corner Cracks at a Hole to Handle Small Cracks – 100%
- Updated Solution for a Single Through Crack at a Hole Under Bearing Load – 100%
- Improved Offset Correction for Cracks at Holes Under Bearing Load – 100%
- Multi-Channel Spectrum Format – 75%
- Spectrum Tool – 90%
- Warning Messages When K-Solution Limits are Exceeded – 50%
- ~~• Ability to Replicate Results From Previous Versions (back to Version 5.01)~~
- Expanded Input Table Size (virtually unlimited) – 75%
- ~~• Option to Save Input File With Retardation State Data for Later Restart~~
- Improved COM and Plug-In Interface – 75%
- New GUI – 95%
- Corner Crack at a Countersunk Hole Solution – 90%
- Beta Sub-R – 100%
- Complete Beta Correction Capability for Advanced Models – 60%
- Fix known bugs – 80%
- Create new AFGROW installation

NEW GUI

The screenshot displays the AFGROW software interface with the following components:

- Menu Bar:** File, Input, Edit, View, Predict, Tools, Repair, Initiation, Window, Help
- Tree View (Left):**
 - Example Problem
 - Specimen
 - 2024 T-3 Bare Sheet LONG CRACK DATA (Harter T-method)
 - Stress State
 - Spectrum
 - No Spectrum Filters
 - No Retardation
 - No K-Solution Filters
 - No Residual Stresses
- Specimen View (Center):** A 2D schematic of a rectangular specimen with a central crack and loading points.
- Properties Panel (Right):**
 - Specimen**
 - Appearance: (Name) Specimen
 - Size: Width 4.000000, Thickness 0.250000
 - Load: Axial 1.000000, Bending 0.000000, Bearing 0.000000
 - Solution: -
- Output Window (Bottom):**

```

Crack #1
Left Tip C= 0.11072 Beta Tension=1.4760 Beta Compression=1.4760 R(k)= 0.0000 R(final)= 0.0000
Right Tip C= 0.11072 Beta Tension=1.4760 Beta Compression=1.4760 R(k)= 0.0000 R(final)= 0.0000
Left Tip A= 0.22901 Beta Tension=1.0956 Beta Compression=1.0956 R(k)= 0.0000 R(final)= 0.0000
Right Tip A= 0.22901 Beta Tension=1.0956 Beta Compression=1.0956 R(k)= 0.0000 R(final)= 0.0000
Max stress 14.000, r = 0.00, 21600 Cycles, Constant amp.: 217, Pass: 217
Delta k=1.2188e+001 D()/DN=5.8241e-006
Delta k=1.2188e+001 D()/DN=5.8241e-006
Delta k=1.3010e+001 D()/DN=7.0812e-006
Delta k=1.3010e+001 D()/DN=7.0812e-006

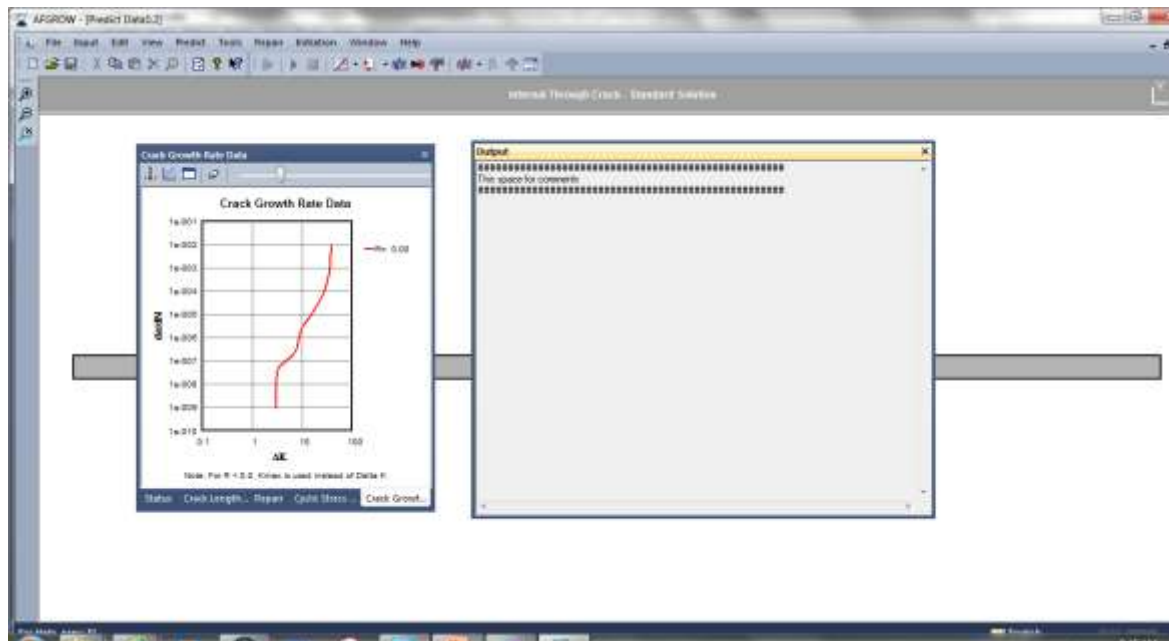
Crack #1
Left Tip C= 0.1113 Beta Tension=1.4760 Beta Compression=1.4760 R(k)= 0.0000 R(final)= 0.0000
Right Tip C= 0.1113 Beta Tension=1.4760 Beta Compression=1.4760 R(k)= 0.0000 R(final)= 0.0000
Left Tip A= 0.22371 Beta Tension=1.0956 Beta Compression=1.0956 R(k)= 0.0000 R(final)= 0.0000
Right Tip A= 0.22371 Beta Tension=1.0956 Beta Compression=1.0956 R(k)= 0.0000 R(final)= 0.0000
Max stress 14.000, r = 0.00, 21700 Cycles, Constant amp.: 218, Pass: 218
Delta k=1.2220e+001 D()/DN=5.8700e-006
Delta k=1.2220e+001 D()/DN=5.8700e-006
Delta k=1.3030e+001 D()/DN=7.1140e-006
Delta k=1.3030e+001 D()/DN=7.1140e-006

```

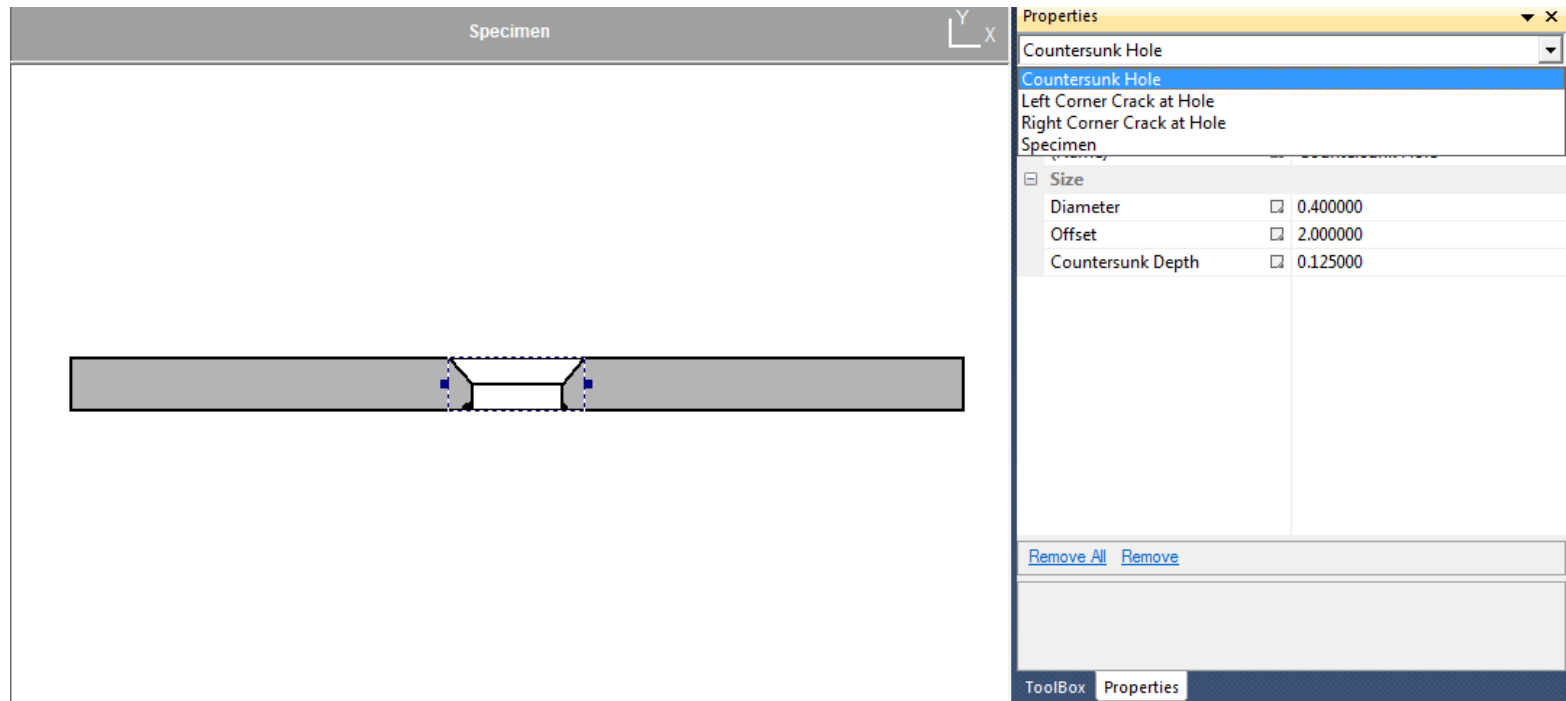
Output Frame – Copy and Paste



Floating Dockable Views



Advanced Model – Switch Objects

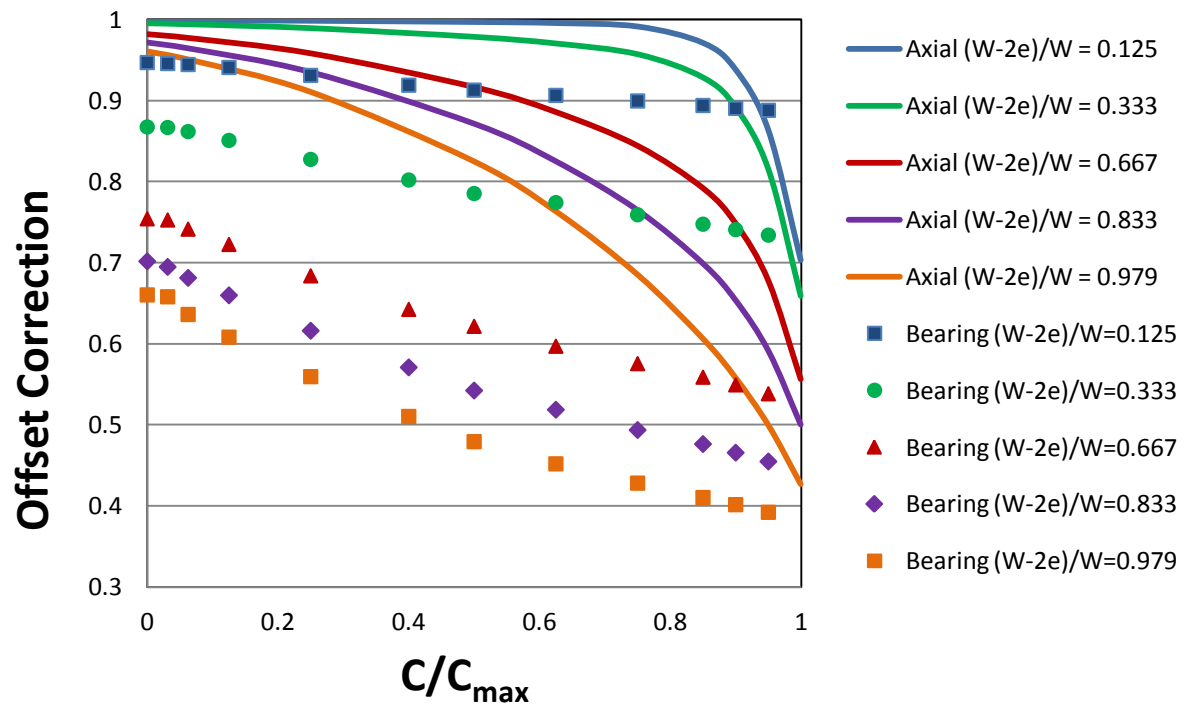
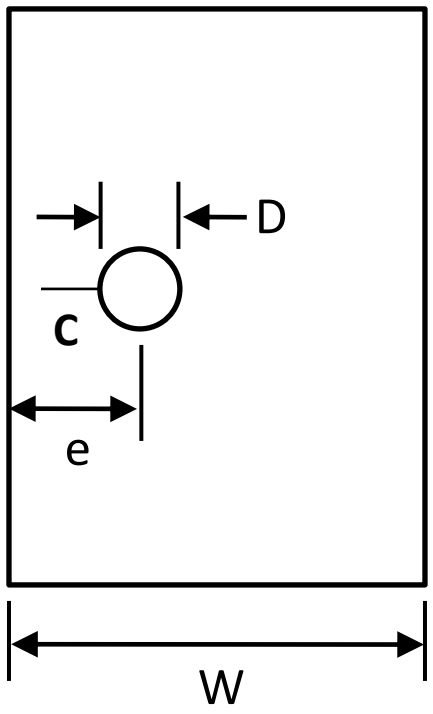


The screenshot displays a CAD application window titled "Specimen". The main view shows a 3D model of a cylindrical specimen with a countersunk hole. The hole is highlighted with a blue dashed outline. To the right, a "Properties" panel is open, showing the selected object is a "Countersunk Hole". The panel lists several properties, including "Size", "Diameter", "Offset", and "Countersunk Depth".

Size	
Diameter	<input checked="" type="checkbox"/> 0.400000
Offset	<input checked="" type="checkbox"/> 2.000000
Countersunk Depth	<input checked="" type="checkbox"/> 0.125000

At the bottom of the properties panel, there are two buttons: "Remove All" and "Remove". The bottom status bar of the application shows "ToolBox" and "Properties".

New Offset Hole Solution Bearing Load Case



Solution Matrix

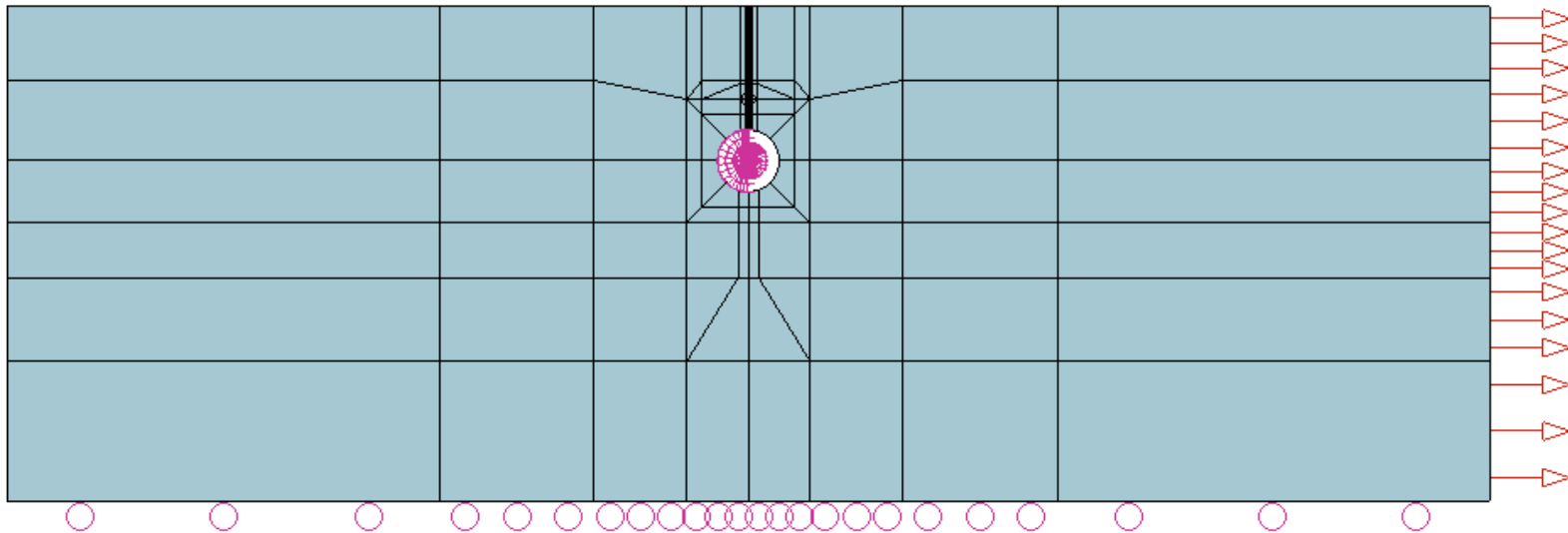
e/D : 0.75, 1, 2, 4, 8, 16

$(W-2e)/W$: 0.125, 0.25, 0.333, 0.667, 0.833,
0.918, 0.958, 0.979

C/C_{\max} : 0 to 0.95

Note: The zero crack length correction was determined by the ratio of the local K_T values

FEM* Boundary Conditions



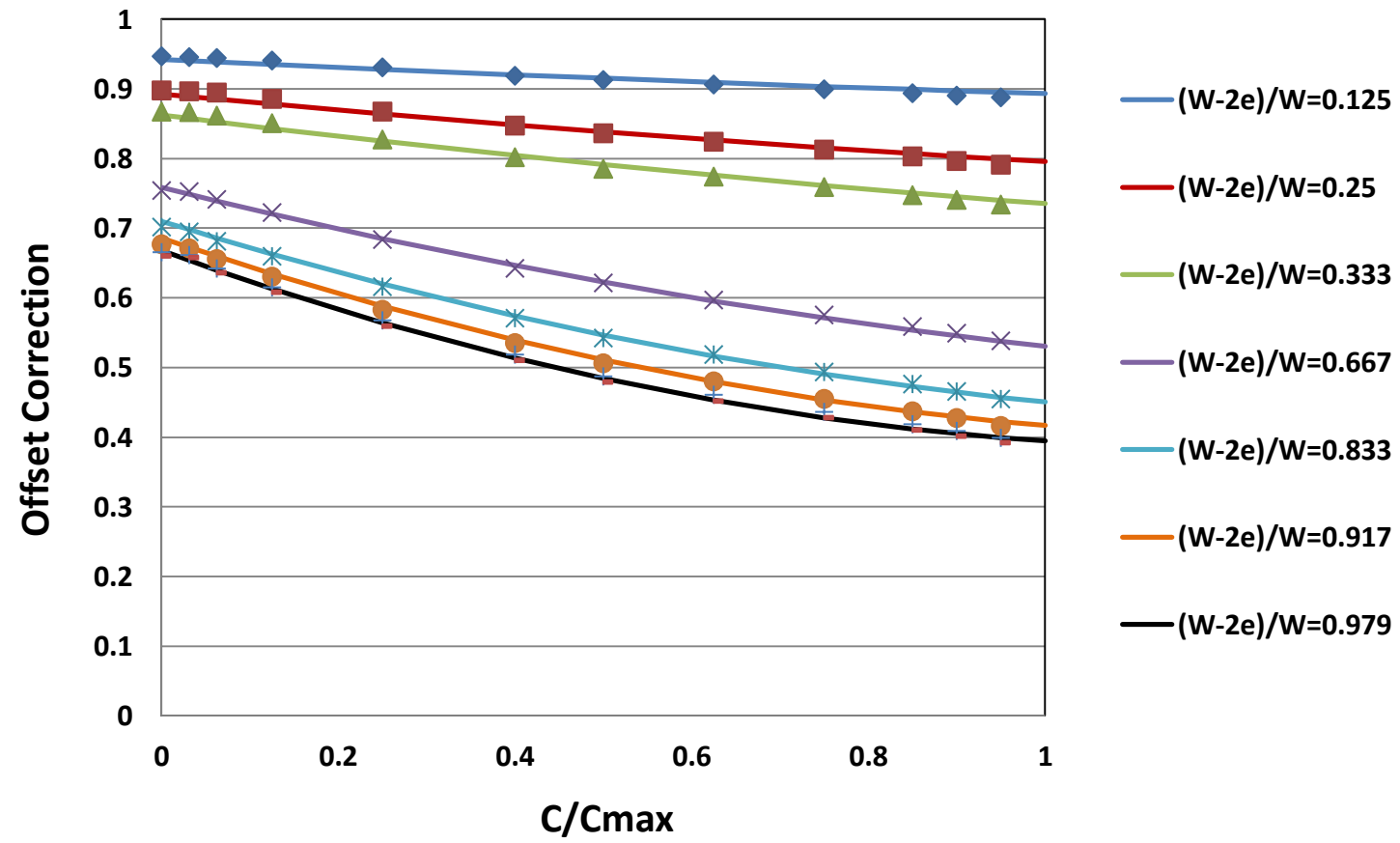
Model Thickness = 1.0

Loading to produce a unit resultant force at the hole ($1/W$)

Spring ($E_{\text{Spring}} = 3X E_{\text{Plate}}$) B.C. along $\frac{1}{2}$ hole

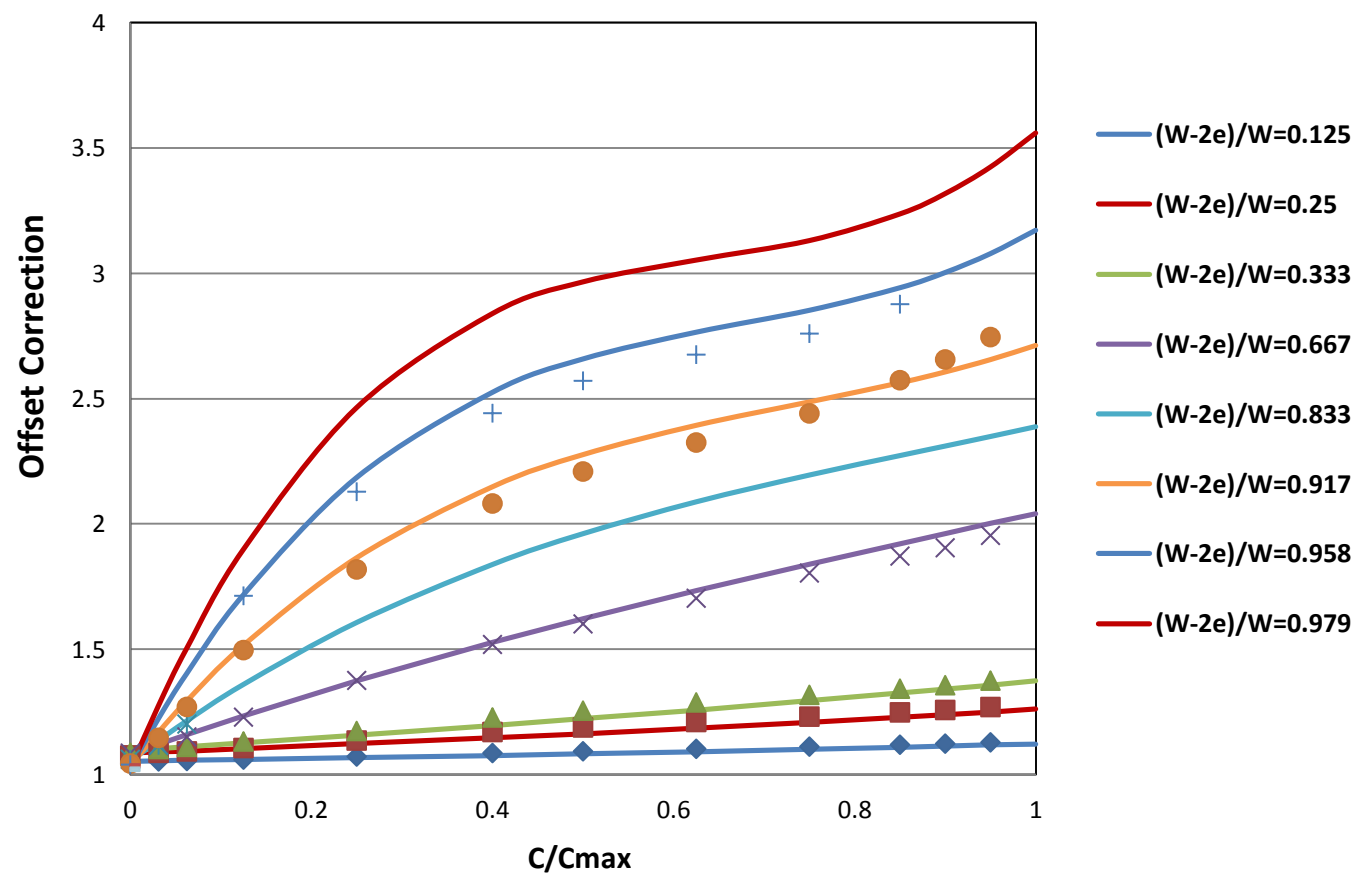
Near Edge Offset Correction

$e/D = 2$



Far Edge Offset Correction

$e/D = 2$



Advanced Model Solution Approach for Small Cracks ($a/t < 0.1$)



- Single Corner at a Hole



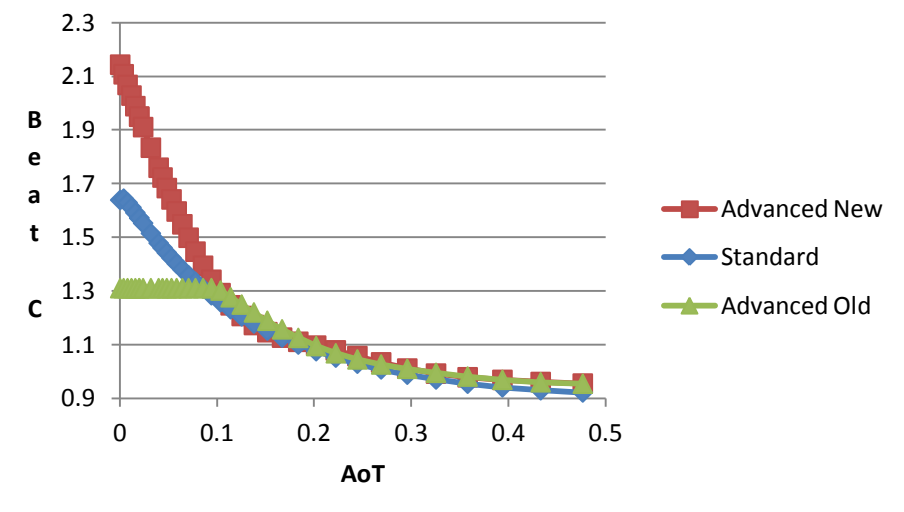
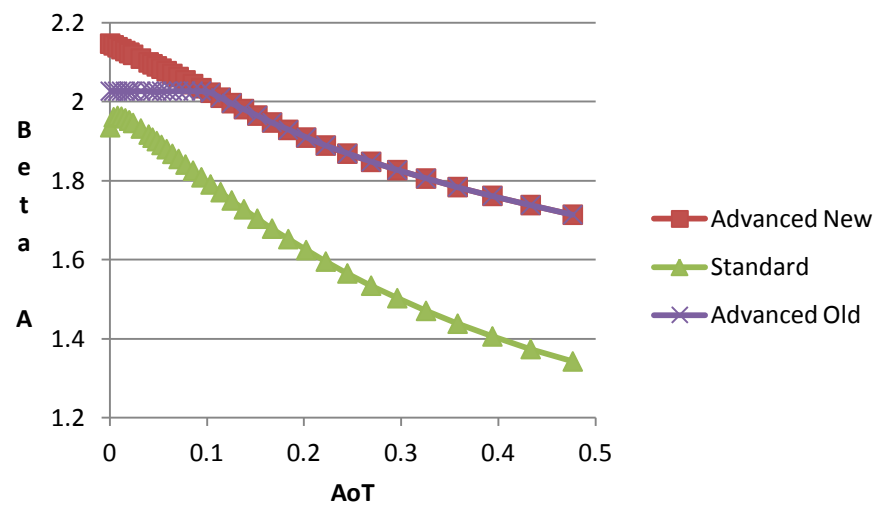
- Double Corner at a Hole

As the crack length goes to zero, the beta for both crack growth directions converge to :

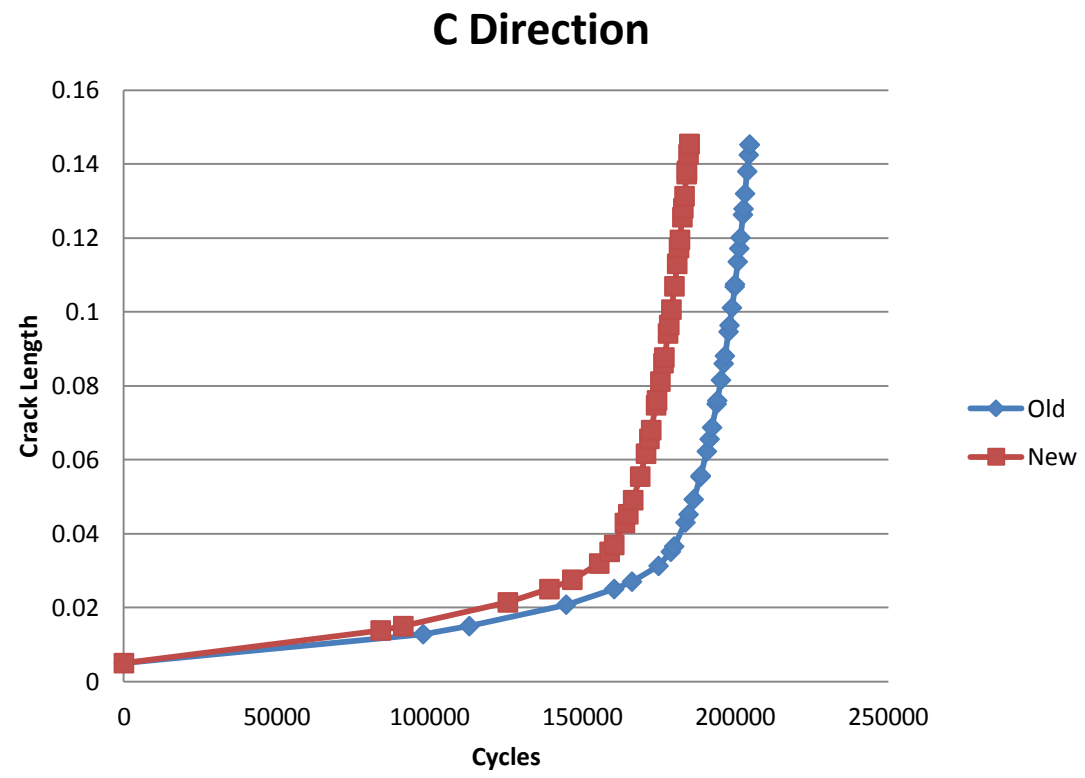
$$\beta = 1.122 K_t \frac{2}{\pi}$$

Tension and Bending = 2.142, Bearing = 0.625 (W/D = 100, same as Fawaz/Andersen)

Advanced Corner Cracked Hole Model (Small Crack Beta Values)



Advanced Corner Cracked Hole Model (Small Crack Life Comparison)



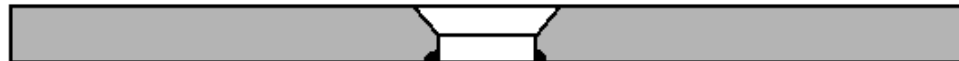
Countersunk Hole Solution

- Base on PHD thesis of the Reinier de Rijck
- Bending, Tension ad Bearing Solutions for the symmetric corner crack

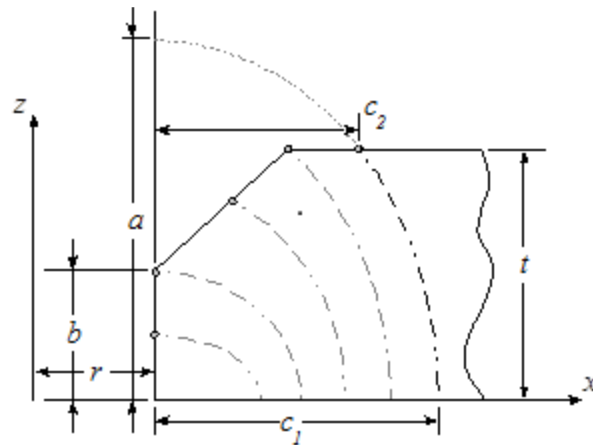
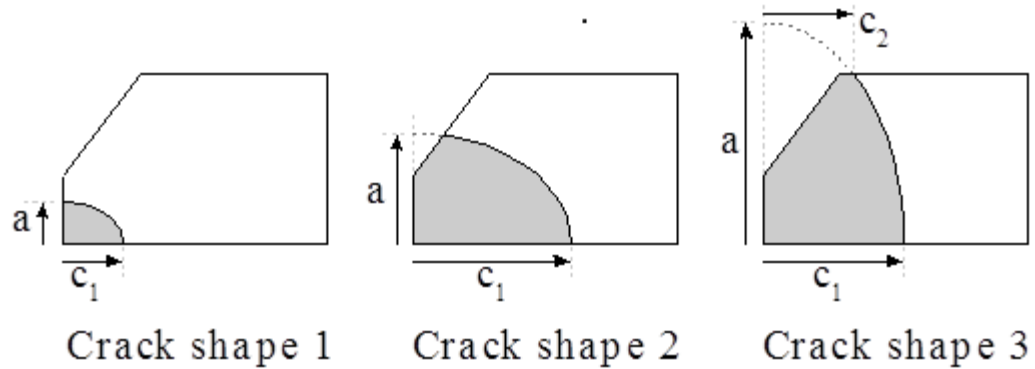
- Centered or offset hole with single corner crack



- Centered hole with symmetric double corner crack



Countersink Dimensions



Countersunk Solution Workspace

Countersink Angle – 100 Degrees

Depth to Thickness Ratios (B/T)

0.05, 0.25, 0.5

Virtual Crack Depth to Thickness Ratios (A/T)

0.025, 0.0294467, 0.0333167, 0.0371867, 0.0410568, 0.0449268, 0.05,
0.149025, 0.24687, 0.344714, 0.442559, 0.540403, 0.646563, 0.752822,
0.849658, 0.946494, 1.04333, 1.14017, 1.25287, 1.47261, 1.6767, 1.8808,
2.0849, 2.28899, 2.50574

Crack Depth to Crack Length Ratios (A/C)

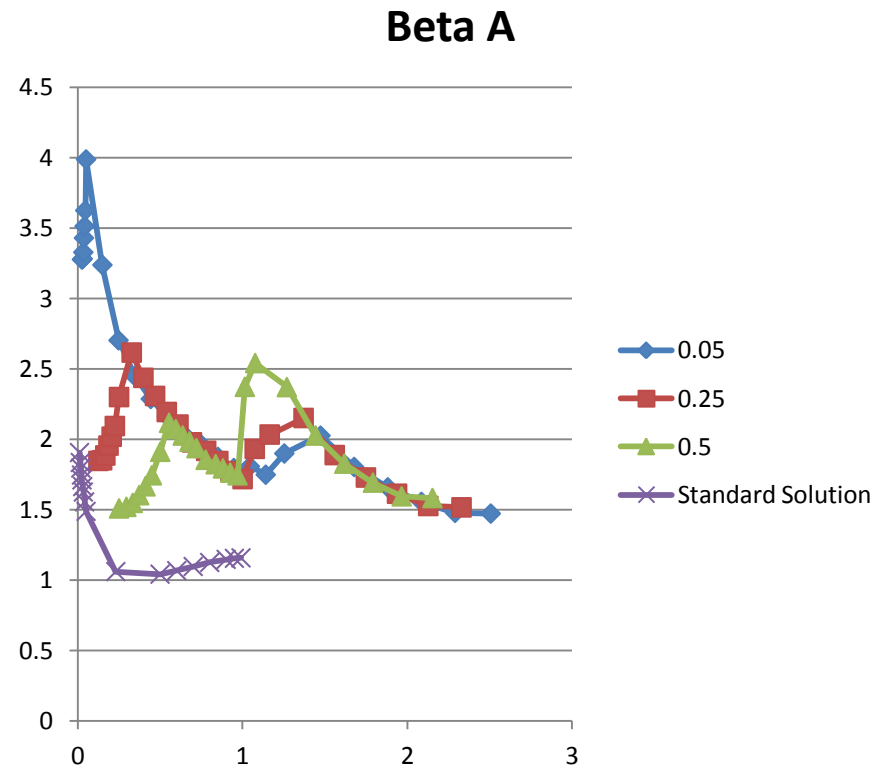
0.5, 0.67, 0.75, 1., 1.5, 2., 5.

Hole Radius to Thickness Ratios (R/T)

0.1, 0.25, 0.5, 0.67, 1.0, 1.2, 1.5, 2.0, 2.4

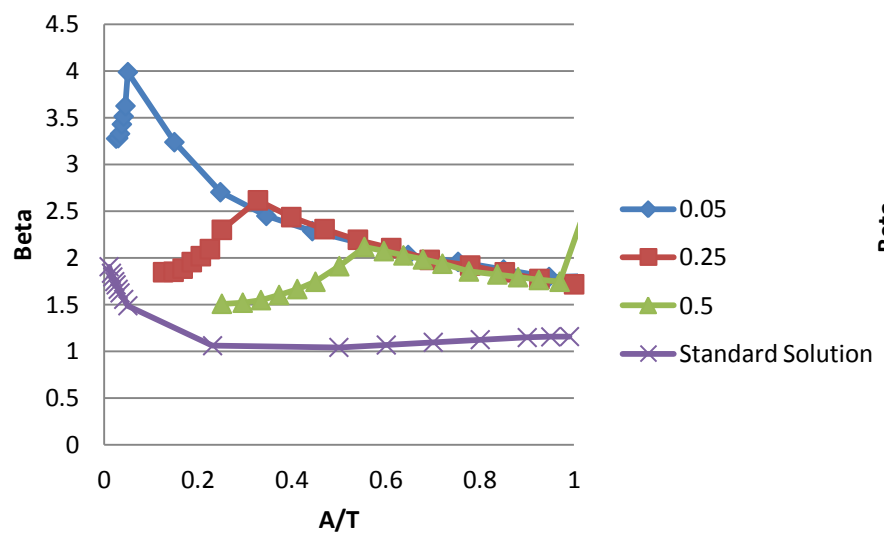
Countersunk Hole Transitions

- Through the knuckle
- To an oblique crack
- To a through crack

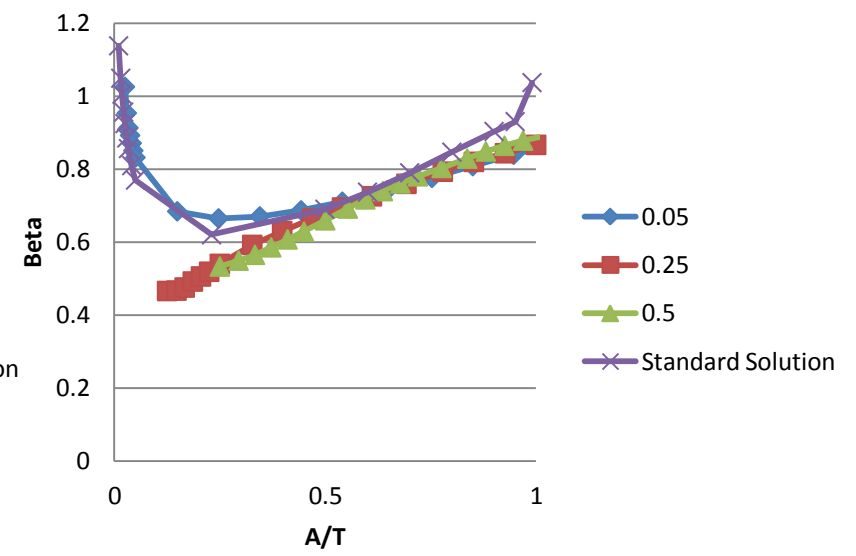


Countersunk Solution Betas

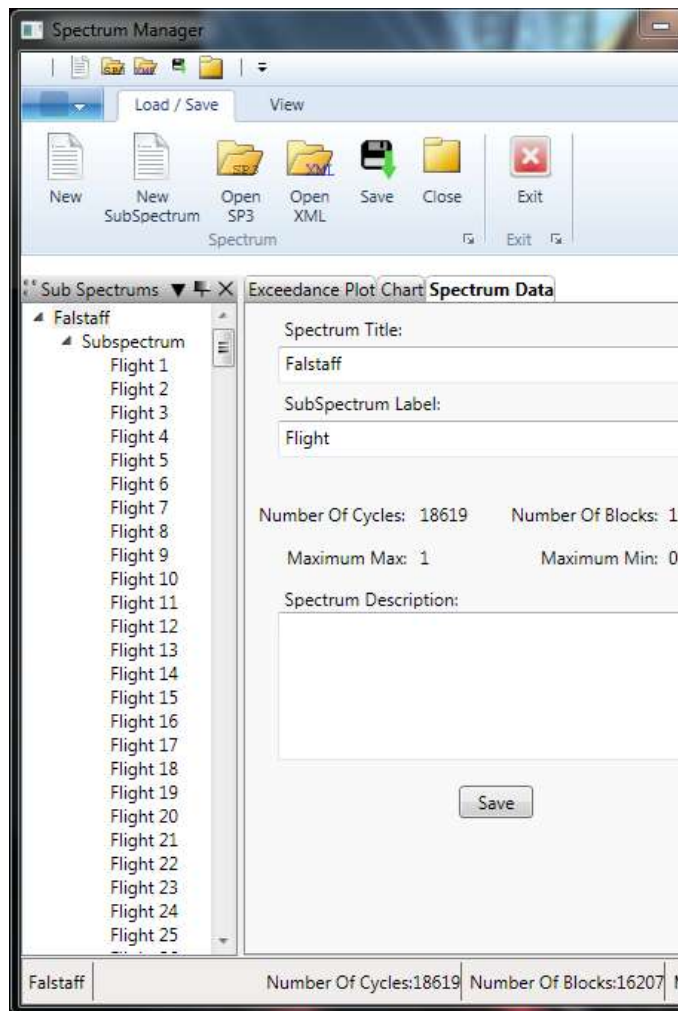
Beta A



Beta C



Spectrum Tool



Spectrum Manager

Load / Save View

New New SubSpectrum Open SP3 Open XML Save Close Exit

Sub Spectrums

- Falstaff
 - SubSpectrum
 - Flight 1
 - Flight 2
 - Flight 3
 - Flight 4
 - Flight 5
 - Flight 6
 - Flight 7
 - Flight 8
 - Flight 9
 - Flight 10
 - Flight 11
 - Flight 12
 - Flight 13
 - Flight 14
 - Flight 15
 - Flight 16
 - Flight 17
 - Flight 18
 - Flight 19
 - Flight 20
 - Flight 21
 - Flight 22
 - Flight 23
 - Flight 24
 - Flight 25

Exceedance Plot Chart Spectrum Data

Spectrum Title: Falstaff

SubSpectrum Label: Flight

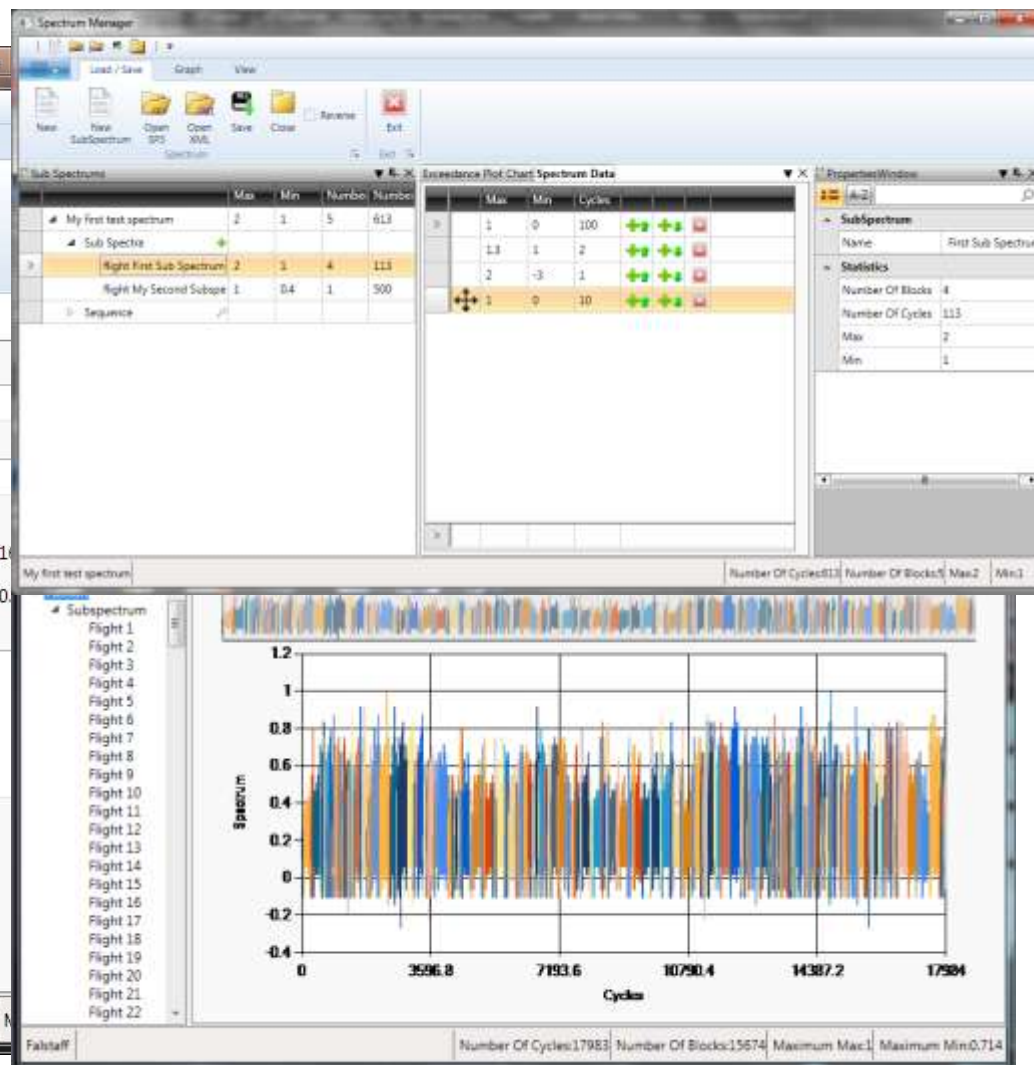
Number Of Cycles: 18619 Number Of Blocks: 16207

Maximum Max: 1 Maximum Min: 0.714

Spectrum Description:

Save

Falstaff Number Of Cycles:18619 Number Of Blocks:16207



Spectrum Manager

Load / Save Graph View

New New SubSpectrum Open SP3 Open XML Save Close Reverse Exit

Sub Spectrums	Max	Min	Number	Number
My first test spectrum	2	1	5	613
Sub Spectra				
Flight First Sub Spectrum	2	1	4	113
Flight My Second Subspe	1	0.4	1	300
Sequence				

Exceedance Plot Chart Spectrum Data	Max	Min	Cycles
1	0	100	
1.3	1	2	
2	-3	1	
1	0	10	

My first test spectrum

Number Of Cycles:613 Number Of Blocks:Max:2 Min:1

SubSpectrum

Name: First Sub Spectrum

Statistics

Number Of Blocks: 4

Number Of Cycles: 113

Max: 2

Min: 1

Falstaff

Number Of Cycles:17983 Number Of Blocks:15674 Maximum Max:1 Maximum Min:0.714

Spectrum

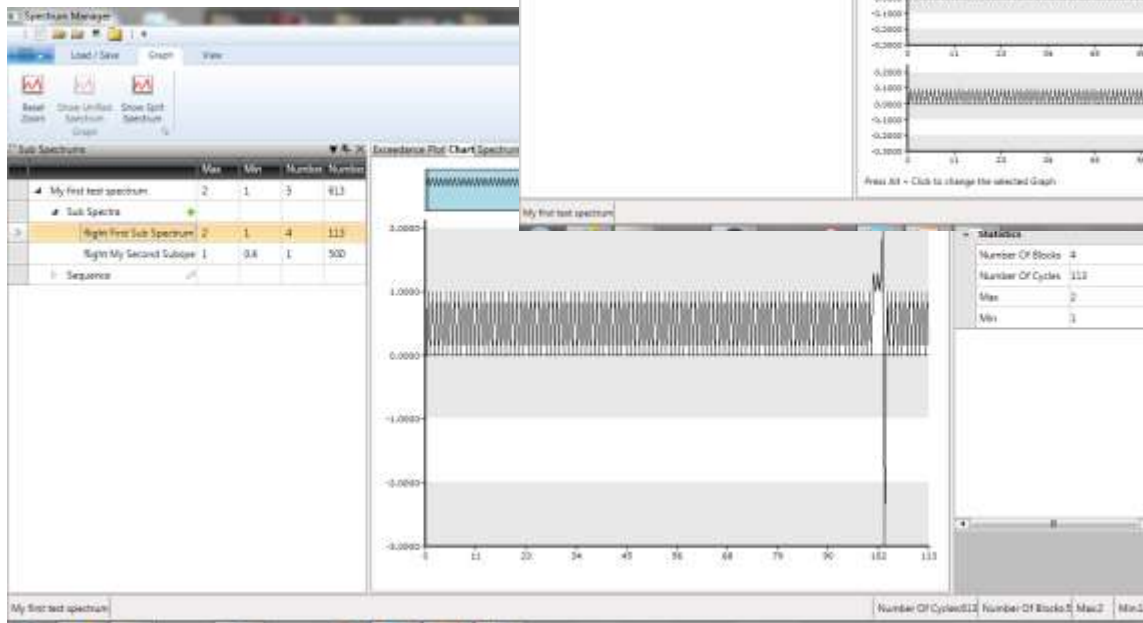
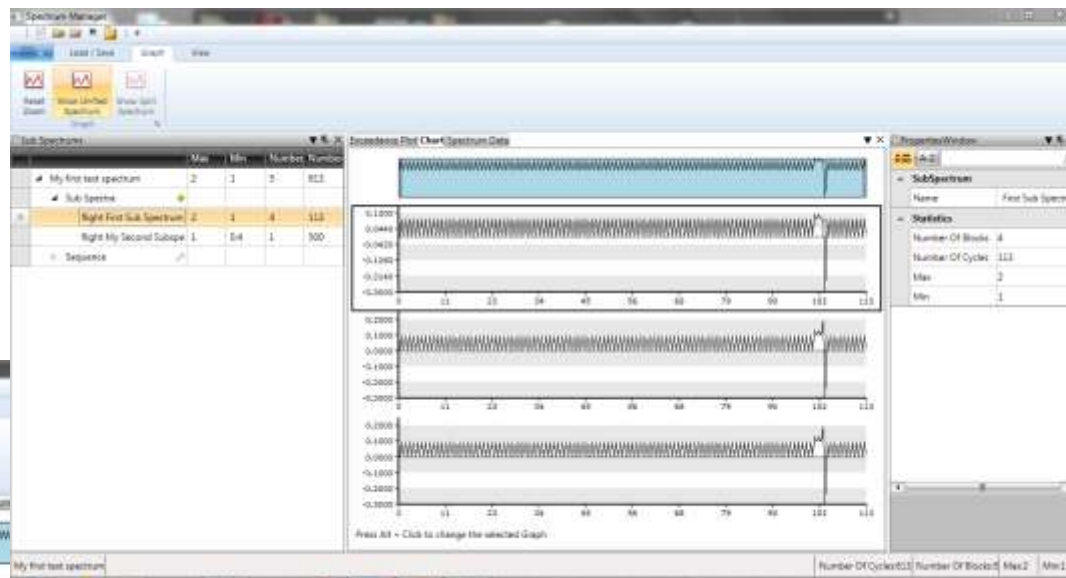
Cycles

0 3596.8 7193.6 10790.4 14387.2 17984

Spectrum Tool

Single or Multi Channel Loading:

- Axial
- Bending
- Bearing



Spectrum Tool

- Visual spectrum design
- Spectrum Statistics at a glance
- Clipping
- Truncation
- Spectrum reversal (flip Min with Max, requested by Northrop)
- Spectrum level reordering
- Copy-Paste from Excel
- Sub spectra re-ordering
- Plug-able architecture – will help handling /convert different spectrum formats

Crack Closure Factor

- Why do we have it?
- Applied only on a crack at the open edge surface
- Added to standard, user defined, advanced and plug-in k solutions

$$K = \beta_r * \sigma \sqrt{Length * \pi} * \beta$$

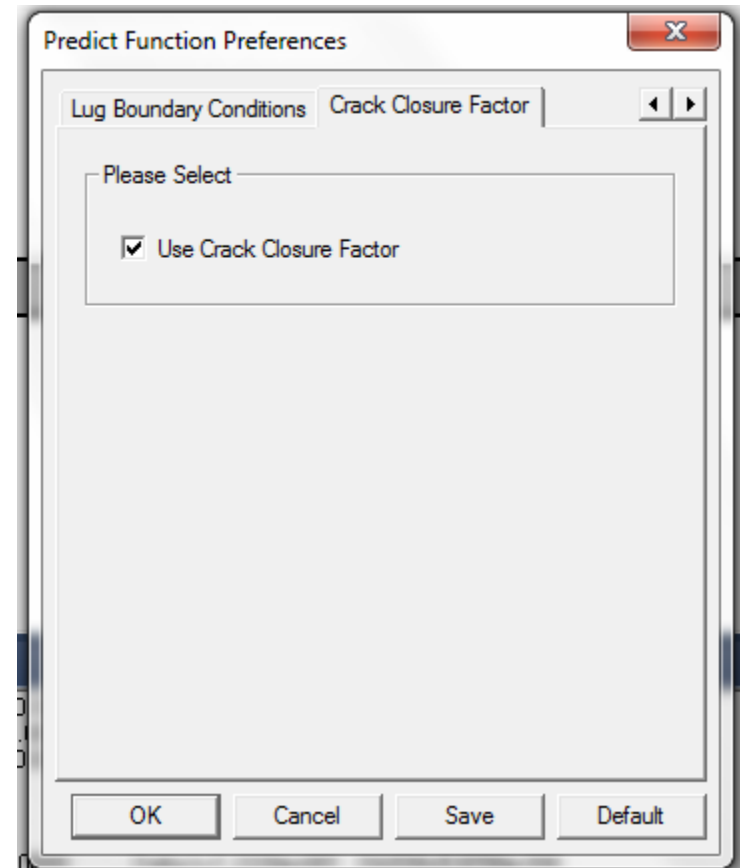
if $R = 0$

then

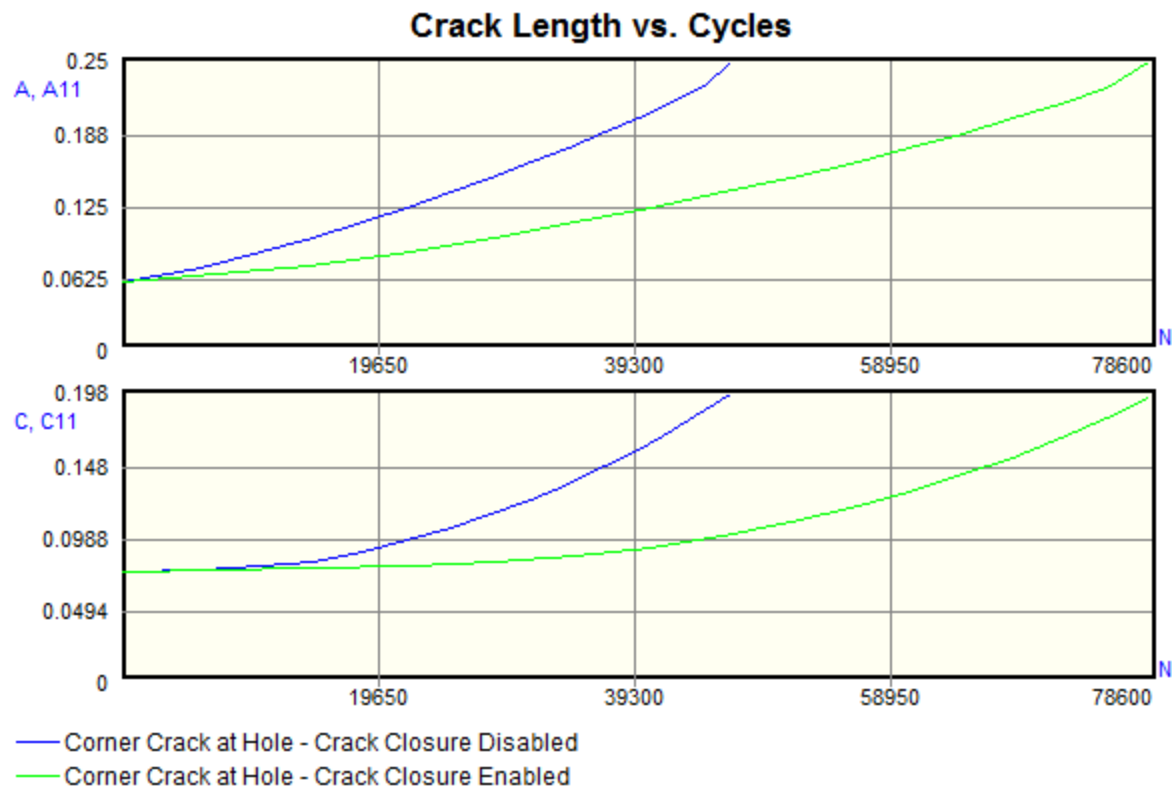
$$\beta_r = 0.9$$

else

$$\beta_r = 0.9 + 0.2 * R^2 - 0.1 R^4$$



Crack Closure Factor



COM and Plug-in API changes

- Add FileName Property to the plug-in API
- Add option to get access to the COM Automation API from plugin API
- Add ability to set NASGRO model parameters through the COM API
- Add ability to display a bitmap in the AFROW plot window using plugin API
- Add ability to do not place exclusive lock on the data data files

Customers

Advanced Technologies Incorporated
Air Force Research Laboratory
Air Spray Aviation Services
Airwork
Airworks
Altep
Australian Aerospace
Australian Department of Defense
Bell Helicopter
Caterpillar Inc.
Cessna
Circor Aerospace
Create
DART Aerospace
Delta Engineering
European Science Foundation
Honda Aerospace
Gulfstream
Italian Air Force
Instytut Techniczny Wojsk Lotniczych /ITWL
ITT
Institute for Materials Applications in Mechanical Engineering
Japan Aerospace Exploration Agency
Kalitta Air, LLC
L-3
Live TV
Lockheed Martin
Marshall Aerospace
Micro Craft, Inc.
MIT
Mitre
NASA
Naval Academy
Northrop Grumman
NRC Institute for Aerospace Research
NTSB
Ogden Air Logistics Center
PACS Engineering
P.B. Engineering Inc.
Pilatus Aircraft Ltd
Precision Engineering LLC
Raytheon
SAFE, Inc.
SwRI
TanBeräkning AB
Tenaris
Tcagi
Textron India
Triumph Group, Inc
TUI Airlines
United States Air Force Academy
University of Ulsan
The University of Utah
Virginia Tech
VZLU - Aeronautical Research & Test Institute
Western Avionics

Questions