

AFGROW Workshop 2011 - Layton, UT

# Using the New Multi-Channel Spectrum Format

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# Current AFGROW Spectrum

To date, AFGROW has used a single channel load spectrum. Because of this limitation, K-solutions for combined loading (axial, bending, and bearing) are limited by the assumption that fractional components of each load case are constant.

# Why Change?

- Several AFGROW Users have expressed an interest in the ability to input independent loading spectra for axial, bending, and bearing loads
- As we move toward a 3-D capability, it will be important to be able to manage applied loading in more than one direction

# Current K Calculation

$$\begin{aligned}\mathbf{Alpha}_{tension} &= \mathbf{Alpha}_{axial} * \mathbf{AxialTensionModifier} + \\ &\quad \mathbf{Alpha}_{bending} * \mathbf{BendingTensionModifier} + \mathbf{Alpha}_{bearing} * \mathbf{BearingTensionModifier} \\ \mathbf{Alpha}_{compression} &= \mathbf{Alpha}_{axial} * \mathbf{AxialCompressionModifier} + \\ &\quad \mathbf{Alpha}_{bending} * \mathbf{BendingCompressionModifier} + \mathbf{Alpha}_{bearing} * \mathbf{BearingCompressionModifier}\end{aligned}$$

$$\begin{aligned}\mathbf{Beta}_{tension} &= (\mathbf{Alpha}_{tension} * \mathbf{Beta}_{Correction}) / \text{sqrt}(\text{Pi} * \text{Crack Length}) \\ \mathbf{Beta}_{compression} &= (\mathbf{Alpha}_{compression} * \mathbf{Beta}_{Correction}) / \text{sqrt}(\text{Pi} * \text{Crack Length})\end{aligned}$$

$$\begin{aligned}\mathbf{K}_{max} &= \text{Stress}_{Max} * \text{sqrt}(\text{Pi} * \text{Crack Length}) * ((\text{Stress}_{Max} \geq 0) ? \mathbf{Beta}_{tension} : \mathbf{Beta}_{compression}) \\ \mathbf{K}_{min} &= \text{Stress}_{Min} * \text{sqrt}(\text{Pi} * \text{Crack Length}) * ((\text{Stress}_{Min} \geq 0) ? \mathbf{Beta}_{tension} : \mathbf{Beta}_{compression})\end{aligned}$$

$$\begin{aligned}\mathbf{K}_{max} &= \mathbf{K}_{max} + \mathbf{K}_{res} \\ \mathbf{K}_{min} &= \mathbf{K}_{min} + \mathbf{K}_{res}\end{aligned}$$

# Proposed K Calculation - Alpha

$$\mathbf{Alpha}_{axial-tension} = \mathbf{Alpha}_{axial} * \mathbf{AxialTensionModifier}$$

$$\mathbf{Alpha}_{bending-tension} = \mathbf{Alpha}_{bending} * \mathbf{BendingTensionModifier}$$

$$\mathbf{Alpha}_{bearing-tension} = \mathbf{Alpha}_{bearing} * \mathbf{BearingTensionModifier}$$

$$\mathbf{Alpha}_{axial-compression} = \mathbf{Alpha}_{axial} * \mathbf{AxialCompressionModifier}$$

$$\mathbf{Alpha}_{bending-compression} = \mathbf{Alpha}_{bending} * \mathbf{BendingCompressionModifier}$$

$$\mathbf{Alpha}_{axial-compression} = \mathbf{Alpha}_{bearing} * \mathbf{BearingCompressionModifier}$$

$$\mathbf{Beta}_{axial-tension} = (\mathbf{Alpha}_{axial-tension} * \mathbf{Beta}_{Correction}) / \text{sqrt}(\text{Pi} * \text{Crack Length})$$

$$\mathbf{Beta}_{bending-tension} = (\mathbf{Alpha}_{bending-tension} * \mathbf{Beta}_{Correction}) / \text{sqrt}(\text{Pi} * \text{Crack Length})$$

$$\mathbf{Beta}_{bearing-tension} = (\mathbf{Alpha}_{bearing-tension} * \mathbf{Beta}_{Correction}) / \text{sqrt}(\text{Pi} * \text{Crack Length})$$

$$\mathbf{Beta}_{axial-compression} = (\mathbf{Alpha}_{axial-compression} * \mathbf{Beta}_{Correction}) / \text{sqrt}(\text{Pi} * \text{Crack Length})$$

$$\mathbf{Beta}_{bending-compression} = (\mathbf{Alpha}_{bending-compression} * \mathbf{Beta}_{Correction}) / \text{sqrt}(\text{Pi} * \text{Crack Length})$$

$$\mathbf{Beta}_{bearing-compression} = (\mathbf{Alpha}_{bearing-compression} * \mathbf{Beta}_{Correction}) / \text{sqrt}(\text{Pi} * \text{Crack Length})$$

# Proposed K Calculation - Beta

$$\begin{aligned}
 K_{\text{max-axial}} &= \text{Stress}_{\text{Max-axial}} * \text{sqrt}(\text{Pi} * \text{Crack Length}) * ((\text{Stress}_{\text{Max-axial}} \geq 0)? \text{Beta}_{\text{axial-tension}} : \text{Beta}_{\text{axial-compression}}) \\
 K_{\text{min-axial}} &= \text{Stress}_{\text{Min-axial}} * \text{sqrt}(\text{Pi} * \text{Crack Length}) * ((\text{Stress}_{\text{Min-axial}} \geq 0)? \text{Beta}_{\text{axial-tension}} : \text{Beta}_{\text{axial-compression}}) \\
 K_{\text{max-bending}} &= \text{Stress}_{\text{Max-bending}} * \text{sqrt}(\text{Pi} * \text{Crack Length}) * ((\text{Stress}_{\text{Max-bending}} \geq 0)? \text{Beta}_{\text{bending-tension}} : \text{Beta}_{\text{bending-compression}}) \\
 K_{\text{min-bending}} &= \text{Stress}_{\text{Min-bending}} * \text{sqrt}(\text{Pi} * \text{Crack Length}) * ((\text{Stress}_{\text{Min-bending}} \geq 0)? \text{Beta}_{\text{bending-tension}} : \text{Beta}_{\text{bending-compression}}) \\
 K_{\text{max-bearing}} &= \text{Stress}_{\text{Max-bearing}} * \text{sqrt}(\text{Pi} * \text{Crack Length}) * ((\text{Stress}_{\text{Max-bearing}} \geq 0)? \text{Beta}_{\text{bearing-tension}} : \text{Beta}_{\text{bearing-compression}}) \\
 K_{\text{min-bearing}} &= \text{Stress}_{\text{Min-bearing}} * \text{sqrt}(\text{Pi} * \text{Crack Length}) * ((\text{Stress}_{\text{Min-bearing}} \geq 0)? \text{Beta}_{\text{bearing-tension}} : \text{Beta}_{\text{bearing-compression}})
 \end{aligned}$$

$$\begin{aligned}
 K_{\text{max}} &= K_{\text{max-axial}} + K_{\text{max-bending}} + K_{\text{max-bearing}} \\
 K_{\text{min}} &= K_{\text{max-bearing}} + K_{\text{min-bending}} + K_{\text{min-bearing}}
 \end{aligned}$$

$$\begin{aligned}
 K_{\text{max}} &= K_{\text{max}} + K_{\text{res}} \\
 K_{\text{min}} &= K_{\text{min}} + K_{\text{res}}
 \end{aligned}$$

# New Spectrum Format Goals

- Forward Compatible – Can be added without breaking older versions
- Simple – Can be easily understood
- Can be created manually in notepad and similar text editors with relatively minor effort
- Can be easily created using programming tools
- Easy to post process by readily available data processing applications (i.e. Excel)
- Easy to edit - Modular

# XML Based New Spectrum Format

- XML was designed to transport and store data with a focus on the data
- Is the basis for a majority document formats today: MS Office for example
- Available software libraries – easy and fast development
- Familiar to software developers
- Easy to read
- Not as easy to create manually
- Tools exists that assist with XML file creation
- Powerful transformation pre and post processor library

# Current Spectrum Format

- Minimum of 2 files – **Information** and **SubSpectrum**
- Text base
- Very easy to create manually or programmatically

## Information

```
AFGROW Tutorial Sample Spectrum  
Block  
BLOCKED  
1
```

## SubSpectrum

```
1 2  
16.000000 0.000000 1  
12.000000 8.000000 1000
```

# Preliminary View of the New Spectrum Format

Header

```
1 <?xml version="1.0" encoding="utf-8"?>
2 <Spectrum xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:xsd="http://www.
  w3.org/2001/XMLSchema">
3   <Description />
4   <SubSpectrumLabel>Block</SubSpectrumLabel>
5   <Title>AFGROW Tutorial Sample Spectrum</Title>
6   <SubSpectra>
7     <SubSpectrum Name="1" Items="2">
8       <Block MinAxial="0" MaxAxial="16" MinBending="0" MaxBending="16" MinBearing="0"
  MaxBearing="16" Cycles="1" />
9       <Block MinAxial="8" MaxAxila="12" MinBending="8" MaxBending="12" MinBearing="8"
  MaxBearing="12" Cycles="1000" />
10    </SubSpectrum>
11  </SubSpectra>
12  <Sequences>
13    <Sequence Position="1" Name="1" />
14  </Sequences>
15 </Spectrum>
```

Sequence

Sub-Spectrum

# Spectrum Header

Title

Description

SubSpectrum Label

Time Dependent or Not

Hours Per Pass

Multi Channel or Not ???

# Sub Spectrum

Name

Description

Multi Channel or Not ???

Block 1

Block 2

...

# Level

MinAxial

MaxAxial

MinBearing

MaxBearing

MinBending

MaxBending

Cycles

Time

Cycle Shape

# New Spectrum Format Sequence

List of sub spectra by name in the order to be applied in the spectrum

- 1
- 1
- 1
- 1
- 3
- 4
- 5
- 5
- 6
- 1
- 2

# New Spectrum Format Application Support

- Afgrow: Open, View, Zoom, Exceedance curve
- New Spectrum Conversion Utility – Afgrow tool
- New Spectrum Design/Editing Application, – Separate, but still part of AFGROW in terms of licensing
- Old AFGROW spectrum creation Wizard will be removed

# New Spectrum Design/Edit Application Capabilities

- Visual representation of spectrum, sub-spectra
- Editing spectrum in the spreadsheet like control
- Editing Sequence using Drag and Drop
- Clipping
- Truncation
- Spectrum generation – from Exceedance Data
- Randomization

# Future Development

- Out of phase spectrum?
- Cycle counting - Jim's Cycle counting app?,
- Any other suggestions?

# Summary

- Afgrow will have Multi-channel spectrum support in the next release
- New spectrum format development has been completed
- A new spectrum tool will be created
- Afgrow will support old spectrum format initially, but we hope to transition everyone to the new format