Current K-Solution Issues

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Out-of-Plane Bending Solutions for Through-the-Thickness Cracks

For the AFGROW Classic model interface, the only through crack models with out-of plane bending capability include:

Single/Double Thru-Crack at a Hole
Pipe
Rod

Solutions for the pipe and rod were available in the literature, but no closed-form solution is known to be available for a straight through crack in a plate. The through crack solution uses a conservative assumption that applies 2/3 of the axial solution to approximate the solution for out-of-plane bending

Why Did We Make the 2/3 Axial Loading Case Assumption?

- The corner cracked hole is probably the most used model in AFGROW and is used extensively to model cases including out-of-plane bending. When these cracks transition through-the-thickness, we had to have some method to continue to account for bending.
- The straight crack front assumption is not truly compatible with out-of-plane bending, and the effect is dependent on the fractional amount of bending to the total loading.
- We wanted to balance the need for a bending solution with the desire to maintain safety with a somewhat conservative solution.

Oblique Crack Solution

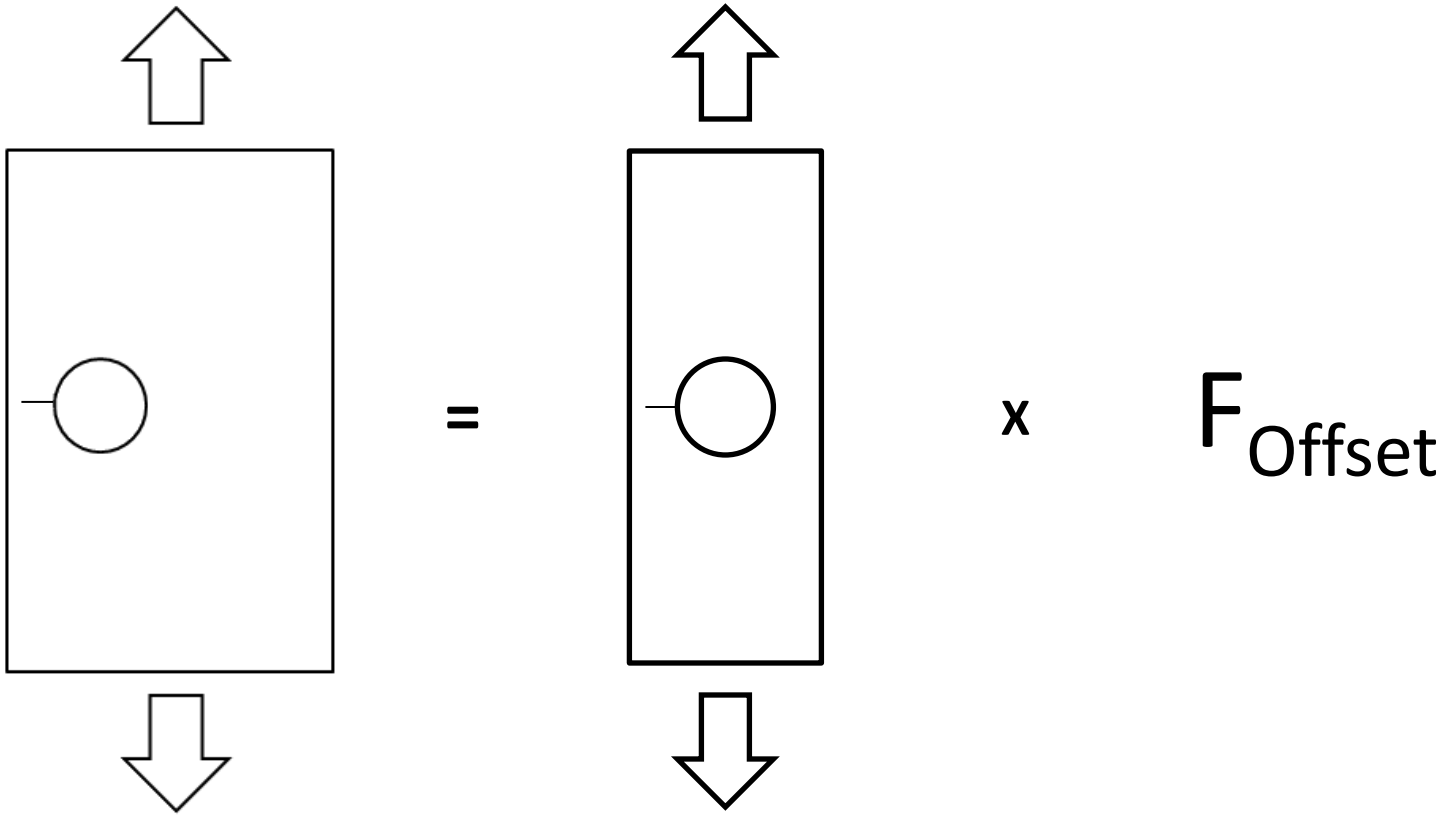
- AFGROW includes the capability for a single oblique thru-crack at a hole so that an additional crack tip is modeled on the opposite side of the thickness.

- A tabular solution is used to determine the K-value at both points for Axial, Bending, & Bearing load.

- This was developed under contract and additional solutions of this type would have to be funded.

Discussion

Current Offset Hole Solution for Bearing Loading



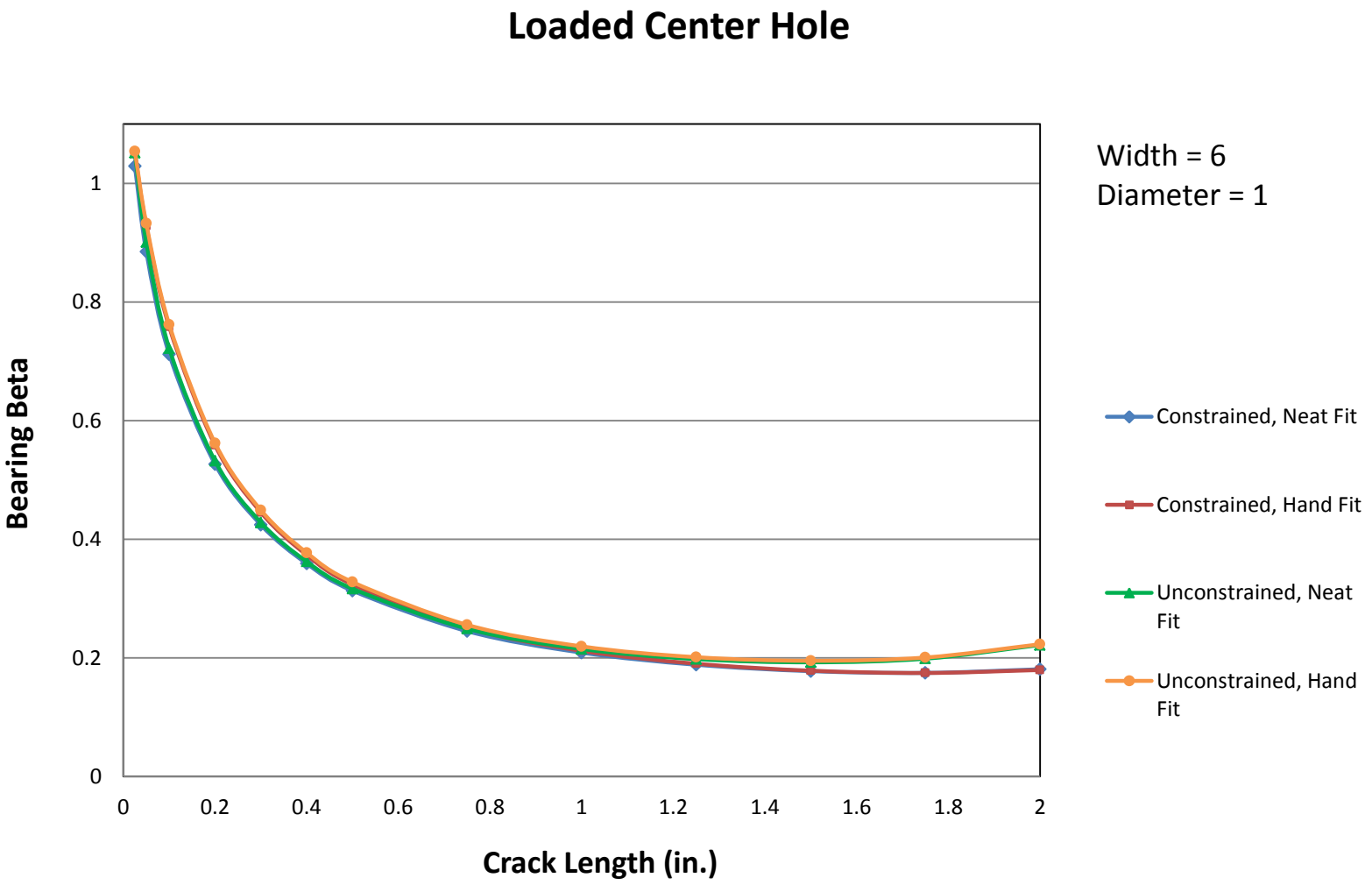
Center Cracked Hole Bearing Solution

- Solution Matrix has been Expanded to Cover the Following W/D values:

  1.3, 1.5, 2, 2.5, 3, 4, 5, 6, 8, 16, 40, 100, 1000

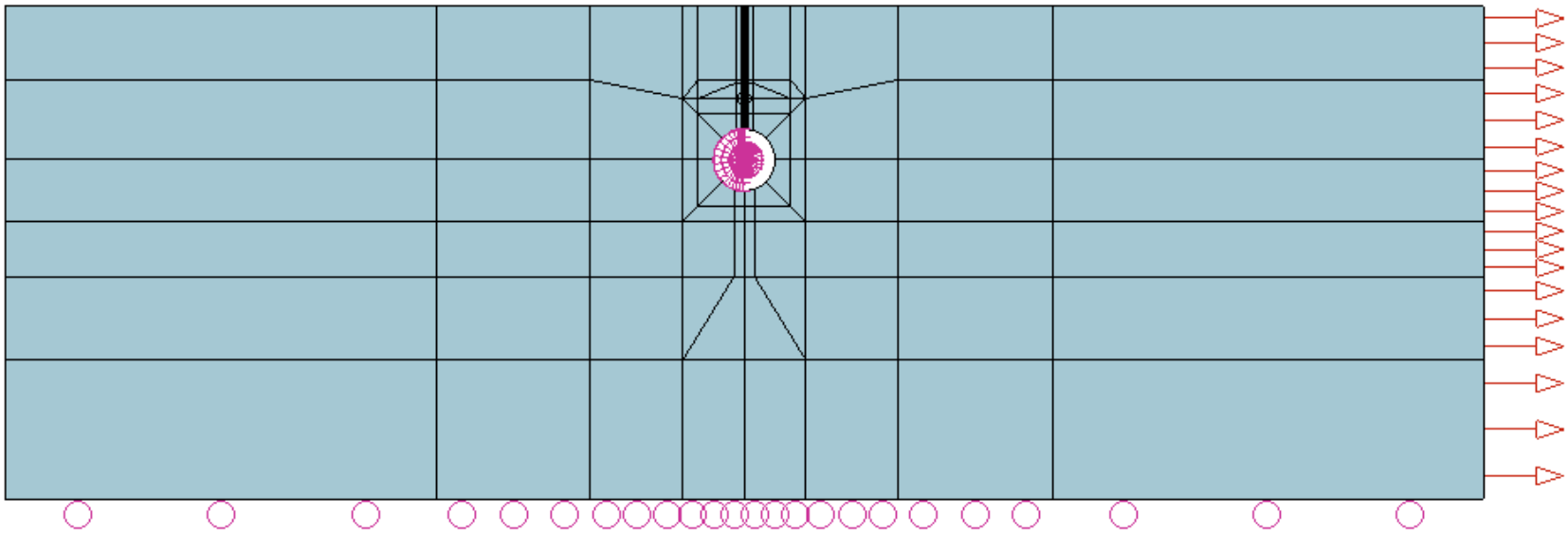
  (this has improved previous interpolation issues)
- Uses Un-Constrained In-Plane Bending Boundary Conditions

Example Centered Hole Case



Boundary Conditions for the Offset Correction

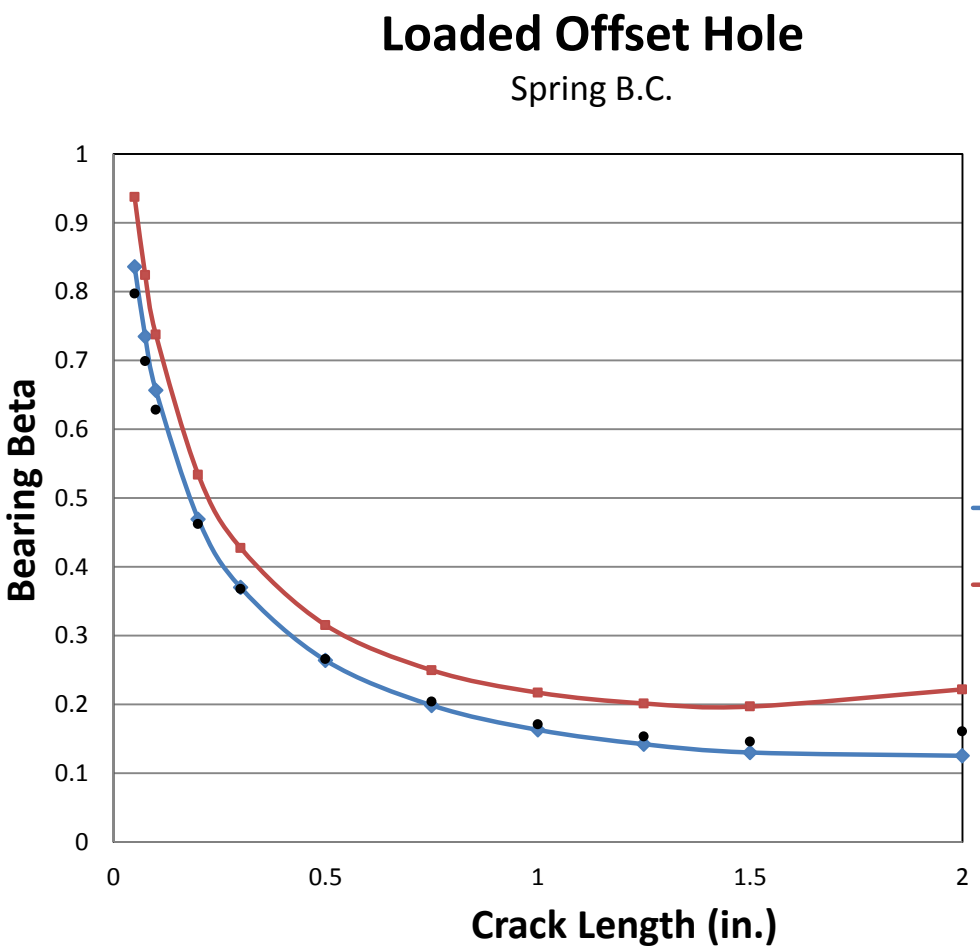
FEM* Boundary Conditions



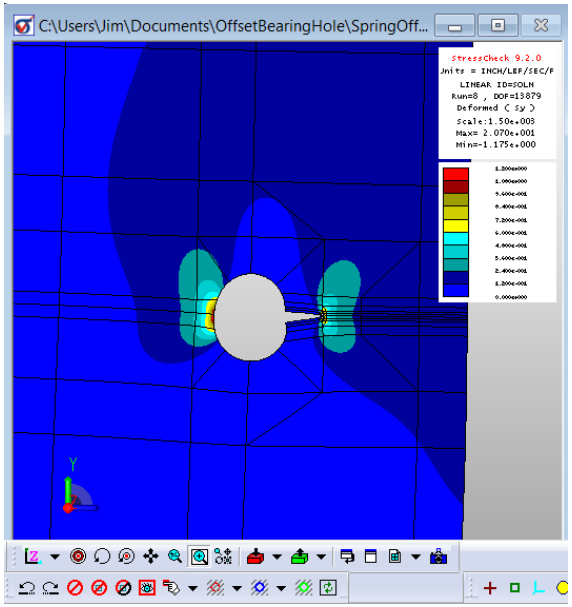
Model Thickness = 1.0
Loading to produce a unit resultant force at the hole (1/W)
Spring (E_{Spring} = 3X E_{Plate}) B.C. along ½ hole

* StressCheck (ESRD, Inc.)

Example Offset Hole Case



Width = 10
Diameter = 1
Offset = 3



Discussion

3.2.3.1.3 Using the Weight Function Solutions

The 2-D solutions (part-through crack) currently allow the input stress field to vary in one direction only (currently the distribution in the thickness (y) direction). The origin of the x-y coordinate system is always at the crack origin, and the x and y values are always positive.

Because of this limitation, the existing weight function solutions in AFGROW (V5.02.02.18) should not be used for cases where the stress field changes in the x-direction (c-direction).

A new weight function solution has been provided for a corner crack with a stress distribution in the x-direction. It has been implemented in AFGROW, but is currently being evaluated prior to release in a future interim version of AFGROW.

Weight Function Alternative for Part-Thru Cracks

The beta correction option is probably the best alternative to the weight function solution for these cases.

Additional Recommendations:

- Choose a baseline solution with an unflawed stress distribution that is as close as possible to the desired case.
- Select integration points to track the (Desired/Baseline) stress ratio distribution (assuming each point is connected linearly) in each growth direction.
- Do not exceed a slope change > |600| between any two integration points.
- Transition the stress distribution ratio back to 1.0 for the y-direction for when r > t using at least 4 integration points through the transition.
- After the transition, include an integration point relatively close to the last transition point with additional points with linearly increasing spacing to increase the accuracy of linear interpolation between points.

Discussion

Advanced Model Limitations

Geometry	Load Case(s)
Double, Non-Symmetric Corner Cracked Hole	A/B/Brg
Double, Symmetric Corner Cracked Countersunk Hole*	A
Single Corner Crack at a Countersunk Hole*	A
Single Corner Crack at a U-Shaped Notch	A
Single Through Crack at a U-Shaped Notch	A
Double, Non-Symmetric Through Cracks**	A

* B & Brg are currently disabled due to incomplete data matrix

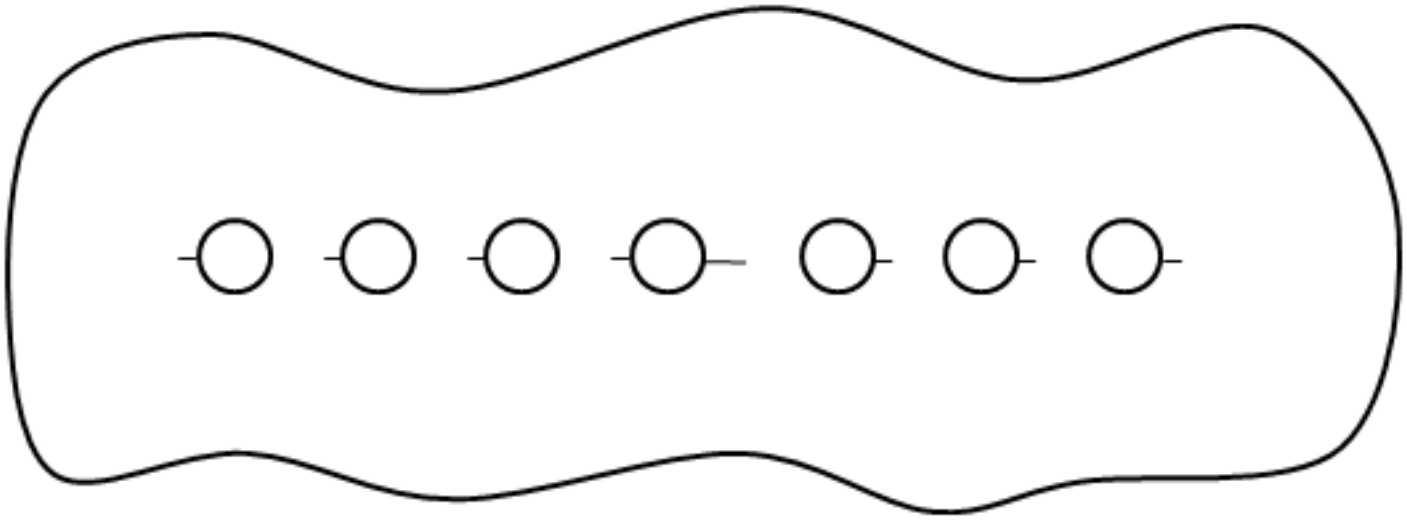
** Through cracks may be placed anywhere on the plate, including at holes and/or growing toward a hole

- Currently Only Capable of Handling Two Cracks in One Instance
- Corner Cracks Must Be Attached to a Single Hole
- Allows Up to Four Holes
- Cannot Mix Part-Through Solutions With Through-Crack Solutions
- Very Large Database is Required

Status of Advanced Solution Update(s)

- Countersunk Hole Bending Solution Has Been Validated with an Independent Solution
- The Countersunk Hole Solution for Bearing Requires More Work
- Corner/Thru Crack Solution Matrix to be Delivered Later this Year
- Improvements to Existing Compounded Solutions (cracks approaching holes and cracks) are Under Development
- Beta Correction Capability Works for Corner Cracks, but has been Temporarily Disabled for Through Cracks

We have begun work on a new MSD solution for cracks in an “infinite” row of fastener holes….



Discussion