K-Solution Approximation Option for Through Cracks Subject to Out-of-Plane Bending

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For

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Background

We have been receiving requests to add the solution for a corner cracked plate under out-of-plane bending.

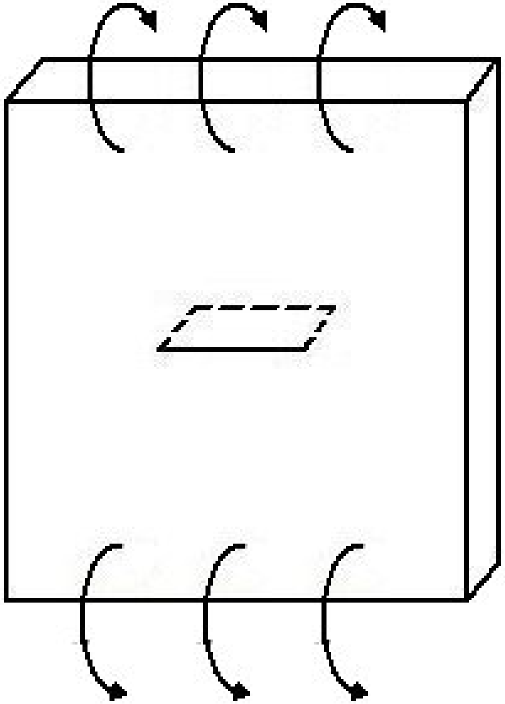
While this solution exists, we have no solution to continue crack growth predictions if the crack transitions to become a through-the-thickness crack (e.g. cases with combined axial & bending loading)

We have included an estimated solution for a single, straight through crack at a hole using a conservative approximation that it is equivalent to 2/3 of the axial load case.

This conservative solution has also come into question as being far too conservative, and there is some interest in allowing users to specify the fraction of the axial solution to be used for the straight through crack.

As a result of a discussion at our recent European Workshop, I have taken the action item to compare the Fawaz/Andersson tabular solution for an oblique crack at a hole under out-of-plane loading to a straight through crack with various axial load fractions

There are no general closed-form K-solutions available for a through-the-thickness crack under out-of-plane loading

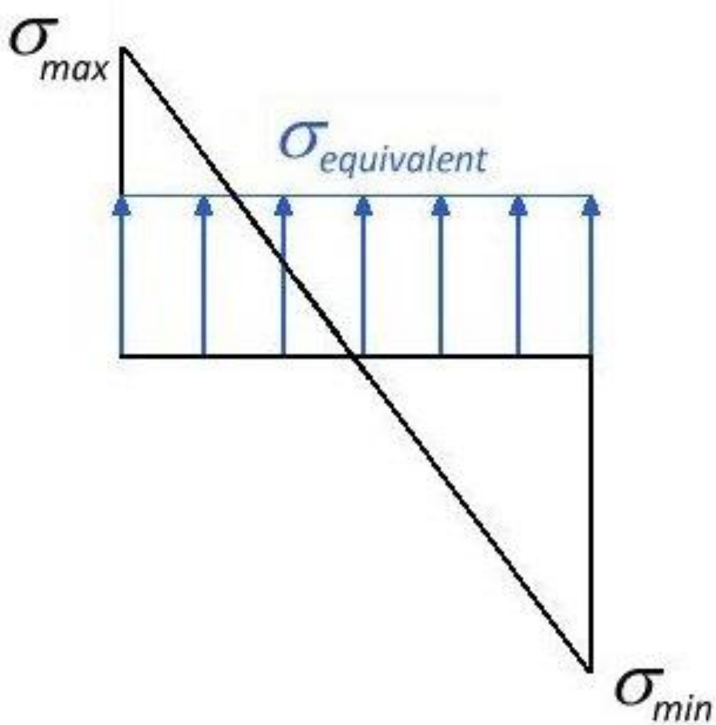


Idealized Case

Reality

The assumption of a straight crack front is poorly suited for the out-of-plane loading case

How to Approximate the Out-of-Plane Bending Effect for a Straight Through-the-Thickness Crack?

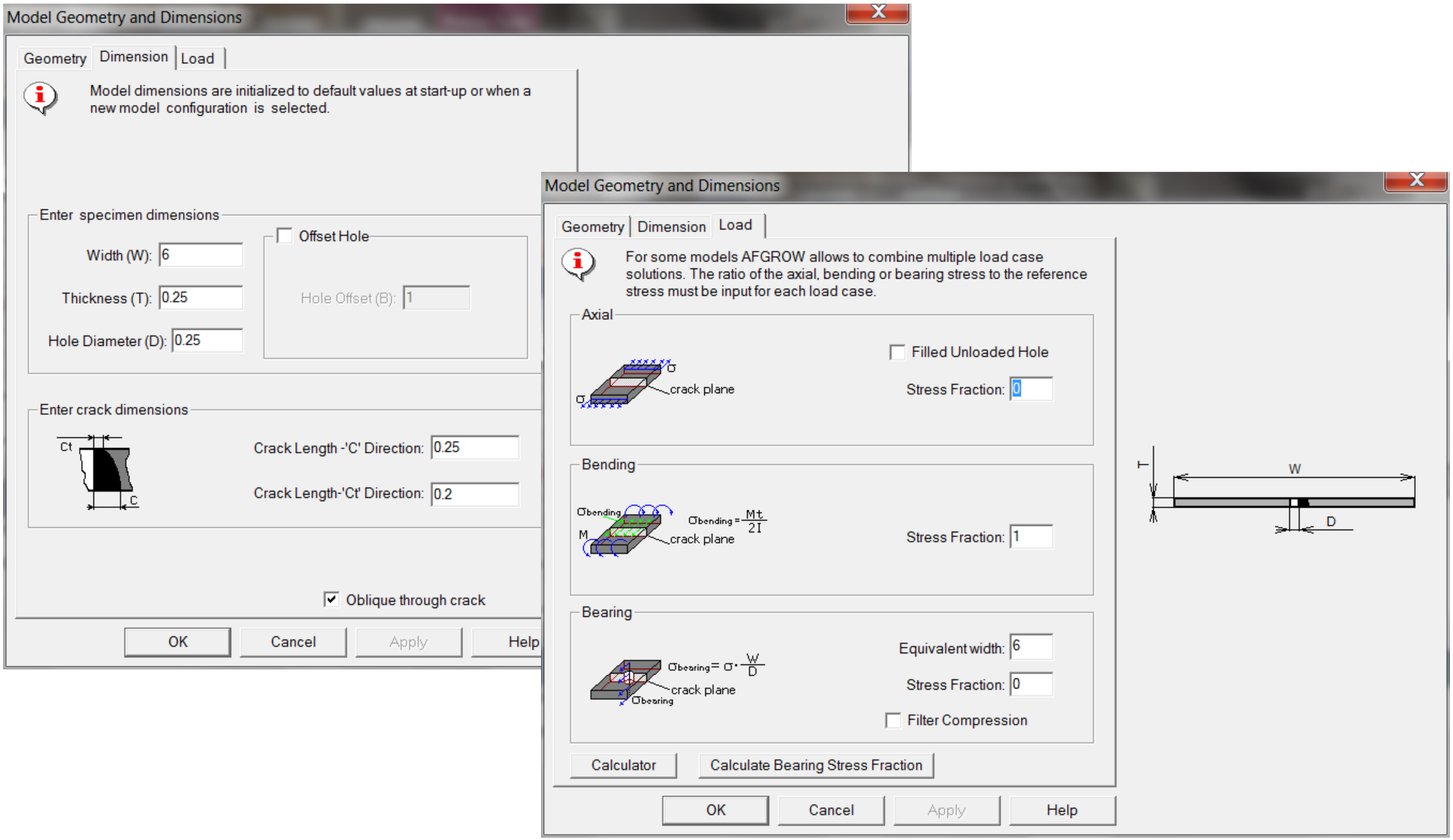


Is there an "equivalent" Axial Stress?

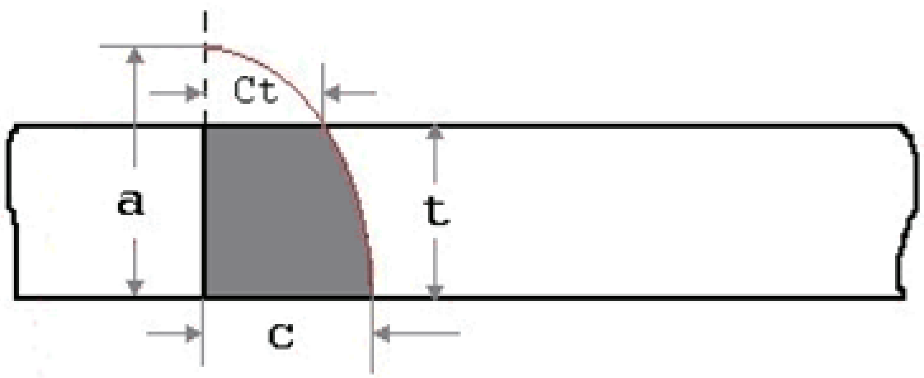
What are the important considerations?

- Maximum Stress?
- Thickness?
- Initial Crack Length?
- ….?

Using the Fawaz/Andersson Tabular Solution for Oblique Through Cracks at Holes



Oblique Solution Limitations

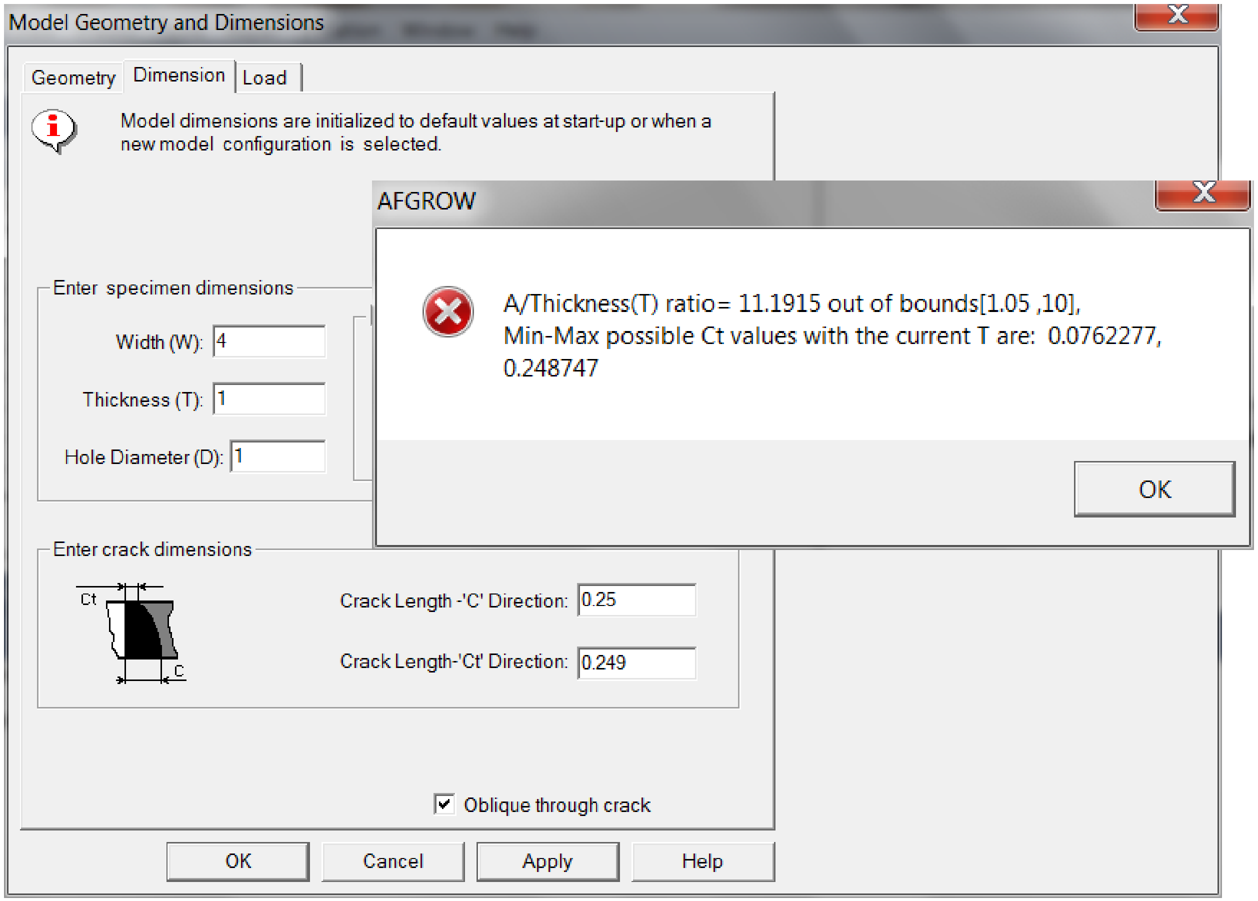


a/c = 0.2, 0.3, 0.4, 0.6, 1.0, 2.0, 5.0, and 10.0

a/t = 1.05, 1.07, 1.09, 1.13, 1.17, 1.21, 2.0, 5.0, and 10.0

R/t = 0.5, 1.0, and 2.0 - where R is the hole radius

Initial Crack Length Limitations



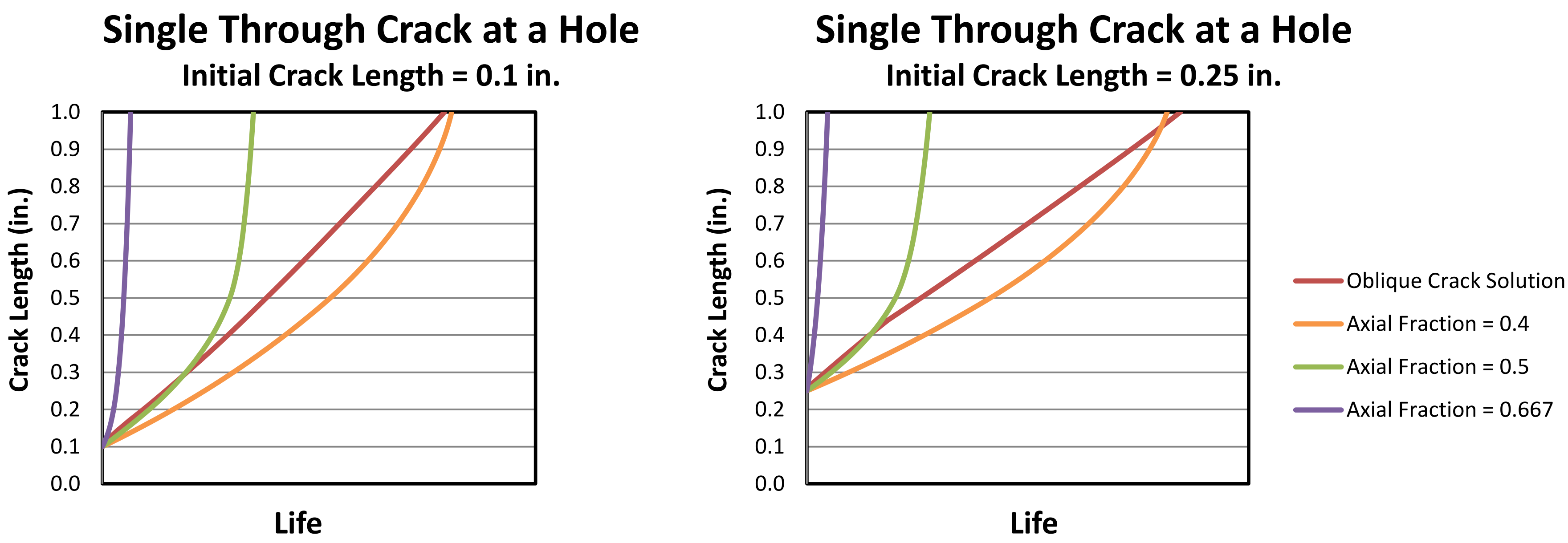
For all oblique crack cases:

$$(C - Ct) < 3\% \text{ of } C$$

Comparison Results Assuming 100% Out of Plane Loading

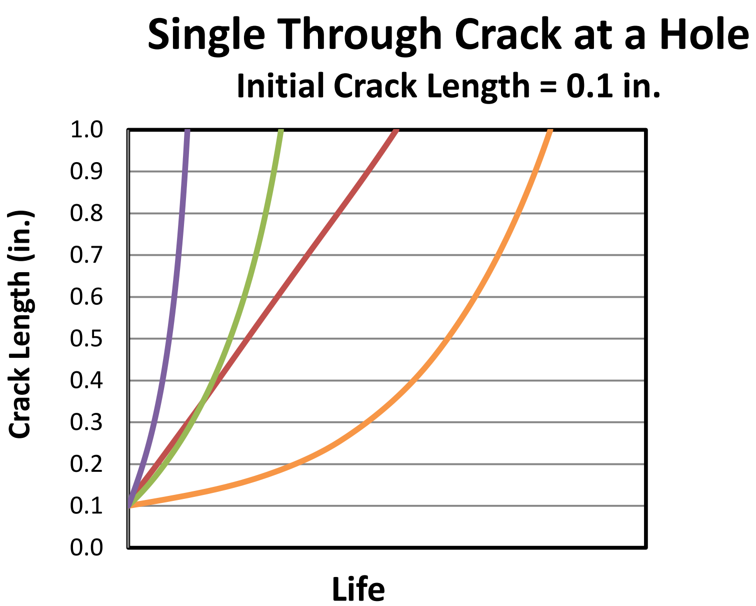
All comparisons are for wide plates to minimize finite width effects

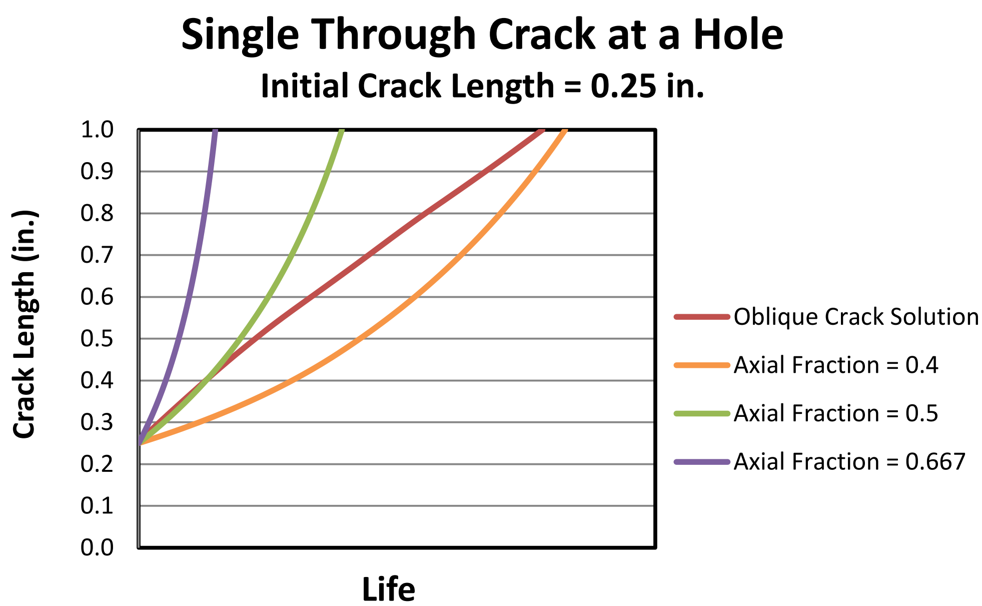
Nominal Hole Diameter and Thickness Under Low Maximum Stress



Hole Diameter = 0.25 in.
Plate Thickness = 0.25 in.
Plate Width = 25 in.
Maximum Bending Stress = 15 ksi

Nominal Hole Diameter and Thickness Under Moderate Maximum Stress





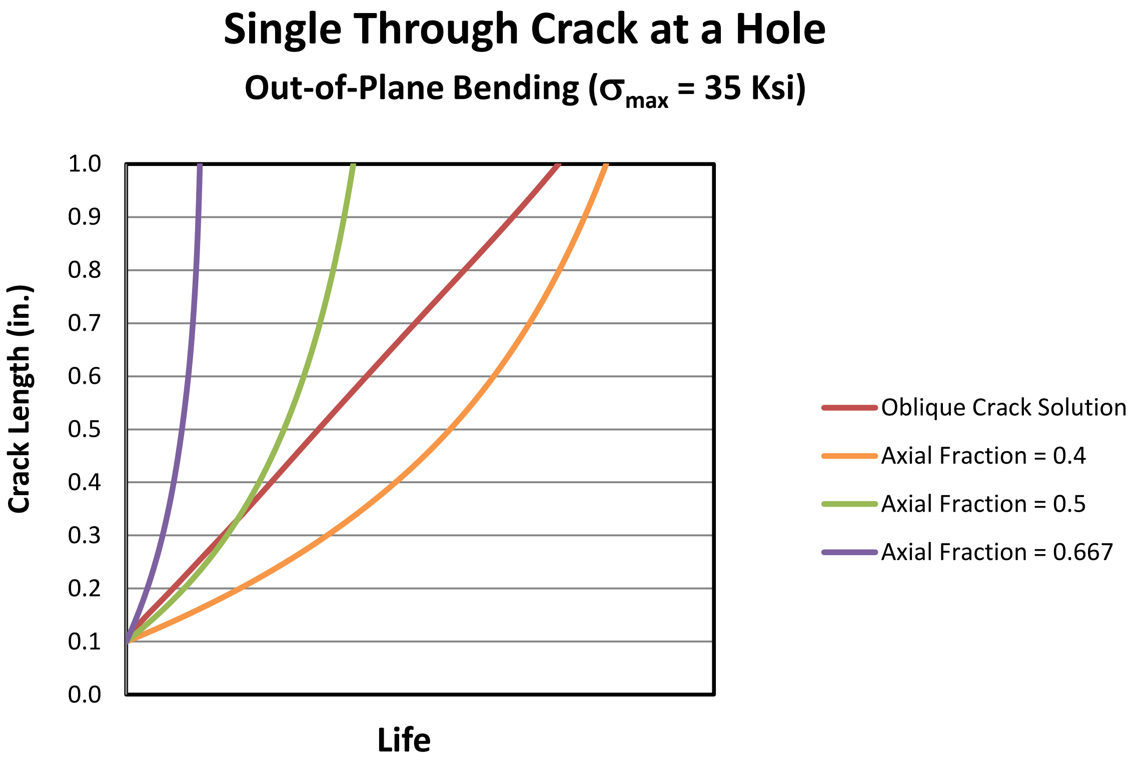
Hole Diameter = 0.25 in.

Plate Thickness = 0.25 in.

Plate Width = 25 in.

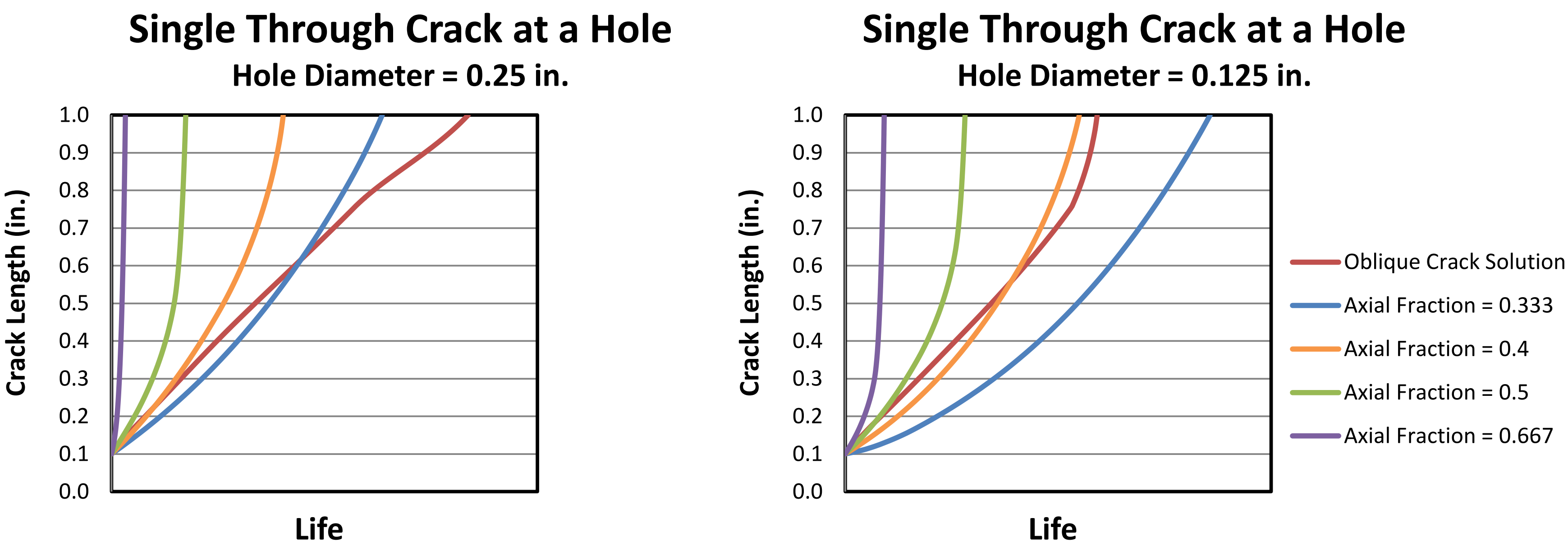
Maximum Bending Stress = 25 ksi

Nominal Hole Diameter and Thickness Under High Maximum Stress



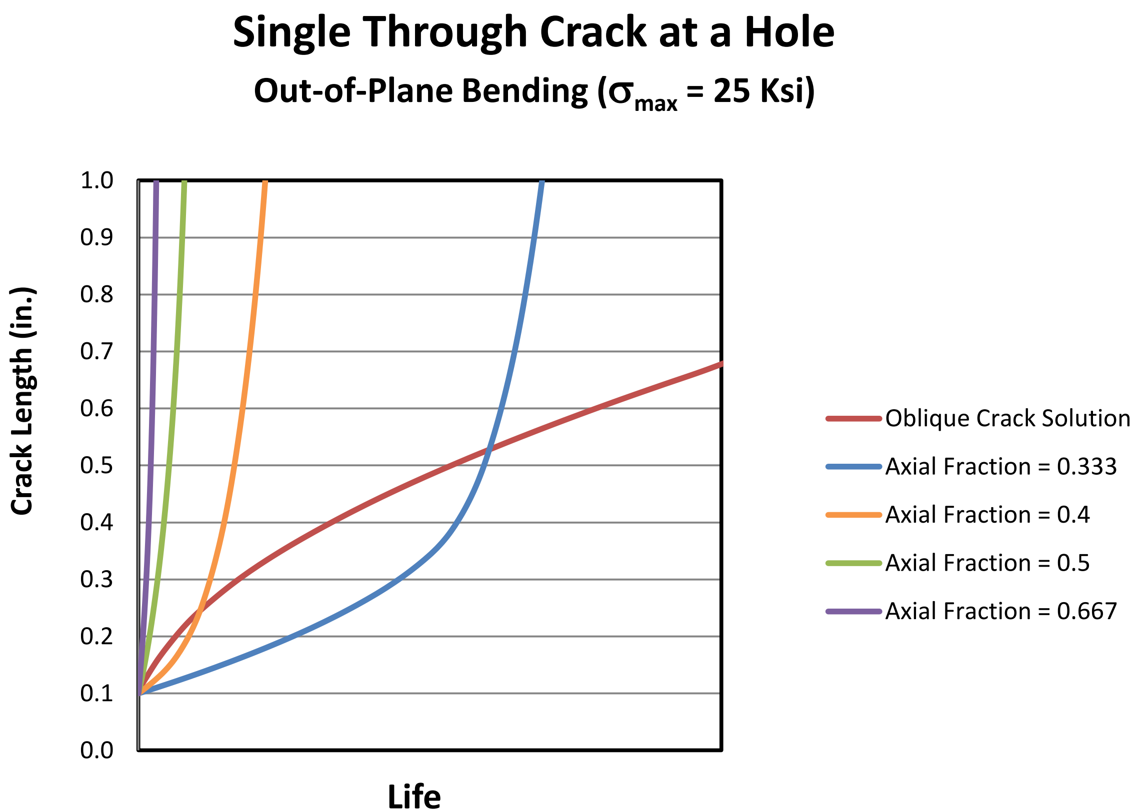
Hole Diameter = 0.25 in.
Plate Thickness = 0.25 in.
Plate Width = 25 in.
Maximum Bending Stress = 35 ksi

Low Thickness and Maximum Stress at Two Thickness Values



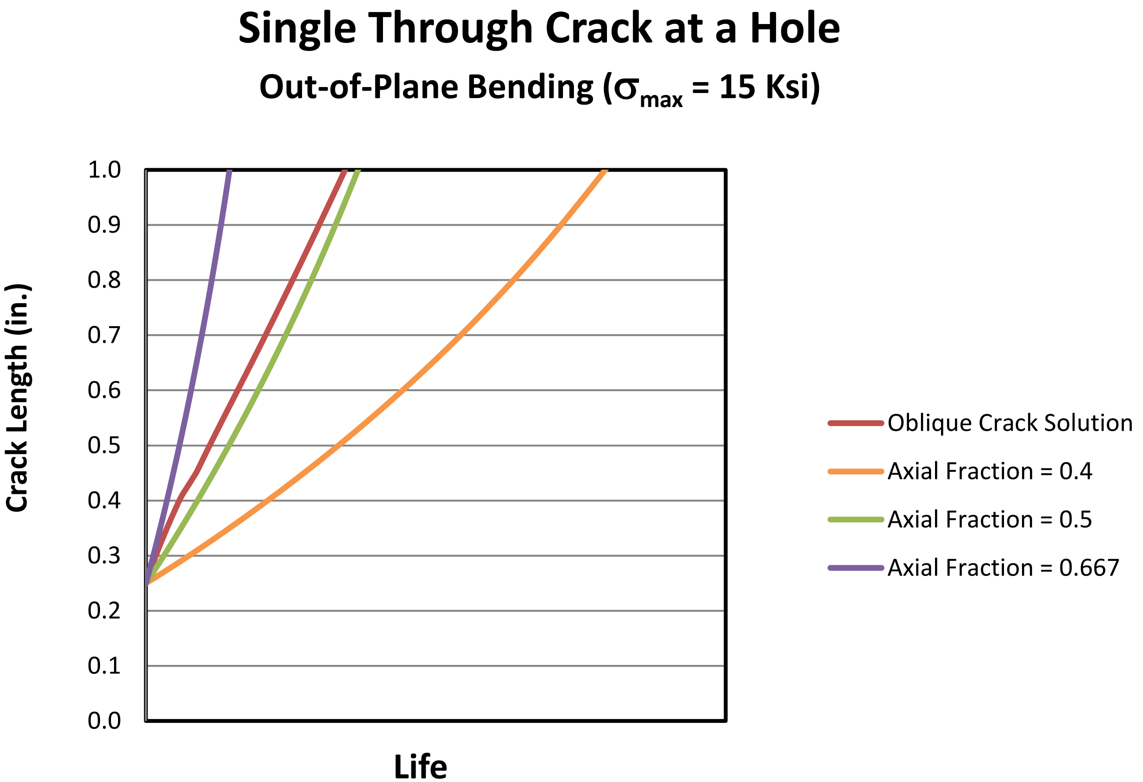
Initial Crack Length = 0.1 in.
Plate Thickness = 0.125 in.
Plate Width = 25 in.
Maximum Bending Stress = 15 ksi

Nominal Hole Diameter, Low Thickness Under Moderate Maximum Stress



Hole Diameter = 0.25 in.
Plate Thickness = 0.125 in.
Plate Width = 25 in.
Maximum Bending Stress = 25 ksi

Large Hole Diameter and Thickness Under Low Maximum Stress



Hole Diameter = 1.0 in.
Plate Thickness = 1.0 in.
Plate Width = 100 in.
Maximum Bending Stress = 15 ksi

Discussion

The straight through-the-thickness crack approximation using an axial load fraction is not ideal, but it appears that the 2/3 fraction is too conservative for most practical cases

The result of this comparison for 100% out-of-plane bending for a through cracked hole indicate that axial stress fractions from 0.333 to 0.5+ may be appropriate for most practical problems.

The appropriate axial stress fraction appears to be a function of the plate thickness more than any other parameter. The fraction appears to increase with plate thickness.

Initial crack length and stress level don't seem to be significant parameters, but hole diameter does influence the results for the cracked hole case.

In the absence of an oblique crack solution, it may be a reasonable approach for the edge cracked plate geometry. However, the effect of combined loading is unknown.

Adding a capability for a user-defined axial stress fraction may also be a good idea. However, because of legacy issues, it may be a good idea to keep the 2/3 fraction as the default value.

Comments?