AFGROW Workshop 2019

Modeling Residual Stresses with the Advanced Model Interface

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Recent Improvements to the AFGROW Residual Stress Capability

Issues Resolved in AFGROW Release 5.3.3.23 (October 19, 2019)

- A Newton Interpolation error was found in the Gaussian integration routine
- Large residual stress distribution slope change at through crack transition
- The part-through crack correction was not being applied properly
- This capability was not available for use with Advanced Models *

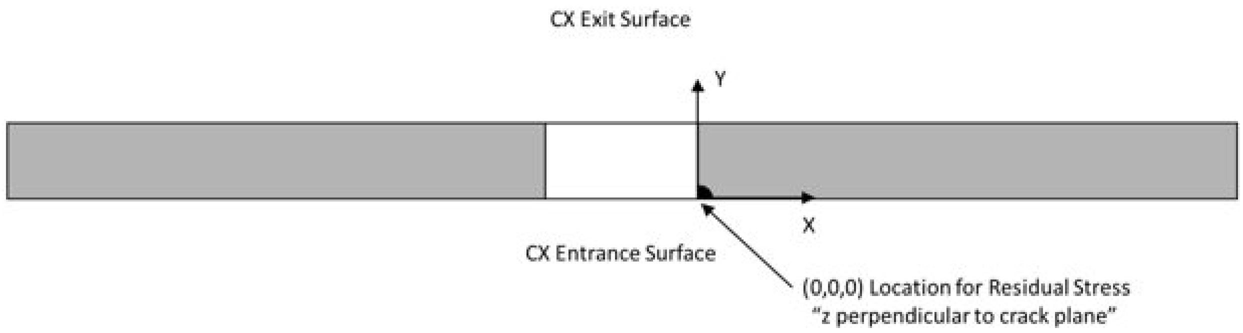
* The Classic Newman-Raju K-solution for a corner cracked hole was determined to be ~10 to 15% lower than the Fawaz/Andersson Advanced Model K-solution. The updated residual stress capability was subsequently used with the ERSI round-robin residual stress data and the Advanced Model Interface. The results were compared to the round-robin test results.

Residual Stress Example

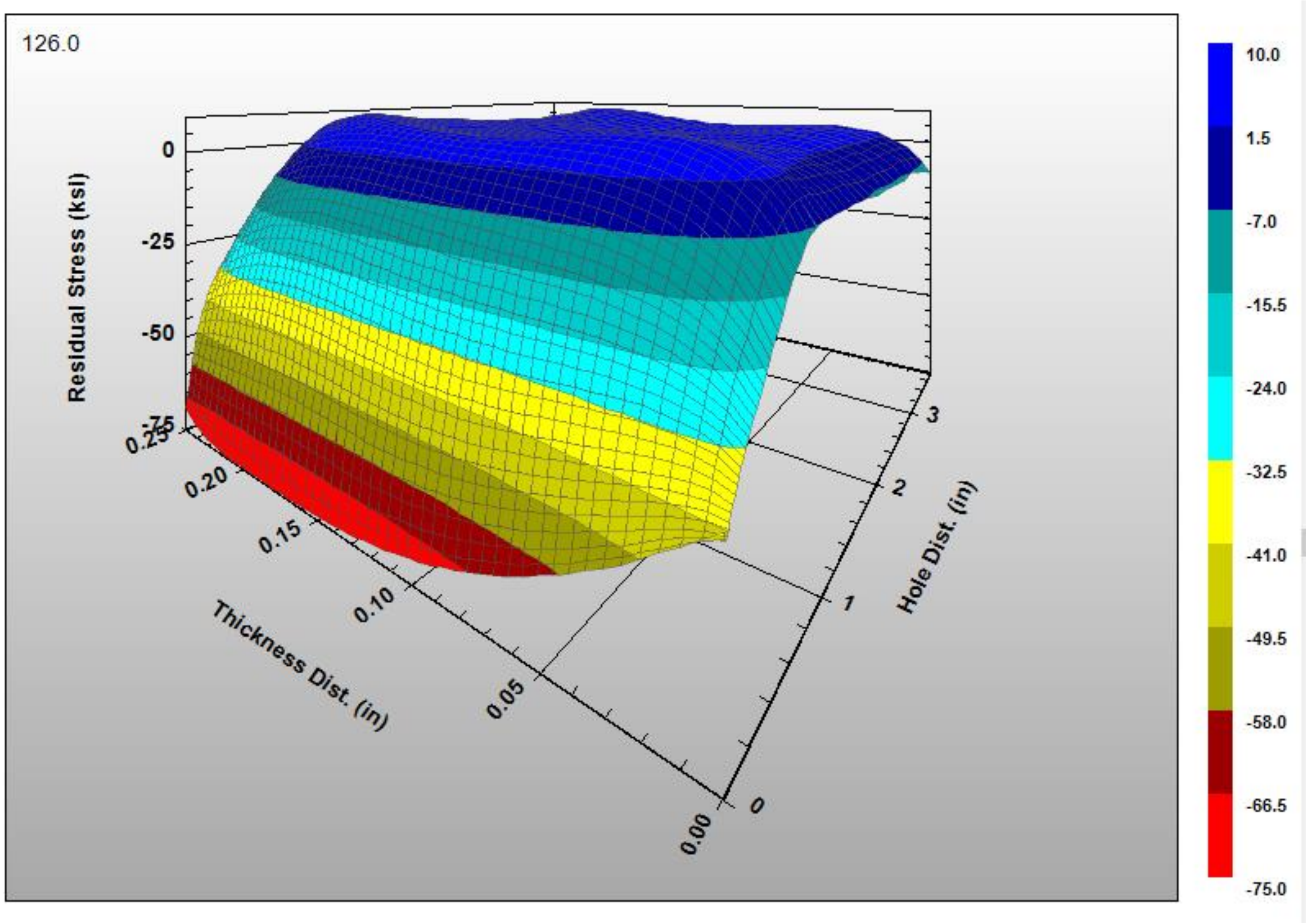
ERSI

Round-robin analysis conditions

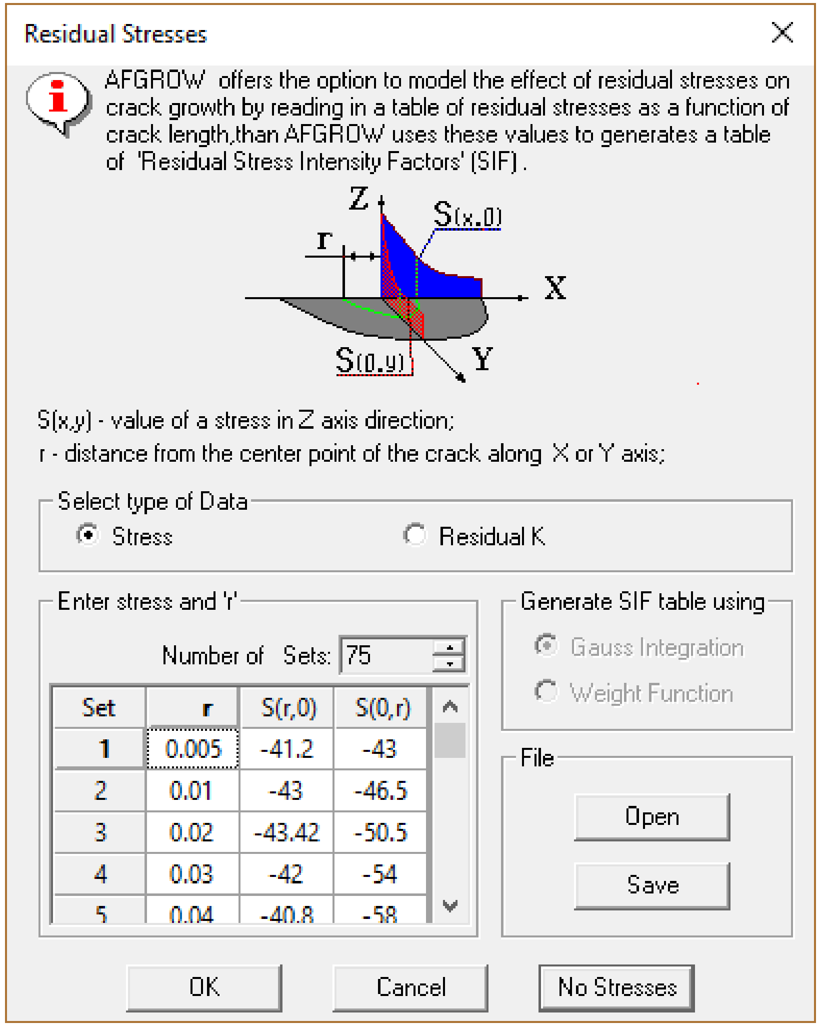
Benchmark Condition #	Material	Specimen Type	Thickness (in)	Width (in)	Hole Diameter (in)	Hole Edge Margin	Loading	Max Stress (ksi)
1	2024-T351	Non-CX Baseline	0.25	4.00	0.50	4.0	CA (R=0.1)	10
2		CX						25
3		Non-CX Baseline				1.2		10
4		CX						25



Residual Stress Field



AFGROW 2-D Gaussian Integration Method

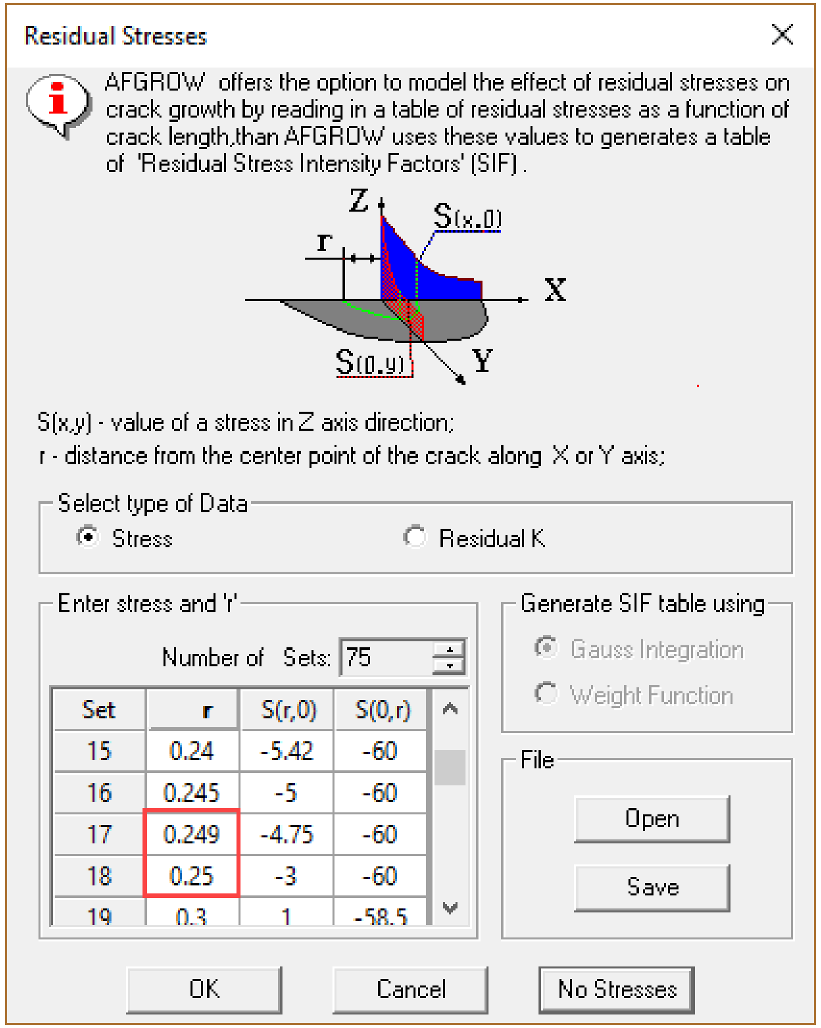


For part-through Cracks, the integration is now performed twice:

Integration is performed first for r <= thickness. This results in a residual K table for the corner crack.

Integration is performed again for all integration points with S(0,r) (a-direction) set to 0.0 (equivalent to a 1-D crack case). This is the residual K table used after transition to a through crack.

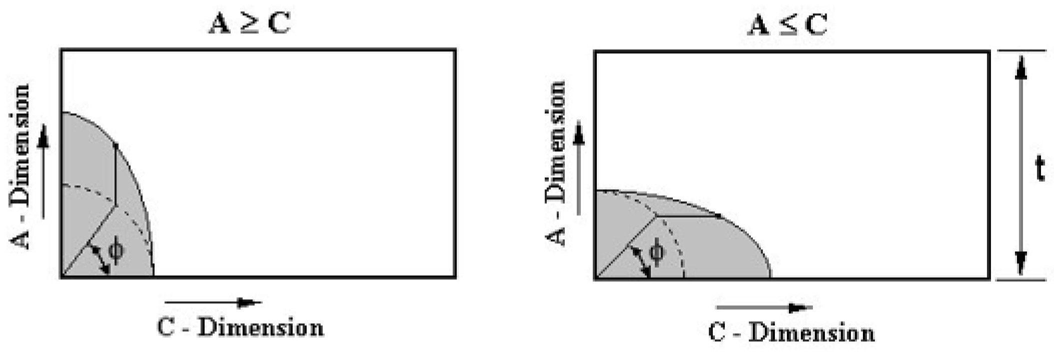
AFGROW 2-D Gaussian Integration Method



Important Note:

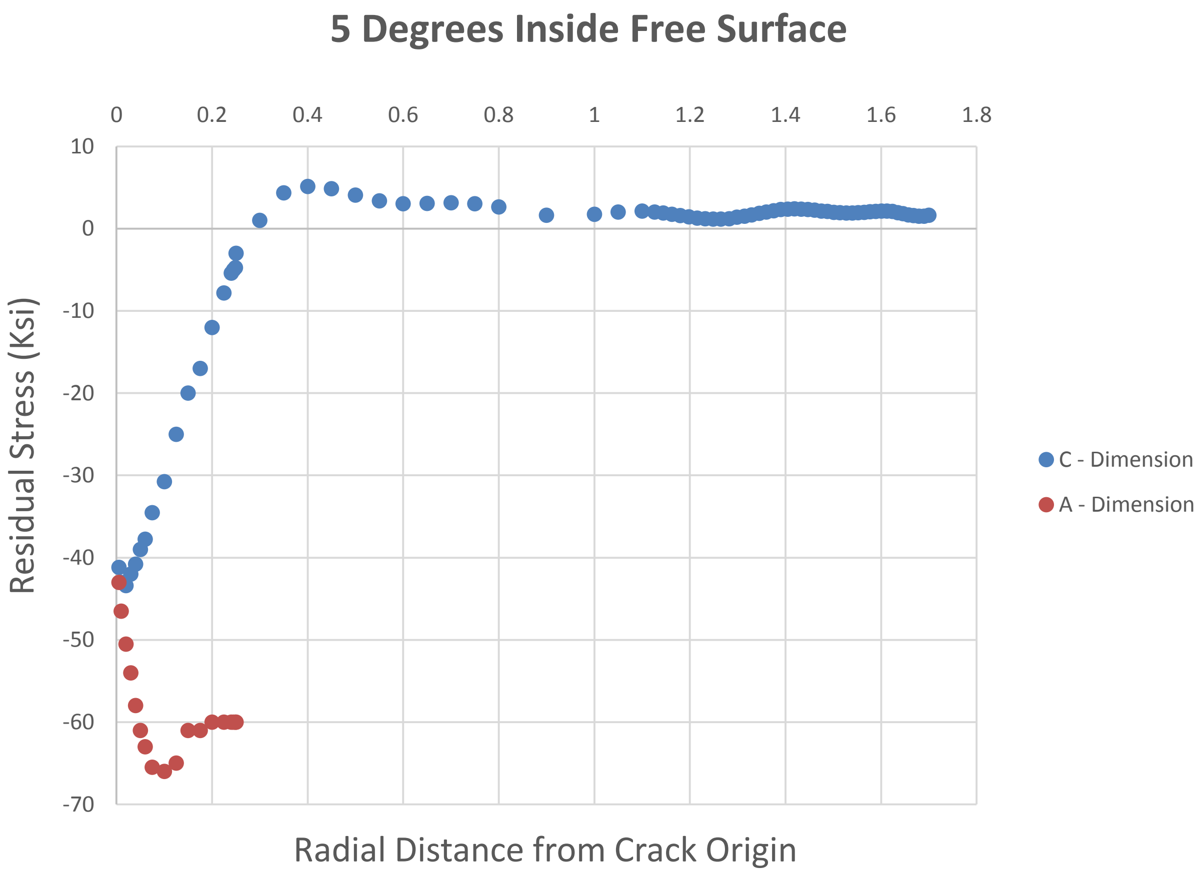
Two integration points are needed beyond the longest crack expected for each integration process. The Gaussian integration method uses a Newton polynomial interpolation method that requires two points ahead of each integration point for valid results.

Two Points on the Crack Front are Currently Used for the Advanced Model Residual Stress Implementation



When performing analyses for the ERSI round robin effort, the best correlation was obtained when mapping the 3-D residual stress field approximately 5 degrees from either free surface.

Two Points on the Crack Front are Currently Used for the Advanced Model Residual Stress Implementation



Life Prediction Parameters

Model

Plate Width: 4 in.
Plate Thickness: 0.25 in.
Hole Diameter: 0.5 in.
Hole Offset: 2.0 in.

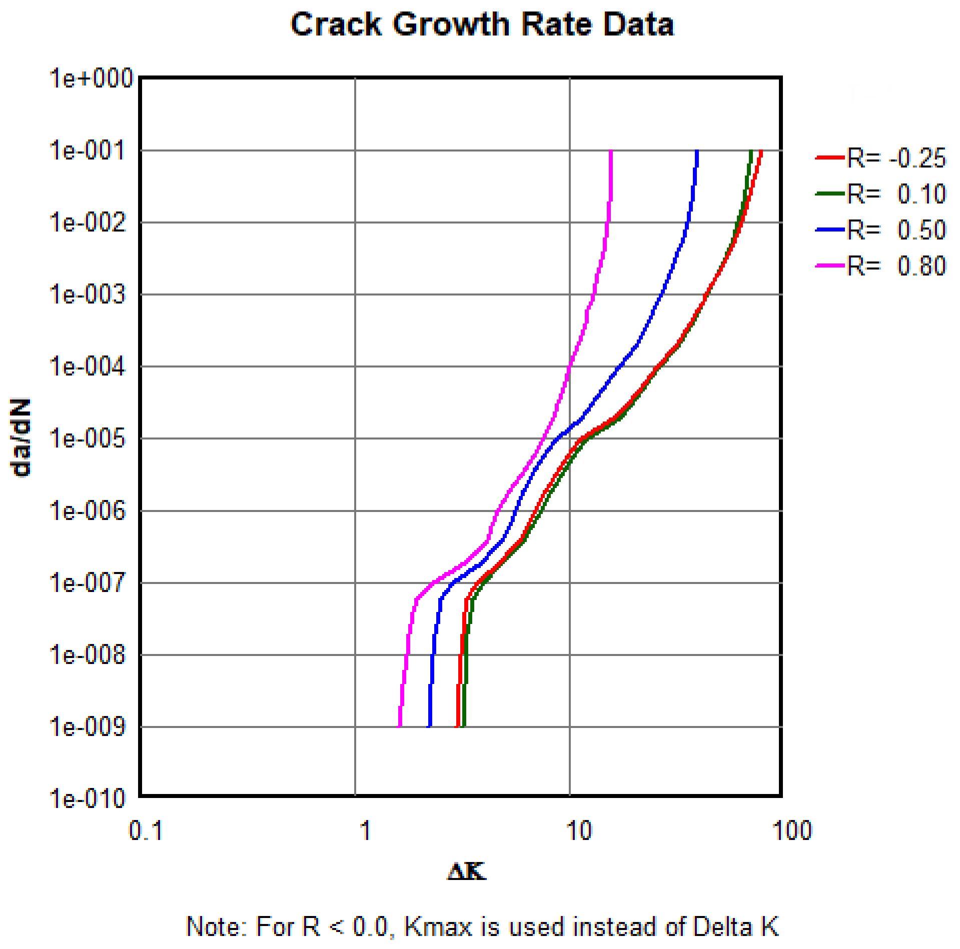
Crack Length (c): 0.05 in.
Crack Length (a): 0.05 in.

Material Data

ERSI Round Robin L-T Curve Fit

2024-T351 Aluminum Plate

Modulus:	10700 Ksi
Poisson's Ratio:	0.33
Ultimate Strength:	66.0 Ksi
Yield Strength:	50.0 Ksi
Plane Stress Toughness:	80 Ksi Sqrt(in)
Plane Strain Toughness:	32 Ksi Sqrt(in)
Rlo	-0.25
Rhi	0.85



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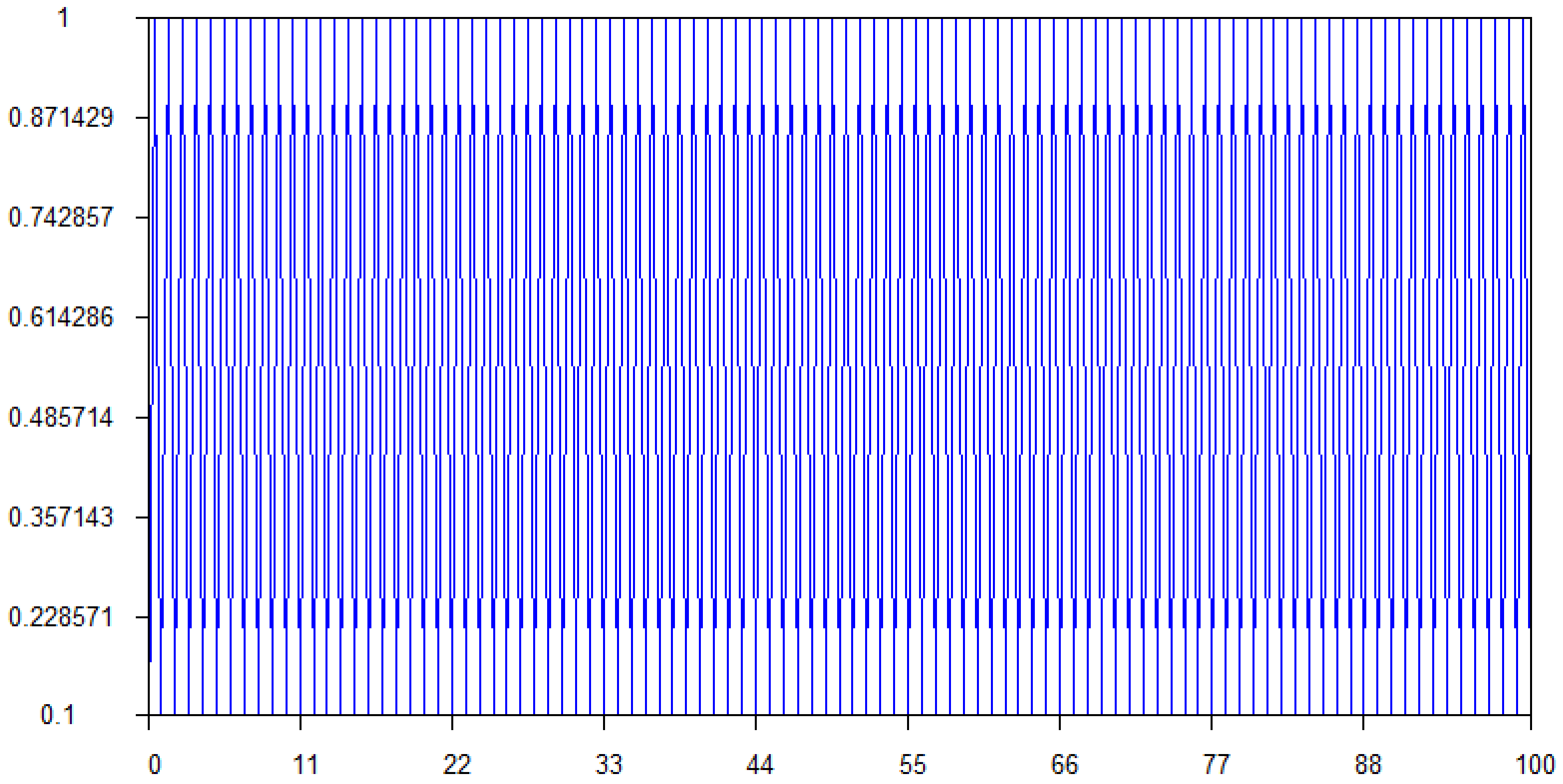
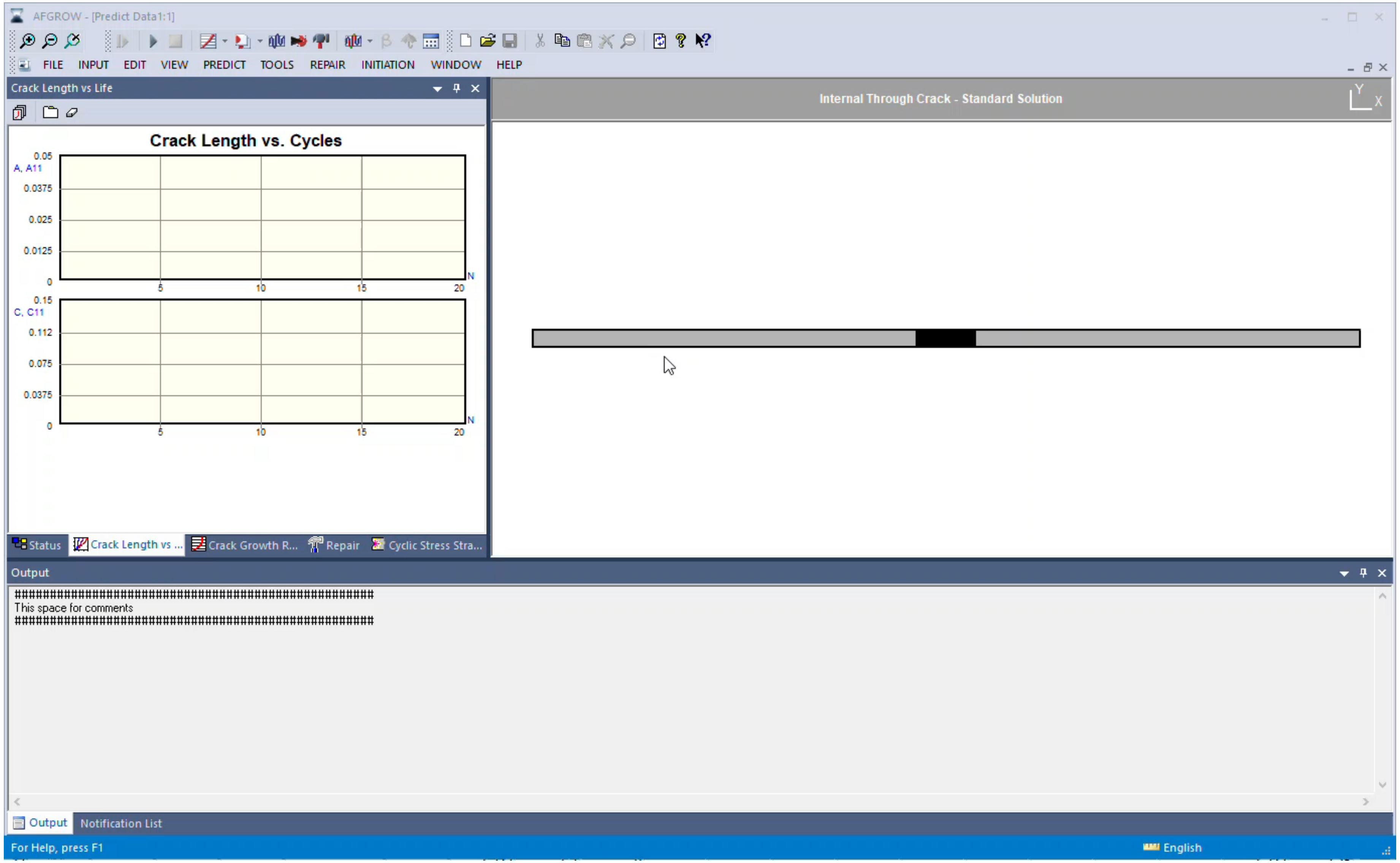
Applied Loading

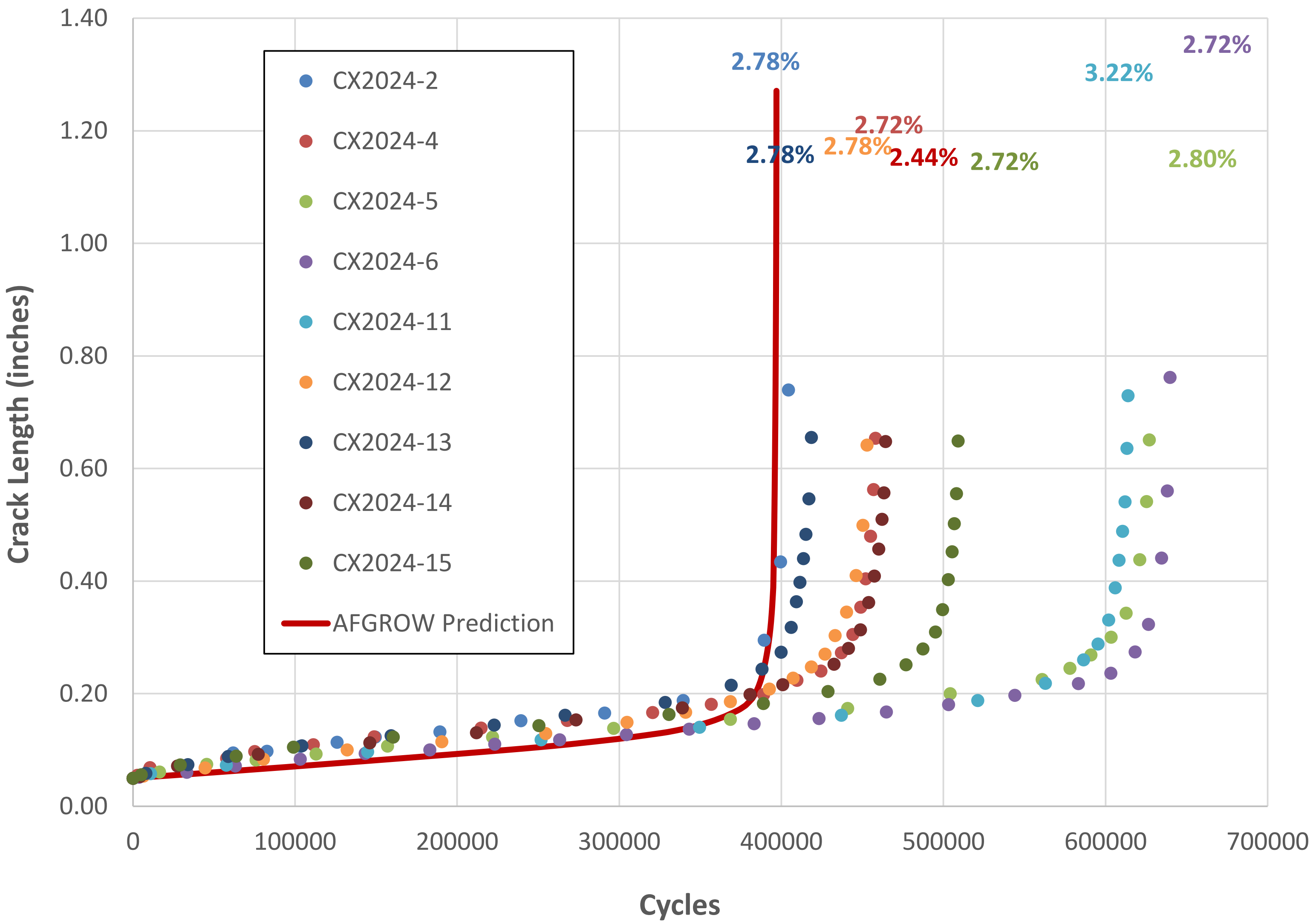


Constant Amplitude Loading (R = 0.1, SMF = 25 Ksi)

Life Prediction Demonstration



Results for the C-Direction



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Results for the A-Direction

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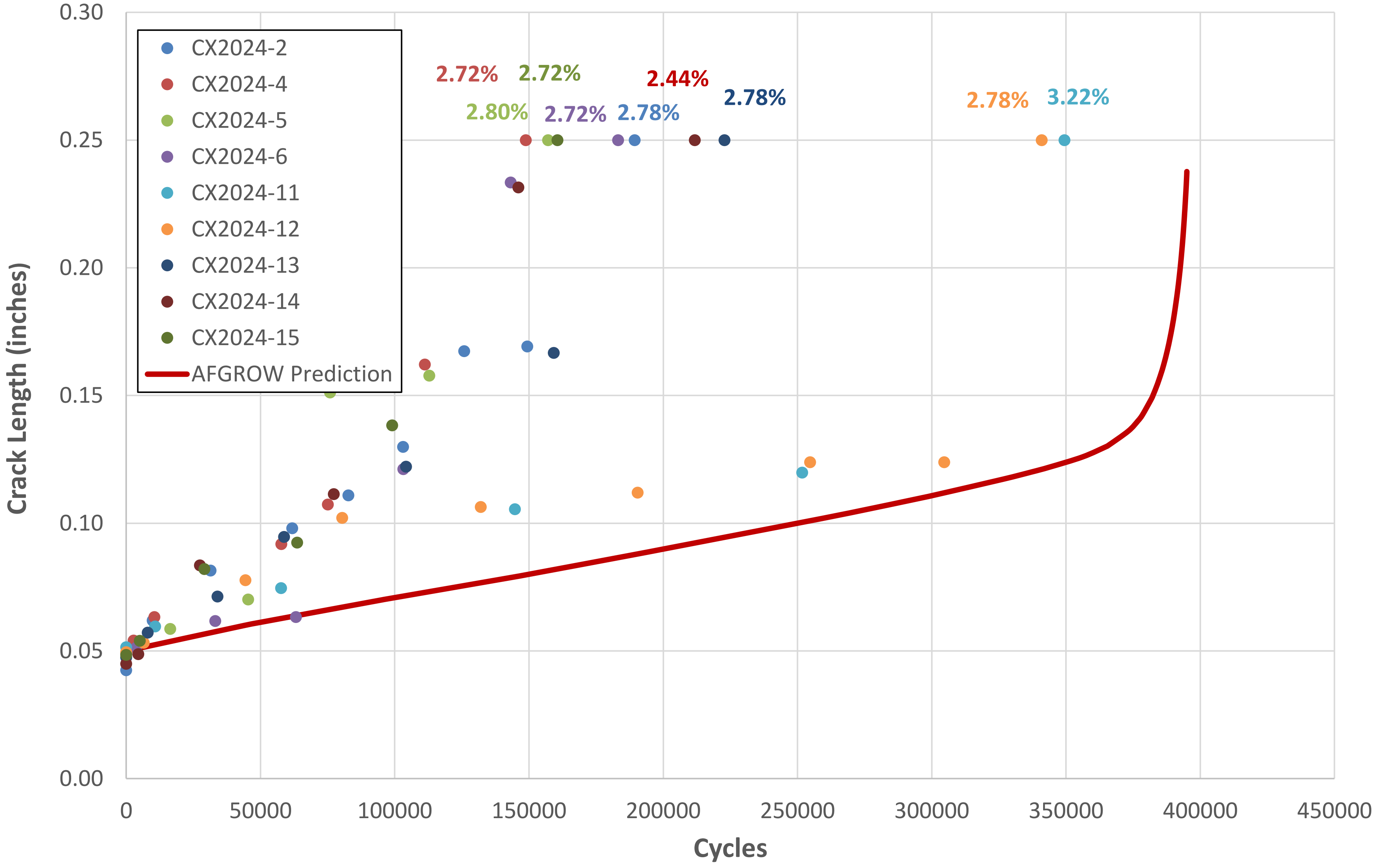

Discussion/Conclusions

- The corrected and improved residual stress capability provided reasonable results for the c-direction
- Using the residual stress distribution mapped to 5 degrees inside each free surface seems to be a logical approach when using a two point (elliptical) crack growth prediction
- The use of a two point method does not allow for the prediction of actual crack shapes that are normally seen in cases with significant residual stress distributions, but does not require the use of complex FEMs
- The use of crack 2-dimensional growth rate data (L-T and L-S) may improve the predictions in the a-direction