Residual Stress Capability

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Discussion

- This method is used to approximate the effect of local residual stresses by using a 2-D Gaussian integration method to calculate “residual” stress intensity values to be added to applied Ks (superposition)
- Although it does not make physical sense to calculate K-values for compression, the resulting net K is used to determine crack growth
- This capability is only provided as an Engineering tool for the purpose of estimating the net effect of local residual stresses

Typical Cold Worked Hole Case

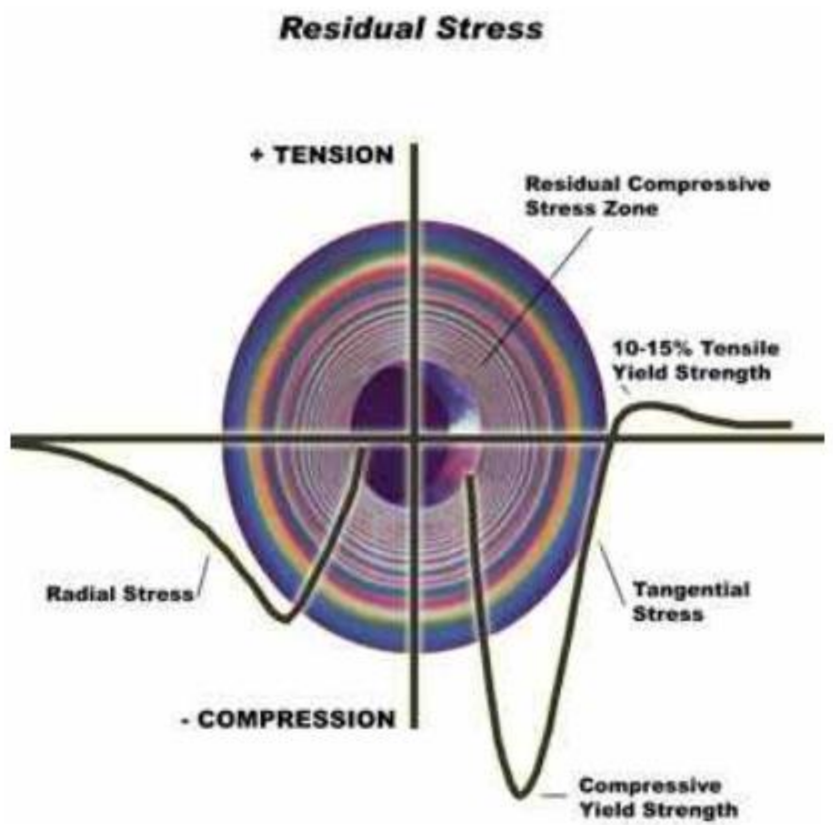
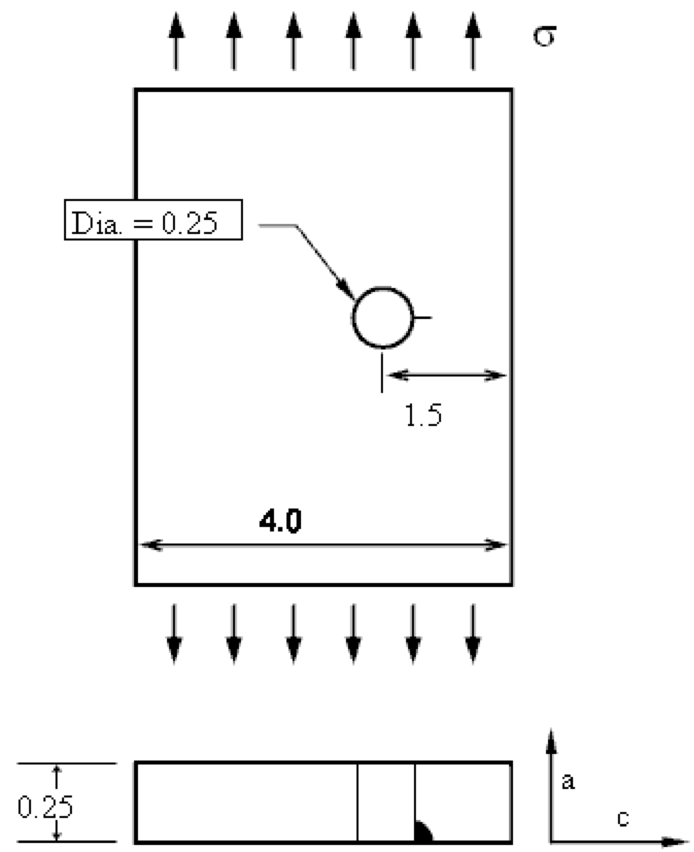


Image from: Fatigue Technolocies , Inc.

Example Case in the User's Guide

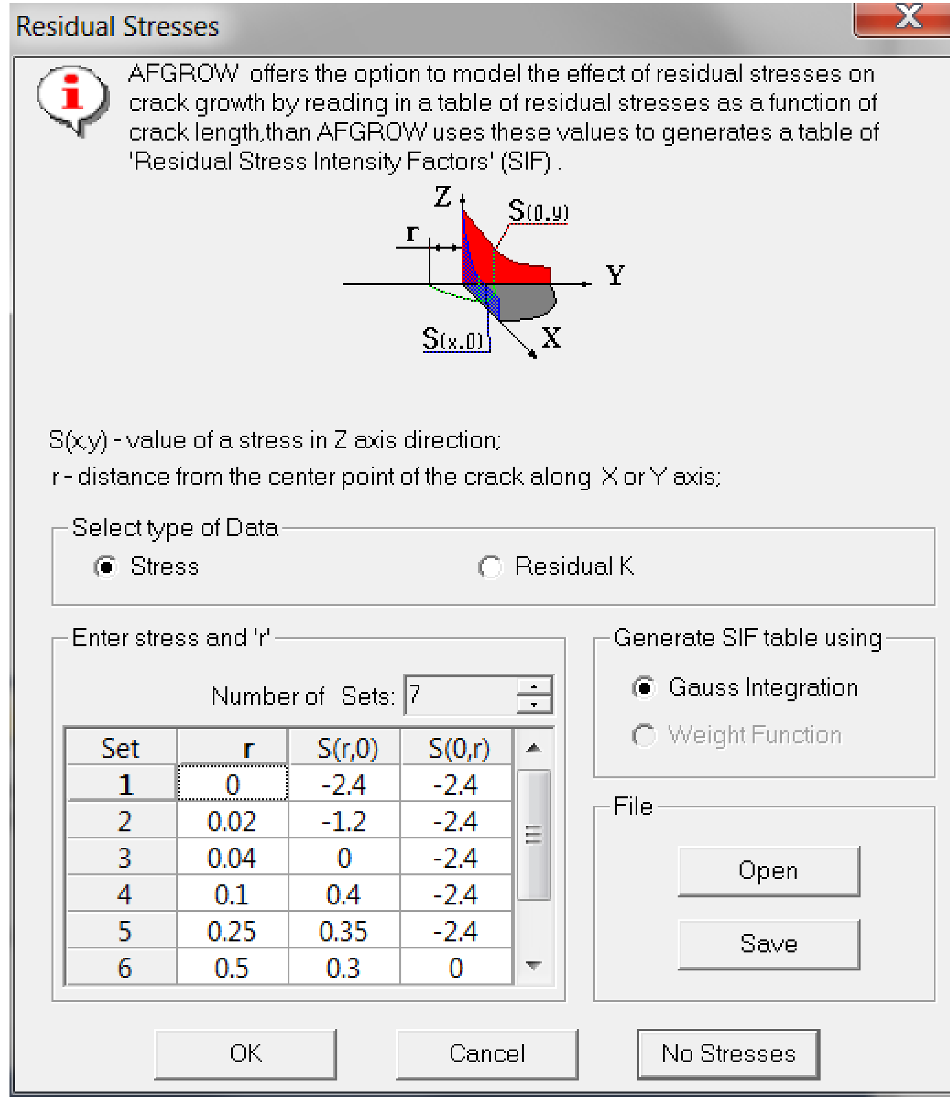
Specimen Geometry:	Corner Crack at an Offset Hole in a Plate	
Dimensions:	W = 4.0 in., T = 0.25 in., Dia. = 0.25 in.	
Hole Offset:	B = 1.5 in.	
Initial Crack Size:	c = 0.05 in., a = 0.05 in.	
Material:	7050-T74 Plate (Harter T-Method)	
St**ress Spectrum:**	16 ksi to 0 ksi	1 Cycle
	12 ksi to 8 ksi	1000 Cycles
Retardation Model:	Generalized Willenborg Model, SOLR = 2.8	



Residual Stress Input

AFGROW uses integration points for each crack growth direction at user-defined radial distances from the crack origin. The residual K value for each crack is determined using the linear interpolation between points.

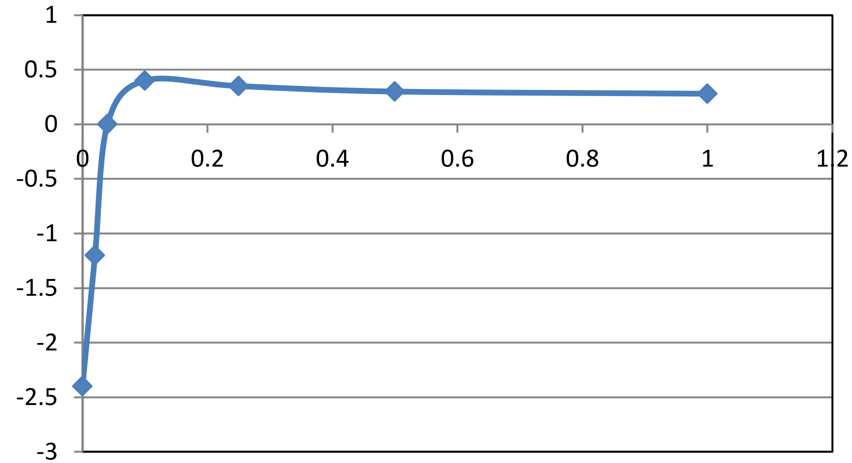
This can be an additional source for error if the crack shape is not relatively close to circular, but it is not practical to anticipate crack shape changes in advance.

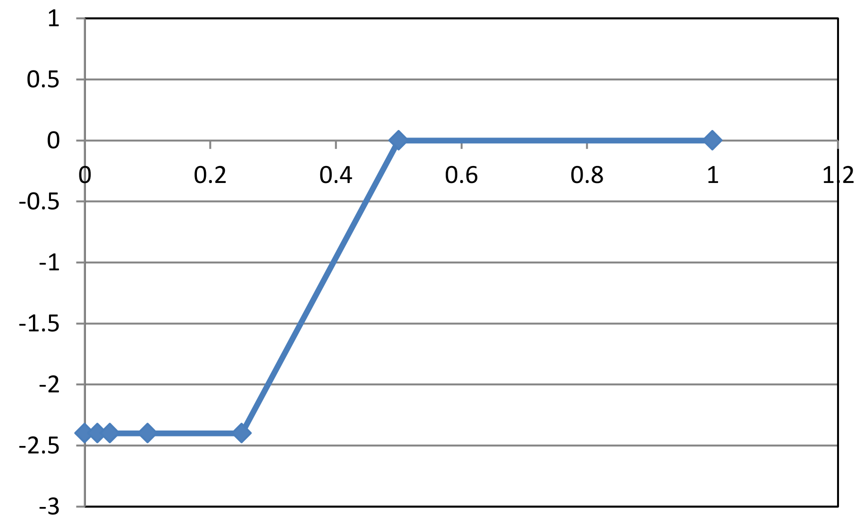


Assumed Residual Stress Distributions

X-Direction Y-Direction

r	Residual Stress (r,0)	Residual Stress (0,r)
0.000	-2.40	-2.40
0.020	-1.20	-2.40
0.040	0.00	-2.40
0.100	0.40	-2.40
0.250	0.35	-2.40
0.500	0.30	0.00
1.000	0.28	0.00

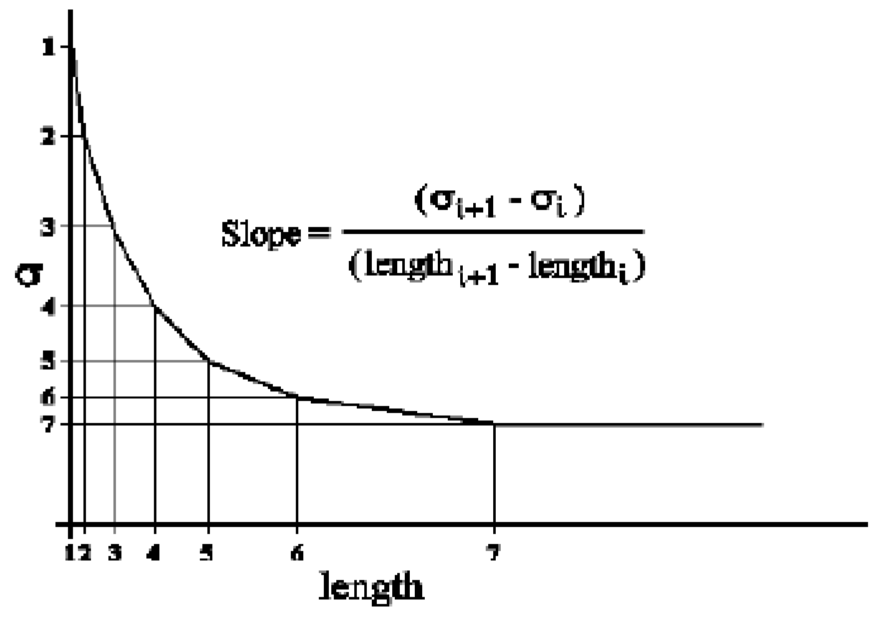




Note: The distribution in the thickness direction must go to zero for radial distances > thickness. Otherwise, the Gaussian integration will include the effect of the distribution on the resulting residual K estimate in the width direction.

Issue

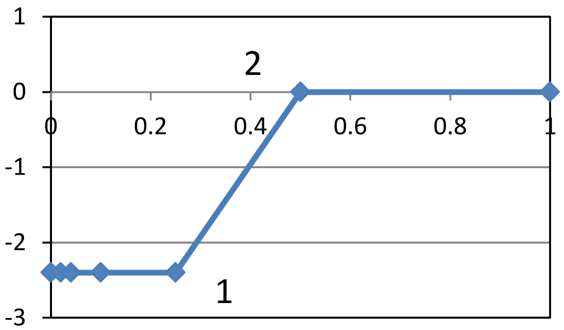
The Gaussian integration method is somewhat sensitive to the change in slope between integration points



Reasonable results have been obtained with the Gaussian method for:

$$\frac{dSlope}{dr} \leq |600|$$

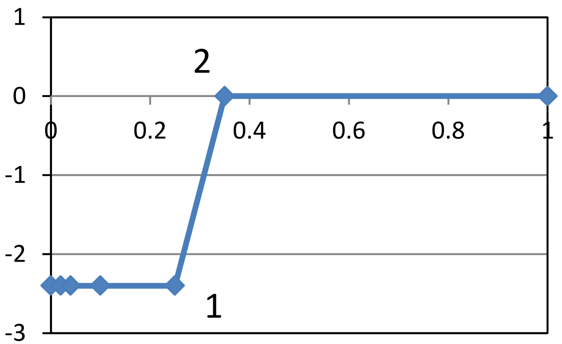
Examples



$dS_1/dR = 38.4$

$dS_2/dR = -19.2$

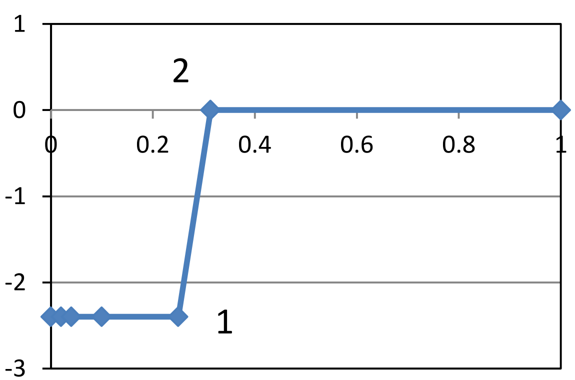
r	σ_a	$K_a$resid	σ_c	$K_c$resid
0.000	-2.400	-0.076	-2.400	-0.076
0.020	-2.400	-0.733	-1.200	-0.518
0.040	-2.400	-0.940	0.000	-0.254
0.100	-2.400	-1.365	0.400	-0.059
0.250	-2.400	-2.482	0.350	-0.226
0.500	0.000	-0.264	0.300	0.132
1.000	0.000	0.002	0.280	0.429



$dS_1/dR = 240$

$dS_2/dR = -36.9$

r	σ_a	$K_a$resid	σ_c	$K_c$resid
0.000	-2.400	-0.076	-2.400	-0.076
0.020	-2.400	-0.733	-1.200	-0.518
0.040	-2.400	-0.940	0.000	-0.254
0.100	-2.400	-1.262	0.400	-0.021
0.250	-2.400	-2.920	0.350	-0.368
0.350	0.000	-0.831	0.300	-0.188
1.000	0.000	-0.025	0.280	0.402

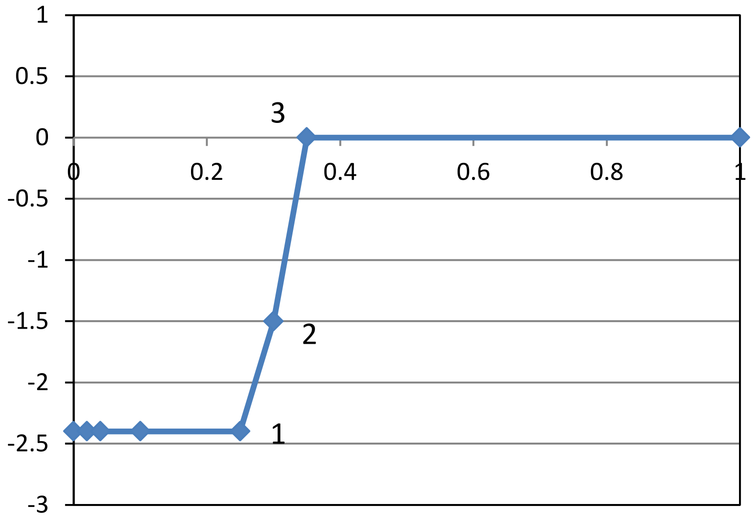


$dS_1/dR = 599$

$dS_2/dR = -55.2$

r	σ_a	$K_a$resid	σ_c	$K_c$resid
0.0000	-2.400	-0.076	-2.400	-0.076
0.0200	-2.400	-0.733	-1.200	-0.518
0.0400	-2.400	-0.940	0.000	-0.254
0.1000	-2.400	-1.144	0.400	0.021
0.2500	-2.400	-3.345	0.350	-0.503
0.3133	0.000	-1.336	0.300	-0.385
1.0000	0.000	-0.051	0.280	0.377

Adding Transition Points

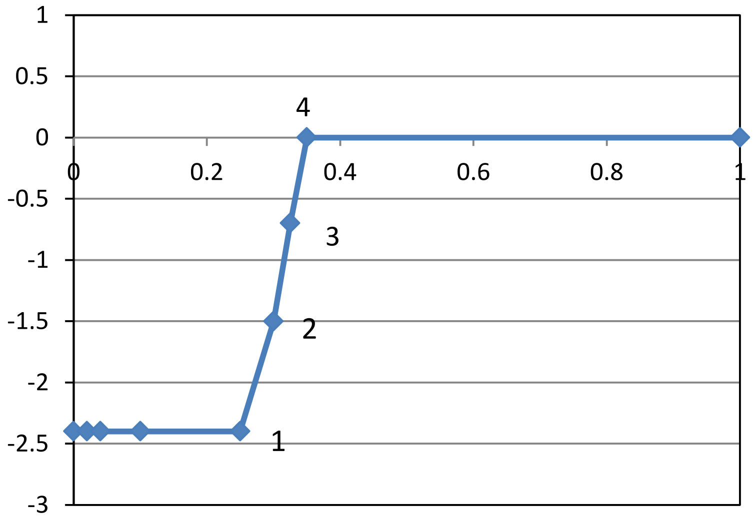


$dS_1/dR = 360$

$dS_2/dR = 240$

$dS_3/dR = -46$

r	σ_a	$K_a$resid	σ_c	$K_c$resid
0.000	-2.400	-0.076	-2.400	-0.076
0.020	-2.400	-0.733	-1.200	-0.518
0.040	-2.400	-0.940	0.000	-0.254
0.100	-2.400	-1.271	0.400	-0.025
0.250	-2.400	-2.256	0.350	-0.097
0.300	-1.500	-2.131	0.325	-0.133
0.350	0.000	-0.981	0.300	-0.094
1.000	0.000	-0.018	0.280	0.413



$dS_1/dR = 360$

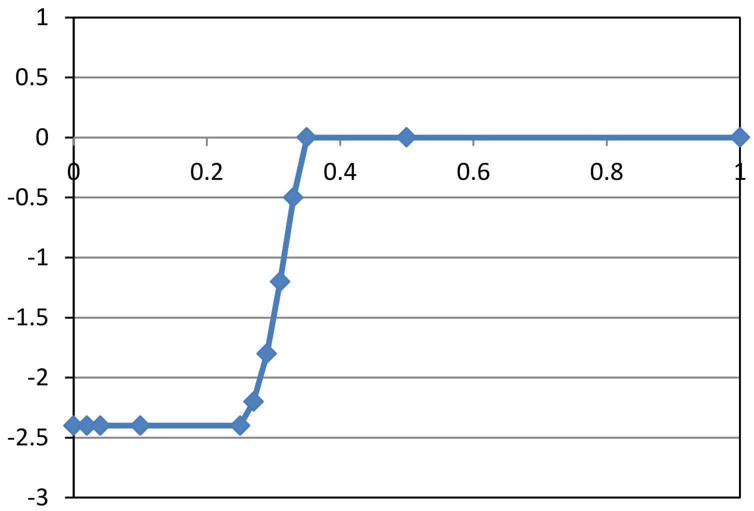
$dS_2/dR = 560$

$dS_3/dR = -160$

$dS_4/dR = -43$

r	σ_a	$K_a$resid	σ_c	$K_c$resid
0.000	-2.400	-0.076	-2.400	-0.076
0.020	-2.400	-0.733	-1.200	-0.518
0.040	-2.400	-0.940	0.000	-0.254
0.100	-2.400	-1.271	0.400	-0.025
0.250	-2.400	-1.993	0.350	0.011
0.300	-1.500	-2.035	0.325	-0.045
0.325	-0.700	-1.632	0.310	-0.054
0.350	0.000	-1.072	0.300	-0.042
1.000	0.000	-0.013	0.280	0.418

Using More Integration Points

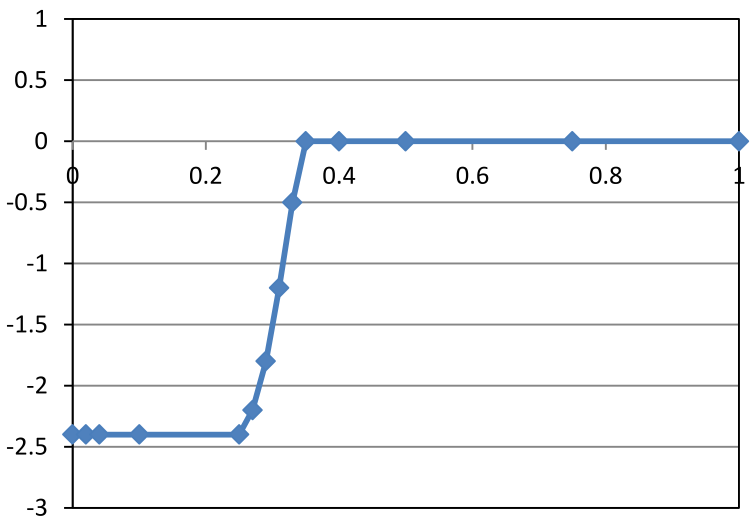


Added 5 new points to transition back to zero, keeping dS/dr < |600|

Point	dS/dr
1	500
2	500
3	500
4	250
5	-500
6	-166.667

r	σ_a	$K_a$resid	σ_c	$K_c$resid
0.000	-2.400	-0.076	-2.400	-0.076
0.020	-2.400	-0.733	-1.200	-0.518
0.040	-2.400	-0.940	0.000	-0.254
0.100	-2.400	-1.316	0.400	-0.042
0.250	-2.400	-1.718	0.350	0.122
0.270	-2.200	-1.834	0.340	0.094
0.290	-1.800	-1.827	0.330	0.069
0.310	-1.200	-1.689	0.320	0.050
0.330	-0.500	-1.352	0.310	0.043
0.350	0.000	-0.942	0.300	0.046
0.500	0.000	-0.287	0.300	0.180
1.000	0.000	0.010	0.280	0.441

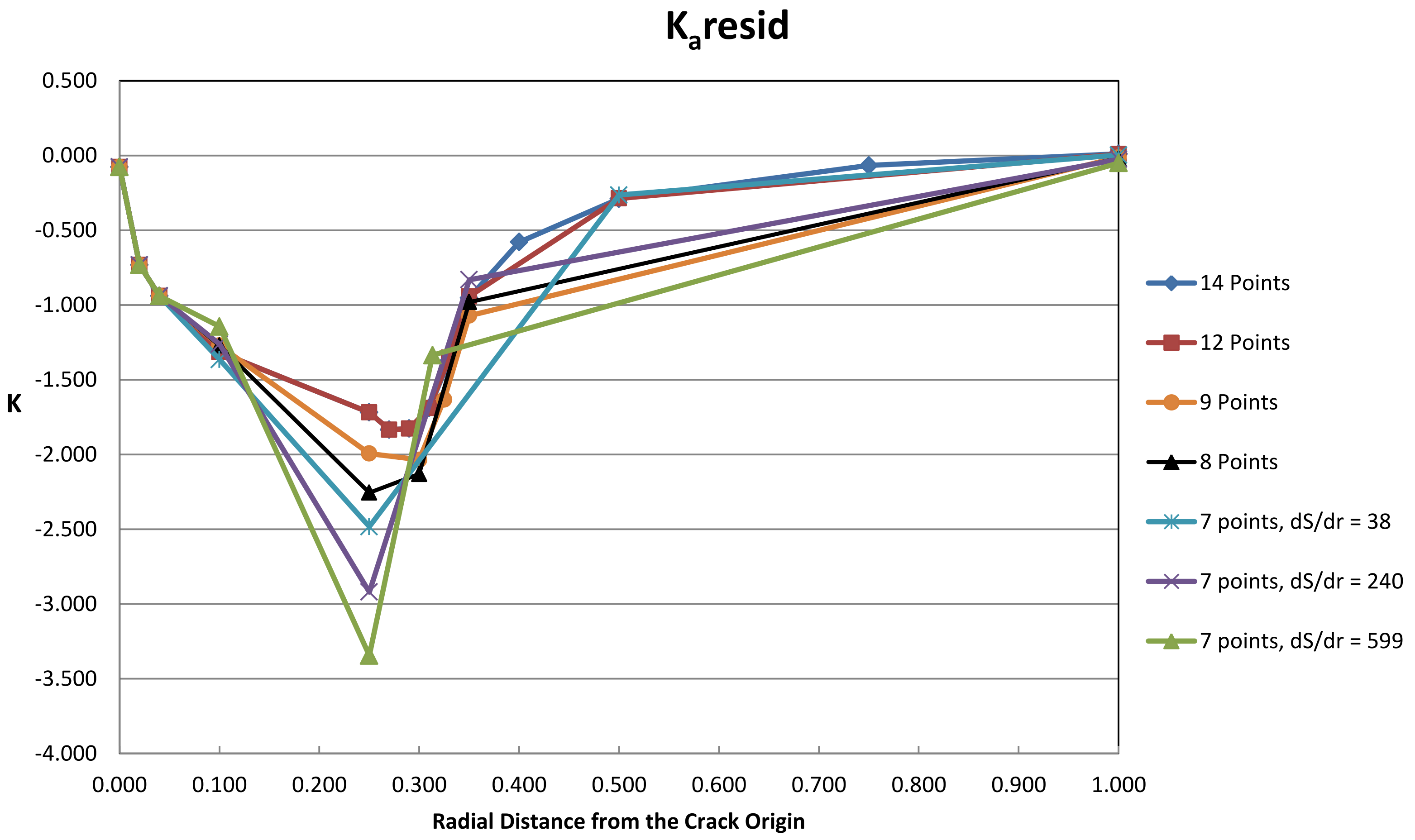
How About a Few More….



Just added two more points after the transition to zero in the y-direction (no difference in the slope changes)

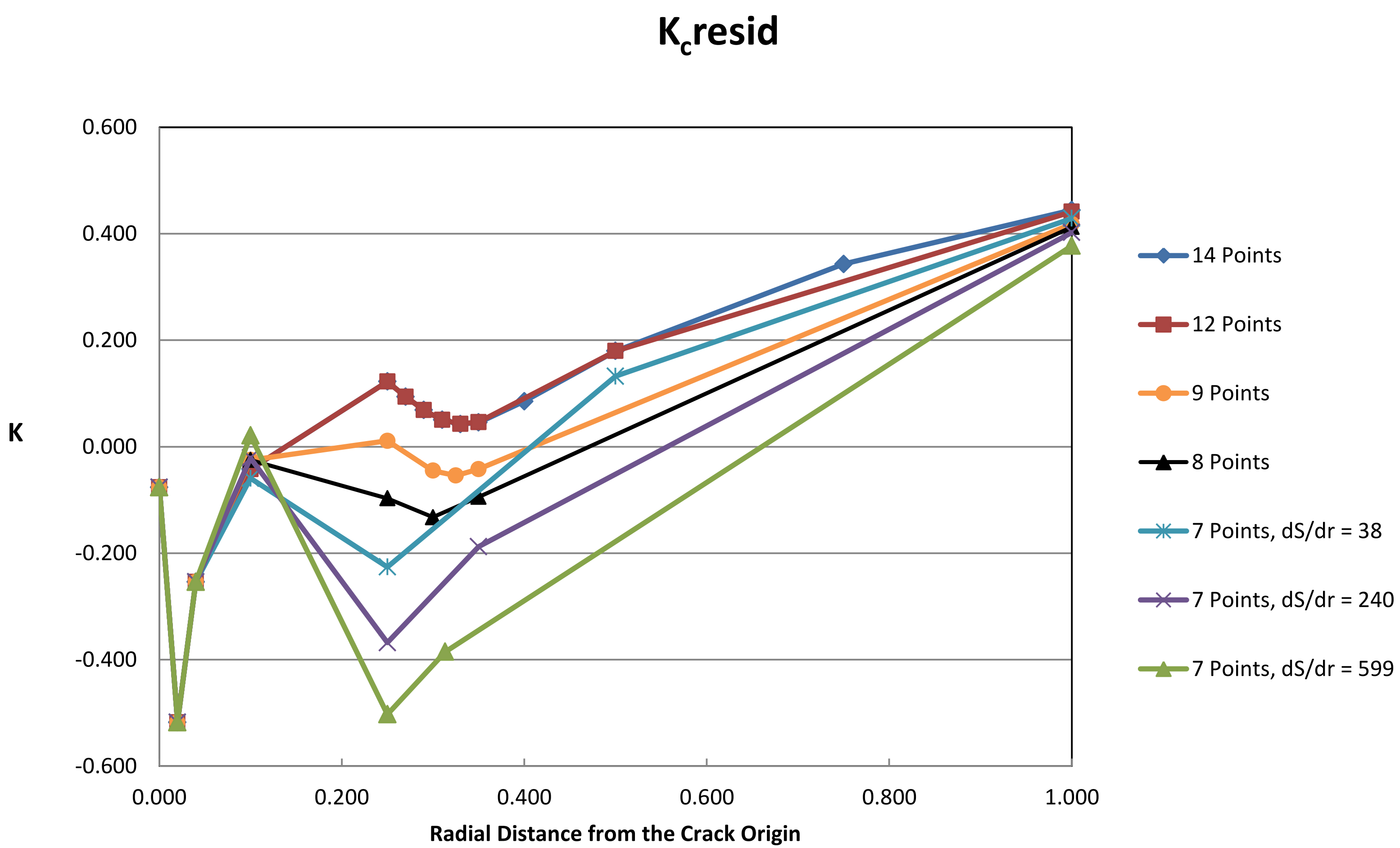
r	σ_a	$K_a$resid	σ_c	$K_c$resid
0.000	-2.400	-0.076	-2.400	-0.076
0.020	-2.400	-0.733	-1.200	-0.518
0.040	-2.400	-0.940	0.000	-0.254
0.100	-2.400	-1.316	0.400	-0.042
0.250	-2.400	-1.718	0.350	0.122
0.270	-2.200	-1.834	0.340	0.094
0.290	-1.800	-1.827	0.330	0.069
0.310	-1.200	-1.689	0.320	0.050
0.330	-0.500	-1.371	0.310	0.042
0.350	0.000	-0.953	0.300	0.045
0.400	0.000	-0.580	0.300	0.085
0.500	0.000	-0.290	0.300	0.180
0.750	0.000	-0.067	0.290	0.343
1.000	0.000	0.011	0.280	0.444

Summary



$K_a$resid
0.500
0.000
-0.500
-1.000
-1.500
-2.000
-2.500
-3.000
-3.500
-4.000
K
0.000
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
0.900
1.000
Radial Distance from the Crack Origin
14 Points
12 Points
9 Points
8 Points
7 points, dS/dr = 38
7 points, dS/dr = 240
7 points, dS/dr = 599

Summary, continued



Conclusions

- Keep slope changes between integration points below |600|
- Use multiple points (>3) to make the transition to s = 0 in the y-direction for r > thickness
- Minimize the transition distance as much as possible to minimize the error caused by the transition points.
- It is generally helpful to include multiple points for uniform stress distributions to decrease potential interpolation errors in the resulting stress intensities.

Remember

The beta correction capability uses the same Gaussian integration method, so the same rules apply with one major exception:

The stress ratio values used for the y-direction for r > t must be set to 1.0 (not 0.0). This is because the beta correction calculations take a ratio of the calculated K for the input stress distributions divided by the K calculated for a unit stress distribution. Using a stress ratio of 1.0 beyond the thickness, means that there will be no net effect on the calculations in the x-direction for r > t.

There is a document on the AFGROW Web page (**Using AFGROW's Beta Correction Capability**) that demonstrates the use of the beta correction capability for a plate with out of plane bending.