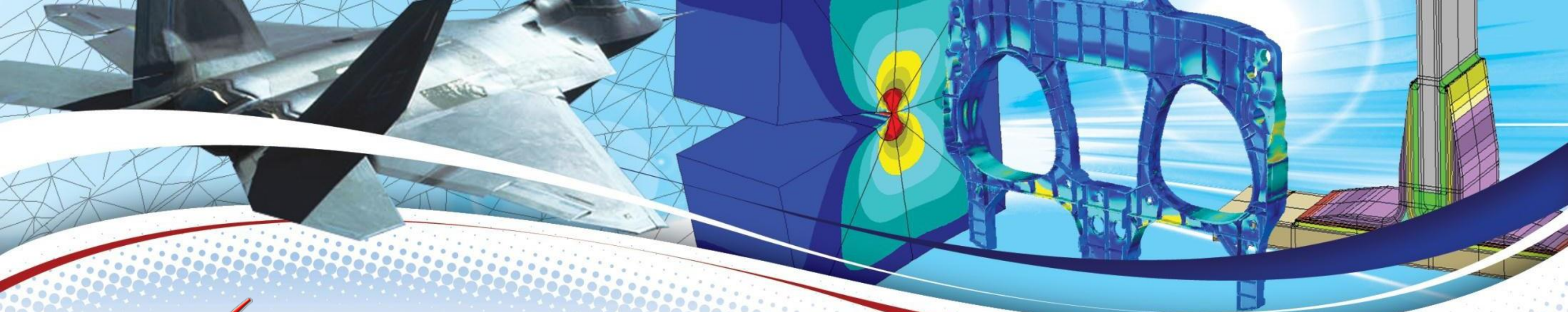


StressCheck®

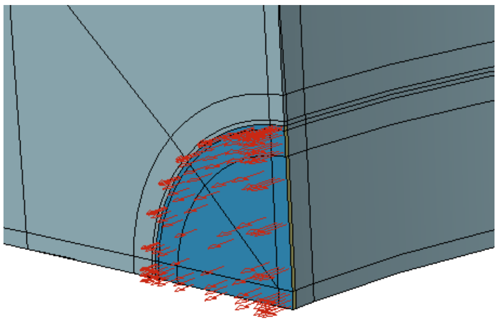
FRACTURE MECHANICS ANALYSIS WITH RESIDUAL STRESS (RS)

Assess the Influence of Residual Stresses on DaDT Predictions

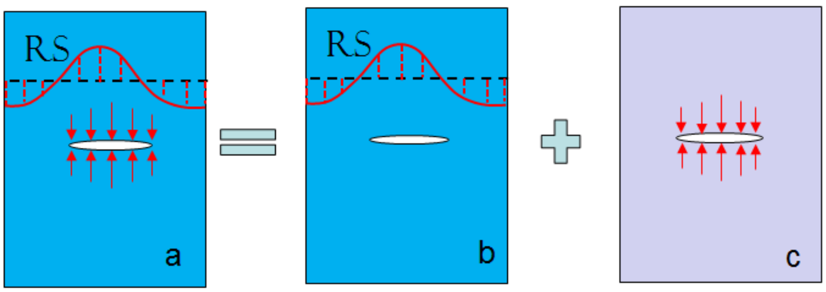
Reliable prediction of crack growth and residual strength in metallic structures requires accurate computation of stress intensity factors. To make these challenging tasks more practical, StressCheck® provides a means for the computation of both the separated J-integral components J_I, J_{II}, J_{III}, and the corresponding stress intensity factors K_I, K_{II}, K_{III} for cracks in the presence of residual stresses.

Contour Integral Method with a Loaded Crack (CIM-LC)

As it is, in general, difficult to measure all six components of residual stress throughout a body, the robust contour integral method has been expanded to compute K_I with only the minimal required residual stress information*. If the residual stress component normal to the crack face is known, it can be applied as a crack face pressure; any residual stress distribution can be represented by a formula as a function of local in-plane spatial variables and applied to the crack face.



Formula-defined residual stress load applied to corner crack face of a finite element mesh



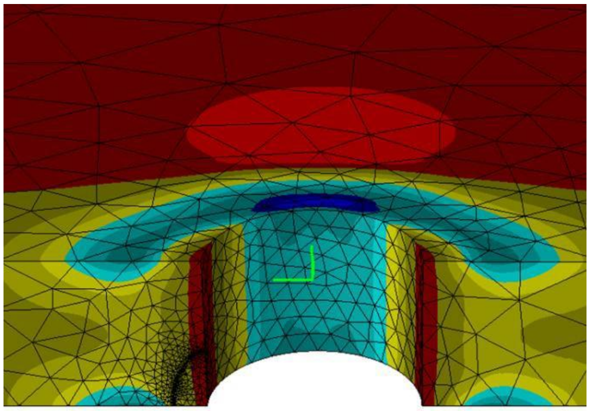
$K_{1a} = K_{1b} + K_{1c} = 0 \rightarrow \mathbf{K_{1b} = -K_{1c}}$

J-Integral for Residual Stresses

If the full residual stress distribution is known, the J-integral can be used to calculate **J_I, J_{II}, and J_{III}****. New in StressCheck 10.1 is the capability to convert J into K, providing **K_I, K_{II}, and K_{III} in a residual stress field**.

$$J = \int_\Gamma \left(W\delta_{1i} - \sigma_{ij} \frac{\partial u_j}{\partial x_1} \right) n_i \, ds + \int_A \sigma_{ij} \frac{\partial \varepsilon_{ij}^0}{\partial x_1} dA = J_\Gamma + J_A$$

$$K_I = \sqrt{\tilde{E} J_I} \qquad K_{II} = \sqrt{\tilde{E} J_{II}} \qquad K_{III} = \sqrt{2 G J_{III}}$$



Corner crack defined by a spline in a residual stress field

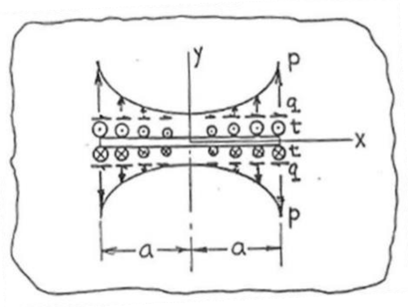
*Pereira, J.P. and Duarte, C.A. (2006). *The Contour Integral Method for Loaded Cracks*, Communication in Numerical Methods in Engineering, Volume 22, pp 421-432. DOI: 10.1002/cnm.824

**Lei, Y., O'Dowd, N.P. and Webster, G.A. (2000). *Fracture Mechanics Analysis of a Crack in a Residual Stress Field*, International Journal of Fracture, Volume 106, pp 195-216.

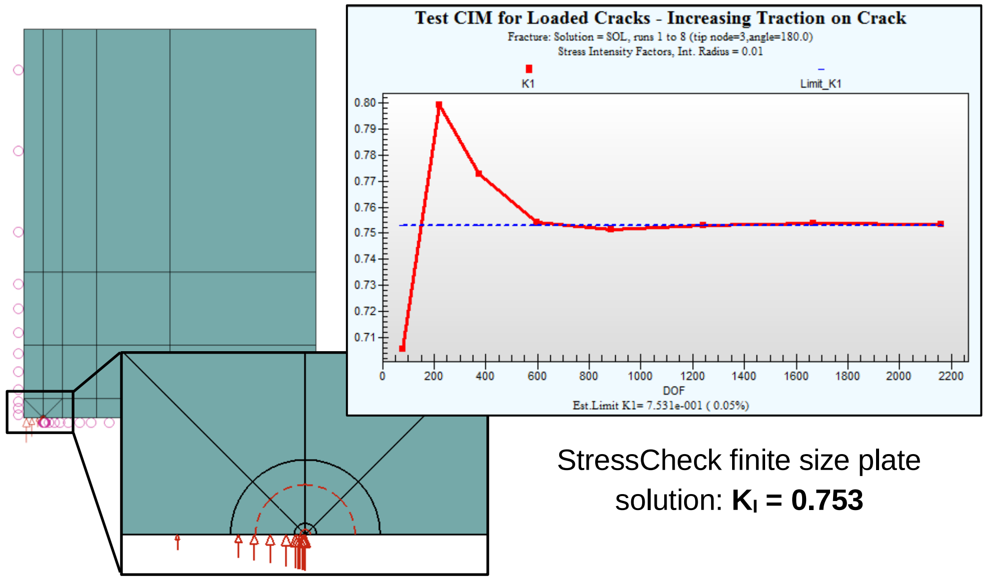
***Tada, H. *Stress Analysis of Cracks Handbook*, Case 11.1.

Comparison with Tada Handbook

Published exact solutions for stress intensity factors with loaded crack faces are available in the Tada Handbook***, providing a benchmark for tools that compute stress intensity factors. The StressCheck solution matched the published solution for all cases considered. For example, consider a loaded crack with increasing pressure toward the crack tip.



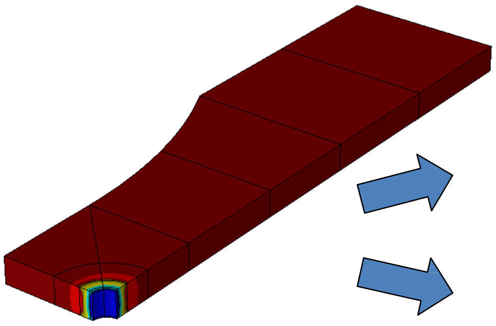
Infinite plate solution: $\mathbf{K_I = 0.752}$



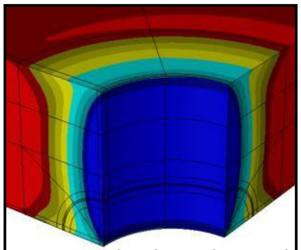
StressCheck finite size plate solution: $\mathbf{K_I = 0.753}$

Comparison of J-Integral and Contour Integral Method

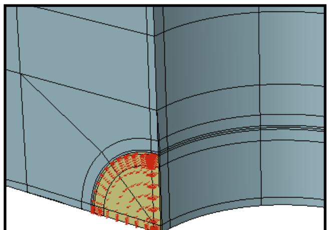
The StressCheck Incremental Plasticity module was used to simulate the coldworking process of a fatigue test specimen, producing the complete residual stress tensor throughout the specimen. The residual stresses were then transferred to a body with a 0.025" corner crack, and used as input for linear analyses leading to stress intensity factor computation by the J-integral and by the contour integral method with a loaded crack face. Both methods provided results which are very close to each other.



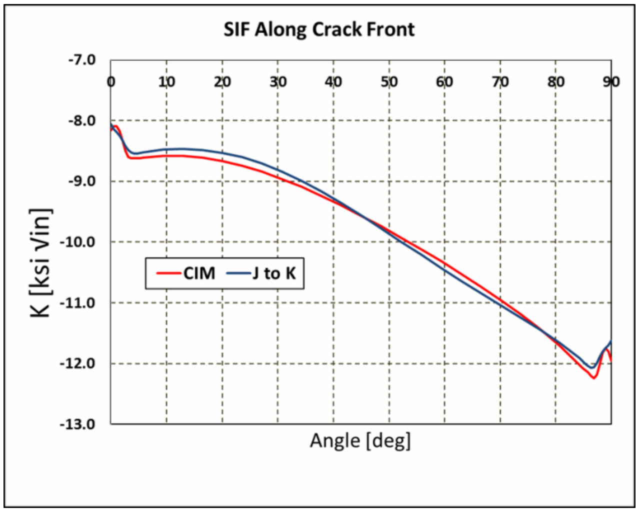
Simulated cold working (no crack)



Computed using J-integral



Computed using CIM-LC



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