Interference Fit Fastener Prediction Challenge

QUESTIONNAIRE

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Name:

Organization:

Please provide information about the analyses completed:

1. Analysis Software (name and version)
    a. FEA software (if applicable): StressCheck
    b. Crack growth software: AFGROW

2. FEA Model Setup (if applicable)
    a. Describe the boundary conditions utilized in the FEMs, to include applied loads and constraints

    I used StressCheck to model the interference effect for the 2-D case (single through crack at a hole) using a fastener element and the specimen geometry provided. The model was constrained on one edge and loaded in traction on the opposite edge. The model height was 5X the width to eliminate any height effect.

    b. Describe the methods to define and control the crack front shape and control meshing along the crack front

    I used the AFGROW Advanced Model interface for a corner crack at a hole with two growth directions. The FE results were only used to estimate the interference effect as described in detail below.

3. Interference Fit Modeling
    a. Describe the methods used to characterize and incorporate the effect of the IFF.

        I used StressCheck to model the effect of interference for a 2-D, single cracked hole with a fastener element set to the appropriate level of interference. Material properties for 7075-T651 were used for the plate and generic steel properties were used for the fastener element.

        Three cases were modeled for several crack lengths:

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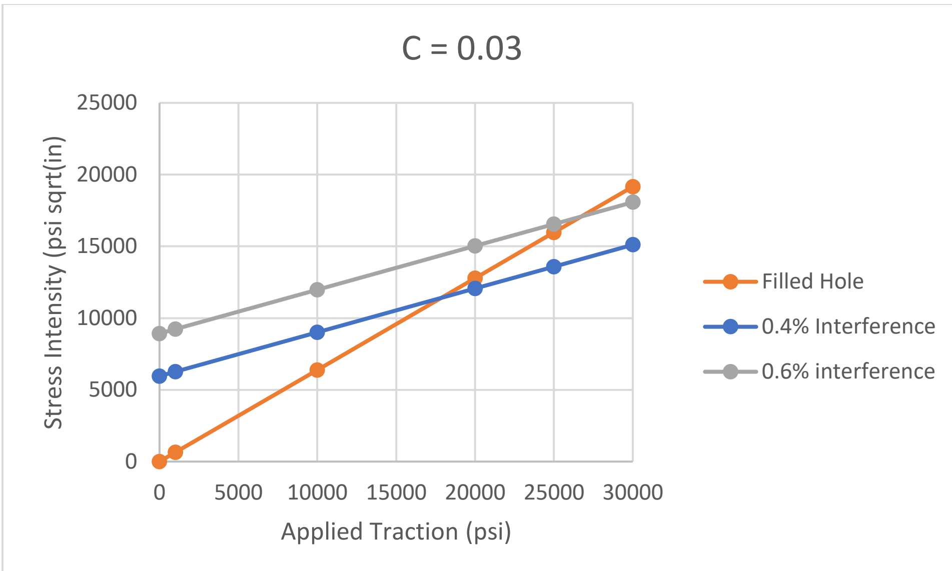
Filled, unloaded hole
0.4% fastener interference
0.6% fastener interference

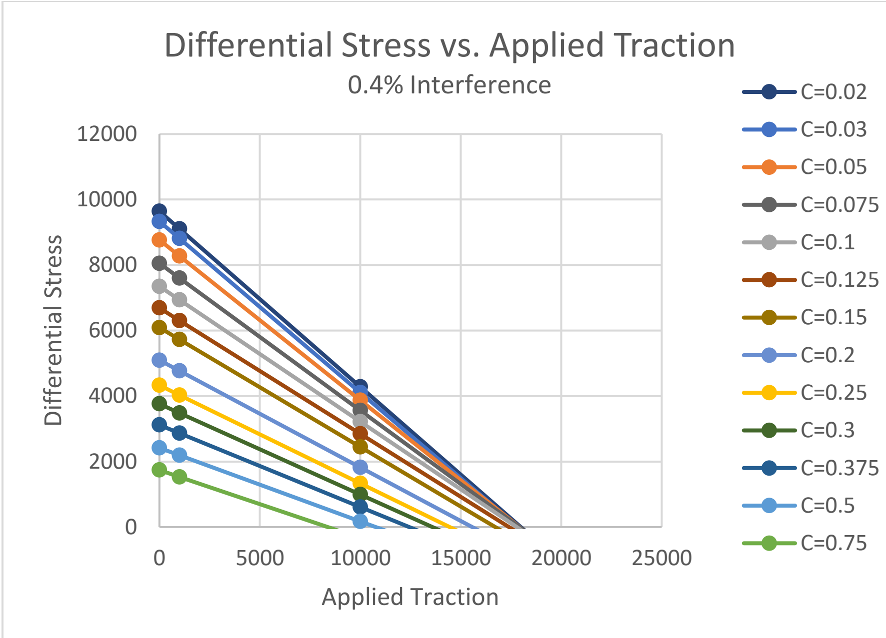
Here is an example of the results for C = 0.03 inches

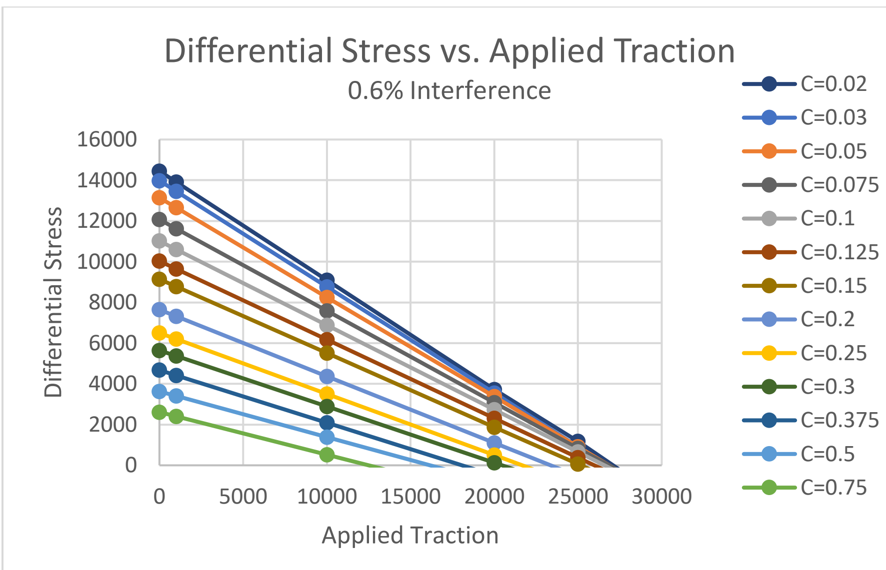


I ran StressCheck for applied tractions between 0 and 30 Ksi and found that the relationship between applied traction and K was nearly linear until the curves approached the filled, unloaded hole curve. I assumed a bi-linear relationship between K and applied traction. The relationship between the applied traction and K would follow the linear interference fit relationship established between 0 and 1Ksi until this line reached the filled hole line. The filled hole line would define K for all traction values above that point.

Since I did not model a corner crack, I estimated the K-solution for the interference fit cases by using a differential stress method. For the through crack cases, K is determined using the bilinear approach described above. The difference between the stress intensity values for the interference case and the filled hole case was used to determine a "differential" stress as a function of applied traction for a number of crack lengths as follows:

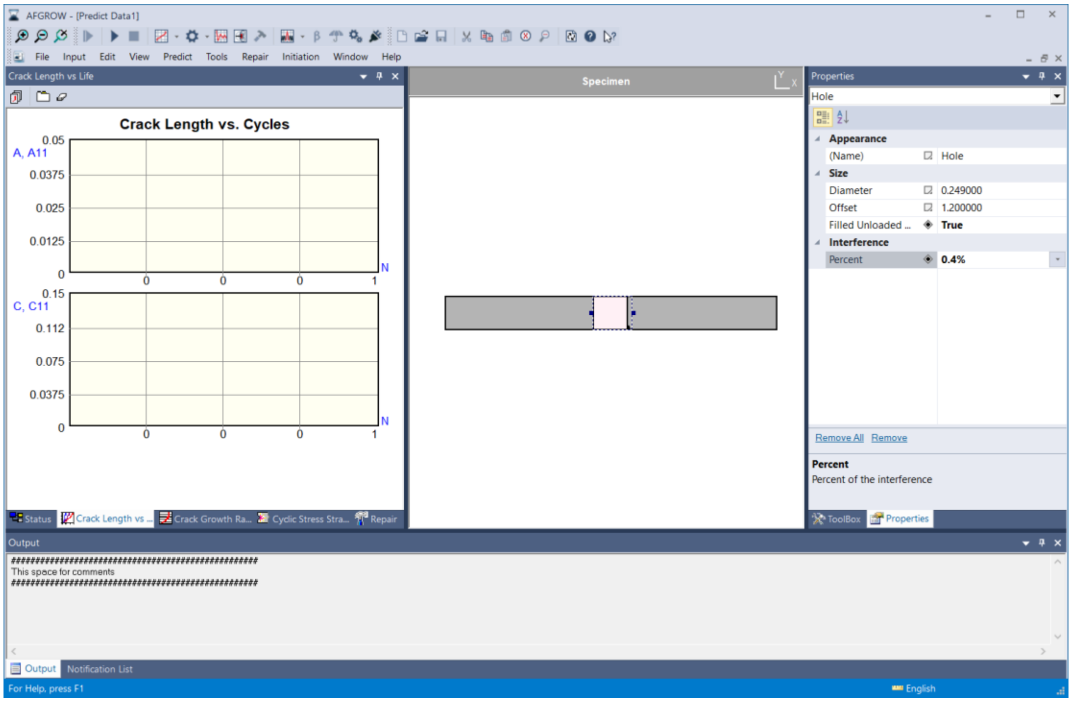
$$\sigma_{differential} = \frac{\left(K_{interference} - K_{filled\ hole}\right)}{\sqrt{\pi\ crack\ length}\ \beta}$$





The beta value is the beta value for the filled hole solution for the 2-D through crack.

The K-solution for a filled, unloaded hole was added to the K-solution for the appropriate differential stress (by interpolation of the data shown above). If the differential stress was negative, then it was set to zero since that defines the point where the two lines intersect. The filled hole correction was added to the Advanced Model interface and the above method was implemented in a beta version of AFGROW. The method used to estimate the equivalent crack length used to estimate the differential stress for the corner crack is provided in paragraph 6.



b. If the fastener effect was derived from a closed form solution, what were the assumptions of the solution? Is the solution based on empirical data or FEM correlations?

Refer to the description above

c. If the fastener was modeled using FEA, does the model consider non-linear effects? Was multi-body contact used? If contact was used, what friction related assumptions were made?

Yes, StressCheck uses a non-linear method to converge the contact solution for the fastener element. However, the material properties used in this prediction were all linear.

4. Stress Intensity Calculations
    a. Describe the methods used to extract and calculate the stress intensities for applied remote loads

       I used the AFGROW Advanced Model Interface with the current AFGROW filled, open hole correction.

    b. Describe the methods used to incorporate the stress intensities into the crack growth code (superposition, etc.)

       As discussed above, superposition of the filled hole and interference fit K's obtained using the differential stress method was used to estimate the total K for each case.

5. Crack Growth Predictions
   a. Describe the material model approach used for the crack growth predictions (NASGRO, tabular, etc.) and the assumptions/approach used for "threshold", stress ratio (R) shift, and negative R behavior.

   I used the tabular data provided and the AFGROW tabular look-up model. The threshold was based on the value of K for the lowest growth rate in the table for R=0. The data shifting uses the Harter T-method as implemented in the AFGROW tabular look-up model.

   b. What growth increment was utilized between stress intensity calculations?

   I used cycle-by-cycle beta and spectrum calculations as the AFGROW Preference setting.

6. Provide any additional details that may be pertinent to the analyses completed

The method used to account for the expected difference between the change in differential stress for a corner crack and the through crack were simply my best guess. The change differential stress for corner cracks will be different than it is for a through crack. I attempted to account for this using an equivalent crack length which would be less than the through crack length until the crack becomes a through crack. The differential stress curves appear to be converging at c=0.02, so I assumed this was the lower limit (for practical purposes). At transition to a through crack, the model must return to the through crack behavior. So, the relationship I assumed for the corner cracks was as follows:

$$C_{equivalent} = 0.02 + a/t\left(C - 0.02(a/t)\right)$$

For all crack lengths, $C_{equivalent}$ must always be <= C. I also assumed that transition to a through crack would occur when K=KIe (or, 140% of KIc)

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