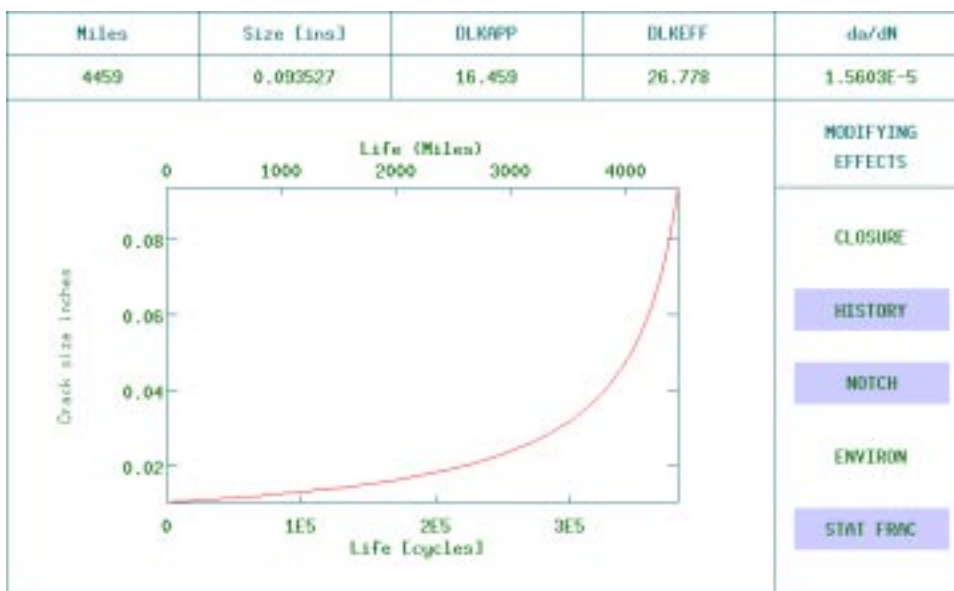


LESSON 8

Crack Growth (LEFM) Analysis of the Keyhole Specimen



Objectives:

- To calculate the life of the specimen during the crack growth phase.
- To investigate the effect of a residual stress on crack growth life.
- To investigate the effect of different environments on fatigue life estimates.



Problem Description:

The main purpose of this exercise is to study the crack growth behavior of the SAE “keyhole” specimen. The geometry of this specimen is defined below where the dimensions are given in inches. The loading location and magnitude in Newtons is shown in FIGURE 7.

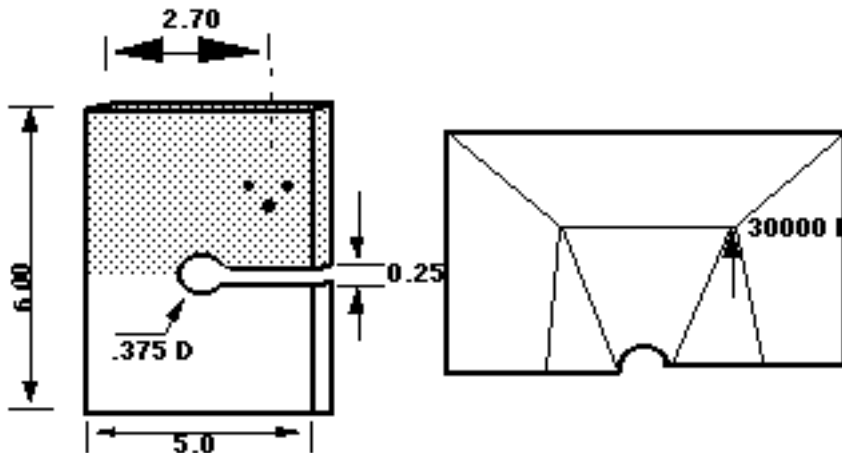
Step 1 Problem Description

FIGURE 7. Geometry and Loading of Keyhole Specimen.

To carry out a crack growth calculation, we need to consider the loading, the shape factor (also known as a Y, Beta, or compliance function) and the materials data.

The loading history, SAETRN, has already been utilized in the previous exercises. This has been scaled to represent the actual loading applied during an operational cycle. The scaled history is obtained by multiplying the unscaled version of SAETRN by 15.87. This loading history represents 10 miles of actual operation of the specimen.

The geometry of this specimen is similar to a compact tension specimen for which we must define a K solution, and store it under filename **keyhole.ksn**.

For the purpose of this exercise, we will assume that the specimen was made of BS4360-50D steel. This is a common low alloy structural steel. Fracture mechanics and crack growth materials data have already been entered into the materials database for this material for a number of environments.

For proper execution of the exercise, be sure you are in the **ex08** directory of your PAT318 account. Also convert the file **key.txt** to **key.res** using RESTXT.

Exercise Procedure

Enter PATRAN 3 and import key.out file as was done in exercises 3 and 5. Inspect the stress results.

Step 2 Using PATRAN

Q1: Which nodes correspond to the remote stress area?

A1:

Step 3 Setting up the P3/FATIGUE job

Go to PATRAN 3 main menu and enter the P3/FATIGUE menus. In the P3/FATIGUE main menu make the following selections:

Crack Growth	The <i>Analysis</i> type that we are performing is Strain Life or crack initiation analysis
Nodal	Use stress <i>Results</i> at nodes.
Stress	Use stress <i>Tensor</i> of the results.
MPa	Stress <i>Units</i> as prescribed from the P3/FEA job are MPa
key	Enter the <i>jobname</i>
	Use the Title to give a description of the job. (LEFM analysis of the plate assembly)

The next step is to define the job parameters. Use the stresses from the FE analysis and you could choose either the Max. Abs. Principal stress or the Signed Von Mises stress, as the principal stress field is highly aligned to the global X-direction. Remember the sum of the point load applied in the FEA is 9.067 kN. Stresses are in MPa.

Solution Params... Click on the Solution Params button in the P3/FATIGUE form.

At this point you are required to define the compliance function. This is done by spawning off a P3/FATIGUE module called PKSOL.

Compliance Gen. Click on the Compliance Generator button on the solutions parameters form.

Enter the following keystrokes once this module appears.

- 3. Inches** Select inches. This must be the same unit system that you used when you defined the crack size.
- 4. Gen. a Y funct.** Option to generate a Y function table.
- keyhole** File name.
- 1. Standard spec** It is a standard specimen
- 8. Comp. ten. spec** It is a compact tension specimen.
- Define** Click on **Define** when the graphics appears.
- 0.375** Dimension B.
- 3.7** Dimension W.
- return** Press **return** key.
- Calculate** Click on **Calculate** to make the function table.
- eXit** Exit from PKSOL.

Now you can continue the job setup in the solution parameters form.

- keyhole** *Select a Compliance Function* from the listbox.
- Inches** *Crack Length Units*
- 0** *Initial Crack*
- 2.357** *Final Crack*
- 2.3** *Notch Depth* due to machined slot.
- 0.1875** *Notch Radius.*
- 1E-4** *Sharp Crack Radius.*
- OK** Click on the OK button to close the Solutions Parameters form.

Since you are using new materials data, you should review the LEFM material data to form the basis for future life estimate conclusions.

Step 4 Materials Data

Materials Info... Click on the **Materials Info** button to review materials data.

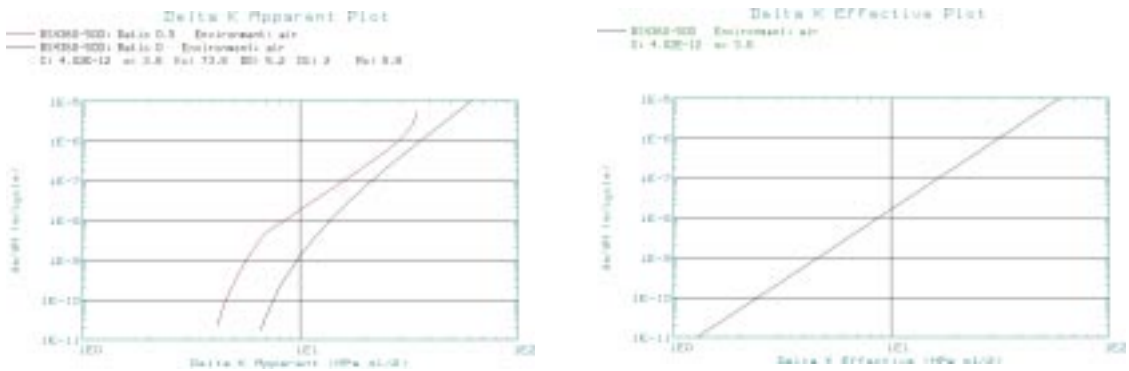
Database Manager This will spawn the PFMAT module.

The P3/FATIGUE materials database manager. The data set we wish to review here is BS4360-50D and in particular we wish to inspect the LEFM properties.

Q2: How can we compare the same crack growth data sets for the R ratios?

A2:

At this stage we can look at the materials data curves using the graph option. You should examine both effective and apparent K da/dN curves as well as the threshold - K plot.



Q3: What is the difference between the effective and apparent values of Δk ?

A3:

Once you return from the PFMAT module, you may resume setting up the Fatigue job as follows:

1 Set the *Number of Materials* to one.

BS4360-50D Click on the *Material* table cell in the Selected Materials Information spread sheet. In the

- Select a Material: listbox, click on the MANTEN material.
- air** Select an Environment from the *Select an Environment* listbox.
- default_group** In the *Select a Group* listbox, select the only group available; default_group.
- OK** Click on the OK button to close the form.

Before we proceed to set up crack growth analysis, we must create a loading time history exactly the same way as exercises 3 and 5, except use a fatigue equivalent unit of 10 Miles, i.e., each repeat of the time history is equivalent to ten miles.

Step 5 Time History Information

Q4: What type of analysis do we wish to carry out?

A4:

Now the job setup is complete. Submit the job and monitor it with the **Monitor Job** option. You observe very slow crack growth. Therefore, abort the job by picking **Abort Job**.

Go to the **Optimize** pick from the **Results...** menu. This will invoke the P3/FATIGUE module called PCRACK which does the actual crack growth calculation. You will be initially presented with six screens as you set up another crack growth job. All the screens will have the default parameters that were originally used when set up in PATRAN. Fill out the screens as follows:

Step 6 Reviewing Results

- F1** Accept screen one as is.
- Output Interval Change to **28.5**.
- Update Interval Change to **28.5**.
- F1** Accept screen two.
- F1** Accept screen three as is.
- F1** Accept screen four as is.

Environment Change this to a harsh environment such as **seawater/H2S**. You can use the **F3** key to obtain a listing after highlighting the environment field.

F1 Accept screen five.

F1 Accept screen six as is.

At this point you can graphically watch the crack grow to failure. The output interval and update interval will ensure a non zero crack growth rate as shown on final situation window.

Q5: What is the failure method?

A5:

Q6: What is the crack size? How many repeats before you observe failure?

A6:

When you have investigated the Final Situation, press the **return** key and you will be presented with the PCRACK main menu. Like DESOPT you can change parameters and recalculate. Parameters may be changed under the **Edit analysis parameters** submenu or you may start another job from scratch as you did when you entered PCRACK. Change some of the analysis parameters such as initial crack size, time history offset (which can simulate a residual stress), scaling factor, or other materials/ environments to see how these affect the crack growth life estimates, if you have time at the end of this exercise.

- A1: By reviewing the stress results, we choose nodes 636, 637, 638, 649, 650, 656, 657, 658, since they correspond to the remote area. By choosing more than one node, we avoid picking one node with non-average results. Basically the far field stress used in a crack growth analysis is that stress which would have been there if there were no crack. So for our simple example, it could simply be P/A . The nodes indicated above are nodes which lie in an area where the stress is fairly even and best represents this P/A stress.
- A2: First load in BS4360-50D into data set one. We need to do this again for materials set 2 so that we have BS4360-50D available in both data sets. Then go into the **Graphical display** option. You can plot apparent Δk , effective Δk , or threshold:ratio Δk curves and enter different R ratios for apparent Δk plots.
- A3: The apparent Δk value is the one calculated from the current stress amplitude with no corrections for notches, load sequence, corrosion and loading rate. The effective Δk is the driving force actually experienced by the crack and includes all the necessary history corrections and is also effectively linearized.
- A4: Crack Growth, option 3.
- A5: The effective stress intensity, K exceeded the fracture toughness of BS4360-50D
- A6: Crack size = approx. 0.7 inches, life (Miles) = approx. 3,500

