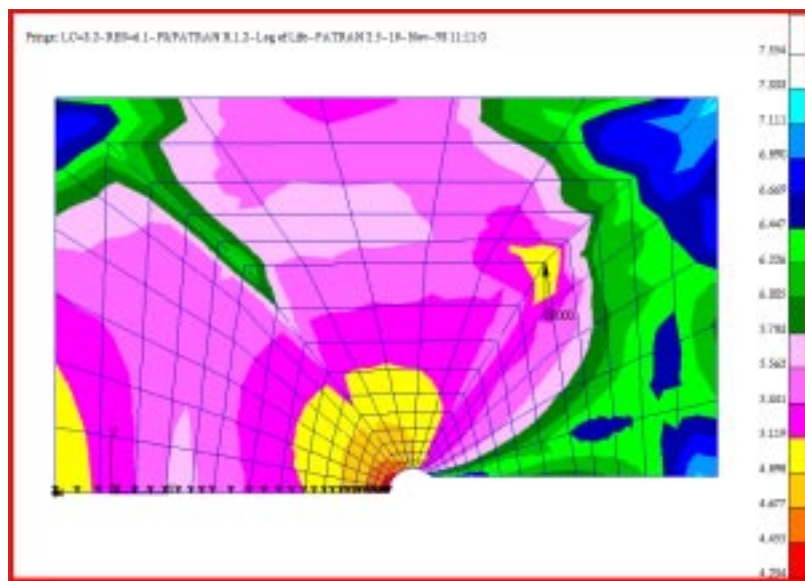# LESSON 3

Total Life (S-N) Analysis of Keyhole Specimen

Objectives:

■ To calculate the fatigue life for a component made from MANTEN under a "transmission" loading with a maximum value of 1.586×10^4 N using the Total Life method.

■ To investigate the effect of scatter on the S-N curve based on the design criterion parameter.

■ To investigate the effect of mean stress on fatigue life.

■ To make a comparison between the two materials MANTEN and RQC100 under the above conditions.

Total Life (S-N) Analysis of Keyhole

Problem Description:

This exercise is concerned with the fatigue analysis of a simple "keyhole" specimen as shown in FIGURE 3. The loading location and magnitude in Newtons is also shown. In a series of experiments, different constant amplitude cyclic loads were applied to a set of specimens until they broke into two pieces. The stress was monitored at the root of the notch (1/2 radius from the hole along the line of direction of the notch) and a stress-life line determined by regression analysis of the scattered points.
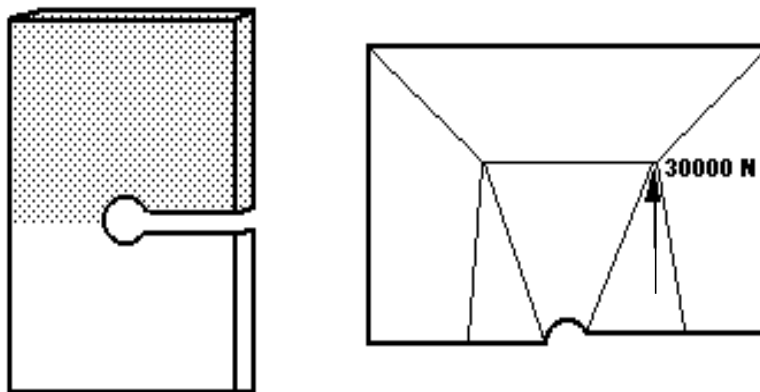

FIGURE 3. **Keyhole Specimen Geometry.**

Two different materials were used for the specimens; MANTEN and RQC100. This lead to two S-N data sets as listed in Table 2-2. In reality, the specimen is loaded with 3 random time histories, corresponding to typical histories (as defined by the SAE) for transmission, suspension and bracket components at different load levels.

To ensure proper execution of the exercise, make sure you are in the **ex03** directory of your PAT318 account.

Table 2-2 Material Properties

Material Properties	MANTEN	RQC100
Stress Range Intercept, SRI1 (MPa)	3162	4680
Slope b1,	-0.2	-0.216
Transition life, NC1 (cycles)	2E8	1E8
Slope b2,	0	0
Fatigue Limit, FL (MPa)	10	10
Standard error, SE	0.137	0.433
Young's Modulus, E (MPa)	2.034E5	2.034E5
UTS (MPa)	600	800

A finite element analysis was performed with a static loading of 30kN and the results stored in the file **key.res**. This file will have to be created by translating a file called **key.txt** from text format to binary format using the PATRAN utility program called RESTXT.

Exercise Procedure

Step 1 Using PATRAN

Enter PATRAN and read the Neutral file **key.ntl** by typing the following PATRAN commands:

p3   Start PATRAN3 from the UNIX prompt.

File/New Database   Open the File pull-down menu. Select New Database from the pull-down menu.

KeyHole   Enter the name KeyHole in the New Database Name databox. Click on the OK button. When the New Model Preferences form

appears, change the preference to P3⁄FEA, click on the OK button to close the form.

File/Import In the Neutral Files listbox, select the file key.out. Click on the OK button to begin the model import operation. Acknowledge the Question form application NEUTLOD.

Import and examine the stress results (this assumes you know how to use PATRAN, if you do not ask the instructor). Also plot the force and constraints.

Analysis Open the analysis form.

Read Results Set the Action option menu to read results.

Select Results File In the Select File form, select the file key.res from the Available Files. Click on the OK button to close the form.

Apply Read the results file into the database.

Load/BCs Open the Load/Boundary Conditions form. Change the Action option menu to Plot Markers.

Select all the Load/BC sets to be plotted to the default_group. Click on the Apply button.

Finally, use the Results Display form to examine the results and answer the following question.

Q1: Which node corresponds to the measurement point for the S-N curve? Which node corresponds to the point of highest stress?

A1: _____

_____

_____

Go back to the PATRAN main menu.

Applications Open the Applications pull-down menu. *Step 2 Materials Data*

P3/FATIGUE Open the P3/Fatigue form.

Now the P3⁄FATIGUE form is displayed. The options are in the correct order for setting up and submitting the fatigue analysis. First you must consider materials data, in this case, the form of a component life curve.

Q2:   What type of analysis is this?

A2:
_____

_____

_____

S-N Comp.   The Analysis type that we are performing is Component Nomial Stress Life

Q3:   What is the difference between a component and a material S-N curve?

A3:
_____

_____

_____

Nodal   Use stress results at nodes.

MPa   Stress units as prescribed from the FEA job are MPa

Max.Abs.Pr.   Select the Maximum Absolute Principal stress.

keysn   Enter the jobname

                        Use the Title to give a description of the job. (S-N analysis of keyhole specimen)

Solution Params…   Click on the Solution Params button in the P3⁄FATIGUE form.

None   Set the Mean Strs Correction option menu to None.

50   Set the Design Criterion (%) to 50. Click on the OK button to close the form.

Material Info…   Click on the Material Info button in the P3⁄FATIGUE form.

Database Manager   Click on the Database Manager button in the Materials Information form.
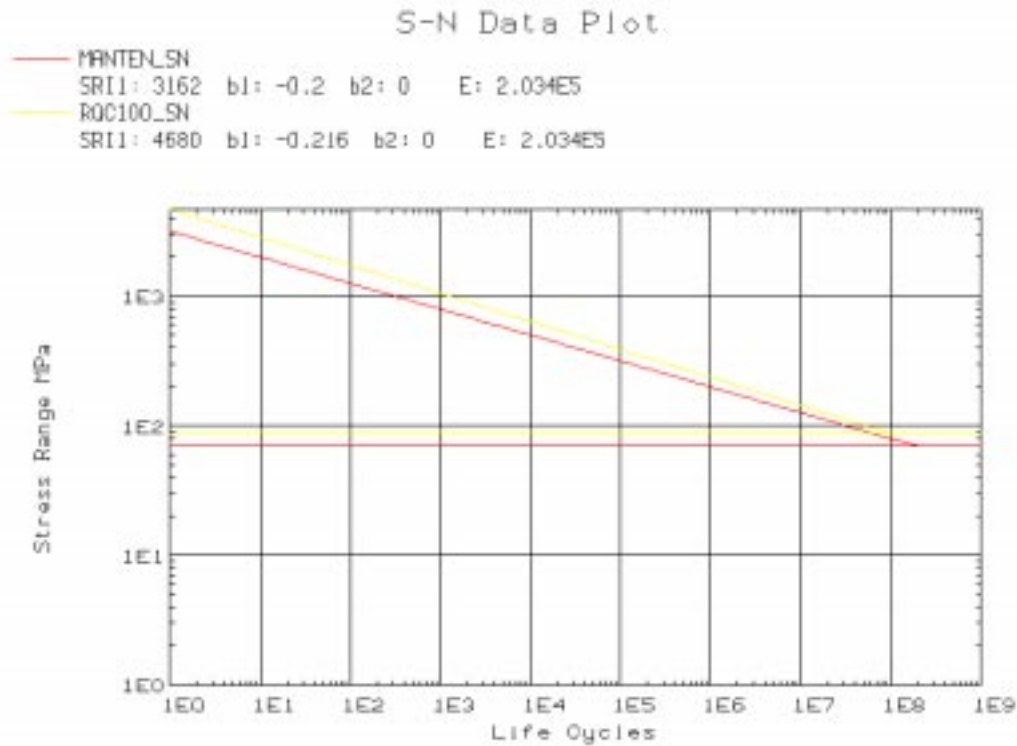
Total Life (S-N) Analysis of Keyhole

This option invokes the program PFMAT, P3´∕FATIGUE's materials database manager. The main menu of this program allows us to list, search, create, edit and graphically display existing data sets as well as helping to classify welded details. In this case the datasets for MANTEN and RQC100 are to be loaded by choosing the options shown below. You can either use the mouse if in the Xwindow environment or use the hot keys (first capital letter) and/or arrow keys.:

Load...   Load option.

data set **1**   Load dataset one first.

Type Name   Choose the type name option.

MANTEN_SN   S-N material name.

Press the **return** key, then repeat the process for the other material.

Load...   Load option.

data set **2**   Load dataset two now.

Type Name   Choose the type name option.

RQC100_SN   S-N material name.

Now you can look at the S-N curves graphically. The
Graphical display option should be selected.

S-N Data Plot

— MANTEN_SN
SRI1: 3162   b1: -0.2   b2: 0   E: 2.034E5
— RQC100_SN
SRI1: 4680   b1: -0.216   b2: 0   E: 2.034E5

[Plot with x-axis "Life Cycles" ranging from 1E0 to 1E9, and y-axis "Stress Range MPa" ranging from 1E0 to values above 1E3]

Q4: Which data set gives longer lives at all stress ranges?

A4:

_____

_____

_____

Exit the graphics by selecting the **Return** option and then
exit from PFMAT by typing **X**. On returning to PATRAN 3,
you have only viewed the materials. Now you will select
the material desired for this run.

Now you have to tell P3⁄FATIGUE which nodes are to be
used in the analysis and assign nodes with materials
information. This is done using the **Material Info** option.

1	Set the Number of Materials to one.
MANTEN_SN	Click on the Material table cell in the Selected Materials Information spread sheet. In the Select a Material: listbox, click on MANTEN_SN.
Node 73	Enter Node 73 as the Reference Node. Click on the <Return> key to accept the data.

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.

Back in the P3⁄FATIGUE form, the next menu item is **Loading Info**. The time history to use is a scaled version of the SAE transmission history, called SAETRN.

When you click on the Database Manager button, a program called PTIME is invoked. PTIME has a central database which holds copies of the SAE histories normalized to +/-999. When you enter PTIME, there is no local database, so you have to create data in some way. In this case, choose the **Copy from central** option to make a local copy of **SAETRN** from the central database. Next you must **Modify** the file through a **Polynomial transformation** (in this case simply linear).

The linear scaling factor to use is 15.87, to convert the maximum value to be equivalent to 15.86 x 10^3N. The following PTIME commands would generate the time history:

Loading Info   Open the Loading Information form.

Static   The results are static

P/FEA   The results code is P3⁄FEA

N/A   Shell Surface is not applicable.

key   Select the P3/FEA job with the stress values for the fatigue analysis.

Database Manager   This will spawn the PTIME module.

Copy from central   Copy from central database option.

At this point you may either type in the name **SAETRN** or press the **F3** key or click **List** in the top header bar to see a list of the central database from which you can select SAETRN. Move the highlighter bar or the cursor over SAETRN using the arrow keys or mouse and then (skip these if you typed the name in) select these options:

Tag/untag   Tags the SAETRN by placing a astrix * next to it.

a**C**cept   Accept all time histories that are tagged.

The time history is copied to your local directory and you will notice that it now says **Number of entries: 1** at the top of the screen just below the top header bar. Now you must modify the time history by doing the following:

Modify a time history Choose the **Modify a time history** option.

Polynomial transform Chose the **Polynomial transform** option.

F1   Accept the next screen. Make sure that SAETRN is the indicated time history. Answer **Ye**s to overwrite.

Press the arrow key to position the cursor to pick the second field and type **15.87** (Case of simply linear). You can use the **Tab** key to clear the field.

Press **F1** key to accept the screen. The transformation will be performed and then you will be asked if you wish to edit the details of the time history. Answer **Ye**s. Fill out the next screen with the following:

Description 1   Leave the same.

Description 2   Change to be more meaningful since we have scaled it now.

Load type   Use the **space bar** to change this to **Force**.
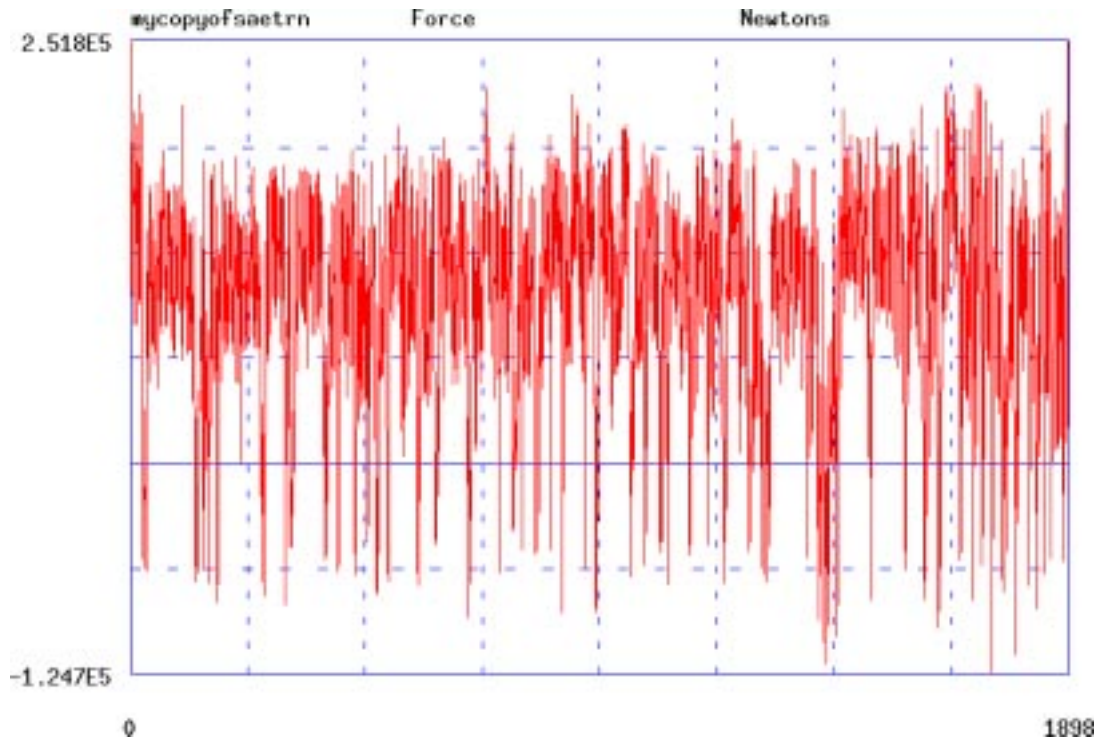
Units   Use the **space bar** to change this to **Newtons**.

No. of equiv units Leave this the same.

Fatigue equiv units Leave this the same.

Press **F1** key to accept from screen.

Choose the **Plot a time history** option to look at the time history. Press **F1**. You will have to use the **Move...** and **Full X** options to see the entire time history.

Q5:   Does the scaled version of **SAETRN** have positive, zero or negative mean?

A5:

_____

_____

_____

Return to the PTIME non-graphical menus by selecting the **Quit** option, then exit back to the P3/FATIGUE main menu by quitting from PTIME by pressing the **X** key. On returning to PATRAN 3, you have only viewed the time histories. Now you will select the time history desired for this run.

1   Set the Number of Static Load Cases to one.

1   Load case number in P3/FEA job.

SAETRN   Enter the modified version of the SAETRN time history with the type of Force and Units of Newtons.

30000   In the Load Magnitude databox, enter the value of one.

Q6:   Why do you need to specify the FEA load magnitude?

A6:

_____

_____

_____

OK   Click on the OK button to close the form.

Step 4 Setting up the P3⁄FATIGUE job

You are now ready to set up the P3/FATIGUE job. Click on the Job Control button in the P3/FATIGUE form. Submit a full analysis of the job. Enter the following keystrokes.

Job Control   Click on the Job Control button in the P3⁄FATIGUE form.

Full Analysis   The Action option menu should be set to Full Analysis.

Apply   Begin the analysis submit.

The job is now submitted and the job progress can be monitored using option **Monitor Job**. Note that various processes will be executed and the whole job is not complete until the **Fatigue analysis completed successfully** message appears.

Step 5 Reviewing Results

When the job is successfully completed, click on the **Results…** button from the main P3⁄FATIGUE menu to review the results.

Results   Click on the Results button in the P3⁄FATIGUE 1.2 menu.

List Results   In the Results form, set the Action to List Results. Click on the Apply button. This will spawn as separate module called PFPOST.

At this point you are in a separate P3⁄FATIGUE module called PFPOST from which you can readily determine the location with the most damage. Use the following keystrokes in PFPOST or use the mouse if you have this option.

F1	Press **F1** or click on **OK** to select the current jobname.

Most damaged nodesTo list the ten most damaged nodes.

Q7:   Which node has the shortest life?

A7:

_____

_____

_____

Q8:   What is the shortest life?

A8:

_____

_____

_____

Now return back to the P3⁄FATIGUE results menu by pressing **return** and use the **eXit** option from PFPOST. Then read the results into the database. In P3⁄PATRAN U produce a fringe plot of the **Log Life (Repeats)** results.

Read Results	In the Results form, change the Action to Read Results. This will take a few seconds to load the results into the database.
Results	In the P3⁄PATRAN Main Window, click on the Results toggle.
Get Results	Highlight the P3⁄PATIGUE Results Case and click on the Get Results button.
Log Life Repeats	In the Select Result listbox, highlight the Log of Life, Repeats result.
Plot	The Plot Type should be Fringe Plot. Click on the Plot to make the fringe plot.

Now you can achieve the rest of the objectives using results option **Design Optimization** from the P3⁄FATIGUE main menu. Reset the graphics and close the Results Display form. Then return to the P3⁄FATIGUE form.

Step 6 Design Optimization

Reset Graphics	Click on the Reset Graphics button to unplot the fringe plot.

Results	Turn off the Results toggle in the Main Window.
P3⁄FATIGUE	Reopen the P3/FATIGUE form.
Results…	Click on the Results button.
Optimization	In the Results form, set the Action to Optimization. Click on the Apply button.
>**6**	Enter the **6.Design Optimization** option. Accept the default jobname.

The design optimization package of P3⁄FATIGUE, DESOPT, will now be spawned. The first screen that appears allows you to pick a node number to analyze and to indicate a design life. Use the following options by picking with the mouse or use the arrow keys and/or hot keys (first capitalized letter):

Worst case node	This is an automatic selection of the worst case node.
F1	Accept the screen and leave the Design Life field blank.

A re-analysis of the worst case node (Node 13) will be performed after accepting the initial screen.

Q9:   What answer does the fatigue analyzer give?

A9:

_____

_____

_____

Press the **return** key and now change the design criterion to 96%.

Sensitivity analysis...	Choose the **Sensitivity analysis** option which will give a submenu.
design **C**riteria	Select the **design Criteria** option and you will be presented with a field where this can be changed.
96	Enter 96% certainty of survival.
Recalculate	Performs a recalculation.

Q10:   What is the life that can be achieved with 96% certainty of survival?

A10:

_____

_____

_____

Now press **return** and change the mean stress correction methods to all.

Sensitivity analysis...Choose the **Sensitivity analysis** option which will give a submenu.

Analysis types (all) A recalculation will be done using all mean stress correction methods.

Recalculate   Performs a recalculation.

Q11:   What effect do the Goodman and Gerber corrections have? What is the most conservative answer?

A11:

_____

_____

_____

Press **return** and change the S-N data set to RQC100_SN. Repeat the nodal analysis.

Material optimization...Choose the **Material optimization** option which will give a submenu.

Material change   Select the **Material change** option. A field will be presented where you can enter a new material name.

RQC100_SN   Type in the new material name. You can clear the existing name by using the **Tab** key.

Recalculate   Performs a recalculation. Press **Return** after you have made note of the life at 96% certainty of survival for RQC100.

Sensitivity analysis...Choose the **Sensitivity analysis** option which will give a submenu.

design **C**riteria   Select the **design Criteria** option and you will be presented with a field where this can be changed.

50   Set the certainty of survival back to 50%.

Recalculate   Performs a recalculation.

Q12:   Why is RQC100 better at 50% certainty but worse at 96% compared to MANTEN?

A12:

      _____

      _____

      _____

When you are finished with the exercise exit from DESOPT and quit from PATRAN.

e**X**it   Exits from DESOPT.

File/Quit   Quits from P3∕PATRAN.

List the files in your directory.

Q13:   What are the files and what do they contain?

A13:

      _____

      _____

      _____

A1:   By measuring the nodal distance along the bottom line of the model, you see that node 73 is closest to the measurement point about 1/2 radius away from the hole. This node number is required in the fatigue job setup. Node 13 exhibits the highest stress.

A2:   RQC100_SN

A3:   Positive mean.

A4:   Nominal stress life, component, option 1.

A5:   A component S-N curve is representative of a specific component and has a reference location associated with it where the stress was monitored, usually not at the highest stress or failure location. The component that you are analyzing must have the same geometry as the S-N curve to be valid. A material S-N curve is independent of geometry and can represent any component made of the same material. In general a component S-N curve can be converted into a material S-N curve by multiplying it by a K_t value transforming the stress at the reference location to that at the highest stress or failure region.

A6:   The finite element stress results act a K_t values for each node, which must be normalized by the load magnitude in order to properly scale the load time history. In short the stress results are normalized to produce a stress distribution due to a unit load. This effectively gives a K_t value of 1.0 for every node.

A7:   Node 13.

A8:   The shortest life is approx. 17,000 repeats of the history.

A9:   The same as the global multi-node/element analysis for node 13, i.e. approx. 17,000 repeats of the history.

A10:   The life is approx. 9,500 repeats of history.

A11:   The life is shortened, Goodman gives the shortest life, i.e., the most conservative prediction.

A12:   Because of the scatter parameter, SE. The data for RQC100 was more variable than for MANTEN.

A13:   This S-N analysis in P3/FATIGUE will create the following files:

        keysn.fin
        keysn.fnf
        keysn.fes
        keysn.fpp

keysn.fef
keysn.rmn
keysn.msg
keysn.sta

The .fin file contains the job setup parameters and is called the Fatigue INput file.

The .fnf file contains the nodal property information in a neutral file format and is called the Fatigue Neutral File. These first two files are created when you submit a job.

The .fes file is the FE fatigue analyzer input file. It contains information from the .fin, .fnf and the FE results file in a compact binary format. It is created by the PATran to FATigue translator called PATFAT.

The .fpp file is the binary, pre-processed (cycle counted) file of the .fes and the time history (.dac) file. It is created by the P3/FATIGUE module FPP.

The .fef file is a ASCII PATRAN results formatted file of the fatigue results which is created by the P3//FATIGUE module FEF.

The .msg and .sta files are message and status files respectively and should be inspected if the analysis did not complete properly.

The .rmn file is a results menu file and is necessary to post-process in PATRAN.