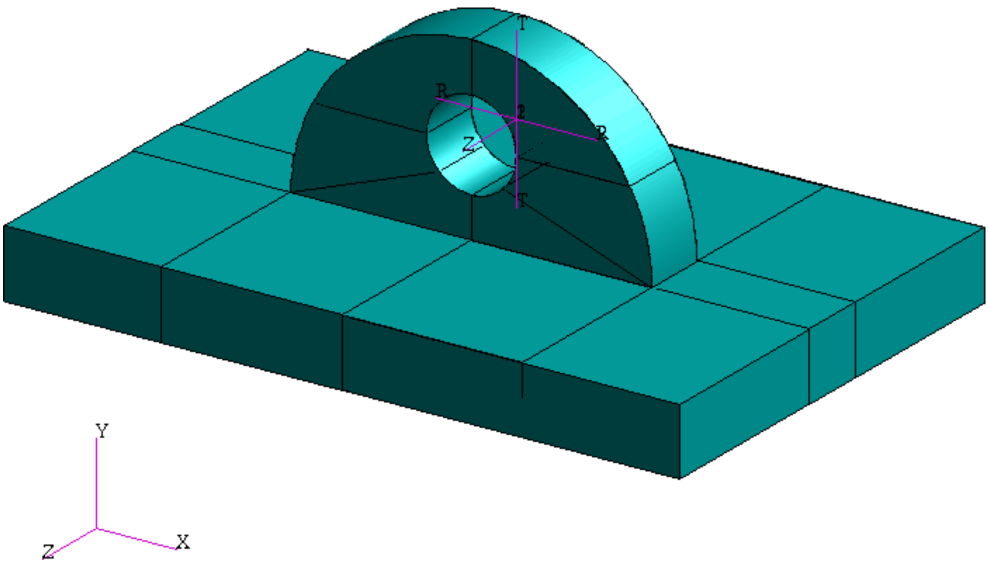
LESSON 9

Fatigue Analysis of a LUG Assembly



Objectives:

- Use all three methods of Fatigue life estimation to design the lug assembly.
- Use the total life method to estimate the fatigue life of the weld.
- Use crack initiation and crack growth to estimate the fatigue life of the lug specimen.

Problem Description:

Step 1 Problem Description

The component we are designing in this exercise is a LUG assembly welded onto a base plate. It is loaded in the opposite direction by a cyclic load acting at the top of the lug. The FE analysis was carried out to simulate the load applied to the assembly during normal operation. (The loading was spatially distributed based on a sinusoidal variation as a function of radial angle.)

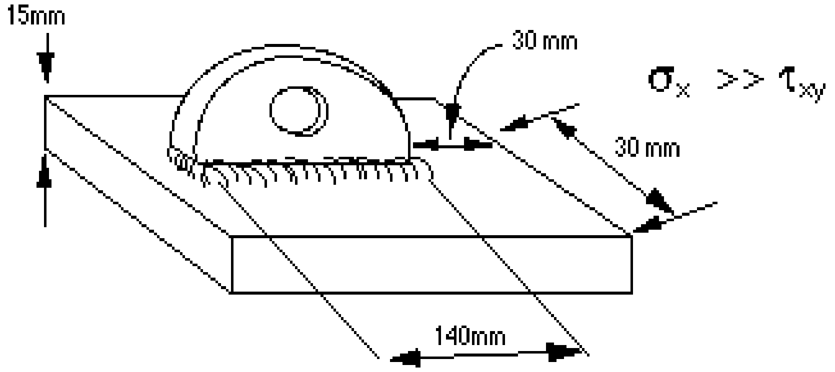


FIGURE 8. Lug Assembly.

In this exercise, we will be using all three methods of fatigue analysis offered by P3/FATIGUE to analyze various parts of the LUG assembly. Namely, we will use the total life approach to determine the useful life of the welded connection. For the non-welded part, we will use the crack initiation approach to investigate crack formation due to stress concentrations at the hole followed by crack growth.

Before we start, let us examine the FE model and stress analysis results to get a feel for the stress distribution under the prescribed static loading condition.

The model Neutral file and P3/FEA results are stored in **lug.out** and **lug.res**, respectively (use RESTXT to create **lug.res** from **lug.txt**). Make sure you are in **ex09** directory of your PAT318 account.

Q1: At what node does the highest stress lie and what is the stress?

A1:

____

____

____

Step 2 Total Life Analysis

Since the assembly has a welded connection, it is appropriate to assess the life of this feature using the total life approach. The fatigue analysis is started by setting up for the total life analysis of the weld as follows:

S-N Comp.	*Analysis* Type.
Nodal	*Results* Type.
MPa	*Units* Type.
lugsn	*Jobname*.
Solution Params	Open the Solution Parameters form.
None	Set the *Mean Stress Correction* option menu to None.
95	*Design Criterion %*
OK	Click on the OK button to close the form.

After entering the jobname, a title and other setup parameters, you will need to find the weld class associated with the lug assembly. Therefore, enter PFMAT using **Materials Database** and select the **Weld classifier** option. The assembly has a **welded detail on the surface of the member**, option 2. You need to enter the location of the potential crack. Select **at a short welded attachment,** option 2. Subsequently, signify that the weld is more than 10 mm and enter **NO** for the shearing stresses are not greater than half of the normal stresses.

Q2: What is the weld classification reported by PFMAT?

A2:

____

____

____

It should be noted that had the user known the weld classification, it could have been specified during the job setup without using PFMAT. This utility just helps the user specify the weld classification if it is not known.

The fatigue loading consists of a time history named LUGLOAD. It needs to be created. It has one cycle with min = 0, max = 10. This is a scalar time history so it has no specific units, however, you need to assign units in PTIME. (Use Force in Newtons.) Enter PTIME using **Loading Database** and create the load as done in previous exercises using the X-Y points option or try using the **Wave creation** option where the frequency is only 1/2 Hz and the total time of the signal is 1 sec. Also assume that the lug is lifted twice a day and you wish to measure life in Years.

Q3: What would the fatigue equivalent units be?

A3:

____

____

____

Enter the **Setup** option and add properties. For the S-N data, enter the weld classification you found in the previous steps. Remember to enter **CLASSF** where **F** denotes a weld class, and answer **Y** to the welded question. Then, enter node **284** to be the reference node. This node is in an area away from the stress concentration but reasonable for definition of **CLASSF**. The following keystrokes should do the trick.

Submit the job and monitor the job as it progresses. Remember the job is only complete when the **Fatigue analysis completed successfully** message is written.

Review the results by first clicking on the **Results** button and subsequently the **List Results** option. Choose any of the PFPOST options to view the damaged nodes.

Q4: What is the life of the weld?

A4:

____

____

____

Do a sensitivity analysis in DESOPT from the **Optimize** option using multiple scale factors. This is accomplished by choosing **Sensitivity analysis** and subsequently entering **Scale factors**. Use the reference node as the node to analyze. You may enter multiple scale factors by entering more than one number separated by commas or spaces in the Scale factors field. You can also specify ranges such as (1,20,2), i.e., use scale factor from 1 to 20 by 2.

You can make a **Sensitivity plot** of the multiple scale factor results under the **results Display** option. This will spawn the PATRAN X-Y plotter program P/PLOT.

Q5: Can this weld withstand significant overloads.

A5:

____

____

____

Q6: What is the fatigue life if you change the weld class from, F to W? (Class W is the worst class). Use the **Material change** option under **Material optimization**.

A6:

____

____

____

Step 3 Crack Initiation Analysis

At this point, we would like to re-analyze the LUG assembly using the crack initiation method. This method of analysis is especially useful for in-expensive components such as automobile parts. The car parts are inexpensive and easy to replace and therefore their useful life is determined based on the initiation of the first engineering crack. In addition, safety critical parts will be analyzed using this approach since these structures cannot tolerate the existence of a crack. Use material BS4360-50D.

Without leaving PATRAN or the P3/FATIGUE menus, set up the new job. The following keystrokes should do the trick:

Crack Init.	*Analysis* Type.
Nodal	*Results* Type.
Stress	*Tensor* Type
MPa	*Units* Type.
lugci	*Jobname*.
Solution Params	Open the Solution Parameters form.

S-T-W	Set the *Analysis Method* option menu to S-T-W, or Smith-Topper-Watson method.
OK	Click on the OK button to close the form.
Material Info…	Open the Materials Information form.
BS4360-50D	Material name.
GOOD Machined	Good machined *Surface Finish*.
No Treatment	No *Surface Treatment*.
default_group	Select a Group.
OK	Click on the OK button to close the form.
Loading Info…	Open the Loading Information form.
1	*Load Case ID*
LUGLOAD	Loading *Time History* name.
1.0	FEA applied *Load Magnitude*.
OK	Click on the OK button to close the form.

Submit the job and monitor the job as it progresses.

Q7: What is the critical life and to which node is the life attached?

A7:

____

____

____

Q8: What area of the LUG seems to have the shortest fatigue life?

A8:

____

____

____

We can carry out an investigation of alternative surface finishes to assess the sensitivity of the fatigue life to change in the finish. Use the **Change parameters** option of DESOPT.

Q9: If you change the surface finish to **POLISHED** what life extension do you get?

A9:

____

____

____

Step 4 Crack Growth Analysis

The crack initiation life may be reasonably acceptable as long as the crack does not grow quickly. At this point, we would like to re-analyze the LUG assembly using the crack growth method to answer the following questions.

- Will the crack grow?
- Is it adequate to inspect it once a year for any crack growth.
- Select nodes along hyperpatch 9, edge 6, which is not too close to the high stress gradient where the influence of the hole is dominant as the are of far field stress region.
- Choose the crack units in millimeters and enter an initial crack size of 2 mm and a final crack size of 55 mm.
- You must create a compliance function for a specimen of double crack at a hole in tension with R = 15 and W = 70.

Without leaving PATRAN or the P3/FATIGUE menus, set up the new job. The following keystrokes should do the trick:

Crack Growth	The *Analysis* type that we are performing is Strain Life or crack initiation analysis
Nodal	Use stress *Results* at nodes.
Stress	Use stress *Tensor* of the results.
MPa	Stress *Units* as prescribed from the FEA job are MPa
lugcg	Enter the *jobname*
	Use the Title to give a description of the job. (LEFM analysis of the lug assembly)
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. Enter the following parameters once this module appears.

1. Millimeters	Unit type, millimeter.
4. Generate Y func table	Generate Y function table.
lug	Output filename.
2. Cracks at holes	Cracks in holes.
2. Double crack in tension	Double crack at a hole in tension.
Define	Click on **Define** in graphics window.
15	Hole radius, R in mm.
70	Half width, W in mm.)
return	No changes.
Calculate	Click on **Calculate** in graphics window.
e**X**it	Exit and go back to P3⁄FATIGUE.
lug	*Select a Compliance Function* from the listbox.
Millimeters	*Crack Length Units*
5	*Initial Crack*
55	*Final Crack*
1E-4	*Notch Depth* due to machined slot.
1E-4	*Notch Radius*.
1E-4	*Sharp Crack Radius*.
OK	Click on the OK button to close the Solutions Parameters form.
Materials Info…	Click on the **Materials Info** button to review materials data.
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.
Loading Info…	Open the Loading Information form.
Static	The results are static
P3/FEA	The results code is P3⁄FEA
N/A	Shell Surface is not applicable.
lug	Select the P3/FEA job with the stress values for the fatigue analysis.
1	Set the Number of Static Load Cases to one.
1	Load case number in P3⁄FEA job.
LUGLOAD	Enter the modified version of the SAEBRAKT time history with the type of Force and Units of Newtons.
1.0	In the Load Magnitude databox, enter the value of one.
OK	Click on the OK button to close the form.

Submit and monitor the crack length as it grows. The current crack size and life will be reported at various intervals as the crack grows.

Q10: Will the crack grow slowly enough for your inspection period?

A10:

____

____

____

When you are satisfied that the crack is growing slow enough, you may abort the job. Assume now that the lug is subjected to a fifty percent over load. Use PCRACK by invoking Optimize and change the **Scale factor** to 1.5. Make sure the initial crack length is 5mm.

Q11: Is it still reasonable to inspect the lug once a year assuming the lug will be in service for 100 years?

A11:

Exercise 9 Solutions

A1: Node 7: 8752
Node 10: 8224

A2: Class F, Type 2.9

A3: One repeat of the time history would simulate (1/365days) years. Two lifts a day would simulate 1/(2lifts*365days) = 0.00137 Years.

A4: There are no damaging nodes. These results indicate that life should be beyond cut-off with node #284 as reference node.

A5: Yes.

A6: There are no damaging nodes for class W weld. Therefore, the weld does not fail.

A7: The life to crack initiation is almost 5 years, assuming 2 lifts per day.

A8: Around the hole in the assembly.

A9: The life increases to over 6 years.

A10: Yes. The crack growth life is long and probably longer than you would wish to wait for. The crack is growing however. Abort the job.

A11: Yes. The life is significantly reduced but still lasts about 165 years which gives a safety factor of roughly 1.5.