Lab 3 Riveted Joint Design, Fabrication and Testing

Objective

(1) Learn how to manufacture riveted joints to the specifications,
(2) Apply stress/load analyses learned in lecture to redesign the riveted joint from the prototype to improve its strength,
(3) Test the redesigned riveted joint to failure, and compare the actual failure mode and location with predictions.

Introduction

Among the common type of fastenings such as bolts, welds, pins, threaded couplings, glued joints, etc., rivets are frequently used in aerostructures. In Week 4 lecture, you have learned stress analysis of riveted joint and its failure mechanism and have also been introduced to a pre-specified riveted joint design (Fig. 1). In this lab, based on this knowledge and experience, you should be able to come up with a new design with better strength. Before the lab, you individually need to review the lecture and related materials and make such new design as the prelab work. Here we will follow military specification MIL-R-47196A, which can be downloaded from the class web site. You will need to study this document and check your work with the specifications throughout the process. In the lab, discuss and compare your design with your partners', work out the best design for the group, fabricate the new sample, test it to failure with tensile test, and record the experimental data. Then after the lab, the group should analyze how and why the new design fails and compare with predictions.

Now is the time for you to gain some hand-on experience. Imagine you work on a production floor and are responsible for riveting together a skin panel on an F-16 wing!

References

[1] MIL-R-47196A specification, 1977 (available in class web site)
[2] Week 4 lecture notes
[3] Peery, pp290-308

Work to be done

1. Prelab

(a) Review Week 4 lecture materials and MIL-R-47196A standard thoroughly.

(b) (80 pts) A pre-specified design of 2-2 rivet pattern is given in Fig. 1 for a riveted sample consisting of two overlapped 2" by 8" test panels. The thickness of each test panel is 0.025" and hole diameter (i.e. rivet diameter) is 1/8". Your first task of the prelab is to evaluate the test panel's joint efficiency for each of the four failure modes as described in Week 4 lecture notes, particularly in the workout example on pages 18-28. Which failure will happen first and why? Next, for each failure mode, predict the maximum load that can cause that type of failure. For tension failure mode, calculate the maximum load and corresponding stress for each row separately, as demonstrated in Part 3 of the workout example. Use the material properties provided below.

(c) (120 pts) Based on what you find in (b), redesign the joint for better strength within the same overlapped area. You may want to consider popular rivet patterns such as 1-3-1 and 2-1-2 or higher density like 2-3-2 and 3-3-3. You can use as many rivets as you like but remember that too many rivets can actually weaken the joint (remember the design rule of thumb on page 17 of lecture notes). Calculate the joint efficiency and predict how and under what load your new design will fail in each failure mode, just like what you did in (b). You don't necessarily need to follow the minimum pitch and edge margins specified in MIL-R-47196A, but if you do decide to disregard standard practice, you should justify why. You will also need to be able to justify if you will take different approaches in redesigning the joint.

We will use the nominal material property values of 2024-O Aluminum alloy for both the test panels and rivets. The values are:

Ultimate tensile strength: 27ksi
Ultimate bearing strength: 50ksi
Shear strength: 18ksi
Tensile yield strength: 11ksi
Elongation at break: 20%
Young's Modulus: 10600ksi
Poisson's ratio: 0.33
Density: 0.1 lb/in^3

As usual, follow the instructions in Canvas to submit this prelab at the specific date and time.

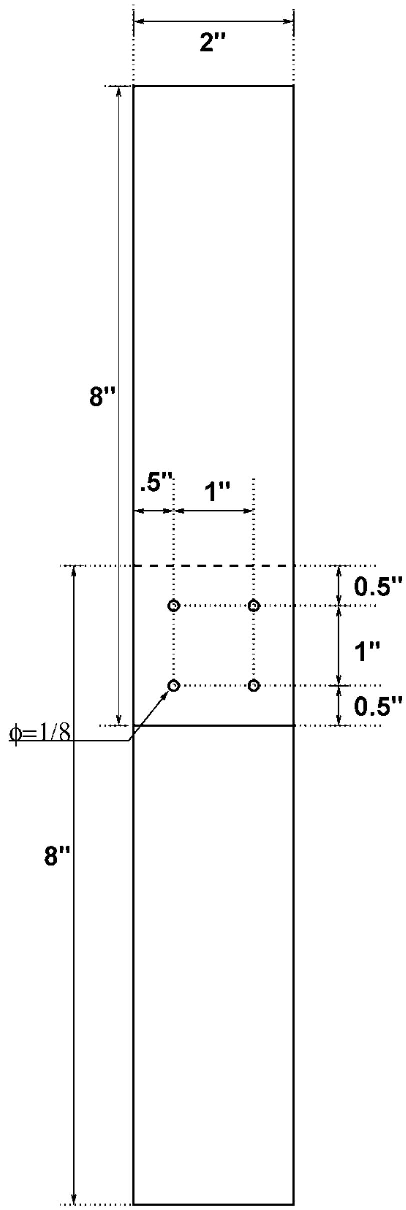

Figure 1 Layout of the pre-specified riveted joint design.

2. In lab

As always, safety comes first. **You MUST wear safety goggle, gloves and ear muffs during the lab.** The latter two are important in handling the sharp edges of the aluminum sheet and in reducing punching noise from rivet gun. **Be particularly careful not to punch**

onto anyone's hands when riveting the sample! Also keep a safe distance from the Instron machine when conducting the tensile test.

Design Selection

Compare your design with those of your lab partners made in terms of joint efficiency. Either select the best design or consolidate the designs into one, then proceed to construct the riveted test sample. You will manufacture and inspect your work according to the standards of MIL-R-47196A. We will be using 1/8"-diameter 1/4"-length dome head, i.e. non-countersunk, rivets and will not be adding any coatings. Review the practices for preparation and installation of rivets in MIL-R-47196A. Make yourself a checklist of installation and inspection steps.

Prepare a USB memory drive for your group to later store the test data created in this lab.

Sample riveting

(a) Make sure there are no plastic film still attached to the samples. Measure and mark the rivet locations of your design on the two strips of sample.
(b) Make holes only in top strip of the sample using the punch. Don't punch through more than one layer at a time.
(c) Line up the two strips against the edge of a ruler and tape the two strips together temporarily with the same 2" by 2" overlap area.
(d) Punch holes in the bottom strip using the holes in the top strip as a punch guide. Once you have punched holes in both strips at the same locations, you can further ensure hole alignment by fastening the existing holes with clekos.
(e) On the side, go practice at least a couple of riveting on some scrap samples. The keys to a successful and safe riveting are (1) pulling the river gun trigger lightly at first and increase punching power gradually but maintain control at all time, (2) keeping the river gun head as normal to the rivet as possible and applying constant pressure to prevent the gun head from slipping. We suggest you **operate the rivet gun with both hands** and have a teammate **hold the sample (through gloves) on the two ends of sample (AWAY from the rivet area!).**
(f) When you are satisfied with your riveting skills, go back to rivet together the two strips of your sample. Try riveting at the corners of the bucking plate so that the clekos stick out to the open air and are not pressed down to the bucking plate directly.
(g) Inspect and evaluate your work against the MIL-R-47196A standards using the metal gage (in black). Take photographs.

Tensile test

In this step, you will test your specimen, i.e. the two aluminum strips riveted together, to failure with tensile test using a dual-column load frame manufactured by Instron (Fig. 2).

On the desktop of the controlling PC, an "AerE 322" folder had been created with "riveting lab XYZ" subfolder in it, where "XYZ" denotes the semester and year, e.g. "S23". Your section/group subfolder can be found further inside "riveting lab XYZ".

(a) Fit the specimen into the flat-end grips of the Instron load frame (Fig. 3). The distance between top and bottom grips should be set just right so that each end of the specimen is fully clamped into the claw face. The grips have been aligned vertically, so just loosen the left screws of the top and bottom grips to allow the specimen to be fitted in. Once the specimen is fitted and aligned between the grips, screw left grip back to the right. Tighten the grips the best you can to minimize "slip" on the claw face.

(b) Pull straight your riveted sample by rolling up the displacement wheel on the console pad, but still retain some lateral wiggle room in the middle rivet area. Press Balance all button on the Bluehill 3 software.

(c) Press the Test button on the lower right corner. In the next dialog, enter Section number and Group number such as "S1G3" as file name. Your test data will be saved to this file. Use the Browse button on the right to navigate to the right file location.

(d) Press the Start button to run the tensile test which increases load at the rate of 10lb/sec. **Do not stand in front of the specimen within 2 feet range – broken pieces may burst out when the specimen fails!** When the load passes its maximum and start declining, stand by on the side at the console pad.

(e) Press the Stop button right at the moment the failure occurs. Press Finish button to save the raw data to the file and location specified in step (c).

(f) Take photographs of the failed sample and fetch the test data file from the Instron PC using the USB drive you prepared.

(g) Report the maximum load your sample has reached to TA for entering the "competition" roster.

3. After Lab

As a group, discuss how did your specimen fail and which of the predicted failure mode(s) apply? Did it fail in any way you did not predict? Consider all possible reasons and analyze them. Include a summary comparison of all designs from your group, and your basis for selecting the one you did. Mention any of manufacturing issues and your evaluation of your riveting job against the standards of MIL-R-47196A. Can you trace any part of the failure back to manufacturing issues and or non-ideal behavior that wasn't included in your analysis?

4. Report

Follow the instructions given in "AerE 322 lab summary instruction.pdf" (available in Misc Module of class Canvas site) to write a 5 to 10-page summary report. Address all these after-lab questions stated above (counted for 80% grade). At the end, insert a photograph of the failed sample (5%) and a plot of the load-elongation from the raw data (15%). Remember to include lab number and title, and your section and group number on all pages as in every lab report.

As usual, follow the instructions in Canvas to submit this summary report at the specific date and time.

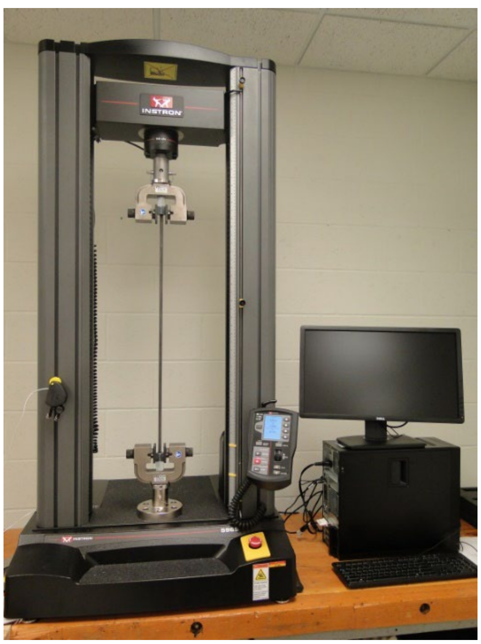

Figure 2 The Instron dual-column load frame used in this lab (pictured for use in column buckling)

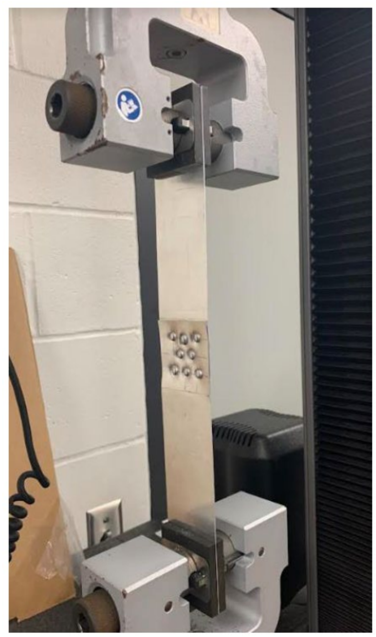

Figure 3 Angular view showing how should the riveted sample be fastened between the flat-end grips