1 Introduction and Objectives

When a column is subjected to a compressive force, it will fail in one of two ways. If the slenderness ratio, $kL/r$, is small, it will fail by compressive yielding of the material. However, for a long slender member, the internal compressive force can induce a geometric instability which results in bowing or bending of the column. This occurs when the compressive stress is still well within the range of linear elasticity (i.e., less than the yield stress). This failure mode is called buckling, and it is an example of an elastic instability.

The objective of this laboratory is to introduce students to the buckling test and to evaluate the effect that specimen length has on the failure load. Before the lab, students should compute the theoretical failure loads for each specimen using Euler’s equation for column buckling,

$$P_{cr} = \frac{\pi^2 EA}{(kL/r)^2}, \quad (1)$$

and compressive yielding

$$P_y = \sigma_y A, \quad (2)$$

using the nominal dimensions provided below where $k$ is the effective length factor and $r$ is the radius of gyration which by definition is equal to $\sqrt{I/A}$ where $I$ is the moment of inertia. During the lab you will make actual measurements which can then be used to update the theoretical prediction. It is important to note from this equation that buckling failure does not depend on the strength of the material, only on its geometry and its modulus of elasticity.
During the course of the lab, different length specimens will be subjected to a compressive load that will result in failure (either buckling or compressive yielding). The experimental failure loads can be plotted versus the slenderness ratio and compared to the theoretical values. There is a fundamental explanation for any discrepancies that arise. Understanding this and noting how a column reacts to a compressive force are the main objectives of this lab.

2 Equipment & Materials

1. The four specimens (as shown in Figure 1) manufactured by either of the following types of Aluminum. Select all four (4) of your specimens from the same material type and indicate this material type on your data sheet:

<table>
<thead>
<tr>
<th>E (ksi)</th>
<th>Al 2024-T4</th>
<th>Al 6061-T6</th>
</tr>
</thead>
<tbody>
<tr>
<td>σ_y (ksi)</td>
<td>10000</td>
<td>10000</td>
</tr>
<tr>
<td>47</td>
<td>37</td>
<td></td>
</tr>
</tbody>
</table>

2. The nominal dimensions of each specimen. During your experiment you will measure the exact dimensions for width, thickness, and length, for each of your four specimens.

- Width = 0.5 inches
- Thickness = 0.125 inches
- Length = 6, 4, 2, 1.5 inches (measured from the knife-edge on one side of the specimen to the knife-edge on the other side)

3. Tinius Olsen machine

4. Dial gauge to provide indication of lateral movement of column during test

5. Magnetic stand to hold dial gauge

3 Procedure

1. Measure and record the length, width, and thickness of the specimens. When measuring the length of the specimen be sure to measure from knife-edge to knife-edge; it is the knife-edges that bear against the supports.

2. Turn on the Tinius Olsen load frame.

3. Mount the cross-head used for compression (see Figure 2) and make sure the two pieces are correctly aligned so that the specimen will fit in.
4. Clear results in memory of Tinius-Olsen machine: Press “menu” (i.e., the “ENTER” button); Press “7” for “Results”; Press “3” to “Clear All”.

5. Start with the 6 in. specimen. Insert it into the machine and adjust the crosshead so that the specimen fits snugly on the support pins but is not under load.

6. Place the dial gauge on the stand and set it so that it will indicate the deflection at approximately the midpoint of the specimen. Make sure that the initial displacement of the dial gauge is about 0.25 to 0.4 inches, since you do not know which way the specimen will deflect (see Figure 3).

7. Press “F1” to zero the load on the Tinius-Olsen machine

8. Press the “Test” button; this will record the maximum force encountered during the test.

9. Load the specimen until the load on the specimen is dropping continuously.

10. Unload the specimen (slowly) and note if the displacement returns to zero. If it does, it indicates a purely elastic deformation of the test specimen.

11. To view maximum load during experiment: Press “menu” (i.e., the “ENTER” button); Press “7” for “Results”; Press “1” for “View”.

12. Repeat for the three other specimens.
4 Results & Discussion (minimum requirements)

For your write-up,

1. Using MATLAB create a plot of Load (P) vs. Slenderness Ratio (kL/r). Plot the theoretical column strength versus $kl/r$ considering both failure modes: compressive yielding and elastic buckling using the nominal dimensions provided above. Add to this plot the four (4) experimental failure loads you measured as well as the theoretical predictions for the four specimens you testing using the specimens actual (not nominal) dimensions.

2. Calculate the percent error between your theoretical (using actual dimensions) and experimental points.

3. Discuss the percent error for the different geometries-why do you think you got these results? Discuss possible sources of error.

4. Why is it important to have the holes in the specimens resemble knife edges?
Figure 3: Dial gauge connected to mid-point of column, with an initial displacement induced. If the column moves to the right or left, you will be able to detect this with the use of this dial gauge.