Lab 7: Column Buckling

Objective

Test column buckling and apply the theory learned in lecture to compare with the actual experimental measurements and to improve on column design.

Introduction

Column buckling occurs in long slender beams/bars when subjected to critical buckling loads. In Week 9 lecture, we learned the concept of structural stability and its importance to column buckling. We have also derived all related formulas to calculate key parameters such as the Euler critical load and the slenderness ratio. Now it is time to put all these theories to work in actual tests.

In this lab, you will be using the computerized high-precision load frame made by Instron to perform the column buckling tests on steel and aluminum specimens of various shapes and lengths (Fig. 1). Before the lab, you need to calculate the Euler critical load and the slenderness ratios for all the specimens and test conditions. In the lab, you will then setup the specimens in the load frame, slowly compress them, observe the buckling phenomenon and record the loads at buckling. In the report, you will compare the experimental data with your predictions, determine the effects of key parameters and how they are correlated with the experiments.

Figure 1 Column buckling test being conducted in the Instron 5969 load frame

References

[1] Week 9 lecture notes
[2] D. Peery, *Aircraft Structures*, 1950, Ch. 14
[3] A. Higdon et al., *Mechanics of Materials* 4e, 1985, Ch. 10

Work to be done

1. Prelab

(a) Review Week 9 lecture and corresponding reference book materials (Peery is available online from ISU library).
(b) For the end condition of one free and one fixed (lecture note page 12), why is the effective length twice as long as the actual length? Could you come up with a simple explanation? Hint: think of "mirror" …
(c) Derive the formulas for critical load P and slenderness ratio L/ρ of a circular rod and a rectangular bar subjected to axial loading, in terms of π, length L, modulus of elasticity E and specimen radius R (for circular rod) or cross sectional dimensions B and/or H (for rectangular bar).
(d) Use the formulas from (c) to calculate the Ps and L/ρs for metal specimens made of stainless 304 annealed cold finish steel (elastic modulus E = 29000 ksi and yield strength = 35ksi) and 6061-T6 aluminum (E=10000 ksi and yield strength = 40 ksi) with the sizes and end conditions given in Table 1.

What equivalent lengths you will use for the pivot-pivot and pivot-fixed end conditions? For the ¼" x 1" aluminum specimen, which dimension you choose to calculate the slenderness ratio? Hint: see the workout example on pages 14-15 in lecture notes. You may want to write yourself a little computer program for these calculations.

The prelab worksheet containing the above questions is available from Canvas. Complete it and submit back to Canvas as usual.

Table 1. Five column buckling test sets

specimen ID	Material	Cross section dimension (inch)	Length (inch)	End condition
I	aluminum	3/8 dia.	30	both pivot (round)
II	aluminum	1/4 x 1	30	both pivot (round)
III	steel	1/4 dia.	30	both pivot (round)
IV	steel	1/4 dia.	24	both pivot (round)
V	steel	1/4 dia.	27.5 (30 original)	one pivot, one fixed

2. In lab

As always, safety comes first. **You MUST wear safety goggles in this lab. This is particularly important during column buckling tests!**

As stated above, you need to compare your prelab results with your lab partners and figure out why if discrepancies occur. Correct any individual or group error.

Three test stations will be set up at the three Instron test frames as labelled. Specimens I though III, i.e. the first three of the five test specimens listed in Table 1, will be tested at station #1, specimen IV at station #2 and specimen V at station #3. Each group then takes turn to perform the test(s) at each of the three stations to complete the lab.

You will only need to use the "fine Position" knob to operate the load frame (Fig. 2). **PLEASE DO NOT TOUCH THE "JOG UP/JOG DOWN" BUTTONS BELOW IT**! It would be better if you also use a reference marking (e.g. a vertical line drawn on a cardboard) in the background (to be visualized against the specimen). This will help you catch the buckling when it happens.

Follow the general procedures below to carry out the tests:

1. With the test specimen in place, push the button on the left on control pad (Fig. 3) and then the "1" button on the right to reset all measurements. Start rolling the "fine position" knob down to narrow the gaps between the specimen ends and the receiving sockets on the frame at speed about 1 click per second.
2. Wiggle and rotate the specimen a bit to ensure the specimen ends are centered in the sockets (Fig. 4). Once the sockets are in firm contact with the specimen (when the load on the display goes above 5 lb), double check and <u>record the distance between the sockets or between socket and grip</u>; this is particularly important for specimen V as one of its ends is fixed! What distance should be measured for specimen V?
3. Align the reference marking with the specimen around the mid-point of specimen. Do not touch the specimen again. Slow down the scrolling. When the load gets closer to your prediction, slow down even further. Do you catch the sudden, tiny "jolt", i.e. the sudden lateral movement, when the column buckling occurs? If so, record the load reading on the display. Does it agree with your prediction? If you miss the buckling instance or are unsure, unload and start over. Always be alert to the "straightness" of the specimens. If you sense any tilting of the specimen, you already pass the initial buckling point! The loads needed for any of the five specimens never go above 200lbs. So **NEVER OVERLOAD: IT IS DANGEROUS!**
4. Once the measurements are completed, unload to near zero lb.
5. Move to the next test station for next round of test.

Figure 2 motion controls on control pad

Figure 3 balance controls on control pad

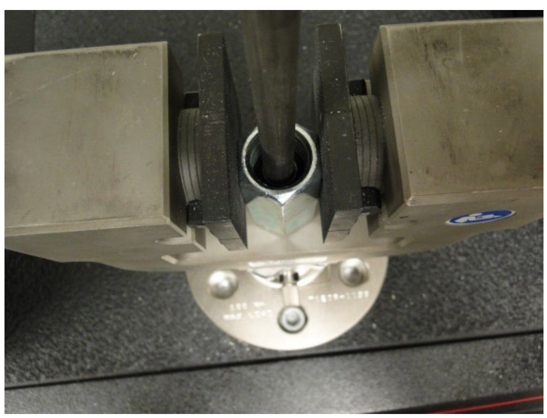

Figure 4 socket to secure the specimen ends

3. After Lab

Below are questions related to the data and observations you have from the experiment.

1. (15%) In testing specimen II, which direction the rectangular bar buckle? Does this agree with your prediction?

2. (15%) In testing specimen III can you catch the "jolt" better than in specimen I test? How does it compare with specimen IV?

3. (20%) Can you still see the "jolt" in specimen V test? Is it harder to determine the buckling instance now? Do you know why either way? Can you see any trend in what you observe above, and draw any correlation to the parameters such as critical load and slenderness ratio?

4. (10%) What sources of errors could be in these four test sets? Discuss possible remedies.

5. (25%) Similar to the lab test cases of steel specimens, calculate the slenderness ratio, critical load and critical stress for a 30-inch rectangular bar having the same cross section area and properties as the 1/4-inch diameter specimen under pivot-pivot end condition. Design the optimal sizes for the two cross-sectional dimensions so that the critical load would be maximum. Without actually doing the calculations, can you see what shape of the cross section would be? Use the same values for mechanical properties.

6. (15%) Given what you learn from this lab, how would you approach designing a cross section for a column? What are the constraints on your design?

4. Report

Work with your group members to write a report summary at least 5 pages (including all figures and code listing). Follow the report template "AerE 322 lab report template.pdf", summary instruction "AerE 322 lab summary instruction.pdf" and the check list "prelabs_labreports.pdf" that are provided to you via e-mail or online in class web site. In addition to answers/analyses to all the After-Lab work items above, you should include descriptions of the experiment specimens, test equipment, and experiment procedures. Also include all necessary pictures, graphs, tables, etc. to better present your work. Make sure your hypotheses are clearly made and if your results support them and why. Submit the report summary to Canvas as before.