AS2070 Project : Plate Buckling

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Summary

Aim

To experimentally observe mode 1 buckling—the most fundamental mode—in a simply supported aluminum plate under uniaxial compression, and compare the results with theoretical predictions.

Apparatus and Materials

The following materials and tools were used in the experiment:

- Specimen plate: Aluminum 6061 sheet, cut to 25 cm $\times$ 25 cm with 0.3 mm thickness
- Support frame: Mild steel bars (5 mm $\times$ 5 mm, resized to 25 cm) with V-grooves milled into them for simply supported boundary conditions
- Universal Testing Machine (UTM): To apply axial compressive load
- Welding and Milling Tools: Used to fabricate the plate support frame

Apparatus and materials

Figure 1: Milling machine used to cut grooves

Apparatus and materials

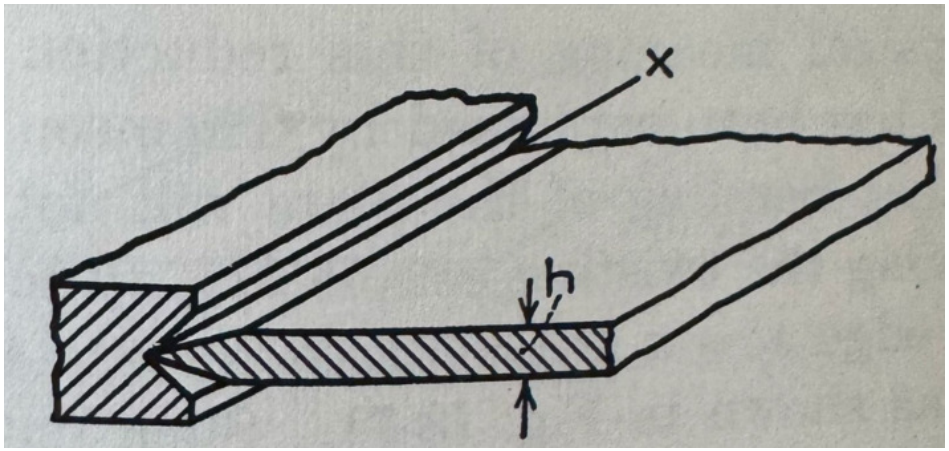


Figure 2: A Simply Supported Edge

Theory

The governing equation for a plate subjected to uniaxial loading is given by:

$$D\nabla^4 w + P w_{xx} = 0$$

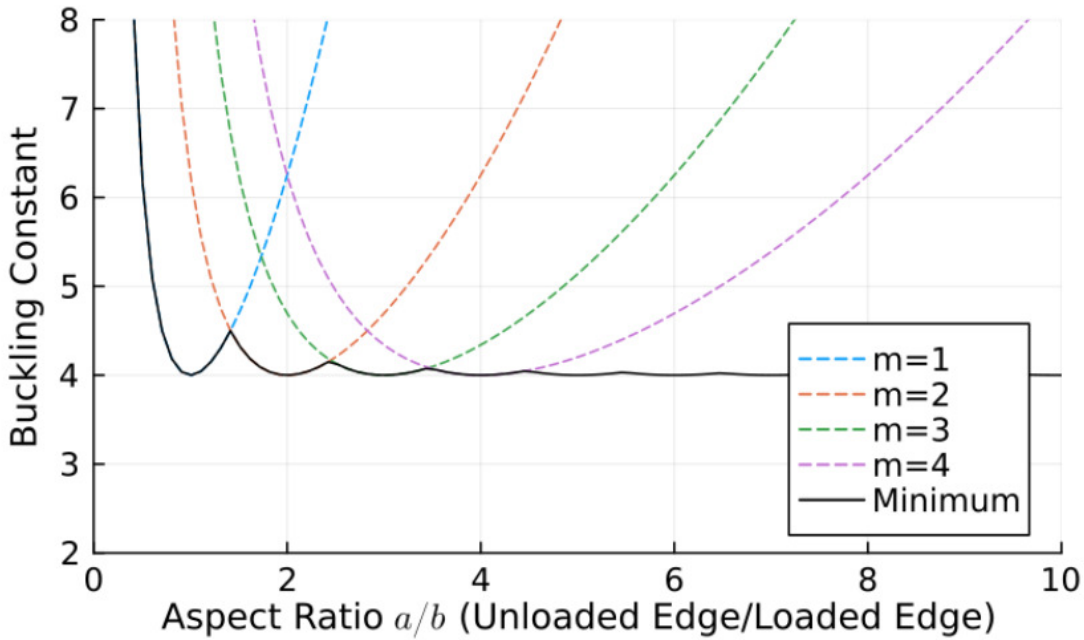
Boundary conditions : $w = 0$ and $M_x = M_y = 0$ along the supports.

$$P_{cr,m} = \frac{\pi^2 D}{b^2}\left(\frac{m}{a/b} + \frac{a/b}{m}\right)^2$$

$$P_{cr} = \frac{\pi^2 D}{b^2} \min_{m \in \mathbb{Z}^+} \left(\frac{m}{a/b} + \frac{a/b}{m}\right)^2$$

Buckling Constant (k_{cr})

$$k_{cr} = \min_{m \in \mathbb{Z}^+} \left(\frac{m}{a/b} + \frac{a/b}{m} \right)^2$$



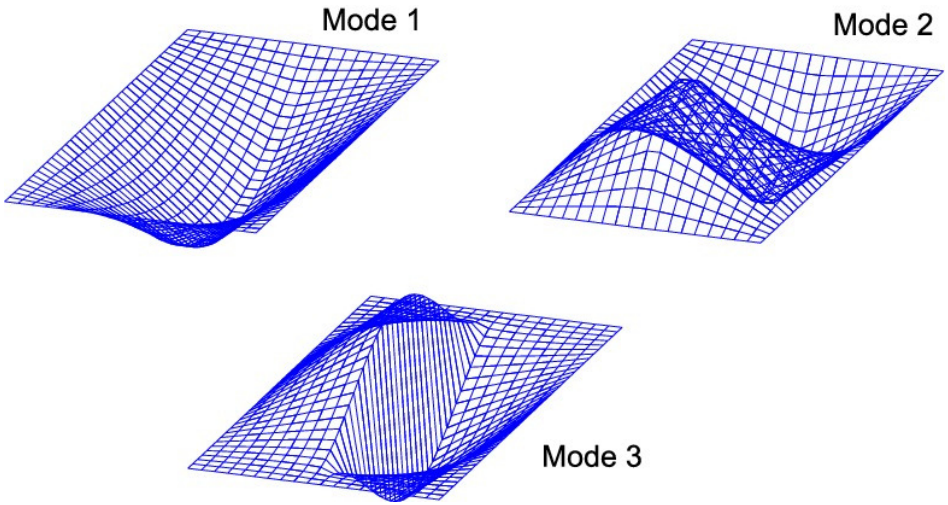


Figure 3: Buckling modes

Procedure

- Initially all the resized mild steel bars were milled to make V-grooves on one side of each bar
- Then 3 of the bars were welded in U-shape along with one more bar to support this U-shape. (refer image 16)
- Two mild steel pieces were welded to the U-shape frame to enable us to mount this setup to the UTM.
- Then the aluminum plate was inserted into the V-grooves of U-shape frame.
- Now, the U-shape frame (along with plate) was fixed to one holder of UTM, and the bar was fixed to another holder of UTM.
- Then, axial compressive load was applied gradually with the help of UTM.

Results

- We observed that the specimen buckled at approximately $60N$. Upon application of a higher load, the plate dislodged from the supports and exhibited localized yielding.
- On our second test, we observed that its load bearing capacity does not cross the $50N$ threshold.

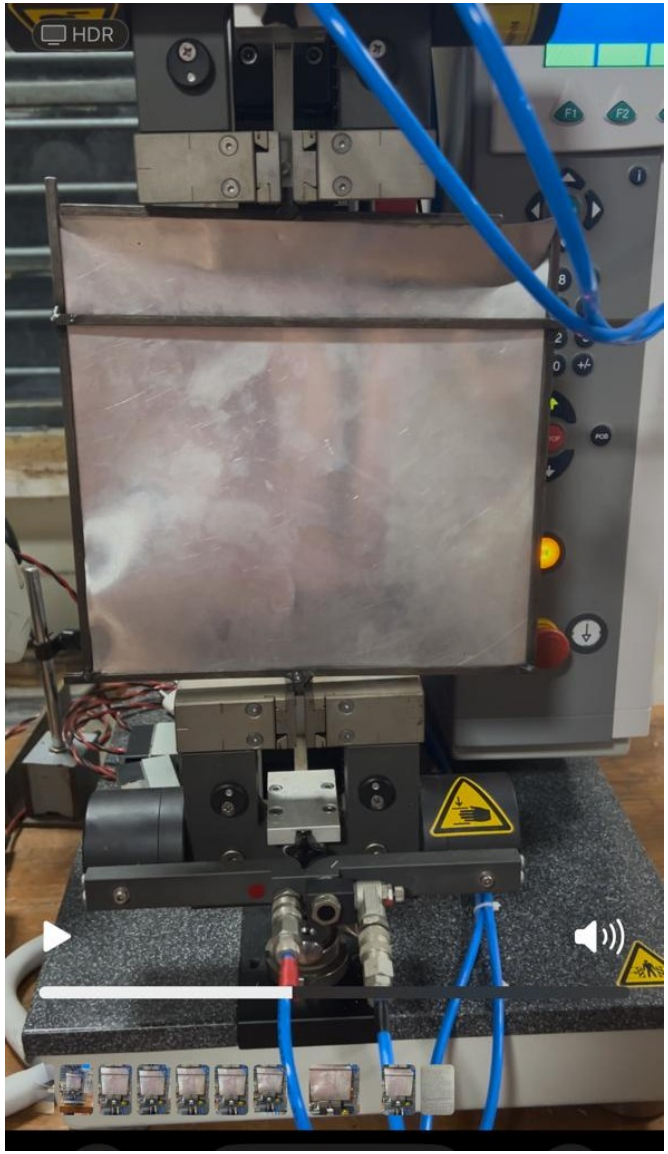


Figure 4: Dislodging of Plate

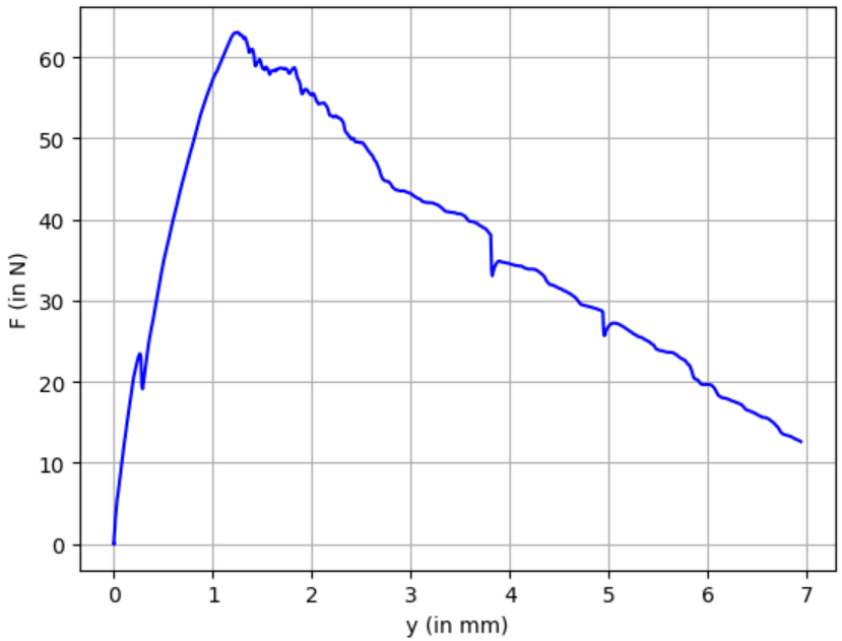


Figure 5: Force v/s displacement (trial 1)

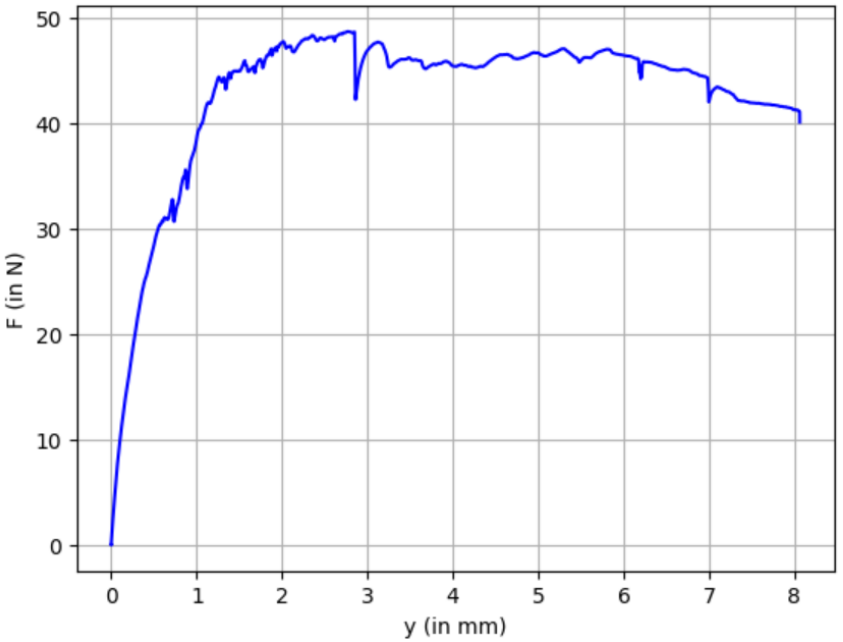
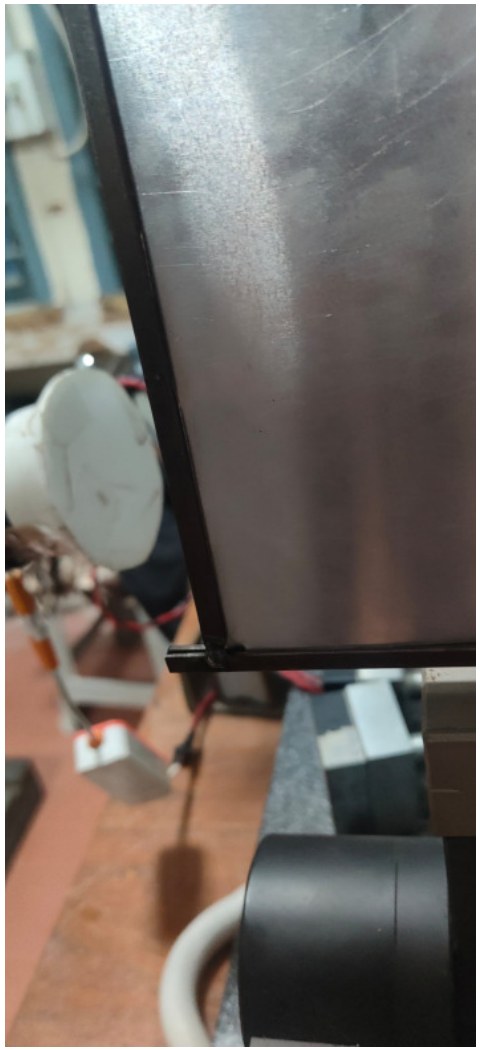


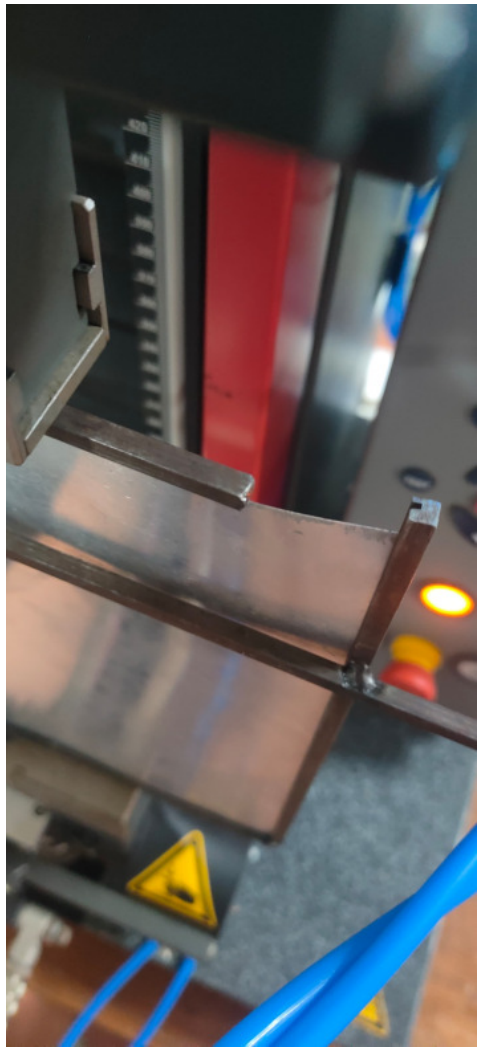
Figure 6: Force v/s displacement (trial 2)

Sources of Error and Problems Faced

- Grooves were not entirely straight, resulting in tilted aluminium sheet.
- Plate did not rest entirely in the grooves (loss of boundary conditions)
- The holder's created to clamp the setup in UTM were not straight (resulted in twisted load in the sheet)
- The MS rods (for supports) were not placed at the right lengths, resulting in errors.
- Aluminium Sheet wasn't cut to the right shape, again resulting in errors.
- Welds at some joints interefed with the plates, resulting in loss of simple supports.

Sources of Error and Problems Faced





Sources of Error and Problems Faced

Figure 7: Imperfections in Plate

Initial Plan

- Initial plan to demonstrate 3 modes of buckling using 3 plates of different aspect ratios.
- Could not do this because of fabrication / machining limitations.
- Another constraint was to make sure that Force needed lies in UTM range.

Conclusion

Although we couldn't demonstrate mode 1 buckling completely due to the errors mentioned, we did successfully observe how a plate buckles under load and then it's further yielding.
One interesting inference we observed is the Force is linear for the initial parts of curve then changes after dislodging.

Acknowledgment

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Most importantly, we sincerely thank our professor **Nidish** for guiding us throughout the project and for creating an environment where we could learn hands-on and think independently.

References

1. Lecture Notes, Prof. Nidish, AS2070, IIT Madras.
2. Timoshenko, S. P., & Gere, J. M. *Theory of Elastic Stability*, McGraw-Hill.