Department of Aerospace Engineering
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AS2070: Aerospace Structural Mechanics

Thin Plate Buckling under Simply Supported Conditions

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1 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.

2 Apparatus and Materials

The following materials and tools were used in the experiment:

- **Specimen plate:** Aluminum 6061 sheet, cut to 24 cm × 24 cm with 0.3 mm thickness
- **Support frame:** Mild steel bars (5 mm × 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

(a) Plate and the supports

(b) Universal Testing Machine

Figure 1: Apparatus

3 Theory and Calculations

For a simply supported rectangular thin plate under uniaxial compression, the critical buckling load P_{cr} is given by:

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

where the flexural rigidity D is:

$$D = \frac{Et^3}{12(1-\nu^2)}$$

with:

- $E = 69\,\mathrm{GPa}$ (Young's modulus for Al 6061)
- $\nu = 0.32$ (Poisson's ratio)
- $t = 0.3\,\mathrm{mm}$
- $a = b = 25\,\mathrm{cm}$

For mode 1 buckling, we take $m = 1$. Substituting the values:

$$\frac{a}{b} = 1 \quad \Rightarrow \quad \left(\frac{1}{1} + \frac{1}{1}\right)^2 = (1+1)^2 = 4$$

Therefore, the critical buckling load simplifies to:

$$P_{\mathrm{cr}} = \frac{4\pi^2 D}{b^2}$$

Using the given values:

$$D = 0.173\,\mathrm{Nm}, \quad b = 0.25\,\mathrm{m}$$

$$P_{\mathrm{cr}} = \frac{4\pi^2 \times 0.173}{(0.25)^2} \approx 109\,\mathrm{N}$$

This theoretical estimate was used to guide our design decisions and ensure the plate remained stable under compressive loading.

4 Methodology: What Happened Behind the Scenes

We initially planned to use three plates with aspect ratios 1, 1.5, and 2.5 (e.g., 7×7, 7×11, and 7×18 cm). However, after checking the UTM dimensions, we realized the minimum workable width had to be 25 cm.

So we planned up to 25×25 cm and 25×40 cm plates to show Mode 1 and Mode 2 buckling. However, the plate for Mode 3 (25×65 cm) exceeded UTM length limits, and we had to discard that configuration.

We then faced another limitation: machining the V-grooves needed for simulating simply supported edges. The workshop could only handle 25 cm rods. We even tried a local shop, but they couldn't help either. So, we had to discard the 25×40 cm plate and proceed with only the 25×25 cm plate.

Initially, we considered a 1 mm thick plate, but the predicted buckling force (about 4.1 kN) was too high for our mild steel supports. So we reduced the thickness to 0.3 mm, which brought the theoretical buckling load down to $\sim 110\,\mathrm{N}$—well within our safe operating range.

We milled the grooves, welded the frame, mounted the plate, and loaded it using the UTM.

5 Experimental Setup and Procedure

Figure 2: Experimental Setup

1. **Fabrication:** Mild steel bars were milled with V-grooves and welded into a square frame of internal dimensions 25 cm $\times$ 25 cm. The aluminum plate was inserted into the V-grooves to allow rotation at the ends (simulating simple supports).
2. **Loading:** The frame was mounted in the UTM, and axial compressive load was applied gradually.

6 Results

6.1 Trial 1

In the first test, the force started increasing and reached around 24 N. At this point, the plate slipped slightly out of the fixture on one side. This made part of the support behave like a **free edge** locally, causing a sudden drop in load. After this, the force continued to rise and peaked at about 64 N. Beyond this point, **local yielding** occurred near the top corner, and the plate began to come out of the setup, leading to a drop in the load.

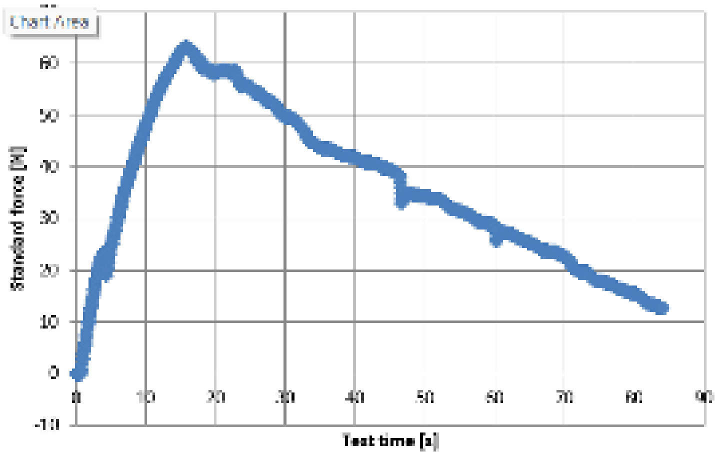

Figure 3: Force vs Time graph for trail 1

6.2 Trial 2

In the second test, the same plate was properly positioned and stayed fully supported. The force rose smoothly without an early dip, confirming that the first trial's drop was due to slipping. However, before reaching 50 N, the plate began to yield again near the boundary, and the test was stopped.

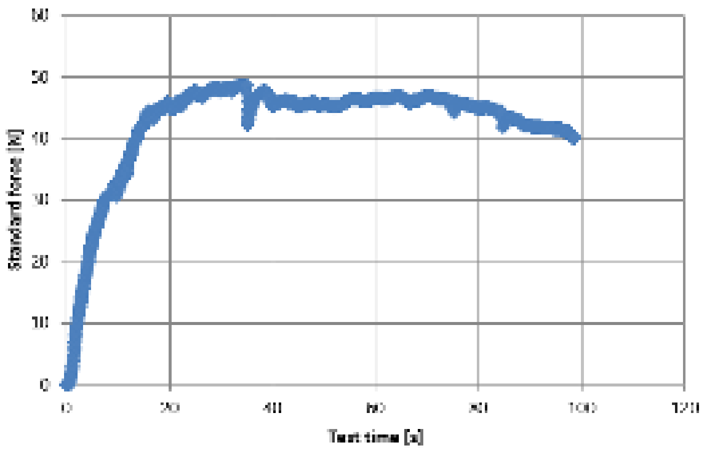

Figure 4: Force vs Time graph for trail 2

7 Discussion

The first trial showed how slipping at the boundary changes the support condition — locally acting like a free edge, reducing load capacity. In the second trial, although the setup was proper, yielding still occurred before the theoretical buckling load (109 N). This suggests that imperfections, yielding, and setup limitations prevented us from observing pure buckling.

8 Contributions

1. Omkar R : Machining, Slides,
2. Nikhil R: Machining, Slides,
3. Abhiram : Report, Material Procurement
4. Varun Bhat: Machining, Slides, Welding.
5. P.G Bharadwaj: Welding, Machining, Report,

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