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Deflection of the Drone Frame

Introduction:

The UxV/35 drone by Kairos Autonomi features a frame where motors are mounted on wing spars. Four of these wing spars can be combined to form the drone frame. Some variations of these drone frames are shown in Figure 1.

Figure 1: Variations of the drone frame to which the motor is mounted to are shown below. The left image is of a carbon fiber drone body. The middle shows a fiberglass circuit supported by the battery base board. The right image is of just the fiberglass circuit board.

While these and other variations have been used, their impact on weight is known, but their effect on vibrations during flight is unknown. Understanding how the deflection of each frame is impacted by changing thrust is crucial for assessing vibrations during flight. By measuring the deflection of each frame at a given weight, we can determine a spring constant, which provides insight into the oscillations experienced during flight.

Setup:

Testing Frame:

A hook screw was secured to the drone frame. The drone frame was then attached to a metal plate, spaced away from the metal plate with an additional nut. Once secured, the metal plate was placed on a wooden test frame where a hanging weight was added.

Figure 2: Drone frame attached to a metal plate.

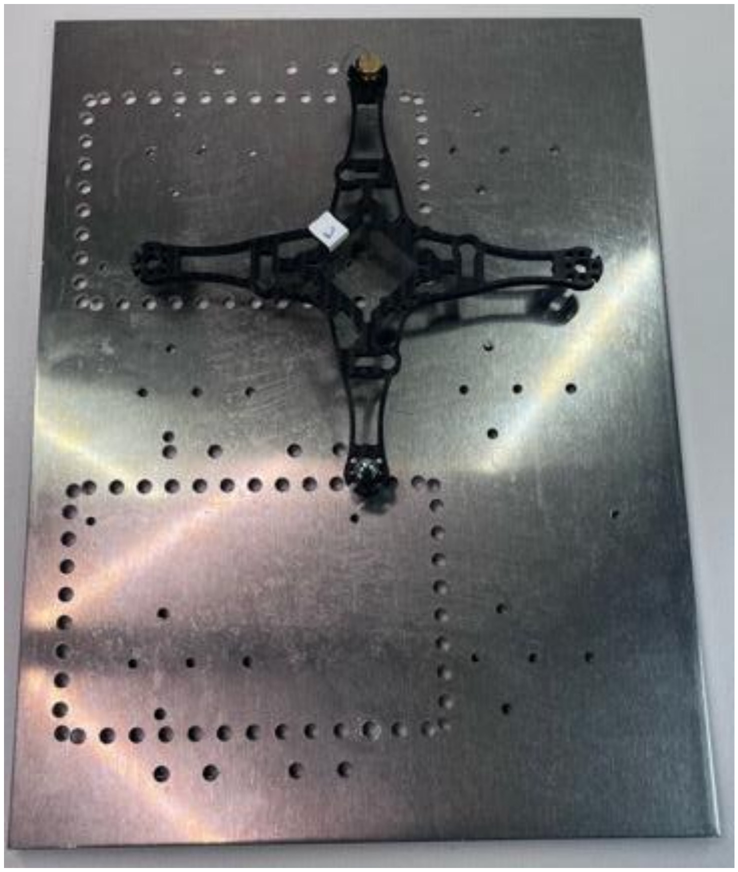


Figure 3: Another angle of the drone frame attached to the metal plate.

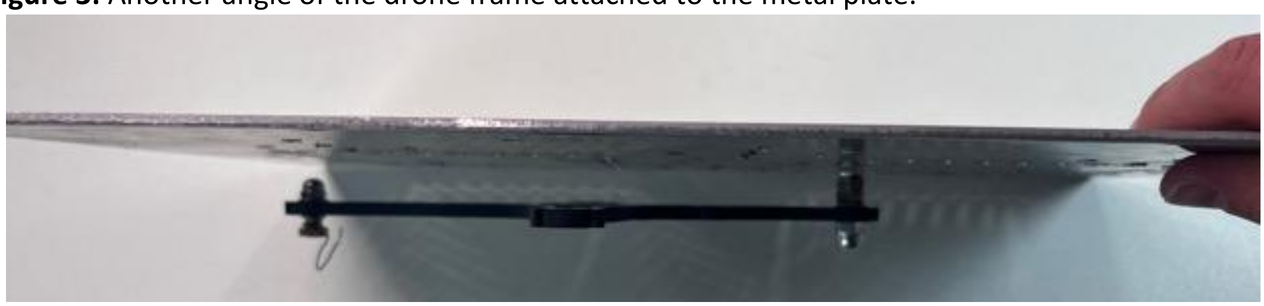


Figure 4: The wooden test frame with the drone frame and metal plate placed on top. The hanging weight is shown that was used to add weight to the data frame.

Testing was done on 6 different drone frames, shown in table 1.

Testing Procedure:

The testing procedure is outlined below. Each length measurement was taken in triplicate to eliminate error due to oscillations.

1. Securing the drone frame to the testing apparatus.
2. Measuring static depth
3. Measuring depth with 300 g
4. Measuring depth with 650 g
5. Measuring depth with 900 g
6. Measuring thickness of drone frame

The thickness found for each drone frame is mentioned in table 1.

Data Analysis

After the depth measurements were taken, the average deflection was calculated by subtracting the static depth from the measured depth underweight. Results are shown in Table 2. Figure 5 presents the deflection results for each mass. Using these results and the formula “F = kx” (Hooke’s Law), the effective spring constant “k” was determined. The force “F” is in

Newtons and is calculated using the mass, “x” as the deflection or displacement. This spring constant provides an idea of how the drone may be affected by motor-induced vibrations.

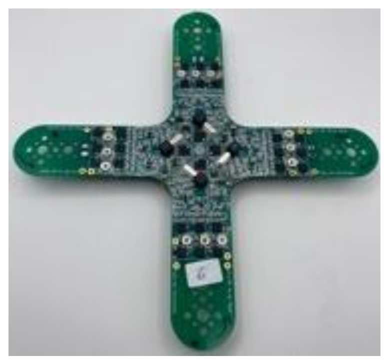
Table 1: The table below shows the drone frames tested. It shows the material and thickness. The label system is also established for convenience for the duration of this document.

Thickness: 4.10 mm
Material: Carbon Fiber
Label: 1

Thickness: 5.03 mm
Material: Carbon Fiber
Label: 2

Thickness: 5.15 mm
Material: Carbon Fiber
Label: 3

Thickness: 2.41 mm
Material: Fiberglass
Label: 4 & 5



Thickness: 1.67 mm
Material: Fiberglass
Label: 6

Table 2: The results from the deflection test. Given is the deflection or displacement caused by the mass added. This can be further used to find the effective spring constant. The deflection is measured in millimeters (mm).

Mass (g)	1	2	3	4	5	6
309.5	13.03	7.43	3.31	14.74	20.88	23.16
654	24.91	16.00	7.64	33.08	45.07	48.73
1005.6	37.09	26.45	12.13	52.39	65.75	72.52

Figure 5: Graphical representation of the deflection test results, showing a linear response, which is necessary for Hooke's Law.

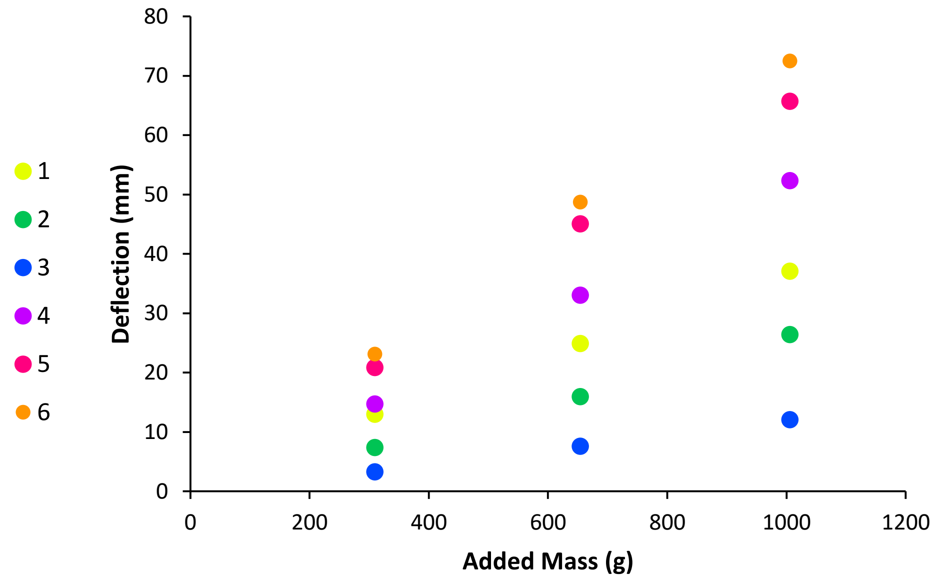


Figure 6: The displacement vs. force graph. The slope of the fitted line is the spring constant. This fitted line data is given in table 3.

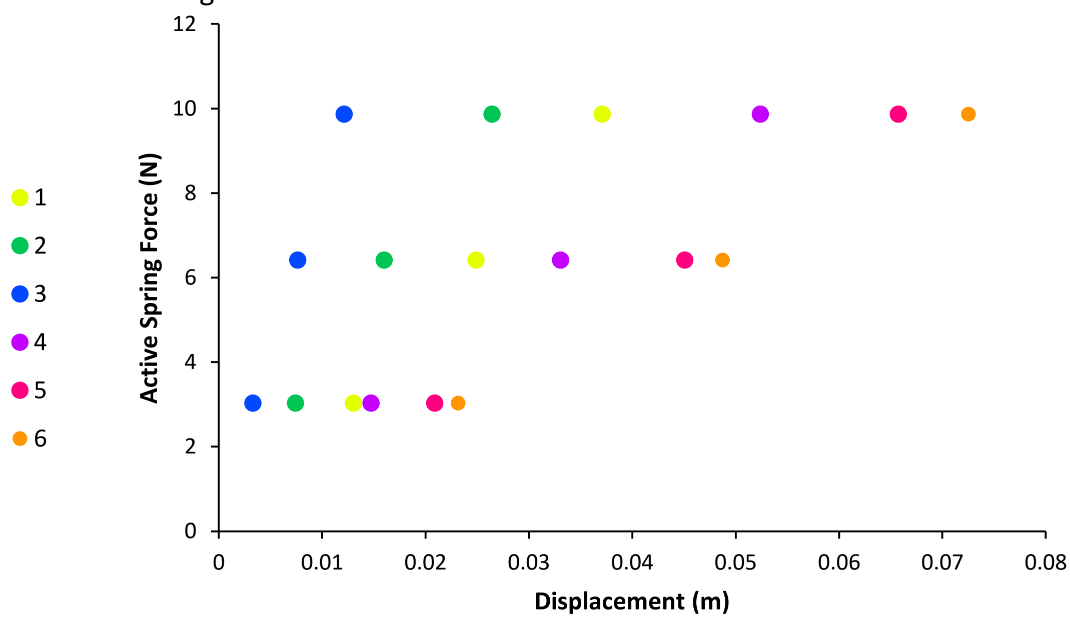


Table 3: The table shows the linest data for the drone frames fitted to Hooke's law. The intercept value and the R^2 value are also given to show the relative fit of the line to the data.

Drone Frame	1	2	3	4	5	6
Spring Constant (N/m)	283.90	358.05	774.49	181.33	151.84	138.27
Intercept	-0.66	0.49	0.48	0.38	-0.23	-0.22
R^2	1.00000	0.99740	0.99998	0.99992	0.99740	0.99928

From the spring constants and deflection data, a ranking was created to evaluate how much vibration each frame may experience, shown in Table 4.

Table 4: The rank of drone frames with their given thicknesses. The higher-ranking drone frames are going to experience less vibrations than the lower ranking drone frames. All testing is assuming no further support to the wing spars.

Ranking	Frame Label	Spring Force	Thickness
1^{st}	3	774.49	5.15
2^{nd}	2	358.05	5.03
3^{rd}	1	283.90	4.10
4^{th}	4	181.33	2.41
5^{th}	5	151.84	2.47
6^{th}	6	138.27	1.67

Conclusion:

The drone frame is a critical component of the drone's structure. Testing its deflection under static weights provides valuable insights into how vibrations from the motor are absorbed. Thicker carbon fiber bodies showed higher spring constants, indicating better vibration dampening. However, this testing is limited to static weight additions and does not account for the dynamic vibrations experienced during flight. Further research is needed to understand how other components contribute to the overall stability and vibration dampening of the drone.

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Revisions

Name/Signature	Date	Description
Cameron H Miller	07-23-2024	Content Addition