WEEK 2

Article: Kim *et.al.*, Acrobatics at the insect scale: A durable, precise, and agile micro–aerial robot, *Science Robotics*, 2025.

QUESTIONS 2a

1. The article presents that a key innovation for durability was to diverge from biological systems and use a longer hinge to reduce flexural stress. Could this be achieved instead by having a more flexible wing, which may also have the benefit of better energy efficiency through aerodynamics? Figures 3A and 3D demonstrate how the redesigned hinge reduces flexural stress by over 1000 times, but this was achieved by extending the hinge along the entire wing instead of restricting it to a localized flexure. How does the elongated hinge compare with biological resilin-based hinges in insects in terms of flight stability, energy dissipation and load distribution? Could there be a more optimal hinge geometry that balances stress reduction while maintaining aerodynamic efficiency?

2. How do you explain the significant differences between the voltage inputs of the four actuators (Figure 4D). I would expect to see the same voltage applied to the actuators because the robot is in hovering flight. Is one wing less powerful than the others, therefore others have to compensate?

3. The authors managed to make the robot to have a relatively low moment of inertia by having a small distance between the robot COM and each module's COM, and a relatively large body torque because of the large robot COM-to-COP distance. The distance between the robot COM and each module's COM is 8.7 mm. Why not reducing it even more, since the moment of inertia would be even lower? And how would it affect the body torque, since it would also decrease the COM-to-COP distance? Is there an optimum that can be found?

4. The MAV's wings have both a stroke motion (41°) and a pitch motion (118°). How do these two degrees of freedom interact to optimize lift generation? Why is the maximum stroke angle frequency (300Hz) different from the maximum lift force frequency (330 Hz)? How does a single DEA mechanically generate both wing stroke and pitch motion? The current design does to seem to have the capability to control its rotation (Movie S8). Can we control the rotation of the robot by changing its wing's pitch to induce a moment?

5. It is said in the article that a large axial force may lead to dynamic buckling along the off axis of the DEA. What would be the risk if that type of event happens? Is it possible to avoid this instability? How would you change the design of the robot to protect the DEA from buckling?

6. The paper describes DEAs with resonance frequencies between 300 and 500 Hz outperforming MAVs that use piezoelectric actuators with significantly higher resonance frequencies. What factors allow the slower DEAs to achieve greater agility than piezoelectric actuators?