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ACTIVE CONTROL OF THE PASSIVE PITCHING AMPLITUDE OF A FLAPPING WING

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Summary: The design and realization of Flapping Wing Micro Air Vehicles (FWMAVs) have attracted much attention over the last decades. This has resulted in, among many other topics, different ways of achieving flapping kinematics for sufficient lift production. To decrease the actuation mechanism complexity, wing designs might include an elastic spring hinge to tune the wing pitching motion. Due to the inertial and aerodynamic loading, a properly tuned elastic hinge results in the required passive wing pitching to achieve the lift to stay aloft.

Practical use of FWMAV designs requires the ability to control the stroke averaged lift force of each wing during flight. Actively adjusting the elastic hinge stiffness is one option to change the passive pitching and, hence, the lift production of a wing. There are several methods to change the stiffness of an elastic element (e.g., smart fluids, or electrostatic forces). Lift force control of flapping wings by adjusting the elastic hinge stiffness is not well established within literature.

This work aims to adjust the stiffness of the elastic hinge using an electrostatically controlled device. The device is composed of stacked metallic sheets (e.g., spring steel) separated by insulating layers (e.g., PVDF). The metallic sheets are alternately connected to high positive and negative voltage sources. By increasing the actuation voltage, the bending stiffness of the stacked structure increases since the electrostatic force induces frictional forces between the different sheets. This electrostatically controlled device is placed into the wing design to change the pitching amplitude during the flapping motion.

An experimental setup is used to drive a flapping wing design with an integrated controllable hinge using a flapping frequency of about 25 Hz. High-speed cameras are used to capture the change of the pitching amplitude as a function of the actuation voltage. The obtained results are compared with that from a quasi-steady aerodynamic model which is able to predict the passive pitching motion. This allows us to determine the actual voltage dependent change of the elastic hinge stiffness. In conclusion, the proposed electrostatically controlled device is a very promising method to control the lift production of flapping wings.