Development of Cyclocopter Micro Air Vehicle

The development of an efficient, maneuverable, and gust tolerant hovering concept with an expanded flight envelope is the key to the success of a micro air vehicle (MAV) in both military and civilian applications. This research investigates a new revolutionary concept of a cycloidal-rotor-based vehicle (cyclocopter), which has the potential of achieving higher levels of aerodynamic efficiency and maneuverability compared to conventional rotary MAVs. The objectives of this research are: (1) design and build the first cyclocopter MAV to successfully achieve stable hover and (2) develop the control strategies to enable the first successful forward flight of a cyclocopter purely using thrust vectoring. The cyclocoper uses two cyclorotors and a third small conventional edge-wise rotor to counteract the torque produced by the cyclorotors spinning in the same direction. As part of this research, a series of flight-capable twin-cyclocopters ranging from 100 grams to 550 grams were successfully developed (Fig. 1).

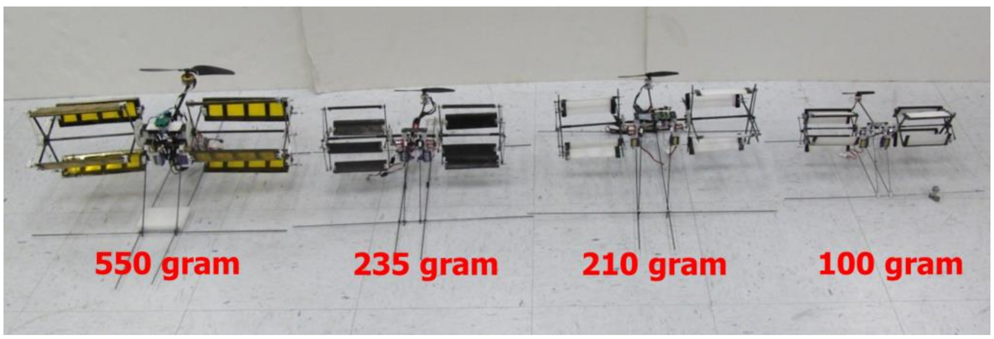

Fig. 1 Flight-capable cyclocopters developed at the University of Maryland

The forward flight control strategy for the twin-cyclocopter uses a unique combination of independent pitch phasing and rotational speed control of the cyclorotors. Unlike a conventional helicopter, a cyclocopter is propelled in forward flight purely by thrust vectoring. This allows the vehicle to maintain a level attitude in forward flight. Even though such a strategy could facilitate power-efficient forward flight, it is accompanied by a strong yaw-roll cross coupling, which is in addition to the inherent gyroscopic coupling that is present in hover. To understand these couplings and characterize the bare airframe dynamics, a 6-DOF flight dynamics model of the cyclocopter was extracted using time domain system identification technique. The model was able to validate the existence of the inherent roll-yaw coupling in forward flight, which was identified by contributions of roll-yaw coupling stability and control derivatives. The gyroscopic coupling is caused by unbalanced angular momentum and the controls coupling arises from increased propulsive forces at high phase angles. Decoupling methods involve simultaneously mixing roll and yaw inputs in the controller. After implementing the controls mixing strategy in the closed-loop feedback system, the cyclocopter successfully achieved steady, level forward flight up to 5 m/s.