Vortex Ring State Simulation in a Wind Tunnel: Drone Flight Stability and Rotor Lift

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This experiment pioneered a technique to locate the descent velocity at which an unmanned aeronautical vehicle (UAV) is susceptible to vortex ring state (VRS). VRS forms when a rotorcraft descends at certain velocities into its own downwash. The aims of the present research were to: exhibit the correlation between descent velocity and VRS; derive an equation relating downward induced velocity and thrust; and to design and construct a viable wind tunnel for airflow observation. In this experiment, a dedicated vertical wind tunnel was constructed to induce VRS on a commercial quadcopter. This tunnel simulated controlled subsonic flight conditions at low angles of attack in order to minimize air turbulence, visualize airflow patterns around the rotor hub, and restrict movement in the horizontal plane. The descent velocity of the quadcopter was determined with Logger Pro software and high-speed video feed over multiple flights. It was initially hypothesized that a Dromida Ominus quadcopter is susceptible to VRS when descent velocity surpasses the downward induced air velocity produced in hovering flight of 2.445 meters per second. However, it was experimentally determined that if the Dromida Ominus' descent velocity is greater than half of the induced hover velocity, 1.22 meters per second, the quadcopter is susceptible to VRS formation. Therefore, VRS creation boundaries, as defined by descent velocity, were observed to be wider than originally hypothesized. Additionally, the experiment proved the viability of the novel vertical wind tunnel design to observe VRS during quadcopter flight, setting the foundation for VRS prevention strategies.

Awards Won:

Second Award of $2,000

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