Aerodynamic and aeroacoustic analysis of distributed-propeller configuration in forward flight

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Distributed propulsion systems are innovative propulsion configurations that are being developed following the trend of aviation towards the enhancement of performance and the reduction of noise and pollutant emissions. Distributed propulsion in aircraft application is the spanwise distribution of the propulsive thrust stream such that overall vehicle benefits in terms of aerodynamic, propulsive, structural, and/or other efficiencies are mutually maximized to enhance the vehicle mission. Recent literature studies have investigated the behaviour of such systems in hover. A common observation is the reduction in aerodynamic performance of multirotor systems in hover. When two rotors/propellers operate in close distance, interactional phenomena are taking place between the rotors. As the separation distance between the rotors of a multirotor configuration decreases, thrust output slightly reduces accompanied by the generation of severe thrust fluctuations (Figure 1). Force fluctuations drastic increase is associated with the turbulence enhancement in the area between the adjacent rotors (Figure 2). As the separation distance decreases, there is a drop in performance which is attributed to the upwash flow from the adjacent rotor. Similarly, there is a negative effect on aeroacoustic performance of a multirotor system in hover. Noise level emission of multirotor systems is dependent on the azimuthal angle and separation distance between the rotors. The noise level is greater in the direction normal to rotor plane than parallel to it, while as the separation distance increases, noise emission reduces. Thrust fluctuations, which are related to blade loading, lead to an increase in the tonal noise, while the increase of turbulent energy leads to broadband noise increase. Based on the literature, the research will focus on the further enlightening of unclear areas of distributed-propellers in forward flight, investigating the interactions and the flow field evolution. So, the research objective is the investigation of the aerodynamic interactions and aeroacoustic behavior of distributed-propeller configuration in forward flight, including the effects of phase angle by performing high fidelity numerical simulations in a multi-propeller configuration.

Figure 1. Normalized thrust coefficient of quadcopter with respect to separation distance variation.

Figure 2. Wake evolution of single rotor (left) and twin rotors (right) at hover.