Aeroacoustics of small propellers in turbulent flows

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Miniature aerial vehicles (MAVs) have gained significant popularity in recent years due to their potential in fields such as search and rescue, wildfire mitigation, agriculture, and package delivery. Unlike their larger counterparts, MAVs are very compact and operate at low Reynolds and Mach numbers in the lower atmosphere region known as the atmospheric boundary layer (ABL). This region is characterized by high levels of freestream turbulence (FST), which exposes MAVs to intensities of 5% to 20% and length-scales on the order of of 1 mm to 1 km. These turbulent conditions further contribute to the sound emitted from propellers. Therefore, MAV performance must consider its interaction with different turbulent flow conditions. Many have shown that the combination of both turbulence intensity and integral length-scale are crucial in understanding both bluff and aerodynamic body performance. Given the varied range of both intensity and length-scale within MAV operating environment, both of these turbulent characteristics should be considered for different turbulent inflows. Therefore, this presentation aims to quantify how propeller aeroacoustics are affected by both turbulence length-scales and intensities. An ISAE-2 150 mm diameter propeller with a 15 mm chord length is subjected to four freestream turbulence conditions. Using four turbulence generating grids, length-scales of $0.5 \leq \Lambda_u/c \leq 1$ and intensities of $5 \leq T_u \leq 8$ were generated. Aero-acoustic measurements were taken in the Université de Sherbrooke anechoic chamber 0.5 m by 0.3 m, with the propeller operated at a constant advance ratio $J = 0.25$ with a rotational speed of 9550 RPM ($\mathrm{Re}_c = 75000$). The addition of turbulence generally increased both thrust and torque, with the overall efficiency remaining relatively unchanged. Acoustic measurements showed clear haystacking around the blade passing frequency, as well as an increase in broadband noise levels, commensurate with turbulence intensity and length scale changes.

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