Propeller Performance in Turbulent Flows

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There is growing interest in using rotorcraft, such as unpiloted aerial aircraft (UAVs), for search and rescue and package delivery. Both of these applications operate within the lower atmosphere, specifically the atmospheric boundary layer (ABL), where they are subjected to highly turbulent flow. The ABL is formed of vortex structures that vary in intensity and scale. Furthermore, in urban environments, turbulent wakes are generated from surrounding buildings as well as other UAVs. The complex turbulent structure created in such an environment interacts with the rotor and its wake directly, consequently changing the generated thrust and thus its overall performance. It is therefore important to understand how turbulence directly affects propeller performance, especially in the lower Reynolds number ranges that UAVs would operate at. To the best of our knowledge, this is still an open area of research, with the handful of studies that have investigated this showing contradicting results. This work aims to address this, by investigating the performance of a propeller in a wide variety of turbulent conditions. A 0.15 m diameter ISAE4 propeller with a 0.015 m chord is subject to varying turbulent inflows generated by a series of turbulence grids. Both the integral scale and the turbulent kinetic energy that the propeller is exposed to are changed. The propeller performance is quantified via its propulsive efficiency ($\eta = J\frac{C_T}{C_P}$) as a function of advance ratio (J). Preliminary results indicate that the manner in which turbulence affects the performance of the propeller is a function of the chord-based Reynolds number $Re_c = V_{tip}c/\nu$, as well as turbulent kinetic energy, with turbulence generally decreasing peak efficiency.

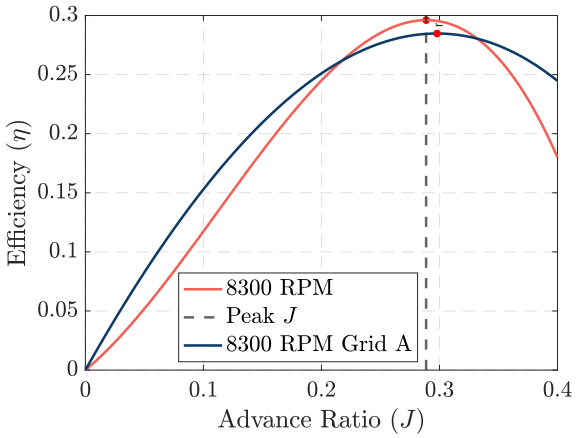

Figure 1: Propeller performance at 8300 RPM for uniform and turbulent inflow (10% intensity and length scale (L/D) 0.12).

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