THE OPTICAL ENVIRONMENT FROM THE TIP VORTICES OF A HELICOPTER IN DIFFERENT FLIGHT REGIMES

Abstract

by

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Aero-optical aberrations associated with turbulent compressible flow fields can seriously degrade the performance of an optical system; the effect of these aberrations increases as the wavelength of the transiting light becomes shorter, and so is particularly strong at visible and near-infrared wavelengths. These aero-optic aberrations originate from both spatial- and temporal-variations of the index-of-refraction, and are associated with the low-pressure cores and concomitant reduced density within the vortical structures in the turbulent flow field. To date, aero-optics research has focused primarily on fixed-wing aircraft travelling at compressible-flow speeds, where compressible shear layers and turbulent boundary layers are the dominant source of aero-optic aberrations. Helicopter platforms, on the other hand, operate at much lower Mach numbers (M<0.3) and are actually best suited for hover. In this case, the optical aberrations produced from shear-layer or turbulent boundary-layer flows are greatly reduced or eliminated in the case of hover; instead, aero-optic aberrations result primarily from the wake of the rotor that can have tip speeds up to a Mach number of one. The tip vortices shed from the rotor blades, have an aberrating effect similar to the vortices in a compressible shear-layer that forms behind a turret on a fixed-wing aircraft.
In this dissertation, experimental and numerical results are presented that both calibrate and validate a scaling relationship derived from Euler’s equations and the Lamb-Oseen vortex model. Extended numerical simulations of basic helicopter flow-field features were performed for a medium-sized helicopter both in hover and in forward flight to determine estimates of the spatial- and temporal-degradation of a collimated beam traveling through the rotor-blade wake. The results indicate that the severity of the aberration is highly dependent on the vortex circulation strength and core radius. Even with the most conservative estimates, the farfield effects of light propagating through these tip vortices greatly reduces the irradiance delivered on target through both tip/tilt and higher order effects. Finally, the use of adaptive optics to correct for these aberrations is examined for the case of hover.