Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

IMPACT OF AERODYNAMIC HEATING ON THE CHARACTERISTICS OF ACCRETED ICE ON A ROTATING BLADE

Arash Bahramitalab[1], Sina Afkhami[2], François Morency[3], Gelareh Momen[4], Derek Harvey[5]

[1] Department of Mechanical Engineering, École de Technologie Supérieure (ÉTS), Montréal, Canada
[2] Department of Mechanical Engineering, École de Technologie Supérieure (ÉTS), Montréal, Canada
[3] Department of Mechanical Engineering, École de Technologie Supérieure (ÉTS), Montréal, Canada
[4] Department of Applied Sciences, Université du Québec à Chicoutimi, Chicoutimi, Canada
[5] Department of Applied Sciences, Université du Québec à Chicoutimi, Chicoutimi, Canada

ABSTRACT

Ice accretion on helicopter blades can significantly affect their performance, making accurate prediction of ice shape and mass essential for designers to implement effective mitigation measures. The heat transfer between ambient air, supercooled droplets, and the blade surface plays a crucial role in ice formation, with aerodynamic heating emerging as a key influencing factor, particularly for rotating blades. Consequently, quantifying the effect of aerodynamic heating on ice accretion helps for more precise prediction of ice thickness. With advances in computational power, numerical simulation has become a reliable and cost-effective alternative to experimental testing. This research investigates the effect of aerodynamic heating on heat transfer during icing on rotating blades, identifying rotational velocity as the primary parameter of interest. The study focuses on the impact of rotational velocity on ice thickness and mass, as these factors significantly influence the aerodynamic performance and balance of the blade. A quasi-three-dimensional (quasi-3D) approach and a 3D approach are applied to the Caradonna-Tung (CT) rotor, which has a NACA 0012 airfoil cross-section, with variations in drag and lift coefficients calculated to establish a link with 3D simulations. Each blade has a chord length of 0.191 m and a radius five times the chord length. The study is conducted under glaze icing conditions (T_∞ = -10°C, MVD = 20 µm, LWC = 0.5 g/m³, icing time = 200 sec) at three rotational speeds (600, 1200, and 1800 rpm). The icing process is modeled numerically using three integrated modules: the flow module, which solves the Reynolds-Averaged Navier-Stokes (RANS) equations with the Spalart-Allmaras turbulence model; the droplet module, which employs a Eulerian framework; and the ice module, which utilizes the Shallow-Water Icing Model (SWIM). Results from the quasi-3D approach are verified by 3D simulations. Results indicate that aerodynamic heating has a greater impact on ice accretion at higher rotational speeds, as seen in the variations of ice mass and thickness with rotation speed. Specifically, increasing rotational velocity enhances heat transfer at the blade tip, thereby reducing the amount of accreted ice.