In-Cloud Icing Effects on Aircraft/UAV Aerodynamics and Flight Operations

Abstract: In-cloud ice accretion on aircraft is a safety challenge as it may affect its external surfaces such as the aircraft frame & engine. Icing occurs when supercooled water droplets suspended in air impinge on the aircraft surface and due to heat transfer/phase change freeze from liquid to ice. In-cloud icing on aircraft can be classified into *rime, glaze, and mixed ice*. Mainly ice accumulates along the leading edge of the aircraft wing surface which changes its aerodynamic shape and leads to loss of aerodynamic performance, increasing the aircraft weight and fuel consumption. Sometimes ice ridges can also form along the fuselage that affects the aircraft sensors such as pitot tube.

Most research work about icing on aircraft has been carried out for manned aircraft at high Reynolds numbers, but a direct transformation of these results into Unmanned Aerial Vehicle (UAV) operating at low Reynolds numbers is not straightforward. Changes in Reynolds number have a significant impact on ice accretion physics. Low Reynolds number airfoils are sensitive and even small changes on the aerodynamic surface could significantly impact its performance. Therefore, ice accretion on UAVs needs to be studied separately from manned aircraft. UAVs are more prone to icing than conventional manned aircraft for the following reasons: ***1)*** The presence of supercooled water droplets is pervasive at low altitudes, as most UAVs fly in the lower atmosphere, they are more susceptible to ice accumulation than manned aircraft. ***2)*** UAVs operating at lower velocities than conventional aircraft have prolonged exposure to icing environments. ***3)*** Manned aircraft operate with ice mitigation systems, but most UAVs operate without any ice protection systems because of their weight and power constraints. ***4)*** Composite materials used in the manufacturing of UAVs have lower thermal conductivity than the conventional metal-based airframes used for manned aircraft. Thus, the rate of heat transfer and dissipation of latent heat of fusion released during solidification is much slower for composite materials, resulting in water runback and the formation of complex rivulet-like ice structures along the UAV surface.

The icing on aircraft is being studied since the 1920s, but still, the icing problem is an area of continuous research due to the complexity of the icing phenomena. The main topics of aircraft icing include *ice accretion physics, ice detection, and ice mitigation*. Ice accretion on manned aircraft/UAVs can be studied using four different methodologies: *1) Analytical methods 2) Field measurements 3) Lab experiments 4) Numerical simulations.* Field measurements provide more reliable results but involve more technical complexities and financial aspects, whereas computational fluid dynamics-based multiphase numerical methods are cost-effective but less accurate. So, it's important to select an appropriate hybrid approach to study the aircraft icing problem for reliable and cost-effective results. This talk will mainly focus on issues related to icing on aircraft and recent advancements in methods to study and mitigate the icing problems.

Keywords: In-cloud icing, aircraft, UAV, aerodynamics, performance.