

Investigation of Relative Humidity and Induced-Vortex Effects on Aircraft Icing

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Aircraft icing is an area of research that has drawn attention since the early times of powered flight at high altitudes. Since World War II, aircraft icing research has gained a great deal of momentum, and several branches of research have developed as a result. These branches include the experimental, analytical and computational methods. With the advent of high-speed computers, the computational methods are becoming the leading icing research area due to their low cost requirements. However, a significant hindrance is the lack of a complete understanding of the icing phenomena, which leads to discrepancies between the predictions and the experiments. In recent years, there have been efforts to improve this situation by accounting for several mechanisms within the computational models. These mechanisms include the droplet splash and re-impingement, water film dynamics, and different heat transfer mechanisms. In support of enhancing the understanding of the aircraft icing process, the present study focuses on the relative humidity effects and the interaction of the induced vortices with the droplets and the surface water.

Currently the relative humidity effects are neglected in the icing prediction codes with the assumption that it can at best be a second-order effect. The present study looks at the conditions in which the relative humidity effects can pose significant impact on the accreted ice shape. It was seen that the flow around the airfoil suction surfaces and the vortices, which have low-pressure cores, shed from the existing ice shape are highly supersaturated. Therefore, the suction surfaces and the aft regions of the main ice shape are exposed to condensation/deposition due to relative humidity effects. The time scales involved in the relative humidity effects were also investigated by using a numerical droplet growth experiment.

As far as the induced vortex phenomena, no past work has been done, because the ice accretion prediction codes are based on potential flow formulation, which ignores the viscous effects. Therefore, the present study is a first approach to show the existence of these mechanisms as potential contributors to the ice growth over the airframe. A Lagrangian particle tracking was performed to investigate the interaction of the droplets with the unsteady vortex shedding from the ice surface. It was seen that the vortices shed from ice surface can alter the trajectory paths of the droplets and change the ice growth process. The altered paths result in impingement on areas that are beyond the direct impingement region. It was also found in this study that the strength of the shed vortices increases with the flow Reynolds number, and therefore they become strong enough to affect the paths of larger droplets.