On behalf of Professors Hui Hu and Alric Rothmayer,
Meet our graduate student:

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Aerospace Engineering Graduate Preliminary Oral Exam:
An Experimental Study on Wind-driven Surface Water Transport Process Pertinent to Aircraft Icing

*** Aircraft icing is widely recognized as a significant hazard to aircraft operations. Surface water transport process plays a very important role in determining the ice formation and accretion over aircraft wings. In glaze icing conditions, water beads, rivulet and film flows run back along the airfoil surface to redistribute the impinging water mass, disturb the local flow field and interact with icing roughness elements, thereby, influence the ice accretion process. A novel Digital Image Projection (DIP) technique was developed to quantify the transient behavior of the surface water transport process driven by boundary layer airflows over airfoil/wing surfaces in order to improve our understanding of the underlying physics for safer and more efficient operation of aircraft in atmospheric icing conditions. The DIP technique is based on the principle of structured light triangulation in a similar manner as a stereovision technique but replacing one of the cameras for stereo imaging with a digital projector. The digital projector projects a grid pattern with known characteristics onto test objects (i.e., water droplet/rivulet flows over icing accreting surfaces). Due to the 3D geometrical profiles of the test objects (i.e., the free surfaces of the water droplet/rivulet flows), the grid pattern is deformed observed from a perspective different from the projection axis. By comparing the distorted grid pattern over the test objects (i.e., with water droplet/rivulet flows over the test surfaces) and a reference grid pattern on a reference plane, the 3D profile of the test objects with respect to the reference plane (i.e., the thickness distributions of the droplet/rivulet flows, thereby, the water mass transport processes over the test surfaces) can be retrieved quantitatively and instantaneously.

After carefully calibrated and validated, the proposed DIP technique was applied to characterize the surface wind-driven water film/rivulet flows over a NACA 0012 airfoil. The measurement results reveal clearly that, after impinging on the leading edge of the NACA0012 airfoil, the micro-sized water droplets would coalesce to form a thin water film in the region near the leading edge of the airfoil. The formation of rivulets was found to be time-dependent process and relies on the initial water runback flow structure. The film thickness icing scaling law is evaluated by the time-average measurement of the film thickness. The measurement results show good consistent with the analytical scaling predictions. The DIP technique was also used to quantify the transient behavior of wind-driven film flow over a surface with roughness arrays in order to examine the effects of the roughness arrays on the surface water transport process, i.e., trapped mass effects, which is pertinent to the surface water runback over airfoils/wings with ice roughness. While surface water mass trapping was observed clearly right downstream of the roughness elements, some other interesting features about the water film flow within roughness elements were also revealed clearly from the quantitative DIP measurements, which were found to agree well with those previous numerical studies.

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