Schlieren Visualization of Anti Icing Thermo Fluid Interaction on an Airfoil

Shane Barker, Ahmed Kandil, Ahmed Aboelezz
Department of Mechanical Engineering, University of Maine

MAINE Student Symposium Research and Creative Activity

ADL AEROSYSTEMS DYNAMICS LABORATORY

Abstract

At the extremely low temperatures of high altitudes, supercooled liquid water droplets freeze on the surface of aircraft wings. Ice accumulation changes the cross sectional shape of the wing, thereby degrading its lift and stall characteristics. To prevent this, heating elements are implemented into aircraft wings to melt ice as it forms. However, the heat produced by these elements also subtly changes the aerodynamics of the aircraft. To visualize how the flow over a heated wing changes with temperature, a schlieren setup was employed. This setup took advantage of the density gradients that were present in air as it changed temperature. As the air density changed and created density gradients, there was a change in the refractive index of air. The schlieren was able to capture these changes as different brightness values on an image. Using this principle, airflow over the wing was visualized at temperatures of 50°C, 100°C, and 150°C. Each of these three wing temperatures were tested at 3°, 9°, and 15° of angle of attack. From this range of testing parameters, images of flow separation and turbulence were captured, allowing for the qualitative analysis of the airflow over a heated wing. From the images, it was seen that higher temperatures contribute to earlier onset of flow separation when compared to lower temperature tests done at the same angle of attack.

Experimental Setup and Objectives

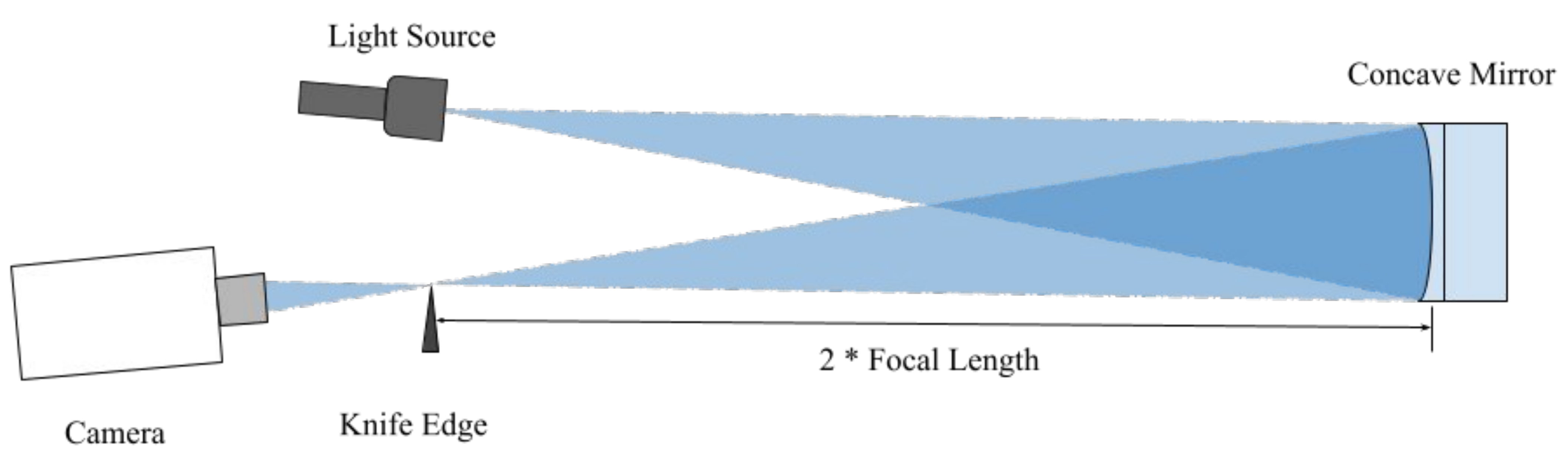

Figure 1. Diagram of Schlieren Setup Used in Experiment

Experimental Setup
The experimental setup consists of a camera, a knife edge (a razor blade was used), a concave mirror, and a point source of light (a flashlight with a specialized cover was used). The light is emitted by the point source and travels to the concave mirror, passing by the test section on the way. The light is reflected by the concave mirror and collimated into a point, where the knife edge is carefully positioned to block a fraction of the light. This is what makes a schlieren setup different from a shadowgraphy setup. Finally, the light that is not blocked travels on to the camera, where the schlieren image is recorded.

Objectives
1. View the density gradients in the airflow
2. Highlight the thermal boundary on the upper surface of the wing section
3. Experimental results will show the effects of a heated wing on the airflow over it

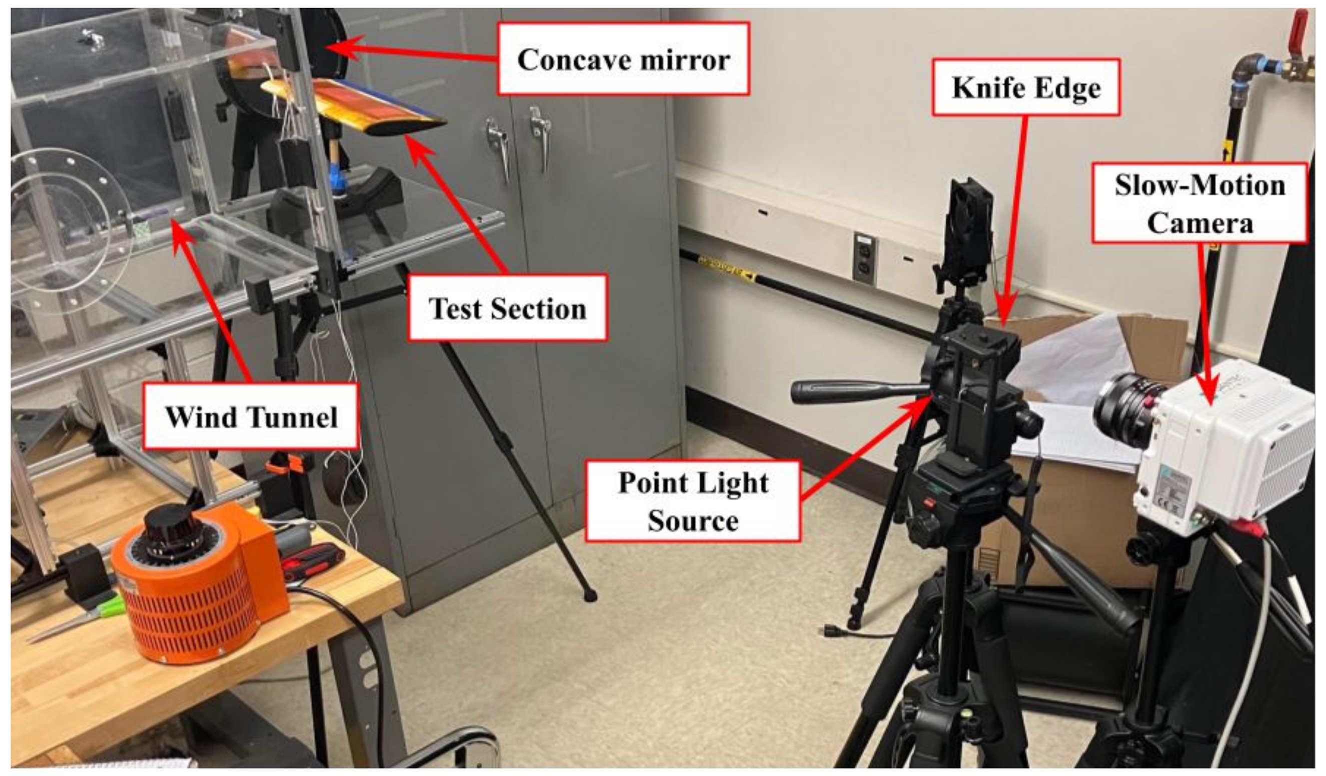

Figure 2. Experimental Setup

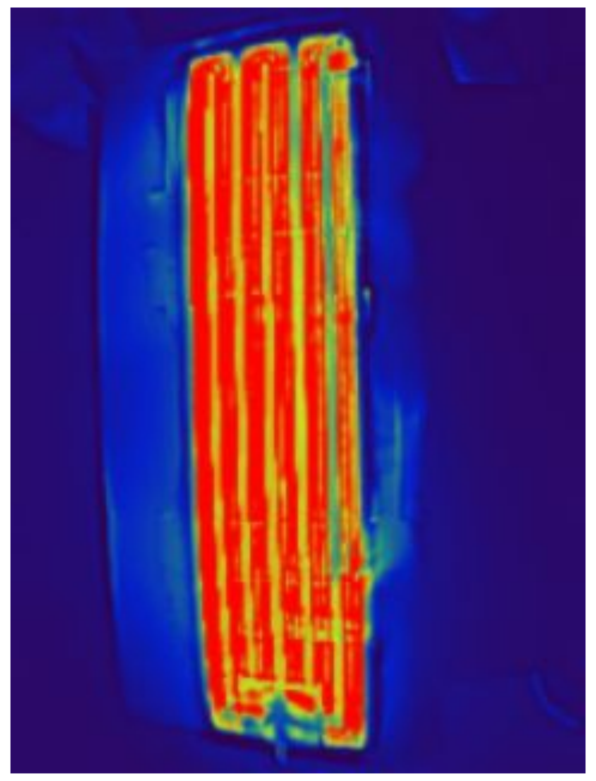

Figure 3. Thermal Image of Heated Wing

Results

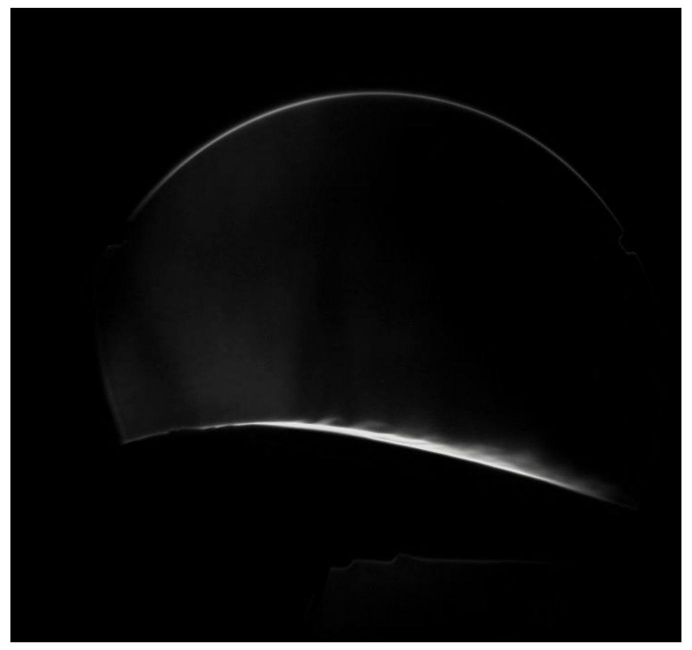

Figure 4. Thermal Boundary at 3° AoA, 50°C

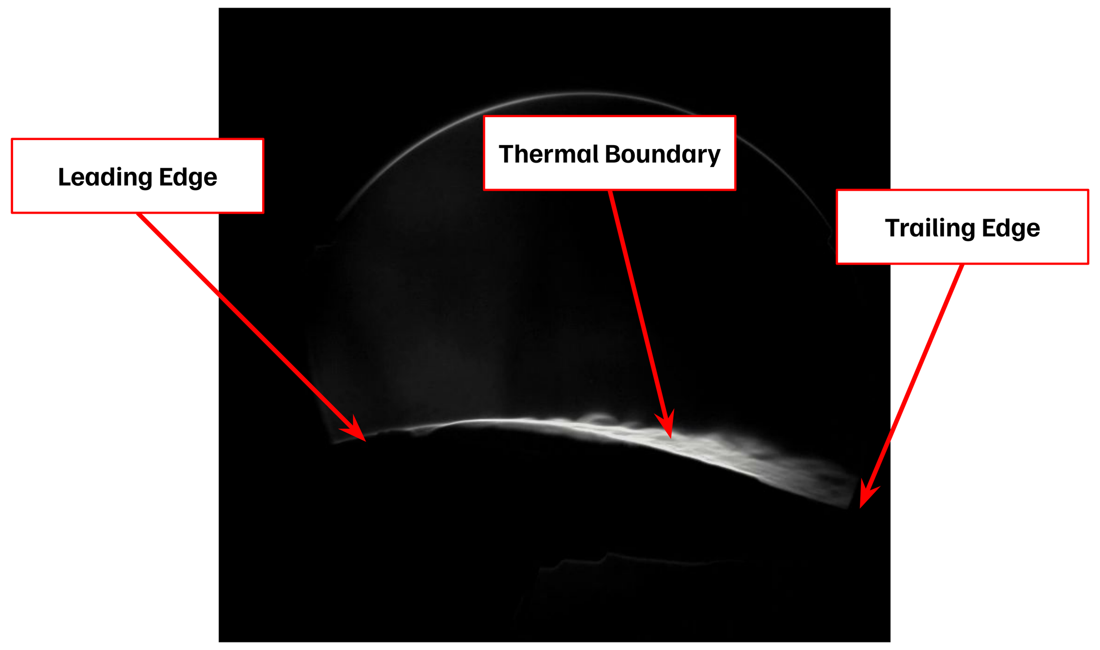

Figure 5. Thermal Boundary at 3° AoA, 100°C

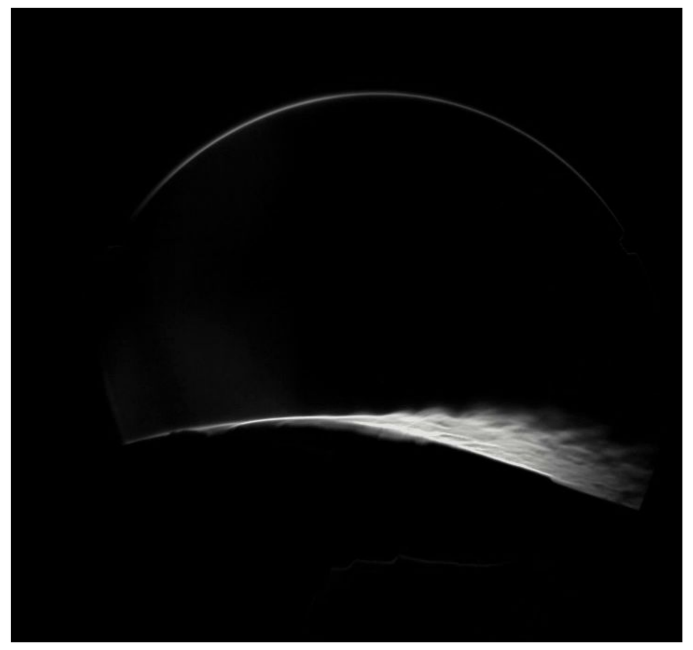

Figure 6. Thermal Boundary at 3° AoA, 150°C

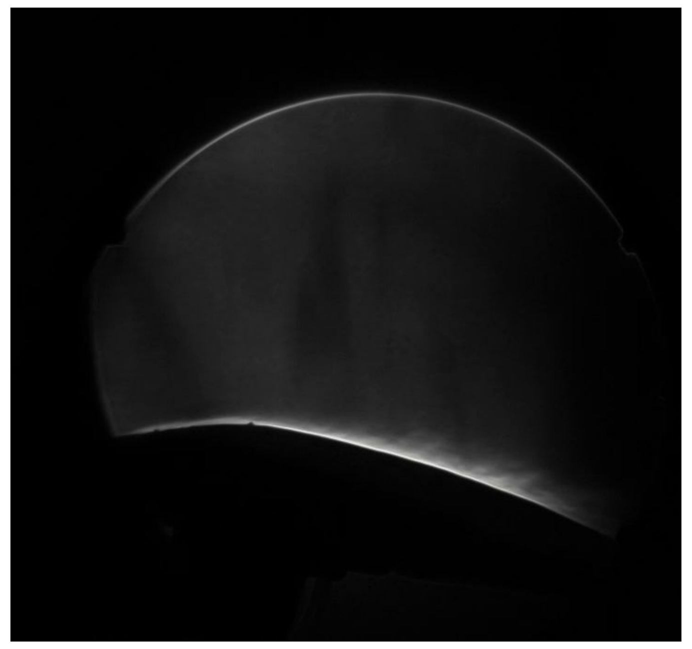

Figure 7. Thermal Boundary at 9° AoA, 50°C

Figure 8. Thermal Boundary at 9° AoA, 100°C

Figure 9. Thermal Boundary at 9° AoA, 150°C

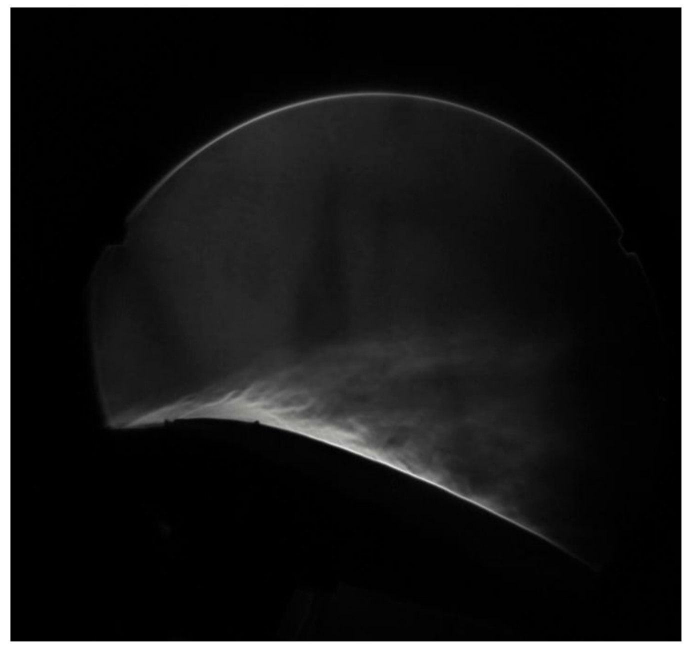

Figure 10. Thermal Boundary at 15° AoA, 50°C

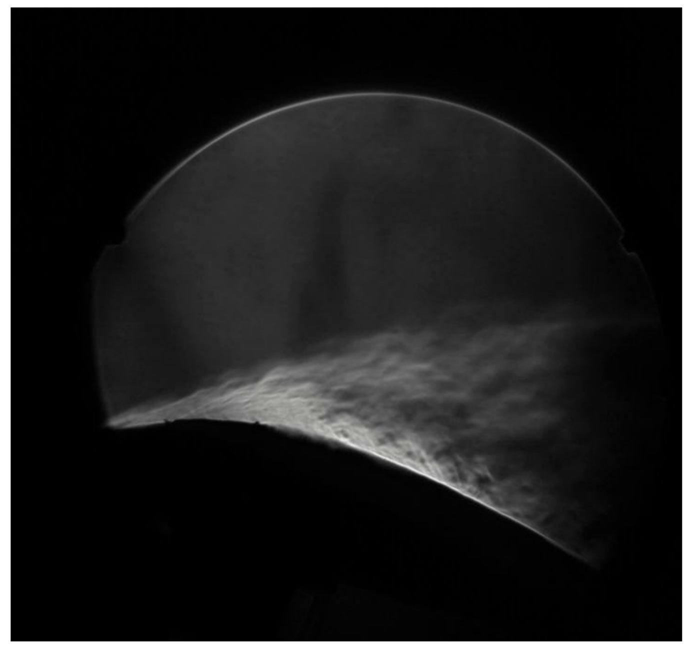

Figure 11. Thermal Boundary at 15° AoA, 100°C

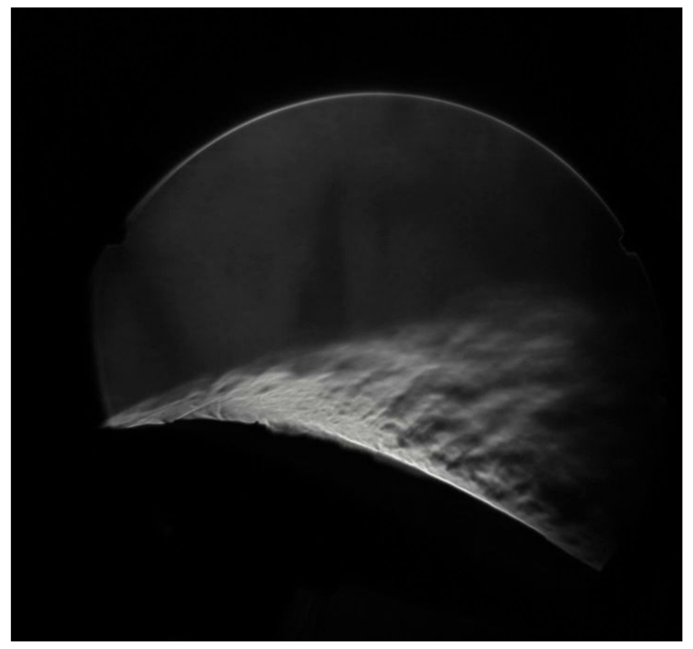

Figure 12. Thermal Boundary at 15° AoA, 150°C

Discussion and Future Work

Discussion
Results indicate that heating a wing causes the flow passing over it to become more unstable than if the wing were unheated. This can be seen by the increasing thicknesses of the thermal boundaries as wing temperature increases. Furthermore, flow separation occurs when the test section is positioned at an angle of attack of 15 degrees. Unfortunately, separation of flow solely due to an increase in wing temperature could not be seen, however if the experiment were repeated with closer spaced angles of attack between 10 and 15 degrees, this phenomenon might be captured. Overall, the results were as expected, as they show the destabilization of the boundary layer as the flow temperature increases.

Future Work
- Create an assembly which combines the knife edge and light source into a single apparatus
- Continue testing to achieve better quality images
- Explore ways in which the mirror can be stabilized to prevent any oscillations which may interfere with clear videos
- Experiment with different mounts for the flashlight cover to reduce wasted space and to optimize the amount of light emitted
- Implement a larger mirror to increase the size of the section which can be analyzed

Acknowledgements

I would like to thank and acknowledge the Maine Space Grant Consortium for their support of this project. I would also like to thank Mr. Yousef Meligy for his assistance with our experiments and for his help with image processing.