UNIVERSITY of WASHINGTON
William E. Boeing Department of Aeronautics and Astronautics

AERODYNAMIC EFFECTS OF TRAILING EDGE SERRATIONS ON A WING AT LOW REYNOLDS NUMBER—WORK IN PROGRESS

Israel Bron Simplicio, Giovanni Nino, Robert Breidenthal
israelbr@uw.edu, gnino@uw.edu, breident@aa.washington.edu

MOTIVATION:

With the advent of the development of smaller air vehicles, such as micro air vehicles (MAVs), there is a need to improve their aerodynamic performance. MAVs' designs include fix wing and flapping wings, among others features. The aim of this project is to study the effects of trailing edge serrations on the air flow around wings under conditions like the ones faced by the MAVs with the goal to improve energy efficiency by drag reduction.

Micro Aerial Vehicle AeroVironment's Black Widow MAV [1]

LOW REYNOLDS NUMBER AERODYNAMICS

MAVs operate at relatively low Reynolds numbers ($Re < 100{,}000$) [2], where the boundary layer is typically laminar. Consequently, flow separation on an airfoil occurs at relatively small angles of attack [2].

MODIFIED WING SECTIONS

Changes in the trailing edge of wing sections have been studied for several decades, especially at higher *Re* for aeronautical or wind turbine applications. Modifications started with simple truncated/blunt trailing edge models provide structural benefits in comparison to a sharp trailing edge, but with disadvantages such as an increase in base drag [3]. Trailing edge serrations have been tested as alternatives to the blunt trailing edges, reducing the negative aerodynamic effects of the bluntness [3].

To study the degree of influence of the surface area in reducing the drag, models with different surface areas based on NACA 0012 airfoil profiles were created, starting from the largest surface area to the lowest: (a) baseline NACA 0012, (b) trailing edge with triangular serrations, (c) trailing edge with 2-arc serrations, and (d) trailing edge with parabolic serrations. Models were 3D printed using a carbon-fiber filled Nylon composite material and can be seen in Fig. 1.

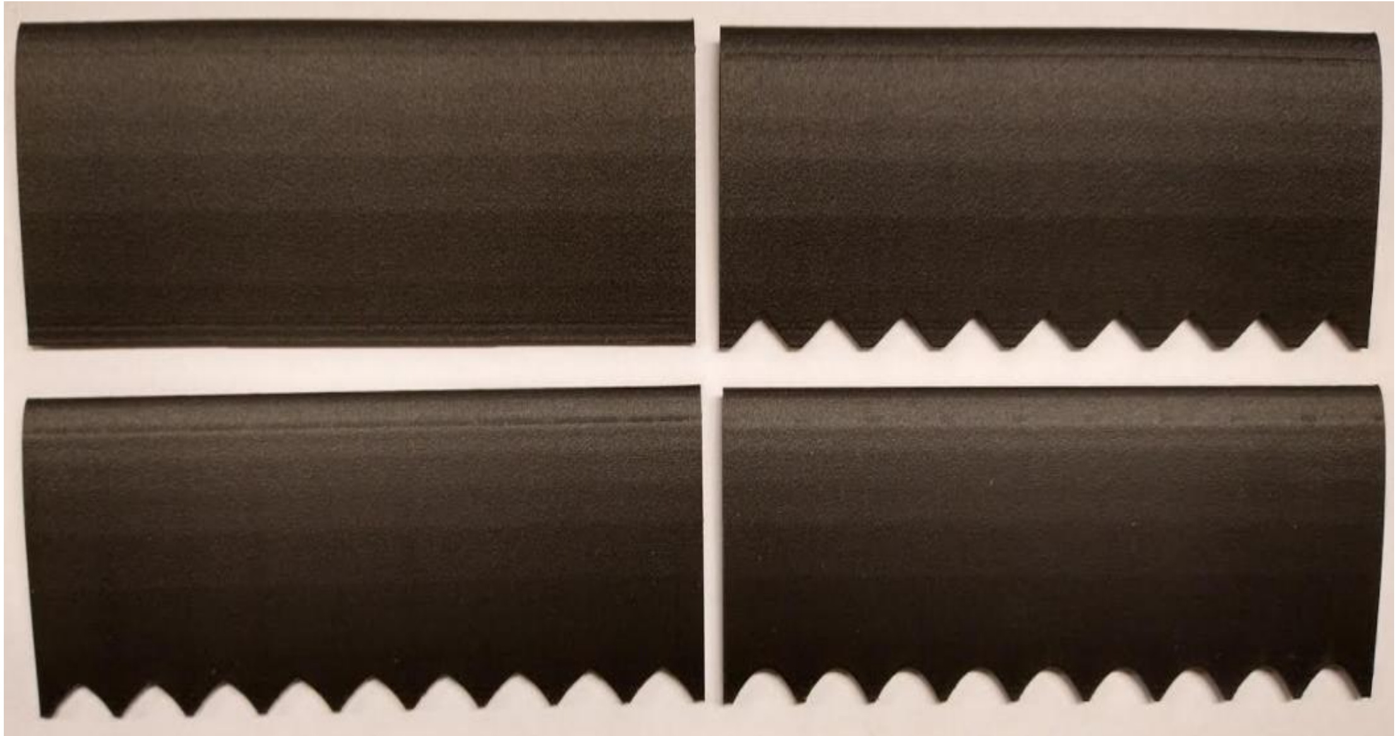

Fig 1: 3D printed wing sections

EXPERIMENTAL TECHNIQUE

The drag of the airfoils was assessed from the dynamic pressure profiles in the wakes. The local dynamic pressure was normalized by its maximum value in the freestream flow (q/q_{max}).

MODEL SPECIFICATIONS

The wing models follow the following specifications as shown in Table 1 and all units are in millimeters (for parameter clarification, see Fig. 2).

Wing Type	***Re***	**c**	**s**	**λ**	**d**	**R**
NACA 0012	20,000	40.0	100.0	—	—	—
Triangular	20,000	40.0	100.0	10.67	5.33	—
2-arc	20,000	40.0	100.0	10.67	5.33	13.33
Parabolic	20,000	40.0	100.0	10.67	5.33	—

Table 1: Experimental specifications for models.

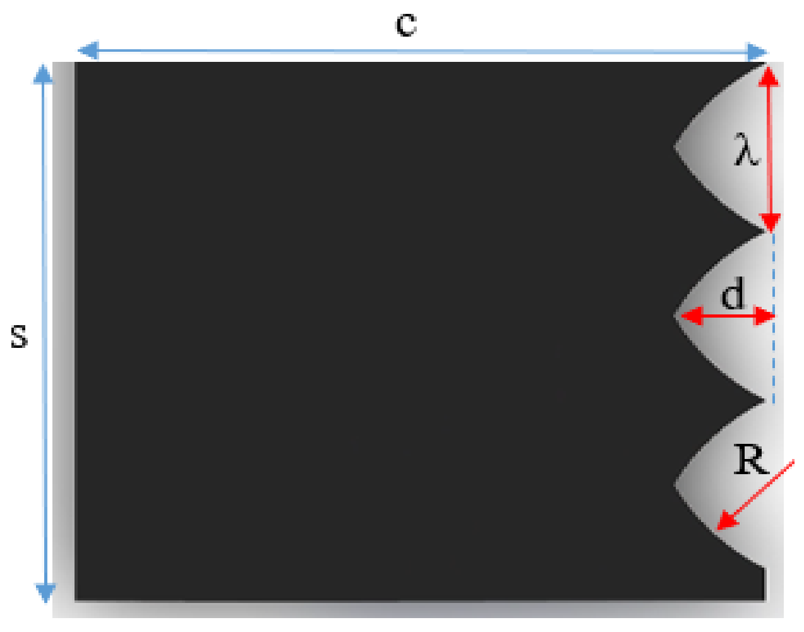

Fig. 2: Diagram for parameter clarification

EXPERIMENTAL LAYOUT

Figs. 3-5 illustrate the testing setup used on this project.

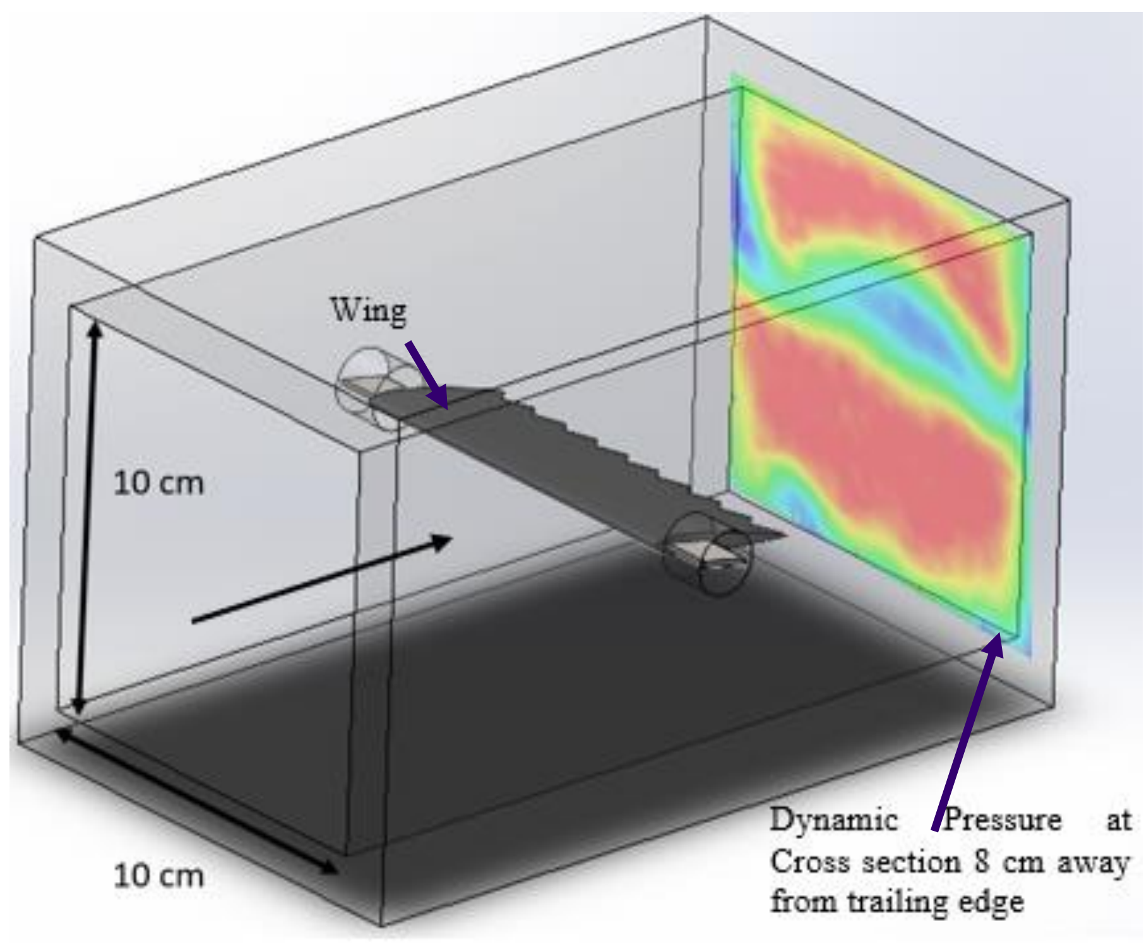

Fig. 3: Diagram of setup with cross section of measurements.

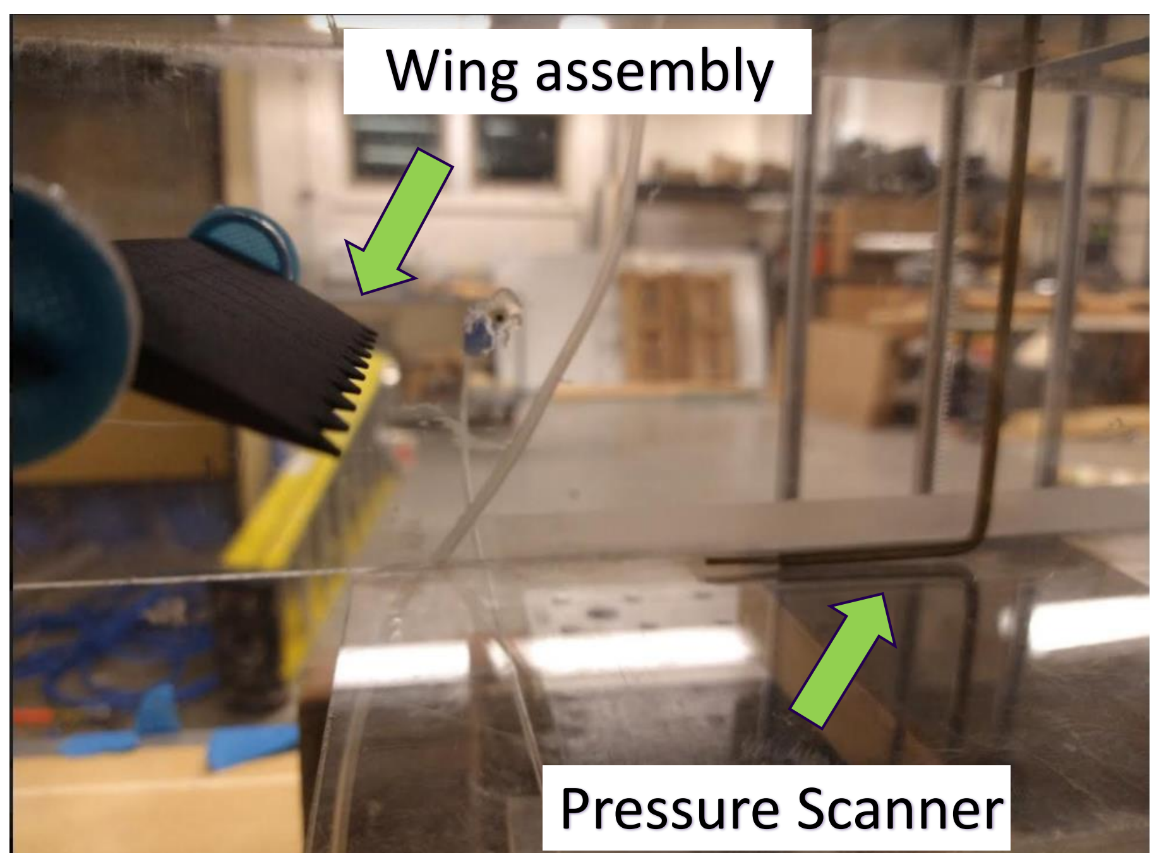

Fig. 4: Side view of physical test setup with wing assembled

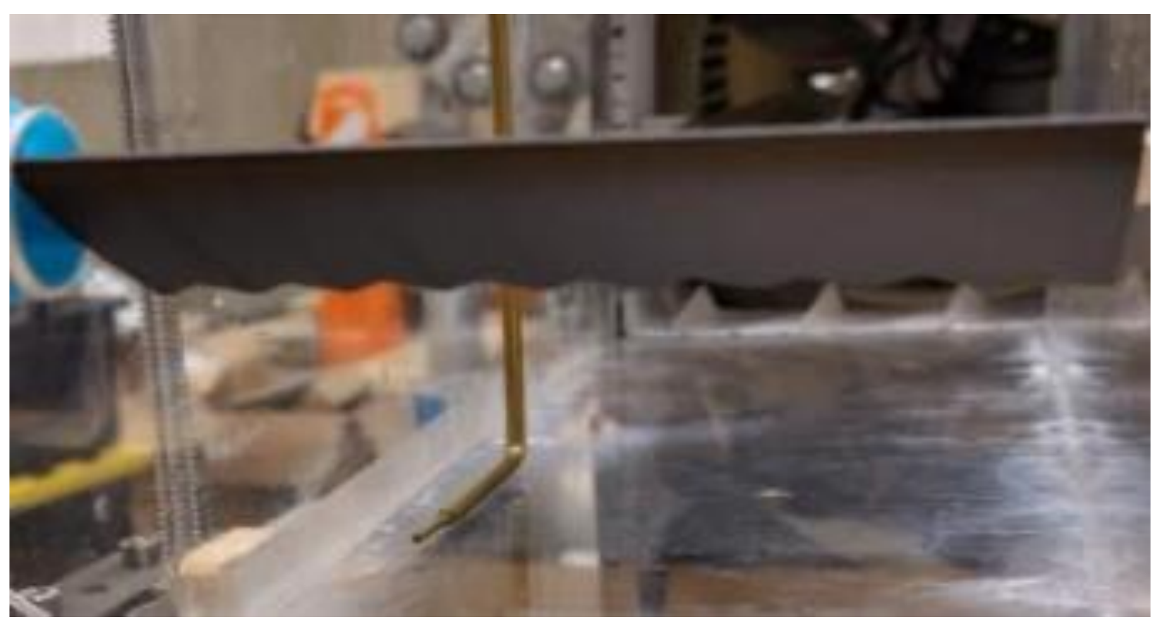

Fig. 5: Front view of physical test setup with wing assembled

PRELIMINARY RESULTS

Data has been collected using a pressure scanner in a cross section located 8 cm downstream of the trailing edge. The dimensionless ratio of dynamic pressure over maximum dynamic pressure (q/q_{max}) was used as a parameter of comparison among the different wing models set at an angle of attack (AoA) of 15° (see Fig. 6).

The NACA 0012 baseline shows the highest gradient between the wake region behind the airfoil and the free stream regions with an area of negative values that indicate the presence of von Karman vortices. All airfoils with serrated trailing edge show a reduction in the gradient of dynamic pressure and in the strength/presence of Von-Karman vortices showing an improvement in aerodynamic performance. Fig. 7 shows the q/q_{max} vertical profile for all models at $z = 49$ mm. Here, the parabolic and 2-arc serration show the most promising results. The percent reduction in the magnitude drop between q/q_{max} at the freestream section and the lowest point of q/q_{max} in the wake region when compared to baseline NACA 0012 airfoil baseline and the serrated models are presented in Table 2.

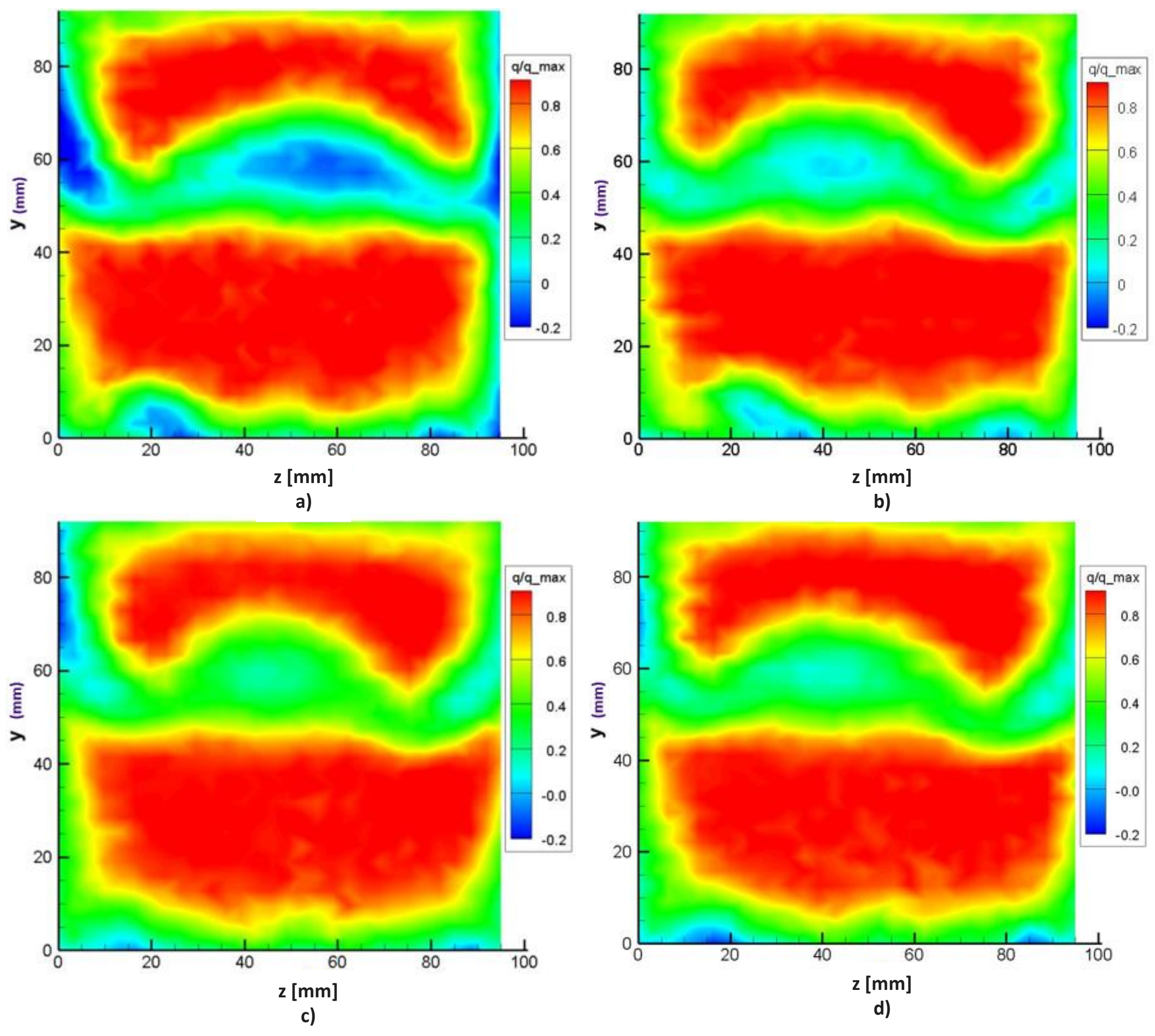

Fig. 6: Contour plots for (a) NACA 0012 baseline, (b) trailing edge with triangular serrations, (c) trailing edge with 2-arc serrations, and (d) trailing edge with parabolic serrations. Same order as on Fig. 1.

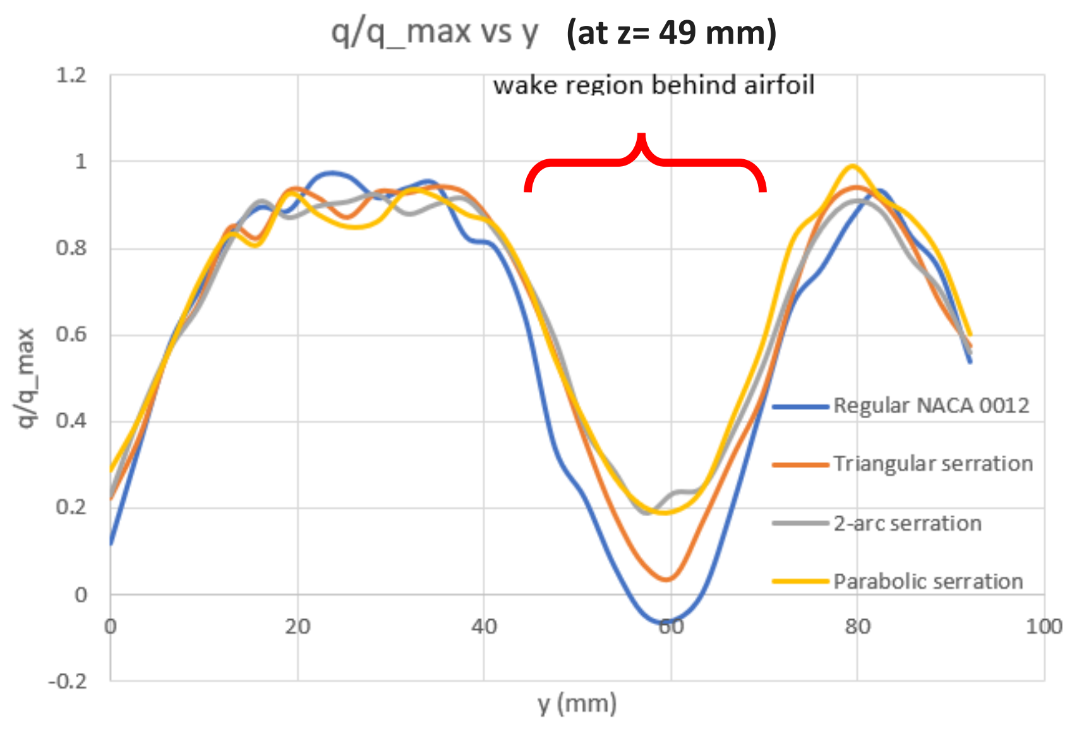

Fig. 7: Plot of q/q_{max} as a function of y at z = 49 mm

Wing Type	**Triangular**	**2-arc**	**Parabolic**
Percent reduction [%]	12.0	28.4	22.5

Table 2: Percent reduction of the magnitude drop between q/q_{max} at the freestream section and the lowest point of q/q_{max} in the wake region compared to baseline NACA 0012 airfoil

NEXT STEPS

This project will continue its studies in three main areas, based on the current results: (i) measure the drag coefficient for each of the cases presented using the wake survey method, (ii) analyze the models at different angles of attack and wind speeds, and (iii) evaluate variations on the ratio d/λ of the serrated trailing edge models.

[1] Grasmeyer, J., Keennon, M. (2001) "Development of the black widow micro air vehicle," *AIAA, 39th Aerospace Sciences Meeting and Exhibit*, 8–11 Jan. 2001. doi: 10.2514/6.2001-127
[2] Watkins, S., Ravi, S., and Loxton, B., "The Effect of Turbulence on the Aerodynamics of Low Reynolds Number Wings," *Engineering Letters*, Vol. 18(3), Aug. 2010.
[3] Tanner, M., "REDUCTION OF BASE DRAG," *Progress in Aerospace Sciences*, Vol. 16, No. 4, 1975, pp. 369–384.