FLOW MODIFICATION

BY TUBERCLES IN BRAZILIAN

FREE-TAILED BATS

By

TREVOR MARTIN

Bachelor of Arts/Science in Mechanical Engineering

Oklahoma Christian University

Edmond, Oklahoma

2015

Submitted to the Faculty of the

Graduate College of the Oklahoma State University

in partial fulfillment of the requirements

for the Degree of

MASTER OF SCIENCE

May 2017

FLOW MODIFICATION

BY TUBERCLES IN BRAZILIAN

FREE-TAILED BATS

Thesis Approved:

B. R. ELBING

Thesis Adviser

J. D. JACOBS

A. SANTHANAKRISHNAN

Name: TREVOR MARTIN

Date of Degree: MAY 2017

Title of Study: FLOW MODIFICATION BY TUBERCLES IN BRAZILIAN FREE-TAILED BATS

Major Field: MECHANICAL ENGINEERING

Abstract: Flow over Brazilian free-tailed bat ears is believed to be modified by tubercles found along their leading edge. The study observes this modification through flow visualization over the bat ear models and through PIV analysis of tubercles transposed onto a NACA-0012 airfoil. Flow visualization depicted a change in flow over the two bat ears, which may be related to modification of flow separation. The PIV study on the airfoils indicated reduction of drag at low angles of attack (< 10°) for the bat ear with tubercles and increased drag past these angles of attack. It was also found that the bumped airfoil experienced a delay in stall compared to the smooth NACA-0012 airfoil. These flow characteristics are beneficial to the bats as they aid in their flying ability and feeding habits.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1 MOTIVATIONS AND INTRODUCTION

Biomimetics is an increasingly prevalent field in which designs found in nature are used in real world engineering applications. Therefore, it is useful for engineers to explore designs found in nature. An example of engineering design found in nature leading to engineering advancement is the flow modification found in the structure of humpback whale flippers. Humpback whale (Megaptera novaeanglia) typically have 9-10 tubercles on the leading edge of their pectoral flippers. Studies have shown that the presence of these tubercles increase the maneuverability of humpback whales due in part to delaying stall at high angles of attack (Fish, Battle 1995). Similarly, Brazilian free-tailed bats also have small tubercles along the leading edge of their ears.

Ground and radar tracking have shown that Tadarida brasiliensis can fly at altitudes of up to 3,000 m and cover up to 100 km in one night (Williams et. al. 1973). The average speed of these bats has in the past been crudely approximated at 9 m/s, but recent NEXRAD Doppler radar images have estimated the average speed to be 7.6 m/s (Horn, Kunz 2008). Maximum flight speeds for Brazilian free-tailed bats have been observed to approach 27 m/s (Davis et. al. 1962).

Most previous studies on the flight of free-tailed bats focus on aspects of wing anatomy, wing motion, and aerodynamics (Hubel et. al. 2012) The goal of the study is to assess whether leading edge tubercles affect the aerodynamic characteristics of the bat ears at different angles of attack across the range of their flight speeds.

Due to the agility of Brazilian free-tailed bats and their unique flying behavior, it is theorized that tubercles found on their ears may similarly help maneuverability. To test this theory, three-dimensional models of a Brazilian free-tailed bat ear were created and examined with PIV measurement by Petrin et. al. (in preparation). A model without tubercles and a model with leading edge tubercles were placed in a water tunnel and tested at various flight speeds typical of free-tailed bats. The results of the measurements revealed that tubercles serve as a drag reduction mechanism at low angles of attack and increase drag at high angles of attack. The wake deficit graph is shown in Figure 1.

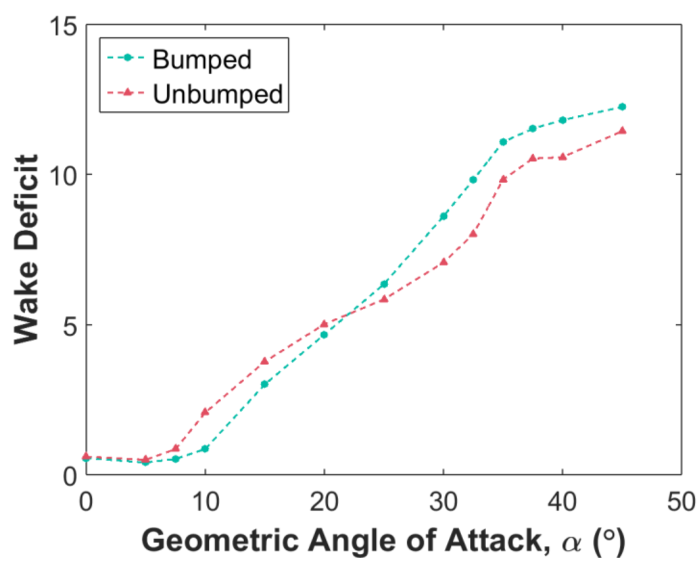


Figure 1 - Wake deficit graph for bumped and unbumped bat ear

Although the previous study showed drag reduction by leading edge tubercles in bat ears, there were additional steps that could be taken to make the results conclusive. Based upon the initial results of the bat ear analysis, it became apparent that the effect of the bat ear tubercles could be better understood if studied in the two-dimensional realm. Two symmetrical NACA-0012 airfoils were chosen for this task and were 3D printed. One airfoil was printed without leading edge tubercles and one was printed with leading edge tubercles. These two airfoils were placed in the water tunnel and were then analyzed using PIV to determine the effect of the leading-edge tubercles on drag and lift.

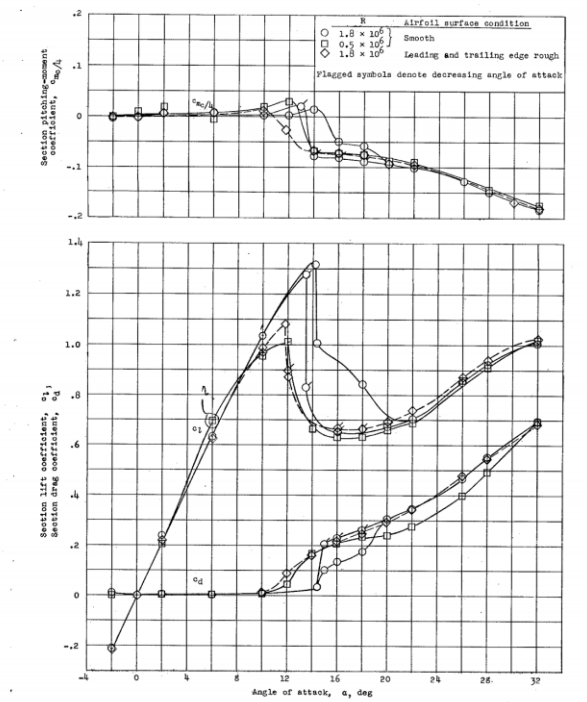
2 REVIEW OF LITERATURE

Tadarida brasiliensis are not the only examples of leading edge tubercles found in nature. A study was conducted on the flippers of humpback whales by *Fish et. al.* A humpback whales' pectoral flippers have eleven tubercles found along their leading edge. These tubercles were spaced relatively constant at 6.5% to 8.5% of the span over the middle of the flipper (tubercles 2-8) (Fish et. al. 1995). Previous to Fish's study it was suggested by Bushnell and Moore (1991) that humpback tubercles may reduce drag on the flipper. Fish found that leading edge tubercles on humpback whale flippers help maintain lift and avoid stall at high angles of attack. Fish suggests that the tubercles may function to generate vortices by unsteady excitation of the flow. The vorticity generation would behave in the same manner as strakes or vortex generators used on aircraft. Vortex generators postpone stall on aircraft because vortices exchange momentum within the boundary layer and keep it attached over the wing surface. In the same way lift is maintained at higher angles of attack, however the maximum lift is not increased. The ability to maintain lift at higher angles of attack is beneficial to the whales as it allows for better maneuverability while feeding. While Fish did not provide direct evidence for flow modification over the flipper, he did note that the pattern of barnacle growth on the leading edge indirectly supports this theory. There is a noted lack of barnacle growth between tubercles, which seems to indicate a modification of flow where water is channeled between the tubercles at high speeds. Furthermore, the feeding behavior of humpback whales is considered to be more physically demanding than that of other baleen whales. These other whales lack the leading-edge tubercles that allow for the increase maneuverability seen with humpback whales.

Further investigation of a scalloped flipper model showed that the presence of the tubercles delays stall to higher angles of attack, increases the maximum lift, as well as decreases drag (Miklosovic et. al. 2004). Investigation of humpback whale flipper models with and without leading edge tubercles revealed increases with the onset of each aerodynamic state (attached flow, partial stall, and deep stall). However, at low angles of attack the drag on the bumped humpback whale flipper model was never greater than the drag on the smooth model. The results of drag and lift were shown to have sensitivity to Reynolds number for Reynolds number under 400,000 and 200,000 respectively. The study found that because of the lift and drag characteristics, aerodynamic efficiency is decremented at some angles of attack for the tubercle flipper, but for most of the angles of attack the aerodynamic efficiency was increased. The findings that the scalloped leading edge of the flipper serves to delay stall by providing lift at higher incidence angles, thus augmenting the performance of the humpback whale’s ability to maneuver would seem to parallel with the Brazilian free-tailed bats need for maneuverability both to feed and to roost. This delay in stall for humpback whale flippers was also found in a study by *Nierop et. al.* (2008).

Knowledge of these findings led to investigation of the flow properties affected by the leading-edge tubercles in Brazilian free-tailed bats. The influence on drag from leading-edge tubercles on the ears of Brazilian free-tailed bats (Tadarida brasiliensis) was experimentally examined with PIV measurements of the downstream wakes. This was accomplished by measuring the wake deficit behind both a smooth and bumped bat ear model. This study by Petrin et al. (in preparation) found that drag reduction was not universal, but was instead dependent on the angle of attack. In their study, it was found that drag was reduced up to nominal angles of 20° angle of attack. The finding showed that at normal cruising flight speeds drag on the bat's ears would in fact be reduced. The reduction of drag allows for the bats to fly with less energy consumption when flying at the same speeds, and also give the bats the ability to fly faster if they choose. Past 20° angle of attack drag was shown to increase for the bat ears with leading edge tubercles. The increase in drag would be beneficial to bats attempting to pull out of dives entering the caves in which they live. Therefore, the leading-edge tubercles were found to be beneficial to Brazilian free-tailed bats in all aspects of their flight. This study only examined the cruise speed for the bats, and was ran with an open tunnel.

Since the airfoil chosen for this study was a NACA-0012, fundamental understanding of the NACA-0012 used in the experimentation will help to interpret the result of the testing. Cristzos et. al. (1955) investigated the flow properties of the NACA-0012 airfoil over multiple angles of attack. Figure 2 shows the relationship of lift and drag to angle of attack for different surface roughness values.

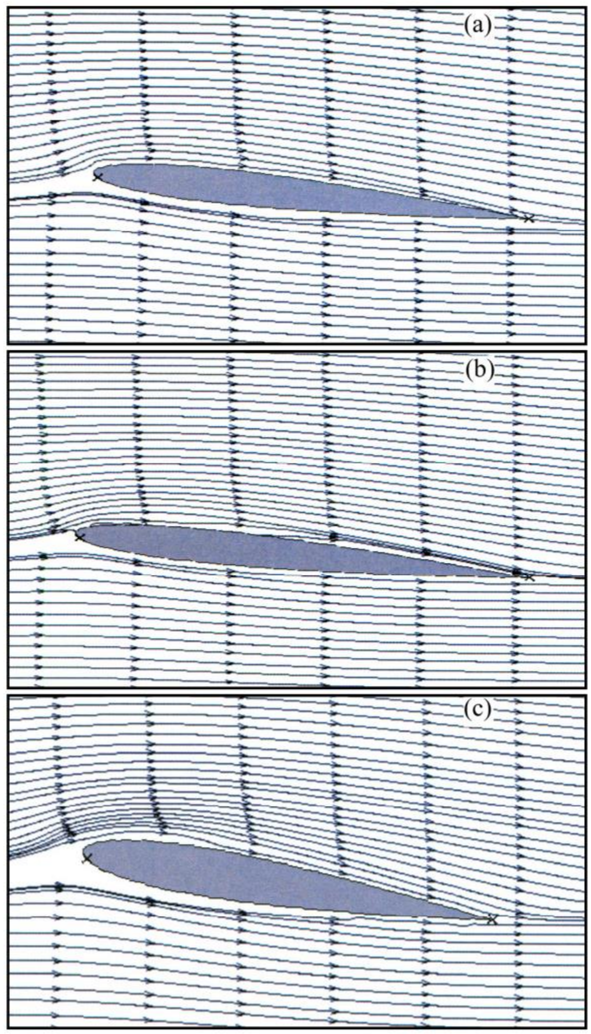


(b) Angles of attack from -2° to 32°.

Figure 2- Lift and Drag Coefficients for NACA-0012 Airfoil

From the figure, it is apparent that the airfoil reaches stall around 12° angle of attack for Reynolds number of 500,000. As Reynolds number decreases so does the angle of attack at which stall is reached. Therefore, we should expect to see stall characteristics in our tests before 12° angle of attack. It is also worth noting that theoretically derived expressions were used to correct the lift and drag data to account for the blockage effects caused by constriction of flow past the model in tunnel. My study encountered similar problems and adjustments to the data were also made with theoretical expressions.

Derksen et. al. found that flow was separated at around 12° angle of attack for a Reynolds number of 5,000. Figure 3 shows the mean streamlines found in their study for angles of attack up to 12°.



The mean streamlines at Re = 5,000; (a) $\theta = 8°$, (b) $\theta = 10°$, and (c) $\theta = 12°$.

Figure 3 - Flow pattern for NACA-0012 airfoil

Tubercles along the leading edge of the bat ear are believed to act as vortex generators. On airplane airfoils, vortex generators reduce drag and improve aerodynamics by delaying boundary layer separation. Vortex generators delay separation by creating minor turbulence that enables the boundary layer to “keep up” with the airfoil for a little longer before separation occurs. This leads to a smaller wake which in turn reduces drag. Additionally, a recent study has shown that vortex generators can also improve plane’s aerodynamics in a second way. A research team from the Linne Flow Center demonstrated that simple vortex generators also minimize the boundary layer’s drag by delaying its transition from laminar to turbulent flow (Shahinfar 2012). Once turbulent flow is reached, the drag on the airfoil increases. The study showed that the disturbance energy inside a boundary layer can be reduced by up to three orders of magnitude, greatly reducing skin-friction drag. It is my belief that the bat ear tubercles act in this manner to reduce drag and improve aerodynamic characteristics

3 EXPERIMENTAL METHODS

3.1 Test Facility

3.1.1 Water Tunnel

The water tunnel used in the experiments is an Engineering Laboratory Design, Inc. Model 503. The test sections dimensions are 30 cm x 30 cm x 100 cm. The maximum power of the tunnel is 15 HP and the total volume capacity of the tunnel is 2,625 liters. Two Gusher pumps (model PGL 4X6-105EH-C-B) provided the flow rate for the tunnel. The maximum attainable flow rate is 1 m/s. Two VFC's (Engineering Laboratory Design) individually controlled each of the pumps. The water tunnel was filled with filtered tap water (WHKF-DWHV, Whirlpool) until the flow channel was filled. The filter removed all particles greater than 5 μm. For the bat ear flow visualization tests, the water tunnel was run with an open top. Because the model needed to have its angle adjusted during testing, it was not feasible to run the experiments with a closed top. The

PIV measurements of the airfoil were performed with the top of the tunnel closed. The tunnel is shown in Figure 4.

Figure 4 - Model 503 30cm, Engineering Laboratory Design

3.1.2 Bat Ear Model Support for Dye Testing

Initial flow visualization was conducted on the bat ears to determine if additional flow testing would be beneficial. This required for the bat ears to be lowered into the center of the tunnel where flow is the most uniform. In order to ensure accurate results, the printed bat ear models were attached to a support structure to be used in the water tunnel. The support structure allows for the bat ear to be lowered into the center of the water tunnel where the flow will be the most uniform. The structure consists of two plywood platforms, a steel rod to which the ear is attached, and two fairing structures. Both fairing structures were constructed from FX 79-L-100 (UIUC Airfoil Coordinates Database) symmetric airfoils. The top plywood platform was even with the top of the tunnel to help provide both rigidity and stability to the model. Because inserting the model required the tunnel to be ran open top, the bottom plywood platform was placed on the top of the water's surface to help prevent negative effects of surface distortion to the flow. A protractor was printed on the top plywood platform to control the angle of attack for the bat ear. The angle of attack was measured within 0.5°. The dye testing needle was attached to the fairing structure, and dye was injected directly behind and below the first leading edge tubercle. The entire structure is shown in Figure 5.

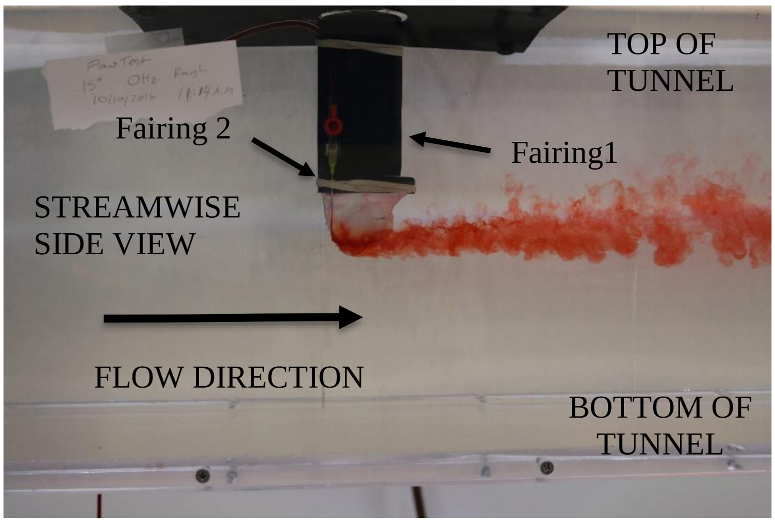


Figure 5 - Dye testing for flow visualization

3.2 Test Models

3.2.1 Bat Ear Model

To create an accurate model of a Brazilian free-tailed bat ear, the models used in the experiment were produced from a three-dimensional scan (Ultra HD, NextEngine) of a formalin preserved bat ear. Therefore, the models used in testing represent the performance of a single bat, not the performance of an average bat ear. The nominal chord length of this bat ear was 14 mm with 8 leading-edge ear tubercles. The model was upsized using a 4:1 scaling ratio to facilitate testing. The distribution of the tubercles in relation to the span, and the height of each respective tubercle are shown in Table 1.

Table 1– Location of tubercles relative to the span

Tubercle	1	2	3	4	5	6	7	8
Span (%)	31%	45%	54%	62%	72%	80%	88%	92%
Height(mm)	1.5	2.0	2.0	1.8	1.5	1.3	1.0	0.8

Additionally, a bat ear model without tubercles was also printed. The smooth bat ear consisted of the same dimensions as the bumped bat ear. The bat ear models were used in the PIV testing performed by Petrin et al. as well as the flow visualization found within this thesis.

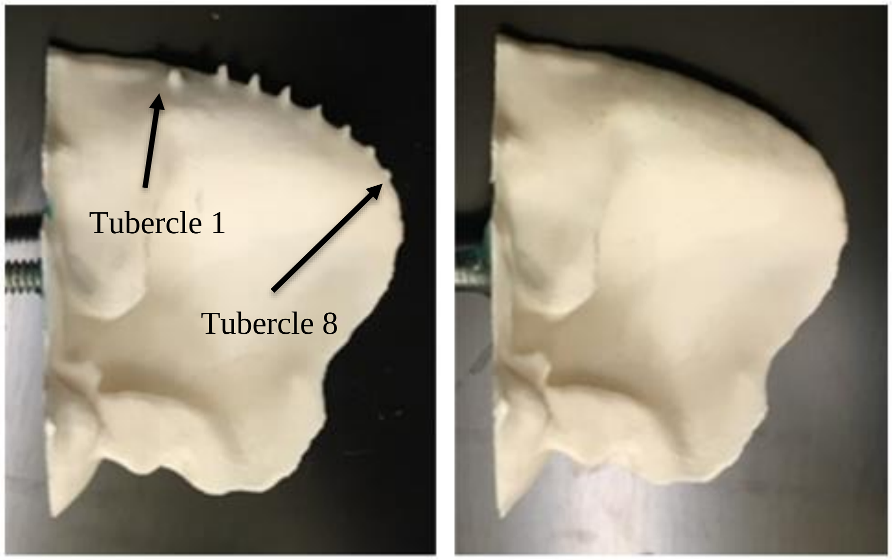


Figure 6 - Bumped ear model (left) smooth ear model (right)

3.2.2 Airfoil Models

The flow visualization testing led to two realizations. The flow was indeed altered by the leading-edge tubercles, and the flow changes would be much simpler to analyze in two dimensions. Therefore, two symmetrical airfoils were printed. The symmetrical airfoil chosen was the NACA-0012 airfoil. The span of the airfoils was set equal to the width of the tunnel (30 cm), and the chord length (11.2 cm) was equal to eight times the chord of the selected bat ear. This results in a 2:1 scaling compared to the bat ear model. The smooth airfoil was printed by a Robo R1 +Plus 3D Printer in PLA and the bumped airfoil was printed using a Formlabs 1+ printer manufactured by Formlabs. Because the printer only allowed for six inch sections to be printed, the airfoil was broken into two parts with fitting joints. The two pieces were then fixed together with waterproof epoxy. The airfoil was then sanded until hydrodynamic smoothness was obtained.

Since the goal is to determine the 2 dimensional effects of the tubercles, an average bump size of 3 mm was used as the standard for the model. The spacing between the bumps was scaled according to the chord length scaling ratio as well. The bump pattern was completed 4 complete times across the span of the 30-*mm* tunnel. Half of the airfoil with tubercles along the leading edge is shown in Figure 7. The PIV Measurement was taken between the 5th and 6th tubercle.

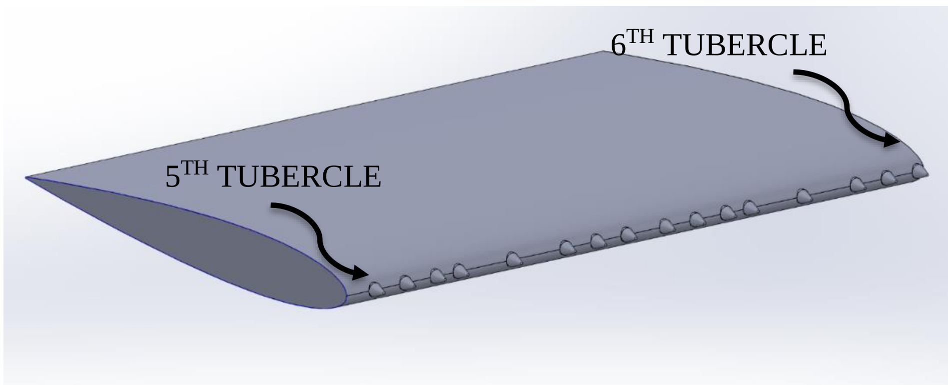


Figure 7– Half of the NACA-0012 Bumped Airfoil

The airfoils were placed horizontally in the tunnel with foam cutouts on each side. Pressure and friction from the attached foam cutouts held the airfoils in place during testing.

3.3 Instrumentation

3.3.1 Laser System

A 200 mJ/pulse, 15 Hz Nd:YAG laser from New Wave Research's Gemini series was used to light the particles for PIV testing. The voltage of the laser was 115V and the current was 10 A. The laser was manufacture in February of 2003. The tunnel was flooded with `18 μm hollow glass spheres (iM30K, 3M) to scatter the light from the Nd-YAG laser. The laser triggering and synchronization was controlled by a programmable timing unit (PTU-9, LaVision) with 10 ns resolution. The starting interrogation window was 512 x 512 pixels and was reduced with multiple passes to a final interrogation window of 32 x 32 pixels with 50% overlap. A time filter that subtracted the average base image was applied to the data set. Vectors that resulted in peak ratios of $Q < 1.1$ were not trusted data points. Groups with less than 5 trusted vectors were removed from the data. Velocity vector fields were produced from the acquired images using DaVis8 (LaVision).

3.3.2 Recording System

The scattered light from the particles was recorded with a high-resolution sCMOS camera (Imager, LaVision). The sCMOS camera has a 50 Hz maximum capture rate and a resolution of 2560x2160 pixels. The camera was fitted with a 60-mm lens (Nikon AF Nikkor, Nikon). The camera was calibrated using a 58x58mm dual plane, stereo PIV calibration target (Type 58-5, LaVision). The laser sheet was aligned along the very front of the calibration plate. A pinhole model was used to perform the calibration. The calibration resulted in a standard deviation of fit equal to 0.28622 pixels for angles of attack of -5°, 5°, and 10°. The focal length was 36.775 mm, and the pixel size was 0.0065 mm. The calibration for 0°, 8°, and 15° angle of attack resulted in a standard deviation of 0.24489 pixels with a focal length of -2.58229 mm and 0.0065 mm pixel size.

3.3.3 Test Matrix

The lab conditions at the time of testing were atmospheric pressure and room temperature between 65° and 75° Fahrenheit. These conditions result in a corresponding kinematic viscosity of 10^{-6} m^2/s and a density of 998 kg/m^3. For the bat ear dye testing, Pump 1 was set to 15 Hz (approximately 0.1 m/s) for 0°, 15°, 30°, and 45°. This corresponds to the cruising speed of the bats. Testing was performed on the airfoil models for approximate angles of attack of -5, 0, 5, 8°, 10°, and 15°. Each angle of attack was tested at speeds of 7 Hz, 15 Hz, and 65 Hz (0.05 m/s, 0.15 m/s, and 0.50 m/s respectively). This corresponds to Reynolds numbers of 5,600, 16,800, and 56,000. The Reynolds number of 5,600 approximately corresponds to the bats cruise speed, and the Reynolds number of 16,800 approximately corresponds to the fastest diving speeds of the bats.

The capture speed and dt of the image capturing system and the laser firing rate were adjusted to properly measure the movement of the glass particles in the tunnel. The firing rate of the laser was set to capture a new image every time a new set of particles entered the laser sheet. The dt value was determined to be the length of time needed between paired images for a particle to move 10 pixels. For 0.05 m/s the capture rate was set to 0.15 Hz and the dt between the images was 19,000 micro-seconds. For 0.15 m/s the capture rate was set to 0.45 Hz and the dt between the images was 9,000 micro-seconds. For 0.5 m/s the capture rate was set to 1.5 Hz and the dt between the images was 3,000 micro-seconds.

4 RESULTS

4.1 Flow Visualization

A fairing system was employed to prevent noise and drag associated with the bat ear mounting method. It is important to understand the flow interaction between the fairing and the bat ear model. Figure 8 shows the time-average flow results for the dye-test at 0° angle of attack for both the smooth and bumped bat ears. The dye testing was performed in the water tunnel at 0.1 m/s, and high speed images of the resulting flow pattern were captured with a digital camera (EOS 70D, Canon). The dye testing was performed using the set-up found in Figure 5. For the interface test, dye was injected at the fairing-to-fairing interface along the leading edge. The acquired images show that the interface does not dramatically affect the flow across the bat ear.

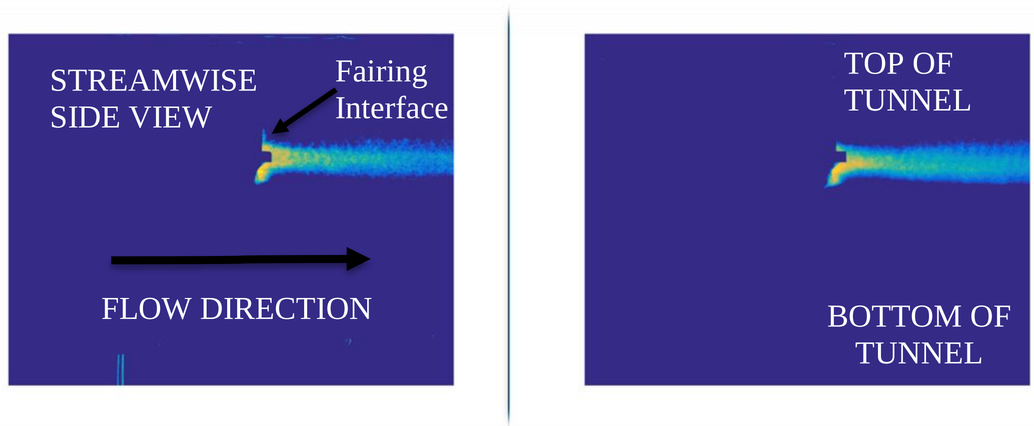


Figure 8 - Dye interface test bumped ear (left) smooth ear (right)

There appears to be an area of low pressure directly below the interface as evidenced by the concentration of dye in that area, however this is present for both ear models. There appears to be some lift associated with the fairing piece, however the lift is present for both the smooth and rough interfaces. Dye testing was also performed to qualitatively assess the flow over the surface of the Brazilian free-tailed bat ear. Red dye was suspended and gravity fed through a needle placed at 20% of the span length. The flow in the water tunnel was set to 0.1 m/s, which produces a Reynolds number of 5700. This Reynolds number is equivalent to the Reynolds number produced by the bat ear during average flight conditions. The images from the dye testing were time-averaged using a commercial computing software package (Matlab, MathWorks) and plotted using a Jet colormap in Figure 9, Figure 10, Figure 11, and Figure 12. These figures show the flow over the two ears at 0°, 15°, 30°, and 45° angle of attack.

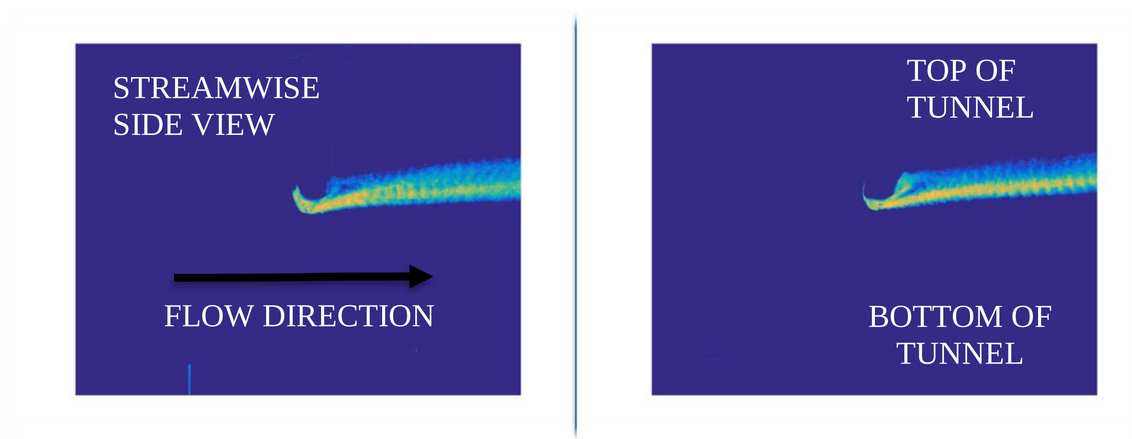


Figure 9 - Dye-test for bumped ear (left) and smooth ear (right) at 0°angle of attack

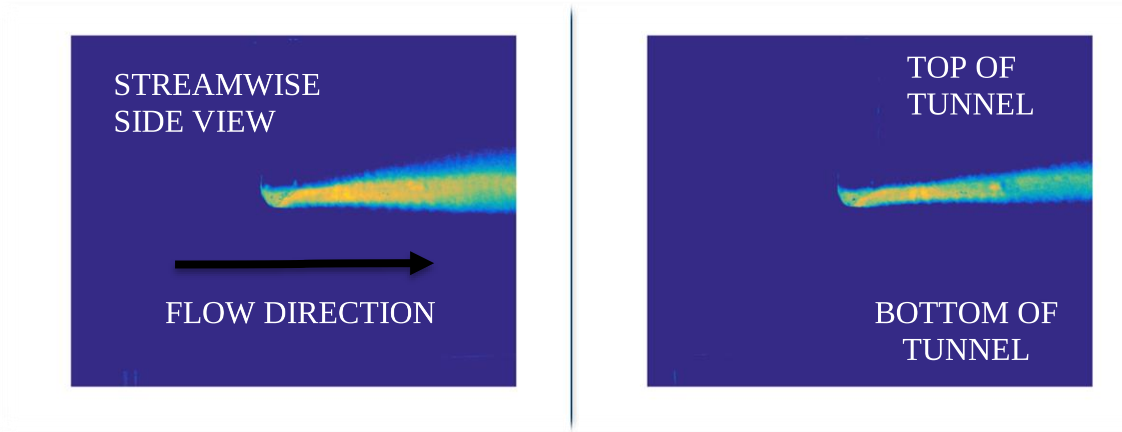


Figure 10 - Dye-test for bumped ear (left) and smooth ear (right) at 15° angle of attack

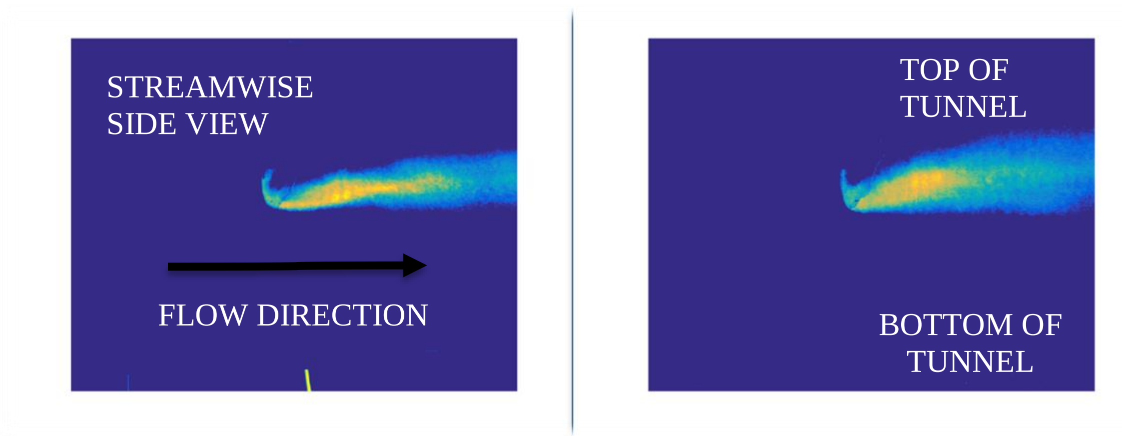


Figure 11 - Dye-test for bumped ear (left) and smooth ear (right) at 30° angle of attack

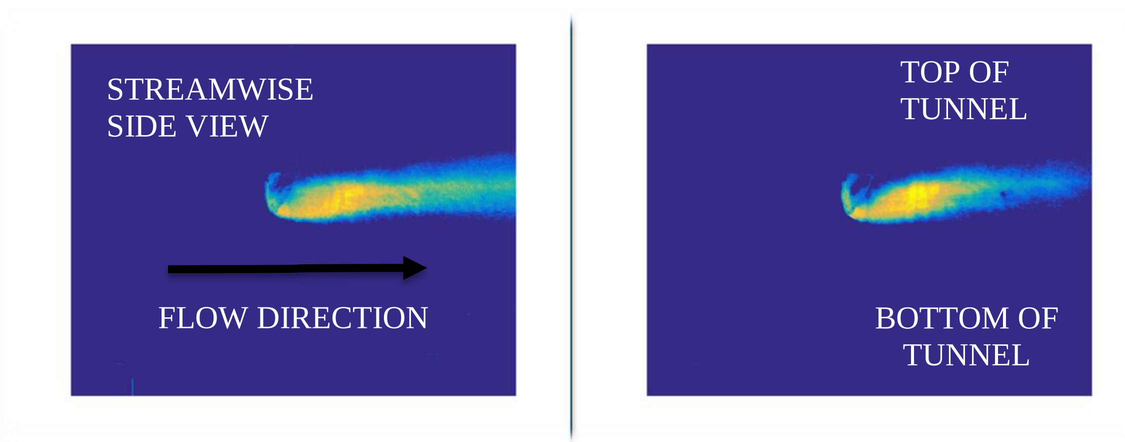


Figure 12 - Dye-test for bumped ear (left) and smooth ear (right) at 45° angle of attack

At 0° angle of attack there is little noticeable change in the flow pattern between the smooth and bumped bat ears. However, there appears to be a larger collection of dye behind the smooth ear. At 15°, 30°, and 45° angle of attack the flow patterns become notably different between the smooth and bumped ear models. It is difficult to make any quantitative analysis from the visual data obtained, but it is apparent that the tubercles on the leading edge of the bat ear do play a role in the flow pattern produced. The difference in the flow pattern may be a result of changes in flow separation caused by the bumps along the leading edge.

4.2 PIV Analysis of Airfoil Models

Based upon the previous PIV measurements of the wake downstream of the bat ear models, it was determined that it would be beneficial to examine the effects of leading edge tubercles on a two-dimensional model. While the flow control effect on the bat ear might be related to the three-dimensional shape, characterization using PIV wake measurements are more robust on a two-dimensional model. Therefore, two symmetric NACA-0012 airfoils were 3D printed, one with leading edge tubercles (Formlabs 1+, Formlabs) and one without leading edge tubercles (R1+Plus 3D, Robo).

The airfoils were placed in the water tunnel and tested using PIV to obtain the wake deficits for the models over a range of angles of attack. Each airfoil was tested at three different speed 0.05, 0.15 and 0.5 m/s. The slowest speed yields the equivalent Reynolds number of the bat at cruise speed (5,700) and the middle speed corresponds to the Reynolds number of the bat diving near terminal velocity (17,100).

4.2.1 Angle Measurement

The airfoils were held by friction inside the tunnel and a protractor was used to draw the angles of attack desired on both sides of the tunnel as shown in Figure 13. The airfoil was then adjusted until both sides were on the desired angle of attack. However, image processing was performed to more precisely determine the angle of attack of the airfoil during testing. Reported angles of attack are within ±0.1°.

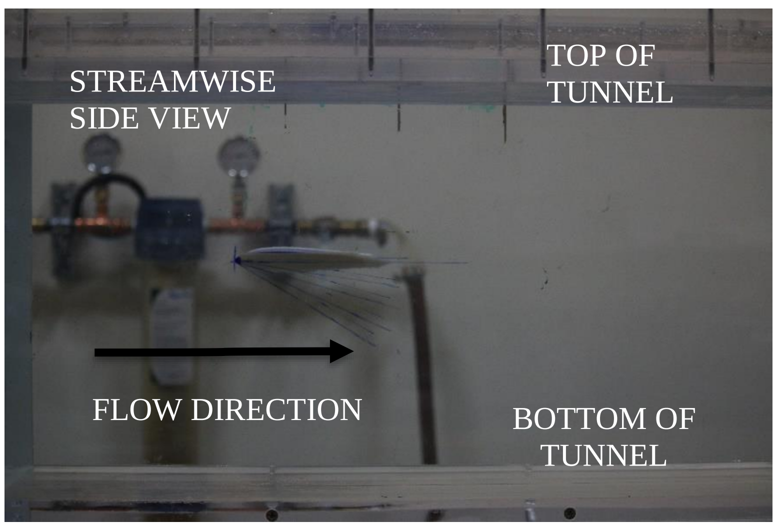


Figure 13 - Smooth airfoil at 0° angle of attack

The images taken of the airfoils were used to calculate the true angles of attack of the airfoil using a Matlab code. The target and measured angles of attack for the smooth and bumped airfoil are provided in Table 2. Each angle of attack was tested three times for each airfoil. The testing was split into two sets of three angles of attack. Originally testing spanned a wider range of angles of attack with measurements at 0°, 8°, 15°, 23°, and 30°.

However, it was found that the blockage effect was too great at angles of attack greater than 15°, so the revised test matrix was used with the additional angles of attack of -5°, 5°, and 10°.

Table 2- Calculated angles of attack

Target	-5°	0°	5°	8°	10°	15°
Smooth	-4.4	0.8	5.2	9.1	11.4	15.8
Bumped	-5.4	0.8	5.5	8.5	11.0	15.7

4.2.2 PIV Results

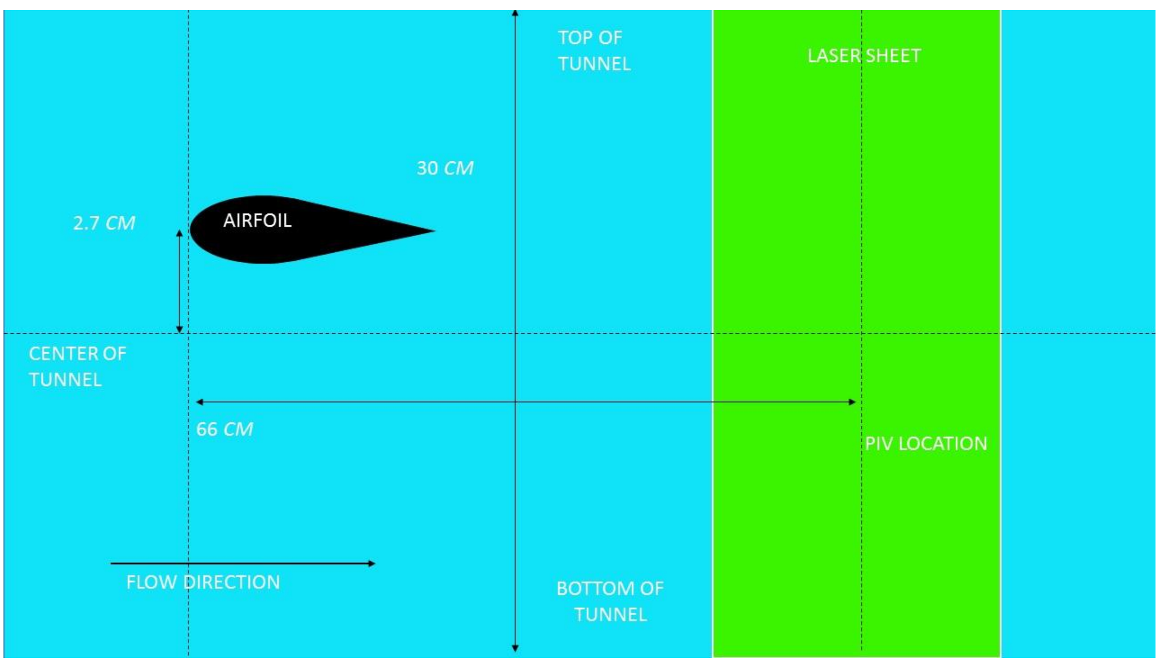


Figure 14 - PIV Test Configuration

The PIV laser sheet was placed vertically in the center of the water tunnel. Figure 15 shows the typical distribution of particles in the tunnel when struck by the laser sheet.

Note that the cameras used for testing have a very large dynamic range (14-bit), which results in most of the particles appearing not very bright even though there is significant deviation from the background. While difficult to see due to the large dynamic range, these images show that the laser sheet is best illuminated near the center of the image. Areas that are not as well illuminated will have greater uncertainty in the results. Therefore, geometric masks were used to isolate the areas within the field-of-view (FOV) that were properly illuminated.

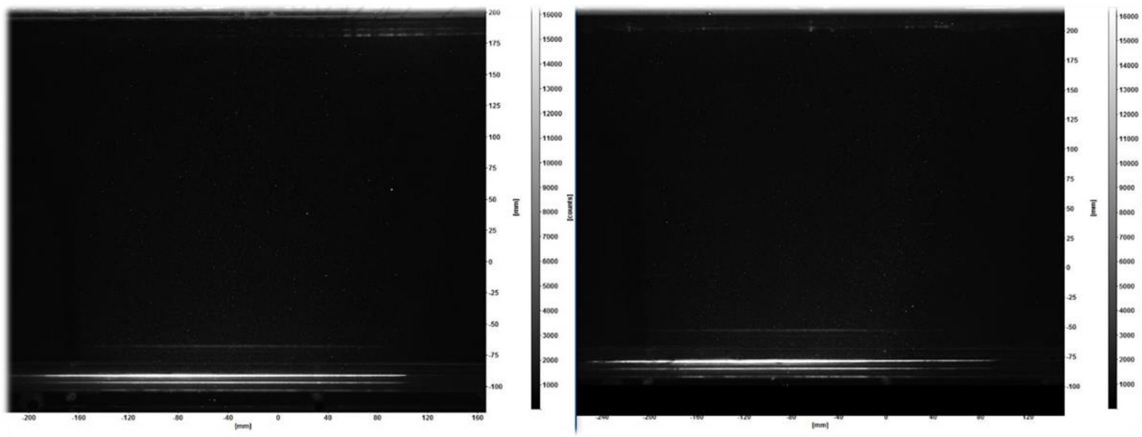


Figure 15 - Particle distribution sample for 0, 8, and 15° AOA testing (left) and -5, 5, -15° AOA testing (right)

One hundred pairs of the above particle images were taken, cross-correlated to find instantaneous velocity fields, and then averaged to yield the average vector fields. An example average vector field for the smooth airfoil at 0° angle of attack and 7 Hz is shown in Figure 16. Images of the remaining PIV vector field results can be found in the appendix.

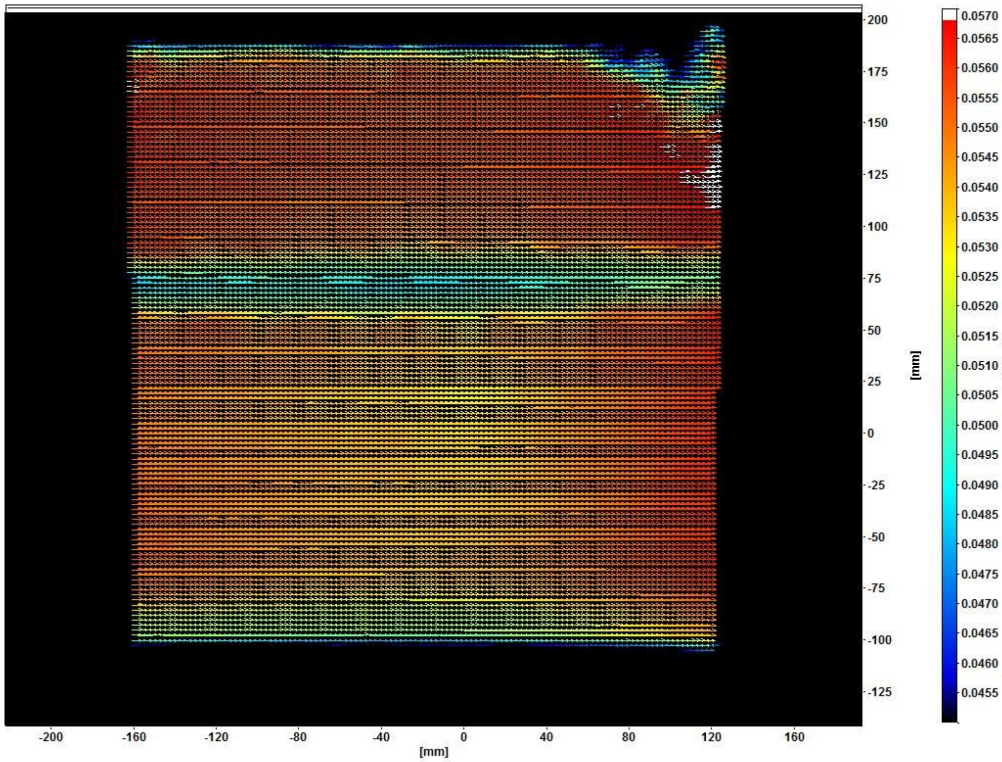


Figure 16 - Smooth airfoil PIV vector fields for 0.05 m/s and 0° angle of attack

Based on the resulting average vector fields and the raw particle images, x = -2.1 *mm* was determined to be the furthest downstream location that yielded accurate results for -5°, 5°, and 10° angle of attack, and x=-11.5 *mm* for angles 0°, 8°, and 15°. These coordinates are directly from the raw PIV data and both correspond to the location 0.66 *m* downstream from the front of the airfoil. The velocity profiles for this location in the tunnel were generated for both airfoils at the six angles of attack and the three test speeds. The three tests for the smooth airfoil at 0° angle of attack are shown in Figure 17. For the tests, the center of the tunnel is found at y = 50 *mm* and the center of the airfoil was found at y = 77 *mm*. These results show that (i) the level of repeatability for the tests, (ii) the wake region is clearly visible, (iii) the model was positioned slightly above the tunnel centerline, and (iii) blockage effects result in a non-symmetric free-stream.

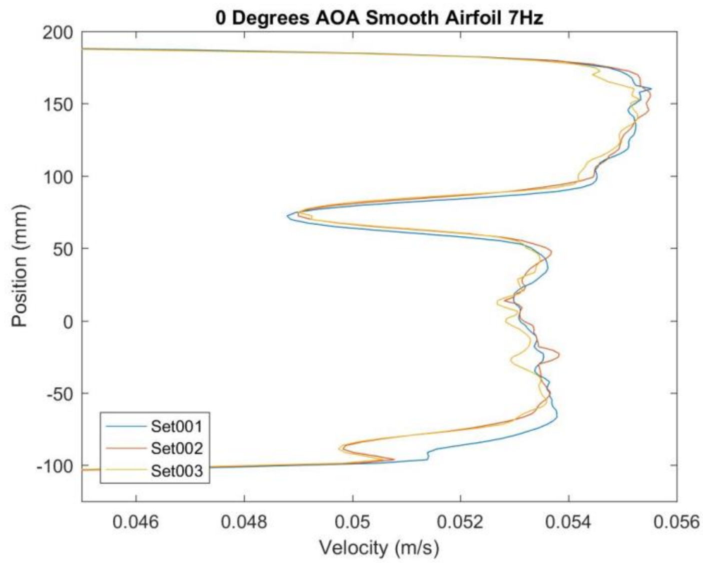


Figure 17 - Smooth airfoil velocity profile for 0.05 m/s and 0° angle of attack. The center of the tunnel is located at y=50 mm. The top and bottom surfaces of the tunnel correspond to y =190 mm and y= -104 mm

Also, worth showing here is the wake profiles of the two airfoils with the greatest difference in overall width. This angle of attack and speed corresponds to what will eventually be determined to yield the greatest difference in drag for the two airfoils. Figure 18 shows the two airfoils at 8° and 0.15 *m/s*. The data art this angle of attack and speed is notably consistent between tests.

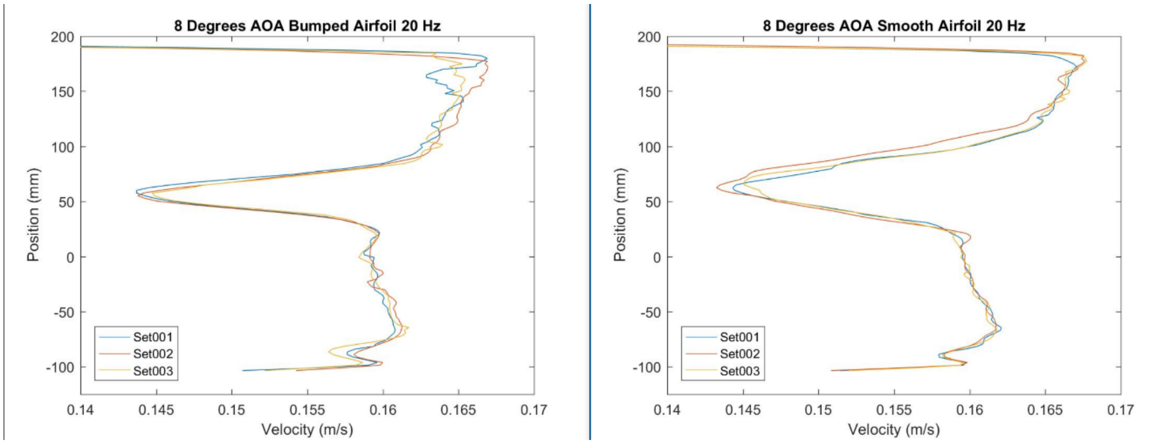


Figure 18 - Comparison of airfoil wakes at maximum drag reduction

4.2.3 Drag Analysis

The drag on the airfoil can be obtained from the wake measurements applying a control volume analysis to the test section from the uniform inlet to the location that the profiles are acquired. This traditional analysis results in the relationship for the drag per unit width for the airfoil,

$$D/L = \rho \int_{Y1}^{Y2} \left(\frac{u}{U_{FS}} \left(1 - \frac{u}{U_{FS}} \right) \right) dY.$$

Here *D* is the total drag, *L* is the airfoil width, ρ is the fluid density, U_{FS} is the local free stream velocity, and *u* is the measured velocity. To be applied to experimental data, the integral needs to discretized,

$$\frac{D}{L} \cong \rho \sum_{i} \frac{1}{2} (Y_{i+1} - Y_i) \left(\left(\left(\frac{u_{i+1}}{U_{FS}} \right) \left(1 - \frac{u_{i+1}}{U_{FS}} \right) \right) + \left(\left(\frac{u_{i+1}}{U_{FS}} \right) \left(1 - \frac{u_{i+1}}{U_{FS}} \right) \right) \right)$$

As the angle of attack increases, the blockage induced shear within the test section free-stream increases due to the reduction in cross-sectional area above the airfoil (especially after separation occurs). This makes it difficult to do the full integral through the wake to get the drag measurement because the free-stream speed and the edge of the wake are hard to define. Fortunately, this is also the region that has the smallest contributions to the wake integral. Therefore, the experimental data will be scaled using a plane wake similarity solution, and the fitted profile integrated to mitigate the uncertainty associated with identifying the wake edge. The stream wise (*x*-direction) velocity upstream of the airfoil is uniform (except in the boundary layers at the tunnel walls), and therefore it is reasonable to assume that the 2D airfoil will generate a plane wake. Here the plane wake similarity solution from Pope (2000) is utilized for the scaling. Using the definition of the scaled wake deficit profiles, the above relationships can be rewritten such that the integral is only dependent on the similarity variables,

$$\frac{D}{L} = \rho {U_\infty}^2 y_{\frac{1}{2}} \int_{\xi 1}^{\xi 2} \left(1 - f\,\frac{U_s}{U_\infty}\right)\left(f\,\frac{U_s}{U_\infty}\right) d\xi \cong \rho {U_\infty}^2 y_{\frac{1}{2}} [\left(\frac{U_s}{U_\infty}\right) \int_{\xi 1}^{\xi 2} f\, d\xi - \left(\frac{U_s}{U_\infty}\right)^2 \int_{\xi 1}^{\xi 2} f^2 d\xi] \;.$$

This allows $\int_{\xi 1}^{\xi 2} f\, d\xi$ and $\int_{\xi 1}^{\xi 2} f^2 d\xi$ to be determined from the average profiles and then used for each conditions drag calculation. Here the scaling parameters are the distance from the center of the wake to the location where half the freestream velocity is achieved ($y_{1/2}$) and the difference between the wake center velocity and the freestream velocity (U_s). The variable *f* is used to represent the value $\frac{U_{FS} - U_x}{U_s}$, which determines the shape of the wake. Here U_∞ is the freestream velocity and U_x is the streamwise (*x*) velocity at the given y-location. The average $y_{1/2}$ values found using the similarity solution are compared between the two airfoils and plotted for each Reynolds number in Figure 19, Figure 20, and Figure 21.

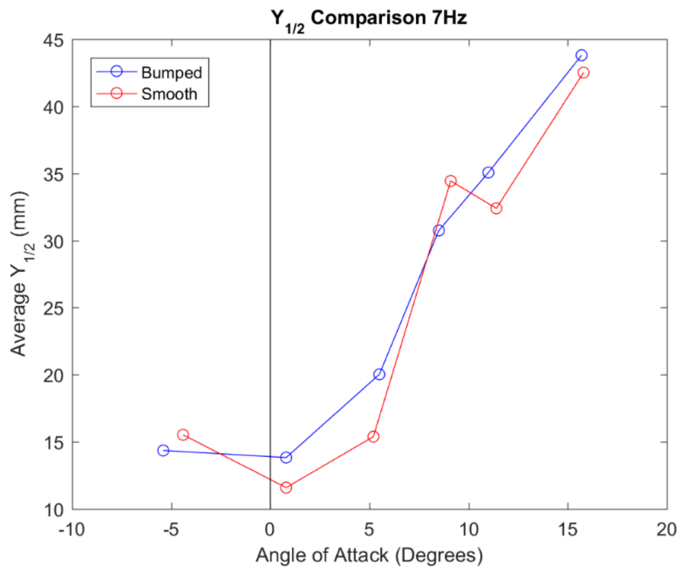


Figure 19 - Y1/2 Comparison vs AOA for 0.05 m/s

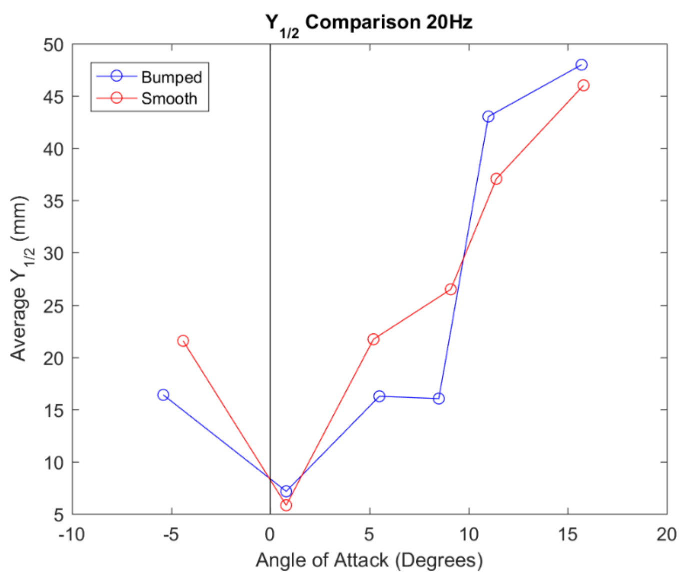


Figure 20 - Y1/2 Comparison vs AOA for 0.15 m/s

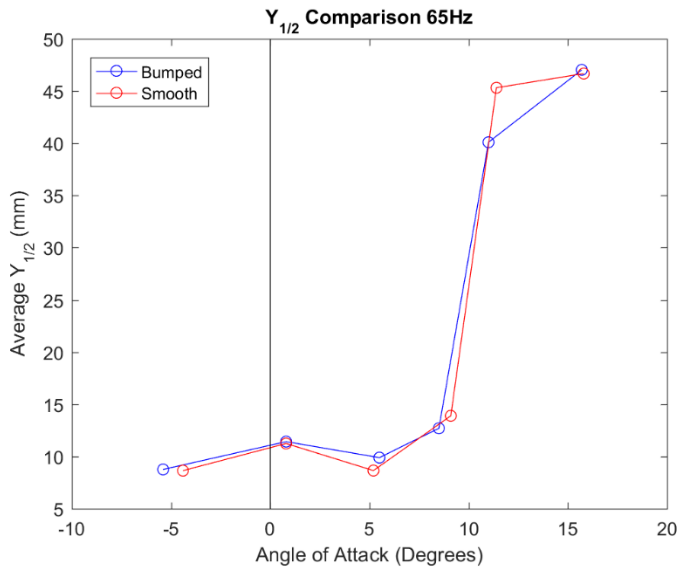


Figure 21 - Y1/2 Comparison vs AOA for 0.5 m/s

Likewise, the average U_s/U_∞ was found for each aifoil and Reynolds number and plotted verses angle of attack in Figure 22, Figure 23, and Figure 24.

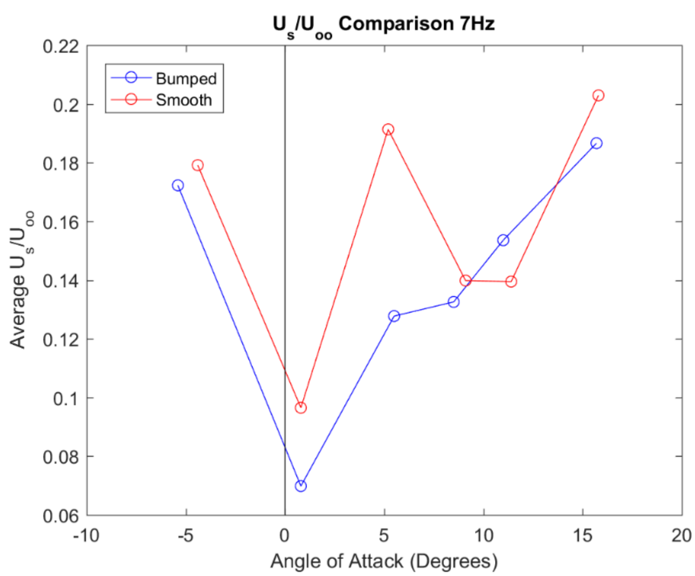


Figure 22 - Us/U∞ vs. AOA for 0.05 m/s

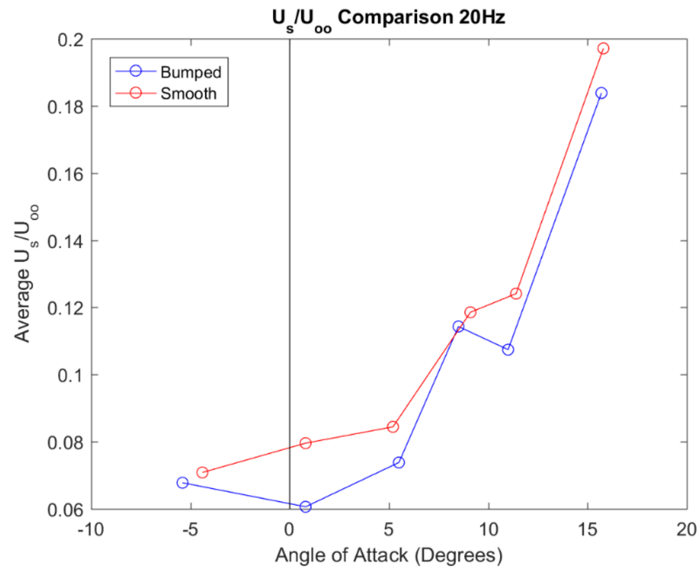


Figure 23 - Us/U∞ vs. AOA for 0.15 m/s

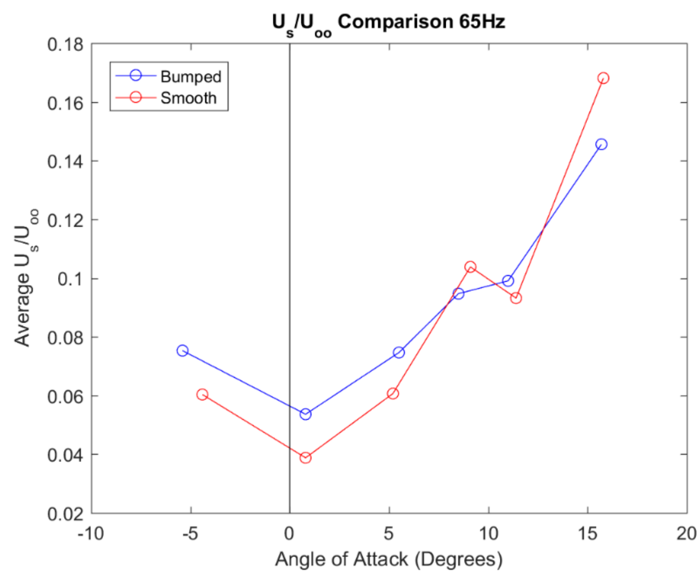


Figure 24 - Us/U∞ vs. AOA for 0.5 m/s

It is interesting to note that wake thickness is not necessarily related to loss of velocity. For the Reynold's number of 5,700 the bumped wake is wider than the smooth wake at the same angle of attack, however the ratio of U_s/U_∞ is smaller in the bumped case.

Fitting the experimental data to this similarity solution yielded the following profiles for the smooth (Figure 25) and bumped (Figure 26) airfoils.

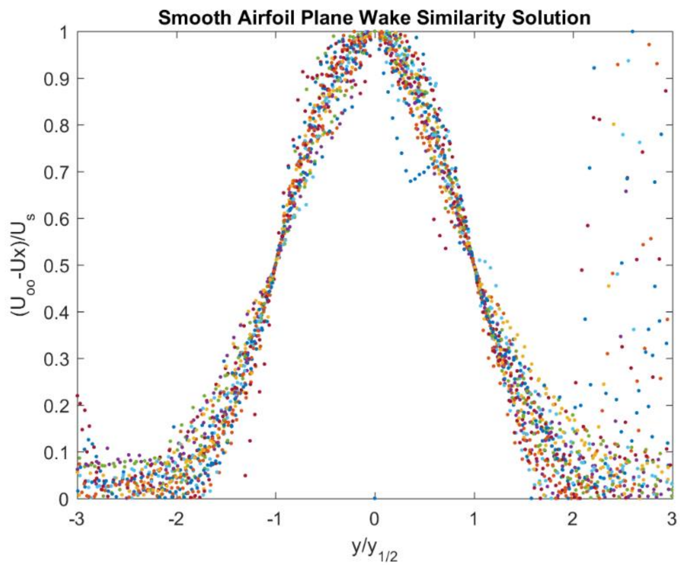


Figure 25 - Smooth Normalized Wake Points

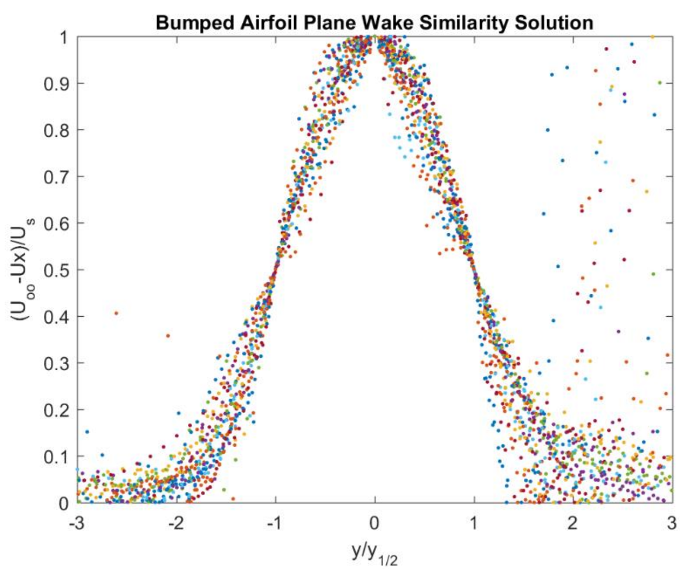


Figure 26 - Bumped Normalized Wake Points

Each individual scaled profile was inspected to determine the region influenced by the blockage effect. All points that were trusted to have not been significantly impacted by the blockage were then combined to produce Figure 27 and Figure 28. The different colored points represent the divison of the three sections; $y/y_{1/2} < -1$, $y/y_{1/2} > 1$, and $-1 < y/y_{1/2} < 1$.

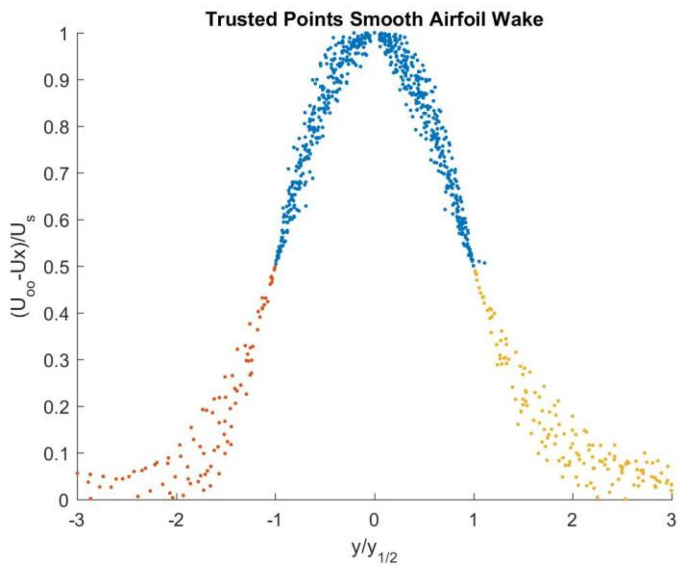


Figure 27 - Selected points from similarity solution for smooth airfoil wake

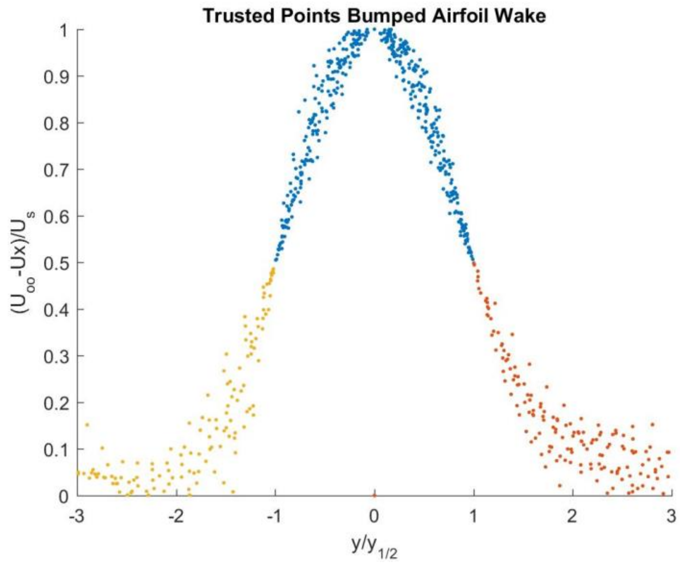


Figure 28 - Selected points from similarity solution for bumped airfoil wake

Then to generate a single smoothed curve for integration, the trusted points were segmented into 0.2 wide bins along the $y/y_{1/2}$ axis. The points in each bin were averaged to construct the scaled plane wake used for integration to get drag for each test condition. The resulting average wake deficit profiles are shown in Figure 29 and Figure 30 for the smooth and bumped airfoils, respectively.

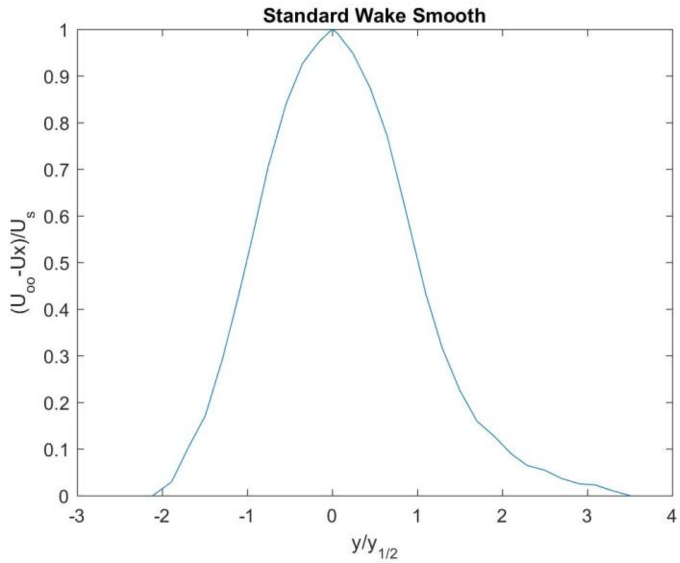


Figure 29 - Plane wake solution for smooth airfoil

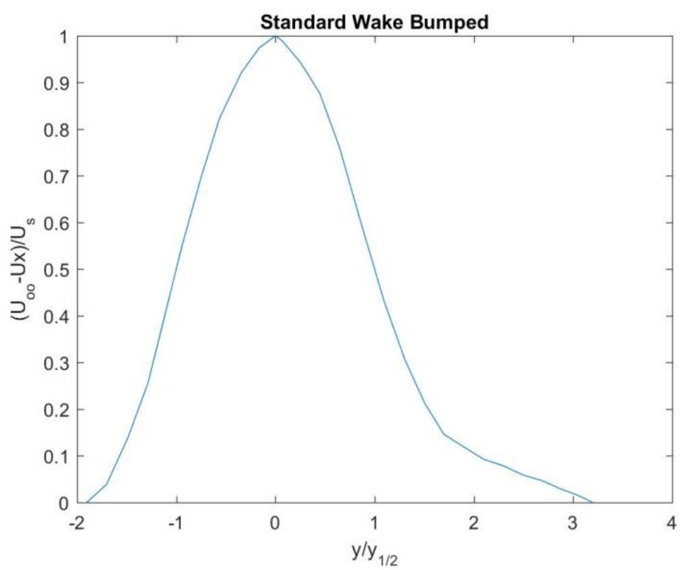


Figure 30 - Plane wake solution for bumped airfoil

The above wake deficit profiles are used to find the integrated values of f and f^2 for both airfoils. These integrals are required for the calculation of the airfoil drag from wake profiles. Negative *y*-values correspond the bottom of the tunnel, and positive *y*-values correspond to the top of the tunnel. While the blockage effects on the freestream are still seen at the top of the tunnel, the area under that portion of the curve is small compared to the rest of the wake.

Averaging the resulting drag from the three tests for each condition yields the drag verses angle of attack plots at 0.05 m/s (Figure 31), 0.15 m/s (Figure 32), and 0.5 m/s (Figure 33). The individual drag results for each test and the average drag with standard deviation are found in the appendices.

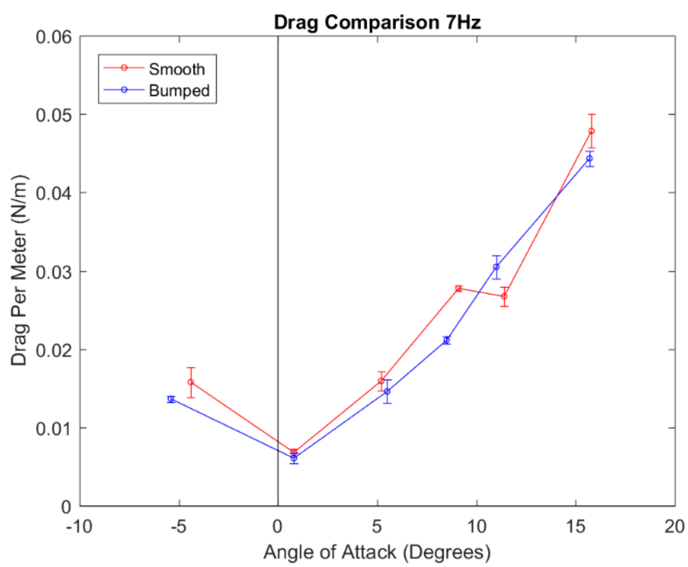


Figure 31 - Smooth Vs. Bumped Airfoil 0.05 m/s (-5° to 15°AOA)

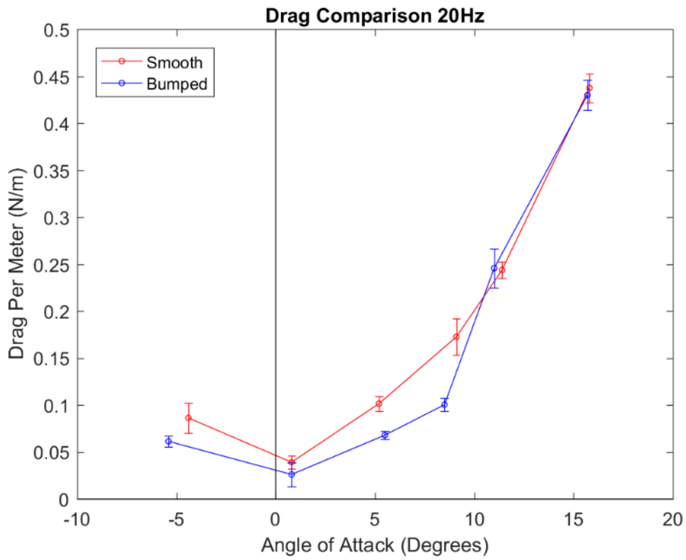


Figure 32 - Smooth Vs. Bumped Airfoil 0.15 m/s (-5° to 15° AOA)

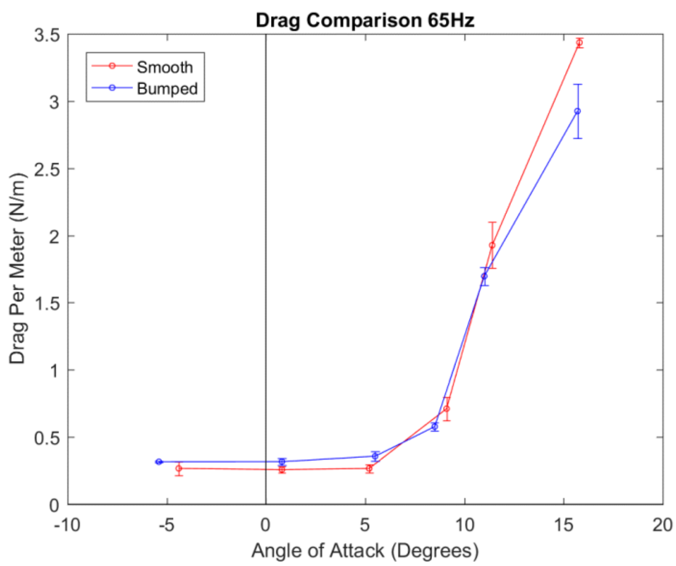


Figure 33 - Smooth Vs. Bumped Airfoil 0.5 m/s (-5° to 15° AOA)

For speeds of 0.05 and 0.15 m/s, it is apparent that drag is reduced by the leading-edge tubercles for angles less than 10°. Past 10° angle of attack the drag on the bumped airfoil is greater than the drag on the smooth airfoil. The percent drag reduction for the bumped airfoil is shown in Table 3. Negative values indicate increased drag.

Table 3 - Drag reduction for each tunnel speed (negative values indicate increased drag)

Angle (°)	0.05 m/s	0.15 m/s	0.5 m/s
0	10.27%	32.84%	-20.71%
5	11.81%	35.98%	-32.70%
8	17.91%	38.00%	8.19%
11	-13.35%	-4.82%	3.11%
15	3.94%	0.09%	13.36%

These drag values were converted to drag coefficients using the chord length as the drag area. X-foil also scales its coefficients of drag using the chord length.

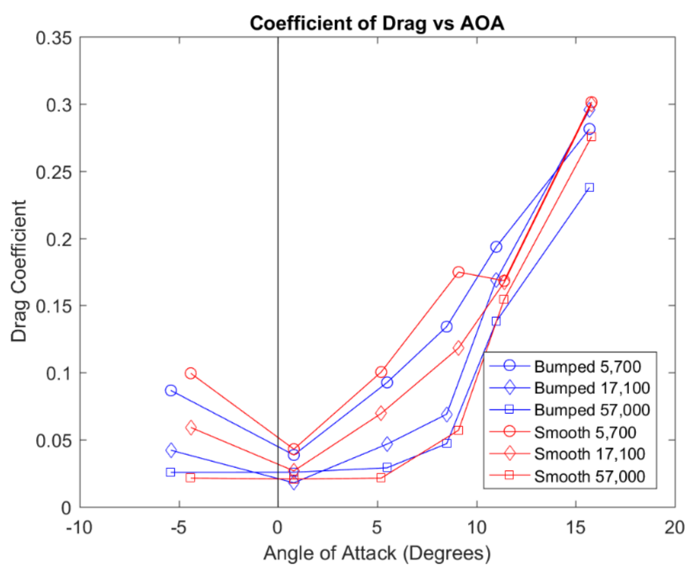


Figure 34 - Coefficient of drag for each Reynold's number

However, this is the uncorrected drag coefficient. There are blockage effects that have led to increased velocity around the airfoil. Barlow and Pope provide a method for calculating the effects of blockage in a tunnel.

$$\epsilon_{wb} = \frac{\Delta U}{U_u} = \frac{c/h}{2} C_{du}$$

Using this formula, the corrected drag is calculated using the new velocity. The corrected drag is then used to recalculate the C_d. The corrected coefficients of drag are plotted in Figure 35.

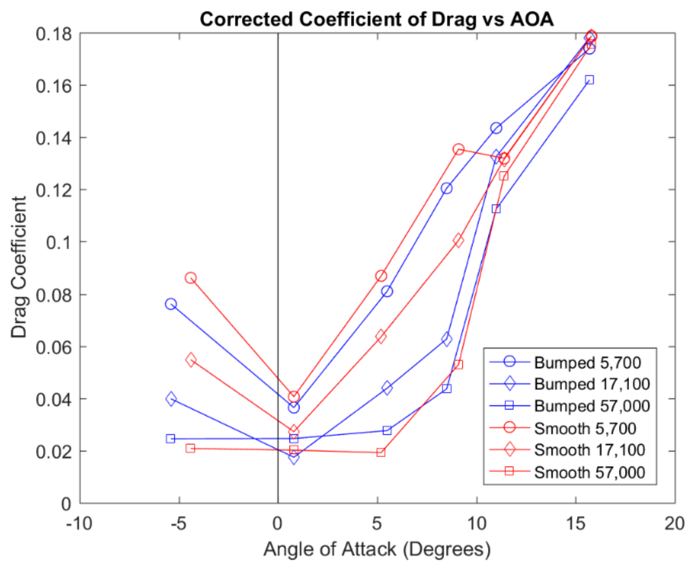


Figure 35 - Coefficient of drag corrected for increased blockage velocity

It is of particular interest that the speed in which the most drag reduction occurs is in the range of Reynold's number where transition from laminar to turbulent flow happens. Based upon X-foil's database the transition would occur on the airfoil for 5 degrees' angle of attack. It is possible that the leading-edge tubercles delay the transition to turbulence and therefore have a positive drag reduction effect. This again would fit with the recent studies on vortex generators.

4.2.4 Stall Analysis

It was conjectured that the leading-edge tubercles on the bumped airfoil were delaying stall. To test this theory, dye was injected at the trailing edge of the airfoil at a flow speed of 0.05 m/s. If flow separation occurs, then the dye will be pulled upstream. Again the angles of attack for the airfoils were determined using in-house Matlab code. Figure 36 shows that stall is present at 11.56° on the smooth airfoil, and Figure 37 shows that 12.20° stall is absent on the bumped airfoil. Thus, confirming that the bumps on the airfoil delay separation on the airfoil.

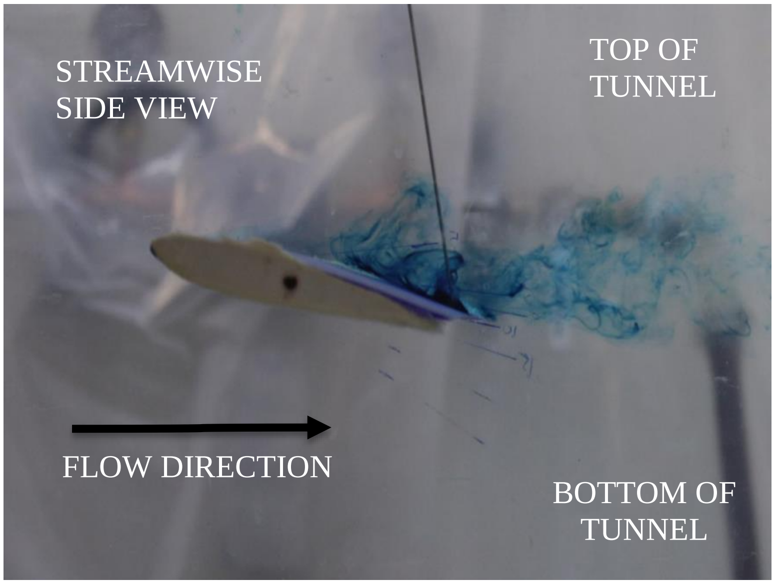


Figure 36 - Dye injection test for smooth airfoil at 11.56° AOA

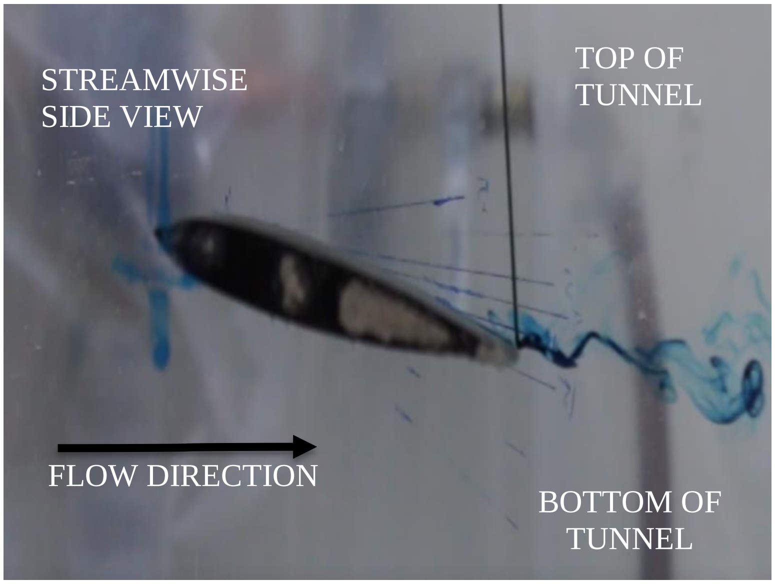


Figure 37 - Dye injection test for bumped airfoil at 12.20° AOA

4.2.5 Uncertainty Analysis

The uncertainty associated with the drag measurement must be quantified, especially the influence of the use of the universal profile for the integration. The uncertainty of these measurements was found using the average percent difference of all the data points with the overall average value. The exception to this is the percent difference in the integrals over f. For these values the uncertainty was calculated by defining the upper and lower limits of the trusted points, and dividing the difference of these values by the magnitude. The uncertainty of the density was estimated over the possible lab temperature and pressure conditions present during testing.

$$\varepsilon_{total} = \sqrt{\left(\frac{\rho_\varepsilon}{\rho}\right)^2 + 2\left(\frac{U_{FS_\varepsilon}}{U_{FS}}\right)^2 + \left(\frac{y_{1/2_\varepsilon}}{y_{1/2}}\right)^2 + \left(\frac{A_\varepsilon}{A}\right)^2}$$

Where A_ε is equal to $B_\varepsilon + C_\varepsilon$

$$B_{\varepsilon_{total}} = \sqrt{\left(\frac{U_{S_\varepsilon}}{U_S}\right)^2 + \left(\frac{U_{FS_\varepsilon}}{U_{FS}}\right)^2 + \left(\frac{\int_{\xi 1}^{\xi 2} f d\xi_\varepsilon}{\int_{\xi 1}^{\xi 2} f d\xi}\right)^2}$$

$$C_{\varepsilon_{total}} = \sqrt{2\left(\frac{U_{S_\varepsilon}}{U_S}\right)^2 + 2\left(\frac{U_{FS_\varepsilon}}{U_{FS}}\right)^2 + \left(\frac{\int_{\xi 1}^{\xi 2} f^2 d\xi_\varepsilon}{\int_{\xi 1}^{\xi 2} f^2 d\xi}\right)^2}$$

The resulting uncertainty was 8.6%. If the experiment were repeated again, the results would fall within the window of plus/minus 8.6%. The resulting windows for the bumped verses smooth drag profile are shown in Figure 38, Figure 39, and Figure 40.

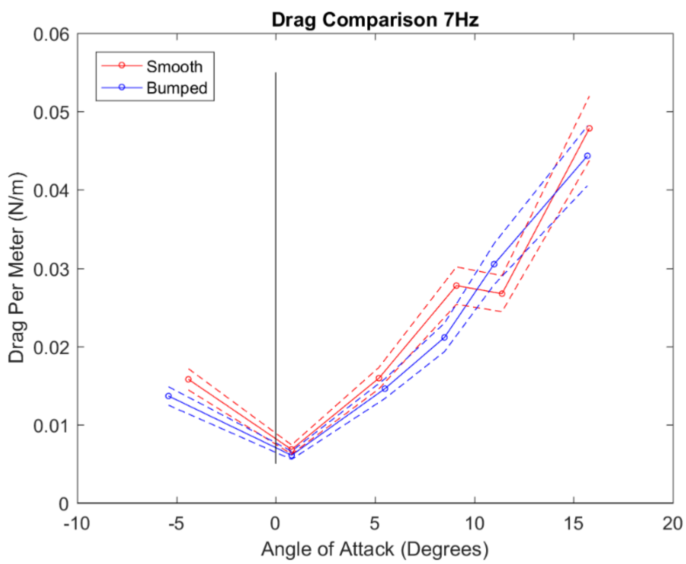


Figure 38 - Drag for 7 Hz with uncertainty windows

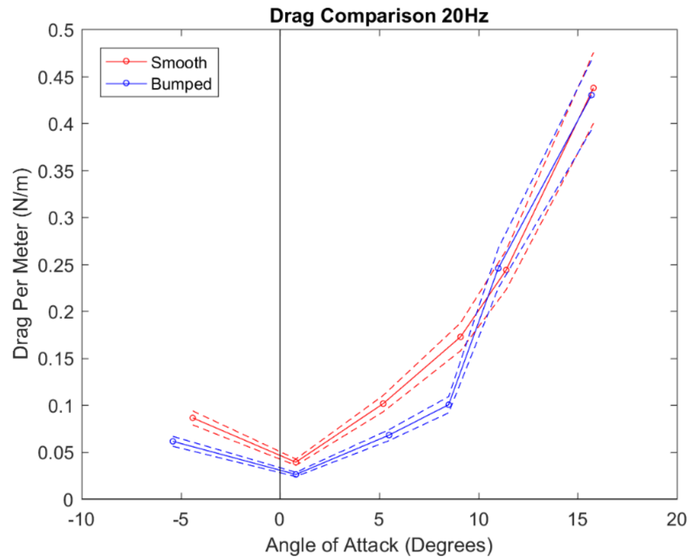


Figure 39 - Drag for 20 Hz with uncertainty windows

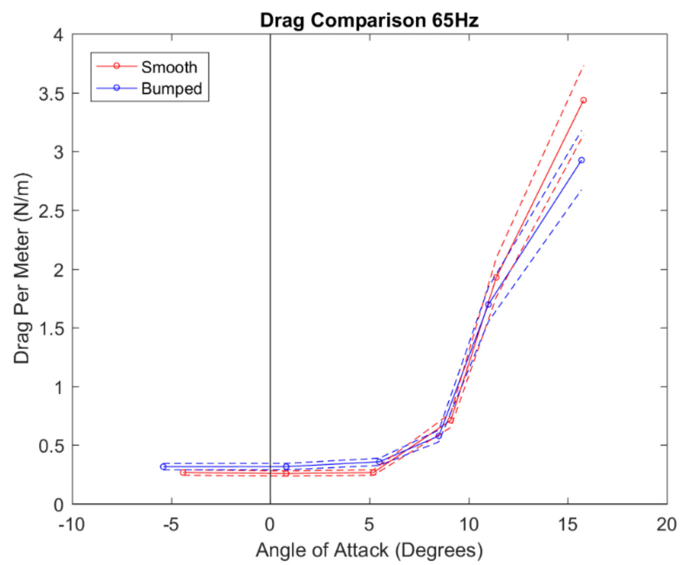


Figure 40 – Drag for 65 Hz with uncertainty windows

The graphs reveal a likely decrease in drag for cruising speeds of the bat and a definite reduction in drag for their fastest flying speeds. For the fastest water tunnel speed tested, any deviation with and without bumps is within the measurement uncertainty.

The data obtained for the smooth airfoil at speed of 7 Hz at 10° angle of attack should be disregarded as it does not follow the trend of increasing drag as should be seen. Figure 41, Figure 42, and Figure 43 show the x-foil drag results compared to experimental results for the investigated angles of attack.

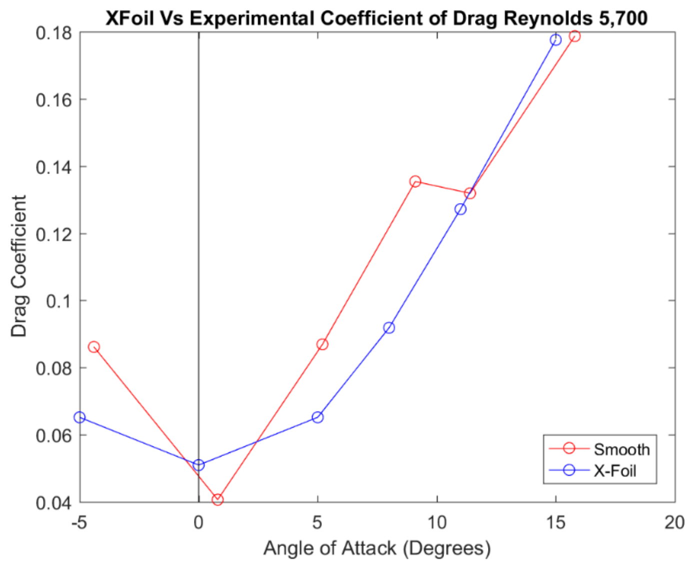


Figure 41 - X-foil vs experimental results for smooth airfoil in flow with Reynolds number equal to 5,700

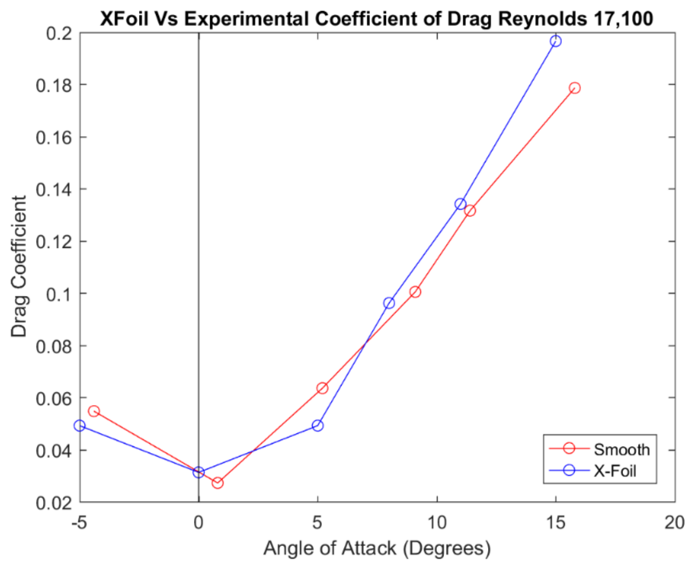


Figure 42 - X-foil vs experimental results for smooth airfoil in flow with Reynolds number equal to 17,100

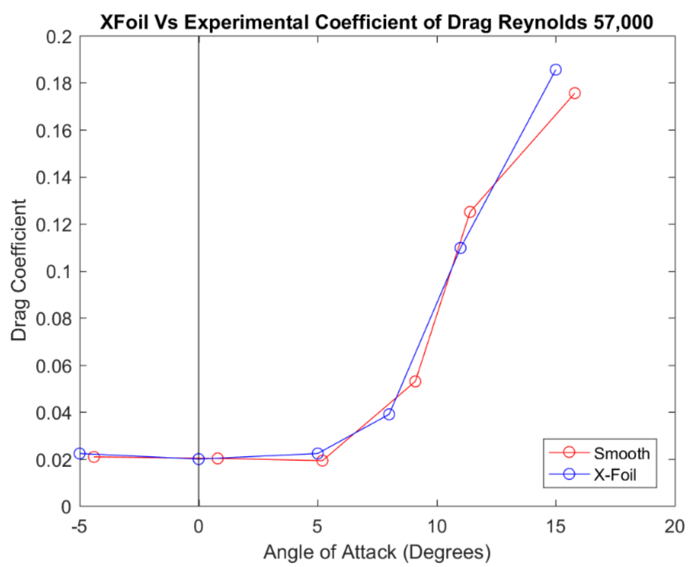


Figure 43 - X-foil vs experimental results for smooth airfoil in flow with Reynolds number equal to 57,000

It is worth noting that the coefficients of drag are somewhat different for the lowest speed case. However, this is commonly observed when obtaining drag data in this way. In fact, in the study by Santos et. al. (2006) the difference between the experimentally measured drag coefficient and the literature drag coefficient was 47%. The drag results obtained in this study however are much more comparable to the experimental data.

4.2.6 Lift Analysis

The deflection of the wake is related to the lift generated by the airfoil. Figure 44, and Figure 45, and Figure 46 depict the geometric center of the wake relative to the airfoil in the tunnel for 0.05, 0.15, and 0.5 m/s, respectively. It is important to note that this is only truly lift if the wake is located in an infinite expanse such that the pressures on the top and bottom of the control volume are at a constant pressure. Since blockage effects impacted the current results it is apparent that this is not a valid assumption. However, the results from tracking the wake are provided since some trends can still be observed at low angles of attack.

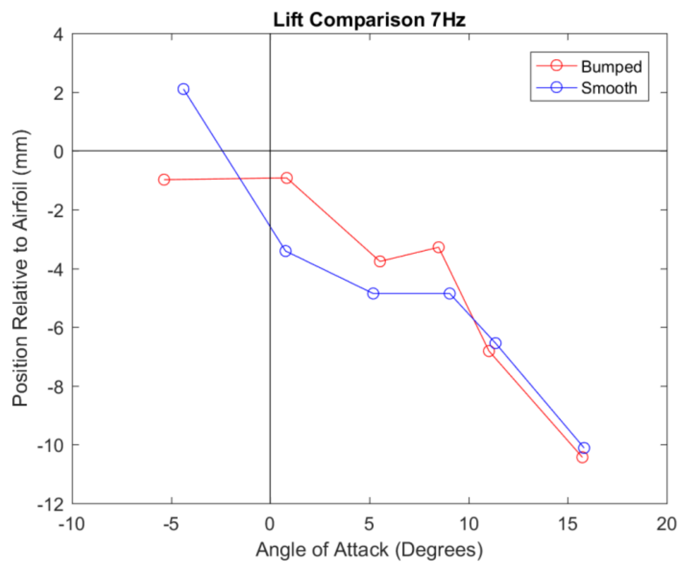


Figure 44 – Geometric center of wake relative to airfoil position 0.05 m/s

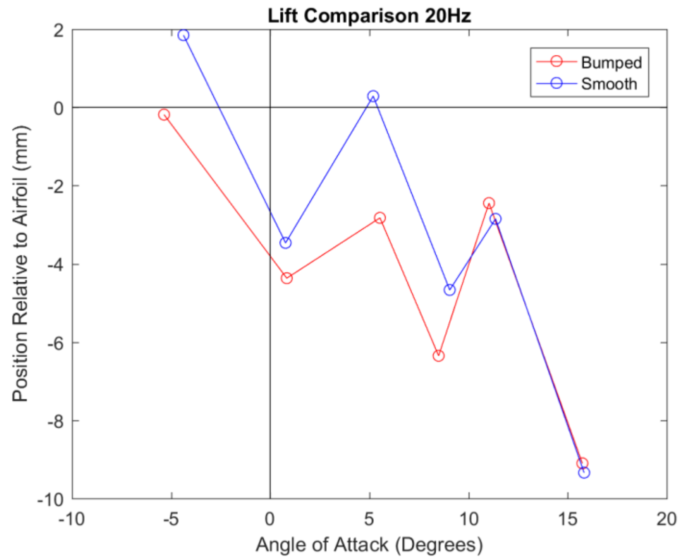


Figure 45 – Geometric center of wake relative to airfoil position 0.15 m/s

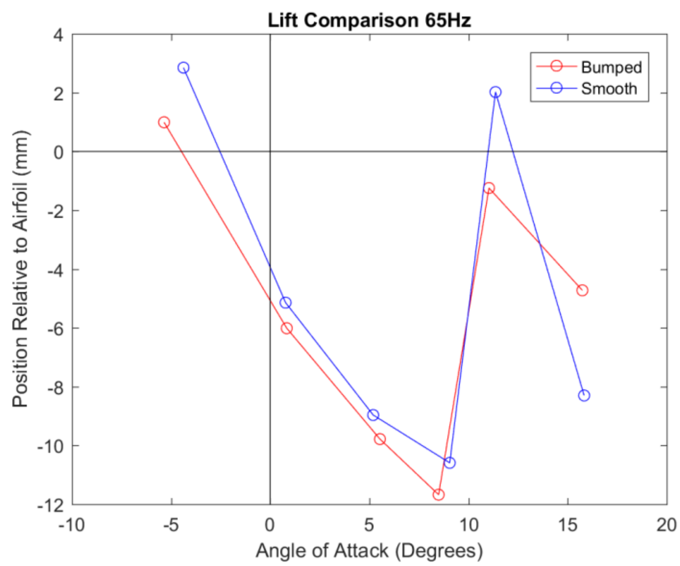


Figure 46 - Geometric center of wake relative to airfoil position 0.5 m/s

For 0.5 m/s, the wake is more streamlined and the geometric center data is more reliable. The lift graph for 0.5 m/s correlates to the one found in the study by Cristzos et. al (1955). Once the airfoil reaches stall there is a decrease in lift noted by the geometric center of the wake rising in the tunnel. However, the results further emphasize the findings that the bumped airfoil delays stall, as the bumped airfoil's geometric center is lower than the smooth airfoil's at 11° angle of attack.

5 CONCLUSIONS

Flow over 3-D printed Brazilian free-tailed bat ears was analyzed using flow visualization to show flow variation between the smooth and bumped bat ears. Dye testing confirmed flow pattern changes for the two cases. The flow visualizations qualitative results are in line with the findings by Petrin et. al. (in preparation) that showed drag changes depending on the angle of attack of the bat ear. These changes are believed to be the result of changes in flow separation caused by tubercles along the leading edge.

The results of the flow visualization led to further investigation of the properties of the leading-edge tubercles. Two NACA-0012 airfoils were printed one with leading-edge tubercles, and one without and analyzed using PIV to obtain flow velocity vectors. The results of the PIV analysis revealed drag reduction for the bumped airfoil from 0° to 10° angle of attack in flow speeds corresponding to the full flight speed range of Brazilian free-tailed bats. The reduction of drag over these angles of attack is beneficial to the bats in conserving energy as well as obtaining faster flight speeds. At larger angles of attack drag is increased for the bumped airfoil. The increase in drag is beneficial to bats pulling out of dives into their roosts. Therefore, the leading-edge tubercles are indeed beneficial to the flight behavior of Brazilian free-tailed bats.

Additionally, it was discovered that the leading-edge tubercles delay the propagation of stall for the NACA-0012 airfoil. The tubercles are believed to act similar to vortex generators on aircraft adjusting the flow rate through the channels formed by the bumps and providing energy to overcome the propagation of a stall bubble. The stall delay would be highly beneficial to the bats during their feeding sessions as they vary their angles of attack to catch insects for food.

Tubercles on Brazilian free-tailed bat ears provide benefits in drag modification as well as in delaying stall. These changes in flow pattern caused by the tubercles may provide opportunities for biomimetic advancements. Tubercle placement on airfoils could be beneficial for applications with low Reynolds number and small angles of attack.

Additional steps can be taken to make the study of Brazilian free-tailed bat tubercles conclusive. This involves addressing some of the difficulties that occurred during this study. The blockage effects can be remedied by reducing the chord length as well as placing the airfoil in the center of the tunnel. Therefore, future testing should include using an airfoil with a shorter chord length to minimize the effects of blockage. This airfoil is currently in the process of being constructed. This study should also examine the properties of the near wake to extract true lift data and examine the stall point using PIV.

This will provide additional information regarding the mechanism by which the vortex generators (tubercles) alter the flow over the bat's ears.

REFERENCES

F.E. Fish and J.M. Battle, "Hydrodynamic design of the humpback whale flipper," *Journal of Morphology*, **225**(1), 51-60 (1995).

D.S. Miklosovic, M.M. Murray, L.E. Howle and F.E. Fish, "Leading-edge tubercles delay stall on humpback whale (*Megaptera novaengliae*) flippers," *Physics of Fluids*, **16**(5), L39 (2004).

E.A. van Nierop, S. Alben and M.P. Brenner, "How bumps on whale flippers delay stall: an aerodynamic model," *Physical Review Letters*, **100**, 5-8 (2008).

R.B. Davis, C.F. Herreid and H.L. Short, "Mexican free-tailed bats in Texas," *Ecological Monographs*, **32**(4), 311-346 (1962).

T.C. Williams, L.C. Ireland and J.M. Williams, "High altitude flights of the free-tailed bats, *Tadarida brasiliensis*, observed with radar," *Journal of Mammalogy*, **54**, 807-21 (1973).

J.W. Horn and T.H. Kunz, "Analyzing NEXRAD Doppler radar images to assess nightly dispersal patterns and population trends in Brazilian free-tailed bats (*Tadarida brasiliensis*)," *Integrative and Comparative Biology*, **48**(1), 24–39 (2008).

T.Y. Hubel, N.I. Hristov, S.M. Swartz and K.S. Breuer, "Changes in kinematics and aerodynamics over a range of speeds in *Tadarida brasiliensis*, the Brazilian free-tailed bat," *Journal of the Royal Society Interface*, **9**(71), 1120-30 (2012).

C. Petrin, W. Caire, M. L. Thies & B. R. Elbing (in preparation) “Modification of drag on the ear of Brazilian free-tailed bats (*Tadarida brasiliensis*) via leading-edge tubercles,” In preparation for *Physics of Fluids.*

C. H. Critzos, H. H. Heyson & R.W. Boswinkle. Aerodynamic characteristics of NACA 0012 airfoil section at angles of attack from 0° to 180°, report, January (1955).

D. M. Bushnell and K. J. Moore. “Drag reduction in nature,” *Annual Review of Fluid Mechanics*, 23.1 (1991)

R. W. Derksen, M. Agelinchaab, and M. Tachie. "Characteristics of the Flow over a NACA 0012 Airfoil at Low Reynolds Numbers." Advances in Fluid Mechanics VII (2008).

S. S. Shahinfar, J. H. Sattarzadeh, M. Fransson, and A. Talamelli. "Revival of Classical Vortex Generators Now for Transition Delay." *Physical Review Letters* 109.7 (2012).

S. B. Pope. *Turbulent Flows*, 1st Edition, Cambridge University Press (2000).

L. Santos, A. Avelar, M. Chiseaki, and O. Mello. "Drag Estimation by Wake Survey Performed Measuring Velocities and Measuring Total and Static Pressures." *11th Brazilian Congress of Thermal Sciences and Engineering* (2006)

J. B. Barlow, and A. Pope. Low-speed Wind Tunnel Testing. New York: Wiley, 2013.

APPENDICES

Appendix A: Average Drag

Smooth 7 Hz AOA (°)	Drag (N/m)	Standard Deviation (N/m)	Bumped 7 Hz AOA (°)	Drag (N/m)	Standard Deviation (N/m)
-4.4	0.01579	0.00192	-5.4	0.01366	0.00040
0.8	0.00682	0.00043	0.8	0.00608	0.00069
5.2	0.01594	0.00123	5.5	0.01460	0.00150
9.1	0.02776	0.00037	8.5	0.02114	0.00047
11.4	0.02673	0.00124	11.0	0.03050	0.00151
15.8	0.04785	0.00214	15.7	0.04434	0.00094

Smooth 20 Hz AOA (°)	Drag (N/m)	Standard Deviation (N/m)	Bumped 20 Hz AOA (°)	Drag (N/m)	Standard Deviation (N/m)
-4.4	0.08625	0.00138	-5.4	0.06129	0.00613
0.8	0.03905	0.00688	0.8	0.02604	0.01301
5.2	0.10144	0.00811	5.5	0.06794	0.00428
9.1	0.17250	0.01951	8.5	0.10029	0.00694
11.4	0.24371	0.00881	11.0	0.24552	0.02100
15.8	0.43746	0.01541	15.7	0.42986	0.01592

Smooth 65 Hz AOA (°)	Drag (N/m)	Standard Deviation (N/m)	Bumped 65 Hz AOA (°)	Drag (N/m)	Standard Deviation (N/m)
-4.4	0.26678	0.05027	-5.4	0.31618	0.00513
0.8	0.25808	0.02243	0.8	0.31699	0.02401
5.2	0.26653	0.02946	5.5	0.35782	0.03415
9.1	0.71102	0.08804	8.5	0.57796	0.02897
11.4	1.92715	0.17172	11.0	1.69645	0.06527
15.8	3.43503	0.03616	15.7	2.92494	0.19958

Appendix B: Individual Drag Values

Smooth 7 Hz AOA (°)	Drag Test 1 (N/m)	Drag Test 2 (N/m)	Drag Test 3 (N/m)
-4.4	0.01379	0.01599	0.01760
0.8	0.00731	0.00656	0.00659
5.2	0.01452	0.01667	0.01663
9.1	0.02744	0.02816	0.02766
11.4	0.02677	0.02795	0.02546
15.8	0.05024	0.04613	0.04718

Bumped 7 Hz AOA (°)	Drag Test 1 (N/m)	Drag Test 2 (N/m)	Drag Test 3 (N/m)
-5.4	0.013109173	0.013816158	0.014049577
0.8	0.006177374	0.006721685	0.005349742
5.5	0.016704404	0.013405366	0.013678206
8.5	0.027076907	0.021471434	0.020805367
11.0	0.029711952	0.029177075	0.032609572
15.7	0.043656559	0.0454054	0.043944283

Smooth 20 Hz AOA (°)	Drag Test 1 (N/m)	Drag Test 2 (N/m)	Drag Test 3 (N/m)
-4.4	0.08641	0.08448	0.08786
0.8	0.03533	0.03484	0.04699
5.2	0.10554	0.10866	0.09011
9.1	0.16979	0.19322	0.15449
11.4	0.25583	0.24013	0.23517
15.8	0.45524	0.42913	0.42801

Bumped 20 Hz AOA (°)	Drag Test 1 (N/m)	Drag Test 2 (N/m)	Drag Test 3 (N/m)
-5.4	0.06987	0.05798	0.05600
0.8	0.03938	0.02535	0.01339
5.5	0.06248	0.07294	0.06840
8.5	0.09778	0.10813	0.09495
11.0	0.21685	0.26656	0.25316
15.7	0.44823	0.42002	0.42134

Smooth 65 Hz AOA (°)	Drag Test 1 (N/m)	Drag Test 2 (N/m)	Drag Test 3 (N/m)
-4.4	0.33487	0.21503	0.25043
0.8	0.26631	0.23269	0.27522
5.2	0.23845	0.25392	0.30722
9.1	0.60944	0.75825	0.76537
11.4	1.84267	1.77221	2.16657
15.8	3.40086	3.43134	3.47290

Bumped 65 Hz AOA (°)	Drag Test 1 (N/m)	Drag Test 2 (N/m)	Drag Test 3 (N/m)
-5.4	0.32228	0.30972	0.31655
0.8	0.28981	0.33532	0.32583
5.5	0.32038	0.36580	0.38727
8.5	0.57088	0.60981	0.55319
11.0	1.75966	1.70039	1.62930
15.7	2.97882	2.70395	3.09204

Appendix C: PIV Vector Fields

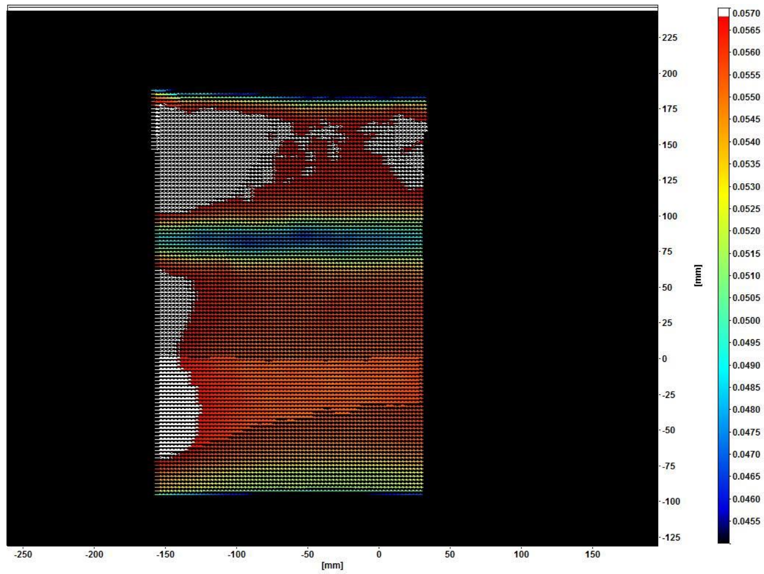


Figure 47 - Smooth Set001 for 7 Hz and -5° AOA

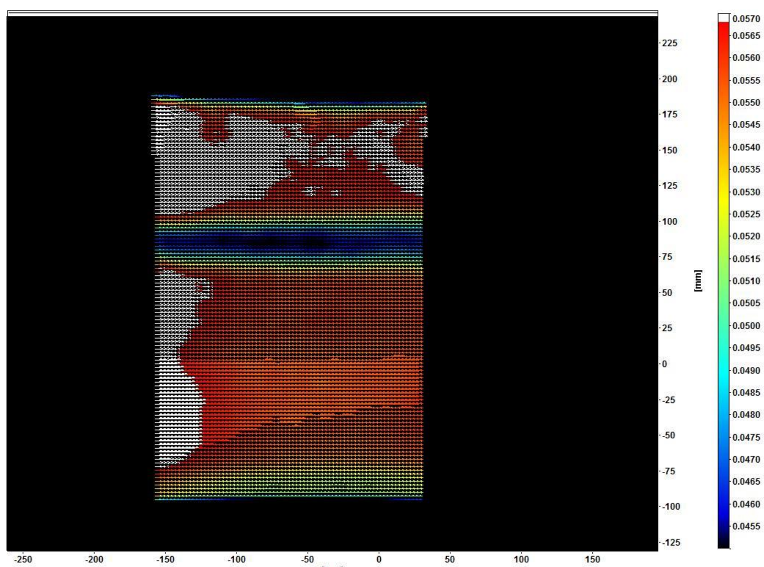


Figure 48 - Smooth Set002 for 7 Hz and -5° AOA

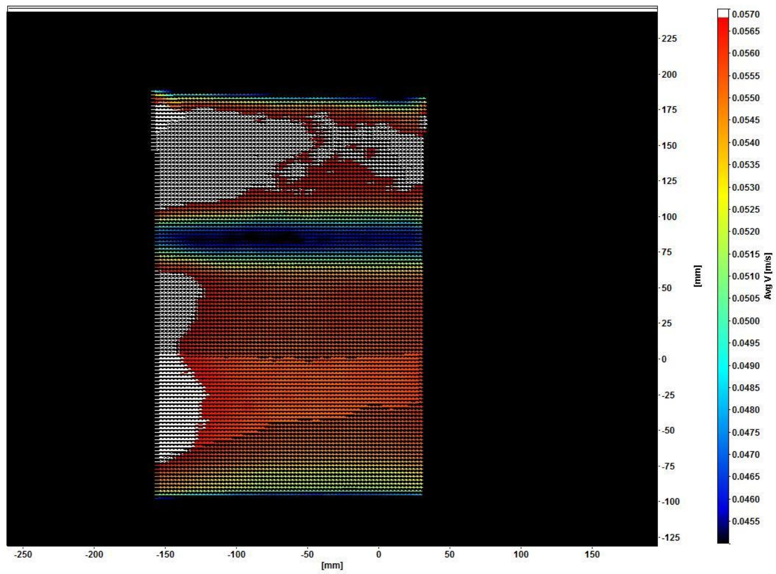


Figure 49 - Smooth Set003 for 7 Hz and -5° AOA

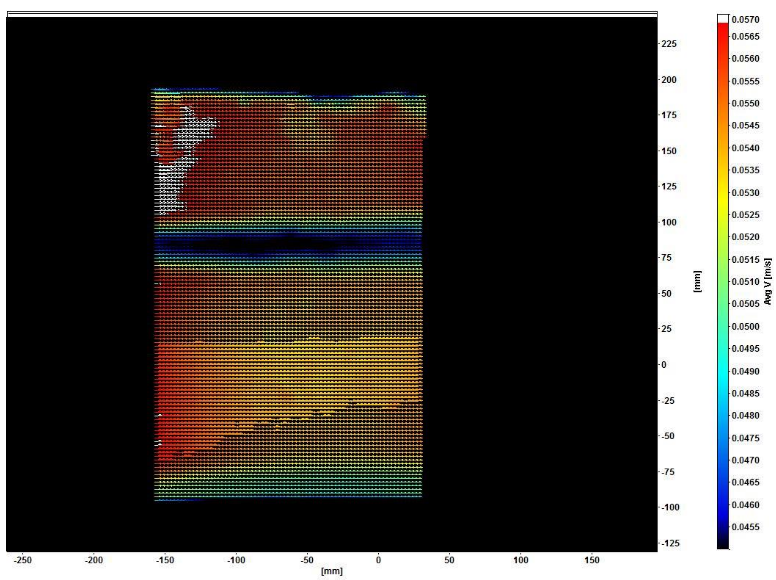


Figure 50 - Bumped Set001 for 7 Hz and -5° AOA

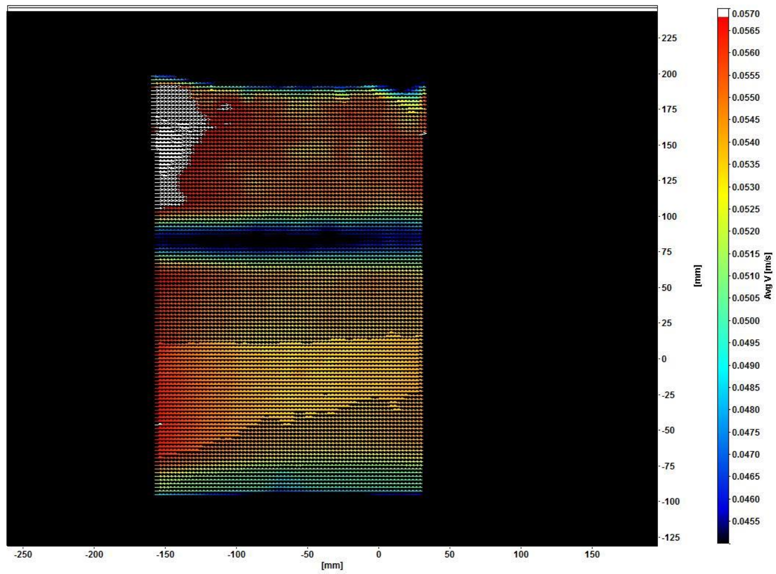


Figure 51 - Bumped Set002 for 7 Hz and -5° AOA

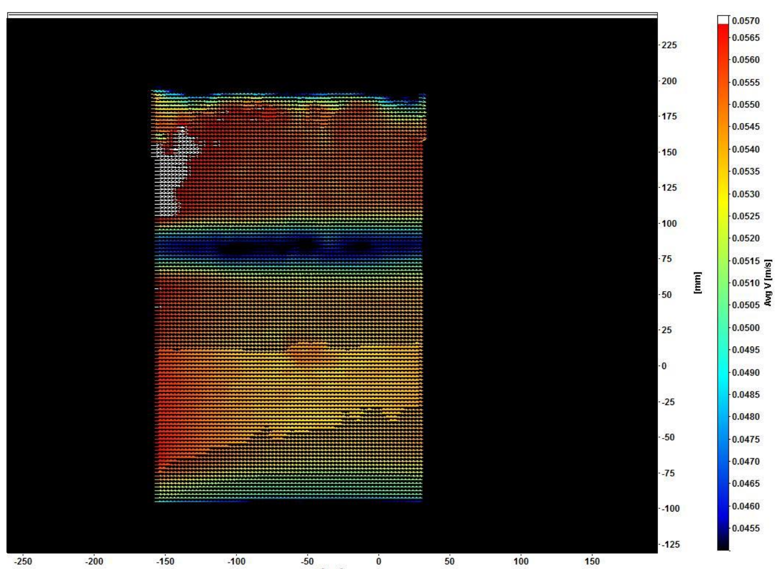


Figure 52 - Bumped Set003 for 7 Hz and -5° AOA

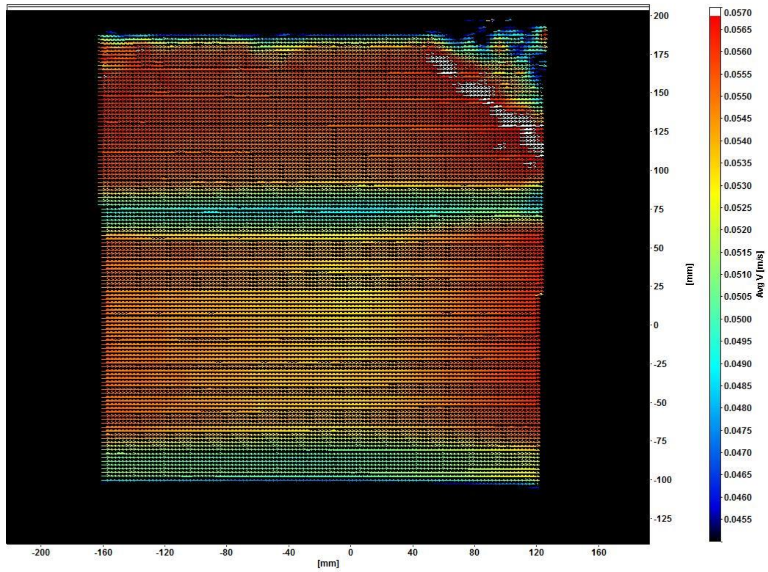


Figure 53 - Smooth Set001 for 7 Hz and 0° AOA

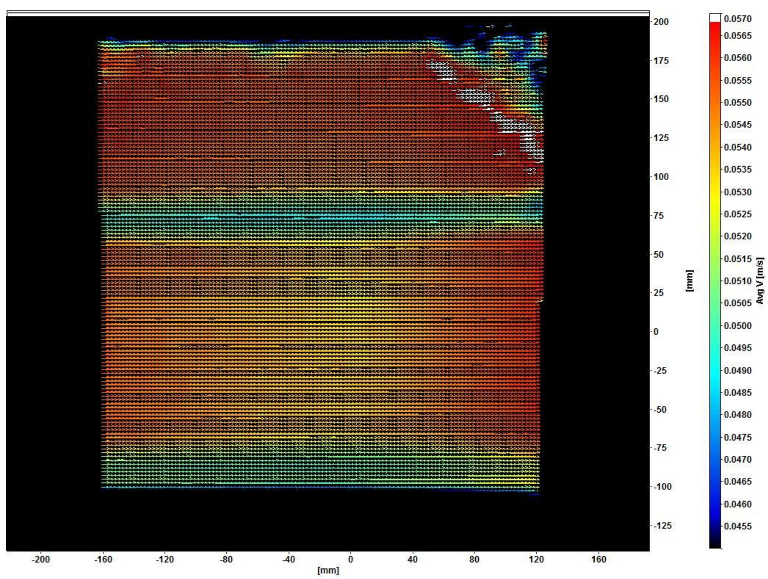


Figure 54 - Smooth Set002 for 7 Hz and 0° AOA

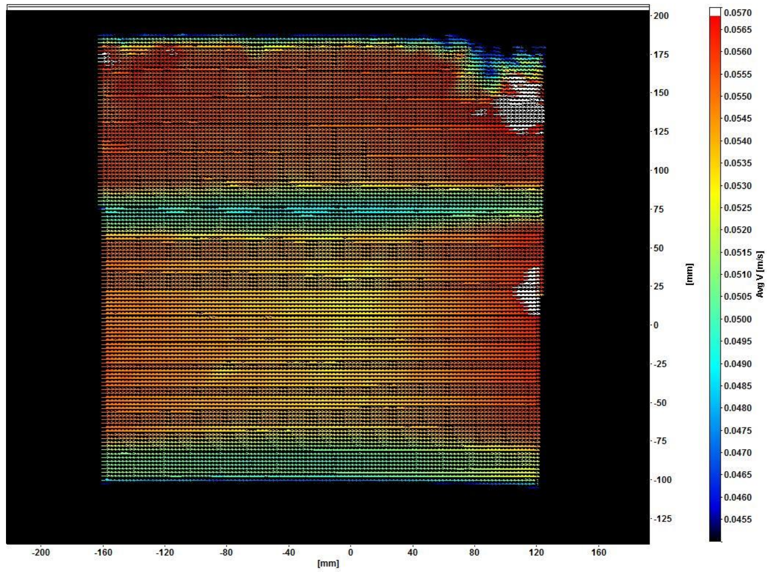


Figure 55 - Smooth Set003 for 7 Hz and 0° AOA

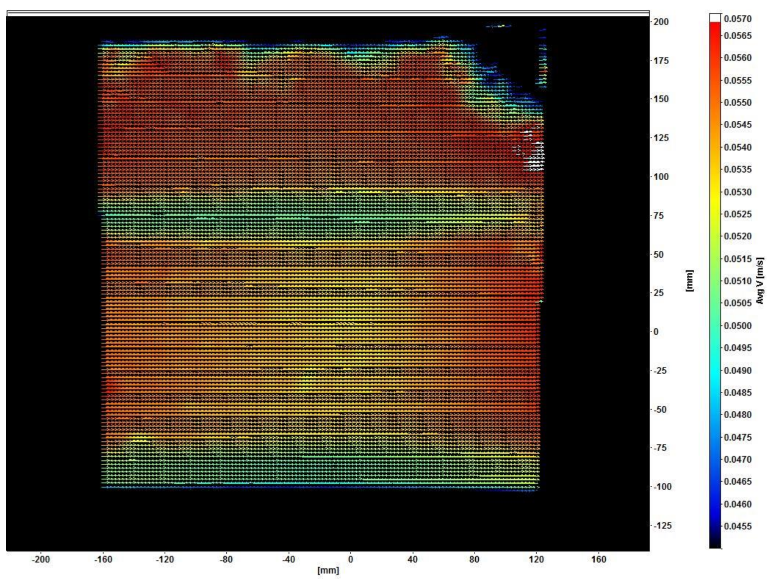


Figure 56 - Bumped Set001 for 7 Hz and 0° AOA

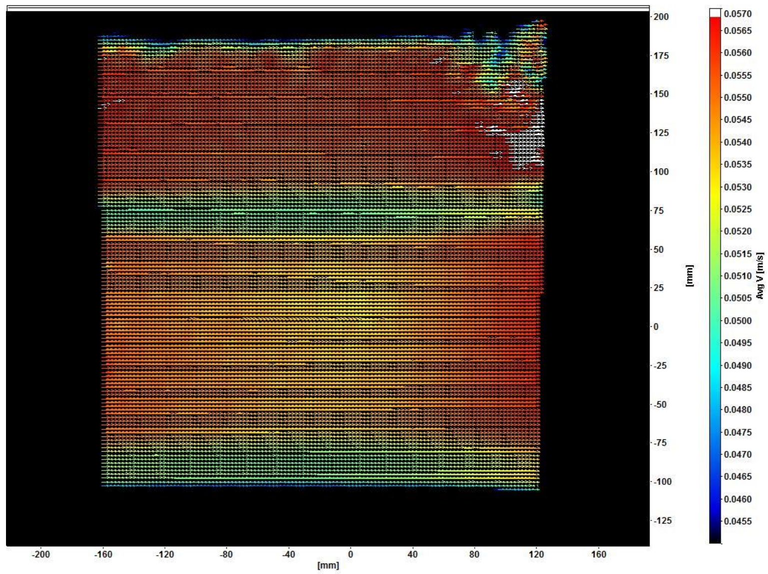


Figure 57 - Bumped Set002 for 7 Hz and 0° AOA

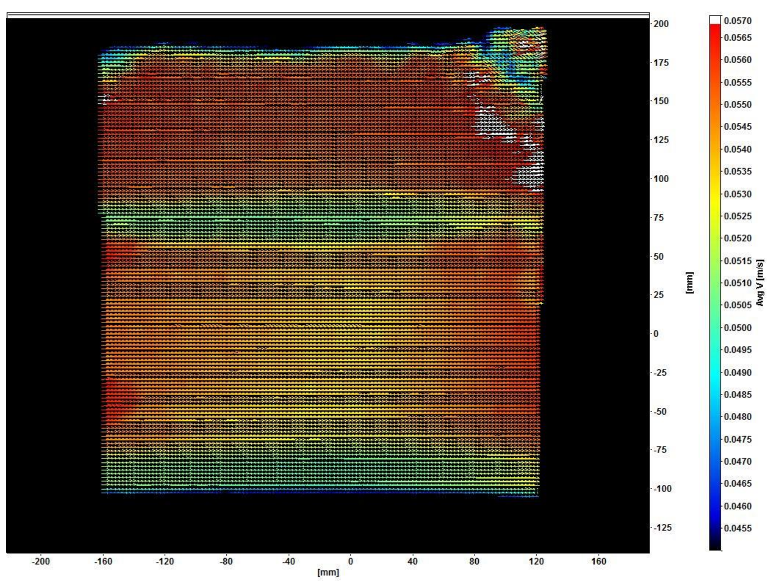


Figure 58 - Bumped Set003 for 7 Hz and 0° AOA

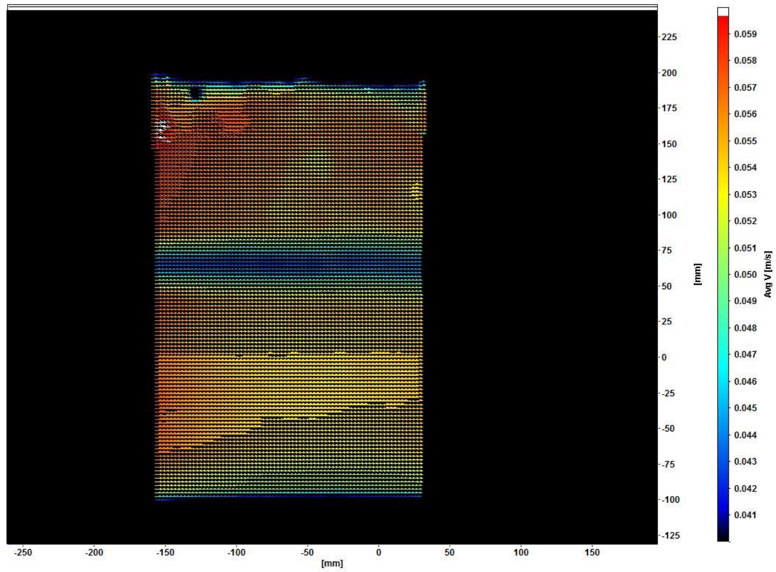


Figure 59 - Smooth Set001 for 7 Hz and 5° AOA

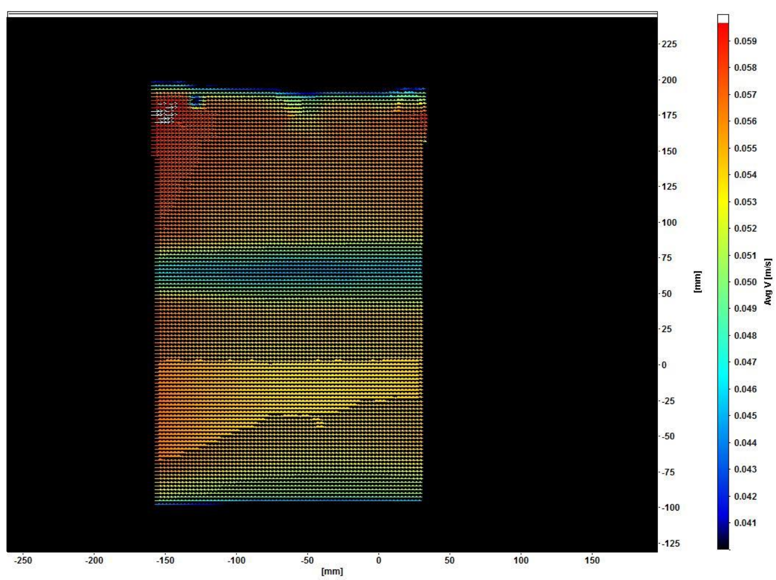


Figure 60 - Smooth Set002 for 7 Hz and 5° AOA

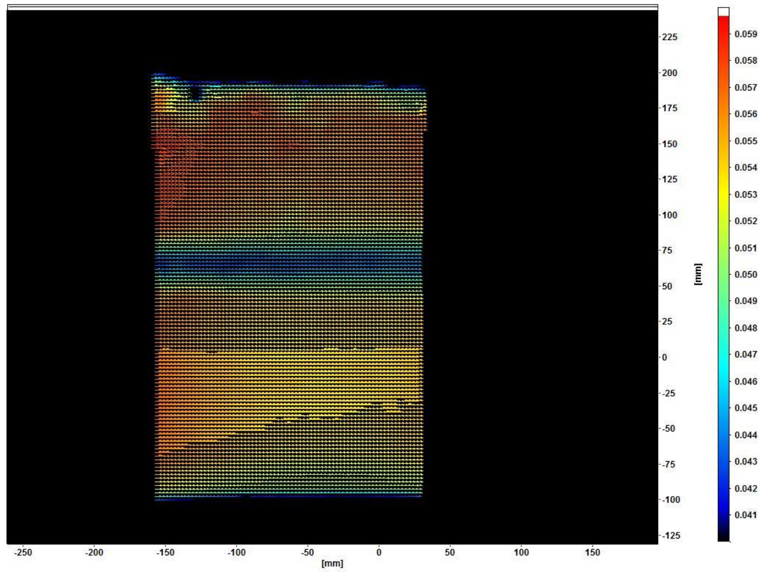


Figure 61 - Smooth Set003 for 7 Hz and 5° AOA

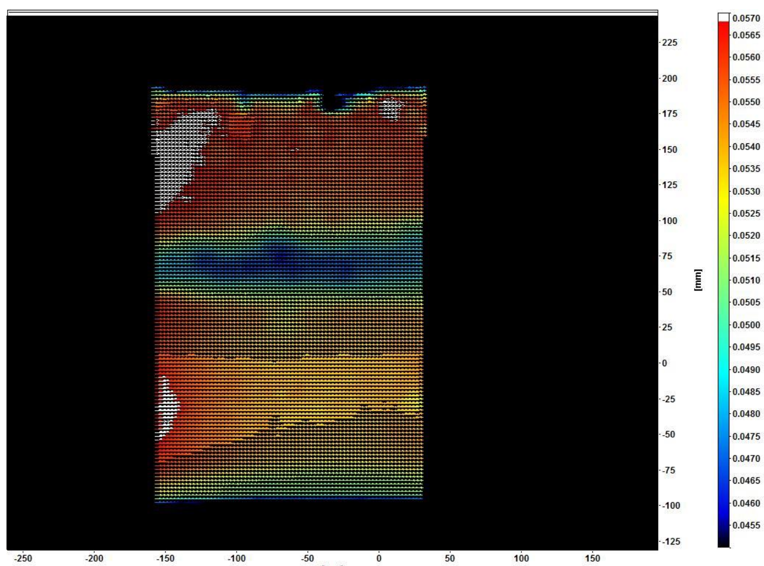


Figure 62 - Bumped Set001 for 7 Hz and 5° AOA

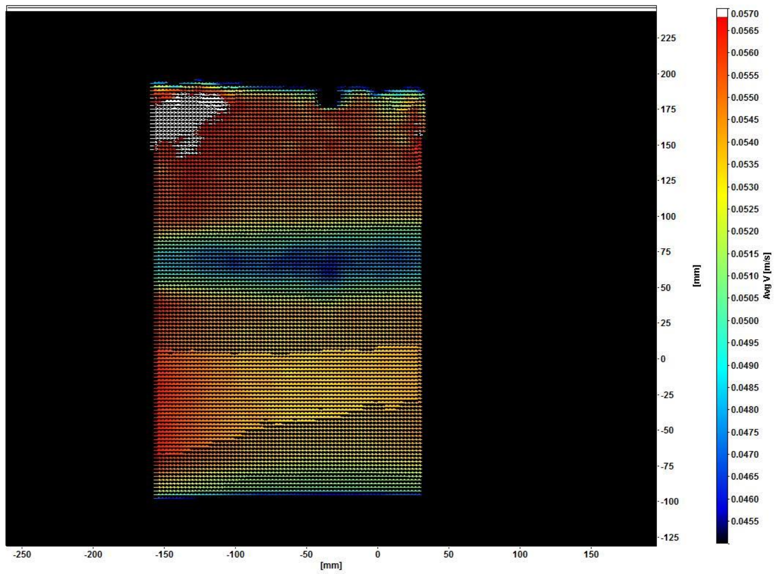


Figure 63 - Bumped Set002 for 7 Hz and 5° AO

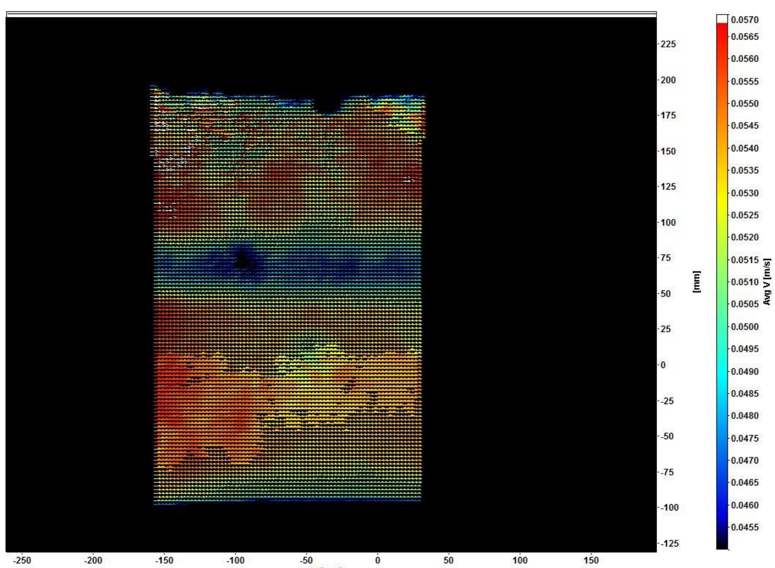


Figure 64 - Bumped Set003 for 7 Hz and 5° AOA

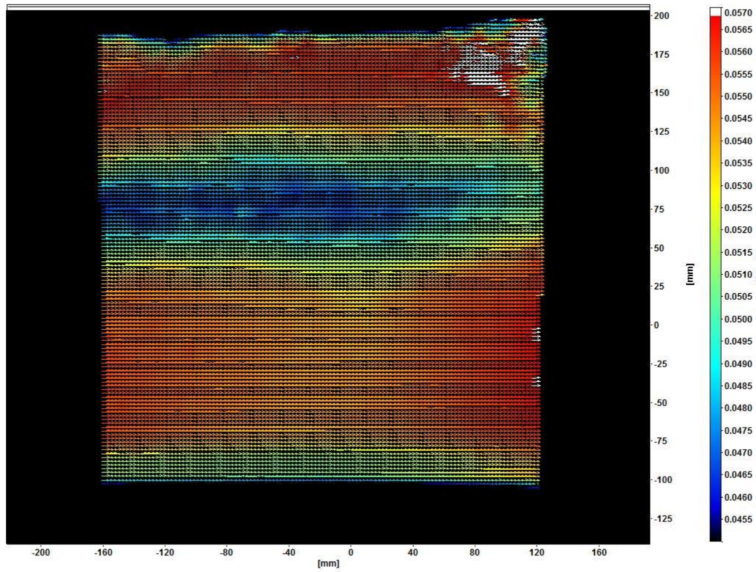


Figure 65 - Smooth Set001 for 7 Hz and 8° AOA

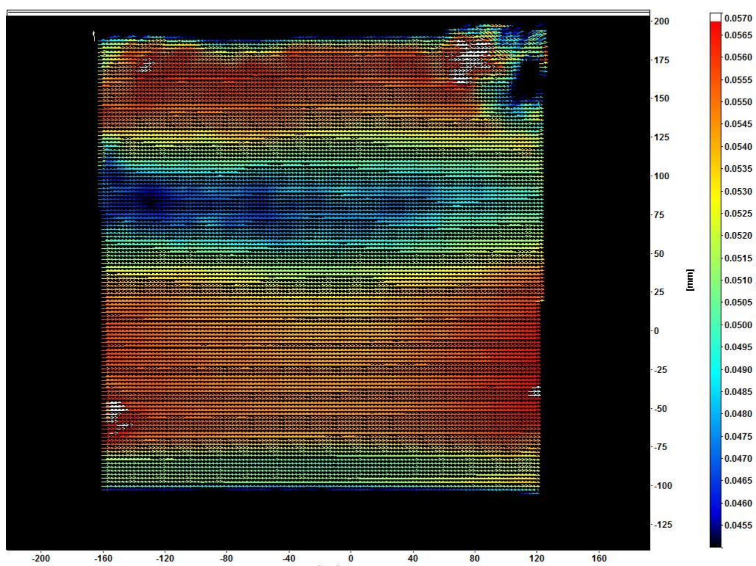


Figure 66 - Smooth Set002 for 7 Hz and 8° AOA

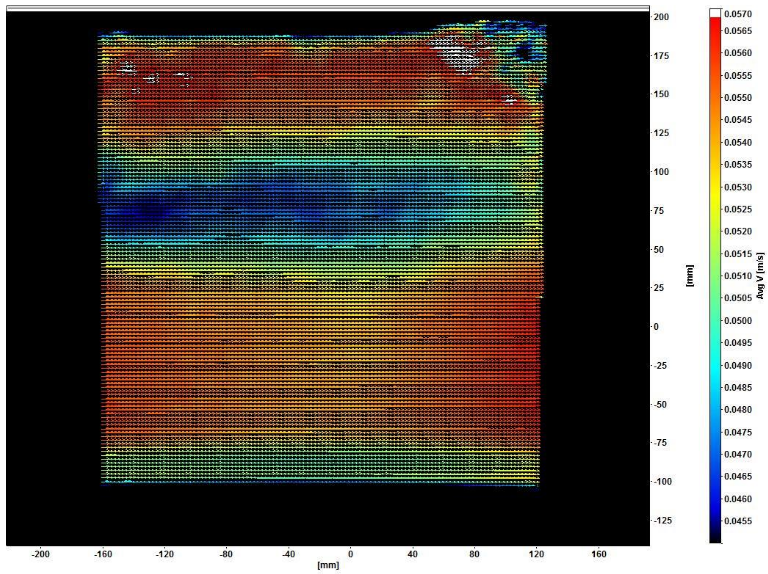


Figure 67 - Smooth Set003 for 7 Hz and 8° AOA

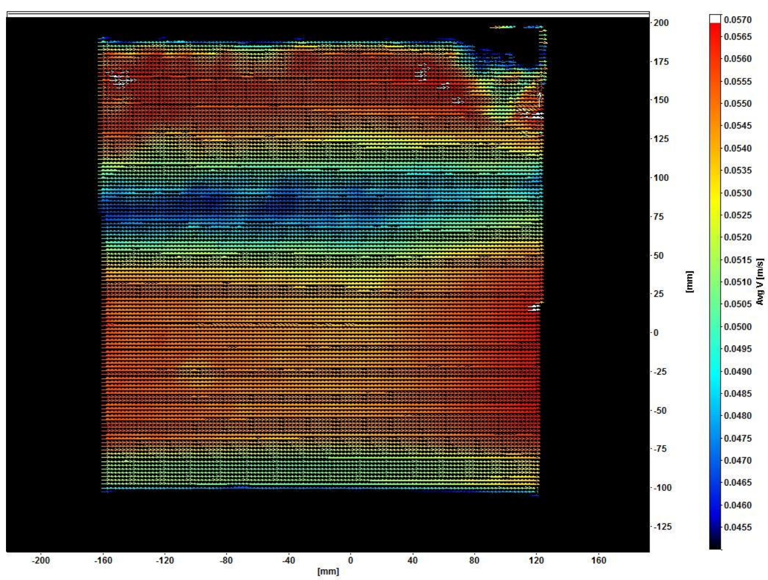


Figure 68 - Bumped Set001 for 7 Hz and 8° AOA

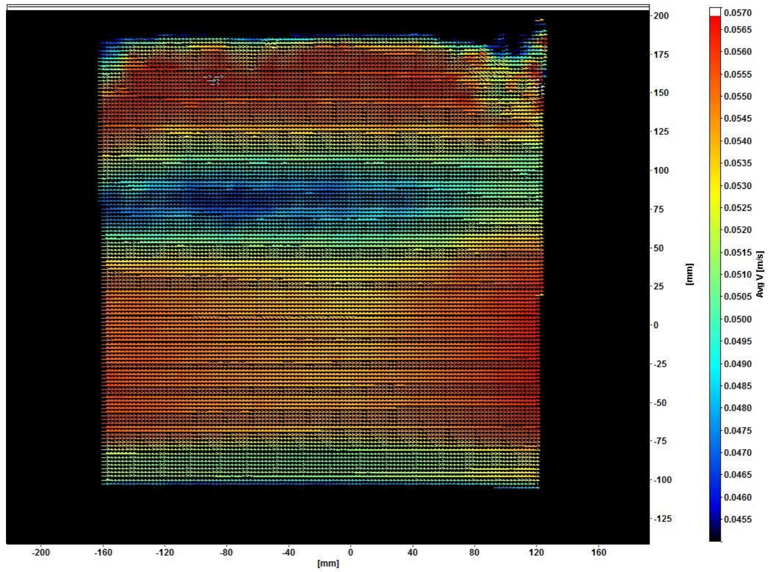


Figure 69 - Bumped Set002 for 7 Hz and 8° AOA

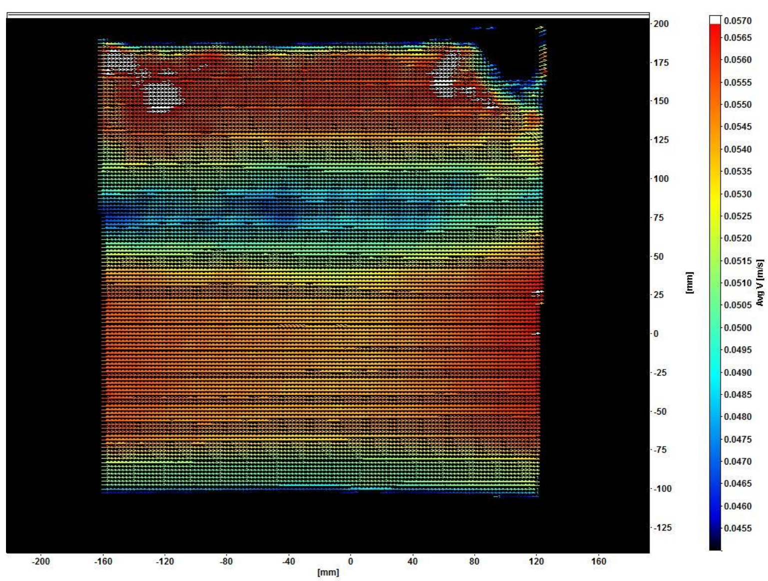


Figure 70 - Bumped Set003 for 7 Hz and 8° AOA

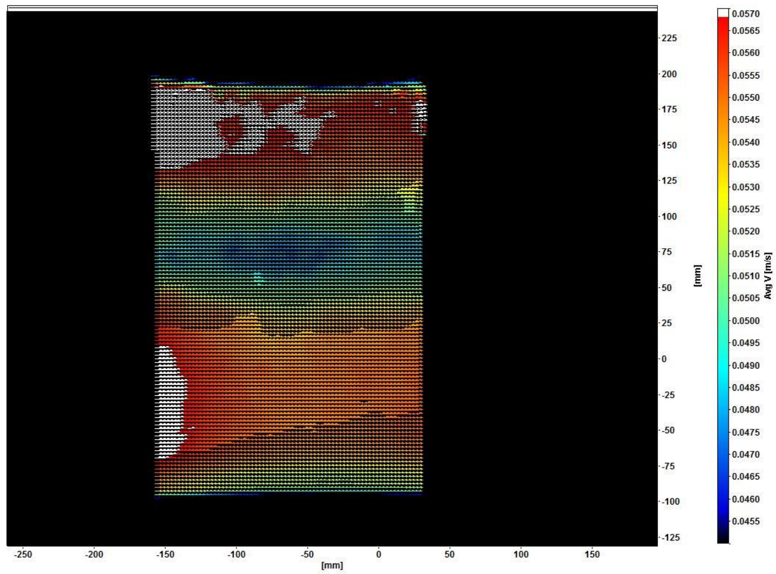


Figure 71 – Smooth Set001 for 7 Hz and 10° AOA

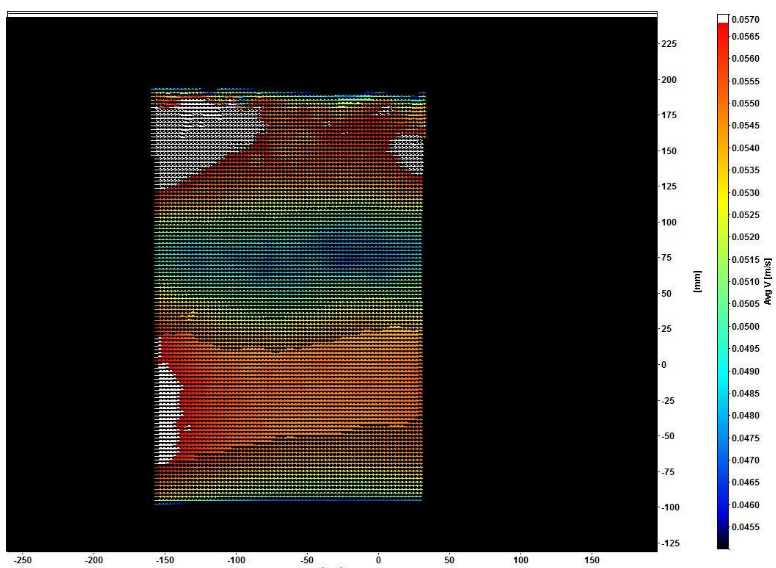


Figure 72 – Smooth Set002 for 7 Hz and 10° AOA

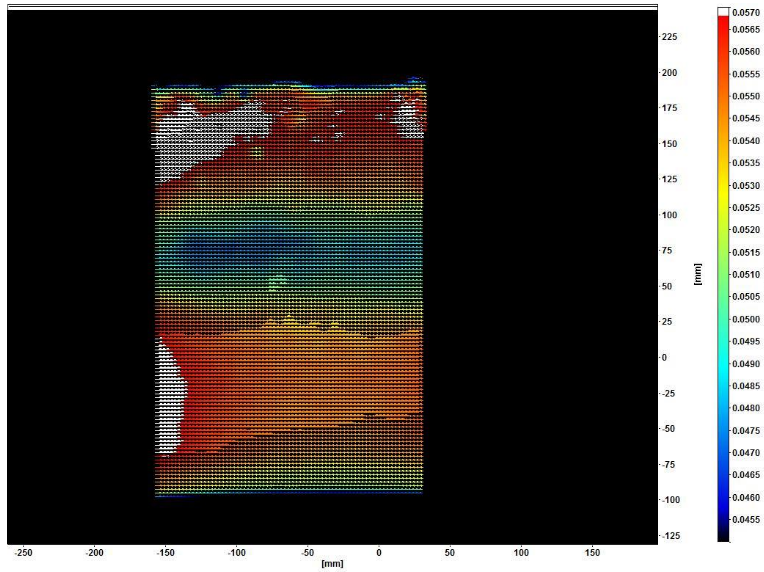


Figure 73 – Smooth Set003 for 7 Hz and 10° AOA

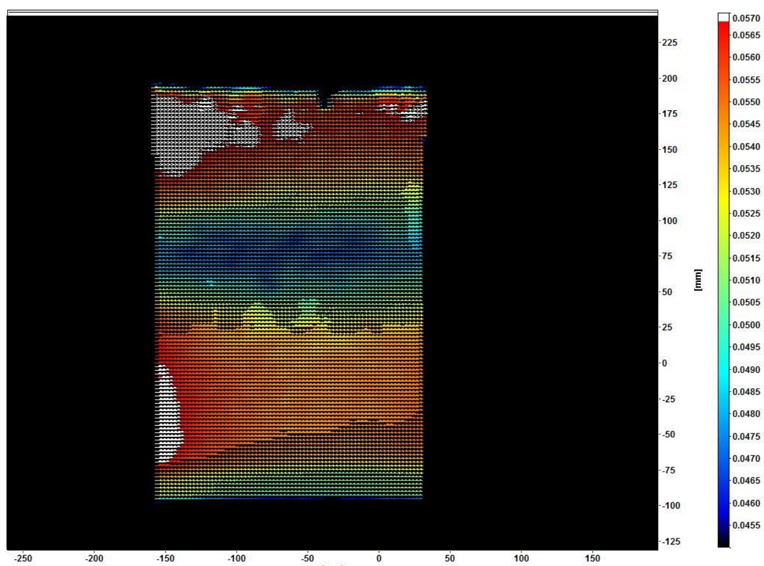


Figure 74 - Bumped Set001 for 7 Hz and 10° AOA

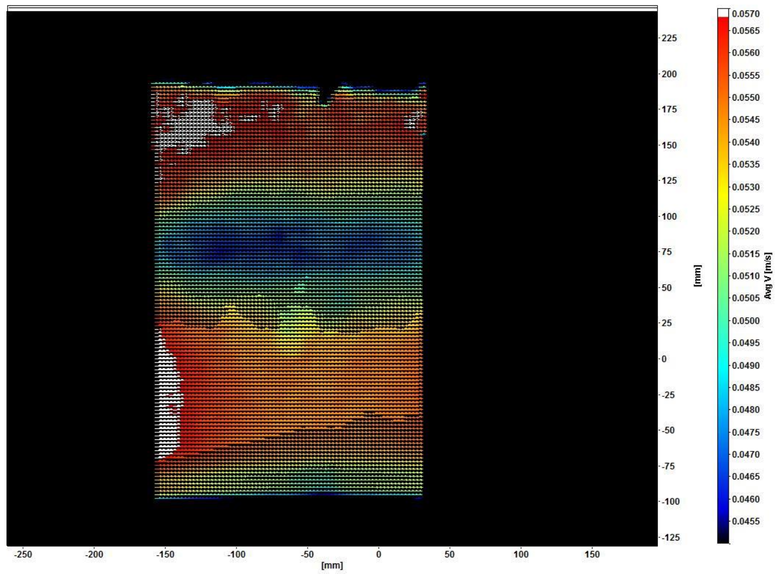


Figure 75 - Bumped Set002 for 7 Hz and 10° AOA

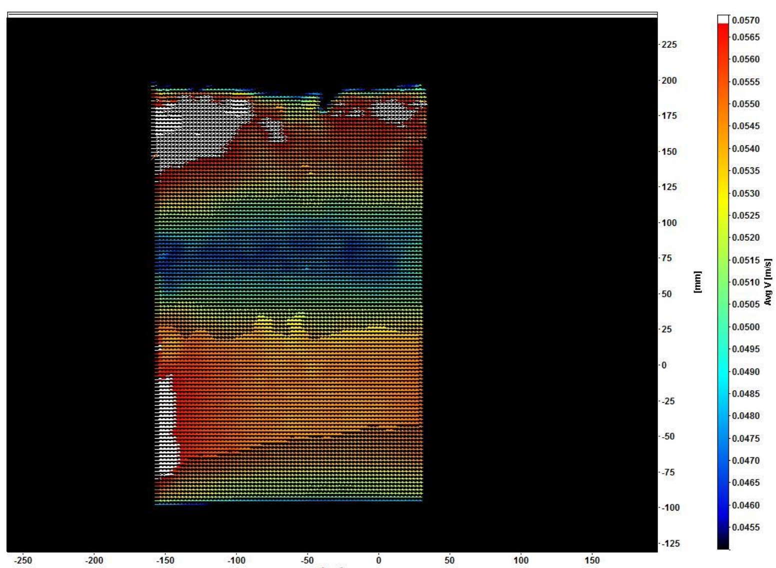


Figure 76 - Bumped Set003 for 7 Hz and 10° AOA

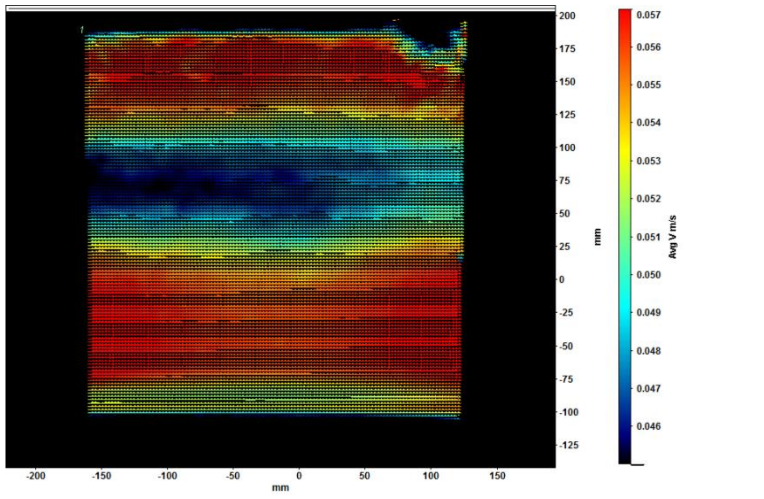


Figure 77 - Smooth Set001 for 7 Hz and 15° AOA

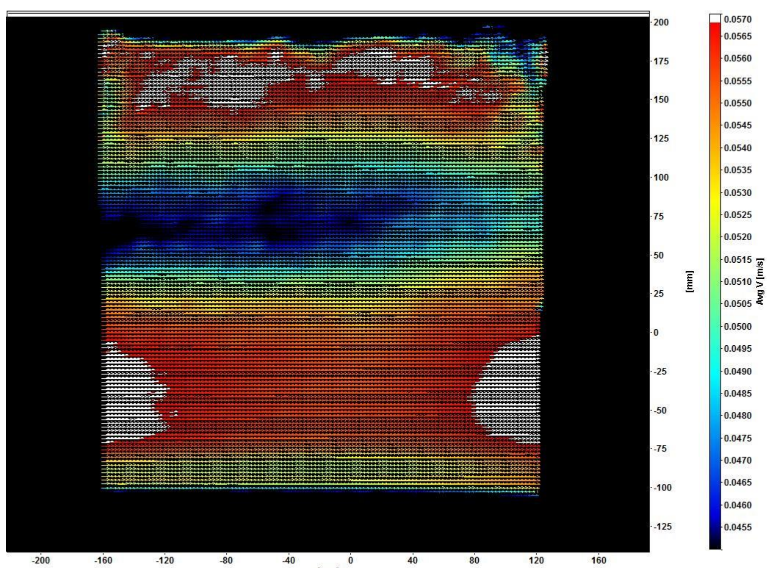


Figure 78 - Smooth Set002 for 7 Hz and 15° AOA

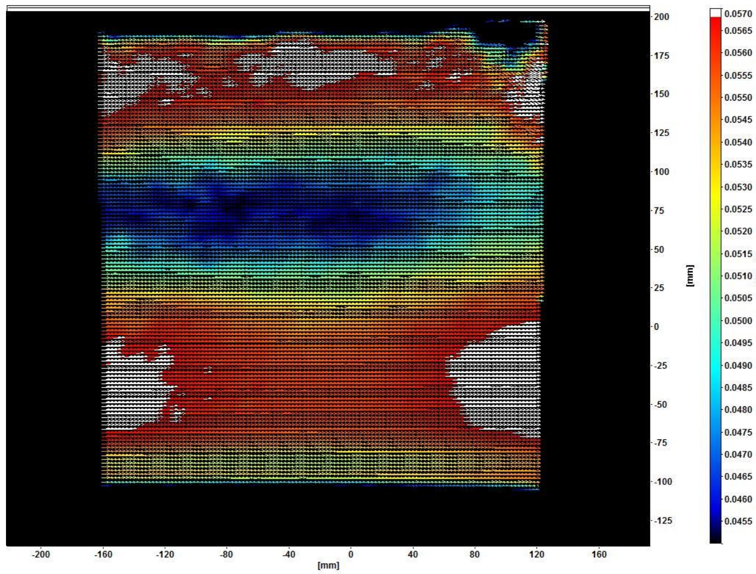


Figure 79 - Smooth Set003 for 7 Hz and 15° AOA

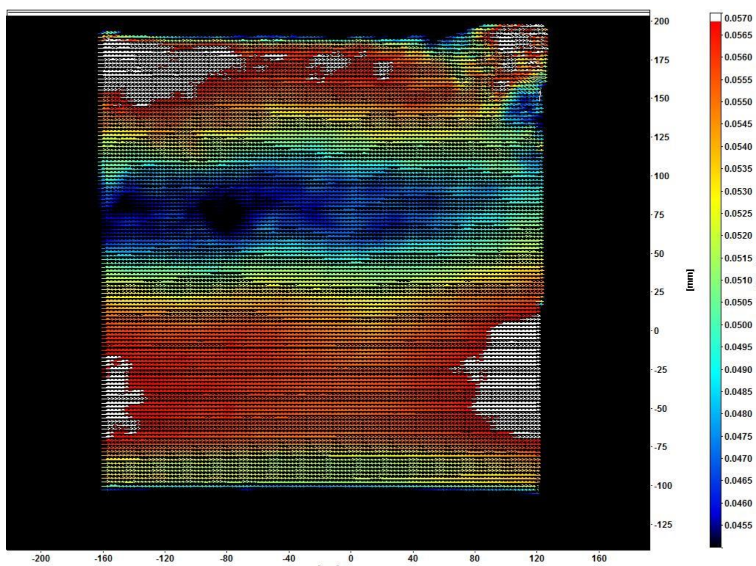


Figure 80 - Bumped Set001 for 7 Hz and 15° AOA

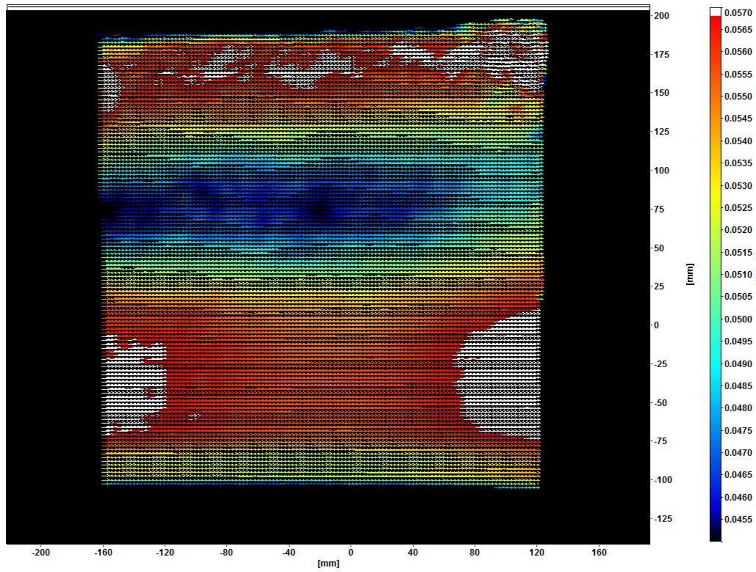


Figure 81 - Bumped Set002 for 7 Hz and 15° AOA

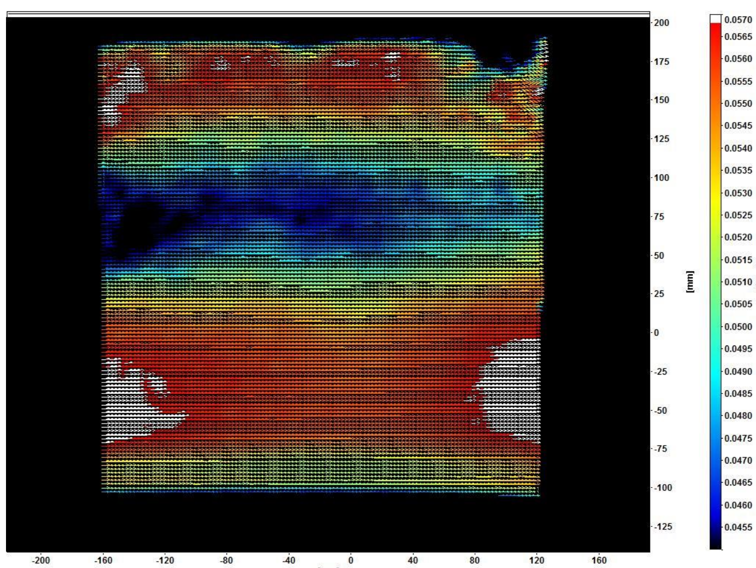


Figure 82 - Bumped Set003 for 7 Hz and 15° AOA

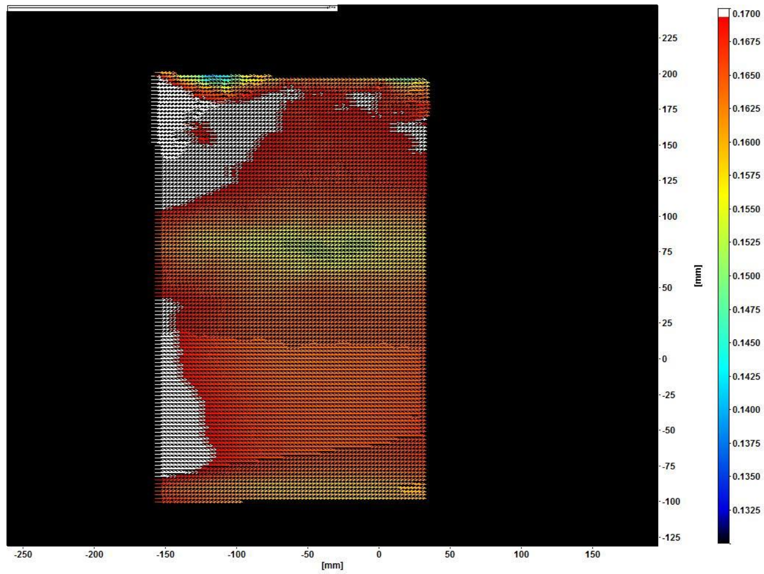


Figure 83 - Smooth Set001 for 20 Hz and -5° AOA

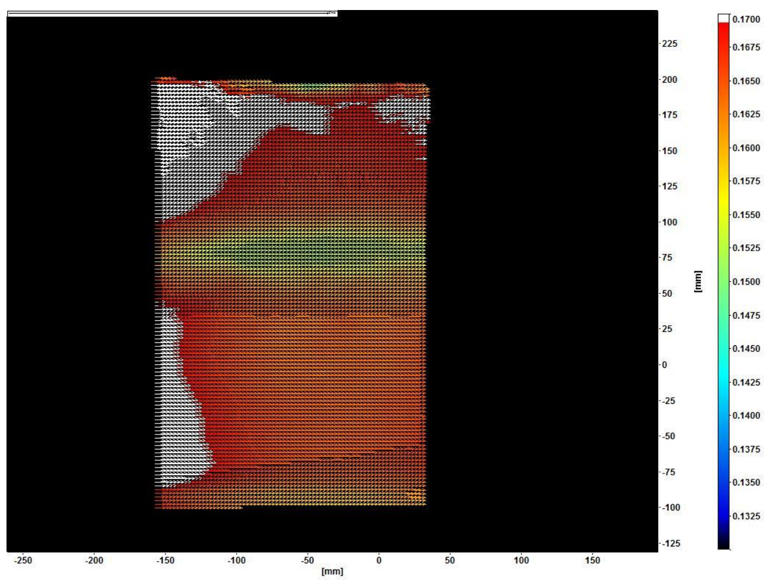


Figure 84 - Smooth Set002 for 20 Hz and -5° AOA

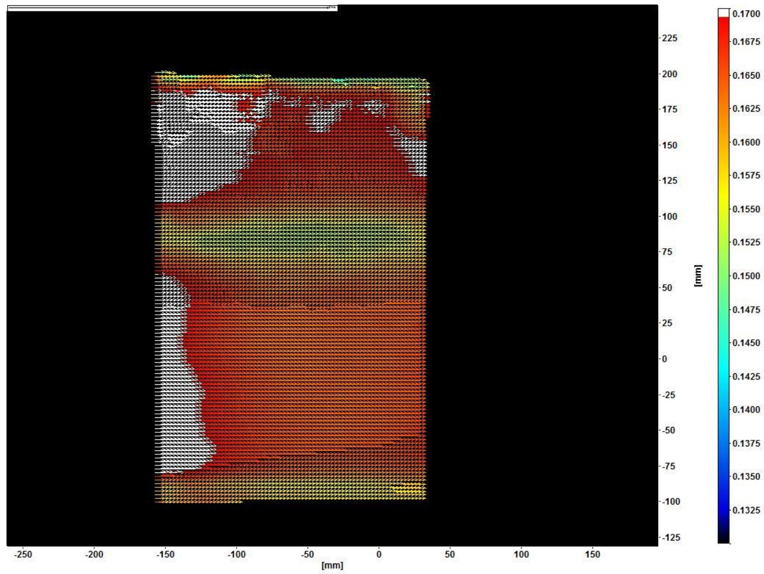


Figure 85 - Smooth Set003 for 20 Hz and -5° AOA

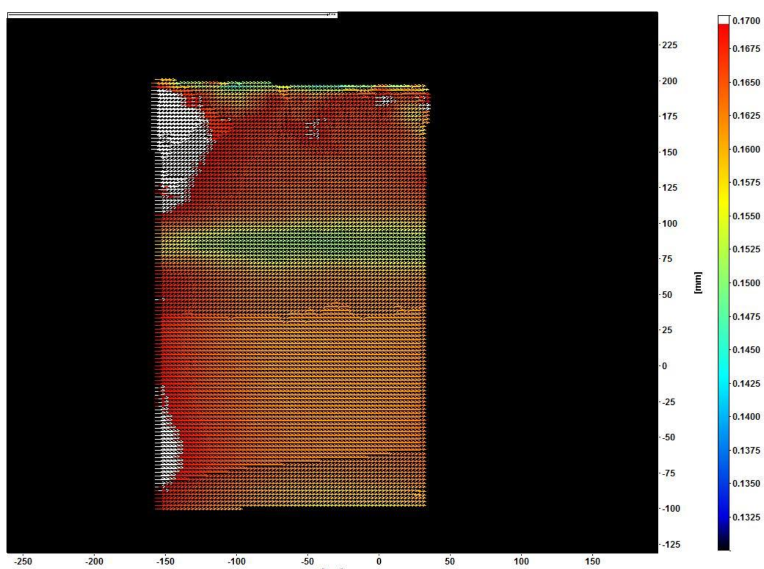


Figure 86 - Bumped Set001 for 20 Hz and -5° AOA

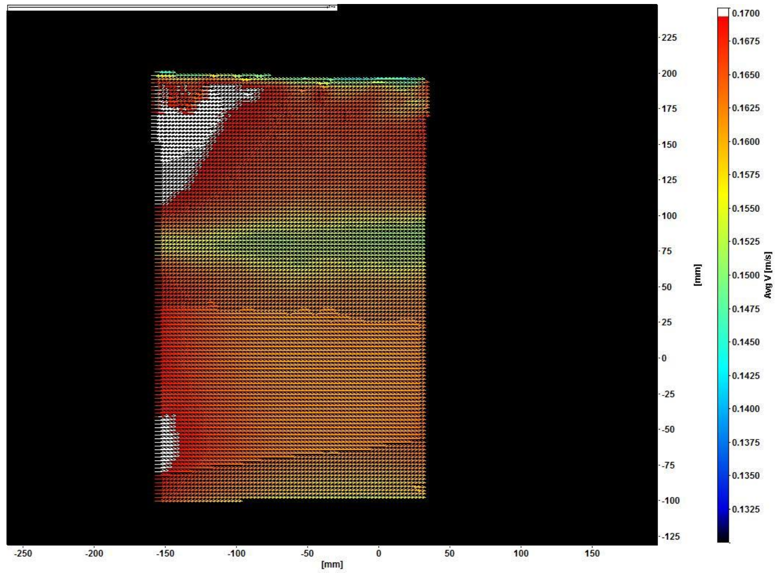


Figure 87 - Bumped Set002 for 20 Hz and -5° AOA

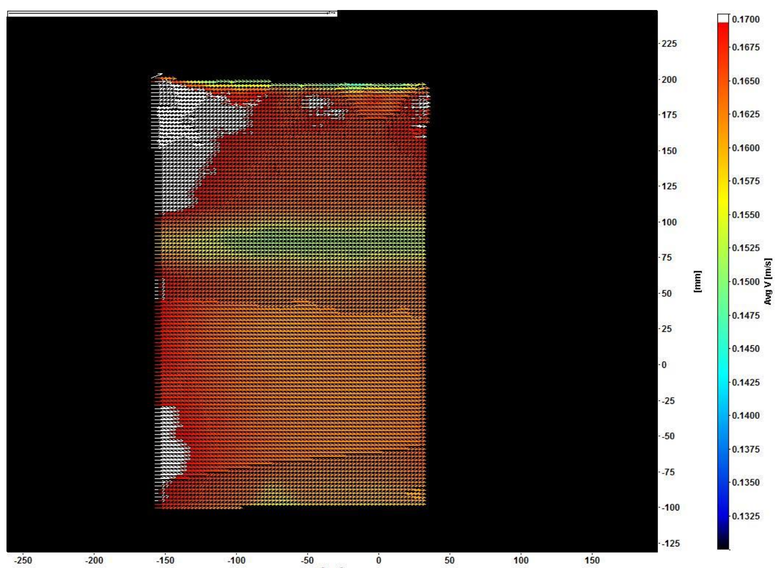


Figure 88 - Bumped Set003 for 20 Hz and -5° AOA

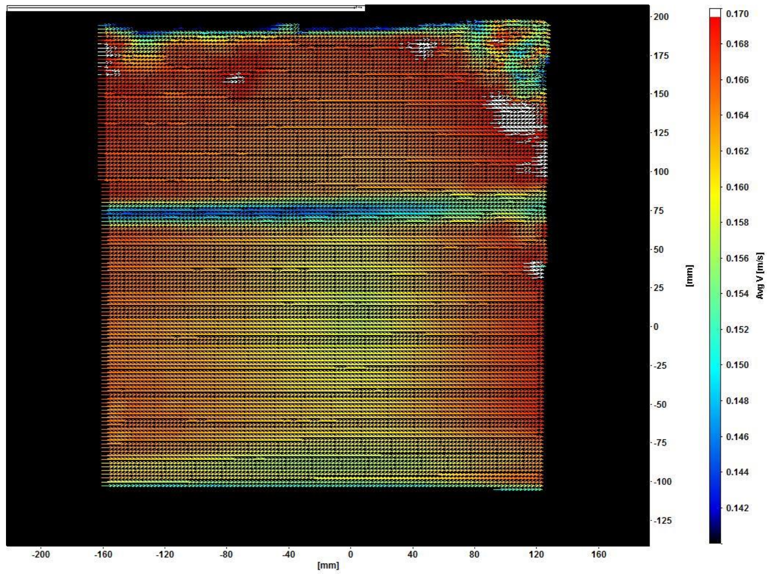


Figure 89 - Smooth Set001 for 20 Hz and 0° AOA

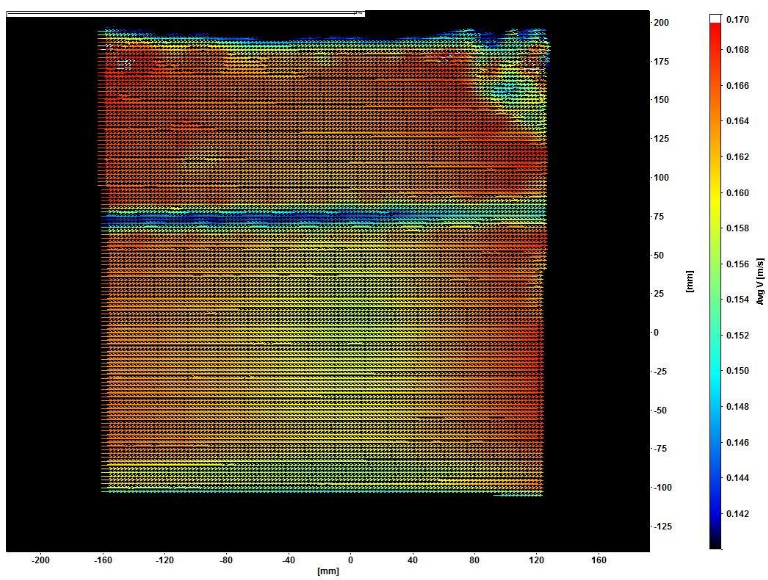


Figure 90 - Smooth Set002 for 20 Hz and 0° AOA

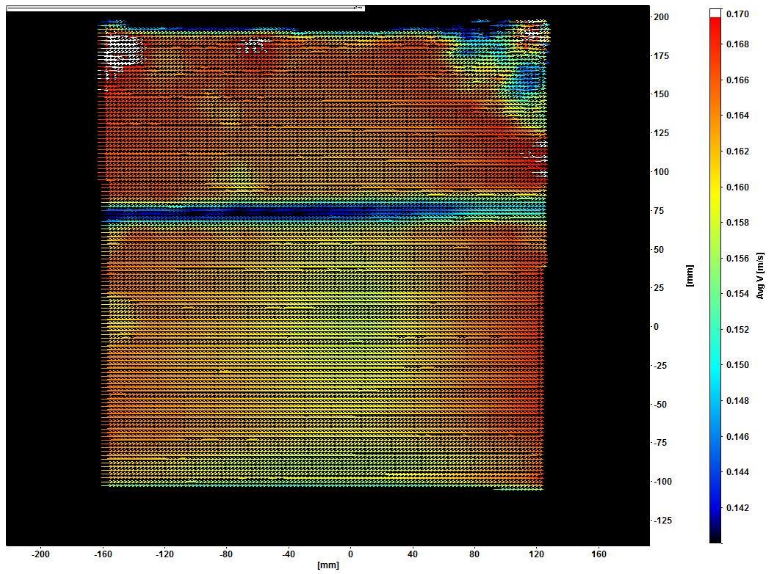


Figure 91 - Smooth Set003 for 20 Hz and 0° AOA

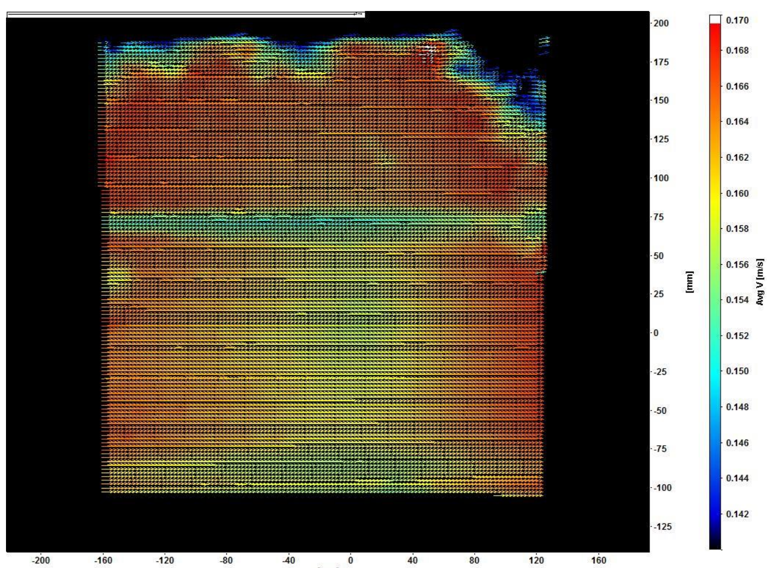


Figure 92 - Bumped Set001 for 20 Hz and 0° AOA

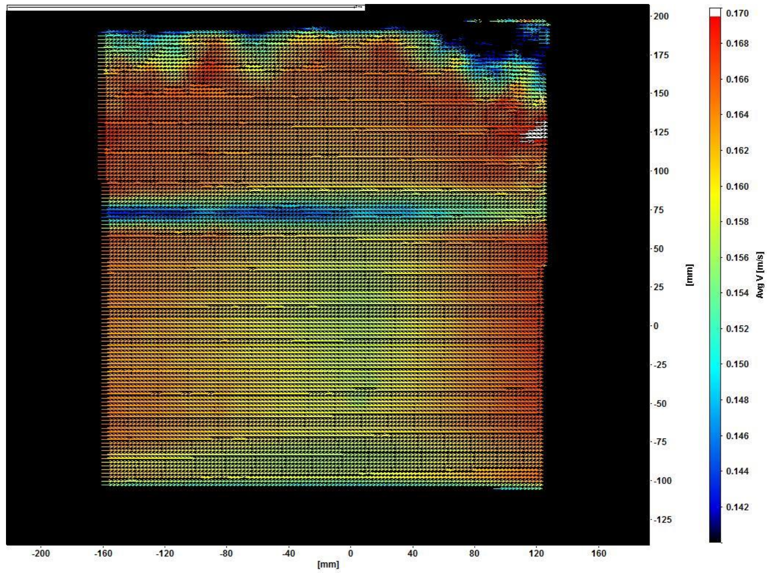


Figure 93 - Bumped Set001 for 20 Hz and 0° AOA

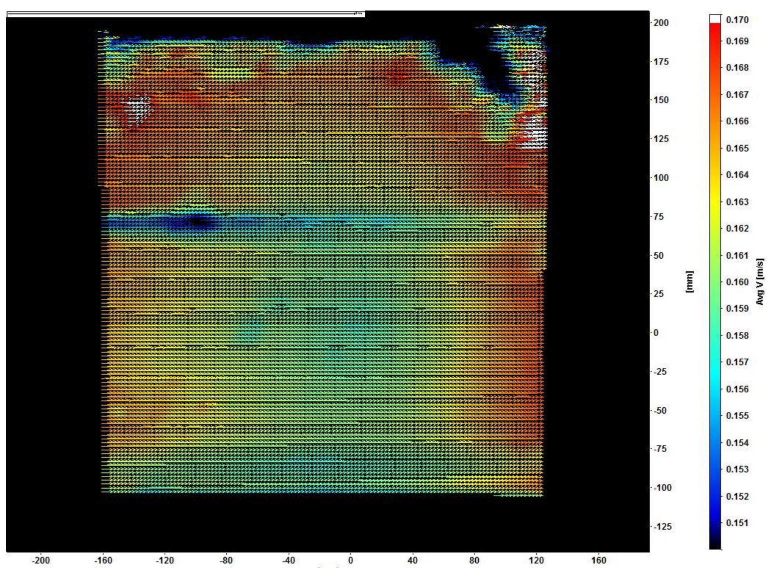


Figure 94 - Bumped Set003 for 20 Hz and 0° AOA

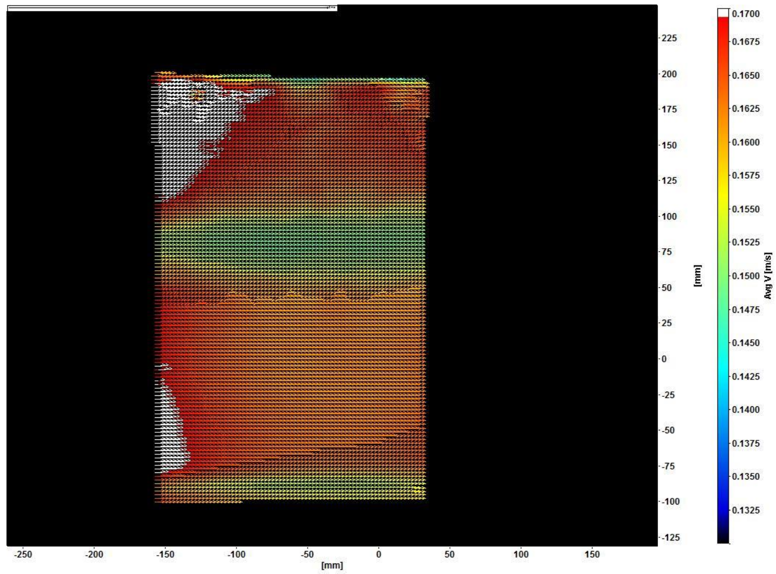


Figure 95 - Smooth Set001 for 20 Hz and 5° AOA

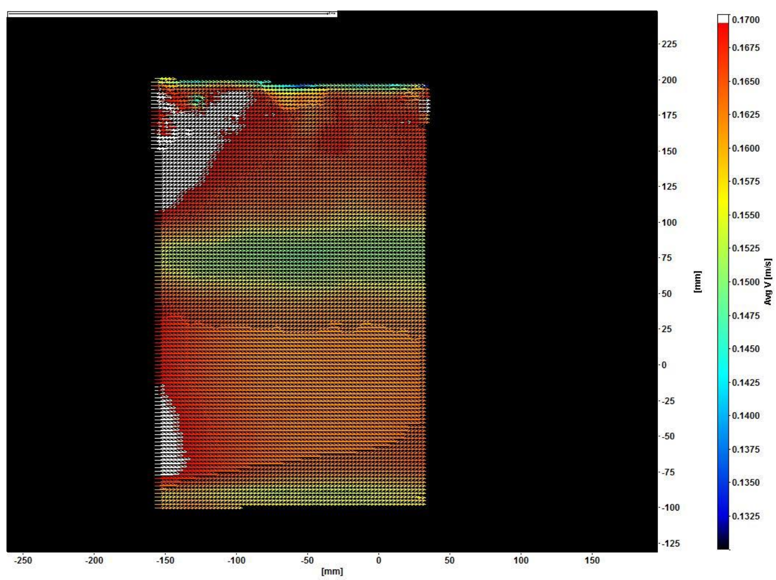


Figure 96 - Smooth Set002 for 20 Hz and 5° AOA

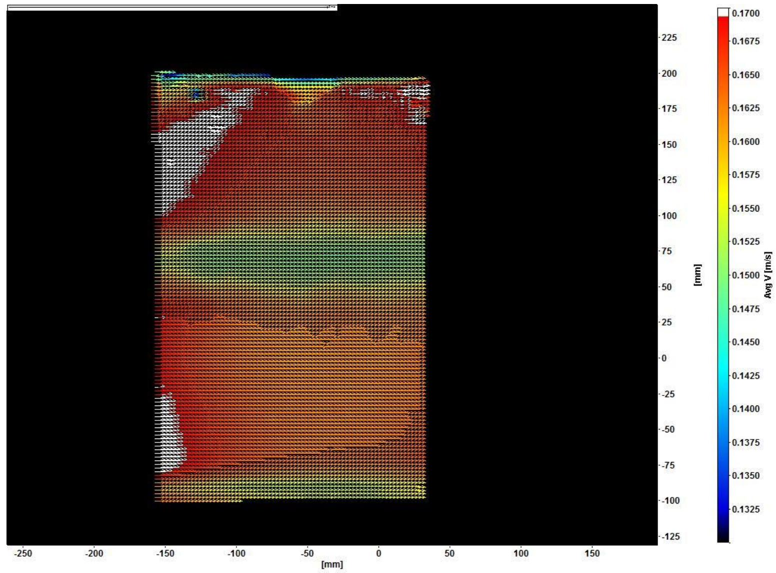


Figure 97 - Smooth Set003 for 20 Hz and 5° AOA

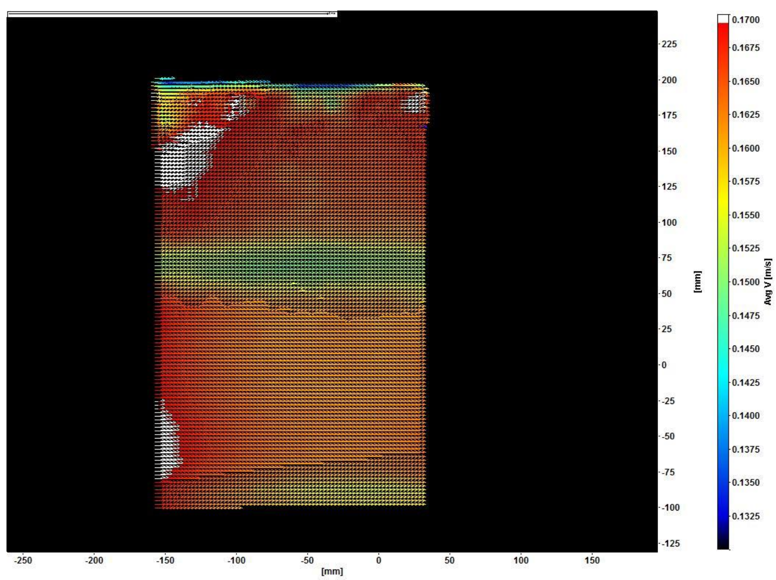


Figure 98 - Bumped Set001 for 20 Hz and 5° AOA

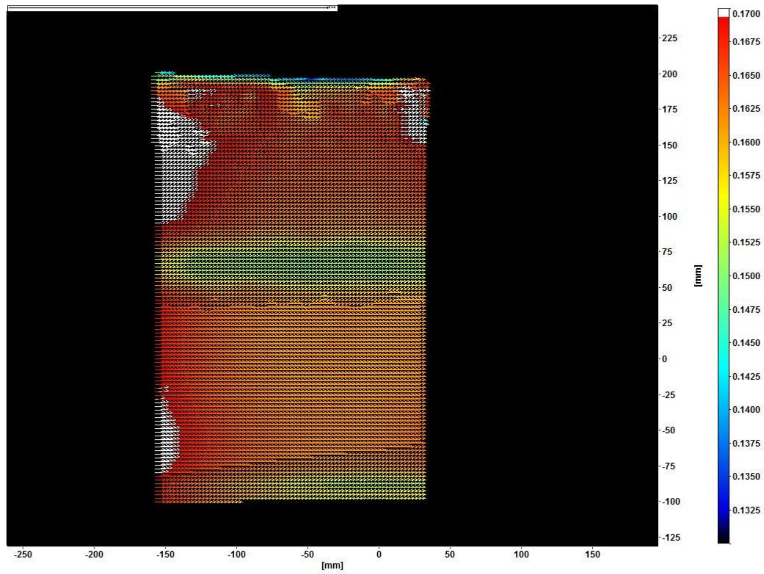


Figure 99 - Bumped Set002 for 20 Hz and 5° AOA

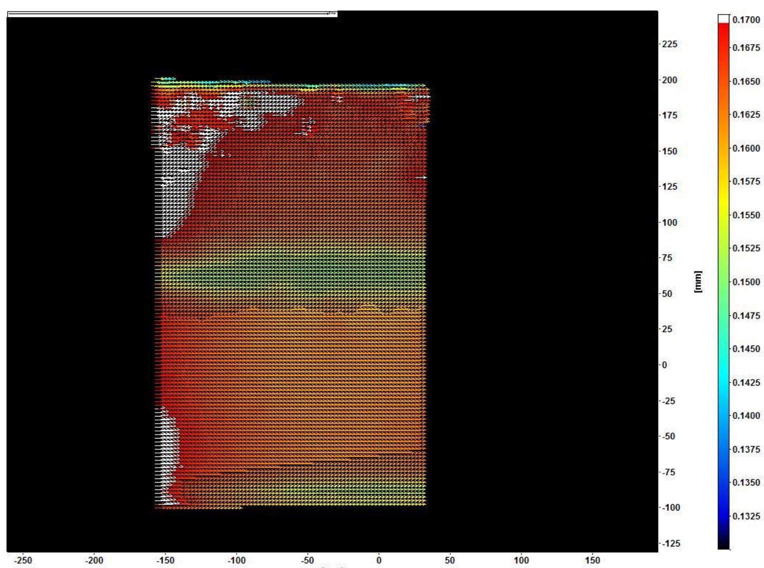


Figure 100 - Bumped Set003 for 20 Hz and 5° AOA

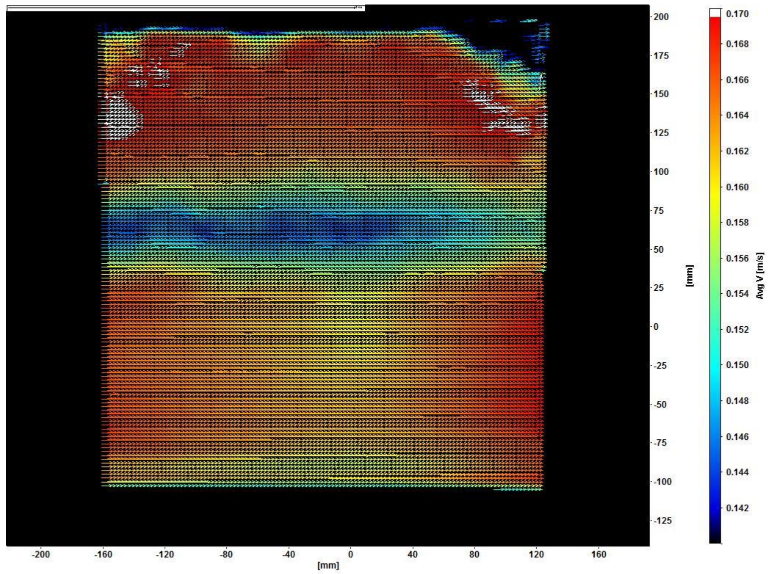


Figure 101 – Smooth Set001 for 20 Hz and 8° AOA

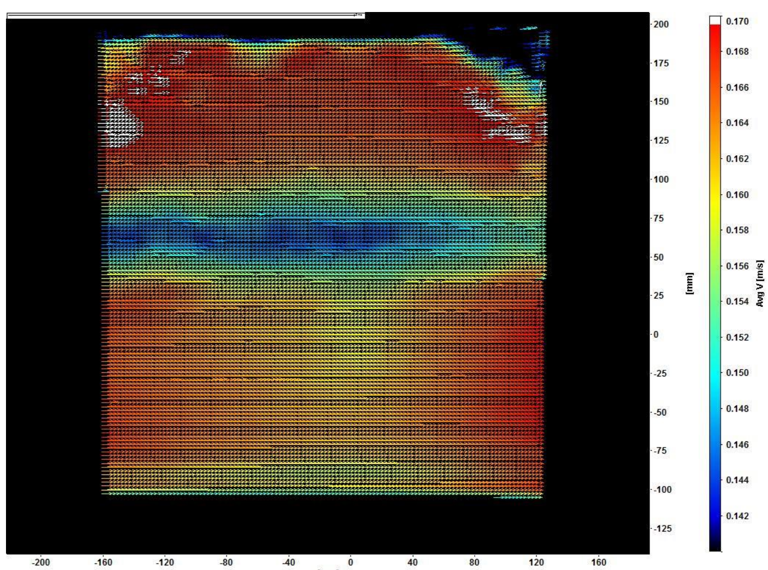


Figure 102 – Smooth Set002 for 20 Hz and 8° AOA

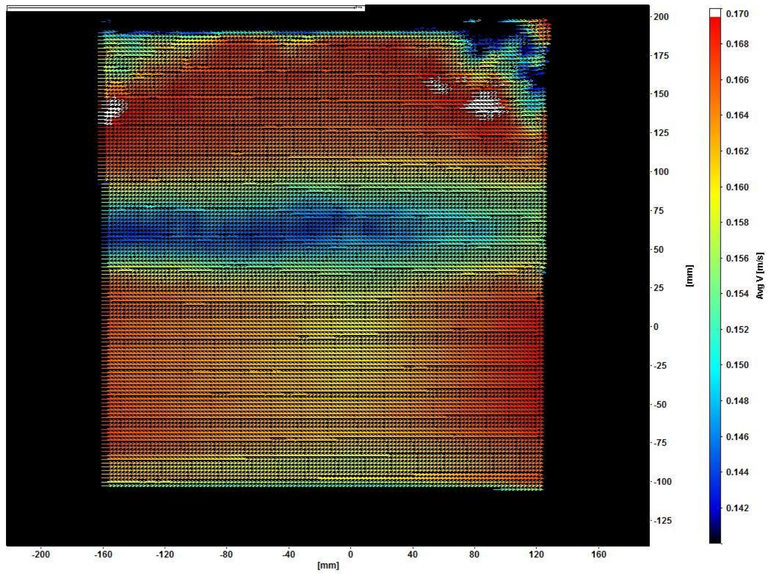


Figure 103 – Smooth Set003 for 20 Hz and 8° AOA

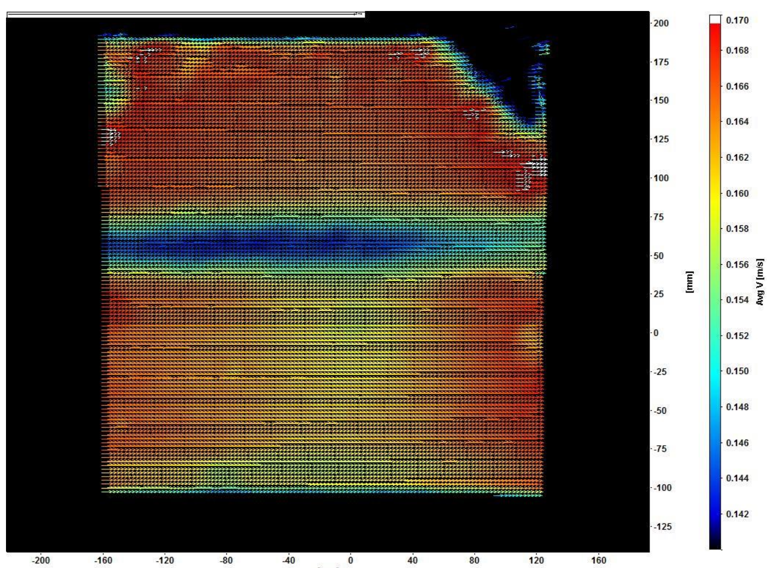


Figure 104 - Bumped Set001 for 20 Hz and 8° AOA

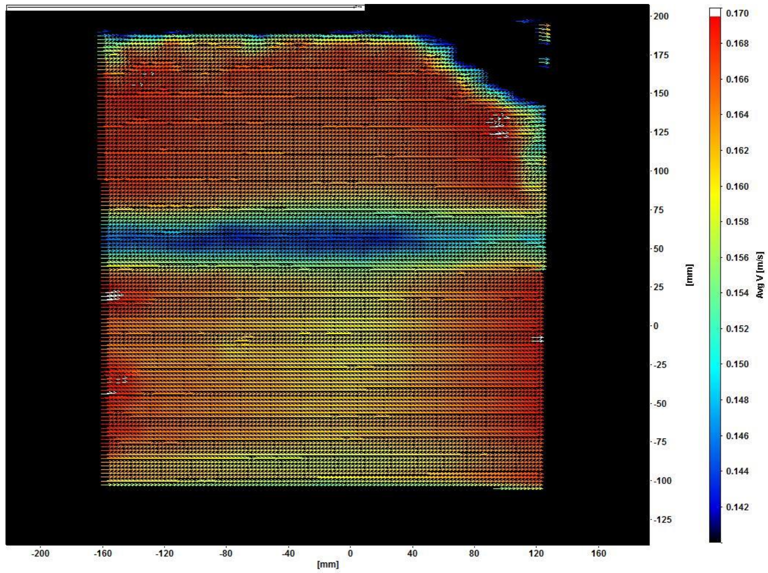


Figure 105 - Bumped Set002 for 20 Hz and 8° AOA

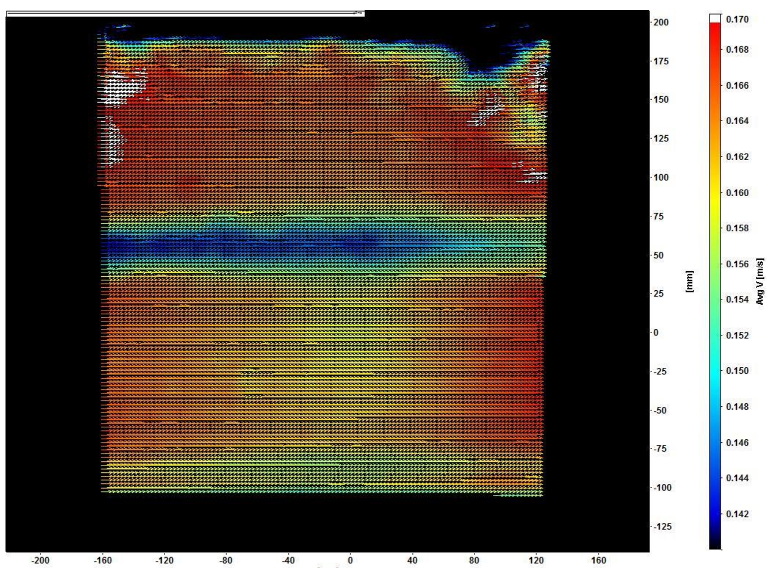


Figure 106 - Bumped Set003 for 20 Hz and 8° AOA

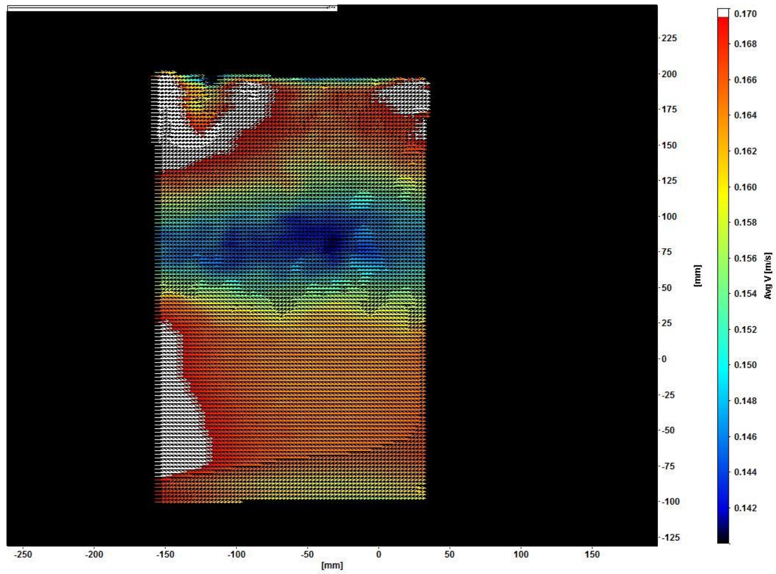


Figure 107 - Smooth Set001 for 20 Hz and 10° AOA

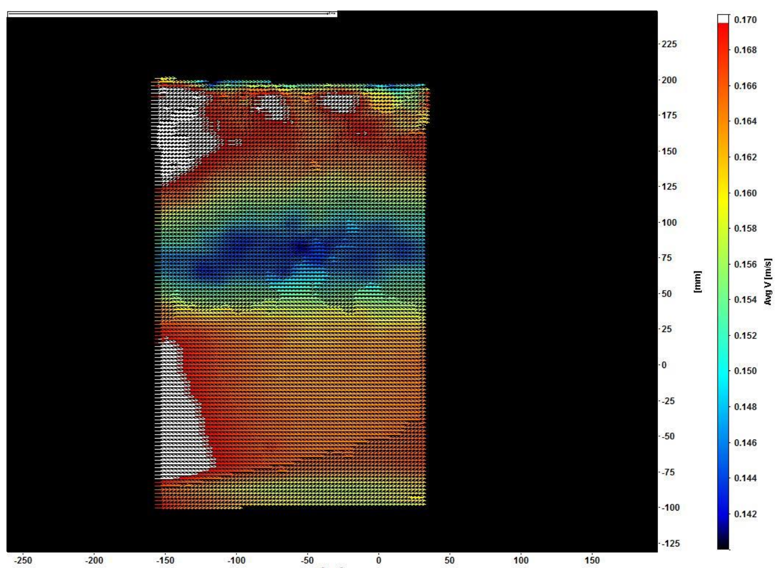


Figure 108 - Smooth Set002 for 20 Hz and 10° AOA

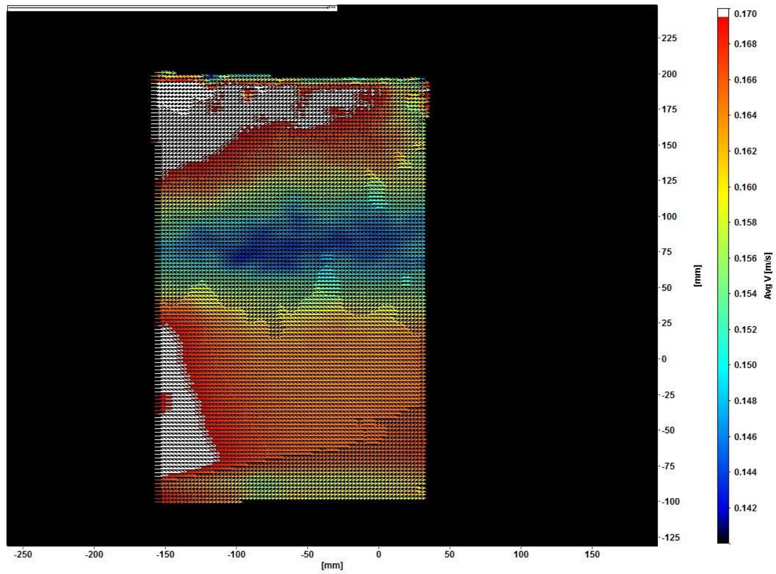


Figure 109 - Smooth Set003 for 20 Hz and 10° AOA

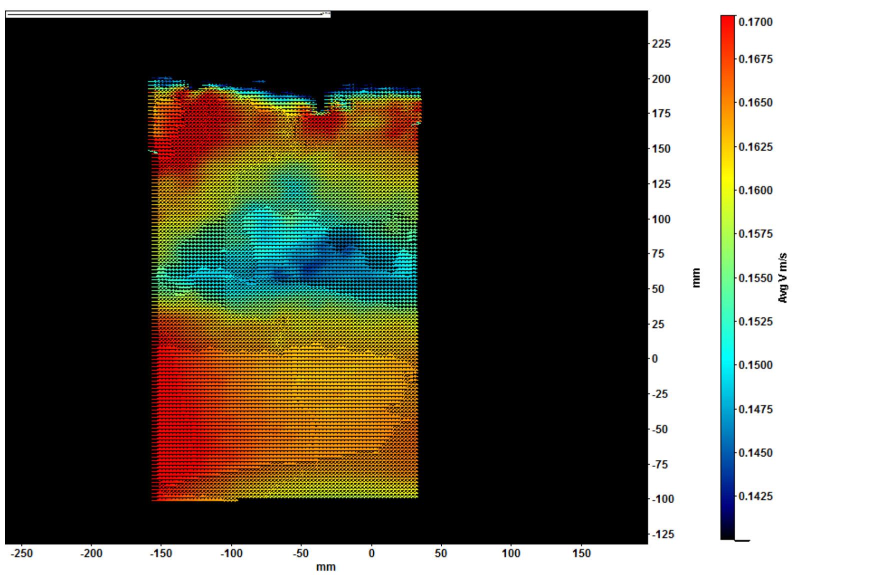


Figure 110 - Bumped Set001 for 20 Hz and 10° AOA

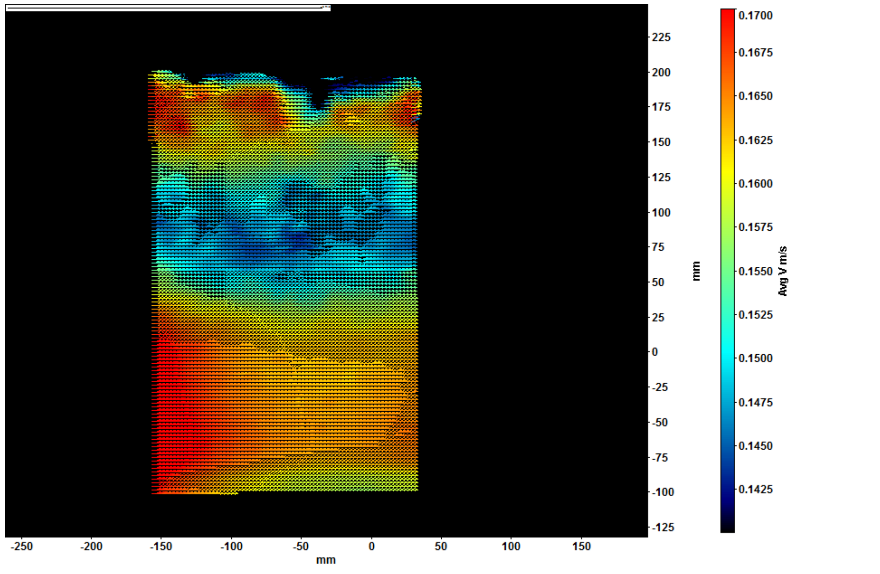


Figure 111 - Bumped Set002 for 20 Hz and 10° AOA

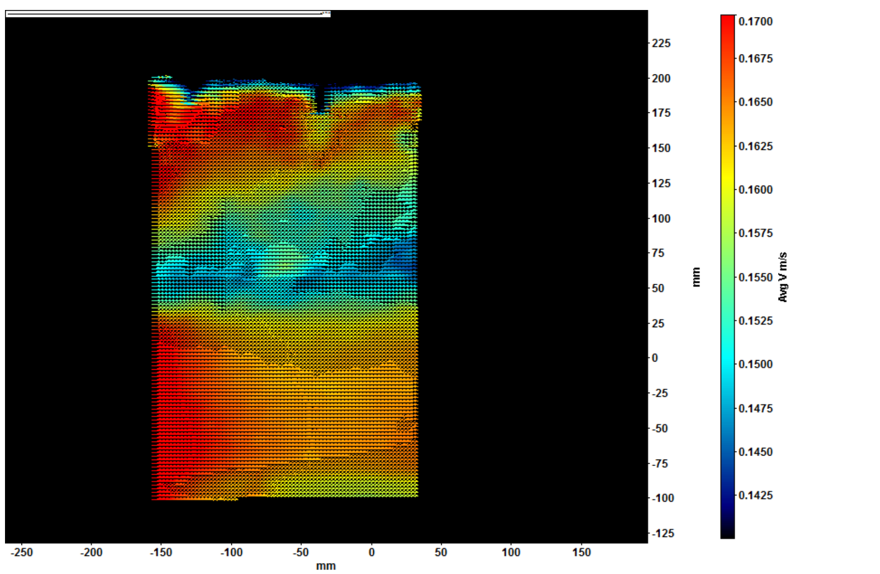


Figure 112 - Bumped Set001 for 20 Hz and 10° AOA

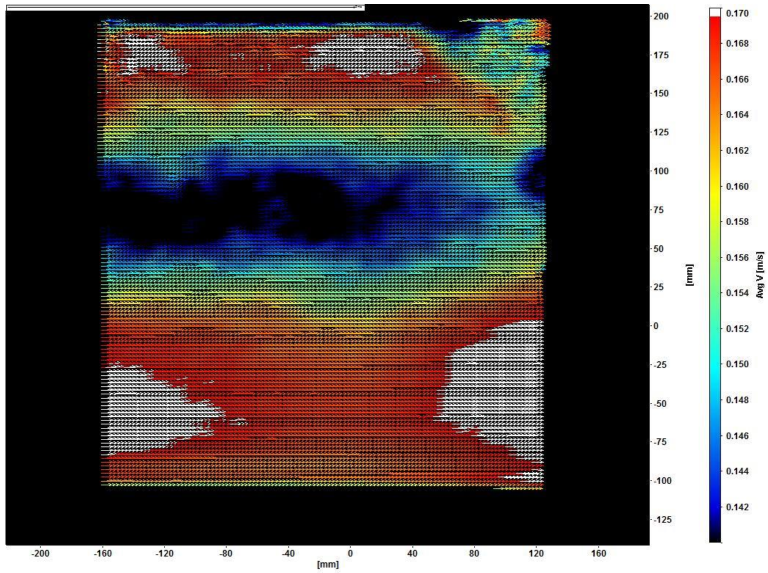


Figure 113 - Smooth Set001 for 20 Hz and 15° AOA

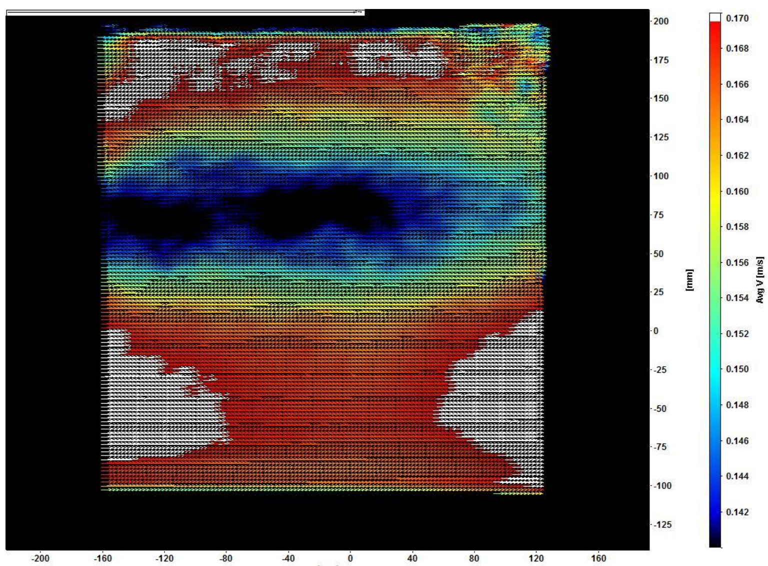


Figure 114 - Smooth Set002 for 20 Hz and 15° AOA

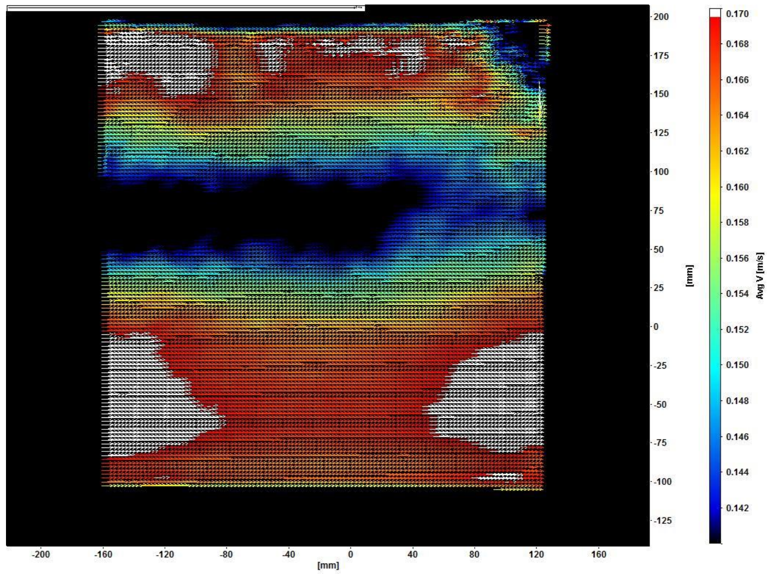


Figure 115 - Smooth Set003 for 20 Hz and 15° AOA

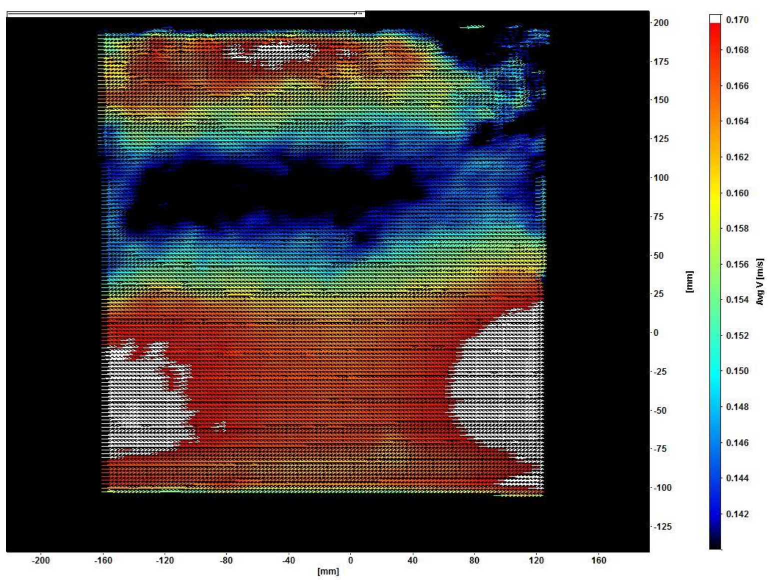


Figure 116 – Bumped Set001 for 20 Hz and 15° AOA

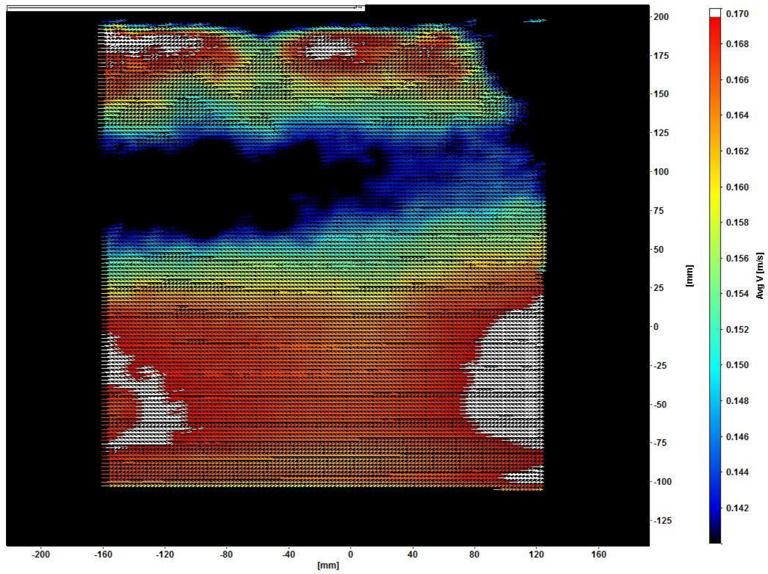


Figure 117 – Bumped Set002 for 20 Hz and 15° AOA

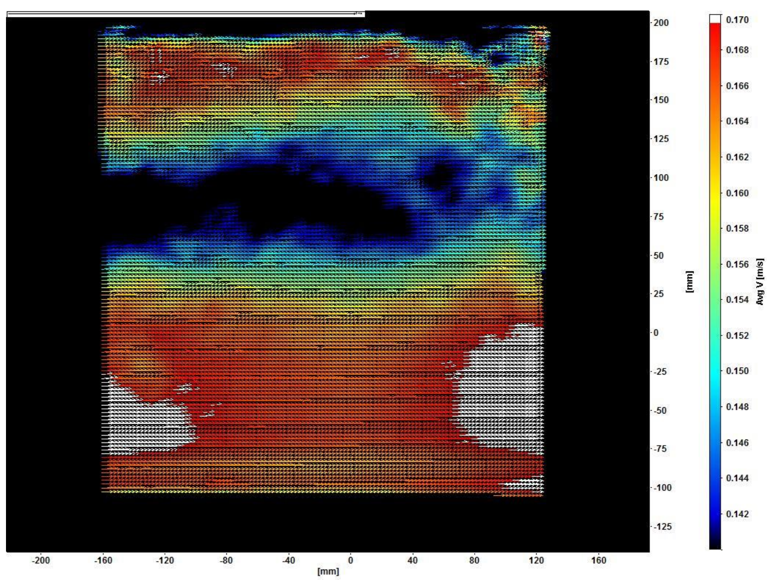


Figure 118 – Bumped Set003 for 20 Hz and 15° AOA

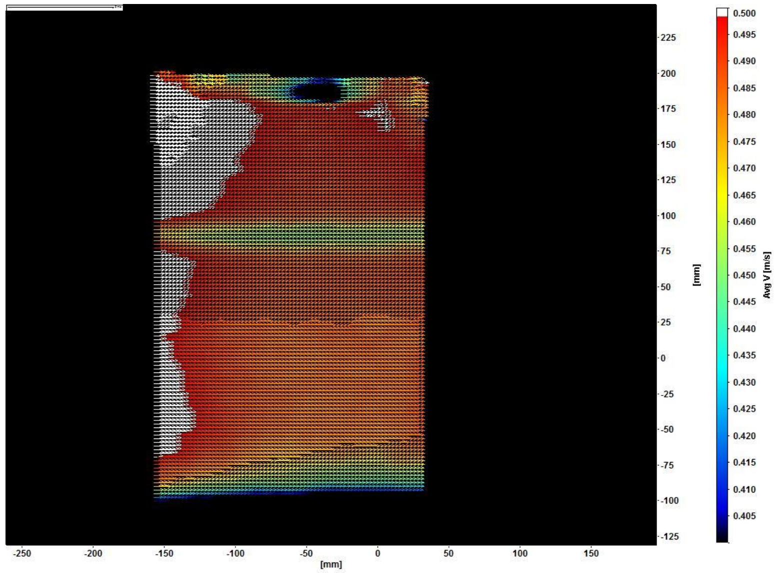


Figure 119 – Smooth Set001 for 65 Hz and -5° AOA

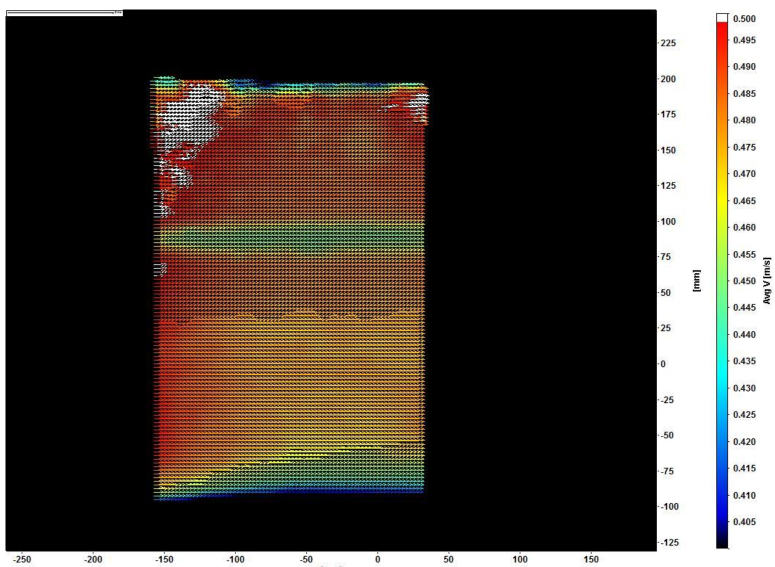


Figure 120 – Smooth Set001 for 65 Hz and -5° AOA

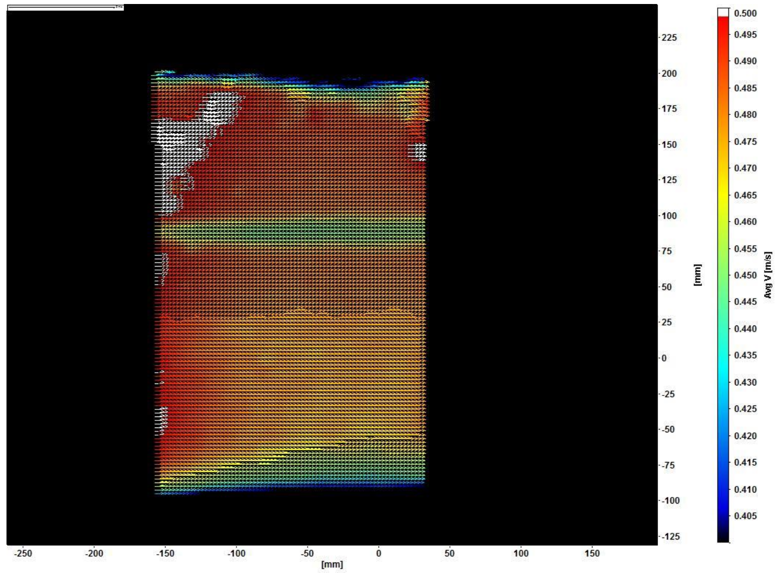


Figure 121 – Smooth Set001 for 65 Hz and -5° AOA

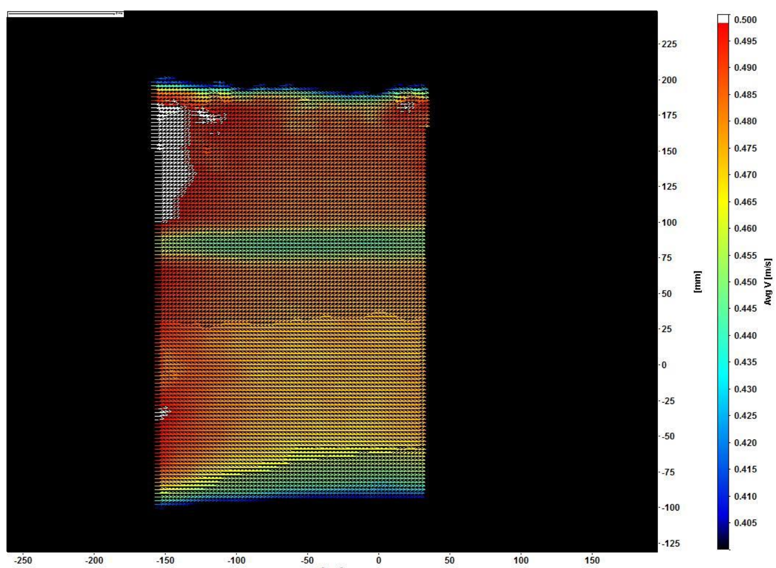


Figure 122 – Bumped Set001 for 65 Hz and -5° AOA

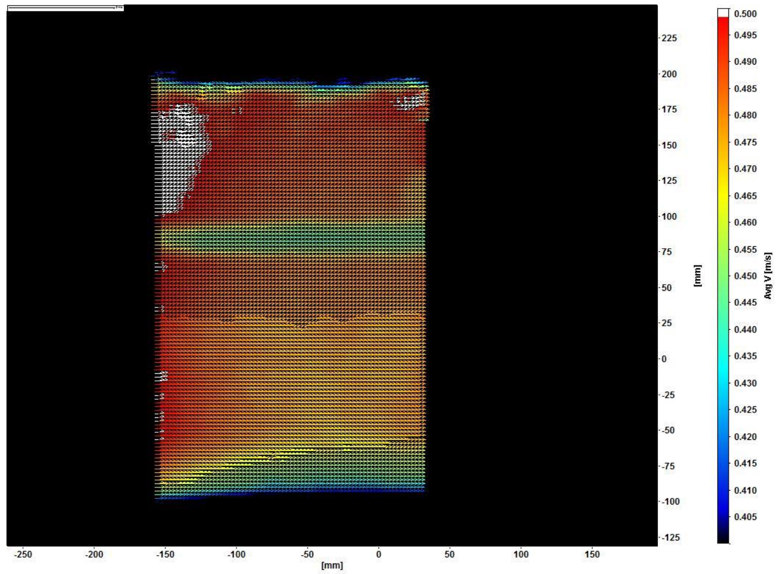


Figure 123 – Bumped Set002 for 65 Hz and -5° AOA

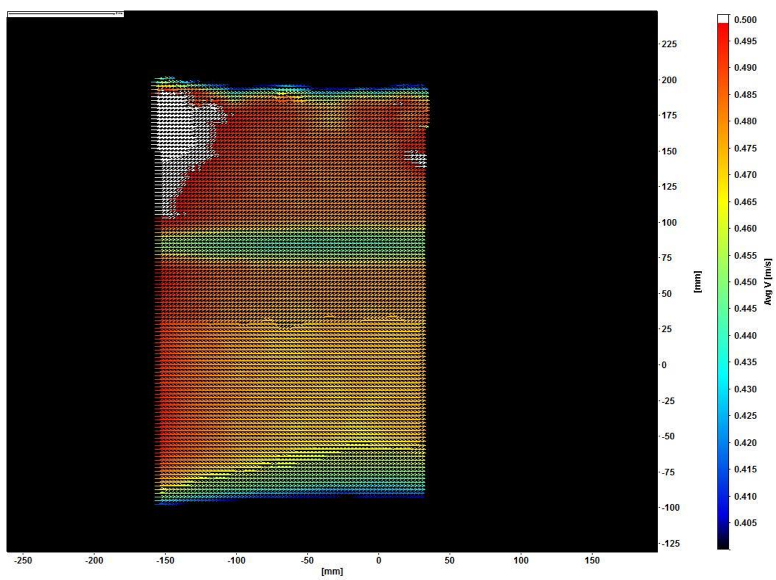


Figure 124 – Bumped Set003 for 65 Hz and -5° AOA

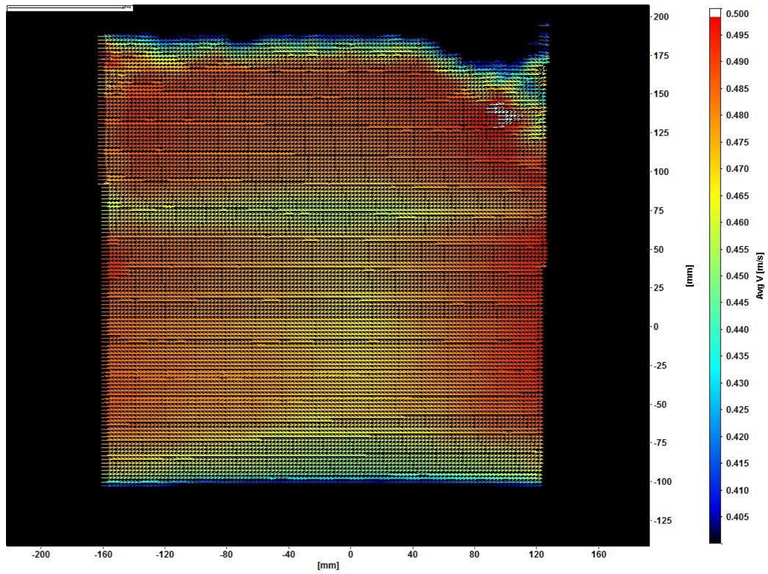


Figure 125 – Smooth Set001 for 65 Hz and 0° AOA

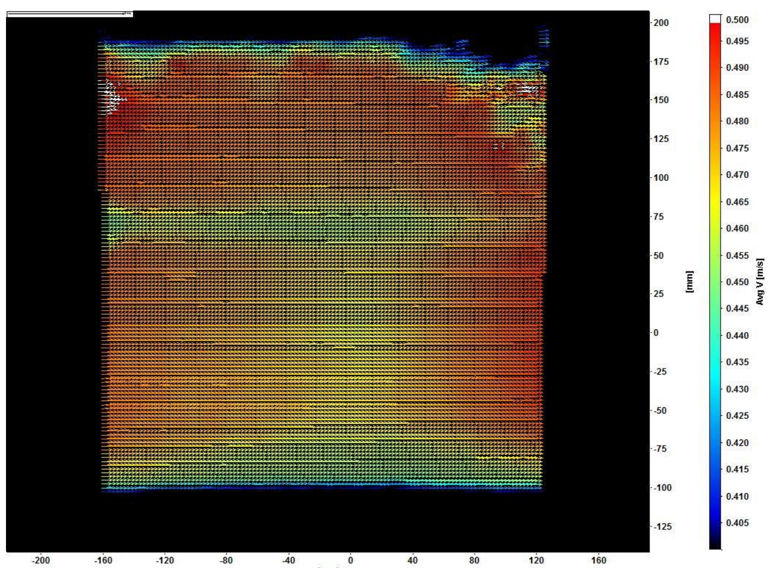


Figure 126 – Smooth Set002 for 65 Hz and 0° AOA

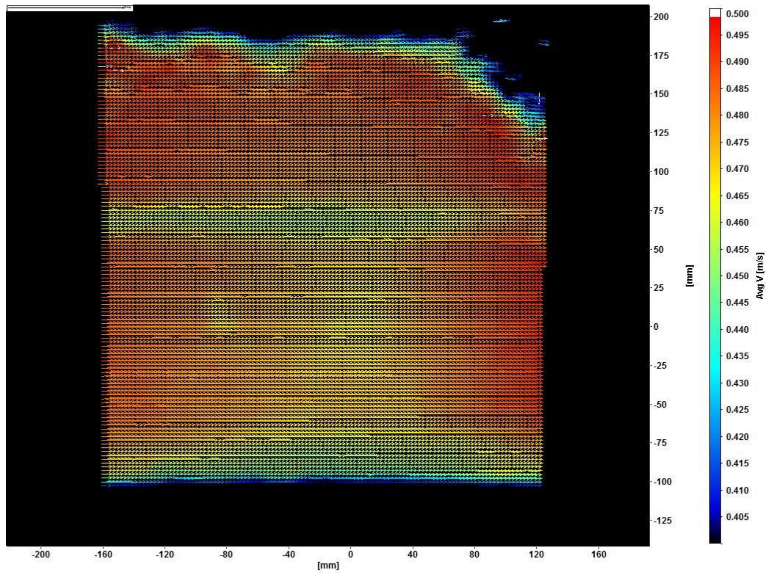


Figure 127 – Smooth Set003 for 65 Hz and 0° AOA

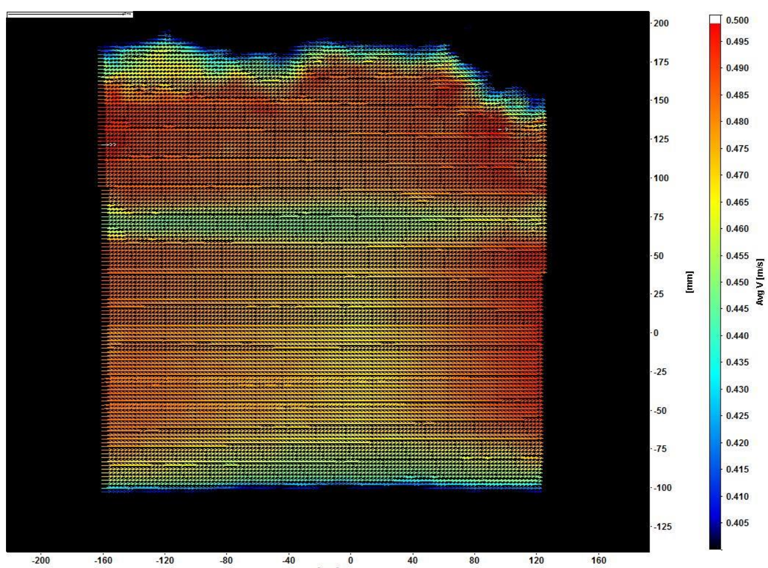


Figure 128 – Bumped Set001 for 65 Hz and 0° AOA

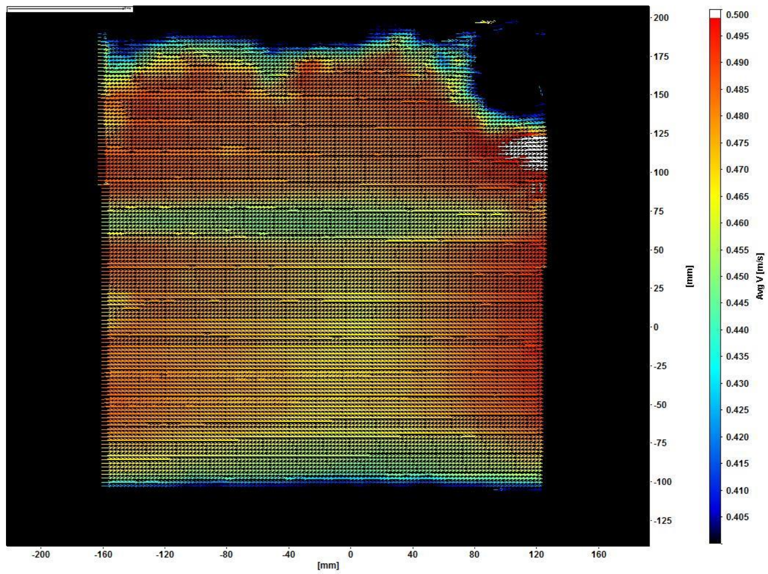


Figure 129 – Bumped Set002 for 65 Hz and 0° AOA

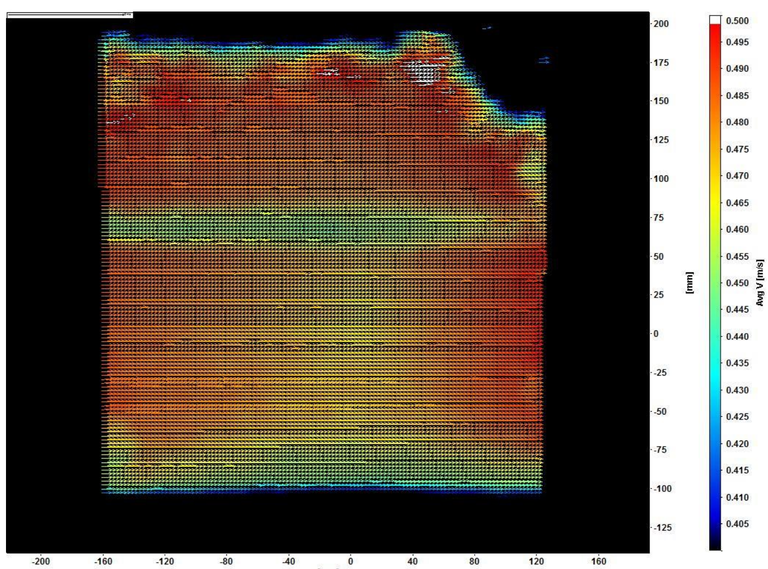


Figure 130 – Bumped Set003 for 65 Hz and 0° AOA

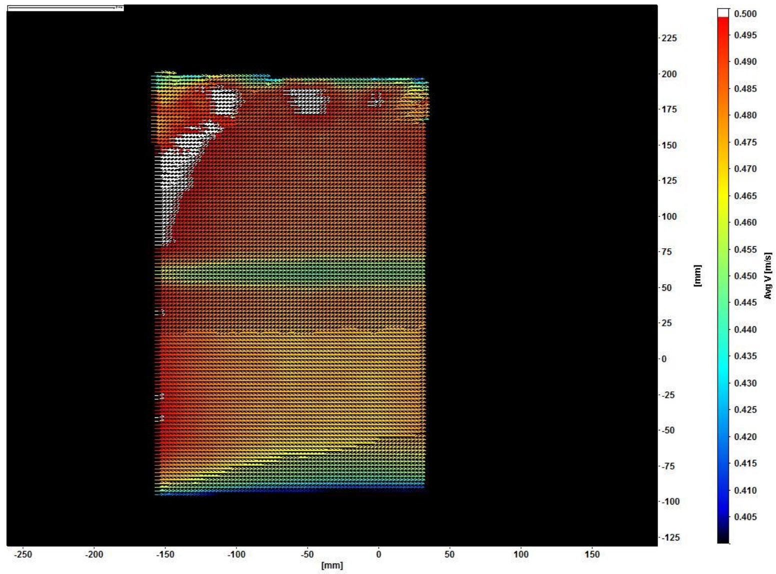


Figure 131 – Smooth Set001 for 65 Hz and 5° AOA

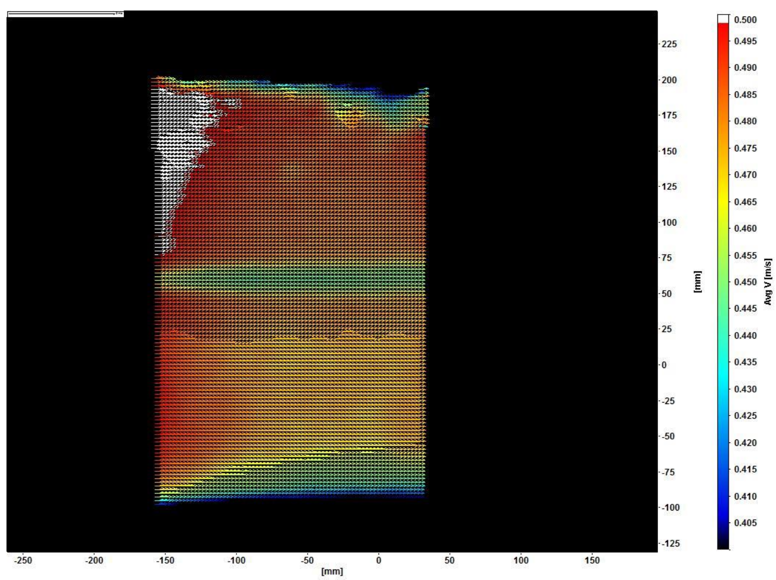


Figure 132 – Smooth Set002 for 65 Hz and 5° AOA

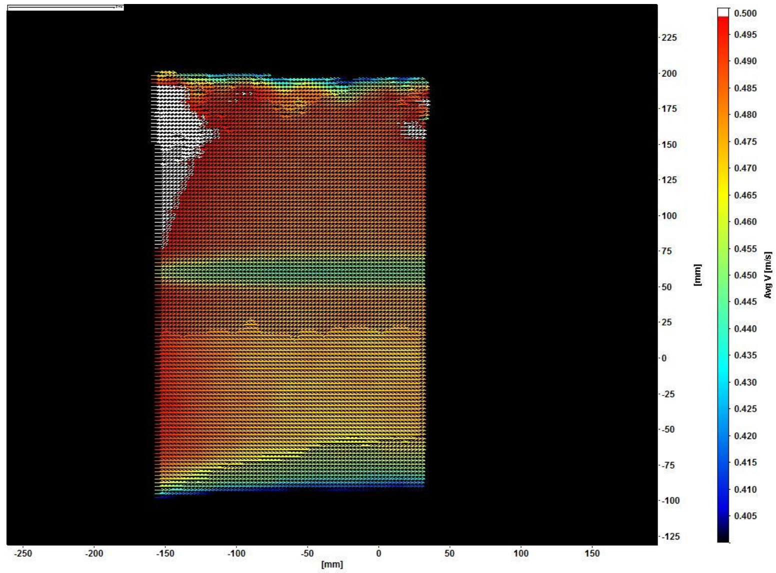


Figure 133 – Smooth Set003 for 65 Hz and 5° AOA

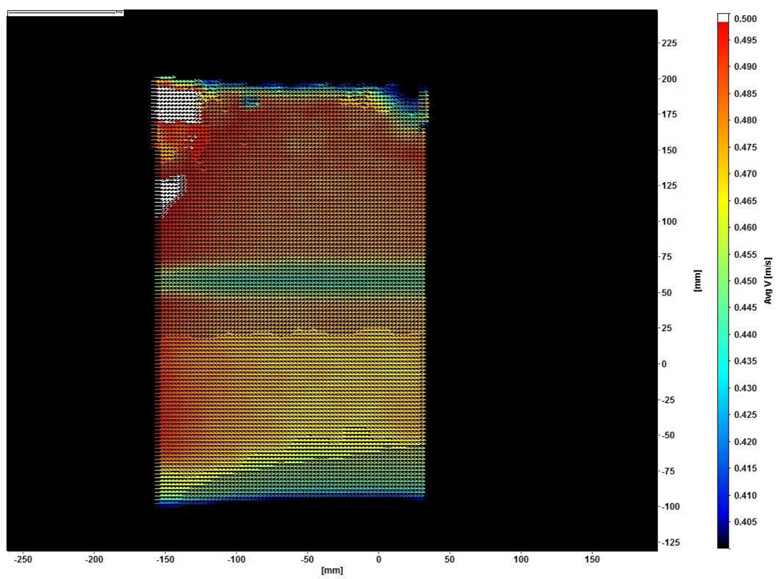


Figure 134 – Bumped Set001 for 65 Hz and 5° AOA

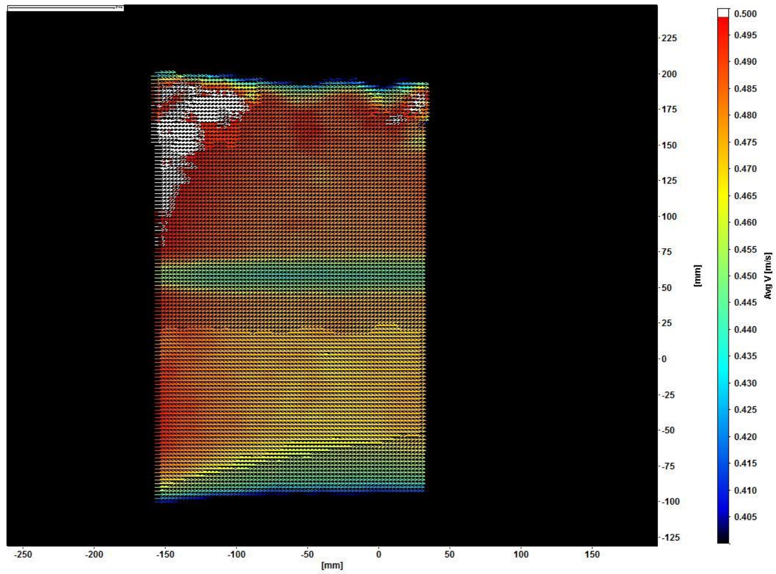


Figure 135 – Bumped Set002 for 65 Hz and 5° AOA

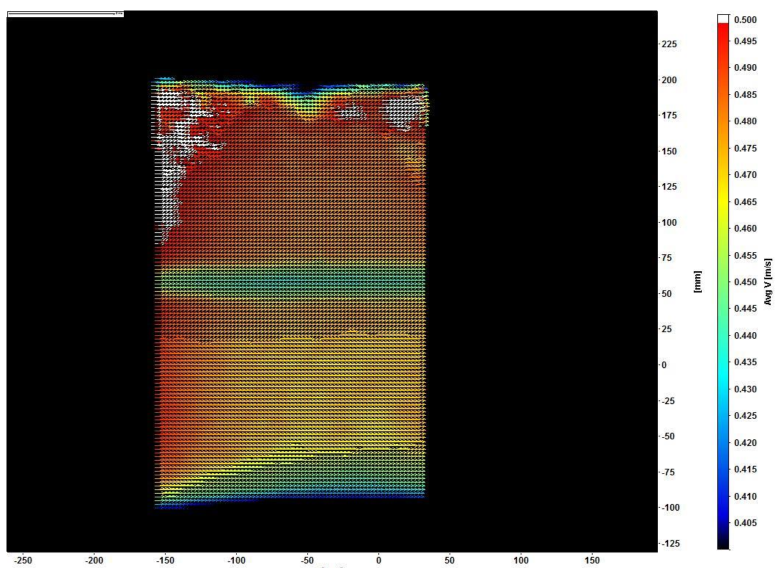


Figure 136 – Bumped Set003 for 65 Hz and 5° AOA

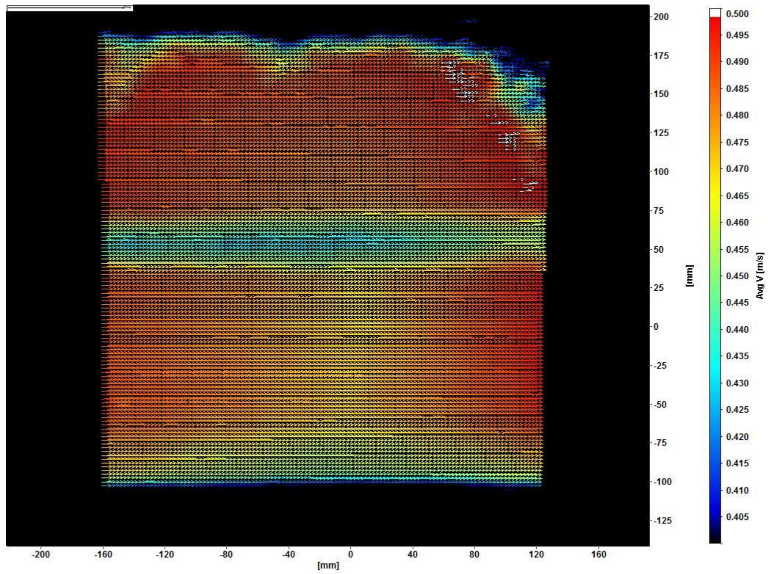


Figure 137 – Smooth Set001 for 65 Hz and 8° AOA

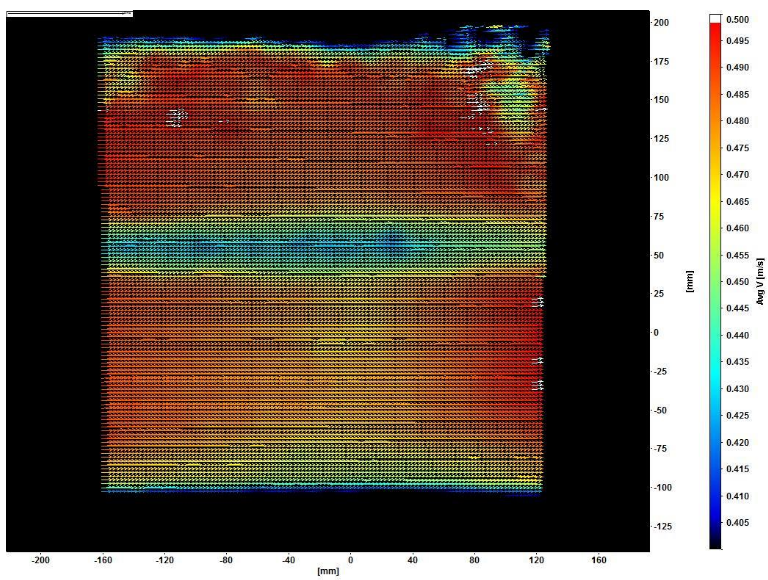


Figure 138 – Smooth Set002 for 65 Hz and 8° AOA

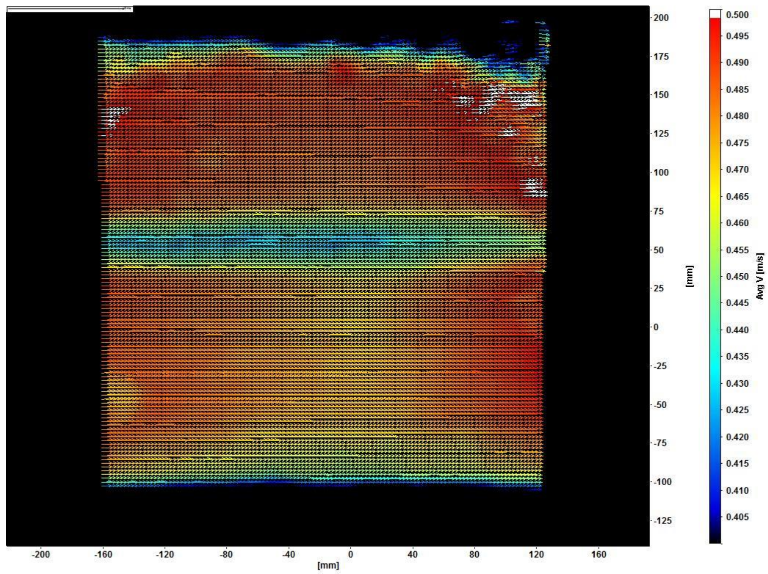


Figure 139 – Smooth Set003 for 65 Hz and 8° AOA

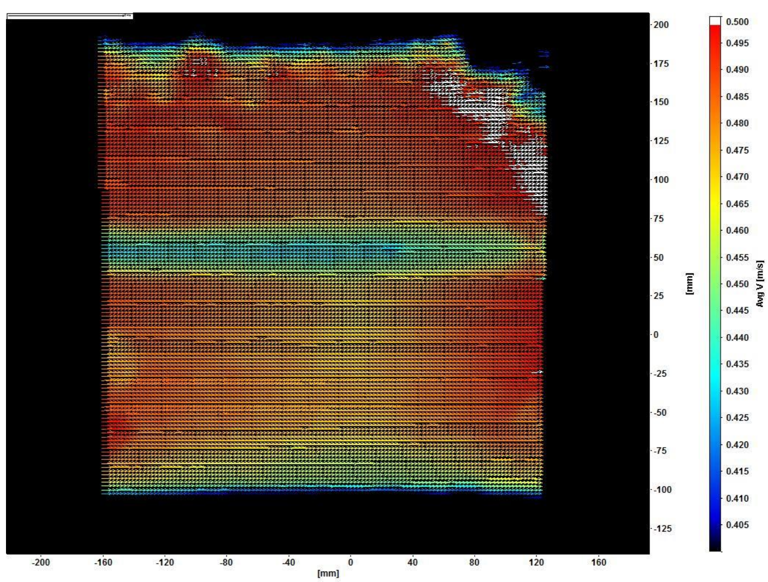


Figure 140 – Bumped Set001 for 65 Hz and 8° AOA

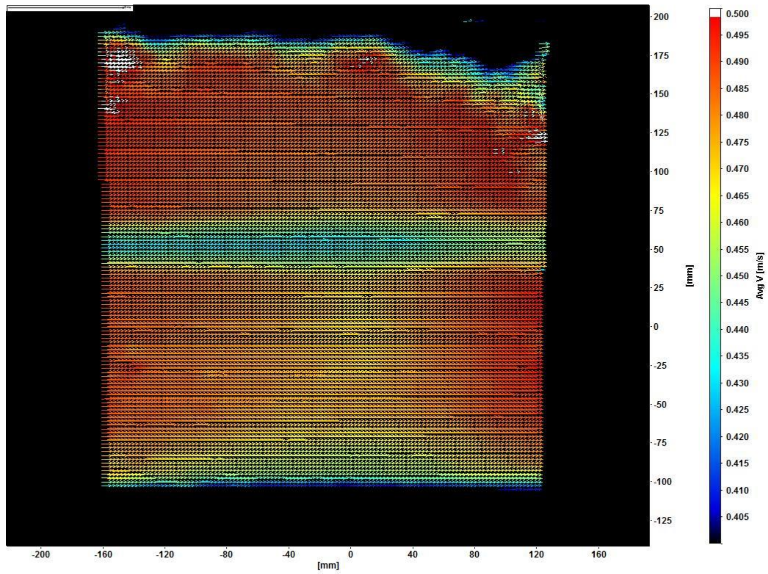


Figure 141 – Bumped Set002 for 65 Hz and 8° AOA

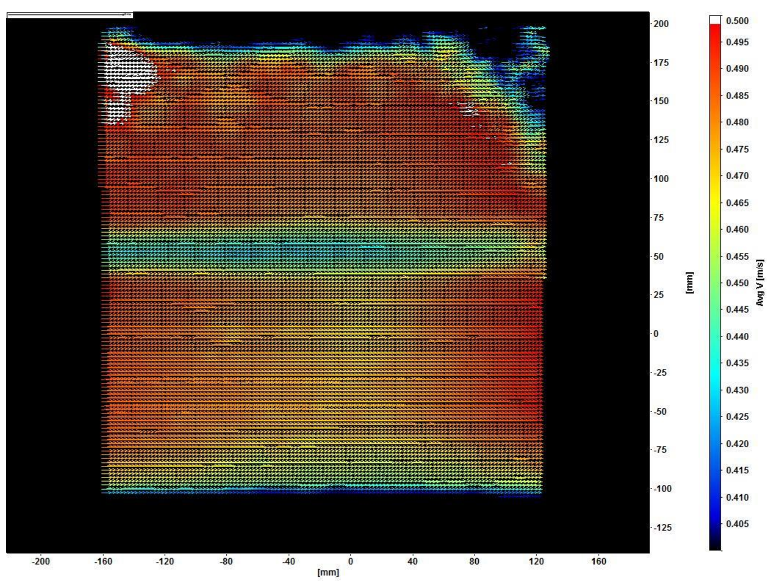


Figure 142 – Bumped Set003 for 65 Hz and 8° AOA

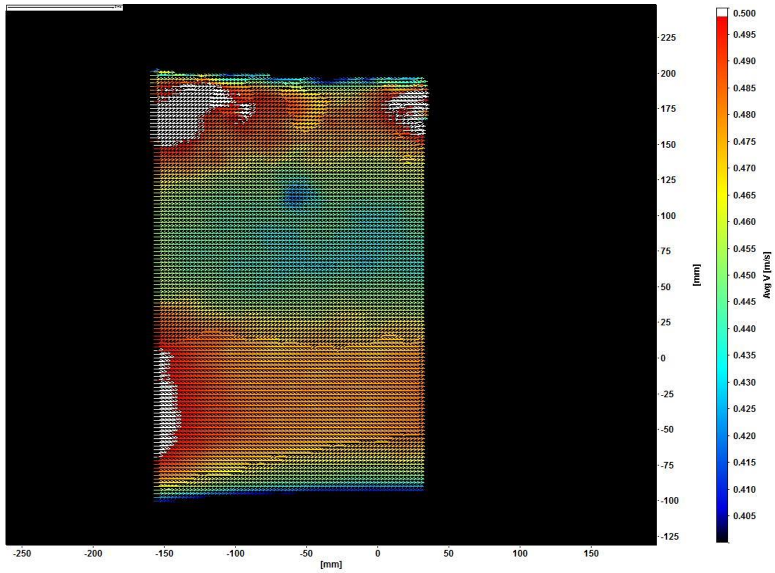


Figure 143 – Smooth Set001 for 65 Hz and 10° AOA

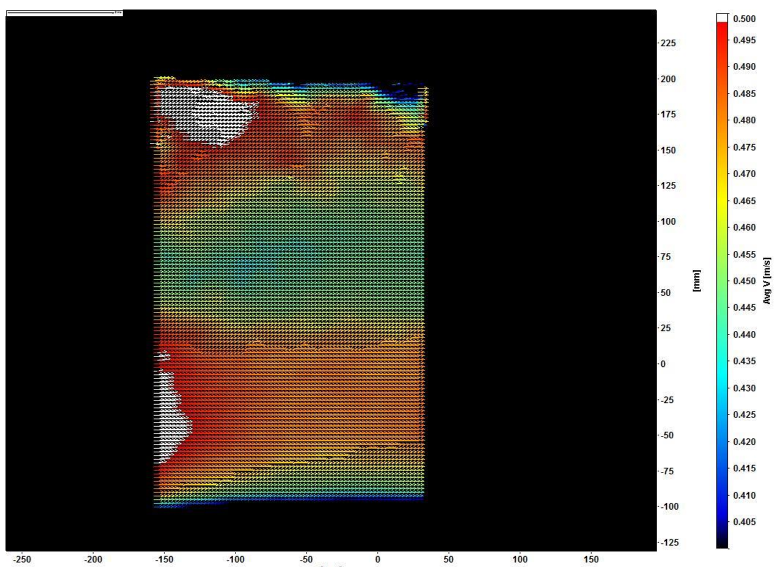


Figure 144– Smooth Set002 for 65 Hz and 10° AOA

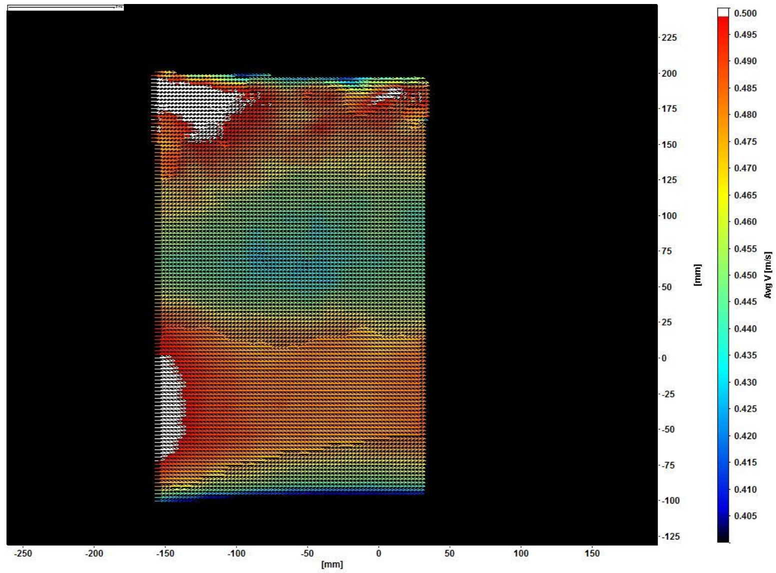


Figure 145 – Smooth Set003 for 65 Hz and 10° AOA

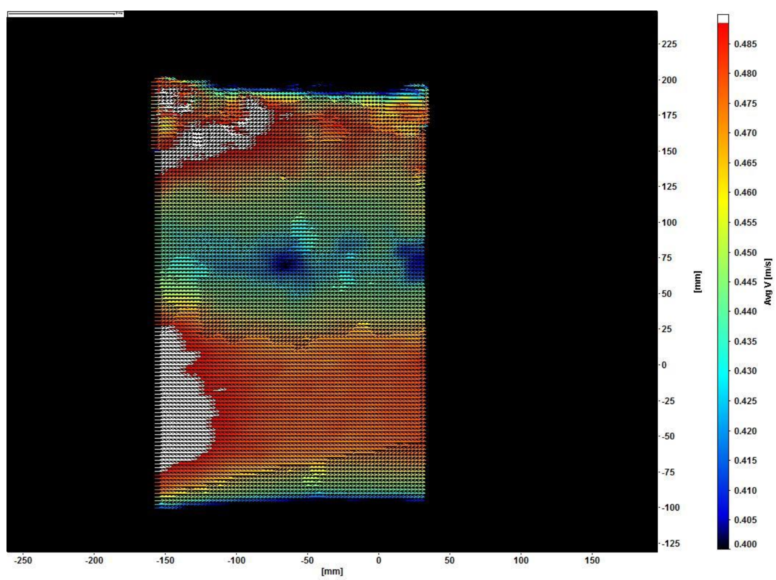


Figure 146 - Bumped Set001 for 65 Hz and 10° AOA

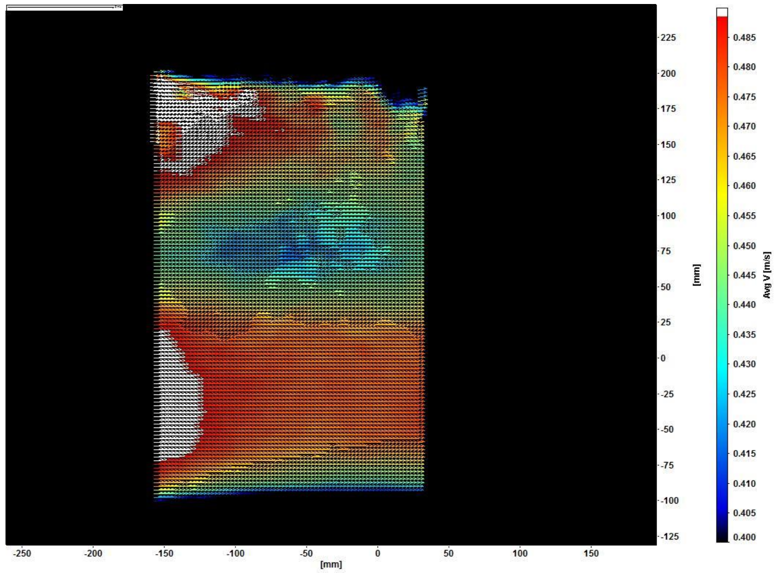


Figure 147 - Bumped Set002 for 65 Hz and 10° AOA

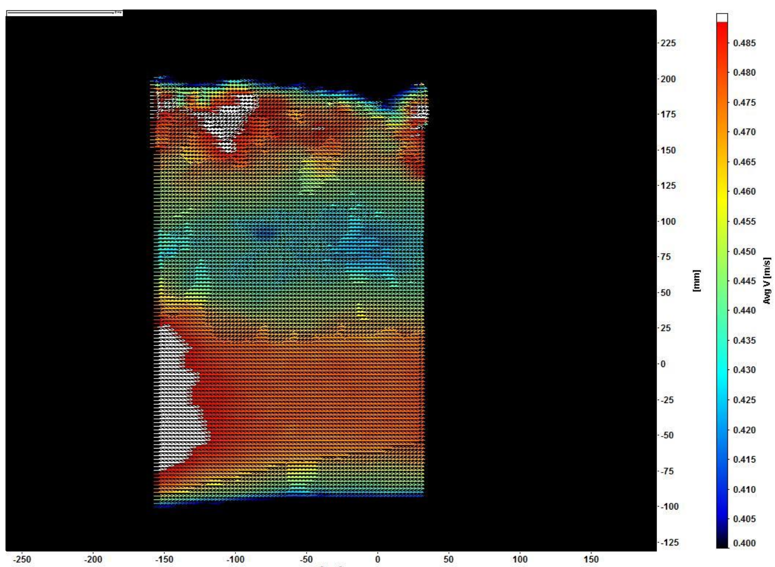


Figure 148 - Bumped Set003 for 65 Hz and 10° AOA

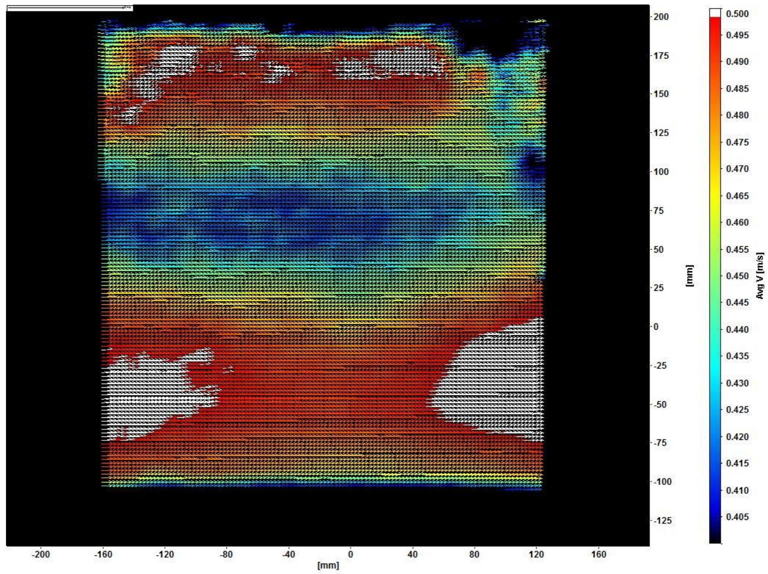


Figure 149 - Smooth Set001 for 65 Hz and 15° AOA

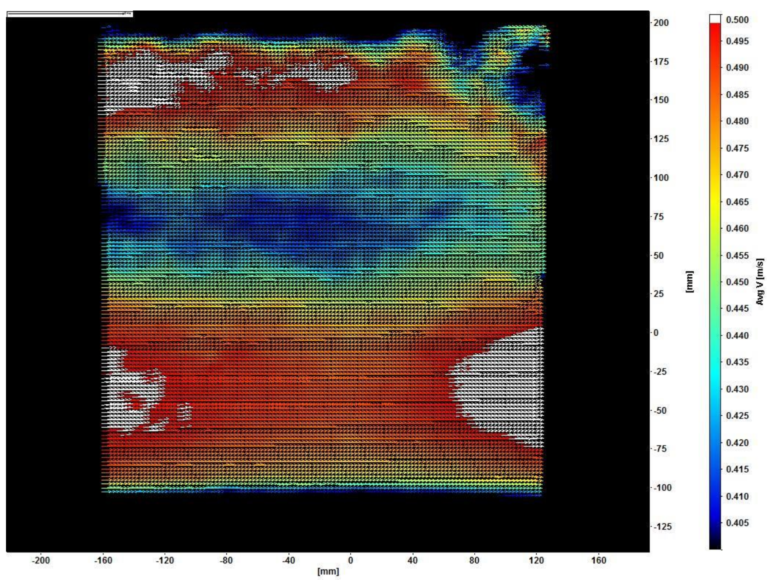


Figure 150 - Smooth Set002 for 65 Hz and 15° AOA

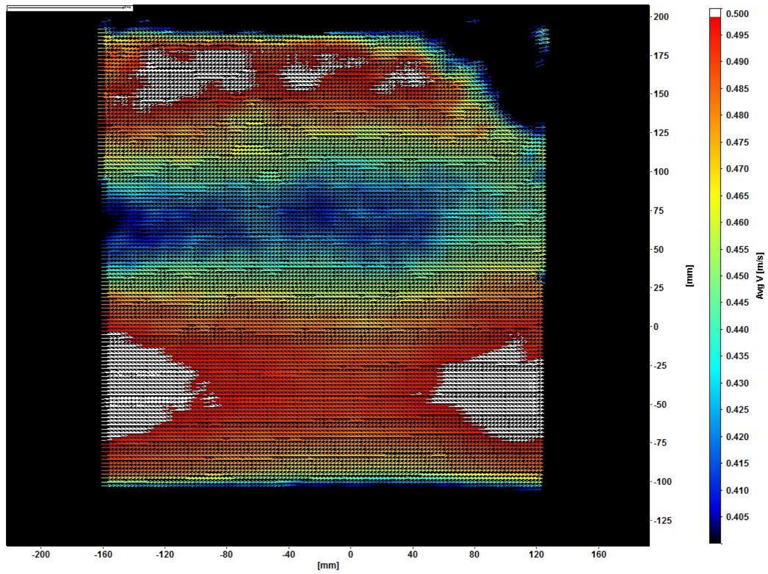


Figure 151 - Smooth Set003 for 65 Hz and 15° AOA

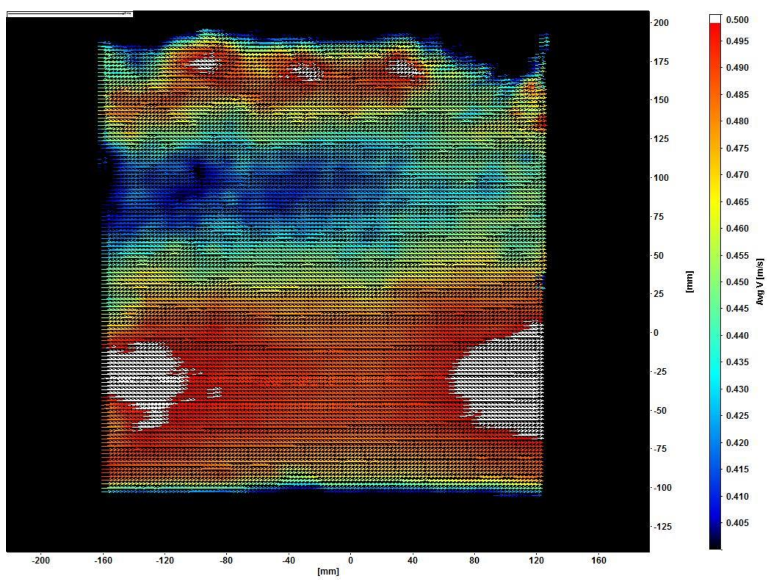


Figure 152 - Bumped Set001 for 65 Hz and 15° AOA

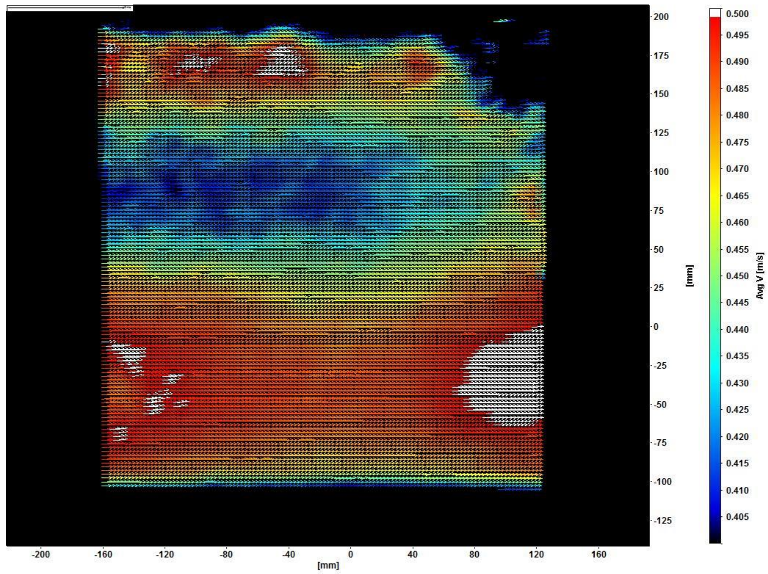


Figure 153 - Bumped Set002 for 65 Hz and 15° AOA

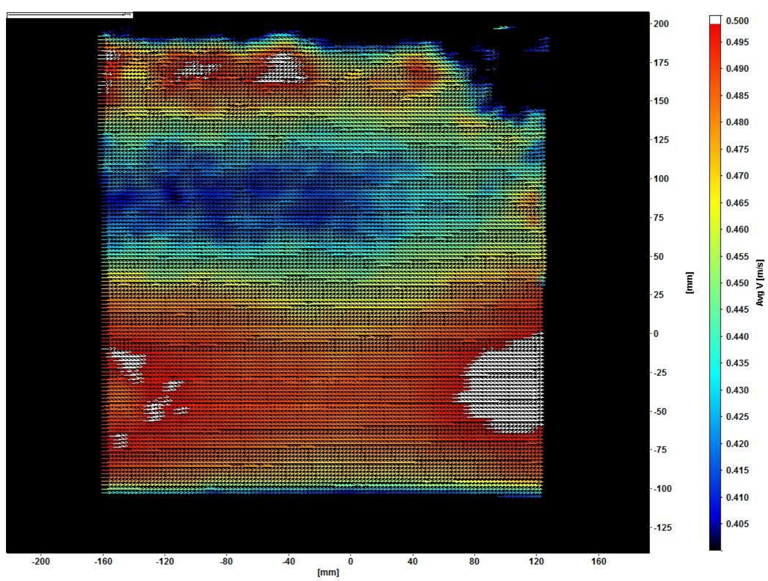


Figure 154 - Bumped Set003 for 65 Hz and 15° AOA

Appendix D: Velocity Profiles

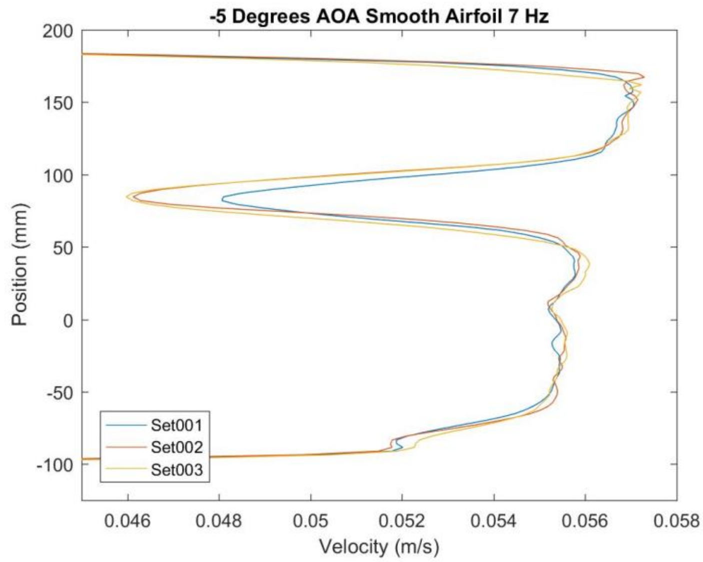


Figure 155– Smooth Airfoil -5° 0.05 m/s

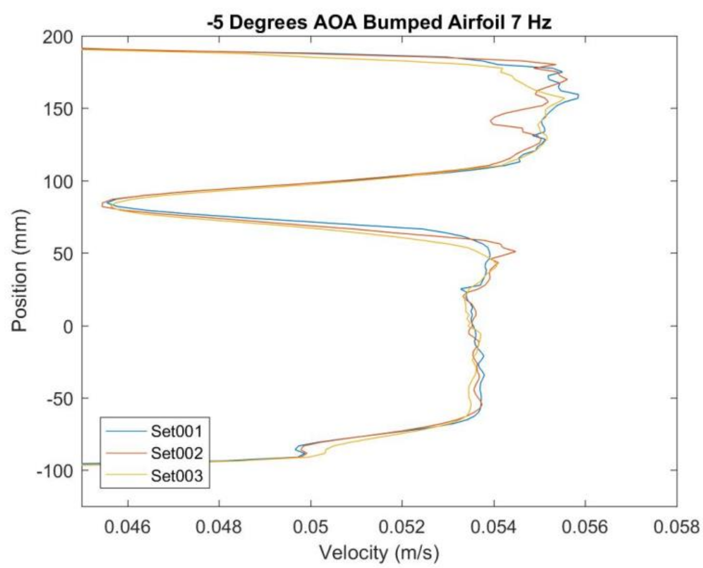


Figure 156 – Bumped Airfoil -5° 0.05 m/s

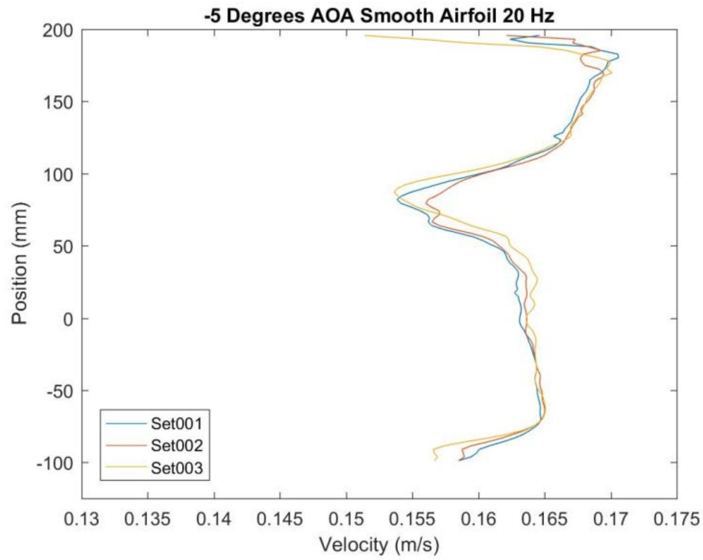


Figure 157– Smooth Airfoil -5° 0.15 m/s

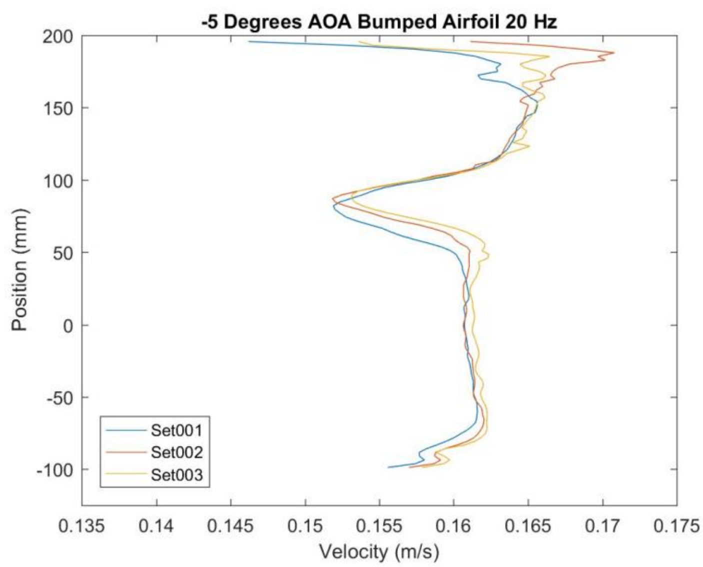


Figure 158 – Bumped Airfoil -5° 0.15 m/s

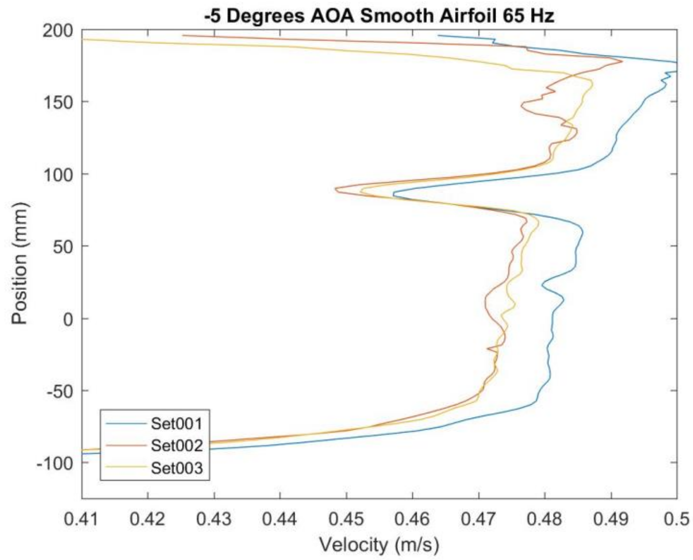


Figure 159– Smooth Airfoil -5° 0.5 m/s

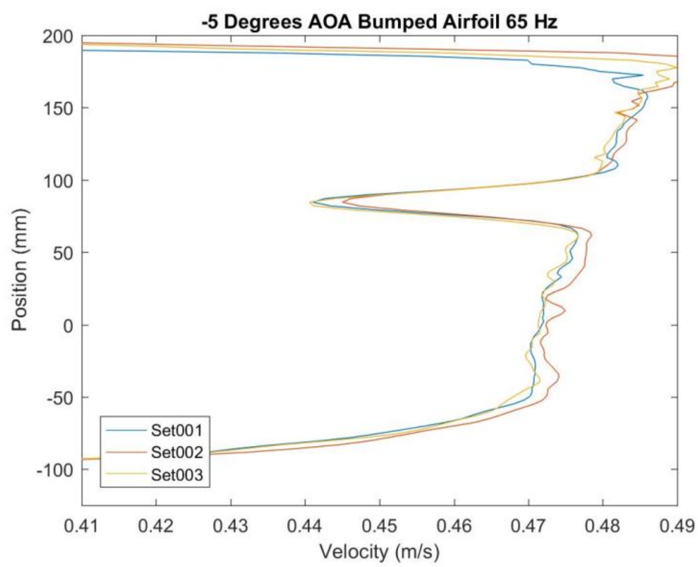


Figure 160 – Bumped Airfoil -5° 0.5 m/s

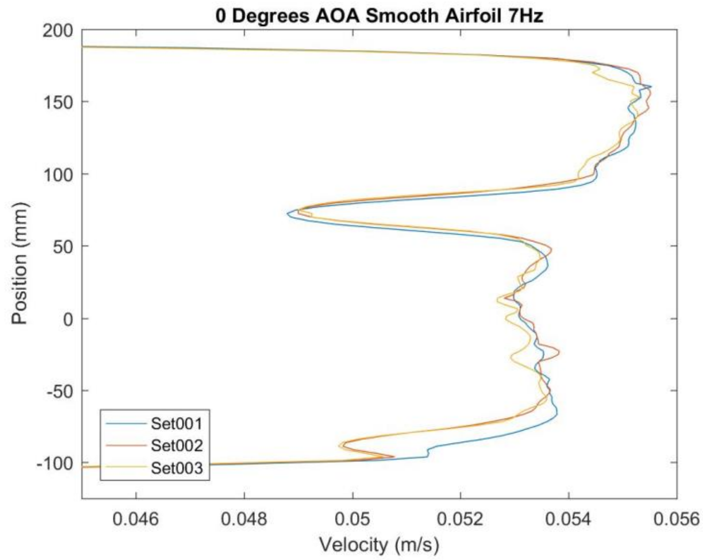


Figure 161 – Smooth Airfoil 0° 0.05 m/s

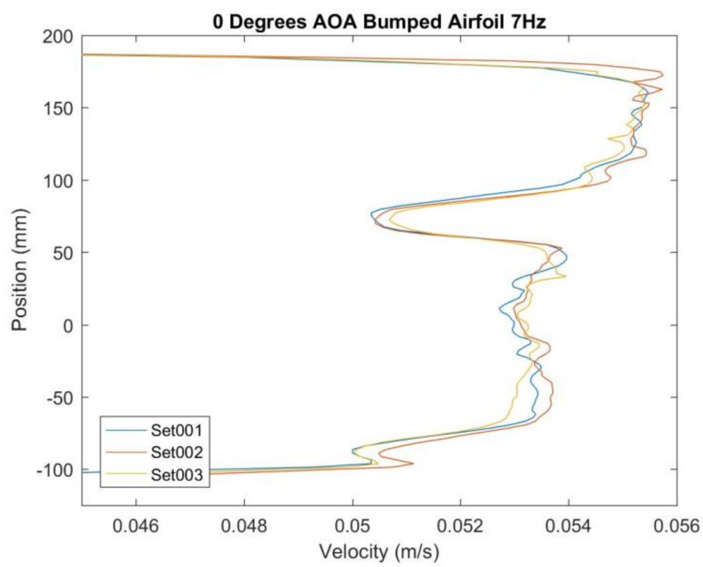


Figure 162 – Bumped Airfoil 0° 0.05 m/s

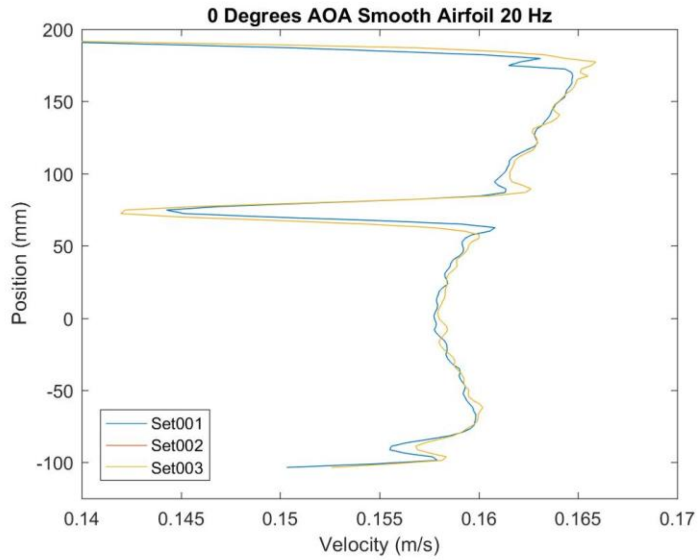


Figure 163 – Smooth Airfoil 0° 0.15 m/s

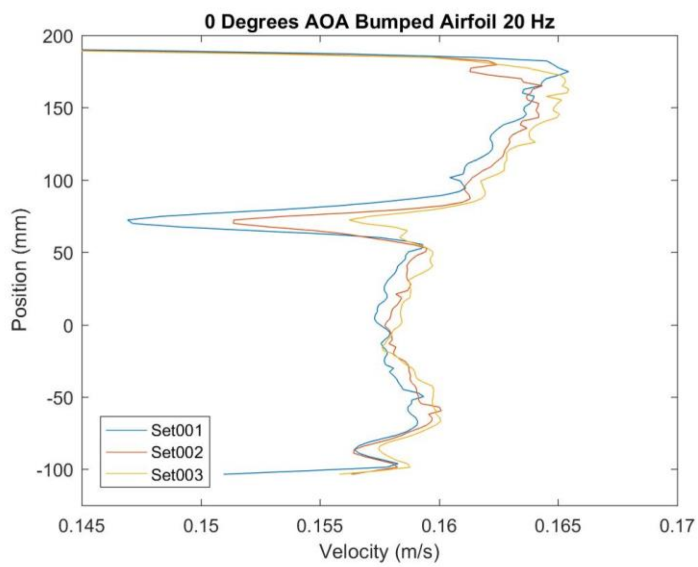


Figure 164 – Smooth Airfoil 0° 0.15 m/s

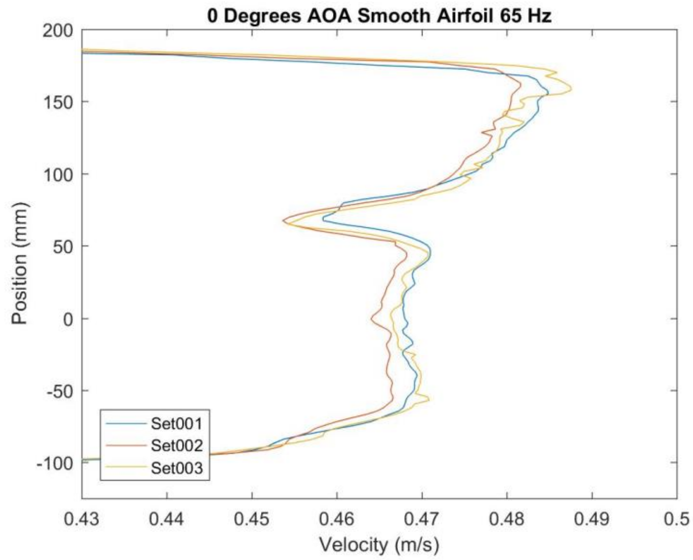


Figure 165 – Smooth Airfoil 0° 0.5 m/s

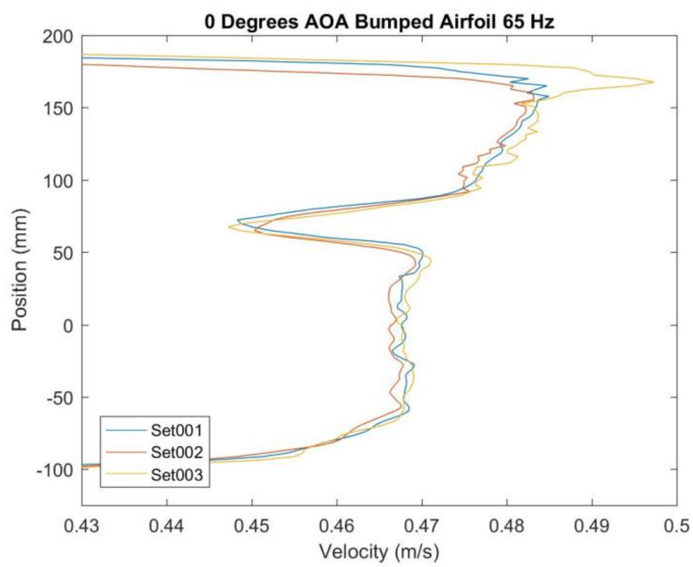


Figure 166 – Bumped Airfoil 0° 0.5 m/s

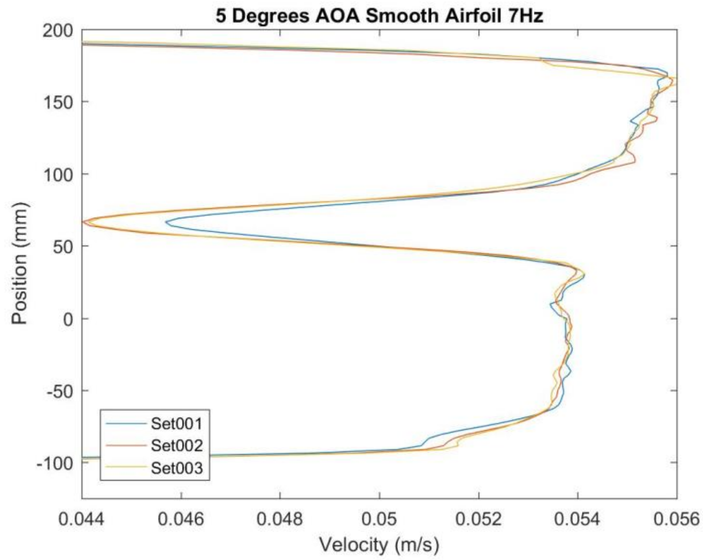


Figure 167 – Smooth Airfoil 5° 0.05 m/s

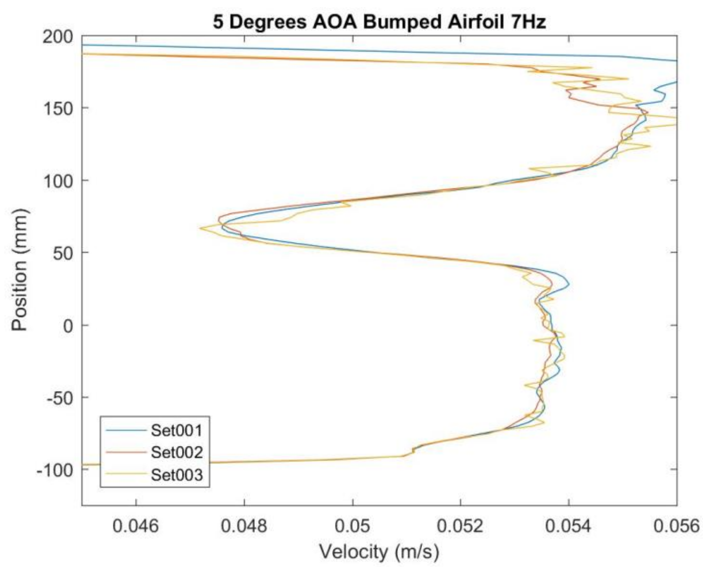


Figure 168 – Bumped Airfoil 5° 0.05 m/s

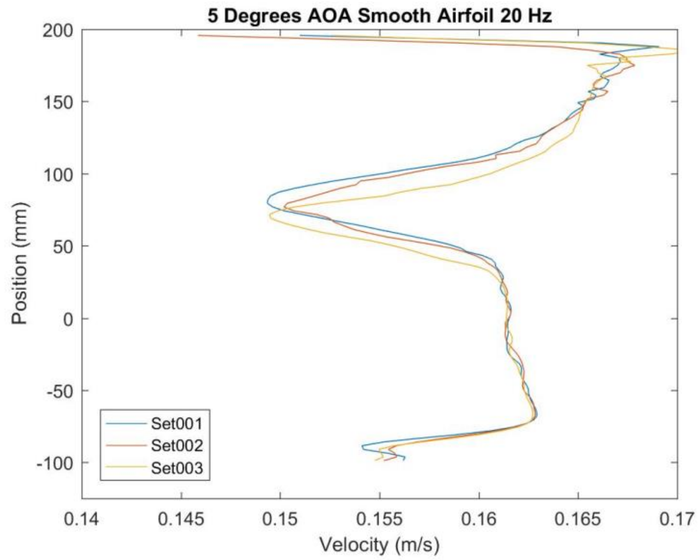


Figure 169 – Smooth Airfoil 5° 0.15 m/s

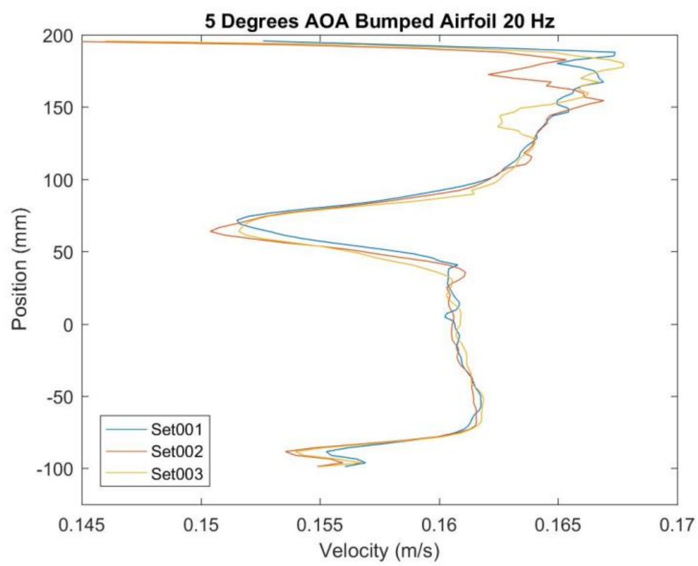


Figure 170 – Smooth Airfoil 5° 0.15 m/s

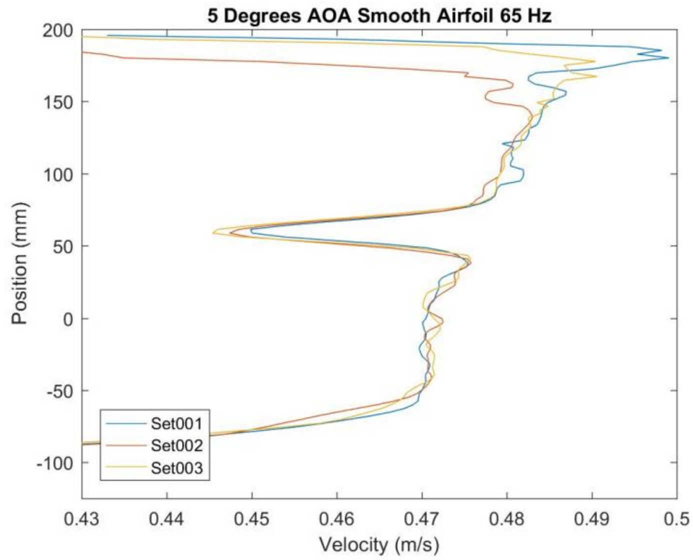


Figure 171 – Smooth Airfoil 5° 0.5 m/s

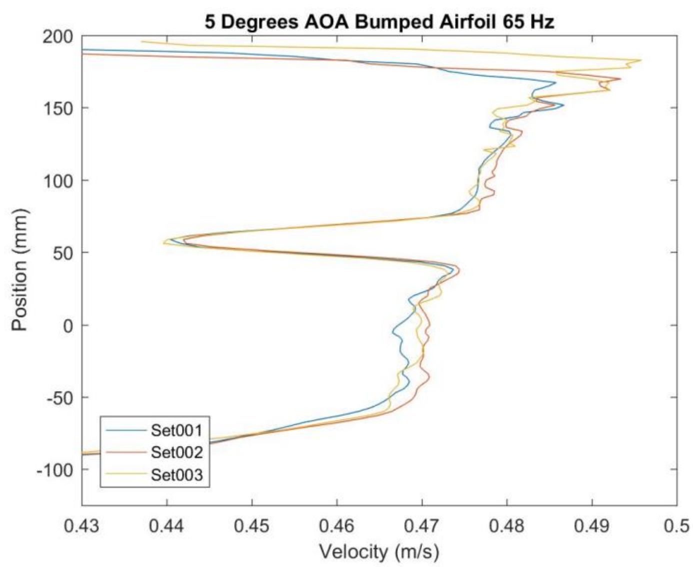


Figure 172 – Bumped Airfoil 5° 0.5 m/s

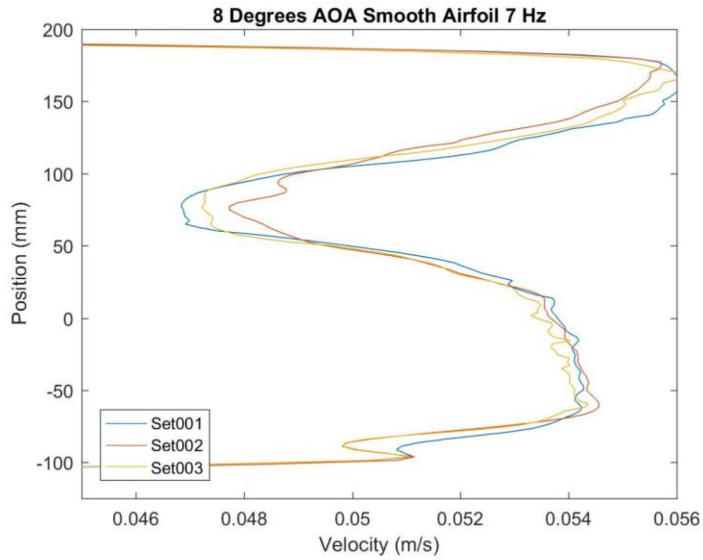


Figure 173 – Smooth Airfoil 8° 0.05 m/s

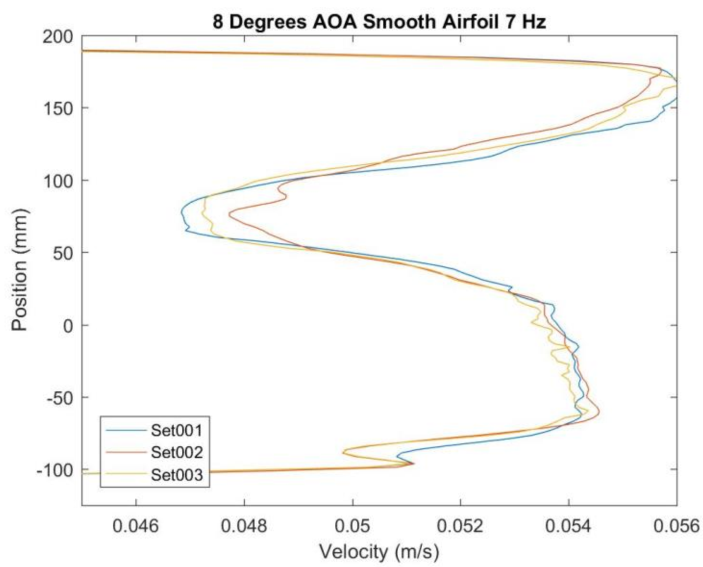


Figure 174 – Bumped Airfoil 8° 0.05 m/s

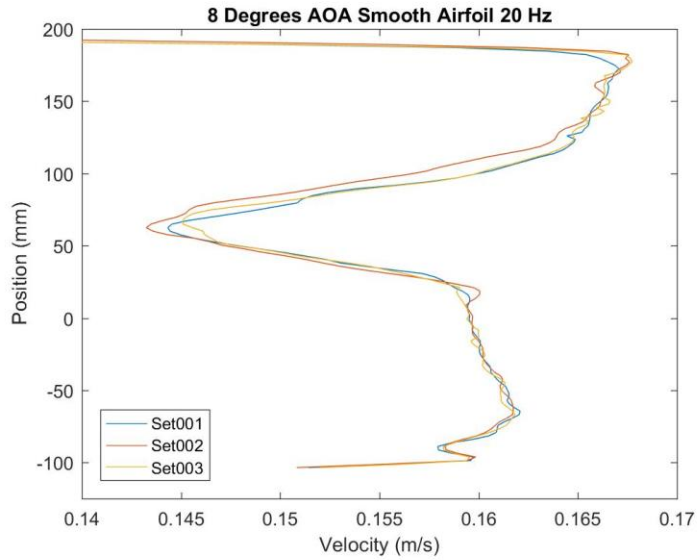


Figure 175 – Smooth Airfoil 8° 0.15 m/s

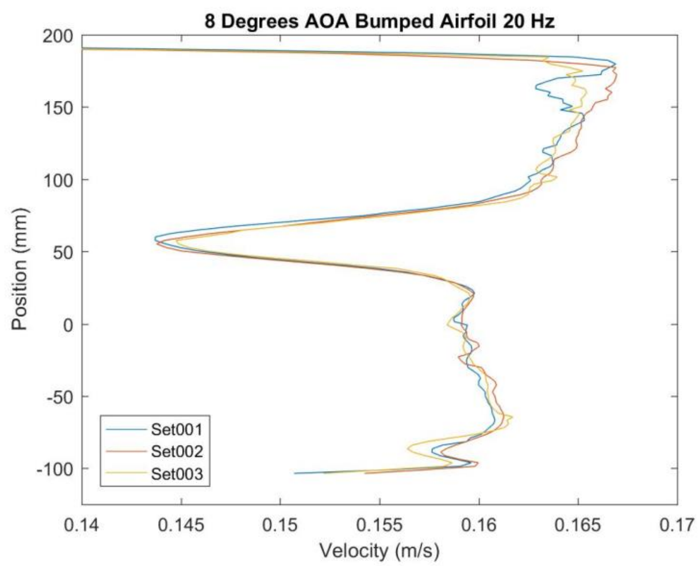


Figure 176 – Bumped Airfoil 8° 0.15 m/s

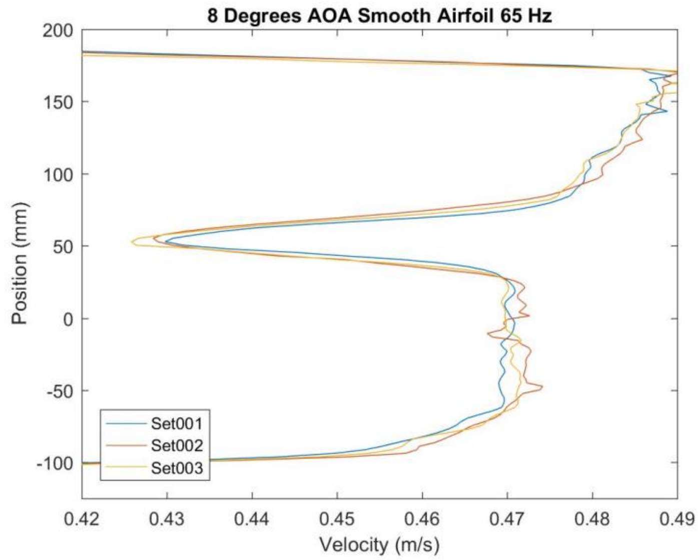


Figure 177 – Smooth Airfoil 8° 0.5 m/s

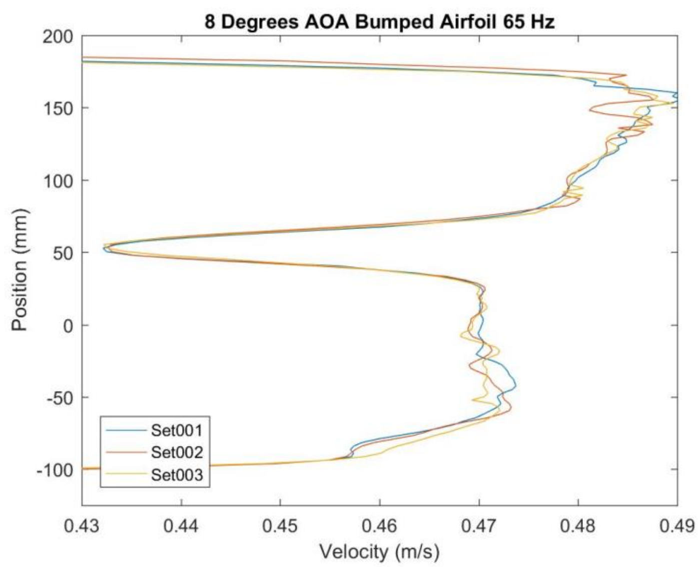


Figure 178– Bumped Airfoil 8° 0.5 m/s

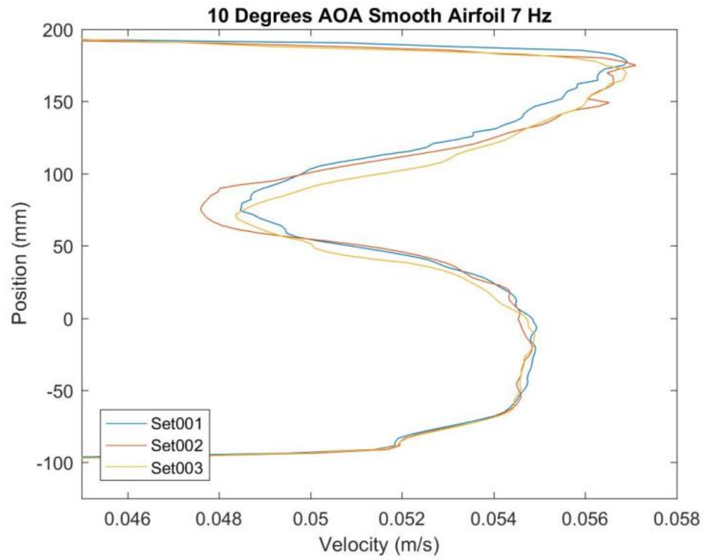


Figure 179 – Smooth Airfoil 10° 0.05 m/s

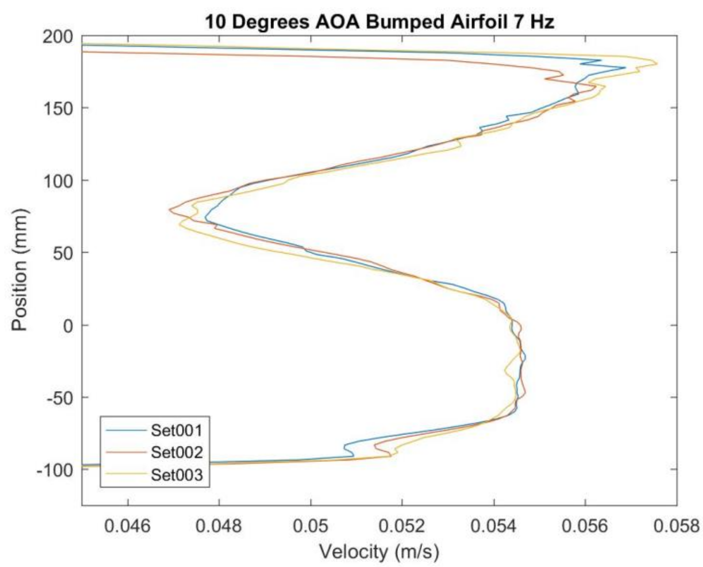


Figure 180 – Bumped Airfoil 10° 0.05 m/s

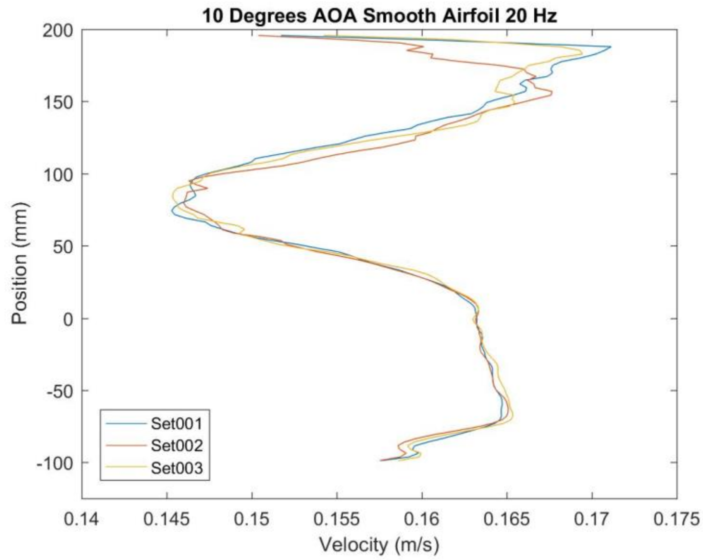


Figure 181 – Smooth Airfoil 10° 0.15 m/s

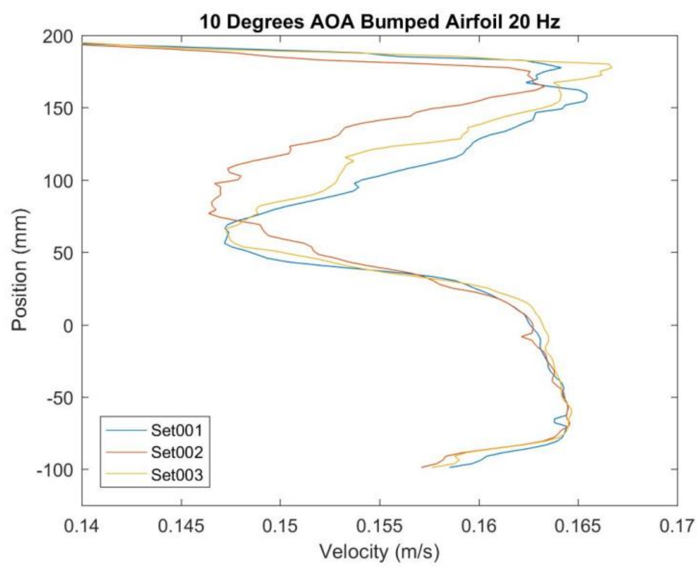


Figure 182 – Bumped Airfoil 10° 0.15 m/s

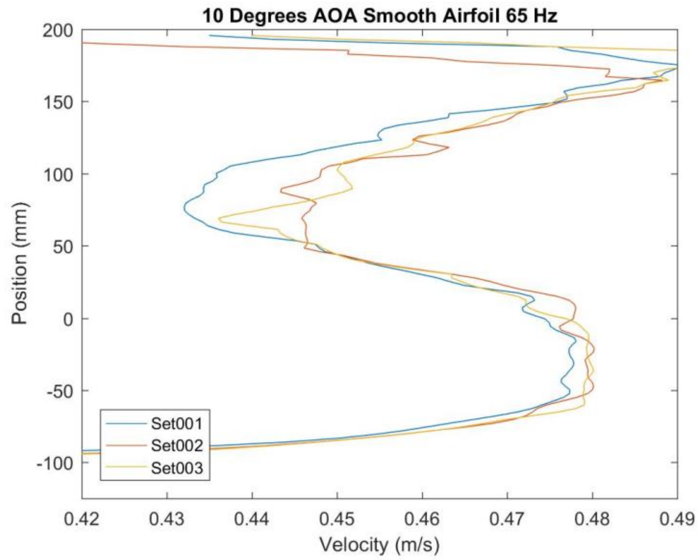


Figure 183 – Smooth Airfoil 10° 0.5 m/s

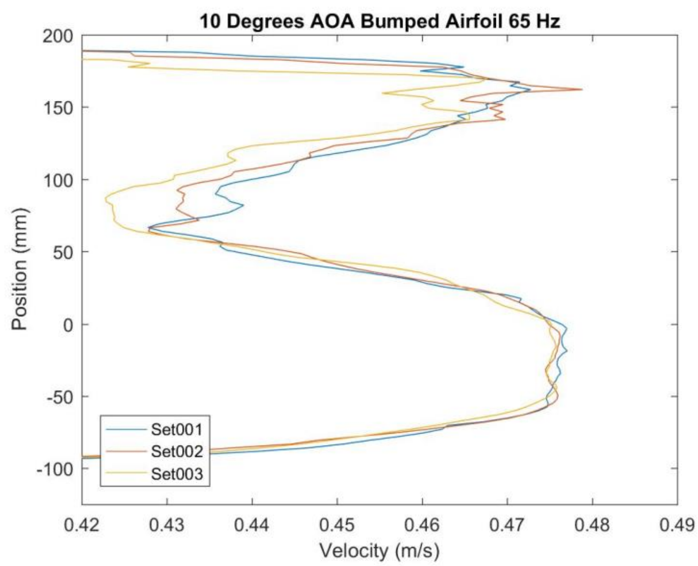


Figure 184 – Bumped Airfoil 10° 0.5 m/s

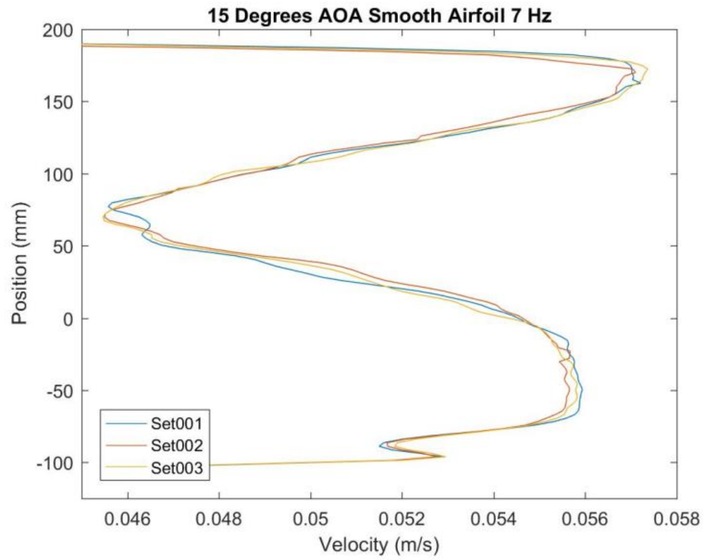


Figure 185 – Smooth Airfoil 15° 0.05 m/s

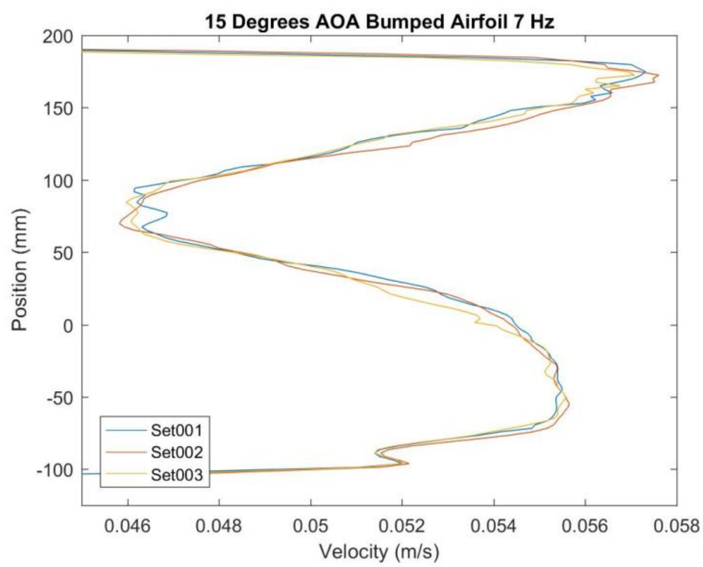


Figure 186 – Bumped Airfoil 15° 0.05 m/s

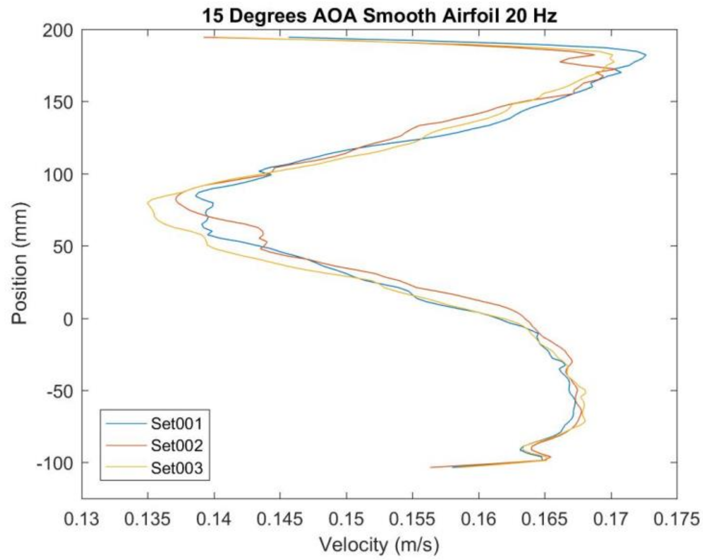


Figure 187 – Smooth Airfoil 15° 0.15 m/s

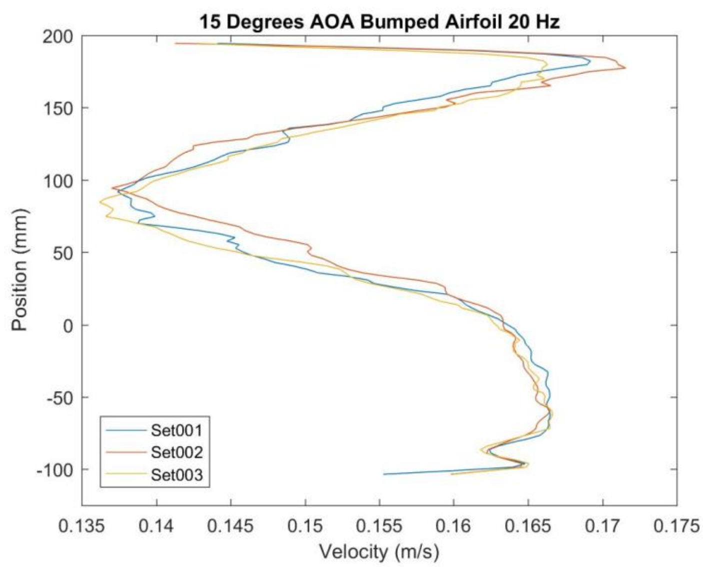


Figure 188 – Bumped Airfoil 15° 0.15 m/s

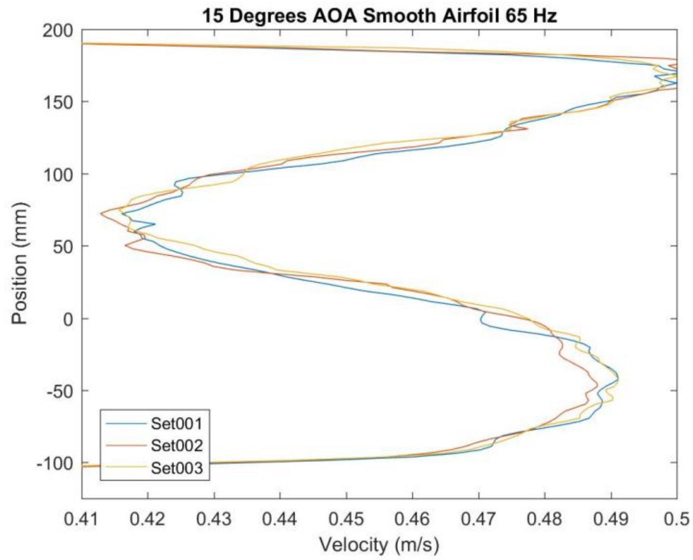


Figure 189 – Smooth Airfoil 15° 0.5 m/s

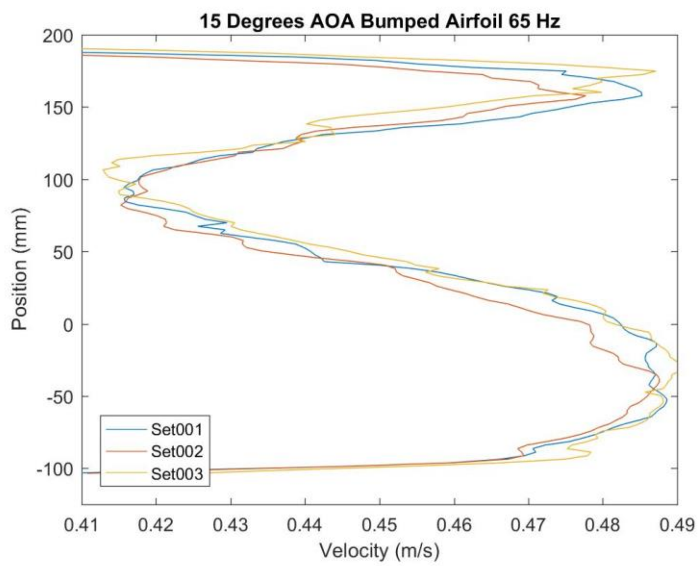


Figure 190 – Bumped Airfoil 15° 0.5 m/s

Appendix E: Profile Velocity Tables

Table 4 - Average PIV velocities smooth airfoil -5° 7 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
195.625	0.0331778	0.0337037	0.0383036
193.042	0.0385864	0.0382741	0.0417363
190.459	0.0434722	0.0418706	0.0454106
187.877	0.0467552	0.0455562	0.0478323
185.294	0.0498637	0.0484348	0.0505416
182.711	0.0520089	0.0507124	0.0518436
180.129	0.0532021	0.05207	0.0532209
177.546	0.0542354	0.0538492	0.053309
174.964	0.0548125	0.0549265	0.0535084
172.381	0.0556239	0.0553312	0.0542742
169.798	0.0558061	0.0555875	0.0550502
167.216	0.0558121	0.0558019	0.0556757
164.633	0.0556217	0.0559222	0.0563881
162.051	0.0556105	0.0558874	0.0560084
159.468	0.0556454	0.0558196	0.055767
156.885	0.0556278	0.0557053	0.0555574
154.303	0.0556069	0.0555612	0.0555017
151.72	0.0555455	0.0554843	0.0555256
149.138	0.0554991	0.0554748	0.0555209
146.555	0.0555438	0.0554763	0.0555359
143.972	0.0553657	0.0554222	0.0554877
141.39	0.0552643	0.0554075	0.0554412
138.807	0.0551582	0.0556091	0.0553791
136.225	0.055058	0.0555772	0.0552673
133.642	0.0552242	0.0553147	0.0552471
131.059	0.0551647	0.0553193	0.0552252
128.477	0.0551508	0.0553086	0.0551255
125.894	0.0551062	0.0552436	0.055064
123.312	0.0550391	0.0550974	0.055034
120.729	0.0550026	0.0549608	0.0550625
118.146	0.0549819	0.0549735	0.0550277
115.564	0.0549366	0.0550021	0.05496
112.981	0.0548754	0.0551205	0.0549042
110.398	0.054766	0.055156	0.0547342
107.816	0.0545952	0.0551562	0.0547354

105.233	0.0543969	0.0548345	0.0545543
102.651	0.0541973	0.054504	0.0542905
100.068	0.0540258	0.0542726	0.0539537
97.4854	0.0538077	0.054124	0.0535958
94.9028	0.0536045	0.0539273	0.0532444
92.3202	0.0533286	0.0536084	0.0528102
89.7376	0.0529191	0.0530238	0.0522737
87.155	0.0522892	0.0521491	0.051557
84.5724	0.0514254	0.0510377	0.0507021
81.9898	0.0505003	0.0497487	0.0496827
79.4072	0.0495003	0.0483589	0.048513
76.8246	0.0485108	0.0470342	0.0472933
74.242	0.0475172	0.0458252	0.0460534
71.6593	0.0466312	0.0448706	0.0450197
69.0767	0.0459605	0.0442576	0.0443749
66.4941	0.0456869	0.0440198	0.0441303
63.9115	0.0457977	0.0441638	0.0443008
61.3289	0.0462128	0.0446813	0.0448006
58.7463	0.0469422	0.045313	0.0455641
56.1637	0.0477736	0.0466088	0.0465598
53.5811	0.0486616	0.0479427	0.0477553
50.9985	0.0495359	0.0492169	0.0489892
48.4159	0.0504456	0.050503	0.0502157
45.8333	0.0513378	0.0516776	0.0513505
43.2507	0.0521656	0.0525756	0.0523616
40.668	0.0528852	0.053173	0.0531081
38.0854	0.0534253	0.0535815	0.0537756
35.5028	0.0538436	0.0538625	0.0539052
32.9202	0.0540652	0.0539791	0.0540677
30.3376	0.0541457	0.0539652	0.0541399
27.755	0.0541136	0.0538763	0.0540263
25.1724	0.0540029	0.0537967	0.05382
22.5898	0.0538543	0.0537443	0.053677
20.0072	0.0537528	0.0536984	0.0536037
17.4246	0.0537019	0.0536516	0.0535455
14.842	0.0537	0.0536092	0.0535476
12.2594	0.0536686	0.0535555	0.0535967
9.67675	0.0534452	0.0535824	0.0536174
7.09415	0.0534807	0.0536654	0.0536408
4.51154	0.0535496	0.0537447	0.0536741
1.92893	0.0536237	0.0538173	0.0536754
-0.653677	0.0537891	0.0538418	0.053726

-3.23629	0.0537565	0.0538486	0.0538056
-5.81889	0.053755	0.0538841	0.0538424
-8.4015	0.0537601	0.0538622	0.0538494
-10.9841	0.0537602	0.0538009	0.0538502
-13.5667	0.0537495	0.0537804	0.0538532
-16.1493	0.0538081	0.0537534	0.0538224
-18.7319	0.0538649	0.0538092	0.0538112
-21.3145	0.0538943	0.0538344	0.0538163
-23.8972	0.0538708	0.0537816	0.0538084
-26.4798	0.0538199	0.0537491	0.0538007
-29.0624	0.053785	0.0537193	0.0537546
-31.645	0.0537599	0.053696	0.0537157
-34.2276	0.0538187	0.0536673	0.053637
-36.8102	0.0538662	0.0536284	0.0535533
-39.3928	0.0538159	0.053631	0.0535066
-41.9754	0.0537192	0.0536666	0.0535391
-44.558	0.0536958	0.0536645	0.0535895
-47.1406	0.0537003	0.0536434	0.0535573
-49.7232	0.0537122	0.0536033	0.0534984
-52.3058	0.0537156	0.0535922	0.0534739
-54.8884	0.0536839	0.0535723	0.0534687
-57.4711	0.0536603	0.0535062	0.0534829
-60.0537	0.0536204	0.0534642	0.0534813
-62.6363	0.0535216	0.0534254	0.0534077
-65.2189	0.0533219	0.053321	0.0532758
-67.8015	0.0530813	0.0531633	0.0531175
-70.3841	0.0527684	0.0529841	0.0529261
-72.9667	0.0524149	0.0527658	0.0527471
-75.5493	0.0520181	0.052466	0.0525275
-78.1319	0.0515911	0.0521102	0.0522299
-80.7145	0.0512459	0.0517697	0.0519331
-83.2971	0.0510029	0.051511	0.0516636
-85.8797	0.0509202	0.0513806	0.0515659
-88.4623	0.0508489	0.0512998	0.0515975
-91.045	0.050386	0.050935	0.0512676
-93.6276	0.0486228	0.0494836	0.0497183
-96.2102	0.0445821	0.0465286	0.0465429
-98.7928	0.0383646	0.0419019	0.0414699

Table 5 - Average velocities smooth airfoil 0° 7 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
194.378	0.0293134	0.0287236	0.0290377
191.937	0.036169	0.0341163	0.0353174
189.495	0.0417882	0.0412321	0.0405593
187.053	0.0470294	0.0462308	0.0459758
184.612	0.0503697	0.0501725	0.0500405
182.17	0.0524018	0.052273	0.0522783
179.728	0.0537666	0.0536846	0.0534128
177.287	0.0542566	0.0544174	0.0541228
174.845	0.0547347	0.0547964	0.0544911
172.404	0.0549519	0.0551118	0.0545828
169.962	0.055087	0.0552732	0.0544368
167.52	0.0551708	0.0553185	0.0545899
165.079	0.0551993	0.0553219	0.0547328
162.637	0.0552369	0.0553256	0.0549858
160.195	0.0555369	0.0554012	0.0552149
157.754	0.0553049	0.0555009	0.0551811
155.312	0.0553272	0.0555147	0.0551722
152.871	0.0553378	0.0554803	0.0553186
150.429	0.0552485	0.0554374	0.0551484
147.987	0.0551416	0.0554501	0.0551655
145.546	0.0550963	0.0554849	0.0552078
143.104	0.0551309	0.0554261	0.0552668
140.663	0.0552091	0.0553131	0.0552825
138.221	0.0552195	0.055232	0.0552493
135.779	0.0552425	0.0552018	0.0551768
133.338	0.0552408	0.0551643	0.0550537
130.896	0.0552299	0.0550949	0.0549683
128.454	0.0552086	0.0550216	0.0549355
126.013	0.0551387	0.0549876	0.0549406
123.571	0.0551081	0.0549684	0.0549576
121.13	0.0551154	0.054948	0.0549153
118.688	0.0550959	0.0549362	0.054826
116.246	0.0550004	0.0548549	0.0547296
113.805	0.0548606	0.0547444	0.0546099
111.363	0.054684	0.0547138	0.0544334
108.922	0.0545753	0.0546176	0.0543398
106.48	0.0545463	0.0545068	0.0543083
104.038	0.0544909	0.0544814	0.0542541
101.597	0.0545171	0.054476	0.0541927

99.1551	0.054525	0.0544562	0.0541743
96.7135	0.0545065	0.0542402	0.0541884
94.2719	0.0544329	0.0539092	0.0541021
91.8302	0.0542234	0.0534678	0.0537475
89.3886	0.0538211	0.052944	0.0530247
86.947	0.0531171	0.0522078	0.0519986
84.5054	0.0521785	0.0512986	0.0509746
82.0638	0.051104	0.0503944	0.0500997
79.6222	0.0501351	0.0496742	0.0495219
77.1805	0.0494151	0.0492309	0.049157
74.7389	0.0489576	0.0490014	0.0489988
72.2973	0.048794	0.0490035	0.049261
69.8557	0.0488637	0.0492531	0.0492365
67.4141	0.0491749	0.0497305	0.0497691
64.9725	0.049665	0.0503908	0.0504859
62.5309	0.0504156	0.05128	0.0513717
60.0892	0.0512538	0.0521123	0.0521862
57.6476	0.0520675	0.052765	0.0527098
55.206	0.0527302	0.053143	0.0530334
52.7644	0.0531277	0.0533743	0.0531709
50.3228	0.0533003	0.0535835	0.0532133
47.8812	0.0533941	0.0536846	0.0533575
45.4395	0.053492	0.053666	0.0534514
42.9979	0.053566	0.0535878	0.0534659
40.5563	0.0535933	0.0534714	0.0534775
38.1147	0.0536098	0.0533746	0.0534086
35.6731	0.0536153	0.0532833	0.0533944
33.2315	0.053574	0.0532267	0.0533729
30.7898	0.0534913	0.0531819	0.0531895
28.3482	0.0534162	0.0531375	0.0530554
25.9066	0.0533271	0.0531459	0.0530795
23.465	0.0531702	0.0532044	0.0531051
21.0234	0.0530668	0.0531759	0.0531464
18.5818	0.0529968	0.0530392	0.0530987
16.1401	0.0529892	0.0529813	0.0528488
13.6985	0.0529823	0.0528084	0.0526825
11.2569	0.0530238	0.0530649	0.0526794
8.8153	0.0531004	0.0531433	0.0528466
6.37368	0.0531079	0.0531024	0.0530617
3.93207	0.0530882	0.0530975	0.0530324
1.49045	0.0530782	0.0531075	0.0528575
-0.951166	0.0531119	0.053194	0.0528337

-3.39278	0.0532032	0.053338	0.052945
-5.8344	0.0532509	0.0533635	0.0530862
-8.27601	0.053319	0.0533564	0.0531773
-10.7176	0.0533989	0.0534023	0.0532549
-13.1592	0.0534185	0.0534166	0.0532982
-15.6009	0.0533937	0.0534398	0.053285
-18.0425	0.0533605	0.0534412	0.053264
-20.4841	0.053422	0.0537062	0.0531955
-22.9257	0.0535328	0.0538273	0.0531005
-25.3673	0.0535398	0.0538104	0.0529558
-27.8089	0.0535242	0.0536707	0.0529252
-30.2506	0.0534499	0.0534418	0.0530012
-32.6922	0.0533886	0.0534623	0.0531477
-35.1338	0.0533727	0.0534773	0.0532894
-37.5754	0.0534367	0.0534911	0.0534171
-40.017	0.0535624	0.0534863	0.0534838
-42.4586	0.0536502	0.0535139	0.0534849
-44.9003	0.0536164	0.0535682	0.0534452
-47.3419	0.0535957	0.0536129	0.0534672
-49.7835	0.0536488	0.0536664	0.0534894
-52.2251	0.0536509	0.0536394	0.0535252
-54.6667	0.0536911	0.0535767	0.0535981
-57.1083	0.0536877	0.0534855	0.0535905
-59.5499	0.0537095	0.053428	0.0535114
-61.9916	0.0537697	0.0533969	0.053321
-64.4332	0.0537825	0.0533236	0.0531643
-66.8748	0.0537877	0.0531594	0.0530595
-69.3164	0.0537159	0.0529114	0.0529694
-71.758	0.0536023	0.0525894	0.0527766
-74.1996	0.0534504	0.0522321	0.0523549
-76.6413	0.053243	0.0517501	0.0518061
-79.0829	0.0530351	0.0511363	0.051147
-81.5245	0.0527666	0.0506058	0.0505453
-83.9661	0.0524181	0.0501773	0.0500918
-86.4077	0.0519727	0.0498784	0.0498147
-88.8493	0.0515625	0.0498268	0.0497447
-91.291	0.0513898	0.0500294	0.0498784
-93.7326	0.0514147	0.0504446	0.0502508
-96.1742	0.0513907	0.050788	0.0505749
-98.6158	0.0504761	0.0500945	0.0498223
-101.057	0.048052	0.0475438	0.0472113
-103.499	0.0453713	0.0449333	0.044402

Table 6 - Average velocities smooth airfoil 5° 7 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
195.625	0.0331778	0.0337037	0.0383036
193.042	0.0385864	0.0382741	0.0417363
190.459	0.0434722	0.0418706	0.0454106
187.877	0.0467552	0.0455562	0.0478323
185.294	0.0498637	0.0484348	0.0505416
182.711	0.0520089	0.0507124	0.0518436
180.129	0.0532021	0.05207	0.0532209
177.546	0.0542354	0.0538492	0.053309
174.964	0.0548125	0.0549265	0.0535084
172.381	0.0556239	0.0553312	0.0542742
169.798	0.0558061	0.0555875	0.0550502
167.216	0.0558121	0.0558019	0.0556757
164.633	0.0556217	0.0559222	0.0563881
162.051	0.0556105	0.0558874	0.0560084
159.468	0.0556454	0.0558196	0.055767
156.885	0.0556278	0.0557053	0.0555574
154.303	0.0556069	0.0555612	0.0555017
151.72	0.0555455	0.0554843	0.0555256
149.138	0.0554991	0.0554748	0.0555209
146.555	0.0555438	0.0554763	0.0555359
143.972	0.0553657	0.0554222	0.0554877
141.39	0.0552643	0.0554075	0.0554412
138.807	0.0551582	0.0556091	0.0553791
136.225	0.055058	0.0555772	0.0552673
133.642	0.0552242	0.0553147	0.0552471
131.059	0.0551647	0.0553193	0.0552252
128.477	0.0551508	0.0553086	0.0551255
125.894	0.0551062	0.0552436	0.055064
123.312	0.0550391	0.0550974	0.055034
120.729	0.0550026	0.0549608	0.0550625
118.146	0.0549819	0.0549735	0.0550277
115.564	0.0549366	0.0550021	0.05496
112.981	0.0548754	0.0551205	0.0549042
110.398	0.054766	0.055156	0.0547342
107.816	0.0545952	0.0551562	0.0547354
105.233	0.0543969	0.0548345	0.0545543

102.651	0.0541973	0.054504	0.0542905
100.068	0.0540258	0.0542726	0.0539537
97.4854	0.0538077	0.054124	0.0535958
94.9028	0.0536045	0.0539273	0.0532444
92.3202	0.0533286	0.0536084	0.0528102
89.7376	0.0529191	0.0530238	0.0522737
87.155	0.0522892	0.0521491	0.051557
84.5724	0.0514254	0.0510377	0.0507021
81.9898	0.0505003	0.0497487	0.0496827
79.4072	0.0495003	0.0483589	0.048513
76.8246	0.0485108	0.0470342	0.0472933
74.242	0.0475172	0.0458252	0.0460534
71.6593	0.0466312	0.0448706	0.0450197
69.0767	0.0459605	0.0442576	0.0443749
66.4941	0.0456869	0.0440198	0.0441303
63.9115	0.0457977	0.0441638	0.0443008
61.3289	0.0462128	0.0446813	0.0448006
58.7463	0.0469422	0.045313	0.0455641
56.1637	0.0477736	0.0466088	0.0465598
53.5811	0.0486616	0.0479427	0.0477553
50.9985	0.0495359	0.0492169	0.0489892
48.4159	0.0504456	0.050503	0.0502157
45.8333	0.0513378	0.0516776	0.0513505
43.2507	0.0521656	0.0525756	0.0523616
40.668	0.0528852	0.053173	0.0531081
38.0854	0.0534253	0.0535815	0.0537756
35.5028	0.0538436	0.0538625	0.0539052
32.9202	0.0540652	0.0539791	0.0540677
30.3376	0.0541457	0.0539652	0.0541399
27.755	0.0541136	0.0538763	0.0540263
25.1724	0.0540029	0.0537967	0.05382
22.5898	0.0538543	0.0537443	0.053677
20.0072	0.0537528	0.0536984	0.0536037
17.4246	0.0537019	0.0536516	0.0535455
14.842	0.0537	0.0536092	0.0535476
12.2594	0.0536686	0.0535555	0.0535967
9.67675	0.0534452	0.0535824	0.0536174
7.09415	0.0534807	0.0536654	0.0536408
4.51154	0.0535496	0.0537447	0.0536741
1.92893	0.0536237	0.0538173	0.0536754
-0.653677	0.0537891	0.0538418	0.053726
-3.23629	0.0537565	0.0538486	0.0538056

-5.81889	0.053755	0.0538841	0.0538424
-8.4015	0.0537601	0.0538622	0.0538494
-10.9841	0.0537602	0.0538009	0.0538502
-13.5667	0.0537495	0.0537804	0.0538532
-16.1493	0.0538081	0.0537534	0.0538224
-18.7319	0.0538649	0.0538092	0.0538112
-21.3145	0.0538943	0.0538344	0.0538163
-23.8972	0.0538708	0.0537816	0.0538084
-26.4798	0.0538199	0.0537491	0.0538007
-29.0624	0.053785	0.0537193	0.0537546
-31.645	0.0537599	0.053696	0.0537157
-34.2276	0.0538187	0.0536673	0.053637
-36.8102	0.0538662	0.0536284	0.0535533
-39.3928	0.0538159	0.053631	0.0535066
-41.9754	0.0537192	0.0536666	0.0535391
-44.558	0.0536958	0.0536645	0.0535895
-47.1406	0.0537003	0.0536434	0.0535573
-49.7232	0.0537122	0.0536033	0.0534984
-52.3058	0.0537156	0.0535922	0.0534739
-54.8884	0.0536839	0.0535723	0.0534687
-57.4711	0.0536603	0.0535062	0.0534829
-60.0537	0.0536204	0.0534642	0.0534813
-62.6363	0.0535216	0.0534254	0.0534077
-65.2189	0.0533219	0.053321	0.0532758
-67.8015	0.0530813	0.0531633	0.0531175
-70.3841	0.0527684	0.0529841	0.0529261
-72.9667	0.0524149	0.0527658	0.0527471
-75.5493	0.0520181	0.052466	0.0525275
-78.1319	0.0515911	0.0521102	0.0522299
-80.7145	0.0512459	0.0517697	0.0519331
-83.2971	0.0510029	0.051511	0.0516636
-85.8797	0.0509202	0.0513806	0.0515659
-88.4623	0.0508489	0.0512998	0.0515975
-91.045	0.050386	0.050935	0.0512676
-93.6276	0.0486228	0.0494836	0.0497183
-96.2102	0.0445821	0.0465286	0.0465429
-98.7928	0.0383646	0.0419019	0.0414699

Table 7 - Average velocities smooth airfoil 8° 7 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)

194.378	0.0321638	0.0326279	0.0299156
191.937	0.0381113	0.0390977	0.0367663
189.495	0.0441049	0.0453556	0.0434016
187.053	0.0493047	0.0494043	0.0482372
184.612	0.0524167	0.0522201	0.0511087
182.17	0.0542235	0.0539941	0.0531272
179.728	0.0552382	0.0552207	0.0544755
177.287	0.0556523	0.0556972	0.0550635
174.845	0.0558121	0.0557161	0.0554199
172.404	0.0558992	0.0556627	0.0556847
169.962	0.0559483	0.0555006	0.0560526
167.52	0.0560151	0.0555126	0.0560386
165.079	0.0560039	0.0554825	0.0559953
162.637	0.0560343	0.0554141	0.0557472
160.195	0.0560583	0.0553404	0.0557083
157.754	0.0560265	0.0552677	0.0556639
155.312	0.055958	0.0551424	0.055365
152.871	0.0558663	0.0550456	0.0551795
150.429	0.0557391	0.0549237	0.0550059
147.987	0.0557757	0.0547259	0.0550579
145.546	0.0556834	0.0544991	0.0549787
143.104	0.0556277	0.0543246	0.054868
140.663	0.0555189	0.0541834	0.0546867
138.221	0.0550596	0.0540368	0.0545203
135.779	0.0549142	0.0537774	0.0544005
133.338	0.0544973	0.0534425	0.05419
130.896	0.0540462	0.053061	0.0538708
128.454	0.0537947	0.052667	0.0535404
126.013	0.0534923	0.052356	0.0531714
123.571	0.0531071	0.0520497	0.0527796
121.13	0.0529051	0.0518649	0.0524046
118.688	0.0527545	0.0513036	0.0520022
116.246	0.0525612	0.050919	0.0515644
113.805	0.0522083	0.0506834	0.0510288
111.363	0.0517199	0.0505032	0.0503966
108.922	0.0511284	0.0502421	0.0498781
106.48	0.0504054	0.0499862	0.049363
104.038	0.0496895	0.0496134	0.0489015
101.597	0.0491146	0.0492021	0.0485402
99.1551	0.0486767	0.0488704	0.0482265
96.7135	0.0483371	0.0486925	0.0480459
94.2719	0.0480211	0.0486239	0.0478853

91.8302	0.0477014	0.0486579	0.04764
89.3886	0.0474135	0.0487845	0.047392
86.947	0.0471693	0.0487698	0.0472741
84.5054	0.0470176	0.048549	0.0472823
82.0638	0.0469189	0.0481995	0.0472672
79.6222	0.0468613	0.0478723	0.0472849
77.1805	0.0468432	0.047731	0.0472177
74.7389	0.0468817	0.0477361	0.047263
72.2973	0.0468957	0.0478692	0.0473478
69.8557	0.0469213	0.0479957	0.0474225
67.4141	0.0469962	0.0481966	0.0474104
64.9725	0.0469174	0.0483543	0.0473868
62.5309	0.0471793	0.0484663	0.0474496
60.0892	0.04755	0.0486243	0.0476368
57.6476	0.0482641	0.048791	0.0478641
55.206	0.0488269	0.0489804	0.0483109
52.7644	0.0493548	0.0491796	0.0488135
50.3228	0.0498613	0.0494754	0.0495742
47.8812	0.0503413	0.0498692	0.0500225
45.4395	0.0508228	0.0503152	0.0504852
42.9979	0.0512321	0.050744	0.0508557
40.5563	0.0516055	0.0511097	0.0511278
38.1147	0.0518939	0.0513602	0.0514231
35.6731	0.0520514	0.0515882	0.0516376
33.2315	0.0522402	0.0518086	0.0517566
30.7898	0.052419	0.0519862	0.0519023
28.3482	0.052691	0.0522685	0.0521706
25.9066	0.0529616	0.0525243	0.0525017
23.465	0.052883	0.0527458	0.0527815
21.0234	0.0529753	0.0530513	0.0529555
18.5818	0.0531698	0.0532966	0.0530339
16.1401	0.0533839	0.053457	0.053071
13.6985	0.0537095	0.0535537	0.0532133
11.2569	0.0537432	0.0535554	0.0534275
8.8153	0.0537304	0.0535507	0.053492
6.37368	0.0536778	0.0535555	0.0534329
3.93207	0.0537	0.0536036	0.0534322
1.49045	0.053766	0.0536218	0.0533047
-0.951166	0.0538131	0.0536935	0.0534669
-3.39278	0.0538647	0.0537764	0.0536848
-5.8344	0.0539244	0.0538559	0.0536978
-8.27601	0.0539406	0.0539333	0.0536243

-10.7176	0.0540191	0.0539302	0.0536384
-13.1592	0.0541448	0.05393	0.0537287
-15.6009	0.0541888	0.0539696	0.0540296
-18.0425	0.0541333	0.0540108	0.0536975
-20.4841	0.0540603	0.0540804	0.053674
-22.9257	0.0540855	0.0541509	0.0537577
-25.3673	0.0541221	0.0541625	0.0537913
-27.8089	0.0541119	0.0541766	0.0540181
-30.2506	0.0541053	0.0541665	0.0539779
-32.6922	0.0541314	0.0542032	0.0540153
-35.1338	0.0541863	0.054234	0.0538679
-37.5754	0.0542235	0.054264	0.0539796
-40.017	0.054198	0.054324	0.0540295
-42.4586	0.0541927	0.0543477	0.0540206
-44.9003	0.0542307	0.0543752	0.0540202
-47.3419	0.0542769	0.0543489	0.0540734
-49.7835	0.0542778	0.0543301	0.0541162
-52.2251	0.0541734	0.0543884	0.0540986
-54.6667	0.0541254	0.0544591	0.054121
-57.1083	0.0541169	0.0545254	0.0541854
-59.5499	0.0541935	0.0545631	0.054366
-61.9916	0.0542454	0.0545506	0.0542838
-64.4332	0.0542091	0.0544594	0.0539298
-66.8748	0.0540884	0.0542818	0.0537924
-69.3164	0.0539133	0.0539584	0.0536408
-71.758	0.0537651	0.0535032	0.0534396
-74.1996	0.0535734	0.0529446	0.0530966
-76.6413	0.0533125	0.0523125	0.0525226
-79.0829	0.0528683	0.0515811	0.0517526
-81.5245	0.0522942	0.0509152	0.0509099
-83.9661	0.0517204	0.0503192	0.0502375
-86.4077	0.0512158	0.0499017	0.049879
-88.8493	0.0509077	0.0498208	0.0498402
-91.291	0.0508195	0.0500643	0.0501164
-93.7326	0.0509715	0.050611	0.0506472
-96.1742	0.0511424	0.0511575	0.0510659
-98.6158	0.0502863	0.050821	0.0502893
-101.057	0.0476623	0.0486233	0.0475894
-103.499	0.0445604	0.0460041	0.0443172

Table 8 - Average velocities smooth airfoil 10° 7 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
195.625	0.0403249	0.0403855	0.0407977
193.042	0.044324	0.0428817	0.0449076
190.459	0.0508383	0.0477355	0.0473783
187.877	0.0531591	0.0506861	0.0492434
185.294	0.0559381	0.0530903	0.0521786
182.711	0.056574	0.054212	0.0546711
180.129	0.0568134	0.0563874	0.0557094
177.546	0.0569182	0.0568225	0.0562367
174.964	0.056838	0.0571074	0.0564367
172.381	0.0564253	0.0567433	0.056818
169.798	0.0563083	0.0564736	0.0569026
167.216	0.0562611	0.0566142	0.0568581
164.633	0.0562771	0.0566109	0.05682
162.051	0.0558326	0.0566198	0.0565314
159.468	0.0558208	0.0564931	0.0564585
156.885	0.0556065	0.0562821	0.0563273
154.303	0.0555455	0.0561306	0.0561446
151.72	0.0554844	0.0560437	0.0560475
149.138	0.055204	0.0565261	0.0560127
146.555	0.0548987	0.056292	0.0559388
143.972	0.0547618	0.0557723	0.0557611
141.39	0.0546614	0.0554964	0.0554941
138.807	0.0546208	0.0553845	0.0552809
136.225	0.0544691	0.0552361	0.0551009
133.642	0.0542252	0.0550386	0.0549028
131.059	0.054044	0.0546734	0.0547006
128.477	0.0535527	0.0543469	0.0545543
125.894	0.053551	0.0541117	0.0544157
123.312	0.0531533	0.0538586	0.0542501
120.729	0.0526725	0.0535925	0.0539982
118.146	0.0525358	0.0532139	0.0536979
115.564	0.0521765	0.0527533	0.0533956
112.981	0.0515813	0.052264	0.0531766
110.398	0.0511285	0.0517554	0.0530433
107.816	0.0506205	0.0512437	0.0528645
105.233	0.0501994	0.0507537	0.0525383
102.651	0.0499586	0.050299	0.0520776
100.068	0.0498322	0.0499071	0.0515763

97.4854	0.049634	0.0495507	0.0510611
94.9028	0.0494484	0.0491901	0.0505972
92.3202	0.0492204	0.0484837	0.0501982
89.7376	0.0489634	0.0480214	0.0499168
87.155	0.0487664	0.0479709	0.0496682
84.5724	0.0486935	0.047815	0.0494117
81.9898	0.0486991	0.0477494	0.0491167
79.4072	0.0485013	0.0476679	0.0488492
76.8246	0.0484923	0.0476116	0.0486666
74.242	0.048463	0.0476058	0.0485093
71.6593	0.0487399	0.0476733	0.0483683
69.0767	0.0488897	0.0477455	0.0483875
66.4941	0.0491237	0.0478805	0.0485445
63.9115	0.049358	0.0480742	0.0487311
61.3289	0.0494513	0.0484074	0.0489352
58.7463	0.049473	0.0488885	0.0491521
56.1637	0.0496887	0.0495344	0.0494287
53.5811	0.0501257	0.050274	0.0498229
50.9985	0.0506512	0.0509591	0.0500329
48.4159	0.0511669	0.0515147	0.0500869
45.8333	0.051664	0.0519791	0.0503472
43.2507	0.0521199	0.0523715	0.050775
40.668	0.052532	0.0526873	0.0513866
38.0854	0.0527541	0.0529571	0.0521453
35.5028	0.0529509	0.0531581	0.0525673
32.9202	0.0532422	0.0532886	0.0528894
30.3376	0.053553	0.0534059	0.0531386
27.755	0.0537884	0.0535447	0.0533261
25.1724	0.0539505	0.0538082	0.0534708
22.5898	0.0540728	0.054129	0.0536222
20.0072	0.0542148	0.0543113	0.053775
17.4246	0.0543645	0.0543576	0.0538974
14.842	0.0544562	0.0543314	0.0539885
12.2594	0.0545006	0.0543418	0.0540684
9.67675	0.0544754	0.0544191	0.0541665
7.09415	0.0544996	0.0545075	0.0543346
4.51154	0.0546217	0.0545755	0.0544921
1.92893	0.0547589	0.0545669	0.0546428
-0.653677	0.054849	0.0545353	0.054728
-3.23629	0.054879	0.0545692	0.0547569
-5.81889	0.0549377	0.0546048	0.0547546
-8.4015	0.0549261	0.0546292	0.0548153

-10.9841	0.0548516	0.0546762	0.0548992
-13.5667	0.0548074	0.0547184	0.0548812
-16.1493	0.0548107	0.0547828	0.0548751
-18.7319	0.0548891	0.0548332	0.0548623
-21.3145	0.0549145	0.0548415	0.0548364
-23.8972	0.0549	0.0548215	0.0547785
-26.4798	0.0548745	0.0547643	0.054691
-29.0624	0.0548485	0.054683	0.0546587
-31.645	0.0548358	0.0546541	0.0546688
-34.2276	0.0548235	0.0546263	0.054639
-36.8102	0.0547839	0.0546028	0.0546133
-39.3928	0.0547487	0.054599	0.0545983
-41.9754	0.054731	0.0545564	0.0545793
-44.558	0.0547458	0.0545114	0.054572
-47.1406	0.0547207	0.0545064	0.0545785
-49.7232	0.0546679	0.0545435	0.0545995
-52.3058	0.0545921	0.0545849	0.054544
-54.8884	0.0545448	0.0545992	0.0544847
-57.4711	0.05449	0.0545478	0.0544429
-60.0537	0.0544153	0.0544967	0.0544478
-62.6363	0.0543362	0.0543919	0.0544367
-65.2189	0.0542269	0.0542501	0.0543255
-67.8015	0.0540302	0.0540656	0.0541062
-70.3841	0.0537056	0.0538145	0.0538262
-72.9667	0.0533405	0.0535036	0.0535045
-75.5493	0.0529394	0.0530801	0.0531443
-78.1319	0.0525374	0.0526767	0.052764
-80.7145	0.0521873	0.052329	0.0523898
-83.2971	0.0519139	0.0520582	0.0520972
-85.8797	0.0518502	0.0519511	0.0519594
-88.4623	0.051836	0.0519499	0.051903
-91.045	0.0513952	0.0516728	0.0514481
-93.6276	0.0494959	0.0501006	0.0497589
-96.2102	0.0450453	0.0466164	0.0463263
-98.7928	0.0384566	0.040946	0.0407425

Table 9 - Average velocities smooth airfoil 15° 7 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
194.378	0.0331617	0.0322368	0.0328664
191.937	0.0392878	0.037076	0.0386178
189.495	0.0459017	0.042189	0.0453322
187.053	0.0507468	0.0477083	0.049377
184.612	0.0540495	0.0515531	0.052918
182.17	0.0557389	0.0538872	0.0549856
179.728	0.0564672	0.0549	0.0561593
177.287	0.0568681	0.0555807	0.056971
174.845	0.0569908	0.0563451	0.0572425
172.404	0.0570208	0.0570418	0.0573644
169.962	0.0570196	0.0570994	0.0573092
167.52	0.0570554	0.0568571	0.0572633
165.079	0.0570335	0.056793	0.0572487
162.637	0.0572153	0.0567499	0.0571422
160.195	0.0568875	0.0566788	0.0569961
157.754	0.0567843	0.056678	0.0568981
155.312	0.0566737	0.0566602	0.0568008
152.871	0.0565191	0.0565209	0.0567414
150.429	0.0563393	0.0562338	0.0565801
147.987	0.0560798	0.0559127	0.0562771
145.546	0.0558097	0.0555558	0.0559656
143.104	0.055622	0.0551532	0.0556882
140.663	0.0554742	0.0546975	0.0554613
138.221	0.0551951	0.0543373	0.0552162
135.779	0.0548073	0.0540031	0.054843
133.338	0.0543355	0.0536504	0.0542194
130.896	0.0538489	0.0532613	0.053583
128.454	0.0534565	0.0528246	0.0531789
126.013	0.0529887	0.0524085	0.0528842
123.571	0.0525686	0.0523363	0.0525798
121.13	0.0520873	0.0516113	0.0522179
118.688	0.0514589	0.0510915	0.0516567
116.246	0.0508541	0.0505346	0.0511831
113.805	0.0503791	0.0500598	0.0509054
111.363	0.0500062	0.0497475	0.0506166

108.922	0.0498632	0.0496223	0.0502086
106.48	0.0496954	0.0494762	0.0496791
104.038	0.0493496	0.0492107	0.0490015
101.597	0.0488866	0.0488915	0.0483634
99.1551	0.0484579	0.0484905	0.0480415
96.7135	0.0481514	0.0481324	0.0478509
94.2719	0.0478429	0.0478427	0.0477494
91.8302	0.0475498	0.0475425	0.0475314
89.3886	0.0472181	0.0470966	0.0471966
86.947	0.0468765	0.0469771	0.0468084
84.5054	0.0464764	0.0467404	0.0464633
82.0638	0.0460055	0.0464848	0.0461889
79.6222	0.0456562	0.0462437	0.0459513
77.1805	0.0455816	0.0459356	0.0457833
74.7389	0.0456952	0.0456397	0.0456362
72.2973	0.0459971	0.0455208	0.0455197
69.8557	0.0462581	0.0455003	0.0454715
67.4141	0.0464031	0.0456088	0.04549
64.9725	0.0464928	0.0459189	0.0457185
62.5309	0.0464822	0.046255	0.0461137
60.0892	0.0463755	0.0465162	0.0463447
57.6476	0.0463113	0.0467142	0.0465298
55.206	0.0464002	0.0468027	0.0465354
52.7644	0.0465399	0.0469985	0.0467219
50.3228	0.0467567	0.0473817	0.0470815
47.8812	0.0471742	0.0478435	0.0475776
45.4395	0.0478019	0.0483479	0.0480972
42.9979	0.0483706	0.0489153	0.0486595
40.5563	0.048775	0.0496341	0.0491819
38.1147	0.0490101	0.0502481	0.0496722
35.6731	0.049264	0.0506488	0.0501159
33.2315	0.0495982	0.0509218	0.0505082
30.7898	0.0499306	0.0511363	0.050785
28.3482	0.0502261	0.0513626	0.0510079
25.9066	0.0506838	0.0516327	0.0512426
23.465	0.0512588	0.0520404	0.0514768
21.0234	0.0518129	0.0525106	0.0517129
18.5818	0.0523588	0.0529165	0.051971
16.1401	0.0527891	0.0532227	0.052352
13.6985	0.0531286	0.0535127	0.0528064
11.2569	0.0534648	0.053841	0.0531492
8.8153	0.0537435	0.054064	0.0533411

6.37368	0.0539382	0.0541552	0.0535132
3.93207	0.0542117	0.0543128	0.0537213
1.49045	0.054424	0.0545463	0.0540683
-0.951166	0.0545882	0.0546714	0.0544465
-3.39278	0.0547163	0.0547896	0.0547507
-5.8344	0.054898	0.054937	0.054958
-8.27601	0.0551284	0.0550539	0.0550636
-10.7176	0.0553158	0.0551273	0.0551558
-13.1592	0.0554891	0.0551982	0.0552263
-15.6009	0.0556132	0.0552782	0.0552634
-18.0425	0.055634	0.0553737	0.0552947
-20.4841	0.0556119	0.0554097	0.0553799
-22.9257	0.0556148	0.0556694	0.0554288
-25.3673	0.0556648	0.0556608	0.0554612
-27.8089	0.0557371	0.0556604	0.0555156
-30.2506	0.0557667	0.0554308	0.0556768
-32.6922	0.0557556	0.055511	0.0557442
-35.1338	0.0557688	0.0555723	0.0557199
-37.5754	0.0558093	0.0556033	0.05568
-40.017	0.0558339	0.0555679	0.0556948
-42.4586	0.0558428	0.0555435	0.055758
-44.9003	0.0558705	0.0555776	0.0558213
-47.3419	0.0559108	0.0556364	0.0558219
-49.7835	0.0559366	0.0556622	0.0557834
-52.2251	0.0559126	0.0556325	0.0558128
-54.6667	0.0558957	0.0555945	0.0558282
-57.1083	0.0558785	0.0555919	0.0557997
-59.5499	0.0558744	0.0555741	0.0557256
-61.9916	0.0558711	0.0555608	0.0556188
-64.4332	0.0558461	0.0554965	0.0555821
-66.8748	0.0557714	0.055349	0.0555406
-69.3164	0.0555925	0.055158	0.05539
-71.758	0.055318	0.0549611	0.0551347
-74.1996	0.0548918	0.0546956	0.0547748
-76.6413	0.0542801	0.054198	0.054268
-79.0829	0.0534692	0.0535024	0.0536147
-81.5245	0.0526341	0.0527651	0.0528797
-83.9661	0.0519924	0.052053	0.052274
-86.4077	0.0515987	0.0516783	0.0518952
-88.8493	0.0514998	0.0516771	0.0518369
-91.291	0.0517674	0.0519823	0.0521377
-93.7326	0.052384	0.052456	0.0526403

-96.1742	0.0528799	0.0527514	0.0529491
-98.6158	0.0519618	0.051788	0.0519824
-101.057	0.0489949	0.048789	0.0488939
-103.499	0.0459594	0.0456264	0.0453979

Table 10 - Average velocities smooth airfoil -5° 20 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
195.625	0.164611	0.16213	0.151405
193.042	0.162373	0.16731	0.155704
190.459	0.163803	0.167136	0.159167
187.877	0.168525	0.168271	0.164526
185.294	0.169245	0.16926	0.166639
182.711	0.170546	0.167958	0.167787
180.129	0.170582	0.167708	0.169135
177.546	0.169807	0.167798	0.169991
174.964	0.169722	0.168048	0.169852
172.381	0.169558	0.169117	0.169707
169.798	0.169298	0.169455	0.170124
167.216	0.168784	0.169433	0.169335
164.633	0.168413	0.168908	0.169275
162.051	0.16839	0.168722	0.16913
159.468	0.168272	0.168754	0.168884
156.885	0.168142	0.168756	0.168619
154.303	0.1679	0.168573	0.168416
151.72	0.167695	0.168411	0.168205
149.138	0.167602	0.168156	0.1681
146.555	0.167471	0.167864	0.167966
143.972	0.167354	0.167728	0.167836
141.39	0.167243	0.167896	0.16759
138.807	0.167145	0.167519	0.167434
136.225	0.167039	0.167364	0.167237
133.642	0.166804	0.167157	0.167022
131.059	0.166552	0.167017	0.166948
128.477	0.166387	0.166881	0.167009
125.894	0.16568	0.166695	0.166982
123.312	0.166231	0.16656	0.166583
120.729	0.166035	0.166362	0.165925

118.146	0.165618	0.165965	0.165258
115.564	0.16498	0.165507	0.164663
112.981	0.164191	0.165081	0.163857
110.398	0.163421	0.164411	0.163016
107.816	0.162762	0.163544	0.16212
105.233	0.162201	0.162531	0.161045
102.651	0.161328	0.161403	0.159821
100.068	0.16019	0.160382	0.15833
97.4854	0.159036	0.159485	0.156824
94.9028	0.157845	0.158712	0.155505
92.3202	0.156851	0.158174	0.154488
89.7376	0.155879	0.157706	0.153878
87.155	0.154918	0.15729	0.153647
84.5724	0.154209	0.156806	0.153887
81.9898	0.153855	0.156196	0.154288
79.4072	0.15413	0.15603	0.154804
76.8246	0.154905	0.156415	0.155313
74.242	0.1556	0.157017	0.156155
71.6593	0.156123	0.157084	0.157195
69.0767	0.156313	0.156678	0.158025
66.4941	0.156198	0.156502	0.158708
63.9115	0.156479	0.157051	0.159439
61.3289	0.157344	0.158139	0.160401
58.7463	0.158528	0.159396	0.161444
56.1637	0.159615	0.160403	0.162154
53.5811	0.160342	0.16107	0.162305
50.9985	0.160903	0.161431	0.162347
48.4159	0.161537	0.16177	0.162598
45.8333	0.161959	0.162076	0.163024
43.2507	0.162085	0.162321	0.163438
40.668	0.162187	0.162443	0.163747
38.0854	0.162384	0.162647	0.163856
35.5028	0.162714	0.162955	0.163992
32.9202	0.162945	0.163241	0.164069
30.3376	0.163047	0.163554	0.164241
27.755	0.162985	0.163639	0.164442
25.1724	0.162884	0.163598	0.164437
22.5898	0.162873	0.163599	0.164322
20.0072	0.162969	0.163633	0.164147
17.4246	0.162733	0.163669	0.163966
14.842	0.163017	0.163654	0.163908
12.2594	0.163071	0.163536	0.164151

9.67675	0.163169	0.163458	0.164264
7.09415	0.163226	0.163511	0.164164
4.51154	0.163225	0.163589	0.163932
1.92893	0.163158	0.163647	0.163662
-0.653677	0.163111	0.163665	0.163605
-3.23629	0.163118	0.163641	0.163636
-5.81889	0.16324	0.163622	0.163801
-8.4015	0.163449	0.163557	0.164066
-10.9841	0.163579	0.163589	0.164214
-13.5667	0.163723	0.163787	0.164326
-16.1493	0.163803	0.163998	0.164358
-18.7319	0.163943	0.164127	0.164332
-21.3145	0.164024	0.164136	0.164272
-23.8972	0.164108	0.164206	0.164288
-26.4798	0.164202	0.164286	0.164312
-29.0624	0.164277	0.164328	0.164312
-31.645	0.164372	0.164367	0.164379
-34.2276	0.164417	0.164407	0.164377
-36.8102	0.164393	0.164546	0.164392
-39.3928	0.164318	0.164664	0.164335
-41.9754	0.16427	0.164664	0.164283
-44.558	0.164311	0.164628	0.164298
-47.1406	0.164395	0.164658	0.164369
-49.7232	0.164442	0.164749	0.16454
-52.3058	0.164452	0.164829	0.164738
-54.8884	0.164524	0.164813	0.16488
-57.4711	0.164588	0.164844	0.164956
-60.0537	0.164655	0.164937	0.165023
-62.6363	0.164681	0.165009	0.165069
-65.2189	0.164655	0.16501	0.165047
-67.8015	0.1647	0.164924	0.164956
-70.3841	0.164723	0.164767	0.164813
-72.9667	0.16459	0.164492	0.164528
-75.5493	0.164262	0.164044	0.163991
-78.1319	0.163838	0.163404	0.163237
-80.7145	0.163354	0.162596	0.162105
-83.2971	0.162691	0.161739	0.160648
-85.8797	0.161818	0.16068	0.158962
-88.4623	0.160843	0.159466	0.157442
-91.045	0.160057	0.158754	0.156597
-93.6276	0.159851	0.158857	0.156657
-96.2102	0.159444	0.15894	0.156907

-98.7928	0.158502	0.158495	0.156679

Table 11 - Average velocities smooth airfoil 0° 20 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
194.378	0.129744	0.127255	0.124966
191.937	0.136507	0.140522	0.137949
189.495	0.143813	0.153514	0.14869
187.053	0.150646	0.161173	0.156959
184.612	0.155588	0.164958	0.160896
182.17	0.160314	0.166159	0.163342
179.728	0.163118	0.166189	0.164393
177.287	0.162087	0.166041	0.165901
174.845	0.161496	0.165797	0.165669
172.404	0.16435	0.165109	0.165167
169.962	0.164679	0.165556	0.165106
167.52	0.164739	0.165409	0.1655
165.079	0.164691	0.165291	0.164944
162.637	0.164697	0.165055	0.164887
160.195	0.164581	0.164845	0.164808
157.754	0.164427	0.164716	0.164654
155.312	0.164378	0.164589	0.164406
152.871	0.164324	0.164532	0.164243
150.429	0.164091	0.164595	0.164063
147.987	0.163874	0.164534	0.163844
145.546	0.163774	0.164245	0.163713
143.104	0.163661	0.163972	0.163833
140.663	0.1636	0.163741	0.164076
138.221	0.163471	0.163650	0.163919
135.779	0.163309	0.163558	0.163646
133.338	0.163193	0.163485	0.163164
130.896	0.162934	0.163484	0.16274
128.454	0.162826	0.163526	0.162689

126.013	0.162808	0.163525	0.162841
123.571	0.162908	0.163516	0.162944
121.13	0.162961	0.163283	0.16293
118.688	0.162788	0.163017	0.162856
116.246	0.162396	0.162833	0.162726
113.805	0.16204	0.162701	0.162347
111.363	0.161709	0.162501	0.162011
108.922	0.161541	0.162388	0.161821
106.48	0.161533	0.162171	0.161765
104.038	0.161437	0.161983	0.161695
101.597	0.161356	0.161963	0.161576
99.1551	0.161184	0.161873	0.161567
96.7135	0.160985	0.161757	0.161573
94.2719	0.16079	0.161534	0.161682
91.8302	0.160982	0.161745	0.162212
89.3886	0.161367	0.162298	0.162639
86.947	0.16134	0.162499	0.162348
84.5054	0.160111	0.161011	0.160603
82.0638	0.156651	0.157654	0.1566
79.6222	0.151764	0.153012	0.151349
77.1805	0.146975	0.148510	0.145736
74.7389	0.14427	0.146114	0.142188
72.2973	0.145162	0.146709	0.141975
69.8557	0.149624	0.149922	0.145071
67.4141	0.155005	0.153923	0.150019
64.9725	0.159138	0.157270	0.154374
62.5309	0.160827	0.159442	0.15771
60.0892	0.160554	0.160168	0.159276
57.6476	0.159649	0.160043	0.160025
55.206	0.159325	0.159881	0.160011
52.7644	0.159166	0.159692	0.15965
50.3228	0.159175	0.159412	0.1595
47.8812	0.159237	0.159284	0.159449
45.4395	0.159198	0.159212	0.159324
42.9979	0.159026	0.159350	0.159143
40.5563	0.15873	0.159418	0.158891
38.1147	0.158597	0.159264	0.158882
35.6731	0.158561	0.159065	0.158913
33.2315	0.158419	0.158867	0.158732
30.7898	0.158292	0.158890	0.158516
28.3482	0.158302	0.158863	0.158387
25.9066	0.158412	0.158764	0.158386

23.465	0.158442	0.158622	0.15841
21.0234	0.158188	0.158506	0.158345
18.5818	0.158014	0.158479	0.158314
16.1401	0.157963	0.158503	0.158312
13.6985	0.157881	0.158476	0.158273
11.2569	0.157872	0.158301	0.158173
8.8153	0.157932	0.158271	0.158103
6.37368	0.1579	0.158260	0.157991
3.93207	0.157805	0.158303	0.157945
1.49045	0.157741	0.158264	0.15796
-0.951166	0.157773	0.158206	0.158014
-3.39278	0.157862	0.158232	0.158201
-5.8344	0.157846	0.158281	0.158385
-8.27601	0.157757	0.158336	0.158426
-10.7176	0.157881	0.158532	0.158319
-13.1592	0.158059	0.158676	0.158164
-15.6009	0.15826	0.158812	0.158016
-18.0425	0.158377	0.158814	0.158024
-20.4841	0.158403	0.158762	0.158145
-22.9257	0.158403	0.158859	0.158334
-25.3673	0.158344	0.159006	0.158562
-27.8089	0.158419	0.159182	0.15873
-30.2506	0.158557	0.159278	0.158803
-32.6922	0.15874	0.159343	0.158754
-35.1338	0.159025	0.159426	0.158865
-37.5754	0.159069	0.159632	0.159075
-40.017	0.159007	0.159837	0.159175
-42.4586	0.159079	0.159871	0.159276
-44.9003	0.159205	0.159765	0.159246
-47.3419	0.159334	0.159726	0.159301
-49.7835	0.159285	0.159861	0.159505
-52.2251	0.159205	0.160027	0.159468
-54.6667	0.159301	0.160134	0.159508
-57.1083	0.159393	0.160226	0.159717
-59.5499	0.159539	0.160281	0.160039
-61.9916	0.159697	0.160424	0.160211
-64.4332	0.159748	0.160534	0.160071
-66.8748	0.15985	0.160606	0.159972
-69.3164	0.159848	0.160442	0.159962
-71.758	0.15981	0.160017	0.159912
-74.1996	0.159768	0.159525	0.159716
-76.6413	0.159588	0.159437	0.159408

-79.0829	0.159185	0.159343	0.159132
-81.5245	0.158559	0.158944	0.158716
-83.9661	0.157518	0.158093	0.158017
-86.4077	0.156365	0.157153	0.15731
-88.8493	0.155599	0.156667	0.156826
-91.291	0.155516	0.156875	0.156919
-93.7326	0.156309	0.157796	0.157585
-96.1742	0.15768	0.158949	0.158371
-98.6158	0.157912	0.158897	0.158174
-101.057	0.154725	0.155695	0.155611
-103.499	0.150336	0.152059	0.152577

Table 12 - Average velocities smooth airfoil 5° 20 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
195.625	0.150985	0.145857	0.152577
193.042	0.158837	0.152629	0.158455
190.459	0.166146	0.158979	0.165355
187.877	0.169084	0.163854	0.168367
185.294	0.167465	0.165687	0.170857
182.711	0.166078	0.16709	0.169611
180.129	0.167064	0.167439	0.166986
177.546	0.167139	0.167491	0.167664
174.964	0.166992	0.167866	0.165466
172.381	0.166712	0.167285	0.165946
169.798	0.166262	0.167118	0.166005
167.216	0.166128	0.16648	0.166425
164.633	0.166567	0.165973	0.166093
162.051	0.166458	0.165767	0.165865
159.468	0.166304	0.165806	0.165749
156.885	0.165505	0.166513	0.165658
154.303	0.165909	0.166287	0.165663
151.72	0.165808	0.165462	0.165577
149.138	0.164983	0.16538	0.165314
146.555	0.165278	0.165271	0.165164
143.972	0.164937	0.165219	0.165154
141.39	0.164666	0.164947	0.165106
138.807	0.164496	0.164678	0.165072
136.225	0.164313	0.164323	0.165

133.642	0.164023	0.164021	0.164875
131.059	0.163662	0.163723	0.164806
128.477	0.163389	0.163422	0.16473
125.894	0.163018	0.163176	0.164508
123.312	0.162342	0.163057	0.164172
120.729	0.161884	0.162909	0.16384
118.146	0.161592	0.162391	0.163594
115.564	0.161102	0.162076	0.163382
112.981	0.160548	0.16085	0.163019
110.398	0.159816	0.160878	0.162578
107.816	0.15882	0.159919	0.162059
105.233	0.157571	0.158465	0.161557
102.651	0.156293	0.157357	0.161077
100.068	0.155192	0.156409	0.160615
97.4854	0.15395	0.15551	0.159963
94.9028	0.152721	0.154037	0.159262
92.3202	0.151663	0.153826	0.158585
89.7376	0.150709	0.153006	0.15711
87.155	0.149934	0.152367	0.156053
84.5724	0.149517	0.151718	0.155271
81.9898	0.149383	0.151069	0.153643
79.4072	0.149352	0.150357	0.152003
76.8246	0.149634	0.150186	0.150709
74.242	0.150192	0.150666	0.149891
71.6593	0.151124	0.151818	0.149462
69.0767	0.152106	0.152481	0.149523
66.4941	0.153062	0.152702	0.150001
63.9115	0.154066	0.153196	0.150654
61.3289	0.154933	0.153697	0.151424
58.7463	0.155875	0.154476	0.15229
56.1637	0.156782	0.15534	0.153384
53.5811	0.15769	0.156481	0.154514
50.9985	0.158488	0.157599	0.155404
48.4159	0.159074	0.158591	0.156172
45.8333	0.159413	0.159282	0.156832
43.2507	0.16019	0.159815	0.157472
40.668	0.160638	0.160227	0.158174
38.0854	0.160826	0.160443	0.15908
35.5028	0.160861	0.160745	0.159937
32.9202	0.161016	0.160951	0.160449
30.3376	0.161178	0.161048	0.160702
27.755	0.161243	0.161132	0.160893

25.1724	0.161174	0.161205	0.16106
22.5898	0.161119	0.161311	0.161198
20.0072	0.161092	0.161408	0.161297
17.4246	0.161188	0.161455	0.161341
14.842	0.161346	0.161395	0.161399
12.2594	0.161453	0.161365	0.161443
9.67675	0.161549	0.161426	0.161453
7.09415	0.161618	0.161526	0.161436
4.51154	0.161623	0.161614	0.16142
1.92893	0.161591	0.161596	0.161402
-0.653677	0.161518	0.161486	0.161392
-3.23629	0.161459	0.161338	0.161413
-5.81889	0.161451	0.16135	0.161394
-8.4015	0.161482	0.161354	0.161487
-10.9841	0.161485	0.161332	0.161609
-13.5667	0.161439	0.161356	0.161681
-16.1493	0.161409	0.161399	0.161686
-18.7319	0.161417	0.161547	0.161607
-21.3145	0.161423	0.161704	0.161535
-23.8972	0.161474	0.161867	0.161534
-26.4798	0.161611	0.162003	0.161624
-29.0624	0.161816	0.162106	0.161729
-31.645	0.162049	0.162189	0.161877
-34.2276	0.162146	0.162232	0.16198
-36.8102	0.162148	0.16228	0.162041
-39.3928	0.162128	0.16227	0.162101
-41.9754	0.162179	0.162243	0.16219
-44.558	0.162315	0.162223	0.162259
-47.1406	0.162431	0.162199	0.16228
-49.7232	0.162501	0.162254	0.162285
-52.3058	0.162513	0.162396	0.16235
-54.8884	0.162564	0.162589	0.162419
-57.4711	0.162639	0.162696	0.162513
-60.0537	0.162748	0.162764	0.162612
-62.6363	0.162853	0.162788	0.162681
-65.2189	0.162918	0.162835	0.162723
-67.8015	0.16293	0.162837	0.16272
-70.3841	0.162784	0.162727	0.162671
-72.9667	0.162426	0.162442	0.162461
-75.5493	0.161737	0.161855	0.16197
-78.1319	0.160608	0.160914	0.161152
-80.7145	0.158986	0.159645	0.160041

-83.2971	0.157021	0.158252	0.158656
-85.8797	0.155201	0.156913	0.15709
-88.4623	0.154115	0.155854	0.155726
-91.045	0.154197	0.155446	0.154968
-93.6276	0.155398	0.155761	0.155079
-96.2102	0.156288	0.155874	0.155197
-98.7928	0.1562	0.155219	0.154773
-86.4077	0.156365	0.158710475	0.15731
-88.8493	0.155599	0.157932985	0.156826
-91.291	0.155516	0.15784874	0.156919
-93.7326	0.156309	0.158653635	0.157585
-96.1742	0.15768	0.1600452	0.158371
-98.6158	0.157912	0.16028068	0.158174
-101.057	0.154725	0.157045875	0.155611
-103.499	0.150336	0.15259104	0.152577

Table 13 - Average velocities smooth airfoil 8° 20 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
194.378	0.114191	0.124096	0.11666
191.937	0.131669	0.14183	0.131487
189.495	0.148266	0.154116	0.148531
187.053	0.158906	0.162385	0.160105
184.612	0.163525	0.166473	0.165383
182.17	0.165448	0.167563	0.167399
179.728	0.166095	0.167392	0.167642
177.287	0.166495	0.167607	0.167742
174.845	0.166873	0.167432	0.167541
172.404	0.167069	0.167103	0.167311
169.962	0.166882	0.167147	0.166957
167.52	0.166766	0.166825	0.166327
165.079	0.166722	0.166332	0.166466
162.637	0.166494	0.165896	0.166354
160.195	0.166551	0.165839	0.166304
157.754	0.166534	0.166072	0.16635
155.312	0.166497	0.166313	0.166358
152.871	0.166401	0.166316	0.166274
150.429	0.166197	0.166168	0.166621
147.987	0.165968	0.166125	0.166556

145.546	0.165786	0.166036	0.165923
143.104	0.165657	0.165769	0.166329
140.663	0.165621	0.165555	0.166015
138.221	0.165612	0.165441	0.165157
135.779	0.165572	0.165266	0.165558
133.338	0.165538	0.164851	0.165365
130.896	0.165341	0.164335	0.164924
128.454	0.165197	0.16405	0.164724
126.013	0.164446	0.163937	0.164789
123.571	0.164877	0.163841	0.164799
121.13	0.164764	0.163554	0.164669
118.688	0.164524	0.16311	0.164344
116.246	0.164242	0.162372	0.163981
113.805	0.163793	0.161377	0.163525
111.363	0.163069	0.160407	0.162863
108.922	0.162452	0.159595	0.162265
106.48	0.1618	0.158747	0.161669
104.038	0.161194	0.157962	0.160928
101.597	0.160569	0.157355	0.160292
99.1551	0.15967	0.156362	0.159692
96.7135	0.158801	0.155089	0.158822
94.2719	0.157476	0.153809	0.15767
91.8302	0.155788	0.152737	0.156004
89.3886	0.153793	0.151712	0.15434
86.947	0.152468	0.150684	0.152937
84.5054	0.151571	0.1494	0.151831
82.0638	0.151068	0.14792	0.150784
79.6222	0.150857	0.146615	0.149447
77.1805	0.149816	0.14573	0.147809
74.7389	0.148813	0.145393	0.146446
72.2973	0.147707	0.14522	0.145628
69.8557	0.146529	0.144784	0.145259
67.4141	0.145341	0.144074	0.145077
64.9725	0.144547	0.143486	0.145091
62.5309	0.144333	0.143246	0.14557
60.0892	0.144445	0.143581	0.146101
57.6476	0.144956	0.144314	0.146186
55.206	0.145653	0.145666	0.146502
52.7644	0.146616	0.146452	0.146829
50.3228	0.1477	0.147081	0.147575
47.8812	0.148919	0.148158	0.148903
45.4395	0.150142	0.149127	0.149989

42.9979	0.151206	0.15027	0.150955
40.5563	0.152286	0.151277	0.152175
38.1147	0.153027	0.152134	0.153408
35.6731	0.154364	0.153063	0.154536
33.2315	0.155673	0.154203	0.15538
30.7898	0.157154	0.155498	0.156191
28.3482	0.157796	0.156779	0.156962
25.9066	0.158202	0.157919	0.157725
23.465	0.158484	0.158878	0.158384
21.0234	0.158785	0.159754	0.159072
18.5818	0.159178	0.160062	0.158887
16.1401	0.159454	0.160044	0.158947
13.6985	0.159553	0.159845	0.159075
11.2569	0.159544	0.159555	0.159201
8.8153	0.159459	0.15936	0.159313
6.37368	0.15942	0.159467	0.159429
3.93207	0.159483	0.159572	0.159509
1.49045	0.159555	0.159695	0.159504
-0.951166	0.15952	0.159682	0.159398
-3.39278	0.159599	0.159658	0.159592
-5.8344	0.159733	0.159678	0.159688
-8.27601	0.159665	0.159687	0.15999
-10.7176	0.159774	0.159682	0.159982
-13.1592	0.159923	0.159799	0.160002
-15.6009	0.160072	0.159976	0.159613
-18.0425	0.160077	0.160095	0.15971
-20.4841	0.160031	0.160193	0.15997
-22.9257	0.160035	0.160225	0.160235
-25.3673	0.160089	0.160211	0.160318
-27.8089	0.160212	0.160208	0.160239
-30.2506	0.160358	0.160325	0.160223
-32.6922	0.160532	0.160452	0.160188
-35.1338	0.160614	0.160627	0.160307
-37.5754	0.160616	0.160809	0.160509
-40.017	0.160772	0.161097	0.160792
-42.4586	0.160915	0.161211	0.161153
-44.9003	0.161129	0.161149	0.161335
-47.3419	0.16136	0.161076	0.161267
-49.7835	0.161445	0.161124	0.161116
-52.2251	0.161526	0.161305	0.161089
-54.6667	0.161513	0.161522	0.161133
-57.1083	0.161431	0.161644	0.161126

-59.5499	0.161554	0.161699	0.161238
-61.9916	0.161803	0.161746	0.161489
-64.4332	0.162088	0.161738	0.161708
-66.8748	0.162048	0.161708	0.161833
-69.3164	0.161701	0.161418	0.161678
-71.758	0.161302	0.161062	0.161561
-74.1996	0.160982	0.160846	0.161393
-76.6413	0.160927	0.160639	0.161048
-79.0829	0.16089	0.160358	0.160563
-81.5245	0.160511	0.1599	0.159964
-83.9661	0.159714	0.1592	0.159344
-86.4077	0.158638	0.158606	0.158741
-88.8493	0.157945	0.158302	0.158222
-91.291	0.157974	0.158369	0.158238
-93.7326	0.158695	0.158966	0.158766
-96.1742	0.159735	0.15985	0.159545
-98.6158	0.159596	0.159429	0.159401
-101.057	0.156032	0.155413	0.156395
-103.499	0.151415	0.150834	0.152034

Table 14 - Average velocities smooth airfoil 10° 20 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
195.625	0.151724	0.150393	0.154234
193.042	0.15913	0.155119	0.161437
190.459	0.165261	0.158722	0.164839
187.877	0.171147	0.160123	0.168151
185.294	0.170749	0.159111	0.169303
182.711	0.170221	0.160668	0.169452
180.129	0.169369	0.160518	0.167895
177.546	0.168225	0.162262	0.167454
174.964	0.167713	0.164537	0.1663
172.381	0.167593	0.165994	0.16605
169.798	0.167694	0.166172	0.165632
167.216	0.16738	0.166729	0.16532
164.633	0.166074	0.166227	0.164623
162.051	0.16576	0.166593	0.164502
159.468	0.166172	0.166661	0.164409
156.885	0.166099	0.167663	0.164304

154.303	0.165378	0.167602	0.165437
151.72	0.164515	0.166701	0.165306
149.138	0.163809	0.165833	0.165486
146.555	0.16363	0.164931	0.165167
143.972	0.163331	0.163966	0.163997
141.39	0.162894	0.163332	0.163524
138.807	0.161483	0.162797	0.163439
136.225	0.160563	0.162119	0.163278
133.642	0.159753	0.161359	0.162594
131.059	0.15931	0.16088	0.161412
128.477	0.157894	0.160479	0.160104
125.894	0.156668	0.159639	0.15863
123.312	0.155923	0.159619	0.157149
120.729	0.155224	0.158682	0.155833
118.146	0.153843	0.157649	0.154583
115.564	0.152639	0.156161	0.153209
112.981	0.151432	0.154938	0.152276
110.398	0.150223	0.153874	0.151851
107.816	0.149969	0.152961	0.150866
105.233	0.149202	0.151753	0.149496
102.651	0.148291	0.150045	0.148436
100.068	0.147382	0.148394	0.147525
97.4854	0.14673	0.147054	0.147146
94.9028	0.146507	0.146301	0.147019
92.3202	0.146368	0.146739	0.146356
89.7376	0.146458	0.147422	0.14561
87.155	0.146623	0.146216	0.145409
84.5724	0.146711	0.146174	0.145346
81.9898	0.14637	0.146083	0.145405
79.4072	0.145815	0.146016	0.145609
76.8246	0.145453	0.146154	0.145675
74.242	0.1453	0.146651	0.146
71.6593	0.145464	0.147192	0.146583
69.0767	0.146137	0.147504	0.146839
66.4941	0.147264	0.14783	0.147969
63.9115	0.147617	0.148087	0.149171
61.3289	0.14833	0.148246	0.149594
58.7463	0.149072	0.14894	0.149274
56.1637	0.149991	0.15058	0.149921
53.5811	0.151244	0.15172	0.15074
50.9985	0.152678	0.15204	0.151596
48.4159	0.15381	0.152957	0.152795

45.8333	0.155087	0.153856	0.154386
43.2507	0.155806	0.155028	0.155692
40.668	0.156385	0.156119	0.156502
38.0854	0.157054	0.157006	0.157427
35.5028	0.157904	0.157792	0.158521
32.9202	0.158744	0.158568	0.159553
30.3376	0.159386	0.15934	0.160292
27.755	0.160036	0.16004	0.160772
25.1724	0.160678	0.160628	0.161111
22.5898	0.161272	0.16112	0.161397
20.0072	0.161737	0.16159	0.161777
17.4246	0.162022	0.162108	0.162223
14.842	0.162292	0.162581	0.162682
12.2594	0.162619	0.162916	0.163038
9.67675	0.162938	0.163191	0.163221
7.09415	0.163122	0.163322	0.163345
4.51154	0.163158	0.163344	0.163313
1.92893	0.163204	0.163274	0.163168
-0.653677	0.163246	0.163173	0.163007
-3.23629	0.163233	0.163195	0.163089
-5.81889	0.163242	0.163312	0.163332
-8.4015	0.163341	0.163368	0.163505
-10.9841	0.16352	0.16338	0.163559
-13.5667	0.163588	0.163472	0.163531
-16.1493	0.163525	0.163487	0.163527
-18.7319	0.163506	0.16344	0.163619
-21.3145	0.163597	0.163425	0.163708
-23.8972	0.163699	0.163495	0.163846
-26.4798	0.163736	0.16367	0.16402
-29.0624	0.163828	0.163832	0.164228
-31.645	0.16402	0.163943	0.164412
-34.2276	0.164148	0.163994	0.164485
-36.8102	0.164163	0.164068	0.164481
-39.3928	0.164166	0.164129	0.16448
-41.9754	0.164174	0.164181	0.164536
-44.558	0.16419	0.164208	0.16466
-47.1406	0.164258	0.16424	0.164768
-49.7232	0.16437	0.164372	0.164882
-52.3058	0.164525	0.16459	0.164961
-54.8884	0.16467	0.164825	0.165062
-57.4711	0.164726	0.164959	0.165127
-60.0537	0.16474	0.165043	0.165168

-62.6363	0.164679	0.165088	0.165217
-65.2189	0.164667	0.165073	0.165327
-67.8015	0.16469	0.165005	0.165361
-70.3841	0.164612	0.164742	0.165256
-72.9667	0.164307	0.164157	0.16481
-75.5493	0.163683	0.163229	0.163861
-78.1319	0.162912	0.162027	0.162704
-80.7145	0.162099	0.160769	0.161509
-83.2971	0.16128	0.15973	0.160432
-85.8797	0.160368	0.158989	0.159572
-88.4623	0.159597	0.158599	0.159159
-91.045	0.159447	0.158705	0.159347
-93.6276	0.159807	0.159098	0.159967
-96.2102	0.159257	0.158747	0.159857
-98.7928	0.157647	0.157527	0.158628
-86.4077	0.158638	0.158606	0.158741
-88.8493	0.157945	0.158302	0.158222
-91.291	0.157974	0.158369	0.158238
-93.7326	0.158695	0.158966	0.158766
-96.1742	0.159735	0.15985	0.159545
-98.6158	0.159596	0.159429	0.159401
-101.057	0.156032	0.155413	0.156395
-103.499	0.151415	0.150834	0.152034

Table 15 - Average velocities smooth airfoil 15° 20 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
194.378	0.145645	0.139225	0.140359
191.937	0.156043	0.150668	0.150055
189.495	0.164248	0.157841	0.159347
187.053	0.169709	0.163207	0.164812
184.612	0.171979	0.167002	0.16912
182.17	0.172684	0.1688	0.170166
179.728	0.172414	0.166833	0.169937
177.287	0.171809	0.166158	0.170278
174.845	0.171386	0.167945	0.169682
172.404	0.170254	0.170413	0.169511
169.962	0.170812	0.168865	0.169168
167.52	0.16981	0.169466	0.168361

165.079	0.169136	0.169063	0.167754
162.637	0.168479	0.16794	0.167223
160.195	0.168643	0.167641	0.166661
157.754	0.167983	0.167218	0.165869
155.312	0.167181	0.167212	0.16486
152.871	0.166467	0.165454	0.164646
150.429	0.16573	0.163736	0.163974
147.987	0.164836	0.162383	0.162537
145.546	0.163962	0.161392	0.16237
143.104	0.163296	0.160637	0.162054
140.663	0.162801	0.15961	0.161442
138.221	0.162375	0.158372	0.160666
135.779	0.161624	0.157335	0.159626
133.338	0.160785	0.155555	0.158566
130.896	0.159546	0.15496	0.157339
128.454	0.158443	0.15449	0.156498
126.013	0.157111	0.154121	0.155991
123.571	0.155388	0.153291	0.155628
121.13	0.153434	0.152193	0.155008
118.688	0.151599	0.151248	0.153799
116.246	0.150058	0.150532	0.152915
113.805	0.148747	0.149911	0.151691
111.363	0.147706	0.148913	0.150036
108.922	0.146585	0.147623	0.148916
106.48	0.145651	0.145966	0.147828
104.038	0.144127	0.144596	0.146265
101.597	0.143397	0.14443	0.144779
99.1551	0.14435	0.144064	0.143294
96.7135	0.143523	0.142364	0.141704
94.2719	0.142514	0.140834	0.140422
91.8302	0.141342	0.139266	0.139245
89.3886	0.1398	0.138295	0.138326
86.947	0.138851	0.137635	0.13758
84.5054	0.138609	0.137222	0.136335
82.0638	0.139132	0.137109	0.135307
79.6222	0.139954	0.137287	0.134968
77.1805	0.139895	0.137711	0.135163
74.7389	0.13945	0.13813	0.135362
72.2973	0.139365	0.138854	0.135484
69.8557	0.139583	0.139721	0.135521
67.4141	0.139458	0.14094	0.135805
64.9725	0.139088	0.142375	0.136291

62.5309	0.13922	0.143349	0.137042
60.0892	0.139876	0.143682	0.13822
57.6476	0.139517	0.143744	0.139075
55.206	0.140471	0.143417	0.139328
52.7644	0.142031	0.144038	0.139443
50.3228	0.143184	0.143841	0.139507
47.8812	0.144361	0.143511	0.140101
45.4395	0.14515	0.144328	0.141117
42.9979	0.146178	0.145506	0.142193
40.5563	0.147073	0.147133	0.143443
38.1147	0.147737	0.148143	0.144528
35.6731	0.14834	0.149297	0.145662
33.2315	0.149226	0.150778	0.146991
30.7898	0.149991	0.152165	0.148644
28.3482	0.150629	0.152933	0.150383
25.9066	0.151469	0.15399	0.151895
23.465	0.152691	0.154692	0.152532
21.0234	0.153967	0.155315	0.152886
18.5818	0.154716	0.156814	0.153748
16.1401	0.155011	0.158193	0.154783
13.6985	0.15531	0.159292	0.155942
11.2569	0.156068	0.160402	0.156919
8.8153	0.157236	0.161538	0.157773
6.37368	0.158529	0.162331	0.158936
3.93207	0.159966	0.162911	0.159979
1.49045	0.160901	0.163313	0.161021
-0.951166	0.161664	0.16358	0.162094
-3.39278	0.162329	0.163911	0.162911
-5.8344	0.163301	0.164083	0.163416
-8.27601	0.163915	0.164376	0.163793
-10.7176	0.164527	0.164605	0.163966
-13.1592	0.164414	0.164895	0.164263
-15.6009	0.164536	0.165377	0.164479
-18.0425	0.164649	0.165789	0.164699
-20.4841	0.164963	0.166217	0.165147
-22.9257	0.165284	0.166558	0.165601
-25.3673	0.165419	0.166727	0.165807
-27.8089	0.165579	0.166958	0.166045
-30.2506	0.166342	0.167114	0.166423
-32.6922	0.166578	0.166904	0.166695
-35.1338	0.166113	0.166666	0.166771
-37.5754	0.16626	0.166597	0.166689

-40.017	0.166561	0.166746	0.166753
-42.4586	0.166801	0.166993	0.167031
-44.9003	0.166891	0.167151	0.167359
-47.3419	0.16688	0.167367	0.167588
-49.7835	0.166836	0.167502	0.16808
-52.2251	0.166945	0.167418	0.168091
-54.6667	0.167158	0.167331	0.167722
-57.1083	0.167323	0.167335	0.167898
-59.5499	0.167303	0.167456	0.168006
-61.9916	0.167249	0.16768	0.167989
-64.4332	0.167182	0.167811	0.167883
-66.8748	0.167188	0.167743	0.16785
-69.3164	0.167091	0.16762	0.167984
-71.758	0.166859	0.167503	0.168087
-74.1996	0.166548	0.167318	0.167715
-76.6413	0.166379	0.167044	0.167049
-79.0829	0.166216	0.166635	0.16653
-81.5245	0.165759	0.166127	0.165972
-83.9661	0.16501	0.165416	0.165158
-86.4077	0.164142	0.164594	0.164191
-88.8493	0.163391	0.164051	0.163412
-91.291	0.16313	0.164	0.163341
-93.7326	0.163708	0.164622	0.163963
-96.1742	0.164785	0.165489	0.165153
-98.6158	0.164826	0.164931	0.165185
-101.057	0.161818	0.160928	0.162121
-103.499	0.15802	0.156364	0.158607

Table 16 - Average velocities smooth airfoil -5° 65 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
195.625	0.46386	0.425236	0.387586
193.042	0.472568	0.440944	0.409795
190.459	0.472115	0.460781	0.421476
187.877	0.475863	0.477241	0.441661
185.294	0.482451	0.477422	0.449322
182.711	0.486294	0.480304	0.459214
180.129	0.493058	0.489842	0.465463
177.546	0.498982	0.491833	0.469936
174.964	0.502722	0.489349	0.473964

172.381	0.503246	0.488256	0.475113
169.798	0.498191	0.485614	0.482865
167.216	0.499093	0.483844	0.484697
164.633	0.497589	0.48243	0.487025
162.051	0.498427	0.481267	0.487283
159.468	0.498124	0.480232	0.487057
156.885	0.4972	0.481663	0.486372
154.303	0.496036	0.47955	0.485928
151.72	0.495243	0.479724	0.485712
149.138	0.494904	0.476782	0.485719
146.555	0.49458	0.476453	0.485338
143.972	0.494065	0.47718	0.484901
141.39	0.493458	0.478645	0.484618
138.807	0.492999	0.482268	0.484333
136.225	0.49249	0.483304	0.483258
133.642	0.491877	0.482453	0.484285
131.059	0.491397	0.484842	0.484079
128.477	0.491046	0.484937	0.483804
125.894	0.490825	0.484548	0.483451
123.312	0.490885	0.48378	0.483062
120.729	0.490653	0.481066	0.482309
118.146	0.490333	0.480698	0.481749
115.564	0.490191	0.480791	0.481426
112.981	0.48971	0.480951	0.481317
110.398	0.488927	0.480783	0.481332
107.816	0.487931	0.47999	0.48075
105.233	0.486977	0.478469	0.479137
102.651	0.485142	0.475812	0.4766
100.068	0.481594	0.471789	0.473079
97.4854	0.476614	0.466108	0.468521
94.9028	0.470832	0.458899	0.462244
92.3202	0.465402	0.45207	0.456249
89.7376	0.460463	0.448292	0.452575
87.155	0.457237	0.448796	0.452131
84.5724	0.457107	0.453139	0.454379
81.9898	0.45998	0.459257	0.458654
79.4072	0.464867	0.464854	0.464541
76.8246	0.469766	0.469093	0.47078
74.242	0.474357	0.472754	0.475388
71.6593	0.478557	0.475587	0.477678
69.0767	0.481673	0.477188	0.478687
66.4941	0.483871	0.477343	0.479164

63.9115	0.485173	0.476721	0.479047
61.3289	0.485653	0.476384	0.478555
58.7463	0.485788	0.476578	0.477968
56.1637	0.485568	0.476825	0.477724
53.5811	0.485304	0.476534	0.477513
50.9985	0.485113	0.475924	0.477129
48.4159	0.484808	0.475349	0.476752
45.8333	0.484679	0.475014	0.476567
43.2507	0.484724	0.475267	0.476525
40.668	0.484753	0.475236	0.476549
38.0854	0.48474	0.474838	0.47645
35.5028	0.484627	0.474652	0.476529
32.9202	0.484061	0.474606	0.476676
30.3376	0.482791	0.474556	0.476283
27.755	0.481183	0.474421	0.475434
25.1724	0.480018	0.473961	0.474665
22.5898	0.479573	0.473147	0.474294
20.0072	0.480314	0.472228	0.474288
17.4246	0.481642	0.471678	0.474368
14.842	0.482662	0.471135	0.474573
12.2594	0.482922	0.471035	0.475118
9.67675	0.482486	0.47105	0.475599
7.09415	0.481896	0.471077	0.475286
4.51154	0.481375	0.471385	0.474125
1.92893	0.481212	0.471669	0.473423
-0.653677	0.481188	0.472084	0.473716
-3.23629	0.481203	0.472769	0.474174
-5.81889	0.48113	0.473367	0.474462
-8.4015	0.481038	0.473704	0.474105
-10.9841	0.481276	0.473998	0.473736
-13.5667	0.481304	0.474056	0.473196
-16.1493	0.480941	0.473917	0.472822
-18.7319	0.480551	0.4735	0.472775
-21.3145	0.480395	0.471274	0.472924
-23.8972	0.480547	0.472913	0.472959
-26.4798	0.480664	0.472854	0.472629
-29.0624	0.480551	0.472708	0.472353
-31.645	0.480496	0.472437	0.472402
-34.2276	0.480694	0.472508	0.472723
-36.8102	0.480823	0.472429	0.472933
-39.3928	0.480874	0.471984	0.47253
-41.9754	0.480783	0.471287	0.47198

-44.558	0.48035	0.4709	0.471395
-47.1406	0.479757	0.470844	0.470745
-49.7232	0.479355	0.47069	0.470316
-52.3058	0.479063	0.470059	0.470067
-54.8884	0.478946	0.469151	0.469997
-57.4711	0.478745	0.468097	0.469665
-60.0537	0.47796	0.466616	0.468135
-62.6363	0.476233	0.464804	0.46624
-65.2189	0.47376	0.46279	0.464858
-67.8015	0.470792	0.460632	0.463398
-70.3841	0.468179	0.458265	0.461254
-72.9667	0.466196	0.455734	0.457725
-75.5493	0.464141	0.453381	0.45345
-78.1319	0.460802	0.449962	0.448894
-80.7145	0.45571	0.444148	0.444204
-83.2971	0.449959	0.436444	0.438846
-85.8797	0.444186	0.429008	0.432558
-88.4623	0.437934	0.421375	0.424182
-91.045	0.428837	0.411473	0.412336
-93.6276	0.413773	0.397023	0.396432
-96.2102	0.393642	0.37796	0.376082
-98.7928	0.373614	0.359139	0.355472
-86.4077	0.164142	0.164594	0.164191
-88.8493	0.163391	0.164051	0.163412
-91.291	0.16313	0.164	0.163341
-93.7326	0.163708	0.164622	0.163963
-96.1742	0.164785	0.165489	0.165153
-98.6158	0.164826	0.164931	0.165185
-101.057	0.161818	0.160928	0.162121
-103.499	0.15802	0.156364	0.158607

Table 17 - Average velocities smooth airfoil 0° 65 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
194.378	0.323958	0.355439	0.354624
191.937	0.355053	0.37737	0.380212
189.495	0.382488	0.402342	0.405313

187.053	0.409612	0.419776	0.426213
184.612	0.41757	0.429752	0.43606
182.17	0.440858	0.443938	0.451745
179.728	0.447332	0.454857	0.461932
177.287	0.457163	0.470887	0.472682
174.845	0.465382	0.474367	0.480917
172.404	0.475038	0.478607	0.484441
169.962	0.477706	0.479506	0.48595
167.52	0.482507	0.48015	0.484524
165.079	0.483491	0.480911	0.486023
162.637	0.483769	0.481632	0.486827
160.195	0.484091	0.481622	0.487495
157.754	0.484762	0.481189	0.487572
155.312	0.484893	0.480736	0.486522
152.871	0.484069	0.480525	0.482444
150.429	0.483635	0.480524	0.48151
147.987	0.483624	0.480427	0.482103
145.546	0.483747	0.480347	0.481871
143.104	0.483685	0.480135	0.479758
140.663	0.483309	0.4799	0.479497
138.221	0.482981	0.479179	0.480618
135.779	0.482506	0.478437	0.482079
133.338	0.482112	0.478475	0.481547
130.896	0.481583	0.478697	0.479273
128.454	0.480876	0.476999	0.47952
126.013	0.480495	0.478302	0.479212
123.571	0.480048	0.478068	0.479194
121.13	0.47988	0.477874	0.479179
118.688	0.479747	0.477455	0.479061
116.246	0.478982	0.476845	0.478846
113.805	0.478209	0.476163	0.478384
111.363	0.47839	0.475396	0.477851
108.922	0.478077	0.475009	0.477486
106.48	0.47712	0.474785	0.476117
104.038	0.476914	0.474512	0.477204
101.597	0.476377	0.474069	0.474997
99.1551	0.47531	0.473647	0.474499
96.7135	0.474164	0.473111	0.475806
94.2719	0.472985	0.472363	0.475214
91.8302	0.471708	0.471684	0.474553
89.3886	0.470693	0.470735	0.473602
86.947	0.468894	0.469714	0.471892

84.5054	0.46625	0.46832	0.46992
82.0638	0.462958	0.465971	0.469091
79.6222	0.460786	0.463129	0.466485
77.1805	0.46042	0.460582	0.463538
74.7389	0.460232	0.458035	0.46077
72.2973	0.45952	0.455924	0.457835
69.8557	0.458412	0.454455	0.456215
67.4141	0.458403	0.453617	0.455256
64.9725	0.460528	0.454331	0.454213
62.5309	0.463617	0.456111	0.456613
60.0892	0.466123	0.458166	0.461408
57.6476	0.467717	0.461026	0.464204
55.206	0.468937	0.463565	0.466194
52.7644	0.469937	0.466927	0.467557
50.3228	0.470667	0.466887	0.468722
47.8812	0.470985	0.467654	0.469931
45.4395	0.471022	0.468185	0.470702
42.9979	0.470988	0.468269	0.470779
40.5563	0.47079	0.468045	0.470384
38.1147	0.470332	0.467478	0.469917
35.6731	0.469715	0.467056	0.469422
33.2315	0.469131	0.466756	0.468755
30.7898	0.468899	0.466796	0.468063
28.3482	0.468904	0.466627	0.467736
25.9066	0.469082	0.466356	0.467682
23.465	0.469207	0.466145	0.467972
21.0234	0.468729	0.465899	0.468234
18.5818	0.468213	0.465773	0.467925
16.1401	0.467975	0.465635	0.467703
13.6985	0.467826	0.465405	0.467644
11.2569	0.467826	0.465228	0.467735
8.8153	0.4679	0.465347	0.467458
6.37368	0.467758	0.465246	0.46678
3.93207	0.467879	0.464797	0.466425
1.49045	0.467941	0.464263	0.466315
-0.951166	0.468034	0.464028	0.466512
-3.39278	0.468377	0.464441	0.466691
-5.8344	0.46823	0.465232	0.466631
-8.27601	0.467739	0.466029	0.466732
-10.7176	0.467867	0.466418	0.466998
-13.1592	0.468375	0.466356	0.467162
-15.6009	0.468843	0.466172	0.467218

-18.0425	0.468973	0.465858	0.467159
-20.4841	0.468364	0.46592	0.467269
-22.9257	0.46778	0.466112	0.467819
-25.3673	0.467773	0.466273	0.469301
-27.8089	0.468084	0.466192	0.46876
-30.2506	0.468388	0.466069	0.469154
-32.6922	0.468546	0.465952	0.469346
-35.1338	0.468864	0.465876	0.469618
-37.5754	0.469291	0.465846	0.469864
-40.017	0.469471	0.465998	0.469929
-42.4586	0.469243	0.466352	0.469875
-44.9003	0.469149	0.466569	0.469832
-47.3419	0.469163	0.466445	0.46966
-49.7835	0.469126	0.466353	0.469559
-52.2251	0.468785	0.466421	0.469193
-54.6667	0.468365	0.466647	0.470696
-57.1083	0.468137	0.466548	0.470884
-59.5499	0.468019	0.466038	0.469128
-61.9916	0.467861	0.465566	0.468858
-64.4332	0.467301	0.464765	0.468003
-66.8748	0.466156	0.463413	0.466785
-69.3164	0.465129	0.46166	0.465141
-71.758	0.46403	0.460021	0.46331
-74.1996	0.46225	0.458663	0.461398
-76.6413	0.459993	0.457463	0.459729
-79.0829	0.457834	0.456763	0.458532
-81.5245	0.455631	0.455478	0.458411
-83.9661	0.45377	0.454406	0.457186
-86.4077	0.452741	0.454064	0.455047
-88.8493	0.451928	0.45347	0.452283
-91.291	0.450348	0.451876	0.449104
-93.7326	0.447767	0.447483	0.445768
-96.1742	0.441294	0.438917	0.438648
-98.6158	0.428585	0.424344	0.424907
-101.057	0.410102	0.403142	0.404282
-103.499	0.39218	0.385045	0.389111

Table 18 - Average velocities smooth airfoil 5° 65 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
195.625	0.433005	0.397758	0.427042

193.042	0.460853	0.400715	0.437802
190.459	0.475999	0.407094	0.461127
187.877	0.494479	0.417065	0.477151
185.294	0.498242	0.428101	0.479033
182.711	0.495323	0.432375	0.482788
180.129	0.499081	0.434933	0.486895
177.546	0.494863	0.451233	0.490458
174.964	0.492661	0.460221	0.486751
172.381	0.49003	0.468353	0.487128
169.798	0.483544	0.475514	0.487647
167.216	0.482591	0.475024	0.490618
164.633	0.482532	0.479873	0.486778
162.051	0.483269	0.480784	0.486157
159.468	0.485489	0.480579	0.485804
156.885	0.486996	0.477892	0.485492
154.303	0.486897	0.477516	0.485456
151.72	0.485816	0.477485	0.485535
149.138	0.484797	0.478495	0.48357
146.555	0.484372	0.481896	0.484879
143.972	0.484178	0.482581	0.483941
141.39	0.48411	0.482865	0.483937
138.807	0.483973	0.483036	0.482566
136.225	0.483794	0.482795	0.482625
133.642	0.483533	0.482467	0.482836
131.059	0.482627	0.482018	0.482715
128.477	0.482618	0.481593	0.482112
125.894	0.482418	0.481113	0.481709
123.312	0.482152	0.480853	0.481698
120.729	0.479462	0.480688	0.481704
118.146	0.480816	0.48053	0.48135
115.564	0.480578	0.480048	0.480631
112.981	0.480514	0.479632	0.480033
110.398	0.480754	0.47943	0.479675
107.816	0.480444	0.479385	0.479673
105.233	0.480449	0.479388	0.479755
102.651	0.481931	0.479289	0.47956
100.068	0.481991	0.479265	0.479222
97.4854	0.481901	0.478945	0.478987
94.9028	0.481612	0.478162	0.478778
92.3202	0.479314	0.477468	0.478766
89.7376	0.478858	0.477251	0.4788
87.155	0.478757	0.477272	0.47868

84.5724	0.478602	0.477163	0.478474
81.9898	0.478062	0.476436	0.477759
79.4072	0.477059	0.476002	0.476735
76.8246	0.475346	0.474976	0.474471
74.242	0.472801	0.472631	0.470727
71.6593	0.469059	0.468191	0.465997
69.0767	0.464411	0.462619	0.460697
66.4941	0.458727	0.456867	0.455105
63.9115	0.453666	0.451749	0.449782
61.3289	0.449864	0.448477	0.445993
58.7463	0.450064	0.447399	0.445414
56.1637	0.453719	0.449653	0.448839
53.5811	0.459704	0.454937	0.455483
50.9985	0.466065	0.460783	0.462712
48.4159	0.470732	0.466298	0.469184
45.8333	0.473068	0.470317	0.472492
43.2507	0.474235	0.473403	0.475409
40.668	0.474912	0.475443	0.475753
38.0854	0.475452	0.475833	0.475203
35.5028	0.475303	0.475238	0.47467
32.9202	0.474396	0.474234	0.474298
30.3376	0.473281	0.473842	0.474336
27.755	0.472391	0.47386	0.474352
25.1724	0.471998	0.473993	0.473802
22.5898	0.47205	0.473886	0.472735
20.0072	0.471986	0.473212	0.471563
17.4246	0.47176	0.47249	0.470695
14.842	0.4716	0.471843	0.470414
12.2594	0.471469	0.471316	0.470272
9.67675	0.471026	0.470956	0.47016
7.09415	0.470858	0.470707	0.470179
4.51154	0.470782	0.470776	0.470795
1.92893	0.470647	0.471568	0.471114
-0.653677	0.470457	0.472428	0.471499
-3.23629	0.47008	0.472503	0.471988
-5.81889	0.470211	0.471845	0.472158
-8.4015	0.470312	0.470909	0.472131
-10.9841	0.470536	0.470396	0.471769
-13.5667	0.470469	0.47031	0.471308
-16.1493	0.470218	0.470671	0.470703
-18.7319	0.469855	0.47103	0.470489
-21.3145	0.469688	0.47103	0.470937

-23.8972	0.469859	0.470755	0.471377
-26.4798	0.470049	0.4706	0.471497
-29.0624	0.470522	0.47079	0.471456
-31.645	0.470961	0.470787	0.471345
-34.2276	0.470908	0.47071	0.471263
-36.8102	0.470713	0.470716	0.471396
-39.3928	0.470438	0.471105	0.471487
-41.9754	0.470469	0.47115	0.471179
-44.558	0.470475	0.47088	0.47049
-47.1406	0.47026	0.470541	0.469528
-49.7232	0.470086	0.470029	0.468732
-52.3058	0.469733	0.469471	0.468184
-54.8884	0.469646	0.468446	0.46786
-57.4711	0.469563	0.466838	0.467304
-60.0537	0.468987	0.464757	0.466393
-62.6363	0.467996	0.462399	0.465308
-65.2189	0.466275	0.460005	0.463754
-67.8015	0.463978	0.457793	0.462178
-70.3841	0.461296	0.455738	0.460512
-72.9667	0.458353	0.453579	0.457959
-75.5493	0.455096	0.451614	0.45379
-78.1319	0.450935	0.449276	0.448515
-80.7145	0.446438	0.446603	0.443065
-83.2971	0.441071	0.442437	0.437301
-85.8797	0.434837	0.436326	0.431151
-88.4623	0.426733	0.428146	0.42421
-91.045	0.415631	0.416352	0.415024
-93.6276	0.401567	0.400814	0.400881
-96.2102	0.383371	0.380827	0.382156
-98.7928	0.364612	0.36066	0.363145
-86.4077	0.452741	0.454064	0.455047
-88.8493	0.451928	0.45347	0.452283
-91.291	0.450348	0.451876	0.449104
-93.7326	0.447767	0.447483	0.445768
-96.1742	0.441294	0.438917	0.438648
-98.6158	0.428585	0.424344	0.424907
-101.057	0.410102	0.403142	0.404282
-103.499	0.39218	0.385045	0.389111

Table 19 - Average velocities smooth airfoil 8° 65 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
194.378	0.358253	0.327192	0.304992
191.937	0.376895	0.349015	0.334885
189.495	0.392113	0.370504	0.360138
187.053	0.411617	0.390282	0.382907
184.612	0.420328	0.415502	0.402543
182.17	0.433667	0.429187	0.416449
179.728	0.448692	0.447827	0.439218
177.287	0.461133	0.463167	0.451364
174.845	0.477678	0.473452	0.470073
172.404	0.485646	0.486547	0.484775
169.962	0.486674	0.490593	0.494069
167.52	0.489316	0.48867	0.49612
165.079	0.486696	0.488383	0.494697
162.637	0.487428	0.489428	0.489085
160.195	0.487634	0.488223	0.493009
157.754	0.487658	0.488408	0.494231
155.312	0.487994	0.488317	0.488295
152.871	0.487455	0.488198	0.487019
150.429	0.486799	0.487979	0.487227
147.987	0.486295	0.488092	0.48514
145.546	0.487492	0.488079	0.48563
143.104	0.488878	0.487194	0.485581
140.663	0.485734	0.486677	0.485503
138.221	0.485554	0.486079	0.48538
135.779	0.485139	0.485755	0.484868
133.338	0.484431	0.485516	0.484584
130.896	0.483758	0.485181	0.484201
128.454	0.48341	0.485156	0.48374
126.013	0.483507	0.485565	0.483586
123.571	0.483416	0.485922	0.483346
121.13	0.483252	0.484714	0.483203
118.688	0.482858	0.483815	0.482908
116.246	0.481988	0.483648	0.48228
113.805	0.480857	0.483278	0.481649
111.363	0.480023	0.482692	0.480456
108.922	0.479631	0.482043	0.479323
106.48	0.479792	0.481442	0.478973
104.038	0.479822	0.481121	0.479005
101.597	0.479399	0.481129	0.478984

99.1551	0.479117	0.481243	0.478495
96.7135	0.479102	0.480704	0.478206
94.2719	0.479013	0.479572	0.477859
91.8302	0.478592	0.478393	0.477376
89.3886	0.478095	0.477267	0.476752
86.947	0.47778	0.476091	0.476229
84.5054	0.477371	0.474551	0.475964
82.0638	0.476283	0.472253	0.475062
79.6222	0.475011	0.469089	0.472616
77.1805	0.473136	0.465102	0.469595
74.7389	0.470787	0.461134	0.465897
72.2973	0.466924	0.456564	0.461069
69.8557	0.461181	0.451403	0.455567
67.4141	0.454113	0.446113	0.449084
64.9725	0.44697	0.440604	0.443078
62.5309	0.440692	0.435873	0.438024
60.0892	0.436591	0.43224	0.433492
57.6476	0.433442	0.429557	0.429775
55.206	0.430737	0.428402	0.426679
52.7644	0.429806	0.42895	0.425856
50.3228	0.432089	0.430734	0.426388
47.8812	0.437048	0.434042	0.434286
45.4395	0.44499	0.438489	0.439058
42.9979	0.450872	0.44291	0.444371
40.5563	0.457428	0.450794	0.449611
38.1147	0.462062	0.454507	0.45618
35.6731	0.465256	0.458785	0.461403
33.2315	0.467341	0.462625	0.465312
30.7898	0.468706	0.46663	0.467825
28.3482	0.469376	0.469109	0.469163
25.9066	0.470053	0.470773	0.469846
23.465	0.470506	0.471736	0.470059
21.0234	0.470819	0.472117	0.470181
18.5818	0.470959	0.471677	0.470115
16.1401	0.470727	0.471246	0.469805
13.6985	0.470247	0.471254	0.469532
11.2569	0.469835	0.47177	0.469305
8.8153	0.46969	0.472275	0.46945
6.37368	0.46986	0.471882	0.469714
3.93207	0.470116	0.471381	0.469818
1.49045	0.470344	0.472654	0.46975
-0.951166	0.470682	0.47003	0.469782

-3.39278	0.470902	0.469549	0.469891
-5.8344	0.470813	0.469901	0.469763
-8.27601	0.470723	0.469332	0.469943
-10.7176	0.470557	0.467665	0.470468
-13.1592	0.470181	0.468267	0.47128
-15.6009	0.469617	0.4713	0.47169
-18.0425	0.469233	0.471638	0.471128
-20.4841	0.469528	0.472528	0.470445
-22.9257	0.47	0.472821	0.470425
-25.3673	0.469819	0.472588	0.47075
-27.8089	0.469389	0.472296	0.470568
-30.2506	0.469182	0.472175	0.47038
-32.6922	0.469345	0.472251	0.470612
-35.1338	0.469655	0.472139	0.471077
-37.5754	0.46974	0.472063	0.471497
-40.017	0.469434	0.471901	0.471552
-42.4586	0.469185	0.472191	0.471501
-44.9003	0.469012	0.472312	0.471652
-47.3419	0.469061	0.474194	0.471394
-49.7835	0.46921	0.473859	0.471239
-52.2251	0.469335	0.471861	0.471144
-54.6667	0.469606	0.471407	0.471064
-57.1083	0.469678	0.471008	0.471308
-59.5499	0.469586	0.470374	0.471257
-61.9916	0.469343	0.469905	0.470894
-64.4332	0.468234	0.469641	0.469916
-66.8748	0.466759	0.469202	0.468815
-69.3164	0.465369	0.468503	0.468031
-71.758	0.464585	0.46736	0.467551
-74.1996	0.464067	0.466055	0.467127
-76.6413	0.463221	0.465135	0.465706
-79.0829	0.46201	0.464452	0.46342
-81.5245	0.460547	0.463454	0.460939
-83.9661	0.458826	0.462499	0.458912
-86.4077	0.456975	0.461451	0.458199
-88.8493	0.455288	0.45967	0.457701
-91.291	0.453272	0.459381	0.456407
-93.7326	0.449758	0.45807	0.453779
-96.1742	0.443303	0.451346	0.448006
-98.6158	0.431996	0.438377	0.436194
-101.057	0.41548	0.419051	0.422753
-103.499	0.400268	0.402477	0.4067

Table 20 - Average velocities smooth airfoil 10° 65 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
195.625	0.434984	0.381307	0.439944
193.042	0.442315	0.395416	0.45045
190.459	0.456172	0.420233	0.466335
187.877	0.475792	0.432076	0.475393
185.294	0.477374	0.451411	0.490326
182.711	0.481067	0.451251	0.4998
180.129	0.483543	0.461094	0.501704
177.546	0.486415	0.465154	0.497534
174.964	0.49053	0.475431	0.493847
172.381	0.489759	0.482042	0.488819
169.798	0.488512	0.481973	0.487169
167.216	0.487989	0.481523	0.487866
164.633	0.48359	0.48827	0.489002
162.051	0.481758	0.486149	0.486164
159.468	0.478427	0.485984	0.485145
156.885	0.476664	0.485028	0.480755
154.303	0.477028	0.482576	0.477456
151.72	0.477085	0.478792	0.476013
149.138	0.475602	0.476102	0.475342
146.555	0.471939	0.474798	0.473881
143.972	0.46803	0.472441	0.472586
141.39	0.463165	0.471166	0.470038
138.807	0.463097	0.47053	0.468222
136.225	0.460523	0.4696	0.467307
133.642	0.457315	0.467693	0.466041
131.059	0.455544	0.465174	0.464596
128.477	0.45493	0.462977	0.462519
125.894	0.454787	0.459637	0.460264
123.312	0.455279	0.458884	0.459082
120.729	0.45196	0.460744	0.458988
118.146	0.449607	0.463181	0.458307
115.564	0.447289	0.462015	0.456527
112.981	0.445717	0.460527	0.454422
110.398	0.44245	0.453136	0.452677
107.816	0.439882	0.451657	0.450824

105.233	0.437478	0.449064	0.450318
102.651	0.436732	0.448198	0.45003
100.068	0.435809	0.448079	0.450383
97.4854	0.435925	0.447981	0.450899
94.9028	0.435409	0.447088	0.451146
92.3202	0.434446	0.445384	0.451608
89.7376	0.434313	0.443511	0.451845
87.155	0.434351	0.443361	0.450745
84.5724	0.433869	0.445045	0.448896
81.9898	0.432908	0.446814	0.447325
79.4072	0.432218	0.447619	0.445209
76.8246	0.432061	0.447027	0.442473
74.242	0.432116	0.446796	0.440499
71.6593	0.432592	0.446214	0.437994
69.0767	0.433276	0.445841	0.436095
66.4941	0.43422	0.446216	0.436393
63.9115	0.434791	0.446407	0.439425
61.3289	0.436075	0.446348	0.44303
58.7463	0.437988	0.446308	0.443338
56.1637	0.441399	0.446394	0.444109
53.5811	0.445003	0.446544	0.445246
50.9985	0.447461	0.446479	0.4476
48.4159	0.447904	0.446137	0.448249
45.8333	0.448609	0.448066	0.449242
43.2507	0.450607	0.450795	0.450316
40.668	0.452076	0.452587	0.451752
38.0854	0.453653	0.454429	0.453982
35.5028	0.455575	0.457174	0.456756
32.9202	0.457789	0.460345	0.459907
30.3376	0.459776	0.463488	0.463455
27.755	0.461789	0.466165	0.463479
25.1724	0.463266	0.46806	0.464633
22.5898	0.464951	0.469613	0.465786
20.0072	0.467843	0.47142	0.467399
17.4246	0.471213	0.4738	0.46939
14.842	0.472905	0.475964	0.471332
12.2594	0.473251	0.477308	0.472254
9.67675	0.47239	0.477872	0.472188
7.09415	0.471773	0.478074	0.472531
4.51154	0.471904	0.477985	0.473525
1.92893	0.473103	0.477855	0.475023
-0.653677	0.474454	0.477769	0.477033

-3.23629	0.474938	0.476953	0.478084
-5.81889	0.475101	0.476142	0.478656
-8.4015	0.475728	0.476342	0.47909
-10.9841	0.476837	0.477522	0.479545
-13.5667	0.477857	0.47877	0.479597
-16.1493	0.478118	0.479572	0.479569
-18.7319	0.477625	0.479991	0.479415
-21.3145	0.477287	0.480253	0.479324
-23.8972	0.477276	0.480106	0.479396
-26.4798	0.477422	0.479597	0.479415
-29.0624	0.47772	0.479148	0.479619
-31.645	0.477852	0.479284	0.479802
-34.2276	0.477672	0.479431	0.480039
-36.8102	0.477256	0.479515	0.480164
-39.3928	0.47694	0.479448	0.479833
-41.9754	0.476415	0.479603	0.47938
-44.558	0.476342	0.480006	0.479133
-47.1406	0.476812	0.480154	0.479024
-49.7232	0.477375	0.48002	0.479058
-52.3058	0.477357	0.479484	0.478935
-54.8884	0.476664	0.478223	0.478959
-57.4711	0.47547	0.476506	0.479109
-60.0537	0.47419	0.474749	0.479103
-62.6363	0.472997	0.473567	0.478101
-65.2189	0.471122	0.472952	0.47594
-67.8015	0.468709	0.472169	0.472801
-70.3841	0.465962	0.470645	0.469809
-72.9667	0.463168	0.46833	0.467312
-75.5493	0.460503	0.465054	0.464586
-78.1319	0.457714	0.461128	0.461219
-80.7145	0.454344	0.457291	0.457448
-83.2971	0.45015	0.452688	0.452917
-85.8797	0.444218	0.447537	0.447897
-88.4623	0.435685	0.441578	0.442413
-91.045	0.424606	0.433633	0.43546
-93.6276	0.410752	0.421934	0.424342
-96.2102	0.39367	0.405199	0.406625
-98.7928	0.376733	0.38779	0.386176
-86.4077	0.456975	0.461451	0.458199
-88.8493	0.455288	0.45967	0.457701
-91.291	0.453272	0.459381	0.456407
-93.7326	0.449758	0.45807	0.453779

-96.1742	0.443303	0.451346	0.448006
-98.6158	0.431996	0.438377	0.436194
-101.057	0.41548	0.419051	0.422753
-103.499	0.400268	0.402477	0.4067

Table 21 - Average velocities smooth airfoil 15° 65 Hz

Y-Position (mm)	Smooth 1 (m/s)	Smooth 2 (m/s)	Smooth 3 (m/s)
194.378	0.377861	0.389508	0.337266
191.937	0.39757	0.397533	0.389586
189.495	0.414493	0.412884	0.421501
187.053	0.437158	0.44122	0.458511
184.612	0.455921	0.457452	0.472723
182.17	0.474863	0.483758	0.482822
179.728	0.484342	0.498362	0.489931
177.287	0.490402	0.50292	0.494591
174.845	0.497163	0.49871	0.497177
172.404	0.498111	0.500078	0.496407
169.962	0.501464	0.503969	0.497721
167.52	0.496604	0.504444	0.500289
165.079	0.497682	0.503917	0.497924
162.637	0.500024	0.504122	0.497371
160.195	0.497629	0.502768	0.498352
157.754	0.496933	0.497289	0.495234
155.312	0.49513	0.495058	0.49165
152.871	0.490843	0.492696	0.489802
150.429	0.489931	0.490075	0.490585
147.987	0.486937	0.489401	0.489817
145.546	0.484626	0.48783	0.488056
143.104	0.483279	0.485205	0.485356
140.663	0.482294	0.48067	0.480922
138.221	0.480041	0.476761	0.478417
135.779	0.477508	0.475669	0.474817
133.338	0.475384	0.474605	0.474784
130.896	0.474194	0.477509	0.474928
128.454	0.47368	0.472362	0.473507
126.013	0.473463	0.46887	0.468585
123.571	0.47191	0.464663	0.461898
121.13	0.468929	0.464037	0.455897

118.688	0.46512	0.46058	0.452307
116.246	0.459977	0.455335	0.448745
113.805	0.454647	0.449419	0.445866
111.363	0.451865	0.44455	0.442436
108.922	0.449616	0.441073	0.43946
106.48	0.445853	0.440218	0.436945
104.038	0.440377	0.436767	0.435385
101.597	0.435881	0.433209	0.434597
99.1551	0.430621	0.429262	0.434427
96.7135	0.426315	0.427587	0.433735
94.2719	0.424242	0.426767	0.432808
91.8302	0.424008	0.42622	0.429367
89.3886	0.42494	0.424838	0.425245
86.947	0.425286	0.423688	0.42171
84.5054	0.425073	0.421392	0.419034
82.0638	0.422733	0.420439	0.417547
79.6222	0.421227	0.419042	0.417228
77.1805	0.41983	0.416651	0.416735
74.7389	0.418489	0.414257	0.415608
72.2973	0.416059	0.412845	0.416462
69.8557	0.417191	0.413667	0.417097
67.4141	0.417665	0.415003	0.417457
64.9725	0.421206	0.415893	0.417247
62.5309	0.419177	0.417128	0.416992
60.0892	0.41791	0.416948	0.418321
57.6476	0.418911	0.419395	0.420309
55.206	0.419117	0.419656	0.42159
52.7644	0.420949	0.418061	0.424494
50.3228	0.421728	0.416545	0.42704
47.8812	0.422855	0.417748	0.428387
45.4395	0.424434	0.42042	0.430418
42.9979	0.426228	0.423718	0.433549
40.5563	0.428281	0.426402	0.43491
38.1147	0.430593	0.428598	0.43607
35.6731	0.433381	0.429936	0.438214
33.2315	0.43629	0.433143	0.439495
30.7898	0.43881	0.438959	0.444267
28.3482	0.441056	0.445453	0.449114
25.9066	0.444018	0.45029	0.451925
23.465	0.447241	0.456064	0.454184
21.0234	0.449937	0.457051	0.458033
18.5818	0.452862	0.460139	0.46165

16.1401	0.457056	0.463084	0.463594
13.6985	0.460205	0.465441	0.465298
11.2569	0.462957	0.466743	0.467446
8.8153	0.466776	0.467597	0.470376
6.37368	0.469729	0.4692	0.473544
3.93207	0.471087	0.471478	0.475221
1.49045	0.47059	0.474566	0.476441
-0.951166	0.470315	0.477249	0.477785
-3.39278	0.470503	0.479026	0.478455
-5.8344	0.471794	0.480106	0.47914
-8.27601	0.474609	0.480837	0.480548
-10.7176	0.478594	0.481069	0.483264
-13.1592	0.4818	0.481634	0.485277
-15.6009	0.484241	0.482393	0.485402
-18.0425	0.485975	0.482739	0.484739
-20.4841	0.48691	0.482702	0.484655
-22.9257	0.486682	0.482313	0.485593
-25.3673	0.486937	0.482227	0.48717
-27.8089	0.487411	0.482847	0.488132
-30.2506	0.488133	0.483876	0.488259
-32.6922	0.489102	0.484865	0.488971
-35.1338	0.490062	0.485856	0.48968
-37.5754	0.490747	0.48658	0.490282
-40.017	0.491039	0.486756	0.490775
-42.4586	0.491149	0.487237	0.491178
-44.9003	0.490337	0.487904	0.490991
-47.3419	0.489268	0.487986	0.490566
-49.7835	0.488468	0.487249	0.489214
-52.2251	0.487979	0.486205	0.489547
-54.6667	0.488332	0.486342	0.490368
-57.1083	0.48873	0.486662	0.490259
-59.5499	0.488651	0.486218	0.487856
-61.9916	0.488422	0.484699	0.486657
-64.4332	0.487656	0.483153	0.485893
-66.8748	0.487226	0.482378	0.485371
-69.3164	0.486764	0.481748	0.485339
-71.758	0.485217	0.480801	0.483016
-74.1996	0.482429	0.479566	0.480059
-76.6413	0.479295	0.478369	0.477893
-79.0829	0.47608	0.47673	0.476886
-81.5245	0.473667	0.474164	0.475796
-83.9661	0.472638	0.471643	0.474376

-86.4077	0.472296	0.469609	0.472771
-88.8493	0.472016	0.468062	0.470573
-91.291	0.470316	0.465874	0.468544
-93.7326	0.466648	0.462315	0.464875
-96.1742	0.460274	0.45634	0.456758
-98.6158	0.446956	0.443355	0.441367
-101.057	0.428608	0.424149	0.41975
-103.499	0.412757	0.406949	0.40183

Table 22 - Average velocities bumped airfoil -5° 7 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
195.625	0.0357473	0.0407399	0.0365623
193.042	0.04107	0.0434402	0.0396655
190.459	0.045397	0.0458559	0.0449329
187.877	0.0502323	0.0496825	0.0483969
185.294	0.0529685	0.0526608	0.0499111
182.711	0.0537472	0.0545919	0.051974
180.129	0.0540878	0.0553629	0.053448
177.546	0.0552946	0.0548742	0.0542029
174.964	0.0555048	0.0554035	0.054144
172.381	0.0551861	0.0554465	0.0543977
169.798	0.0552062	0.0556131	0.054461
167.216	0.0554477	0.0554349	0.0546231
164.633	0.0554122	0.0551766	0.054759
162.051	0.0554623	0.0549504	0.0549343
159.468	0.0558525	0.0549087	0.0552074
156.885	0.0558406	0.0551236	0.0555476
154.303	0.0555548	0.0551939	0.0554323
151.72	0.0553795	0.0550582	0.0552522
149.138	0.0552876	0.054639	0.0551387
146.555	0.0551963	0.0542627	0.055129
143.972	0.0551164	0.0540294	0.0551537
141.39	0.0550434	0.0539266	0.0550466
138.807	0.0550576	0.0539846	0.0549615
136.225	0.055113	0.0546297	0.055
133.642	0.0551157	0.0546349	0.0550193
131.059	0.0548506	0.0549572	0.0551598
128.477	0.055131	0.0550386	0.0551651

125.894	0.0550667	0.0550006	0.0550939
123.312	0.0549551	0.054836	0.0550155
120.729	0.0549168	0.0546437	0.05492
118.146	0.0546572	0.0544852	0.0547663
115.564	0.0545437	0.0543726	0.0545928
112.981	0.0545793	0.0541651	0.0543515
110.398	0.0542438	0.0538879	0.0541751
107.816	0.0536748	0.0533397	0.0534436
105.233	0.0529285	0.0525826	0.0528275
102.651	0.0519739	0.0516912	0.0520269
100.068	0.050849	0.0507302	0.0511263
97.4854	0.0496599	0.049688	0.0501072
94.9028	0.0484274	0.0484595	0.0489623
92.3202	0.0472927	0.047259	0.0478078
89.7376	0.046369	0.0463906	0.0467892
87.155	0.0457578	0.0456896	0.0461089
84.5724	0.0455484	0.0454538	0.0457384
81.9898	0.0457962	0.0454456	0.0456307
79.4072	0.0464263	0.0459291	0.0458458
76.8246	0.0474017	0.0467957	0.0463699
74.242	0.0485883	0.0478384	0.0472445
71.6593	0.0498904	0.0488458	0.0482791
69.0767	0.0511473	0.0498659	0.0493359
66.4941	0.0524513	0.0509584	0.0502294
63.9115	0.0529561	0.0518275	0.0510428
61.3289	0.0533462	0.052828	0.0518073
58.7463	0.0535715	0.0537801	0.0524387
56.1637	0.0537661	0.0541466	0.0530148
53.5811	0.0538755	0.0542056	0.0534445
50.9985	0.0539028	0.0544844	0.0536314
48.4159	0.0539222	0.0542167	0.0537878
45.8333	0.0538997	0.0539234	0.0539537
43.2507	0.0538296	0.0541063	0.0540407
40.668	0.0538119	0.0540015	0.0540653
38.0854	0.0538402	0.0539175	0.0539624
35.5028	0.0538279	0.0539052	0.0538522
32.9202	0.0537914	0.0539241	0.0537759
30.3376	0.0537487	0.0538798	0.0537145
27.755	0.0537129	0.0538119	0.0535818
25.1724	0.0532764	0.0536706	0.0534587
22.5898	0.0534227	0.053414	0.0534288
20.0072	0.0534016	0.0533264	0.0533886

17.4246	0.0534304	0.0534066	0.0533646
14.842	0.0534969	0.0535197	0.0533875
12.2594	0.0535366	0.0535684	0.0533921
9.67675	0.0535061	0.0536098	0.0533906
7.09415	0.0535327	0.0536167	0.0534691
4.51154	0.0535083	0.0535561	0.0534095
1.92893	0.0535174	0.0535231	0.0534836
-0.653677	0.05356	0.0535346	0.0534415
-3.23629	0.0535927	0.0534611	0.053616
-5.81889	0.0536134	0.0534541	0.0537211
-8.4015	0.0536058	0.0535688	0.0537145
-10.9841	0.0535799	0.0536706	0.0536951
-13.5667	0.0536003	0.0536753	0.0536671
-16.1493	0.0536582	0.0535945	0.0536483
-18.7319	0.0537308	0.0535488	0.0536339
-21.3145	0.0537885	0.0535437	0.0535707
-23.8972	0.053733	0.0535924	0.0535299
-26.4798	0.0536639	0.0536448	0.0535785
-29.0624	0.0536842	0.0536321	0.0536178
-31.645	0.0537481	0.0536411	0.0536141
-34.2276	0.0537996	0.0536827	0.0536006
-36.8102	0.053764	0.0536848	0.053545
-39.3928	0.0537206	0.0536357	0.0535036
-41.9754	0.053706	0.0535952	0.0534624
-44.558	0.0537012	0.0535668	0.0534524
-47.1406	0.0537225	0.0535985	0.0534591
-49.7232	0.0537305	0.0536536	0.0534561
-52.3058	0.0537247	0.0537152	0.0534958
-54.8884	0.0537244	0.0537466	0.0535075
-57.4711	0.0537102	0.0536947	0.0534887
-60.0537	0.0536712	0.0535768	0.053466
-62.6363	0.0535825	0.0534184	0.0534076
-65.2189	0.0534211	0.0531991	0.053268
-67.8015	0.0531283	0.0528829	0.0530453
-70.3841	0.0526766	0.0524765	0.0527063
-72.9667	0.0520783	0.0519961	0.0523073
-75.5493	0.0514281	0.05141	0.0518368
-78.1319	0.0507707	0.0507911	0.0513406
-80.7145	0.0501754	0.0502325	0.050879
-83.2971	0.0497408	0.0498461	0.0505015
-85.8797	0.0496612	0.0497866	0.0503337
-88.4623	0.049875	0.0499242	0.0503194

-91.045	0.0497183	0.0497861	0.0499641
-93.6276	0.0480892	0.0484801	0.0484486
-96.2102	0.0440246	0.0455768	0.0451957
-98.7928	0.0376259	0.0403018	0.0397071

Table 23 - Average velocities bumped airfoil 0° 7 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
194.378	0.0280039	0.0271513	0.0224568
191.937	0.0325315	0.0315727	0.0299544
189.495	0.0375771	0.0383431	0.0382985
187.053	0.0435313	0.0447258	0.0439559
184.612	0.0480534	0.0495426	0.0484274
182.17	0.0500805	0.0529639	0.0505127
179.728	0.052013	0.0544812	0.0521278
177.287	0.0535373	0.0551691	0.0537328
174.845	0.0539856	0.0556822	0.0545397
172.404	0.0544403	0.0557487	0.0545147
169.962	0.0548264	0.0556252	0.0549257
167.52	0.0551657	0.055162	0.0551907
165.079	0.0553067	0.0554745	0.0553218
162.637	0.0554189	0.0557331	0.0553766
160.195	0.0554694	0.0555559	0.0552866
157.754	0.055432	0.0552362	0.0553533
155.312	0.0553863	0.0551787	0.0553599
152.871	0.0554198	0.0554911	0.0554315
150.429	0.0553634	0.0554643	0.0553622
147.987	0.055202	0.0553654	0.0553383
145.546	0.0551588	0.0553526	0.0552214
143.104	0.055229	0.0553633	0.0552107
140.663	0.0553151	0.055348	0.0551713

138.221	0.0553563	0.0552733	0.0550694
135.779	0.0552779	0.0552055	0.0551916
133.338	0.0552067	0.0552062	0.0551589
130.896	0.0551977	0.055199	0.0550937
128.454	0.0552179	0.0551477	0.0547222
126.013	0.0552578	0.0551627	0.0549673
123.571	0.0552194	0.0551716	0.0550262
121.13	0.0551904	0.0554172	0.0550255
118.688	0.055155	0.0554423	0.0549592
116.246	0.055044	0.0554103	0.0548612
113.805	0.0549223	0.0551026	0.0546844
111.363	0.0546914	0.0548968	0.0544552
108.922	0.0545027	0.0547356	0.0542955
106.48	0.0543743	0.0546709	0.0543114
104.038	0.0542434	0.0547046	0.0544009
101.597	0.0542092	0.0547892	0.0544376
99.1551	0.0540453	0.0547262	0.0544215
96.7135	0.0538771	0.0544933	0.0543403
94.2719	0.0534829	0.0541172	0.0541321
91.8302	0.0529331	0.0536692	0.0537429
89.3886	0.0524131	0.0530915	0.0532368
86.947	0.0519312	0.0524348	0.0526808
84.5054	0.051412	0.0518215	0.0521452
82.0638	0.0508953	0.0512132	0.0514669
79.6222	0.0505176	0.0507315	0.0510454
77.1805	0.0503507	0.0505734	0.0508021
74.7389	0.0503619	0.0504816	0.0507429
72.2973	0.050422	0.0504217	0.0506801
69.8557	0.0504927	0.0504347	0.0507732
67.4141	0.0505969	0.050557	0.0509404
64.9725	0.0509078	0.0508167	0.0511511
62.5309	0.0515232	0.0513196	0.0515461
60.0892	0.0522409	0.0521001	0.0521643
57.6476	0.0529513	0.0530159	0.0527523
55.206	0.0535985	0.0536076	0.0531637
52.7644	0.0537882	0.0538782	0.0534635
50.3228	0.0538836	0.0537559	0.0535753
47.8812	0.0539604	0.0536568	0.0535995
45.4395	0.0539675	0.0536416	0.0536009
42.9979	0.0539101	0.0536041	0.0536568
40.5563	0.0538128	0.0535013	0.0537269
38.1147	0.0536141	0.0534763	0.053777

35.6731	0.0534125	0.0533604	0.0537622
33.2315	0.0531738	0.0533007	0.0539586
30.7898	0.0530175	0.0533212	0.0534994
28.3482	0.0529594	0.0532813	0.053308
25.9066	0.0529811	0.0532348	0.0532047
23.465	0.0531893	0.0532494	0.0532809
21.0234	0.0531276	0.053219	0.0533326
18.5818	0.0530945	0.0532136	0.0532986
16.1401	0.0529492	0.0531702	0.0532957
13.6985	0.0528125	0.0530324	0.0532713
11.2569	0.0527187	0.0529807	0.0532043
8.8153	0.0527605	0.0530096	0.0530801
6.37368	0.0528857	0.0530188	0.0530443
3.93207	0.0529392	0.053048	0.0530907
1.49045	0.0529993	0.0531044	0.0532104
-0.951166	0.0529857	0.0531204	0.0532613
-3.39278	0.0529574	0.0531675	0.0532525
-5.8344	0.0529881	0.0532029	0.0531766
-8.27601	0.0530846	0.0532563	0.0531914
-10.7176	0.0532931	0.053449	0.0532958
-13.1592	0.0532997	0.0536189	0.0534552
-15.6009	0.0531755	0.053662	0.0534577
-18.0425	0.0530726	0.0536579	0.0533596
-20.4841	0.0530432	0.0535758	0.0532735
-22.9257	0.0532347	0.0534518	0.0532856
-25.3673	0.0533564	0.0533918	0.0533409
-27.8089	0.0534671	0.0533656	0.0533188
-30.2506	0.0534998	0.0534277	0.0532776
-32.6922	0.0534172	0.053506	0.0532298
-35.1338	0.0533348	0.0535025	0.0531806
-37.5754	0.0533038	0.0535878	0.0531326
-40.017	0.0533022	0.0536859	0.0530671
-42.4586	0.0533561	0.0536983	0.0530449
-44.9003	0.0534087	0.0537081	0.053046
-47.3419	0.0534354	0.0537132	0.053049
-49.7835	0.0534216	0.0536661	0.0530395
-52.2251	0.0533888	0.0536672	0.0529659
-54.6667	0.0533716	0.0536814	0.0529601
-57.1083	0.0533332	0.053663	0.0529531
-59.5499	0.053327	0.0536163	0.0529129
-61.9916	0.0533946	0.053535	0.0528885
-64.4332	0.0533437	0.0534467	0.0528478

-66.8748	0.0531987	0.0533869	0.0527542
-69.3164	0.0529173	0.0532093	0.0525573
-71.758	0.0525306	0.0528661	0.0523059
-74.1996	0.0520652	0.0524611	0.0519474
-76.6413	0.05155	0.0520257	0.051484
-79.0829	0.051066	0.0516779	0.0509602
-81.5245	0.0506283	0.0512515	0.0505348
-83.9661	0.0502356	0.0509156	0.0502451
-86.4077	0.0500091	0.0506283	0.0500718
-88.8493	0.0500097	0.0504904	0.0500423
-91.291	0.0501556	0.0505346	0.0501538
-93.7326	0.0503585	0.0508379	0.0503952
-96.1742	0.0503493	0.0511395	0.0504911
-98.6158	0.0492803	0.0507507	0.0498671
-101.057	0.0464947	0.0489799	0.0479545
-103.499	0.0436097	0.0471865	0.0459446

Table 24 - Average velocities bumped airfoil 5° 7 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
195.625	0.0406101	0.0332999	0.033772
193.042	0.0454694	0.0384772	0.0356033
190.459	0.0487128	0.0411948	0.0394099
187.877	0.0516763	0.0442638	0.0440853
185.294	0.0549716	0.0468634	0.0479401
182.711	0.0558241	0.0496623	0.050201
180.129	0.0567319	0.0524955	0.0521466
177.546	0.056338	0.0533196	0.0544416
174.964	0.0565947	0.0534919	0.053234
172.381	0.0560108	0.0540577	0.0543234
169.798	0.0562151	0.0545861	0.055116
167.216	0.0559558	0.0542687	0.0537038
164.633	0.0556984	0.0545193	0.0539332
162.051	0.055574	0.0539441	0.054434
159.468	0.0557887	0.0540495	0.0549674
156.885	0.0557688	0.0539999	0.0550327
154.303	0.055722	0.0542673	0.0553462
151.72	0.0552387	0.054564	0.0548408
149.138	0.0553284	0.0553222	0.0547575

146.555	0.0553646	0.0554731	0.0547376
143.972	0.0554156	0.0552963	0.0557139
141.39	0.0554317	0.0552743	0.0564946
138.807	0.0553127	0.055213	0.0562043
136.225	0.0552265	0.0550862	0.0553993
133.642	0.0551833	0.0549912	0.0554964
131.059	0.0551754	0.0549721	0.0550158
128.477	0.0550768	0.0549971	0.0551771
125.894	0.05495	0.0549492	0.054912
123.312	0.0549009	0.0548972	0.0555239
120.729	0.0548985	0.0547539	0.0550817
118.146	0.0548355	0.0546481	0.0548843
115.564	0.0547948	0.0545809	0.0548816
112.981	0.0546912	0.0544892	0.0545709
110.398	0.05453	0.0544018	0.054496
107.816	0.0543109	0.0541999	0.0532605
105.233	0.0539609	0.0539855	0.0535913
102.651	0.0534984	0.0537203	0.0537753
100.068	0.0530047	0.0533673	0.0531746
97.4854	0.0526369	0.0528543	0.0528496
94.9028	0.0523568	0.0521804	0.0522172
92.3202	0.0517774	0.0514796	0.0517448
89.7376	0.0509934	0.0508555	0.0513168
87.155	0.0503941	0.0502547	0.0505178
84.5724	0.0497964	0.0495461	0.0497906
81.9898	0.0492425	0.0488833	0.0499834
79.4072	0.0487297	0.0483208	0.0492913
76.8246	0.0482742	0.0477713	0.048989
74.242	0.0479606	0.0475459	0.0488753
71.6593	0.0477266	0.0475288	0.0486824
69.0767	0.0476091	0.0476008	0.0475294
66.4941	0.0475955	0.0477257	0.0471745
63.9115	0.0477087	0.0479354	0.0474333
61.3289	0.0480274	0.0479402	0.0475863
58.7463	0.0484654	0.0481165	0.0480301
56.1637	0.0489451	0.0484263	0.0484555
53.5811	0.0494875	0.0491108	0.0490977
50.9985	0.0501234	0.0499424	0.0499436
48.4159	0.0507873	0.0508993	0.0507718
45.8333	0.0515178	0.0517188	0.0515839
43.2507	0.0522936	0.052364	0.0522738
40.668	0.0529641	0.0528837	0.052823

38.0854	0.0534343	0.0532636	0.0530292
35.5028	0.0537574	0.0534828	0.0533146
32.9202	0.0539006	0.0535889	0.053142
30.3376	0.0539628	0.053668	0.0532544
27.755	0.0540114	0.0536997	0.0533421
25.1724	0.053927	0.0536522	0.0536778
22.5898	0.0537383	0.0535209	0.0536274
20.0072	0.0535874	0.0534549	0.0535381
17.4246	0.0534588	0.0533874	0.0537301
14.842	0.0534552	0.0533809	0.053413
12.2594	0.0535118	0.0534575	0.053446
9.67675	0.053571	0.0535015	0.0535506
7.09415	0.0536586	0.0535504	0.0536196
4.51154	0.0536732	0.0535728	0.0534846
1.92893	0.0536698	0.0535215	0.0536469
-0.653677	0.0536938	0.0535313	0.0536345
-3.23629	0.0536918	0.0536293	0.0536105
-5.81889	0.0537568	0.0537318	0.0538743
-8.4015	0.0537932	0.0537693	0.0539302
-10.9841	0.0537946	0.0536995	0.0533442
-13.5667	0.0538296	0.0536532	0.0537368
-16.1493	0.0538709	0.0536441	0.053811
-18.7319	0.0538451	0.0536537	0.0538516
-21.3145	0.0538377	0.0536744	0.0539317
-23.8972	0.0537812	0.0536164	0.0539079
-26.4798	0.0537301	0.053565	0.0537581
-29.0624	0.0538026	0.0535616	0.053614
-31.645	0.0538372	0.053541	0.053506
-34.2276	0.053788	0.0535409	0.053605
-36.8102	0.0536763	0.053502	0.0536223
-39.3928	0.0535491	0.0534851	0.0535158
-41.9754	0.0534755	0.0534568	0.0531797
-44.558	0.0534228	0.0535023	0.0534279
-47.1406	0.0534067	0.0535075	0.0535052
-49.7232	0.0534557	0.0534705	0.0535098
-52.3058	0.0534967	0.0534697	0.0535269
-54.8884	0.0535449	0.0534272	0.0535451
-57.4711	0.0535584	0.0534054	0.0535071
-60.0537	0.0535267	0.0533643	0.0535171
-62.6363	0.0534664	0.0532719	0.0531887
-65.2189	0.0533764	0.0531508	0.0534049
-67.8015	0.0532453	0.0530199	0.0535576

-70.3841	0.0530347	0.0529061	0.0533142
-72.9667	0.0527366	0.0527543	0.0527325
-75.5493	0.0523782	0.0524787	0.0525116
-78.1319	0.0519965	0.0520811	0.0520129
-80.7145	0.0516514	0.0516588	0.0516141
-83.2971	0.0513365	0.0513023	0.0512663
-85.8797	0.051156	0.0511099	0.0511341
-88.4623	0.0511243	0.0511288	0.0511511
-91.045	0.0509148	0.0509527	0.0508977
-93.6276	0.0496433	0.049433	0.0496036
-96.2102	0.0466816	0.0460543	0.046408
-98.7928	0.0418912	0.0411971	0.0414693
-86.4077	0.0500091	0.0506283	0.0500718
-88.8493	0.0500097	0.0504904	0.0500423
-91.291	0.0501556	0.0505346	0.0501538
-93.7326	0.0503585	0.0508379	0.0503952
-96.1742	0.0503493	0.0511395	0.0504911
-98.6158	0.0492803	0.0507507	0.0498671
-101.057	0.0464947	0.0489799	0.0479545
-103.499	0.0436097	0.0471865	0.0459446

Table 25 - Average velocities bumped airfoil 8° 7 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
194.378	0.030821	0.0255317	0.0285401
191.937	0.0372664	0.0323207	0.033966
189.495	0.0427805	0.0395716	0.0406194
187.053	0.0484289	0.0459273	0.0465796
184.612	0.05189	0.0505196	0.0506263
182.17	0.0536874	0.0532976	0.0530462
179.728	0.0550999	0.0549074	0.0546841
177.287	0.0556249	0.0554664	0.0547022
174.845	0.055615	0.0555419	0.0549849
172.404	0.0557766	0.0555692	0.055653
169.962	0.0558675	0.0555825	0.0556562
167.52	0.055913	0.0556004	0.0558208
165.079	0.0558716	0.0557521	0.0559367
162.637	0.0558798	0.0557828	0.0562659
160.195	0.0560236	0.0558247	0.0558638

157.754	0.0559702	0.0558938	0.0556959
155.312	0.0556863	0.0557908	0.0556792
152.871	0.0555154	0.0557135	0.0557129
150.429	0.0553079	0.0555939	0.0557729
147.987	0.0550982	0.0554217	0.0557652
145.546	0.0549667	0.0552142	0.0556926
143.104	0.0548609	0.0549986	0.0555636
140.663	0.0551066	0.0549047	0.0553388
138.221	0.0546822	0.0549544	0.0552333
135.779	0.0543236	0.0549097	0.0550882
133.338	0.0538792	0.0548206	0.0547933
130.896	0.0534679	0.0545735	0.0545377
128.454	0.0530915	0.0541897	0.0539894
126.013	0.0527699	0.0538036	0.0538329
123.571	0.0525588	0.0534087	0.0532882
121.13	0.052339	0.0529338	0.0529524
118.688	0.052056	0.0525497	0.0530094
116.246	0.051695	0.0521357	0.0526792
113.805	0.0513012	0.0517504	0.0521264
111.363	0.0509084	0.0513472	0.0516284
108.922	0.0505869	0.0507332	0.0511289
106.48	0.0502096	0.0501201	0.0507059
104.038	0.049823	0.0495625	0.0503146
101.597	0.0495042	0.0490727	0.0499943
99.1551	0.0491216	0.0486201	0.0496766
96.7135	0.0486827	0.0482791	0.049349
94.2719	0.0483222	0.0480194	0.0489435
91.8302	0.0480239	0.0477718	0.0484835
89.3886	0.0478729	0.0474628	0.0481832
86.947	0.0478163	0.0472958	0.048131
84.5054	0.0477636	0.0473006	0.0481709
82.0638	0.047671	0.0473718	0.0482956
79.6222	0.047587	0.0476049	0.0484391
77.1805	0.0476799	0.0476799	0.048442
74.7389	0.0476595	0.0477421	0.0484811
72.2973	0.0476294	0.0477076	0.0486091
69.8557	0.0477751	0.047968	0.0486927
67.4141	0.04804	0.0484083	0.0487651
64.9725	0.0484176	0.0488333	0.0489142
62.5309	0.0487732	0.0491849	0.0492429
60.0892	0.0490818	0.0494471	0.0496215
57.6476	0.0494588	0.0497712	0.0499333

55.206	0.0499625	0.0501463	0.0501826
52.7644	0.0505421	0.0504898	0.0503522
50.3228	0.0510507	0.0508292	0.0507391
47.8812	0.05149	0.0511901	0.0511086
45.4395	0.0519389	0.0515214	0.0516209
42.9979	0.0522748	0.0518431	0.0517528
40.5563	0.0525586	0.0523563	0.0517223
38.1147	0.0527408	0.0525369	0.052075
35.6731	0.0529016	0.0527802	0.0523407
33.2315	0.0531377	0.0528698	0.0525904
30.7898	0.0533318	0.0528921	0.0527406
28.3482	0.0535626	0.0529007	0.0529401
25.9066	0.0536608	0.0529885	0.0532255
23.465	0.0536187	0.0530397	0.053446
21.0234	0.0535295	0.0531152	0.0535531
18.5818	0.0534579	0.0531464	0.0535526
16.1401	0.053479	0.0531219	0.0534905
13.6985	0.0535561	0.0531382	0.0534993
11.2569	0.0536556	0.0532737	0.0535676
8.8153	0.0536352	0.0534351	0.0535236
6.37368	0.0535292	0.0535252	0.0535093
3.93207	0.0534783	0.0534879	0.053532
1.49045	0.0535398	0.0534239	0.0536052
-0.951166	0.0537922	0.0534175	0.0537066
-3.39278	0.0539005	0.0534578	0.0537117
-5.8344	0.0538478	0.0535719	0.0536602
-8.27601	0.0537623	0.0536593	0.0537142
-10.7176	0.053786	0.053799	0.053858
-13.1592	0.0538815	0.0538415	0.053961
-15.6009	0.0539701	0.0538032	0.0539377
-18.0425	0.0540483	0.0538259	0.0537823
-20.4841	0.0540829	0.0541172	0.0536944
-22.9257	0.0541657	0.0542676	0.0537025
-25.3673	0.0541743	0.0543895	0.053719
-27.8089	0.054209	0.0542946	0.0537456
-30.2506	0.0542011	0.0539502	0.0537516
-32.6922	0.0541845	0.0539081	0.053786
-35.1338	0.0541725	0.0538758	0.0537531
-37.5754	0.0541314	0.0538662	0.0537728
-40.017	0.0541553	0.053787	0.0538747
-42.4586	0.0542061	0.0538285	0.0537522
-44.9003	0.0542684	0.0539347	0.0536576

-47.3419	0.0539537	0.0540694	0.0535747
-49.7835	0.0539811	0.0542138	0.053693
-52.2251	0.0543705	0.0542431	0.05394
-54.6667	0.0544082	0.0542183	0.0541209
-57.1083	0.0543943	0.0541113	0.0539755
-59.5499	0.0543023	0.0540241	0.0537314
-61.9916	0.0542679	0.054036	0.0535469
-64.4332	0.0541992	0.0539919	0.0533648
-66.8748	0.0540368	0.0539107	0.0533536
-69.3164	0.0536947	0.0537453	0.0533346
-71.758	0.0532952	0.053416	0.0530825
-74.1996	0.0528067	0.052954	0.0526588
-76.6413	0.0522761	0.0523726	0.0521418
-79.0829	0.0517956	0.0517289	0.0515278
-81.5245	0.0512712	0.0511562	0.0510109
-83.9661	0.0508018	0.0506621	0.0506199
-86.4077	0.0505128	0.0503198	0.0503188
-88.8493	0.0504383	0.0502538	0.050194
-91.291	0.0506391	0.0504548	0.0502275
-93.7326	0.0510529	0.0508897	0.0503271
-96.1742	0.0513963	0.051342	0.0502367
-98.6158	0.050546	0.0510592	0.0492961
-101.057	0.0477865	0.0492936	0.0469998
-103.499	0.0447043	0.047289	0.0446911

Table 26 - Average velocities bumped airfoil 10° 7 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
195.625	0.039589	0.0369964	0.0422389
193.042	0.0452525	0.0391762	0.047139
190.459	0.049074	0.04229	0.0501828
187.877	0.0529848	0.0460032	0.0543178
185.294	0.0549556	0.0500909	0.0568895
182.711	0.0563586	0.0529602	0.0574487
180.129	0.0558831	0.0539722	0.0575768
177.546	0.0568889	0.0548114	0.0571026
174.964	0.0564478	0.0554253	0.0571964
172.381	0.0560781	0.0555276	0.0567165
169.798	0.055976	0.0551105	0.056214

167.216	0.0558233	0.0557132	0.0560694
164.633	0.0557767	0.0562411	0.0564468
162.051	0.0558159	0.0561377	0.0563334
159.468	0.0558587	0.0557583	0.0562972
156.885	0.0556112	0.0556246	0.0561575
154.303	0.0554204	0.0557843	0.055849
151.72	0.0552266	0.0553743	0.055599
149.138	0.0550058	0.0552409	0.0552383
146.555	0.0548146	0.0550687	0.0549266
143.972	0.0542738	0.0549753	0.0546914
141.39	0.0543324	0.0547397	0.0545758
138.807	0.0540786	0.0543508	0.0544048
136.225	0.0536906	0.054068	0.0543503
133.642	0.0537598	0.05373	0.0540266
131.059	0.0536043	0.0537348	0.0535987
128.477	0.0532748	0.0531957	0.0531342
125.894	0.0529305	0.0529466	0.0532559
123.312	0.0525621	0.0526414	0.0532877
120.729	0.0523308	0.0523003	0.0530186
118.146	0.052114	0.0519053	0.0525046
115.564	0.0517951	0.0515413	0.0520955
112.981	0.0513678	0.0510785	0.0516524
110.398	0.0509267	0.0506845	0.0511811
107.816	0.0504752	0.0503921	0.0507384
105.233	0.049993	0.0500578	0.0503377
102.651	0.0495583	0.0495887	0.0497901
100.068	0.0491186	0.0490538	0.049523
97.4854	0.0487414	0.0486624	0.0494087
94.9028	0.0484729	0.0484552	0.0490666
92.3202	0.0483483	0.048235	0.0487097
89.7376	0.0482576	0.0478723	0.0483326
87.155	0.0481294	0.0475244	0.0479524
84.5724	0.0480342	0.0472632	0.047518
81.9898	0.0479662	0.0471223	0.0474012
79.4072	0.0478374	0.0469091	0.0475369
76.8246	0.0477723	0.0470164	0.0475272
74.242	0.047697	0.0473318	0.0473824
71.6593	0.0477387	0.0474518	0.0472096
69.0767	0.0479875	0.0479625	0.0471279
66.4941	0.0482408	0.0479005	0.0472874
63.9115	0.0485093	0.0482319	0.0475356
61.3289	0.0488193	0.0485462	0.0478257

58.7463	0.0491713	0.0488763	0.0481059
56.1637	0.0495251	0.0492546	0.048394
53.5811	0.0498309	0.0496678	0.0487381
50.9985	0.0499003	0.0501097	0.0491418
48.4159	0.0501315	0.0505563	0.0496316
45.8333	0.0506519	0.0509839	0.0500488
43.2507	0.0509747	0.0513274	0.0505092
40.668	0.0512674	0.0515494	0.0510253
38.0854	0.0515736	0.051751	0.0513761
35.5028	0.0519065	0.0520271	0.0518454
32.9202	0.0522201	0.0523208	0.052225
30.3376	0.0526175	0.0525296	0.0526324
27.755	0.0531026	0.0527582	0.0527991
25.1724	0.0533579	0.0529731	0.05299
22.5898	0.0535891	0.0532716	0.0532745
20.0072	0.0538643	0.0536509	0.053598
17.4246	0.0540867	0.0539553	0.0538161
14.842	0.0542209	0.0541119	0.0539426
12.2594	0.0542582	0.0541281	0.0540682
9.67675	0.054265	0.0541444	0.0541891
7.09415	0.0543175	0.054249	0.0543008
4.51154	0.0543799	0.0543332	0.0543717
1.92893	0.0544053	0.0545078	0.0543956
-0.653677	0.0544027	0.0545892	0.0543579
-3.23629	0.0543972	0.0546049	0.0543546
-5.81889	0.0544261	0.054553	0.0544077
-8.4015	0.054497	0.0545355	0.054482
-10.9841	0.0545694	0.0545823	0.0545069
-13.5667	0.054582	0.0545913	0.0545362
-16.1493	0.054588	0.0546002	0.054568
-18.7319	0.0546347	0.054595	0.0545838
-21.3145	0.0546893	0.054575	0.0545124
-23.8972	0.0546878	0.0545966	0.0544323
-26.4798	0.0546198	0.0546352	0.0543662
-29.0624	0.0545861	0.0546111	0.054292
-31.645	0.0545758	0.0545946	0.0542394
-34.2276	0.054572	0.0545974	0.0542839
-36.8102	0.0545653	0.0545965	0.0543926
-39.3928	0.0545158	0.0546155	0.0544527
-41.9754	0.0544983	0.0546388	0.054446
-44.558	0.0545102	0.05467	0.0544689
-47.1406	0.0545095	0.0546906	0.0544799

-49.7232	0.0545372	0.0546264	0.0544863
-52.3058	0.0545071	0.0544897	0.0544541
-54.8884	0.0544932	0.0544707	0.0543908
-57.4711	0.0545083	0.0544713	0.0542764
-60.0537	0.0544635	0.0543937	0.0541828
-62.6363	0.0543301	0.0543095	0.0541078
-65.2189	0.0540693	0.0541135	0.053965
-67.8015	0.0536844	0.0538251	0.0538023
-70.3841	0.0532068	0.0534435	0.0535881
-72.9667	0.0526887	0.0529801	0.0532809
-75.5493	0.0520935	0.0524801	0.0528989
-78.1319	0.0515252	0.052007	0.052474
-80.7145	0.0510524	0.051625	0.0522415
-83.2971	0.0507492	0.0513897	0.0519965
-85.8797	0.050734	0.0514381	0.0518392
-88.4623	0.0509041	0.0517068	0.0519073
-91.045	0.0509473	0.0517655	0.0517143
-93.6276	0.0497021	0.0508283	0.0505608
-96.2102	0.0463989	0.0483287	0.0478176
-98.7928	0.0412104	0.0435957	0.0430973
-86.4077	0.0505128	0.0503198	0.0503188
-88.8493	0.0504383	0.0502538	0.050194
-91.291	0.0506391	0.0504548	0.0502275
-93.7326	0.0510529	0.0508897	0.0503271
-96.1742	0.0513963	0.051342	0.0502367
-98.6158	0.050546	0.0510592	0.0492961
-101.057	0.0477865	0.0492936	0.0469998
-103.499	0.0447043	0.047289	0.0446911

Table 27 - Average velocities bumped airfoil 15° 7 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
194.378	0.0329949	0.0318471	0.0311482
191.937	0.0386124	0.039617	0.0372958
189.495	0.0450431	0.0469824	0.0433423
187.053	0.0493767	0.0515619	0.0472395
184.612	0.0534438	0.0548663	0.0524397
182.17	0.055798	0.0557366	0.0544345
179.728	0.0570043	0.0564295	0.0556735

177.287	0.0571515	0.0564954	0.0561636
174.845	0.0573153	0.057173	0.0569306
172.404	0.057222	0.057606	0.0570789
169.962	0.0570458	0.0574787	0.0562498
167.52	0.0567052	0.0575169	0.0562215
165.079	0.0563244	0.0570548	0.0567683
162.637	0.0564173	0.0565651	0.055994
160.195	0.0565924	0.056533	0.0561861
157.754	0.0561197	0.0565618	0.0558595
155.312	0.0562263	0.0564124	0.0557913
152.871	0.0559459	0.0560988	0.0557066
150.429	0.0549646	0.0557082	0.0551208
147.987	0.0543739	0.0553322	0.0547122
145.546	0.0541881	0.0550424	0.0546759
143.104	0.0539388	0.0548166	0.0543296
140.663	0.0536649	0.0545803	0.0539557
138.221	0.0534626	0.0542702	0.0534441
135.779	0.0533041	0.0538934	0.052812
133.338	0.0524176	0.053423	0.052306
130.896	0.0518512	0.0528551	0.051704
128.454	0.0513746	0.0526107	0.0515783
126.013	0.0510282	0.0522229	0.0511877
123.571	0.0508838	0.0521726	0.0508502
121.13	0.0507084	0.0515284	0.0505881
118.688	0.0504365	0.0508406	0.0502596
116.246	0.050085	0.0502964	0.0499422
113.805	0.0495852	0.0497458	0.0495499
111.363	0.0492494	0.0492237	0.0491587
108.922	0.0484948	0.0489638	0.0488466
106.48	0.0481401	0.0486379	0.0485818
104.038	0.0479544	0.0483256	0.0481646
101.597	0.0476118	0.0478866	0.0476383
99.1551	0.0470642	0.0475136	0.0469318
96.7135	0.0466169	0.0472663	0.0468001
94.2719	0.046162	0.0470135	0.0467123
91.8302	0.0461426	0.0467398	0.0465668
89.3886	0.0463905	0.0464996	0.0463124
86.947	0.0462834	0.0463591	0.0460888
84.5054	0.0462054	0.0463304	0.0459724
82.0638	0.0463222	0.0462768	0.0460841
79.6222	0.0466231	0.0461824	0.0461938
77.1805	0.0468767	0.0460852	0.0462339

74.7389	0.0468395	0.0459823	0.046164
72.2973	0.0466612	0.0458733	0.0460848
69.8557	0.0464512	0.0458257	0.0461044
67.4141	0.046315	0.0459384	0.0462105
64.9725	0.0464335	0.0461749	0.0462846
62.5309	0.0466435	0.0466977	0.0463574
60.0892	0.0468283	0.0470584	0.0466163
57.6476	0.0471079	0.0474715	0.0468353
55.206	0.0474988	0.0478135	0.0472059
52.7644	0.0478808	0.0479992	0.0476946
50.3228	0.0482607	0.0483891	0.0482211
47.8812	0.0485988	0.0487984	0.0487067
45.4395	0.048936	0.0491316	0.0491392
42.9979	0.0494562	0.049317	0.0495479
40.5563	0.0501072	0.0495009	0.0499578
38.1147	0.0506341	0.0498216	0.0503509
35.6731	0.0510564	0.0502608	0.0506243
33.2315	0.0513929	0.0507018	0.0507811
30.7898	0.0517281	0.0510813	0.0509612
28.3482	0.0521301	0.0515514	0.0512074
25.9066	0.0525034	0.0520826	0.0514581
23.465	0.0527237	0.0525916	0.0515994
21.0234	0.0528443	0.0529813	0.0517583
18.5818	0.0530131	0.053216	0.0520516
16.1401	0.0532664	0.0534087	0.0523771
13.6985	0.0535274	0.0536082	0.0527127
11.2569	0.0538727	0.053769	0.0530881
8.8153	0.0541099	0.0538846	0.0533901
6.37368	0.0543002	0.0540352	0.0536357
3.93207	0.0544036	0.0542091	0.0537094
1.49045	0.0544393	0.0543072	0.053582
-0.951166	0.0545043	0.0544202	0.0540644
-3.39278	0.0545882	0.0545062	0.0541756
-5.8344	0.0547306	0.054551	0.0543789
-8.27601	0.0548062	0.0545974	0.0545887
-10.7176	0.0548351	0.0546929	0.0547431
-13.1592	0.0549185	0.0547976	0.054943
-15.6009	0.0550516	0.0548769	0.0550778
-18.0425	0.0551527	0.0549741	0.0551597
-20.4841	0.0552134	0.0550643	0.05519
-22.9257	0.0552513	0.0551493	0.0552164
-25.3673	0.0553318	0.0552622	0.055251

-27.8089	0.0553856	0.0553686	0.0552256
-30.2506	0.0554049	0.0553908	0.0551562
-32.6922	0.0553966	0.0553708	0.0551178
-35.1338	0.0553977	0.0553338	0.055164
-37.5754	0.0553909	0.0553139	0.0552961
-40.017	0.0554167	0.0553353	0.0553835
-42.4586	0.0554697	0.0553778	0.0553888
-44.9003	0.0555	0.0554362	0.0554431
-47.3419	0.0554444	0.0555165	0.0555208
-49.7835	0.0553745	0.05557	0.055573
-52.2251	0.0553576	0.0556027	0.0555451
-54.6667	0.0553687	0.0556518	0.0554731
-57.1083	0.055375	0.0556237	0.0554258
-59.5499	0.0553696	0.0555597	0.055399
-61.9916	0.0553306	0.0555061	0.0554043
-64.4332	0.0552667	0.0554312	0.0553399
-66.8748	0.0551482	0.0553745	0.055124
-69.3164	0.0549034	0.0553123	0.0547649
-71.758	0.0548336	0.0551676	0.0543721
-74.1996	0.0541426	0.0548492	0.0539491
-76.6413	0.0536543	0.0543136	0.0535427
-79.0829	0.0530182	0.0536334	0.05299
-81.5245	0.0524438	0.052887	0.0523569
-83.9661	0.0519108	0.0522027	0.0518202
-86.4077	0.051519	0.0517137	0.0514665
-88.8493	0.0513995	0.0515312	0.0514073
-91.291	0.0515142	0.0516298	0.0515732
-93.7326	0.0518144	0.0519287	0.0519014
-96.1742	0.0520004	0.0521585	0.0520197
-98.6158	0.0510772	0.0515249	0.0511935
-101.057	0.0481077	0.04935	0.0488723
-103.499	0.0447488	0.0471444	0.0465095

Table 28 - Average velocities bumped airfoil -5° 20 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
195.625	0.146217	0.16113	0.153604
193.042	0.152891	0.165772	0.154607
190.459	0.157298	0.168482	0.158496

187.877	0.159973	0.170816	0.163656
185.294	0.161515	0.169687	0.166461
182.711	0.162334	0.17019	0.165311
180.129	0.163191	0.167812	0.164457
177.546	0.162868	0.167025	0.164773
174.964	0.162963	0.166657	0.165769
172.381	0.161633	0.166509	0.166213
169.798	0.161838	0.166812	0.166001
167.216	0.163517	0.165776	0.164659
164.633	0.164013	0.165995	0.164636
162.051	0.164585	0.165567	0.165211
159.468	0.164912	0.165438	0.165998
156.885	0.165147	0.1647	0.166138
154.303	0.165592	0.164448	0.165702
151.72	0.165634	0.165023	0.165575
149.138	0.165566	0.164935	0.1655
146.555	0.165485	0.164854	0.165388
143.972	0.164903	0.164777	0.165195
141.39	0.164733	0.164704	0.164969
138.807	0.164501	0.164647	0.164779
136.225	0.164265	0.16446	0.164585
133.642	0.164187	0.164225	0.164926
131.059	0.16415	0.16396	0.164751
128.477	0.164049	0.163769	0.164626
125.894	0.163904	0.163673	0.163985
123.312	0.163745	0.163504	0.165128
120.729	0.163582	0.163375	0.16438
118.146	0.163281	0.16325	0.163562
115.564	0.162926	0.163071	0.163254
112.981	0.162542	0.162713	0.162821
110.398	0.162	0.161484	0.16231
107.816	0.161353	0.161282	0.161671
105.233	0.160596	0.160222	0.160623
102.651	0.15962	0.158704	0.159237
100.068	0.158278	0.15763	0.157639
97.4854	0.156743	0.156254	0.156052
94.9028	0.155444	0.154785	0.15464
92.3202	0.154547	0.153604	0.15361
89.7376	0.153894	0.152522	0.153159
87.155	0.153112	0.151854	0.15315
84.5724	0.152315	0.152056	0.153366
81.9898	0.151913	0.152757	0.153895

79.4072	0.152041	0.153674	0.154678
76.8246	0.152388	0.15453	0.155719
74.242	0.152775	0.155284	0.156882
71.6593	0.153469	0.156289	0.158065
69.0767	0.154332	0.157607	0.159192
66.4941	0.15521	0.158556	0.160115
63.9115	0.155806	0.159387	0.160867
61.3289	0.156489	0.159861	0.161362
58.7463	0.157363	0.160073	0.161807
56.1637	0.158333	0.160419	0.162082
53.5811	0.159198	0.1609	0.162082
50.9985	0.159805	0.161098	0.161907
48.4159	0.160177	0.161042	0.16238
45.8333	0.160312	0.161048	0.162292
43.2507	0.160463	0.161049	0.161682
40.668	0.160572	0.161057	0.161744
38.0854	0.160598	0.161004	0.161713
35.5028	0.160673	0.160949	0.161619
32.9202	0.160778	0.160917	0.161523
30.3376	0.160854	0.1608	0.161354
27.755	0.160886	0.160688	0.161226
25.1724	0.160929	0.160659	0.161098
22.5898	0.160975	0.160663	0.16108
20.0072	0.161028	0.160658	0.161142
17.4246	0.161004	0.160699	0.161231
14.842	0.160844	0.160783	0.161277
12.2594	0.160694	0.160868	0.16128
9.67675	0.160708	0.160886	0.161336
7.09415	0.160772	0.160838	0.161398
4.51154	0.160773	0.160783	0.161403
1.92893	0.16074	0.1607	0.161359
-0.653677	0.160727	0.160649	0.161298
-3.23629	0.160749	0.1607	0.16126
-5.81889	0.160795	0.160782	0.161275
-8.4015	0.160849	0.160833	0.161374
-10.9841	0.160891	0.160801	0.161473
-13.5667	0.160911	0.16076	0.161544
-16.1493	0.160974	0.160808	0.161629
-18.7319	0.160964	0.160958	0.161703
-21.3145	0.160916	0.161113	0.161693
-23.8972	0.160984	0.161254	0.161627
-26.4798	0.161079	0.161264	0.161532

-29.0624	0.161115	0.161277	0.161473
-31.645	0.16117	0.161319	0.161466
-34.2276	0.161202	0.161334	0.161585
-36.8102	0.161257	0.161401	0.161787
-39.3928	0.161326	0.161421	0.161962
-41.9754	0.161327	0.161418	0.161999
-44.558	0.161319	0.161371	0.161897
-47.1406	0.161326	0.161328	0.161812
-49.7232	0.161398	0.161353	0.161846
-52.3058	0.16151	0.161474	0.161944
-54.8884	0.161571	0.161665	0.162088
-57.4711	0.161573	0.161868	0.162186
-60.0537	0.161595	0.161924	0.162243
-62.6363	0.161566	0.161954	0.162259
-65.2189	0.161544	0.162042	0.162233
-67.8015	0.161463	0.162025	0.162219
-70.3841	0.161228	0.161964	0.162238
-72.9667	0.16091	0.161819	0.162234
-75.5493	0.160469	0.161643	0.162111
-78.1319	0.160042	0.161377	0.161853
-80.7145	0.159496	0.160922	0.161412
-83.2971	0.158856	0.16023	0.160732
-85.8797	0.158169	0.159392	0.159374
-88.4623	0.157688	0.158777	0.158826
-91.045	0.157706	0.158734	0.159386
-93.6276	0.158042	0.159128	0.159744
-96.2102	0.157424	0.158682	0.159328
-98.7928	0.155582	0.157008	0.157884
-86.4077	0.051519	0.0517137	0.0514665
-88.8493	0.0513995	0.0515312	0.0514073
-91.291	0.0515142	0.0516298	0.0515732
-93.7326	0.0518144	0.0519287	0.0519014
-96.1742	0.0520004	0.0521585	0.0520197
-98.6158	0.0510772	0.0515249	0.0511935
-101.057	0.0481077	0.04935	0.0488723
-103.499	0.0447488	0.0471444	0.0465095

Table 29 - Average velocities bumped airfoil 0° 20 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
194.378	0.117899	0.118116	0.115655
191.937	0.133664	0.130732	0.129604
189.495	0.147513	0.144637	0.143519
187.053	0.156338	0.15395	0.152686
184.612	0.161617	0.159963	0.159664
182.17	0.164529	0.162082	0.161332
179.728	0.164796	0.16246	0.162547
177.287	0.165031	0.161335	0.163723
174.845	0.16544	0.161293	0.164381
172.404	0.165019	0.162149	0.165081
169.962	0.164493	0.163454	0.165288
167.52	0.164325	0.163541	0.165306
165.079	0.164272	0.16434	0.165166
162.637	0.163565	0.163929	0.165452
160.195	0.163497	0.163849	0.165368
157.754	0.164001	0.163664	0.164493
155.312	0.163924	0.163716	0.165147
152.871	0.163818	0.164188	0.164972
150.429	0.163592	0.164144	0.164842
147.987	0.163555	0.164068	0.164785
145.546	0.16367	0.16418	0.165055
143.104	0.163537	0.16419	0.164953
140.663	0.163186	0.163493	0.164479
138.221	0.162719	0.163403	0.16413
135.779	0.162507	0.163691	0.163924
133.338	0.162333	0.163342	0.163789
130.896	0.162189	0.163068	0.163784
128.454	0.162137	0.162944	0.163822
126.013	0.162227	0.162973	0.164043
123.571	0.162252	0.162889	0.163304
121.13	0.162235	0.16278	0.162973
118.688	0.162094	0.162729	0.162836
116.246	0.161856	0.162681	0.162841
113.805	0.161572	0.162502	0.162847
111.363	0.161213	0.162322	0.16275
108.922	0.161089	0.16217	0.162742
106.48	0.161063	0.161846	0.162734
104.038	0.161009	0.161642	0.162481
101.597	0.160449	0.161399	0.162082

99.1551	0.1609	0.161281	0.161741
96.7135	0.160997	0.161137	0.161813
94.2719	0.161119	0.161034	0.161858
91.8302	0.160825	0.161129	0.161937
89.3886	0.160164	0.161271	0.161926
86.947	0.158901	0.161311	0.161781
84.5054	0.157452	0.16098	0.161373
82.0638	0.155746	0.160122	0.16068
79.6222	0.15354	0.158548	0.159843
77.1805	0.150771	0.156246	0.158561
74.7389	0.148336	0.153451	0.15705
72.2973	0.146925	0.151386	0.156219
69.8557	0.147141	0.151372	0.156839
67.4141	0.149171	0.152904	0.15811
64.9725	0.152111	0.154755	0.158675
62.5309	0.155327	0.156124	0.158518
60.0892	0.157508	0.157043	0.158345
57.6476	0.15862	0.158018	0.158662
55.206	0.159321	0.158915	0.15914
52.7644	0.159287	0.159494	0.159518
50.3228	0.158733	0.159438	0.159735
47.8812	0.158598	0.15908	0.15973
45.4395	0.158589	0.158884	0.159619
42.9979	0.15845	0.158734	0.159642
40.5563	0.158278	0.158646	0.159737
38.1147	0.158222	0.158679	0.159576
35.6731	0.158161	0.158654	0.159301
33.2315	0.158009	0.158635	0.158985
30.7898	0.157868	0.158681	0.158736
28.3482	0.157767	0.158811	0.158774
25.9066	0.157696	0.158769	0.158787
23.465	0.157704	0.158678	0.158817
21.0234	0.157808	0.158183	0.158789
18.5818	0.157828	0.158435	0.158781
16.1401	0.157689	0.158355	0.158543
13.6985	0.157478	0.158246	0.158441
11.2569	0.157404	0.158076	0.158411
8.8153	0.157405	0.158002	0.158378
6.37368	0.157317	0.157982	0.158379
3.93207	0.157285	0.157938	0.158418
1.49045	0.157381	0.157781	0.158443
-0.951166	0.157587	0.157726	0.158346

-3.39278	0.157805	0.157892	0.15811
-5.8344	0.15795	0.157978	0.158017
-8.27601	0.157894	0.158019	0.157994
-10.7176	0.157696	0.158035	0.157817
-13.1592	0.157564	0.157896	0.15774
-15.6009	0.157657	0.158197	0.15761
-18.0425	0.157801	0.158122	0.157671
-20.4841	0.157827	0.158072	0.15812
-22.9257	0.157727	0.158275	0.158272
-25.3673	0.157697	0.158565	0.158438
-27.8089	0.157761	0.158704	0.158615
-30.2506	0.158099	0.158738	0.158878
-32.6922	0.15792	0.158747	0.158985
-35.1338	0.158077	0.158805	0.159009
-37.5754	0.158219	0.158778	0.159088
-40.017	0.158292	0.158844	0.159361
-42.4586	0.158403	0.158994	0.15971
-44.9003	0.158492	0.159062	0.159779
-47.3419	0.159128	0.159069	0.159757
-49.7835	0.159361	0.159141	0.159758
-52.2251	0.158855	0.159146	0.159713
-54.6667	0.158845	0.159241	0.159714
-57.1083	0.158689	0.160013	0.159766
-59.5499	0.158694	0.160096	0.159867
-61.9916	0.158821	0.159559	0.159877
-64.4332	0.159023	0.159707	0.160026
-66.8748	0.159099	0.159689	0.160075
-69.3164	0.159084	0.159502	0.159882
-71.758	0.158888	0.15918	0.159565
-74.1996	0.158622	0.158749	0.159239
-76.6413	0.158186	0.158425	0.158875
-79.0829	0.157574	0.158001	0.158367
-81.5245	0.157006	0.157437	0.157856
-83.9661	0.156621	0.156869	0.157517
-86.4077	0.156443	0.15644	0.157464
-88.8493	0.156628	0.15641	0.157624
-91.291	0.157049	0.156882	0.157893
-93.7326	0.157684	0.157477	0.158197
-96.1742	0.15828	0.158078	0.158672
-98.6158	0.157811	0.158261	0.158794
-101.057	0.154542	0.157309	0.157499
-103.499	0.150955	0.156329	0.155816

Table 30 - Average velocities bumped airfoil 5° 20 Hz

Y-Position (mm)	Bumped1 5 Deg 20Hz	Bumped2 5 Deg 20Hz	Bumped3 5 Deg 20Hz
195.625	0.152614	0.143353	0.145977
193.042	0.158092	0.153717	0.156761
190.459	0.163122	0.159228	0.161349
187.877	0.167391	0.16265	0.164739
185.294	0.167348	0.163981	0.165773
182.711	0.165747	0.165351	0.167136
180.129	0.164951	0.16438	0.16775
177.546	0.165914	0.163767	0.167735
174.964	0.166525	0.162936	0.166799
172.381	0.166661	0.162059	0.166273
169.798	0.166714	0.163175	0.165944
167.216	0.166901	0.164716	0.166698
164.633	0.166017	0.164502	0.165976
162.051	0.165659	0.165571	0.165869
159.468	0.165608	0.166077	0.166274
156.885	0.165212	0.166078	0.166077
154.303	0.164949	0.166924	0.165411
151.72	0.164957	0.166214	0.164684
149.138	0.165419	0.165691	0.163412
146.555	0.165447	0.165145	0.163158
143.972	0.164785	0.164641	0.162549
141.39	0.164592	0.164511	0.162616
138.807	0.164475	0.16456	0.162655
136.225	0.16434	0.16437	0.162452
133.642	0.164174	0.164221	0.163325
131.059	0.164084	0.164082	0.163465
128.477	0.164117	0.164007	0.163952
125.894	0.163939	0.163978	0.164052
123.312	0.163703	0.16392	0.163968
120.729	0.163542	0.163775	0.163888
118.146	0.163412	0.16356	0.163693
115.564	0.163364	0.163896	0.163476
112.981	0.16322	0.16382	0.163321
110.398	0.16299	0.163639	0.163268
107.816	0.162754	0.162899	0.163134

105.233	0.162606	0.162604	0.162928
102.651	0.162423	0.162368	0.162687
100.068	0.162049	0.162125	0.162558
97.4854	0.161535	0.161811	0.162345
94.9028	0.160898	0.161448	0.161886
92.3202	0.160064	0.160873	0.161362
89.7376	0.159193	0.159908	0.161483
87.155	0.158292	0.158838	0.160193
84.5724	0.157295	0.15774	0.158884
81.9898	0.15599	0.156485	0.157083
79.4072	0.154384	0.155046	0.155373
76.8246	0.153006	0.153619	0.153864
74.242	0.151972	0.15267	0.152794
71.6593	0.151515	0.152079	0.152195
69.0767	0.151633	0.151449	0.151885
66.4941	0.152167	0.150758	0.151709
63.9115	0.152862	0.150393	0.151589
61.3289	0.153473	0.150989	0.151892
58.7463	0.154332	0.152181	0.152643
56.1637	0.155433	0.153474	0.153808
53.5811	0.156654	0.155063	0.155029
50.9985	0.157838	0.156378	0.155957
48.4159	0.158908	0.157363	0.156725
45.8333	0.15966	0.158415	0.157313
43.2507	0.160057	0.159513	0.158058
40.668	0.160791	0.160388	0.158874
38.0854	0.16041	0.16088	0.159433
35.5028	0.160381	0.161116	0.159946
32.9202	0.160396	0.161063	0.160358
30.3376	0.16038	0.160838	0.160565
27.755	0.160355	0.16052	0.16053
25.1724	0.160416	0.160318	0.160507
22.5898	0.160516	0.160392	0.160409
20.0072	0.1606	0.160472	0.160307
17.4246	0.16071	0.160427	0.16037
14.842	0.160854	0.160392	0.160539
12.2594	0.16084	0.160415	0.160726
9.67675	0.160725	0.160497	0.160882
7.09415	0.160317	0.16059	0.160917
4.51154	0.160247	0.160619	0.1609
1.92893	0.160605	0.160603	0.160893
-0.653677	0.160671	0.160551	0.160896

-3.23629	0.160683	0.160536	0.160778
-5.81889	0.160793	0.160524	0.160727
-8.4015	0.160863	0.160533	0.160716
-10.9841	0.160821	0.160553	0.160798
-13.5667	0.16078	0.160654	0.160951
-16.1493	0.160727	0.160792	0.161019
-18.7319	0.160776	0.160823	0.161108
-21.3145	0.16086	0.160771	0.161162
-23.8972	0.16093	0.160764	0.161171
-26.4798	0.160956	0.160826	0.161164
-29.0624	0.160993	0.160926	0.161184
-31.645	0.161095	0.161094	0.161263
-34.2276	0.161217	0.161245	0.161343
-36.8102	0.161335	0.161375	0.161345
-39.3928	0.161417	0.161419	0.161345
-41.9754	0.16148	0.161379	0.161376
-44.558	0.161537	0.161374	0.161572
-47.1406	0.16166	0.161414	0.161732
-49.7232	0.161748	0.161436	0.161822
-52.3058	0.16175	0.161456	0.161878
-54.8884	0.161765	0.161453	0.161846
-57.4711	0.161755	0.16152	0.161812
-60.0537	0.161677	0.161566	0.161799
-62.6363	0.1615	0.161562	0.161779
-65.2189	0.161398	0.161562	0.161791
-67.8015	0.161333	0.161565	0.16177
-70.3841	0.161242	0.161536	0.161618
-72.9667	0.161049	0.161297	0.161348
-75.5493	0.160656	0.160773	0.160919
-78.1319	0.159958	0.159946	0.160165
-80.7145	0.158877	0.15853	0.158811
-83.2971	0.157522	0.156662	0.156994
-85.8797	0.15615	0.154728	0.155105
-88.4623	0.155268	0.153553	0.153975
-91.045	0.155467	0.153972	0.154316
-93.6276	0.156551	0.155445	0.155727
-96.2102	0.156921	0.155964	0.156773
-98.7928	0.156052	0.154888	0.155033
-86.4077	0.156443	0.15644	0.157464
-88.8493	0.156628	0.15641	0.157624
-91.291	0.157049	0.156882	0.157893
-93.7326	0.157684	0.157477	0.158197

-96.1742	0.15828	0.158078	0.158672
-98.6158	0.157811	0.158261	0.158794
-101.057	0.154542	0.157309	0.157499
-103.499	0.150955	0.156329	0.155816

Table 31 - Average velocities bumped airfoil 8° 20 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
194.378	0.11723	0.102867	0.115448
191.937	0.133602	0.124143	0.128524
189.495	0.147377	0.143019	0.144473
187.053	0.158475	0.152831	0.154641
184.612	0.164743	0.158496	0.163534
182.17	0.166519	0.162775	0.16323
179.728	0.166904	0.165262	0.163605
177.287	0.166588	0.166911	0.164552
174.845	0.166202	0.166745	0.165247
172.404	0.166162	0.166948	0.164393
169.962	0.163973	0.166898	0.164851
167.52	0.163417	0.166831	0.164864
165.079	0.162898	0.166665	0.164686
162.637	0.162862	0.166375	0.16533
160.195	0.163609	0.166709	0.165436
157.754	0.163479	0.166505	0.165324
155.312	0.164246	0.166495	0.165135
152.871	0.164246	0.165868	0.165197
150.429	0.164723	0.165756	0.165183
147.987	0.164105	0.165683	0.164557
145.546	0.165216	0.165404	0.165077
143.104	0.165296	0.165278	0.164961
140.663	0.165326	0.165174	0.164831
138.221	0.164965	0.165156	0.164666
135.779	0.164602	0.165176	0.16462
133.338	0.164319	0.165054	0.164586
130.896	0.164153	0.165019	0.164123
128.454	0.164107	0.164913	0.163766
126.013	0.163984	0.164892	0.163738
123.571	0.163913	0.16497	0.163785

121.13	0.163261	0.164898	0.163866
118.688	0.163219	0.164645	0.163868
116.246	0.163676	0.164193	0.163715
113.805	0.1637	0.163802	0.163515
111.363	0.163743	0.163759	0.16321
108.922	0.163614	0.163774	0.162969
106.48	0.163217	0.16371	0.162872
104.038	0.162946	0.16357	0.163076
101.597	0.162481	0.163279	0.163955
99.1551	0.162615	0.163136	0.16371
96.7135	0.162393	0.16317	0.162812
94.2719	0.162181	0.162994	0.162571
91.8302	0.161832	0.162683	0.162547
89.3886	0.161188	0.162129	0.16249
86.947	0.160619	0.16126	0.162132
84.5054	0.160049	0.160395	0.161411
82.0638	0.15871	0.159585	0.160117
79.6222	0.157406	0.158214	0.158556
77.1805	0.155606	0.156506	0.157012
74.7389	0.154195	0.154784	0.155512
72.2973	0.151892	0.153156	0.153734
69.8557	0.149739	0.15158	0.152063
67.4141	0.147621	0.150061	0.150096
64.9725	0.145933	0.148273	0.148221
62.5309	0.144529	0.146595	0.147315
60.0892	0.143716	0.145262	0.14605
57.6476	0.143704	0.144166	0.144749
55.206	0.144238	0.143779	0.144883
52.7644	0.144939	0.144267	0.145413
50.3228	0.145906	0.145042	0.146314
47.8812	0.147313	0.146708	0.147794
45.4395	0.148997	0.148598	0.1497
42.9979	0.151046	0.150632	0.151886
40.5563	0.15311	0.1527	0.153765
38.1147	0.154954	0.154537	0.155957
35.6731	0.156403	0.156107	0.156863
33.2315	0.157302	0.157369	0.157791
30.7898	0.158039	0.158142	0.158281
28.3482	0.158777	0.158796	0.158556
25.9066	0.15934	0.159188	0.158846
23.465	0.159675	0.159505	0.159196
21.0234	0.159793	0.159745	0.159507

18.5818	0.159601	0.159731	0.159577
16.1401	0.159278	0.159615	0.159496
13.6985	0.159151	0.15949	0.159429
11.2569	0.159212	0.159348	0.159197
8.8153	0.159189	0.159217	0.159051
6.37368	0.158997	0.15917	0.158881
3.93207	0.158728	0.159155	0.158637
1.49045	0.158769	0.159158	0.158513
-0.951166	0.159435	0.159122	0.15841
-3.39278	0.159365	0.15923	0.158772
-5.8344	0.159348	0.159401	0.159162
-8.27601	0.159205	0.159382	0.159306
-10.7176	0.15931	0.159492	0.159365
-13.1592	0.159482	0.159936	0.159257
-15.6009	0.159635	0.160028	0.159215
-18.0425	0.159654	0.159753	0.159242
-20.4841	0.159597	0.159549	0.159348
-22.9257	0.159443	0.158962	0.159524
-25.3673	0.159389	0.159105	0.159619
-27.8089	0.159408	0.159304	0.159743
-30.2506	0.159459	0.16013	0.159926
-32.6922	0.159728	0.160263	0.160102
-35.1338	0.159978	0.160345	0.160333
-37.5754	0.160085	0.160608	0.160352
-40.017	0.159998	0.16082	0.160381
-42.4586	0.159993	0.160894	0.160476
-44.9003	0.160173	0.160778	0.160443
-47.3419	0.160331	0.160689	0.160425
-49.7835	0.160325	0.1608	0.16049
-52.2251	0.160406	0.160852	0.160492
-54.6667	0.16048	0.160884	0.160547
-57.1083	0.160607	0.161042	0.160635
-59.5499	0.160661	0.161127	0.160795
-61.9916	0.160684	0.161232	0.160994
-64.4332	0.160764	0.161262	0.161716
-66.8748	0.160812	0.161209	0.161413
-69.3164	0.160741	0.161143	0.161509
-71.758	0.160542	0.16097	0.161302
-74.1996	0.160344	0.160722	0.160655
-76.6413	0.160096	0.160359	0.15979
-79.0829	0.159564	0.159861	0.158578
-81.5245	0.159386	0.159363	0.157399

-83.9661	0.158185	0.158822	0.156653
-86.4077	0.157669	0.158363	0.156403
-88.8493	0.157628	0.158085	0.156681
-91.291	0.158056	0.15829	0.157301
-93.7326	0.158864	0.159012	0.158087
-96.1742	0.15962	0.159981	0.158661
-98.6158	0.159064	0.15982	0.158262
-101.057	0.155462	0.157289	0.155224
-103.499	0.150703	0.154252	0.15218

Table 32 - Average velocities bumped airfoil 10° 20 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
195.625	0.11723	0.102867	0.115448
193.042	0.133602	0.124143	0.128524
190.459	0.147377	0.143019	0.144473
187.877	0.158475	0.152831	0.154641
185.294	0.164743	0.158496	0.163534
182.711	0.166519	0.162775	0.16323
180.129	0.166904	0.165262	0.163605
177.546	0.166588	0.166911	0.164552
174.964	0.166202	0.166745	0.165247
172.381	0.166162	0.166948	0.164393
169.798	0.163973	0.166898	0.164851
167.216	0.163417	0.166831	0.164864
164.633	0.162898	0.166665	0.164686
162.051	0.162862	0.166375	0.16533
159.468	0.163609	0.166709	0.165436
156.885	0.163479	0.166505	0.165324
154.303	0.164246	0.166495	0.165135
151.72	0.164246	0.165868	0.165197
149.138	0.164723	0.165756	0.165183
146.555	0.164105	0.165683	0.164557
143.972	0.165216	0.165404	0.165077
141.39	0.165296	0.165278	0.164961
138.807	0.165326	0.165174	0.164831
136.225	0.164965	0.165156	0.164666
133.642	0.164602	0.165176	0.16462
131.059	0.164319	0.165054	0.164586
128.477	0.164153	0.165019	0.164123

125.894	0.164107	0.164913	0.163766
123.312	0.163984	0.164892	0.163738
120.729	0.163913	0.16497	0.163785
118.146	0.163261	0.164898	0.163866
115.564	0.163219	0.164645	0.163868
112.981	0.163676	0.164193	0.163715
110.398	0.1637	0.163802	0.163515
107.816	0.163743	0.163759	0.16321
105.233	0.163614	0.163774	0.162969
102.651	0.163217	0.16371	0.162872
100.068	0.162946	0.16357	0.163076
97.4854	0.162481	0.163279	0.163955
94.9028	0.162615	0.163136	0.16371
92.3202	0.162393	0.16317	0.162812
89.7376	0.162181	0.162994	0.162571
87.155	0.161832	0.162683	0.162547
84.5724	0.161188	0.162129	0.16249
81.9898	0.160619	0.16126	0.162132
79.4072	0.160049	0.160395	0.161411
76.8246	0.15871	0.159585	0.160117
74.242	0.157406	0.158214	0.158556
71.6593	0.155606	0.156506	0.157012
69.0767	0.154195	0.154784	0.155512
66.4941	0.151892	0.153156	0.153734
63.9115	0.149739	0.15158	0.152063
61.3289	0.147621	0.150061	0.150096
58.7463	0.145933	0.148273	0.148221
56.1637	0.144529	0.146595	0.147315
53.5811	0.143716	0.145262	0.14605
50.9985	0.143704	0.144166	0.144749
48.4159	0.144238	0.143779	0.144883
45.8333	0.144939	0.144267	0.145413
43.2507	0.145906	0.145042	0.146314
40.668	0.147313	0.146708	0.147794
38.0854	0.148997	0.148598	0.1497
35.5028	0.151046	0.150632	0.151886
32.9202	0.15311	0.1527	0.153765
30.3376	0.154954	0.154537	0.155957
27.755	0.156403	0.156107	0.156863
25.1724	0.157302	0.157369	0.157791
22.5898	0.158039	0.158142	0.158281
20.0072	0.158777	0.158796	0.158556

17.4246	0.15934	0.159188	0.158846
14.842	0.159675	0.159505	0.159196
12.2594	0.159793	0.159745	0.159507
9.67675	0.159601	0.159731	0.159577
7.09415	0.159278	0.159615	0.159496
4.51154	0.159151	0.15949	0.159429
1.92893	0.159212	0.159348	0.159197
-0.653677	0.159189	0.159217	0.159051
-3.23629	0.158997	0.15917	0.158881
-5.81889	0.158728	0.159155	0.158637
-8.4015	0.158769	0.159158	0.158513
-10.9841	0.159435	0.159122	0.15841
-13.5667	0.159365	0.15923	0.158772
-16.1493	0.159348	0.159401	0.159162
-18.7319	0.159205	0.159382	0.159306
-21.3145	0.15931	0.159492	0.159365
-23.8972	0.159482	0.159936	0.159257
-26.4798	0.159635	0.160028	0.159215
-29.0624	0.159654	0.159753	0.159242
-31.645	0.159597	0.159549	0.159348
-34.2276	0.159443	0.158962	0.159524
-36.8102	0.159389	0.159105	0.159619
-39.3928	0.159408	0.159304	0.159743
-41.9754	0.159459	0.16013	0.159926
-44.558	0.159728	0.160263	0.160102
-47.1406	0.159978	0.160345	0.160333
-49.7232	0.160085	0.160608	0.160352
-52.3058	0.159998	0.16082	0.160381
-54.8884	0.159993	0.160894	0.160476
-57.4711	0.160173	0.160778	0.160443
-60.0537	0.160331	0.160689	0.160425
-62.6363	0.160325	0.1608	0.16049
-65.2189	0.160406	0.160852	0.160492
-67.8015	0.16048	0.160884	0.160547
-70.3841	0.160607	0.161042	0.160635
-72.9667	0.160661	0.161127	0.160795
-75.5493	0.160684	0.161232	0.160994
-78.1319	0.160764	0.161262	0.161716
-80.7145	0.160812	0.161209	0.161413
-83.2971	0.160741	0.161143	0.161509
-85.8797	0.160542	0.16097	0.161302
-88.4623	0.160344	0.160722	0.160655

-91.045	0.160096	0.160359	0.15979
-93.6276	0.159564	0.159861	0.158578
-96.2102	0.159386	0.159363	0.157399
-98.7928	0.158185	0.158822	0.156653
-86.4077	0.157669	0.158363	0.156403
-88.8493	0.157628	0.158085	0.156681
-91.291	0.158056	0.15829	0.157301
-93.7326	0.158864	0.159012	0.158087
-96.1742	0.15962	0.159981	0.158661
-98.6158	0.159064	0.15982	0.158262
-101.057	0.155462	0.157289	0.155224
-103.499	0.150703	0.154252	0.15218

Table 33 - Average velocities bumped airfoil 15° 20 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
194.378	0.144137	0.141281	0.142746
191.937	0.152407	0.152963	0.148983
189.495	0.160981	0.161512	0.156284
187.053	0.166101	0.166606	0.16199
184.612	0.168617	0.170222	0.164885
182.17	0.169195	0.170906	0.166054
179.728	0.168979	0.171071	0.166311
177.287	0.167235	0.171572	0.165937
174.845	0.165734	0.169114	0.165935
172.404	0.164378	0.167995	0.165594
169.962	0.163568	0.166582	0.166128
167.52	0.162593	0.165893	0.164532
165.079	0.162483	0.166536	0.164519
162.637	0.160804	0.164296	0.164226
160.195	0.159726	0.161523	0.163713
157.754	0.159104	0.160584	0.162974
155.312	0.157616	0.15949	0.161067
152.871	0.156078	0.160135	0.160508
150.429	0.155264	0.159494	0.159069
147.987	0.15525	0.157693	0.158704
145.546	0.153896	0.156184	0.15643
143.104	0.153361	0.154717	0.155474
140.663	0.152967	0.152947	0.154341

138.221	0.151401	0.1516	0.153267
135.779	0.148985	0.149425	0.152151
133.338	0.148498	0.148059	0.150823
130.896	0.148776	0.146598	0.149762
128.454	0.148989	0.146095	0.148424
126.013	0.148878	0.143888	0.148173
123.571	0.147963	0.142503	0.147213
121.13	0.146381	0.142516	0.146225
118.688	0.144982	0.141899	0.145814
116.246	0.144377	0.141499	0.144822
113.805	0.143897	0.141152	0.144863
111.363	0.143265	0.140886	0.144052
108.922	0.142549	0.140616	0.143049
106.48	0.141649	0.139922	0.14214
104.038	0.140475	0.13944	0.141459
101.597	0.139421	0.139114	0.140537
99.1551	0.13881	0.138752	0.139824
96.7135	0.138494	0.13794	0.139447
94.2719	0.137945	0.137017	0.139103
91.8302	0.137413	0.138007	0.138662
89.3886	0.137832	0.138587	0.13739
86.947	0.138348	0.139342	0.136585
84.5054	0.138317	0.139774	0.136205
82.0638	0.138303	0.140151	0.136756
79.6222	0.138636	0.140783	0.137147
77.1805	0.139674	0.141561	0.13693
74.7389	0.139933	0.142639	0.136616
72.2973	0.138899	0.143558	0.137853
69.8557	0.138794	0.14467	0.138774
67.4141	0.140975	0.145639	0.13996
64.9725	0.142865	0.145979	0.14041
62.5309	0.144375	0.146625	0.141039
60.0892	0.145325	0.147654	0.14157
57.6476	0.14477	0.149096	0.142171
55.206	0.145584	0.150179	0.143121
52.7644	0.145345	0.150459	0.144055
50.3228	0.14582	0.150166	0.145398
47.8812	0.146415	0.150435	0.146317
45.4395	0.147262	0.151231	0.148012
42.9979	0.147953	0.151761	0.149889
40.5563	0.149186	0.152208	0.151448
38.1147	0.150183	0.152909	0.152392

35.6731	0.150914	0.153909	0.152718
33.2315	0.152899	0.155532	0.153041
30.7898	0.154217	0.15753	0.153546
28.3482	0.154665	0.158882	0.154417
25.9066	0.155977	0.159421	0.155603
23.465	0.157427	0.159448	0.156747
21.0234	0.159532	0.159559	0.15784
18.5818	0.160155	0.160123	0.158443
16.1401	0.160562	0.160824	0.159087
13.6985	0.160827	0.161652	0.160258
11.2569	0.16126	0.162326	0.16057
8.8153	0.161777	0.162711	0.161546
6.37368	0.162403	0.163156	0.162279
3.93207	0.162984	0.163309	0.162499
1.49045	0.163367	0.163342	0.162652
-0.951166	0.163752	0.163333	0.16294
-3.39278	0.164147	0.163431	0.163125
-5.8344	0.164292	0.163888	0.163749
-8.27601	0.164547	0.164159	0.16405
-10.7176	0.164751	0.164152	0.16446
-13.1592	0.164819	0.164013	0.164117
-15.6009	0.16504	0.163996	0.164134
-18.0425	0.165213	0.16413	0.16398
-20.4841	0.165223	0.164236	0.164255
-22.9257	0.165198	0.164467	0.164687
-25.3673	0.165248	0.164668	0.164953
-27.8089	0.165495	0.164691	0.16503
-30.2506	0.165973	0.164757	0.165043
-32.6922	0.16633	0.164944	0.165272
-35.1338	0.166331	0.165154	0.165529
-37.5754	0.16625	0.16531	0.165769
-40.017	0.166192	0.165462	0.165587
-42.4586	0.166227	0.165607	0.165361
-44.9003	0.1664	0.165677	0.165401
-47.3419	0.166456	0.165632	0.166014
-49.7835	0.166468	0.165522	0.166158
-52.2251	0.166364	0.165536	0.166081
-54.6667	0.166248	0.165781	0.166124
-57.1083	0.166277	0.166267	0.166346
-59.5499	0.166417	0.166479	0.166586
-61.9916	0.166491	0.166345	0.166655
-64.4332	0.166448	0.166046	0.166541

-66.8748	0.166361	0.165754	0.166404
-69.3164	0.166399	0.165583	0.166452
-71.758	0.166316	0.165541	0.166477
-74.1996	0.166109	0.16526	0.165674
-76.6413	0.165787	0.164792	0.164814
-79.0829	0.164968	0.164116	0.16399
-81.5245	0.163903	0.163472	0.163153
-83.9661	0.162999	0.162908	0.162276
-86.4077	0.162409	0.16233	0.161803
-88.8493	0.162512	0.162225	0.162123
-91.291	0.16306	0.162883	0.163024
-93.7326	0.163973	0.163747	0.164244
-96.1742	0.164804	0.164603	0.165065
-98.6158	0.163985	0.164486	0.164871
-101.057	0.159938	0.16227	0.162373
-103.499	0.15528	0.159821	0.159956

Table 34 - Average velocities bumped airfoil -5° 65 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
195.625	0.361535	0.401552	0.390751
193.042	0.37332	0.427009	0.415046
190.459	0.396293	0.455666	0.431137
187.877	0.434518	0.481757	0.458162
185.294	0.457038	0.490423	0.471531
182.711	0.469897	0.490254	0.483872
180.129	0.47045	0.489959	0.488412
177.546	0.476954	0.49165	0.490021
174.964	0.479636	0.493438	0.48722
172.381	0.485453	0.492661	0.48751
169.798	0.481276	0.492165	0.488993
167.216	0.481541	0.489586	0.487024
164.633	0.482853	0.489338	0.487448
162.051	0.485244	0.487141	0.484837
159.468	0.485911	0.484707	0.484667
156.885	0.48602	0.485206	0.48523
154.303	0.485705	0.483844	0.485181
151.72	0.485577	0.484896	0.484568
149.138	0.485272	0.483968	0.484192
146.555	0.484683	0.482007	0.481597

143.972	0.484053	0.483371	0.483024
141.39	0.483391	0.484653	0.482834
138.807	0.482843	0.484146	0.482656
136.225	0.482577	0.483558	0.482082
133.642	0.481928	0.483233	0.481641
131.059	0.481872	0.483135	0.481376
128.477	0.481826	0.483185	0.481094
125.894	0.481822	0.483101	0.480682
123.312	0.481632	0.482639	0.480242
120.729	0.481115	0.482015	0.480127
118.146	0.480671	0.481496	0.480461
115.564	0.48051	0.481328	0.478862
112.981	0.481715	0.481226	0.479957
110.398	0.48208	0.48069	0.479842
107.816	0.481655	0.479941	0.479632
105.233	0.480155	0.479338	0.479343
102.651	0.477578	0.477876	0.478035
100.068	0.474429	0.4748	0.475106
97.4854	0.470417	0.470191	0.470709
94.9028	0.464479	0.464065	0.464592
92.3202	0.456614	0.457245	0.457766
89.7376	0.448446	0.450645	0.450128
87.155	0.44271	0.446217	0.444058
84.5724	0.441052	0.445008	0.440586
81.9898	0.443472	0.447338	0.441171
79.4072	0.449223	0.452482	0.446222
76.8246	0.456454	0.458816	0.4536
74.242	0.46434	0.465127	0.460936
71.6593	0.470597	0.470183	0.466734
69.0767	0.474059	0.474356	0.471417
66.4941	0.475787	0.477191	0.474711
63.9115	0.476495	0.478305	0.476349
61.3289	0.476709	0.47851	0.476695
58.7463	0.476525	0.47807	0.476457
56.1637	0.476302	0.4778	0.475713
53.5811	0.47597	0.477837	0.475086
50.9985	0.475593	0.477795	0.474975
48.4159	0.47573	0.477747	0.475197
45.8333	0.47594	0.477644	0.475236
43.2507	0.475565	0.477577	0.47505
40.668	0.474814	0.477572	0.474254
38.0854	0.474144	0.477244	0.473248

35.5028	0.473869	0.476818	0.472588
32.9202	0.474458	0.47643	0.472642
30.3376	0.473727	0.475999	0.473363
27.755	0.473031	0.475589	0.473405
25.1724	0.472405	0.47483	0.472663
22.5898	0.472031	0.47356	0.471886
20.0072	0.471815	0.472525	0.471822
17.4246	0.471871	0.472345	0.472254
14.842	0.472067	0.473192	0.472306
12.2594	0.471999	0.474431	0.472164
9.67675	0.472042	0.474969	0.471771
7.09415	0.472051	0.474395	0.471554
4.51154	0.471891	0.473234	0.471486
1.92893	0.472066	0.472504	0.471338
-0.653677	0.47175	0.472345	0.471323
-3.23629	0.471536	0.472559	0.471528
-5.81889	0.471175	0.472631	0.471528
-8.4015	0.470719	0.472067	0.470878
-10.9841	0.470488	0.471655	0.470424
-13.5667	0.470282	0.471654	0.470534
-16.1493	0.470316	0.471975	0.470455
-18.7319	0.470334	0.472148	0.469918
-21.3145	0.470525	0.472113	0.469588
-23.8972	0.470795	0.472234	0.469795
-26.4798	0.470903	0.472676	0.470217
-29.0624	0.470928	0.473187	0.470509
-31.645	0.470859	0.473606	0.470688
-34.2276	0.470886	0.474063	0.471041
-36.8102	0.470762	0.474067	0.471497
-39.3928	0.470754	0.473825	0.471552
-41.9754	0.470656	0.473192	0.470835
-44.558	0.470482	0.472617	0.46981
-47.1406	0.47048	0.47257	0.468874
-49.7232	0.470191	0.47241	0.468035
-52.3058	0.469375	0.471889	0.467232
-54.8884	0.468002	0.47079	0.46648
-57.4711	0.466084	0.469253	0.465905
-60.0537	0.464118	0.46768	0.4649
-62.6363	0.462517	0.46626	0.463219
-65.2189	0.461016	0.464651	0.461119
-67.8015	0.458682	0.462651	0.459149
-70.3841	0.455838	0.459646	0.457231

-72.9667	0.45279	0.456596	0.455246
-75.5493	0.449629	0.453995	0.452361
-78.1319	0.446143	0.451183	0.447876
-80.7145	0.44133	0.448239	0.442319
-83.2971	0.435521	0.444226	0.436482
-85.8797	0.430531	0.438563	0.431795
-88.4623	0.426545	0.43168	0.427018
-91.045	0.420184	0.422008	0.419269
-93.6276	0.407206	0.407944	0.405655
-96.2102	0.387334	0.390123	0.384757
-98.7928	0.366567	0.371851	0.363109
-86.4077	0.162409	0.16233	0.161803
-88.8493	0.162512	0.162225	0.162123
-91.291	0.16306	0.162883	0.163024
-93.7326	0.163973	0.163747	0.164244
-96.1742	0.164804	0.164603	0.165065
-98.6158	0.163985	0.164486	0.164871
-101.057	0.159938	0.16227	0.162373
-103.499	0.15528	0.159821	0.159956

Table 35 - Average velocities bumped airfoil 0° 65 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
194.378	0.342588	0.336407	0.364229
191.937	0.370584	0.319167	0.393745
189.495	0.386918	0.347932	0.406389
187.053	0.411445	0.370495	0.427794
184.612	0.42761	0.392884	0.446804
182.17	0.450465	0.414174	0.463262
179.728	0.465918	0.43107	0.480609
177.287	0.471946	0.441662	0.488026
174.845	0.474546	0.453995	0.489715
172.404	0.47828	0.466171	0.490267
169.962	0.482566	0.474742	0.495222
167.52	0.480355	0.478123	0.497293
165.079	0.484716	0.480773	0.494832
162.637	0.483491	0.480435	0.48938
160.195	0.482344	0.483014	0.486678
157.754	0.48496	0.483186	0.486061

155.312	0.483738	0.483175	0.484348
152.871	0.483545	0.480856	0.48172
150.429	0.483487	0.482227	0.483268
147.987	0.483185	0.482283	0.483386
145.546	0.483057	0.482095	0.483751
143.104	0.482551	0.481536	0.483667
140.663	0.481812	0.481237	0.483672
138.221	0.481715	0.481143	0.483077
135.779	0.481505	0.480834	0.48246
133.338	0.481065	0.480307	0.48363
130.896	0.480513	0.479738	0.482156
128.454	0.479838	0.479138	0.482288
126.013	0.479361	0.478835	0.48159
123.571	0.479244	0.479851	0.481103
121.13	0.479548	0.478007	0.480146
118.688	0.479372	0.478104	0.480056
116.246	0.478708	0.47657	0.481334
113.805	0.47806	0.476778	0.480934
111.363	0.477565	0.476435	0.480141
108.922	0.477268	0.474808	0.476444
106.48	0.477126	0.474876	0.476243
104.038	0.476776	0.474278	0.475991
101.597	0.476508	0.47535	0.477217
99.1551	0.476292	0.474966	0.476476
96.7135	0.475743	0.474995	0.476288
94.2719	0.474917	0.474826	0.477014
91.8302	0.473932	0.475707	0.475638
89.3886	0.472395	0.472982	0.474718
86.947	0.469745	0.470549	0.472546
84.5054	0.465442	0.467481	0.469739
82.0638	0.460955	0.464204	0.466182
79.6222	0.4569	0.460659	0.463473
77.1805	0.453976	0.457025	0.46063
74.7389	0.451351	0.454262	0.456909
72.2973	0.448307	0.452587	0.452913
69.8557	0.448735	0.4518	0.4489
67.4141	0.450102	0.450774	0.447218
64.9725	0.452189	0.450362	0.448624
62.5309	0.455655	0.451649	0.451864
60.0892	0.458761	0.454639	0.456266
57.6476	0.464171	0.458544	0.460438
55.206	0.467938	0.461928	0.464426

52.7644	0.469556	0.465111	0.467422
50.3228	0.470114	0.467356	0.469031
47.8812	0.470134	0.468619	0.470251
45.4395	0.469972	0.469147	0.471031
42.9979	0.469666	0.469268	0.471121
40.5563	0.469771	0.469254	0.47083
38.1147	0.469517	0.468767	0.470038
35.6731	0.469146	0.468226	0.469749
33.2315	0.467309	0.467794	0.46977
30.7898	0.467682	0.467357	0.46947
28.3482	0.467718	0.46677	0.469183
25.9066	0.467751	0.466317	0.468645
23.465	0.467687	0.466225	0.468252
21.0234	0.467632	0.466115	0.468087
18.5818	0.467627	0.466112	0.467971
16.1401	0.467586	0.466141	0.468133
13.6985	0.467138	0.466303	0.468375
11.2569	0.467158	0.466404	0.468644
8.8153	0.467815	0.466417	0.468415
6.37368	0.468252	0.466707	0.467585
3.93207	0.468237	0.467025	0.467062
1.49045	0.46777	0.466851	0.467139
-0.951166	0.467616	0.466301	0.467716
-3.39278	0.467742	0.46611	0.467976
-5.8344	0.468026	0.46635	0.467744
-8.27601	0.4681	0.466669	0.467679
-10.7176	0.467985	0.466767	0.467683
-13.1592	0.467643	0.466467	0.467909
-15.6009	0.467006	0.466151	0.467945
-18.0425	0.466521	0.466295	0.467804
-20.4841	0.466761	0.466505	0.468087
-22.9257	0.46755	0.466761	0.468153
-25.3673	0.468432	0.467458	0.46841
-27.8089	0.469158	0.467857	0.468867
-30.2506	0.468988	0.467671	0.468882
-32.6922	0.468451	0.467437	0.468924
-35.1338	0.468097	0.467362	0.469087
-37.5754	0.468181	0.467415	0.469032
-40.017	0.468205	0.467102	0.468983
-42.4586	0.468179	0.466743	0.468782
-44.9003	0.468041	0.46641	0.468618
-47.3419	0.467973	0.466226	0.468167

-49.7835	0.467936	0.466637	0.467812
-52.2251	0.467816	0.466986	0.467904
-54.6667	0.468201	0.467471	0.467912
-57.1083	0.468512	0.467631	0.467934
-59.5499	0.468497	0.466914	0.467875
-61.9916	0.467819	0.46595	0.467568
-64.4332	0.466693	0.464938	0.467351
-66.8748	0.465482	0.463935	0.466783
-69.3164	0.464583	0.462933	0.465565
-71.758	0.464077	0.462116	0.463944
-74.1996	0.463285	0.461555	0.46191
-76.6413	0.462006	0.461048	0.460501
-79.0829	0.460309	0.460546	0.459913
-81.5245	0.458484	0.45956	0.458563
-83.9661	0.457212	0.457674	0.457275
-86.4077	0.455699	0.454624	0.456214
-88.8493	0.454225	0.451695	0.456026
-91.291	0.451324	0.448254	0.455014
-93.7326	0.445279	0.443536	0.450829
-96.1742	0.434155	0.437779	0.442515
-98.6158	0.417543	0.426674	0.42985
-101.057	0.397586	0.41154	0.413689
-103.499	0.381906	0.398861	0.40065

Table 36 - Average velocities bumped airfoil 5° 65 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
195.625	0.390162	0.383485	0.436992
193.042	0.417862	0.383761	0.442677
190.459	0.427231	0.399096	0.468586
187.877	0.4467	0.425484	0.47922
185.294	0.455105	0.43986	0.48582
182.711	0.460156	0.461101	0.495849
180.129	0.469404	0.464006	0.494006
177.546	0.471606	0.471154	0.494623
174.964	0.473186	0.484674	0.485689
172.381	0.476447	0.489477	0.485992
169.798	0.482181	0.493444	0.489758
167.216	0.485816	0.490831	0.492047

164.633	0.484816	0.491072	0.491576
162.051	0.483288	0.492168	0.492078
159.468	0.482991	0.487766	0.487428
156.885	0.482994	0.483636	0.482574
154.303	0.484446	0.483456	0.483391
151.72	0.486753	0.485713	0.4824
149.138	0.485651	0.483864	0.478922
146.555	0.481977	0.482768	0.47832
143.972	0.481393	0.482269	0.478813
141.39	0.478607	0.480287	0.480057
138.807	0.47812	0.479881	0.479524
136.225	0.477977	0.479955	0.479704
133.642	0.480283	0.481839	0.479159
131.059	0.480522	0.481688	0.480747
128.477	0.480135	0.481111	0.480537
125.894	0.479785	0.480467	0.480254
123.312	0.479308	0.47994	0.481019
120.729	0.478786	0.479556	0.47724
118.146	0.47825	0.479318	0.478784
115.564	0.477767	0.47903	0.478332
112.981	0.477346	0.478828	0.47774
110.398	0.477083	0.478794	0.477343
107.816	0.476721	0.478614	0.476899
105.233	0.476765	0.478234	0.476943
102.651	0.476695	0.478617	0.47667
100.068	0.476611	0.477629	0.476749
97.4854	0.476618	0.4774	0.476689
94.9028	0.476599	0.477525	0.476061
92.3202	0.476515	0.478539	0.47557
89.7376	0.476344	0.478478	0.475739
87.155	0.475962	0.477078	0.47647
84.5724	0.475484	0.476819	0.476964
81.9898	0.475021	0.476786	0.476607
79.4072	0.474526	0.476805	0.475811
76.8246	0.47354	0.475262	0.474277
74.242	0.471109	0.471316	0.471491
71.6593	0.46701	0.465957	0.467075
69.0767	0.460911	0.459769	0.460862
66.4941	0.454049	0.453973	0.454454
63.9115	0.44738	0.448424	0.448195
61.3289	0.442647	0.444225	0.443116
58.7463	0.44043	0.441945	0.440086

56.1637	0.441611	0.442267	0.439586
53.5811	0.443911	0.445543	0.443219
50.9985	0.449419	0.451796	0.44936
48.4159	0.457902	0.459485	0.45612
45.8333	0.464274	0.466429	0.463253
43.2507	0.469812	0.471459	0.468308
40.668	0.472681	0.473959	0.471085
38.0854	0.47374	0.474434	0.472658
35.5028	0.473381	0.47431	0.473106
32.9202	0.472423	0.473592	0.472784
30.3376	0.47196	0.472735	0.472269
27.755	0.471743	0.471915	0.472016
25.1724	0.471387	0.470982	0.472113
22.5898	0.47027	0.470763	0.472348
20.0072	0.469068	0.470726	0.472118
17.4246	0.468419	0.470039	0.471098
14.842	0.468705	0.46962	0.469851
12.2594	0.46924	0.469838	0.469028
9.67675	0.469235	0.470106	0.469012
7.09415	0.468811	0.470447	0.469604
4.51154	0.468397	0.470652	0.469887
1.92893	0.467834	0.470877	0.47
-0.653677	0.467193	0.470948	0.469757
-3.23629	0.466691	0.470507	0.46939
-5.81889	0.466566	0.470436	0.469438
-8.4015	0.46736	0.470856	0.469505
-10.9841	0.467753	0.470701	0.469757
-13.5667	0.467535	0.470337	0.470046
-16.1493	0.467473	0.470124	0.470189
-18.7319	0.467461	0.470134	0.470262
-21.3145	0.467786	0.470239	0.470061
-23.8972	0.468293	0.470059	0.469714
-26.4798	0.468477	0.469845	0.46941
-29.0624	0.468252	0.469796	0.468666
-31.645	0.467822	0.470235	0.467744
-34.2276	0.467729	0.470784	0.467144
-36.8102	0.468284	0.470889	0.467232
-39.3928	0.468562	0.470544	0.467352
-41.9754	0.468339	0.469911	0.467204
-44.558	0.467826	0.46946	0.466725
-47.1406	0.466916	0.469351	0.46637
-49.7232	0.466389	0.469149	0.466137

-52.3058	0.465778	0.468753	0.466225
-54.8884	0.465011	0.468085	0.466337
-57.4711	0.464003	0.467276	0.466139
-60.0537	0.462558	0.466496	0.465594
-62.6363	0.460645	0.464996	0.463918
-65.2189	0.458262	0.462698	0.461458
-67.8015	0.456034	0.460088	0.458748
-70.3841	0.454305	0.457027	0.456356
-72.9667	0.452471	0.454079	0.453526
-75.5493	0.450366	0.451207	0.450138
-78.1319	0.448168	0.448532	0.446712
-80.7145	0.445931	0.446603	0.442547
-83.2971	0.442856	0.444414	0.438455
-85.8797	0.439189	0.440498	0.434569
-88.4623	0.434708	0.434297	0.430144
-91.045	0.427627	0.425403	0.42327
-93.6276	0.415073	0.412745	0.410768
-96.2102	0.396228	0.39652	0.392627
-98.7928	0.375996	0.37945	0.372221
-86.4077	0.455699	0.454624	0.456214
-88.8493	0.454225	0.451695	0.456026
-91.291	0.451324	0.448254	0.455014
-93.7326	0.445279	0.443536	0.450829
-96.1742	0.434155	0.437779	0.442515
-98.6158	0.417543	0.426674	0.42985
-101.057	0.397586	0.41154	0.413689
-103.499	0.381906	0.398861	0.40065

Table 37 - Average velocities bumped airfoil 8° 65 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
194.378	0.346807	0.359699	0.331875
191.937	0.366295	0.37463	0.360121
189.495	0.380897	0.395756	0.373029
187.053	0.396604	0.412501	0.387825
184.612	0.411278	0.431464	0.398331
182.17	0.428724	0.450801	0.421479
179.728	0.44571	0.460555	0.439525
177.287	0.459785	0.471807	0.455205
174.845	0.469972	0.480155	0.468835
172.404	0.47746	0.484909	0.47576

169.962	0.480354	0.483129	0.481791
167.52	0.481855	0.483513	0.484319
165.079	0.481576	0.484946	0.484943
162.637	0.486924	0.485219	0.48461
160.195	0.48997	0.485086	0.48694
157.754	0.489511	0.487175	0.488066
155.312	0.490513	0.487603	0.487585
152.871	0.489149	0.483117	0.489637
150.429	0.486939	0.481532	0.486257
147.987	0.48728	0.481125	0.485825
145.546	0.487035	0.482756	0.485585
143.104	0.486375	0.485956	0.487519
140.663	0.485777	0.486984	0.485736
138.221	0.485657	0.487537	0.487196
135.779	0.485322	0.484038	0.486768
133.338	0.484613	0.486702	0.484133
130.896	0.484012	0.486026	0.483291
128.454	0.484825	0.483411	0.482856
126.013	0.484907	0.482814	0.483144
123.571	0.484035	0.482857	0.483931
121.13	0.484122	0.482942	0.483937
118.688	0.483637	0.482874	0.483119
116.246	0.482711	0.48242	0.482367
113.805	0.482184	0.481824	0.481847
111.363	0.482034	0.481188	0.481167
108.922	0.481759	0.480852	0.480435
106.48	0.481169	0.480211	0.479979
104.038	0.480584	0.479312	0.479719
101.597	0.479998	0.478918	0.479439
99.1551	0.479709	0.478878	0.479242
96.7135	0.479256	0.478967	0.479134
94.2719	0.478959	0.479146	0.480558
91.8302	0.478962	0.478779	0.478485
89.3886	0.478646	0.478409	0.480496
86.947	0.478028	0.480238	0.478621
84.5054	0.477444	0.479721	0.478193
82.0638	0.476528	0.478863	0.477354
79.6222	0.475568	0.475401	0.476719
77.1805	0.474185	0.473104	0.475679
74.7389	0.47178	0.47013	0.473211
72.2973	0.468399	0.466495	0.469529
69.8557	0.464875	0.461696	0.464562

67.4141	0.460112	0.45605	0.45841
64.9725	0.453343	0.450057	0.45198
62.5309	0.446588	0.443734	0.445428
60.0892	0.440894	0.438636	0.439545
57.6476	0.436034	0.434945	0.434869
55.206	0.433445	0.432947	0.432229
52.7644	0.432152	0.432676	0.43254
50.3228	0.432532	0.433079	0.434653
47.8812	0.43513	0.435276	0.438273
45.4395	0.440704	0.440171	0.443941
42.9979	0.447954	0.446969	0.449158
40.5563	0.455853	0.453611	0.45475
38.1147	0.459432	0.459377	0.45966
35.6731	0.463525	0.462711	0.462798
33.2315	0.466402	0.466769	0.465804
30.7898	0.46832	0.468596	0.467819
28.3482	0.469394	0.469883	0.469264
25.9066	0.470132	0.470579	0.470034
23.465	0.470431	0.470633	0.470052
21.0234	0.470363	0.470282	0.469759
18.5818	0.470076	0.469974	0.470386
16.1401	0.470178	0.470193	0.470196
13.6985	0.470097	0.470376	0.470756
11.2569	0.470148	0.470343	0.470812
8.8153	0.470057	0.470189	0.470402
6.37368	0.47024	0.469722	0.469876
3.93207	0.470445	0.469221	0.469532
1.49045	0.470399	0.469194	0.469339
-0.951166	0.470262	0.469009	0.46939
-3.39278	0.470129	0.468915	0.469298
-5.8344	0.469942	0.469094	0.468336
-8.27601	0.470066	0.469354	0.468159
-10.7176	0.470387	0.470249	0.46921
-13.1592	0.470473	0.470778	0.47051
-15.6009	0.470364	0.471189	0.471708
-18.0425	0.470068	0.471337	0.472107
-20.4841	0.469732	0.471024	0.471931
-22.9257	0.470375	0.470468	0.471033
-25.3673	0.471553	0.469658	0.47043
-27.8089	0.472306	0.469013	0.470416
-30.2506	0.472659	0.469187	0.470788
-32.6922	0.47294	0.469972	0.470805

-35.1338	0.473091	0.470812	0.470772
-37.5754	0.473453	0.471137	0.470789
-40.017	0.47363	0.471328	0.47054
-42.4586	0.473733	0.471661	0.470472
-44.9003	0.47338	0.472154	0.470696
-47.3419	0.472425	0.472464	0.470906
-49.7835	0.471861	0.472402	0.470599
-52.2251	0.472039	0.472619	0.469282
-54.6667	0.472241	0.473069	0.471329
-57.1083	0.471861	0.473272	0.471972
-59.5499	0.47117	0.473067	0.472111
-61.9916	0.470464	0.472183	0.471632
-64.4332	0.469697	0.470879	0.471109
-66.8748	0.468443	0.469008	0.470493
-69.3164	0.467423	0.46718	0.469262
-71.758	0.465931	0.465757	0.468077
-74.1996	0.464159	0.464705	0.467015
-76.6413	0.462005	0.463437	0.465581
-79.0829	0.459884	0.46147	0.464449
-81.5245	0.458259	0.459516	0.463215
-83.9661	0.457416	0.458236	0.461796
-86.4077	0.45707	0.457569	0.46078
-88.8493	0.457384	0.457131	0.4602
-91.291	0.457179	0.456671	0.458513
-93.7326	0.455023	0.454879	0.455091
-96.1742	0.448469	0.449564	0.448133
-98.6158	0.435013	0.438099	0.434914
-101.057	0.414942	0.424504	0.418101
-103.499	0.398274	0.409421	0.40455

Table 38 - Average velocities bumped airfoil 10° 65 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
195.625	0.381777	0.375419	0.339626
193.042	0.380857	0.387014	0.344596
190.459	0.403706	0.405488	0.346552
187.877	0.432827	0.425678	0.370012
185.294	0.439547	0.426198	0.382219
182.711	0.453101	0.44324	0.42345

180.129	0.46167	0.450524	0.428037
177.546	0.464951	0.46245	0.425418
174.964	0.459777	0.464544	0.438411
172.381	0.464672	0.465723	0.457751
169.798	0.466431	0.467799	0.467668
167.216	0.471499	0.470613	0.466832
164.633	0.470346	0.472796	0.463505
162.051	0.472769	0.478857	0.45895
159.468	0.471296	0.468393	0.455275
156.885	0.469968	0.465706	0.460276
154.303	0.469443	0.464479	0.461408
151.72	0.467498	0.469534	0.459943
149.138	0.467715	0.467905	0.460752
146.555	0.466294	0.46951	0.465129
143.972	0.464158	0.468444	0.465593
141.39	0.465149	0.469816	0.46558
138.807	0.463738	0.464316	0.461493
136.225	0.462627	0.461868	0.458867
133.642	0.461084	0.459363	0.456899
131.059	0.460542	0.458728	0.45399
128.477	0.459287	0.458323	0.450239
125.894	0.457627	0.453616	0.444962
123.312	0.455742	0.44975	0.44019
120.729	0.452881	0.448372	0.438081
118.146	0.450237	0.446733	0.437151
115.564	0.447401	0.44694	0.437199
112.981	0.445551	0.445452	0.438137
110.398	0.444971	0.443315	0.437072
107.816	0.444727	0.440859	0.435117
105.233	0.444357	0.437945	0.43318
102.651	0.442617	0.437589	0.430895
100.068	0.440152	0.436313	0.430793
97.4854	0.437815	0.43375	0.429386
94.9028	0.436334	0.431948	0.426127
92.3202	0.436054	0.431171	0.424742
89.7376	0.4357	0.43213	0.423475
87.155	0.436954	0.431863	0.422807
84.5724	0.437447	0.431954	0.422873
81.9898	0.439051	0.431447	0.423656
79.4072	0.43821	0.431072	0.423639
76.8246	0.437234	0.431854	0.423724
74.242	0.435063	0.432813	0.423885

71.6593	0.431785	0.433837	0.423775
69.0767	0.42905	0.431576	0.424294
66.4941	0.427788	0.428092	0.424951
63.9115	0.429518	0.427823	0.42651
61.3289	0.432637	0.429664	0.429338
58.7463	0.435267	0.432328	0.432657
56.1637	0.436611	0.436229	0.435134
53.5811	0.436239	0.440227	0.438161
50.9985	0.436998	0.443399	0.440517
48.4159	0.439329	0.445839	0.442624
45.8333	0.441727	0.447083	0.445544
43.2507	0.444107	0.448522	0.44968
40.668	0.446923	0.450294	0.45373
38.0854	0.450155	0.452246	0.457219
35.5028	0.45335	0.454562	0.459702
32.9202	0.456236	0.457196	0.461365
30.3376	0.45903	0.459749	0.46281
27.755	0.460623	0.462377	0.463655
25.1724	0.462849	0.465012	0.464743
22.5898	0.466368	0.467514	0.466017
20.0072	0.469859	0.469207	0.467284
17.4246	0.471663	0.470301	0.467933
14.842	0.471424	0.471382	0.468673
12.2594	0.472355	0.472328	0.46968
9.67675	0.472958	0.473327	0.471144
7.09415	0.473605	0.473891	0.472605
4.51154	0.47444	0.474307	0.473739
1.92893	0.475536	0.474603	0.474902
-0.653677	0.476505	0.474939	0.475234
-3.23629	0.477021	0.475548	0.475013
-5.81889	0.476805	0.476088	0.474995
-8.4015	0.47651	0.476242	0.475209
-10.9841	0.476397	0.476145	0.47547
-13.5667	0.476453	0.476094	0.475678
-16.1493	0.476609	0.475934	0.475752
-18.7319	0.477071	0.475897	0.475443
-21.3145	0.476404	0.475679	0.475311
-23.8972	0.476012	0.475613	0.475159
-26.4798	0.475878	0.475183	0.474964
-29.0624	0.47589	0.47477	0.474999
-31.645	0.476168	0.47451	0.474767
-34.2276	0.476279	0.474603	0.474587

-36.8102	0.475936	0.474845	0.474725
-39.3928	0.475718	0.474882	0.475092
-41.9754	0.475387	0.475171	0.475673
-44.558	0.475304	0.475551	0.475875
-47.1406	0.475021	0.475801	0.475511
-49.7232	0.474665	0.475984	0.475037
-52.3058	0.474613	0.475852	0.47425
-54.8884	0.474827	0.475405	0.4733
-57.4711	0.474736	0.47452	0.47228
-60.0537	0.473754	0.473484	0.470986
-62.6363	0.472249	0.472171	0.469171
-65.2189	0.470049	0.470307	0.466676
-67.8015	0.467275	0.467654	0.464021
-70.3841	0.462987	0.464247	0.461505
-72.9667	0.462372	0.460668	0.458701
-75.5493	0.46015	0.456771	0.455541
-78.1319	0.457138	0.45228	0.45247
-80.7145	0.453744	0.447697	0.449003
-83.2971	0.450657	0.444587	0.445591
-85.8797	0.446637	0.437703	0.441121
-88.4623	0.440112	0.431702	0.436054
-91.045	0.431642	0.423764	0.428216
-93.6276	0.417974	0.410819	0.414439
-96.2102	0.399083	0.389514	0.393952
-98.7928	0.379568	0.368512	0.372948
-86.4077	0.45707	0.457569	0.46078
-88.8493	0.457384	0.457131	0.4602
-91.291	0.457179	0.456671	0.458513
-93.7326	0.455023	0.454879	0.455091
-96.1742	0.448469	0.449564	0.448133
-98.6158	0.435013	0.438099	0.434914
-101.057	0.414942	0.424504	0.418101
-103.499	0.398274	0.409421	0.40455

Table 39 - Average velocities bumped airfoil 15° 65 Hz

Y-Position (mm)	Bumped 1 (m/s)	Bumped 2 (m/s)	Bumped 3 (m/s)
194.378	0.347934	0.35466	0.388581
191.937	0.365834	0.362875	0.392809

189.495	0.389661	0.382477	0.417807
187.053	0.417566	0.398607	0.436152
184.612	0.438647	0.419201	0.447616
182.17	0.44952	0.430933	0.46135
179.728	0.455301	0.444286	0.472847
177.287	0.462553	0.451131	0.480364
174.845	0.475087	0.456224	0.48712
172.404	0.474466	0.463843	0.485354
169.962	0.478582	0.465051	0.479392
167.52	0.48151	0.470313	0.479921
165.079	0.482824	0.471405	0.478364
162.637	0.484314	0.471292	0.475913
160.195	0.485175	0.474072	0.479868
157.754	0.485268	0.477716	0.470702
155.312	0.482713	0.476327	0.466751
152.871	0.478517	0.471273	0.463082
150.429	0.475945	0.466934	0.459653
147.987	0.473545	0.464998	0.455294
145.546	0.470463	0.461817	0.449906
143.104	0.468787	0.461192	0.445115
140.663	0.464531	0.458431	0.441836
138.221	0.460773	0.453157	0.440167
135.779	0.453084	0.446373	0.443488
133.338	0.449425	0.441529	0.443546
130.896	0.442402	0.439478	0.444091
128.454	0.43999	0.438776	0.438854
126.013	0.437115	0.439632	0.440073
123.571	0.435327	0.438136	0.43302
121.13	0.433526	0.437025	0.431477
118.688	0.433014	0.431094	0.426118
116.246	0.428504	0.430602	0.419531
113.805	0.426052	0.428127	0.414983
111.363	0.424671	0.425459	0.41403
108.922	0.423075	0.422611	0.415159
106.48	0.419607	0.421446	0.412849
104.038	0.418581	0.419645	0.413182
101.597	0.417798	0.417982	0.41361
99.1551	0.417517	0.417702	0.415111
96.7135	0.416273	0.417707	0.417292
94.2719	0.415669	0.418128	0.415959
91.8302	0.416892	0.418883	0.414927
89.3886	0.417049	0.417688	0.415132

86.947	0.41573	0.416245	0.418276
84.5054	0.415824	0.41594	0.421202
82.0638	0.417682	0.415236	0.423248
79.6222	0.421077	0.416204	0.424436
77.1805	0.424041	0.418386	0.425106
74.7389	0.425225	0.420127	0.426448
72.2973	0.426605	0.421233	0.428296
69.8557	0.429522	0.421401	0.430568
67.4141	0.425584	0.421005	0.43004
64.9725	0.429265	0.422484	0.431355
62.5309	0.428648	0.426538	0.433747
60.0892	0.432163	0.43017	0.436168
57.6476	0.435907	0.431701	0.438437
55.206	0.438696	0.431572	0.440515
52.7644	0.43982	0.432091	0.443439
50.3228	0.440679	0.434241	0.445724
47.8812	0.441287	0.437959	0.447625
45.4395	0.44218	0.441931	0.450515
42.9979	0.442577	0.446805	0.453698
40.5563	0.449976	0.450722	0.4549
38.1147	0.454507	0.452116	0.458029
35.6731	0.457896	0.452292	0.456171
33.2315	0.460219	0.453124	0.45774
30.7898	0.462271	0.454952	0.460885
28.3482	0.464461	0.456755	0.464692
25.9066	0.466763	0.45777	0.467076
23.465	0.470087	0.459566	0.472666
21.0234	0.472656	0.461469	0.471969
18.5818	0.473979	0.462938	0.473571
16.1401	0.473144	0.464671	0.476282
13.6985	0.47416	0.467254	0.478208
11.2569	0.476171	0.468797	0.479612
8.8153	0.478489	0.470234	0.48043
6.37368	0.480277	0.471955	0.480141
3.93207	0.481414	0.474443	0.480058
1.49045	0.482042	0.477061	0.480549
-0.951166	0.482495	0.478246	0.482019
-3.39278	0.482823	0.47836	0.483826
-5.8344	0.483443	0.478427	0.486159
-8.27601	0.484513	0.478825	0.486495
-10.7176	0.486199	0.478642	0.486485
-13.1592	0.487184	0.47828	0.487165

-15.6009	0.487216	0.478706	0.487681
-18.0425	0.486538	0.480086	0.488472
-20.4841	0.485857	0.481378	0.488869
-22.9257	0.485695	0.482069	0.489028
-25.3673	0.485714	0.482145	0.489696
-27.8089	0.486044	0.482699	0.490532
-30.2506	0.486179	0.484383	0.490848
-32.6922	0.486704	0.486162	0.490445
-35.1338	0.487086	0.487197	0.489296
-37.5754	0.486782	0.487544	0.489228
-40.017	0.486439	0.487606	0.488788
-42.4586	0.486188	0.487305	0.488495
-44.9003	0.486778	0.486836	0.488088
-47.3419	0.487562	0.486408	0.485655
-49.7835	0.488198	0.486033	0.487794
-52.2251	0.488612	0.485463	0.488102
-54.6667	0.48851	0.484851	0.488103
-57.1083	0.488204	0.483728	0.48766
-59.5499	0.487491	0.483314	0.486898
-61.9916	0.487019	0.483238	0.486315
-64.4332	0.486448	0.482698	0.486261
-66.8748	0.484748	0.481745	0.485844
-69.3164	0.482909	0.480868	0.484835
-71.758	0.481459	0.479431	0.483461
-74.1996	0.480247	0.47844	0.479969
-76.6413	0.478983	0.476909	0.478954
-79.0829	0.477317	0.474979	0.479351
-81.5245	0.475501	0.472438	0.477902
-83.9661	0.472223	0.469829	0.475822
-86.4077	0.470591	0.468552	0.475208
-88.8493	0.471004	0.4691	0.478412
-91.291	0.469487	0.469386	0.477942
-93.7326	0.466145	0.467195	0.474814
-96.1742	0.459532	0.459755	0.466388
-98.6158	0.446115	0.445602	0.453699
-101.057	0.425091	0.427191	0.438704
-103.499	0.407746	0.410747	0.424943

VITA

Trevor James Martin

Candidate for the Degree of

Master of Science/Arts

Thesis: FLOW MODIFICATION BY TUBERCLES IN BRAZILIAN FREE-TAILED BATS

Major Field: Mechanical Engineering

Biographical:

Education:

Completed the requirements for the Master of Science/Arts in Mechanical Engineering at Oklahoma State University, Stillwater, Oklahoma in May 2017.

Completed the requirements for the Bachelor of Science/Arts in your major at Oklahoma Christian University, Edmond, Oklahoma in 2015.