Lab 3
Supersonic Flow Over Diamond Airfoils

Andres's Contribution

Contents

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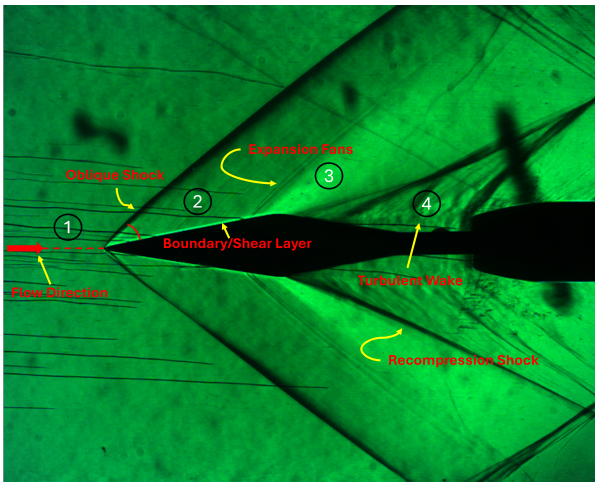
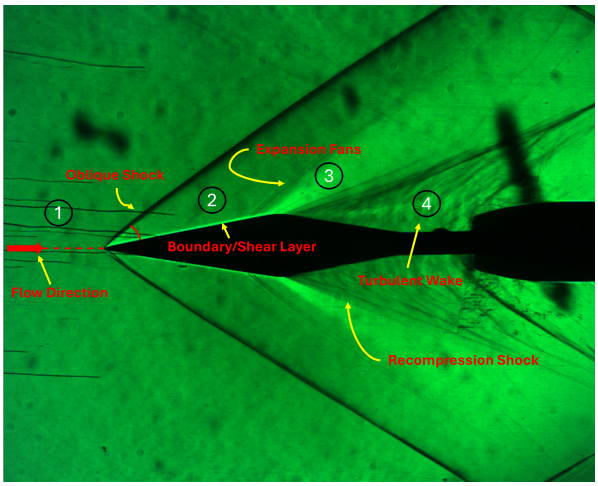
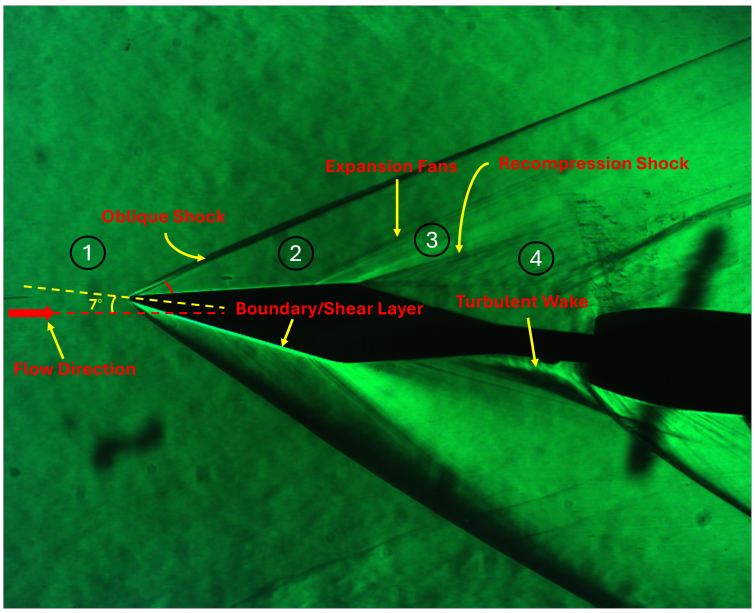
1 7.a



(a) Mach 2 flow at 0° angle of attack



(b) Mach 2.5 flow at 0° angle of attack



(c) Mach 3 flow at 7° angle of attack

Figure 1: Diamond Airfoil at different Machs and Angles of Attack

Similarities and Differences between the different flows in Figure 1 :

- Similarities:
  - Each flow was visualized using a Vertical Schliern setup.
  - The density gradients past the shocks and expansions is visibly clear. That is the density increase across the shock and density drop across the P-M fans are shown clearly by the light captured from the image.
  - In each image there is a visible turbulent wake at the end of the diamond airfoil (zone 4).

  - In each image, the expansion fans and recompression shocks seem to be occuring earlier than on a theoretical diamond airfoil. This discrepancy may be due to the test article not having sharp edges.
  - Unlabeled : At the bottom of images (a) and (b) in Figure 1, a wave reflection can be seen as the shock interacts with the wall enclosing the test section.

- Differences:
  - Between the Mach 2 and Mach 2.5 flows at 0° angle of attack, you can clearly see the shock angle becoming smaller. In addition, the expansion zone is smaller too.
  - At Mach 3 and 7° angle of attack the boundary layer and expansion zone are much tighter on the top of the diamond (top in reference to image; originally the diamond airfoil was tilted 7° counterclockwise).
  - The density gradient is much clearer and bigger on the bottom of the diamond airfoil at 7° angle of attack in Mach 3 flow. More of the flow is hitting that area.

As Mach number increases, the shock wave angle decreases (refer to θ-β-M Relation). These images satisfy shock-expansion theory in this regard. However, as noted previously, the P-M expansion fans and recompression shocks occur much more upstream than shown on a theoretical diamond airfoil.

1.1 Image Correction

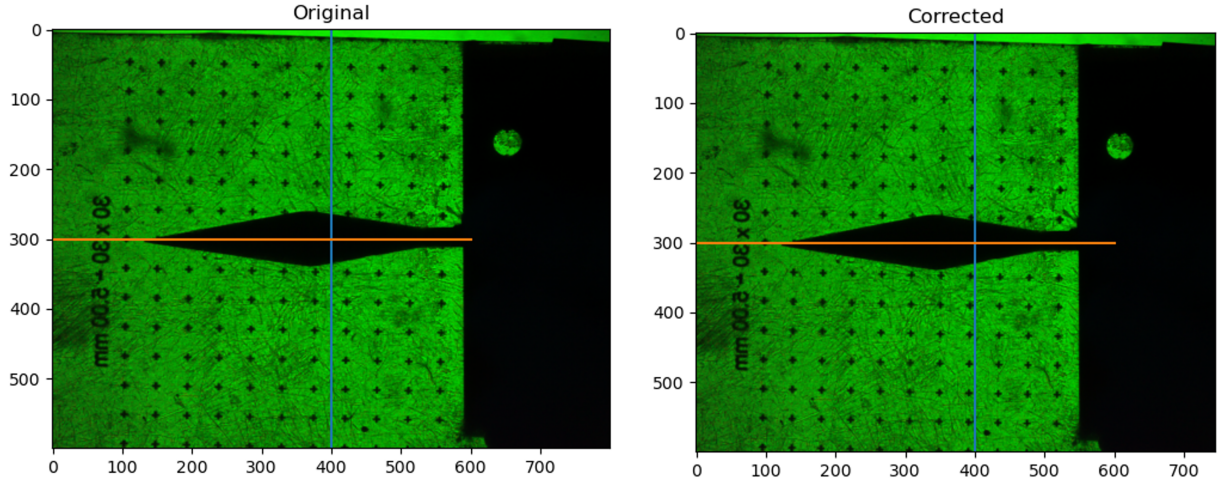


Figure 2: Corrected wind-off grid image, Raw vs Corrected

Given the grid image for correction, there was a noticable distortion as the images were corrected for a stretch along the horizontal.

The raw resolution used was 800 x 600 pixels. After correction this became 745 x 600 pixels.

A calibration factor was calculated using this formula:

$$f = \frac{d_{\text{px}}}{n \cdot (5)}$$

The distance between each grid point is 5 mm and 10 grid points were used to measure the pixel distance along the grid making $n = 10$. It was found that $f_x = 9.06\,\text{pixel/mm}$ and $f_y = 8.44\,\text{pixel/mm}$. Thus there were more pixels in the horizontal direction for the same distance on the grid than in the vertical direction. Therefore the horizontal resolution was corrected by $800 \cdot (f_y/f_x) \approx 745\,\text{px}$. This makes the aspect ratio now approximatly $1:1$.

1.2 Image Correction

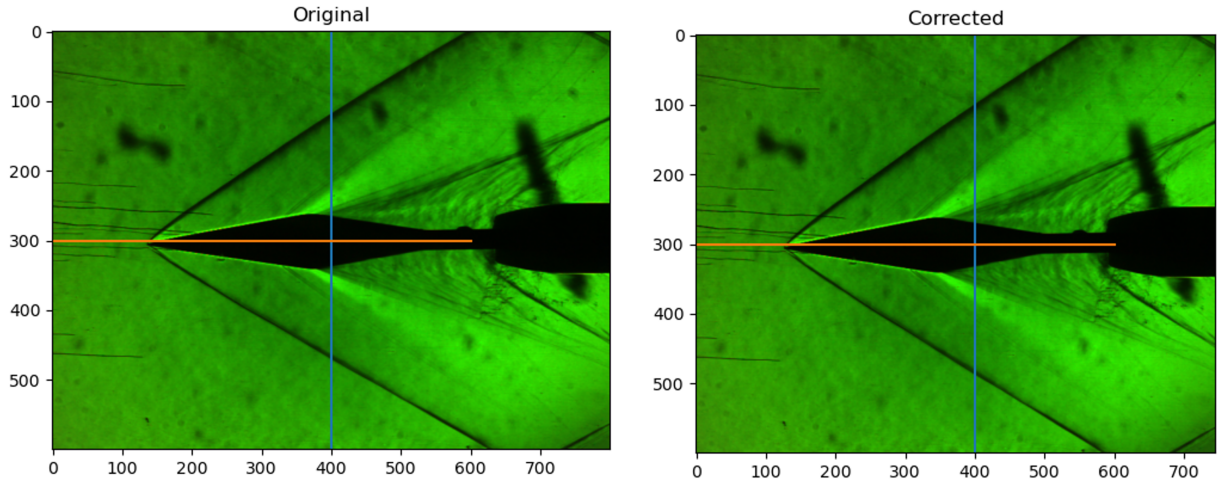


Figure 3: Corrected Example with Mach 2.5 flow at 0° angle of attack, Raw vs Corrected