MAE 352 – Experimental Aerodynamics II
Final Project: Pressure Measurement using Pressure-Sensitive Paint
Final Report Due on 04/29/2019

<u>Problem statement:</u> Obtain pressure measurements on a wedge subjected to supersonic flow using pressure-sensitive paint. Compare the pressure measured using PSP with theoretical predictions and Schlieren results.

<u>Instructions:</u>

- Download the dataset for your group from the Google Drive link provided on Moodle
- The calibration imageset and pressures are in the folder named calibration
    a. calibration.txt contains the gauge pressures in psi for each image
    b. The `*.nef` files are raw files from the camera. These have been converted into the TIF format that MATLAB can read in the "`converted`" folder.
- Data from the wind tunnel runs is in the "`block0818_theta00`" folder for Mach 3, and "`block2102_theta00`" folder for Mach 2.
    a. The first image is the "wind off" image taken before the run is started, and the second image is the "wind on" image taken 3.5 seconds into the run
    b. `data.dat` contains the pressure measurements from the wind tunnel as recorded by the LabView VI. The format of this file is the same as your Schlieren lab data files.
- Follow the steps given in the image processing algorithm below to obtain a pressure distribution over the wedge.
- Next, obtain the pressure behind an oblique shock from
    a. Theoretical oblique shock relations using the turning angle for the geometry we used (turning angle theta = wedge angle = 10 degrees, M = mach based on blocknum)
    b. Oblique shock relations using the shock angle measured in the Schlieren lab (beta = angle from Schlieren image, M = mach from blocknum)
- The oblique shock relations will give you P2/P1. P1 is the static pressure upstream of the shock, measured and recorded in the `data.dat` files in each `block*_theta00` directory. For the first week of the project, we did not measure P1, so you can use the values from the data files obtained in the Schlieren lab.
- The wind-on PSP image was taken at 3.5 seconds. You can use the value of P1 at 3.5 seconds from the data file to find P2.
- Compare the pressure behind the oblique shock from the PSP measurements with the theoretical and Schlieren results.

<u>For the final report:</u>

- Present all results in SI units.
- The report must use the AIAA format provided on Moodle. The following sections are expected in the report: Abstract, Introduction, Methodology, Results, and Conclusions.
- The report must cover all details pertinent to the experiment.
- Include any programs not provided to you as an appendix to your report.
- A single report will be submitted by each group.
- Your submission file must be named MAE352_Final_Project_<day experiment was performed>_Group<group number>.pdf. For example, the group that reported first on Wednesday, March 27th should name their report MAE352_Final_Project_Wednesday_Group1.pdf

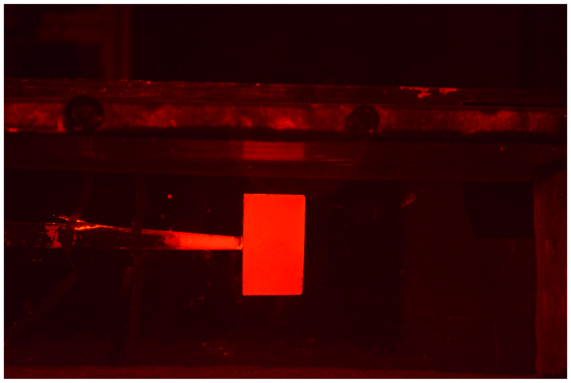
Image processing algorithm:

Like the Schlieren lab, this algorithm is a suggestion. You are free to change it / come up with your own. Obtaining pressure measurements from PSP is a two-stage process.

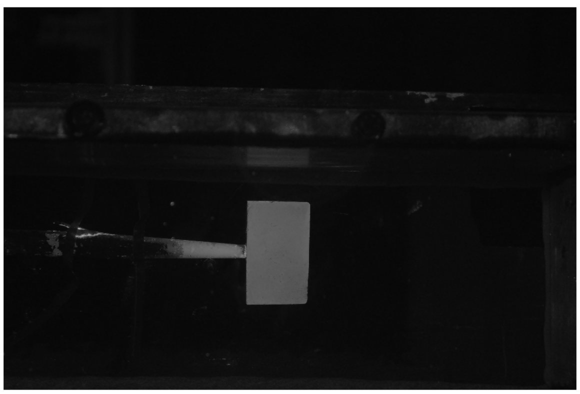
Stage 1: Calibration

Algorithm:

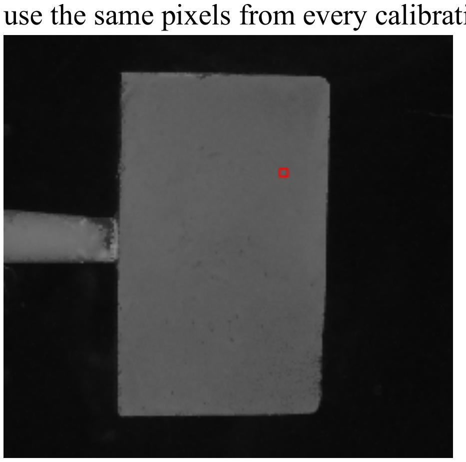
1. Read image



2. Convert image to grayscale



3. Extract a small square of pixels from the image. We found that 25px squares work nicely. You may choose what pixels to extract manually (by hardcoding rows, columns). Remember to use the same pixels from every calibration picture.

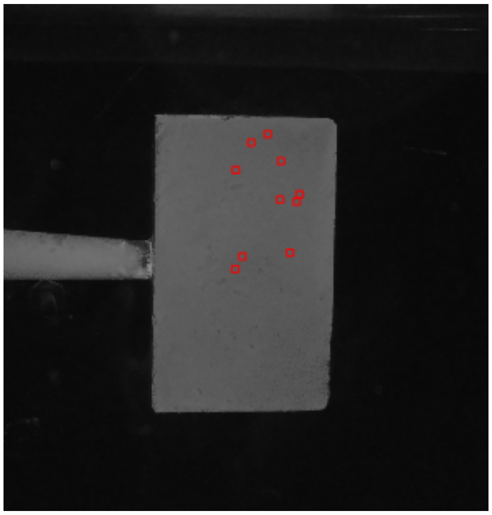


4. Find the mean value of these pixels = signal intensity (I) in that square
5. Save the intensity for later, and repeat for all calibration images

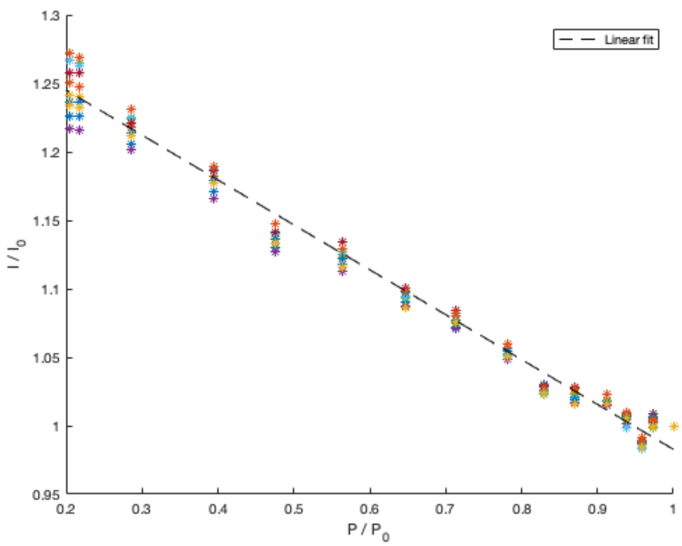
The calibration curve is the curve showing P/P_0 vs. I/I_0, where I_0 is the intensity at P = P_0. P_0 = reference pressure = atmospheric pressure, recorded in the data files from the WT runs.

P, P_0 are absolute pressures. The numbers in your calibration file are gauge pressures. You will have to account for this in your code.

We suggest doing steps 3-5 for a bunch of locations for each image so you have a number of intensity values over the entire wedge. This allows you to account for surface imperfections, variations in the thickness of the applied PSP coat, etc. Remember to divide the intensity in each square with the intensity of the corresponding square from the reference picture (taken at P = P_0). In the picture below, we obtained the intensity ratios from 10 squares randomly placed on the wedge.



Once you have obtained the intensity ratios for all squares, you can plot them vs. pressure ratio. Your plot will look like this:



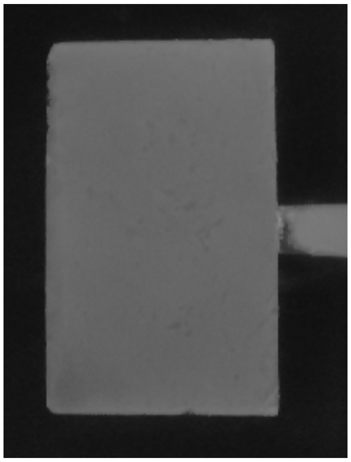
Find the equation of the straight line that best fits all these points. This is the calibration curve you will use in stage 2.

Make sure the squares you're extracting are within the wedge. You can use `imshow()` to show the image in a figure and `ginput()` to interactively obtain the x-y coordinates of any point in the image. MATLAB help will tell you how to use these functions.

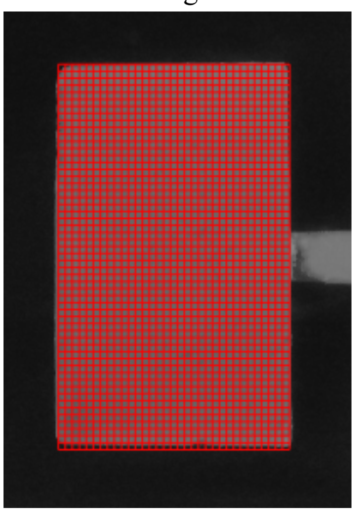
Stage 2: Computing pressures from wind tunnel runs

Algorithm:

1. Read image, convert to grayscale



2. Divide the wedge into small squares. `meshgrid()` will be useful.



3. Find the mean value in each small square in the wind off picture = I_0
4. Find the mean value in each small square in the wind on picture = I
5. Find P/P0 from I/I0, get P in each square

Once you have the pressures, you can plot the contour of pressures over the surface of the wedge using the attached `psp_plotcontour()` function. Your image may look different based on your choice of levels, so remember to include the legend for color -> pressure in your report. Notice that the pressure is not uniform throughout the wedge. What do you think are the reasons for this variation? Discuss this in your report.