Overview and description of the UQ experiment

The UQ experiment database details the effects of small changes to the inlet geometric boundary conditions on an incident shock boundary layer interaction in a Mach 2.05 flow. In total, 45 different perturbed cases are explored and compared to a baseline unperturbed case.

A detailed description of the experiments and analysis of the results are available in the PhD thesis of Laura Campo (Stanford University, 2014). This thesis includes other experiments that are not part of the UQ experiment database, so the relevant sections are listed below.

A PDF copy of the thesis (**Campo_thesis.pdf**) is provided for reference. Please read through these recommended sections carefully:

section 2.1: description of wind tunnel facility

section 2.2: details of the test section geometry

- See especially figure 2.2
- Only the smallest compression ramp (h_{ramp} = 1.1mm, h_{ramp}/δ_0 = 0.20) is used for the UQ experiment test cases. The mid size (h_{ramp} = 3mm, h_{ramp}/δ_0 = 0.56) and large (h_{ramp} = 5mm , h_{ramp}/δ_0 = 0.93) ramp geometries are for different experiments that are not included in the UQ experiment database.
- If you want to include the converging-diverging nozzle in your CFD simulation, please refer to **nozzleCoordinates.xlsx** for the coordinates of the nozzle geometry. Note that the top and bottom walls are symmetrically contoured and the side walls are parallel.

section 2.3: description of PIV setup and measurement domain

- Note that some of the information in this section does not apply to the UQ experiment. The discrepancies are described in section 4.1. They are:
  - Measurements are acquired only in a single camera "tile" in a streamwise-vertical plane positioned at z = 21mm (near the centerline of the duct).
  - 2500 image pairs are acquired for each perturbed case (not 5000). Therefore only mean velocity measurements are available for all of the perturbed cases.
  - Perturbations are introduced into the bottom wall surface of the wind tunnel upstream of the location of the compression ramp. These perturbations are described in sections 4.2 and 4.3 and appendix A.

section 3.1: inflow conditions

- in particular, see tables 3.1 and 3.2
- inflow profiles (including U, V, u', v', and <u'v'>) are available at a location 35mm upstream of the ramp foot. These profiles are acquired at five positions across the span of the tunnel (see figure 3.1). The data are also provided in electronic format for convenience:
  - Data are saved in Matlab .mat file format: **inflowProfiles.mat**. Run the provided script (**plotInflowProfiles.m**) to plot the data.
  - The profiles are also available in the more general ASCII tab-delimited format: **inflowProfilesASCII**.

section 4.1: UQ experiment setup

- be sure to read this after reading about the experimental setup in chapter 2.

section 4.2: design of the perturbation device

- see especially figures 4.1 and 4.2

section 4.3: characterization of the perturbation (bump) shapes

- note that appendix A contains even more details on the characterization of bump shapes

sections 4.4 & 4.5: analysis of UQ experiment data

- description of shock crossing point (scp) and other comparison metrics

section 4.6: some brief recommendations for use of UQ experiment data for CFD validation

chapter 5: modeling of PIV measurement biases

- the ideas presented in this chapter are relevant for CFD comparisons against any PIV measurements of high speed compressible flows. The results that are shown are for stronger shock boundary layer interactions produced by larger compression ramps than the one used in the UQ experiment database. Any PIV measurement biases in the UQ experiment database are expected to be smaller than the estimates for the stronger interactions.

appendix A: more detailed description of perturbation shapes

Organization of the UQ experiment dataset

Each perturbed case is characterized by two parameters:

bump height (h_{bump})
bump location (x_{bump}) – measured relative to the foot of the compression ramp

Each perturbed case is assigned a number between 1-45. Table 1 below describes the bump configuration corresponding to each case.

The position of the shock crossing point (scp) in the UNPERTURBED interaction is:

x_scp_unperturbed = 44.1mm – measured relative to the foot of the compression ramp
y_scp_unperturbed = 4.84mm – distance from the bottom wall

Adding perturbations to the inlet geometry causes the shock crossing point to move around. Therefore, the change in the position of the shock crossing point is provided for each of the 45 perturbed cases. For example, in the j^{th} case it is given as:

Δx_scp(j) = x_scp(j) – x_scp_unperturbed
Δy_scp(j) = y_scp(j) – y_scp_unperturbed

Δx_scp and Δy_scp are also listed in Table 1 below for each of the perturbed cases 1-45.

For your convenience, the main data files are provided in three file formats:

Matlab

data files:	**dataMatlab_caseN.mat**
summary file:	**dataSummary.mat**
script for plotting data:	**plotData.m**

To use the Matlab files, simply save all the .mat and .m files to the same directory and then run the plotData.m script.

Tecplot

data files:	**dataTecplot_caseN.dat**
summary file:	see the ASCII tab-delimited section below
layout files for plotting:	**caseN_U.lay** (streamwise mean velocity)
	caseN_V.lay (vertical mean velocity)

To use the Tecplot files, simply save all the .dat and .lay files to the same directory and then open up the .lay file associated with the case and velocity component you want to look at.

ASCII tab-delimited files:

data files:	**dataASCII_caseN**
summary file:	**dataSummary**

The variables in each of the data files are:

X: streamwise coordinate, measured RELATIVE to the streamwise position of the shock crossing point in the unperturbed interaction: X = x_absolute – x_scp_unperturbed where x_absolute has its origin at the foot of the compression ramp [mm]

Y : vertical coordinate, origin on bottom wall of tunnel [mm]

Z : spanwise coordinate, origin at back wall of tunnel [Z=21mm for ALL cases]

U: mean streamwise velocity [m/s]

V: mean vertical velocity [m/s]

valid: array denoting which data points in U and V are valid. a value of 1 indicates a valid point, and a value of 0 indicates an invalid point (due to low yield of valid PIV vectors at that location). Invalid data are automatically masked when you open the layout files caseN_U.lay or caseN_V.lay or if you plot the data in Matlab using the provided script plotData.m. **If you are using the ASCII tab-delimited files or writing your own script to plot the data, make sure to mask regions of the data files where valid = 0.**

The **dataSummary.mat** and **dataSummary** files contain the same information as presented in Table 1 in electronic format for convenience.

TABLE 1

case number	h_bump [mm]	x_bump [mm]	Delta x_scp [mm]	Delta y_scp [mm]
1	0.11	-75.2	0.09	-0.08
2	0.28	-75.2	-0.62	-0.06
3	0.48	-75.2	-0.36	-0.18
4	0.66	-75.2	-0.42	-0.11
5	0.89	-75.2	-0.36	0.42
6	0.11	-69.2	-0.44	0.16
7	0.28	-69.2	-0.53	0.02
8	0.48	-69.2	-1.23	0.14
9	0.66	-69.2	-1.96	0.22
10	0.89	-69.2	-2.81	0.43
11	0.11	-63.2	-0.43	-0.01
12	0.28	-63.2	-1.02	0.14
13	0.48	-63.2	-2.13	0.38
14	0.66	-63.2	-3.12	0.61
15	0.89	-63.2	-4.18	0.65
16	0.11	-60.2	-0.61	0.07
17	0.28	-60.2	-1.49	0.52
18	0.48	-60.2	-2.11	0.51
19	0.66	-60.2	-3.48	0.64
20	0.89	-60.2	-4.47	0.91
21	0.11	-57.2	0.36	-0.02
22	0.28	-57.2	-0.55	0.05
23	0.48	-57.2	-1.96	0.28
24	0.66	-57.2	-3.42	0.59
25	0.89	-57.2	-4.76	0.76
26	0.11	-54.2	0.06	0.06
27	0.28	-54.2	-0.49	0.04
28	0.48	-54.2	-1.70	0.22
29	0.66	-54.2	-3.21	0.44
30	0.89	-54.2	-4.61	0.90

case number	h_bump [mm]	x_bump [mm]	Delta x_scp [mm]	Delta y_scp [mm]
31	0.11	-51.2	-0.05	0.51
32	0.28	-51.2	-0.04	0.51
33	0.48	-51.2	-0.29	0.73
34	0.66	-51.2	-1.50	0.74
35	0.89	-51.2	-3.38	1.03
36	0.11	-48.2	-0.28	0.75
37	0.28	-48.2	-0.36	0.76
38	0.48	-48.2	-0.65	0.71
39	0.66	-48.2	-1.68	1.12
40	0.89	-48.2	-3.79	1.38
41	0.11	-42.2	-0.54	0.70
42	0.28	-42.2	-0.24	0.61
43	0.48	-42.2	-0.24	0.71
44	0.66	-42.2	-0.52	0.72
45	0.89	-42.2	-0.88	0.90
unperturbed	0	none	0	0

x_scp unperturbed = 44.1 mm

y_scp unperturbed = 4.84 mm