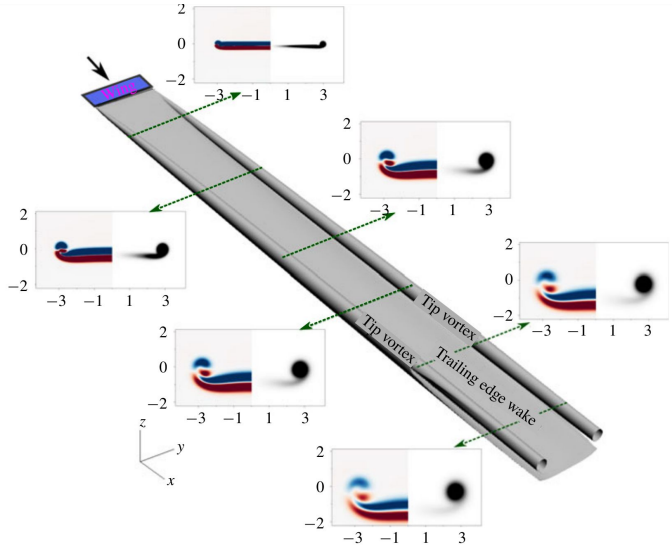
Wingtip Vortices Parameter Estimation to Analyse Instabilities



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2D Curve-fits

Velocity Curvefit :

$$U_\infty + W_0\left(\frac{R_0}{R}\right)^2 e^{-\left(\frac{r}{R}\right)^2}$$

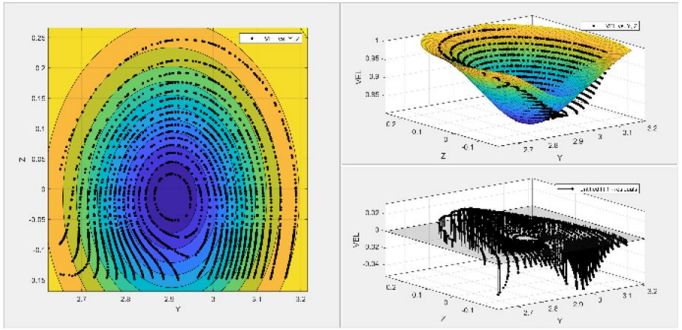
General model used to curvefit:

f(x,y) = a+b*(0.221/c)^2*exp(-((x-y0)^2+(y-z0)^2)/(c^2))

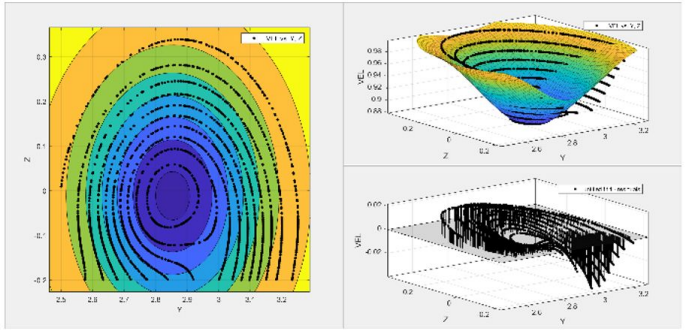
Results :

	X/c=5	X/c=10	X/c=15	X/c=20	X/c=25
a	0.989	0.9947	0.9937	0.9869	0.9825
b	0.005885	0.004812	0.06786	0.05933	0.05704
c	0.1043	0.1281	0.1406	0.1482	0.1567

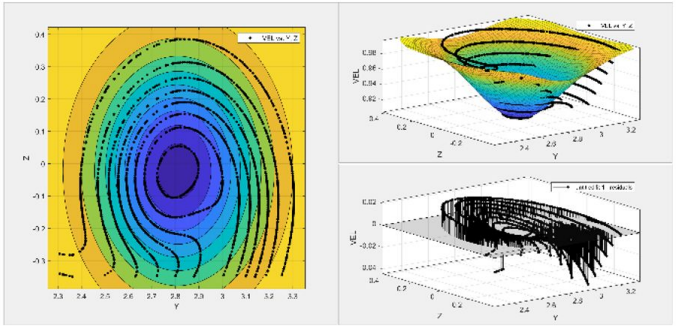
The value of parameter a corresponds to the free stream velocity supposed to be 1 and all the curve fit a parameters are in the near neighbourhood of 1.



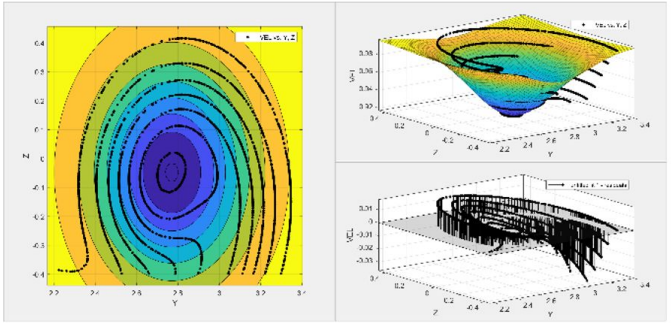
At X/c= 5
Core: Y=2.918, Z=0.3507



At X/c= 10
Core: Y=2.88, Z=0.659



At X/c= 15
Core: Y=2.86, Z=0.915



At X/c= 20
Core: Y=2.871, Z=1.168

2D Curve-fits

Vorticity Curvefit :

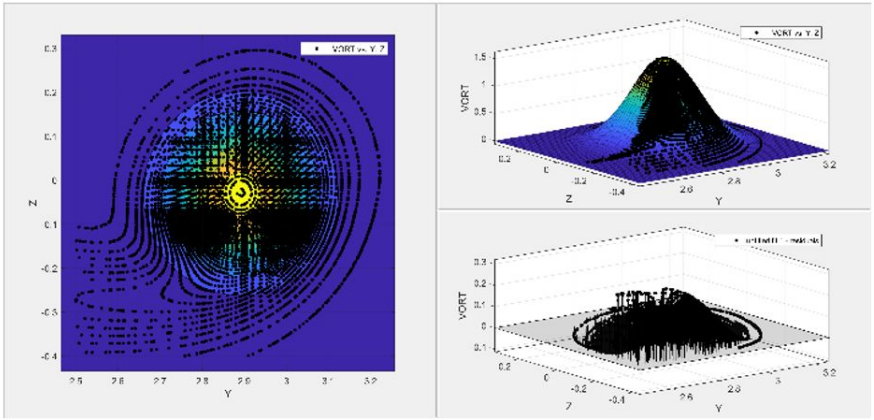
$$W_x = \left(\frac{2RoqWo}{R^2}\right) e^{-\left(\frac{r}{R}\right)^2}$$

General model used to curvefit:

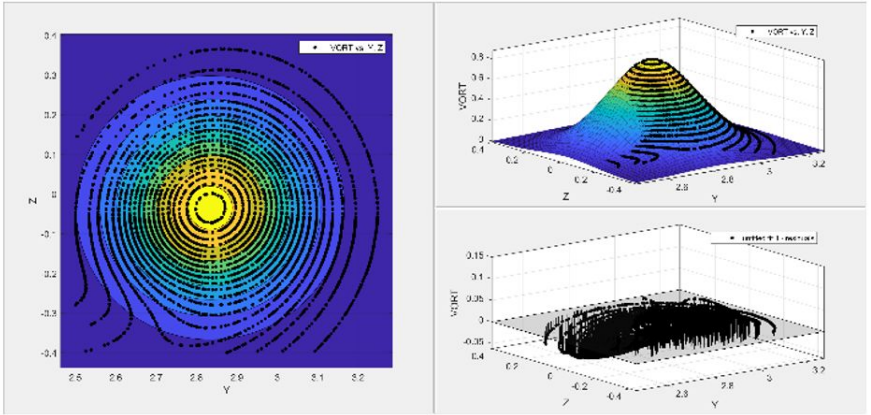
f(x,y) = (a/b^2)* exp(-((x-2.8915)^2+(y+0.03034)^2)/b^2)

Results :

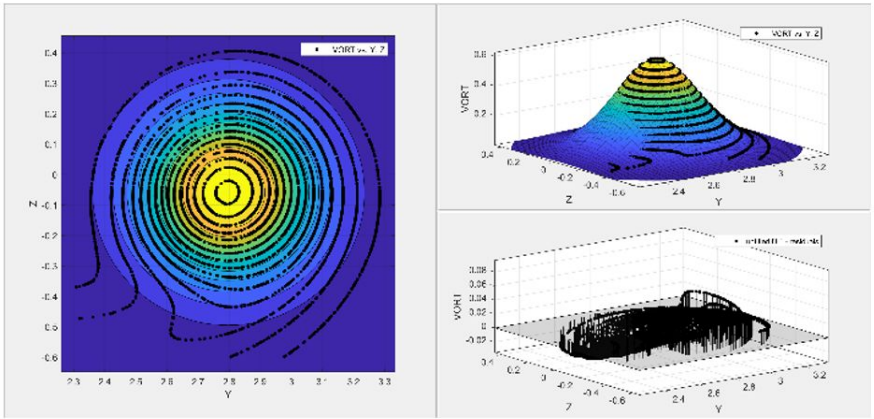
	X/c=	X/c=	X/c=	X/c=	X/c=
a	0.04017	0.0438	0.04591	0.04729	0.04822
b	0.1619	0.2271	0.277	0.3181	0.3537



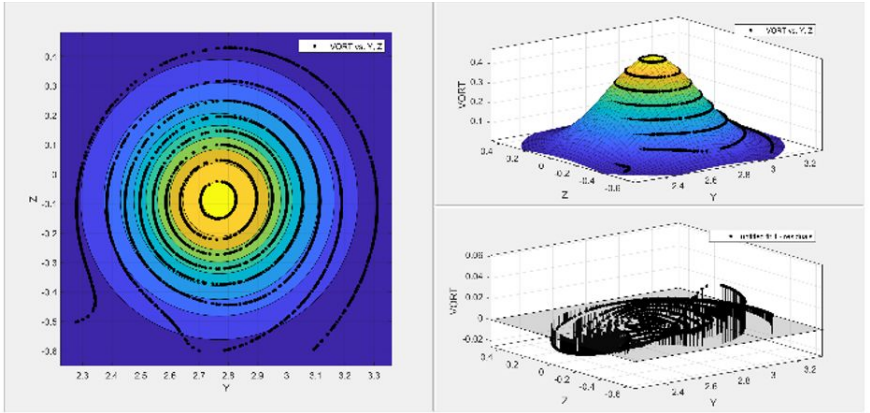
At X/c= 5



At X/c=10



At X/c= 15



At X/c= 20

2D Curve-fits

Azimuthal Velocity Curvefit :

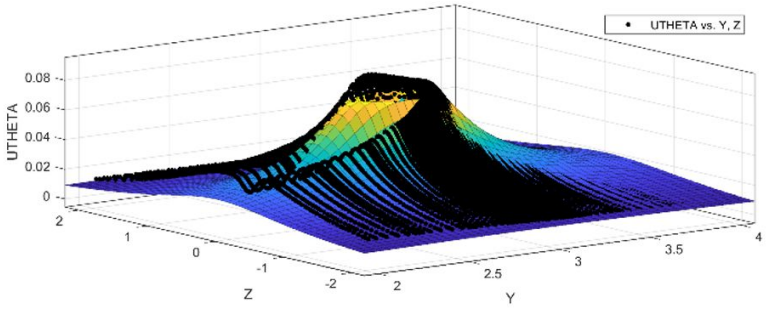
$$U_\theta = \frac{\tau}{2\pi r}\left(1 - e^{-(\frac{r}{R})^2}\right)$$

General model used to curvefit:

f(x,y) = k/sqrt((x-2.8915)^2+(y+0.03034)^2))*(1-exp(-((x-2.8915)^2+(y+0.03034)^2)/c^2)

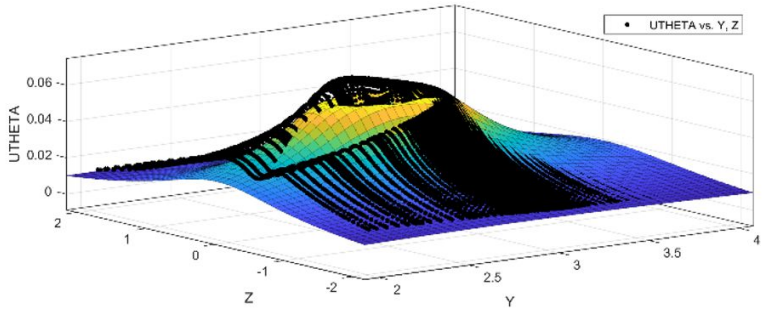
Results :

	X/c=5	X/c=10	X/c=15	X/c=20	X/c= 25
c	0.185	-0.2547	0.3015	-0.34	0.3735
k	0.02238	0.02387	0.02436	0.02461	0.02473



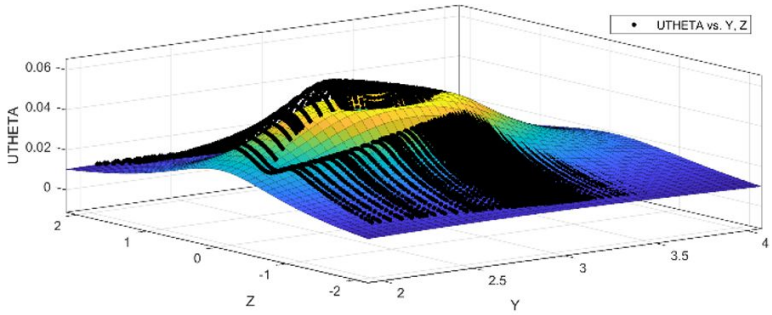
At X/c= 5

Core: Y=2.8915, Z=-0.03034



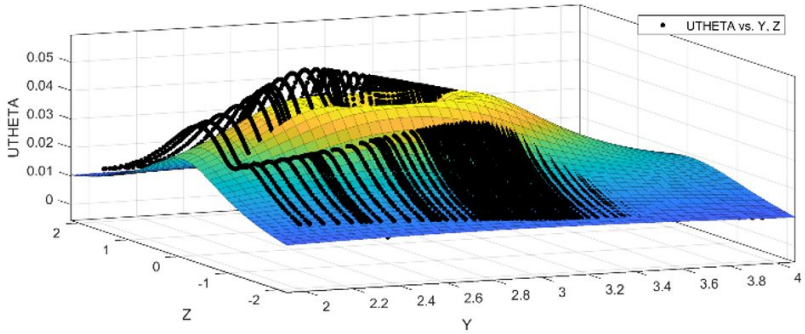
At X/c= 10

Core: Y=2.834, Z=-0.034425



At X/c= 15

Core: Y=2.798, Z=-0.05823



At X/c= 20

Core: Y=2.7685, Z=-0.08635

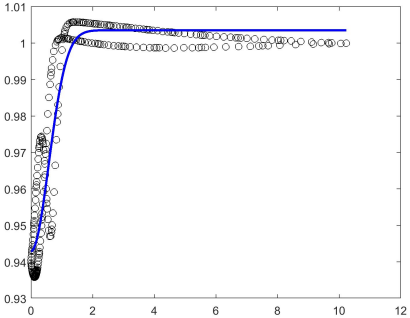
1D curvefits

After 2d fits, 1d fits were performed and it was observed that they were sufficient to capture the properties of the vortex.

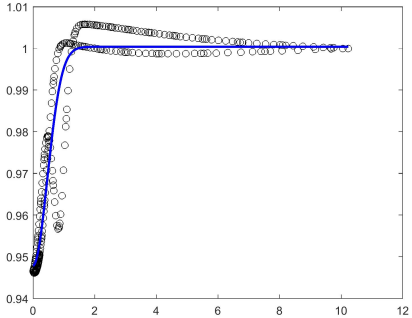
We performed 1d curvefits for velocity and vorticity independently as well as together to optimise the parameters for both velocity and vorticity simultaneously.

1D, 1 Equation Curve Fit

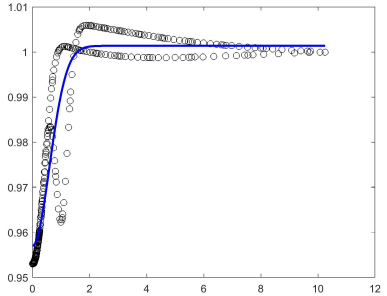
Velocity curvefit



X/c= 30

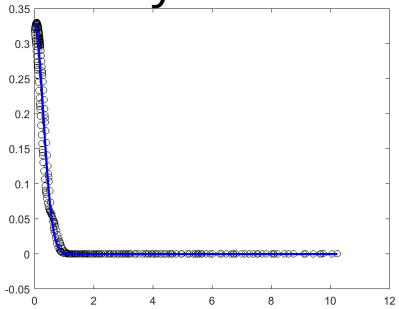


X/c= 40

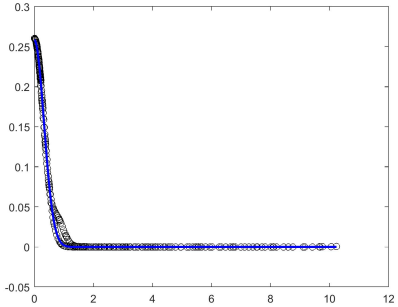


X/c= 50

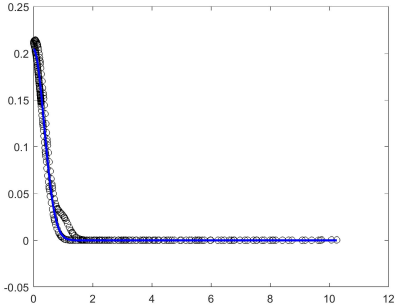
Vorticity curvefit



X/c= 30



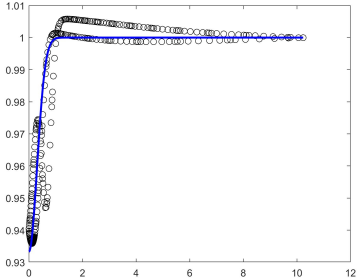
X/c= 40



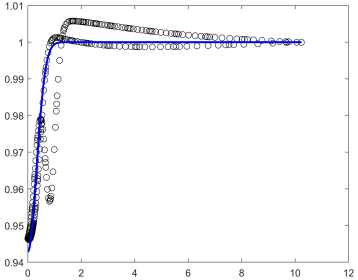
X/c= 50

1D, 2 Equation Curve Fit

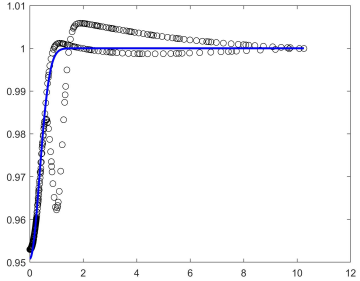
Velocity curvefit



X/c= 30

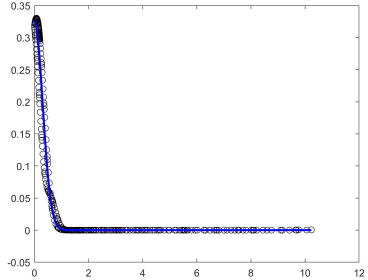


X/c= 40

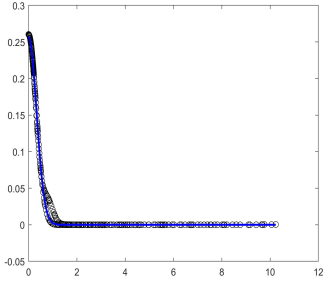


X/c= 50

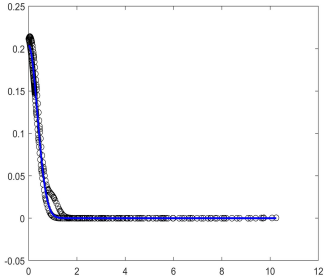
Vorticity curvefit



X/c= 30

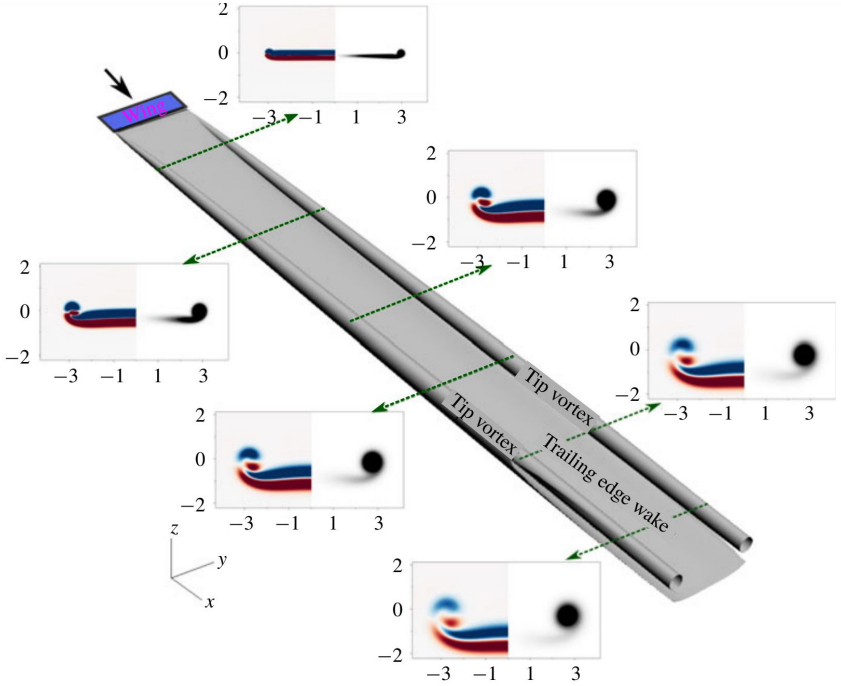


X/c= 40



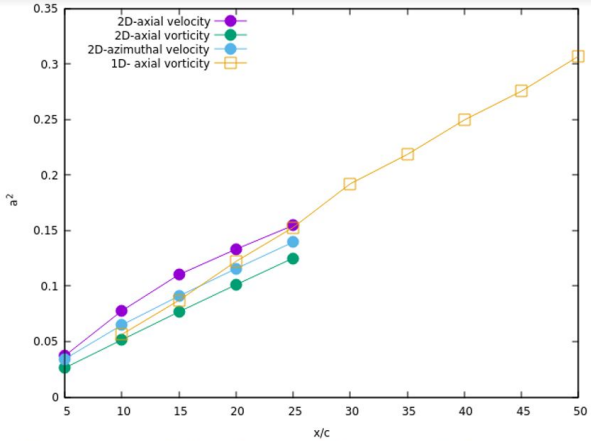
X/c= 50

Bary Center analysis

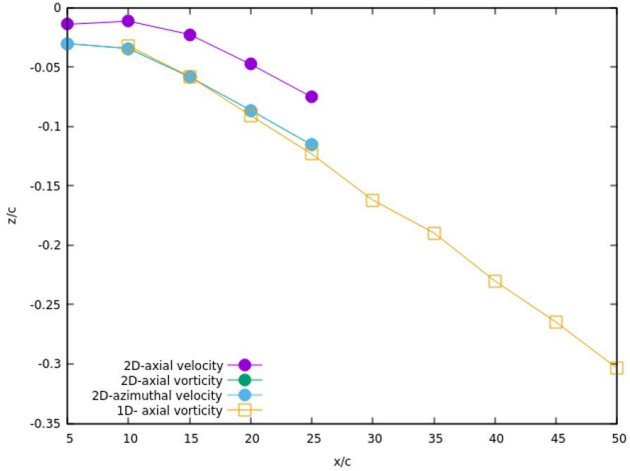


While Z coordinate of the vortex center becomes more negative and the Y coordinate becomes less positive, the bary center position was found to be relatively constant.

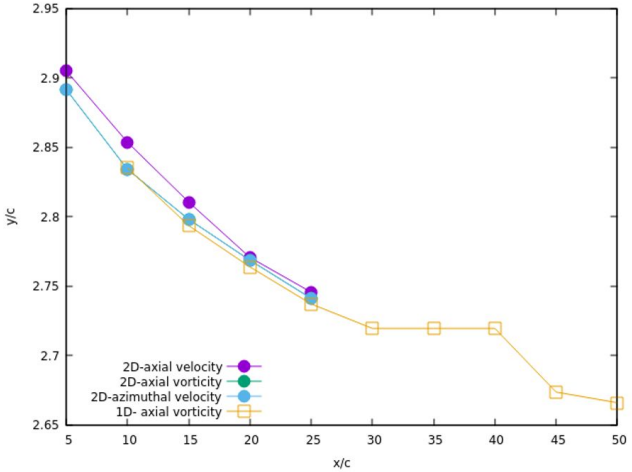
Infact, the vortex was found to finally roll up around the barycenter in the wake of the wing.



The vortex core size from the three different curve fits in comparison to the 1D data in a research paper



The core center Z coordinates from the three curve fits



The core center Y coordinates from the three curve fits

Bary Center

Naca Re = 1000 : y_bary = 2.672876155107226
Z_bary becomes more negative

Naca Re = 5000 : y_bary = 2.663509916623332
Z_bary becomes more negative

FlatPlate Re = 3000 : y_bary = 2.465360501761054
Z_bary becomes more negative

FlatPlate Re = 5000 : y_bary = 2.755718744957201
Z_bary becomes more negative

Circulation

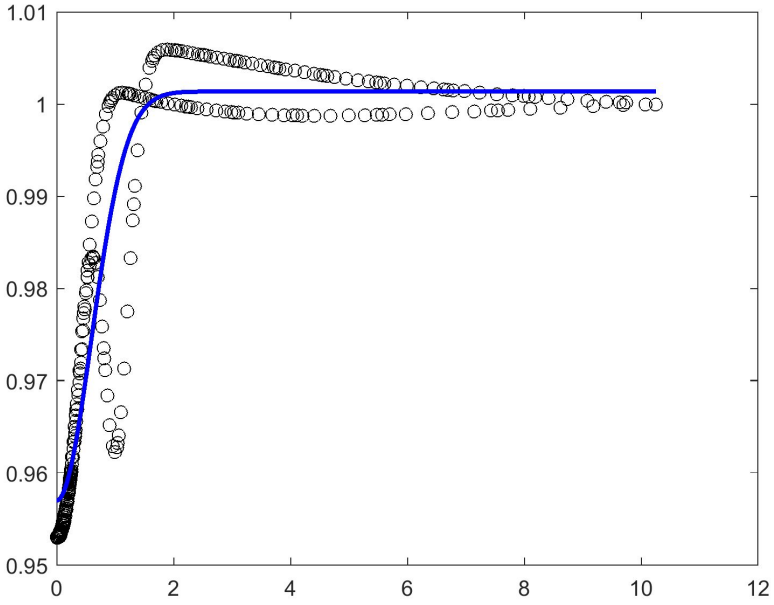
Circulation values were found which were used to cross-check if the barycenter calculations are carried out correctly.
Naca Re = 1000 : 0.112995634770388

Naca Re = 5000 : 0.075610681178494

FlatPlate Re = 3000 : 0.244905983609667

FlatPlate Re = 5000 : 0.276941051376408

Overshoot in velocity raw data



We checked the overshoot with increase in reynolds number to see if it decreases and maybe vanishes at higher reynolds number.

Naca0012 Re = 5000 vel5 : 1.0035

Naca0012 Re = 1000 vel5 : 1.0030

Flatplate Re = 3000 vel5 : 1.0067

Flatplate Re = 5000 vel5 : 1.0052

Since they are not in sync, we can say that this overshoot is due to the CFD calculations done to find the raw data.