On the lock-on of vortex shedding to oscillatory actuation around a circular cylinder[1]

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Objective: To investigate the interaction of von Karman shedding and sinusoidal forcing (sp. single freq lock-on)

Unforced Data/Validation			
	Lift	Drag	St
Present	± 0.328	1.345 ± 0.009	0.165
Liu et al (1998)	± 0.339	1.35 ± 0.012	0.165
Linnick and Fasel (2005)	± 0.337	1.34 ± 0.009	0.166

Control Setup

- Sinusoidal momentum injection near separation point
  - Top and bottom actuation with phase of 180 deg.
- Variable Parameters
  - Forcing frequency of the momentum injection
  - Forcing amplitude
  - Actuator location on the cylinder
  - Actuation direction

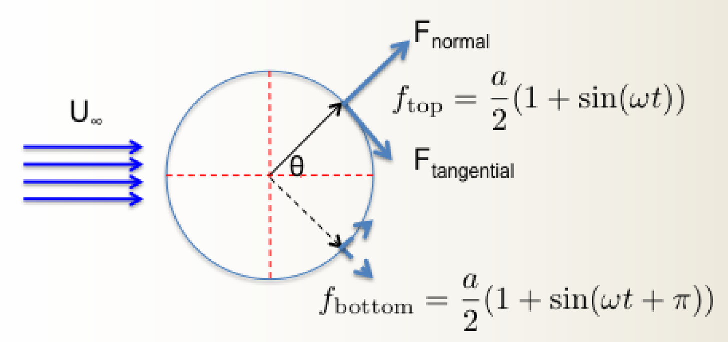

Fig 1: Flow control set-up with different forcing variables

Lock-on definition:

- Define lock-on: single frequency oscillation of the wake
  - Examined with Fourier analysis and phase plots of the drag data.
  - Closed phase plot (left) means the flow is locked on
  - Frequency spectra single peak at $f/f_n = f_a/f_n$ for locked on case
  - Lock-on desired for a predictable flow field

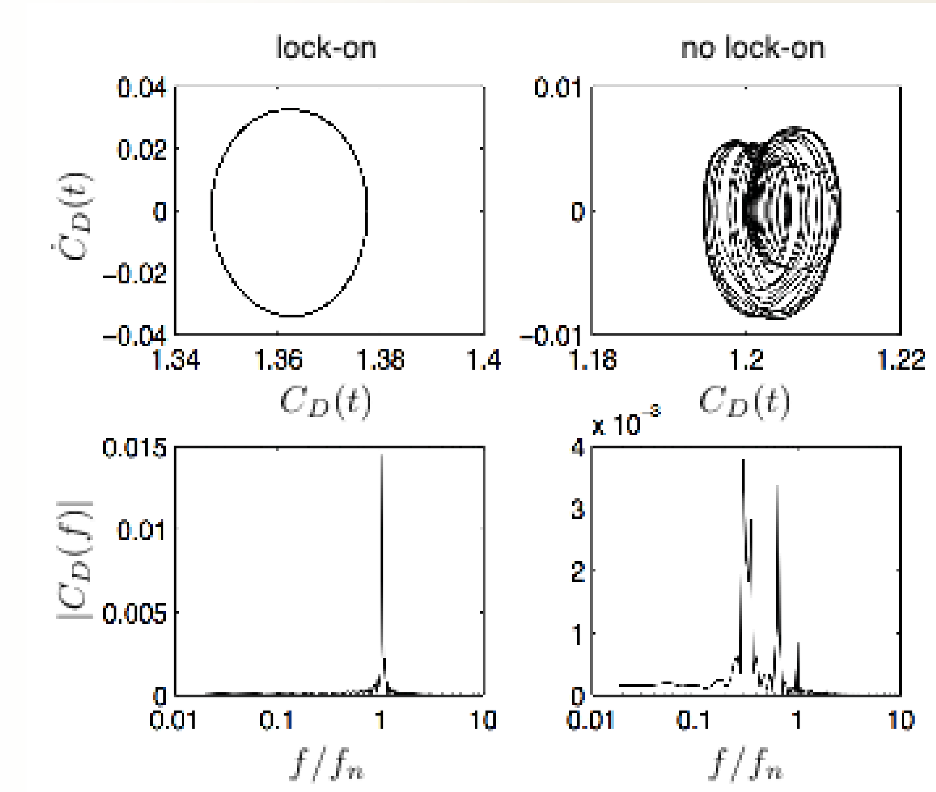

Fig 2: Definition used for single frequency lock-on

Results:

Actuator Direction

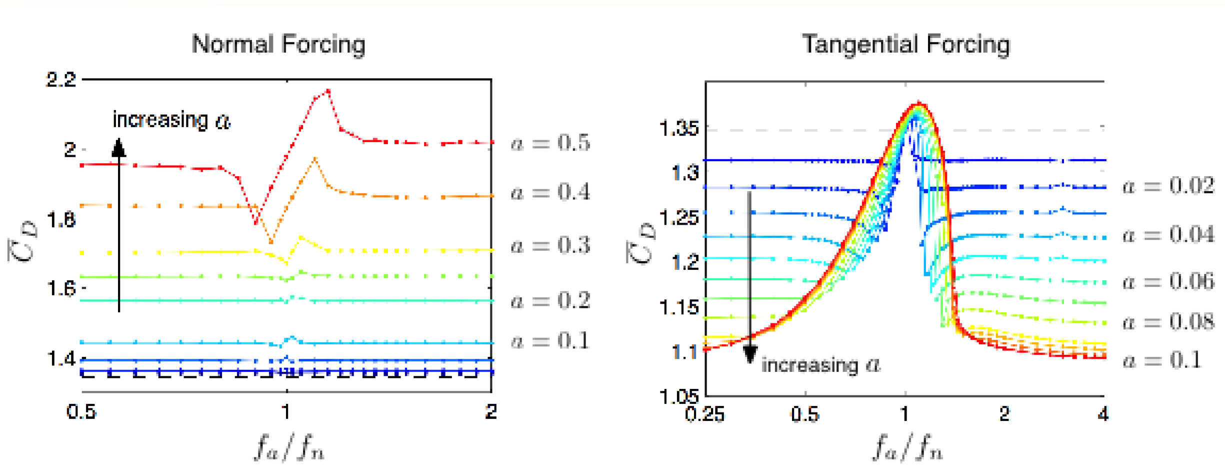

Fig 3: The tangential and normal forcing effects with respect to drag and actuation frequency

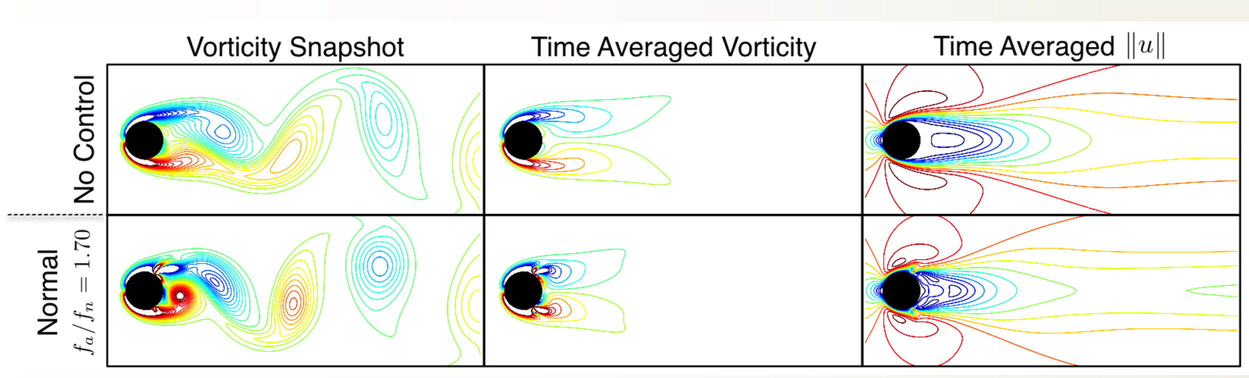

Fig 4: Flow fields for normal and baseline cases, increased drag for the controlled case

Actuator Position

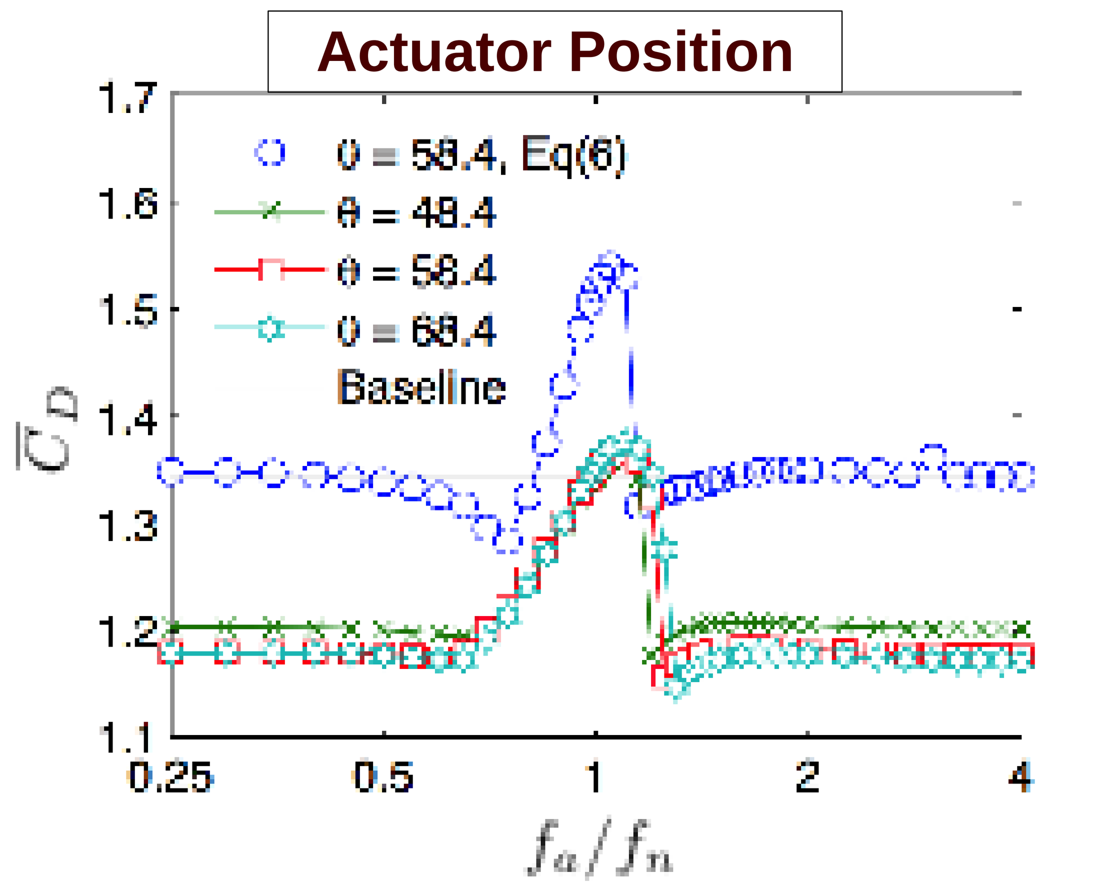

Fig 5: Effects of actuator position, angle with respect to the trailing edge

Actuator Amplitude and Frequency

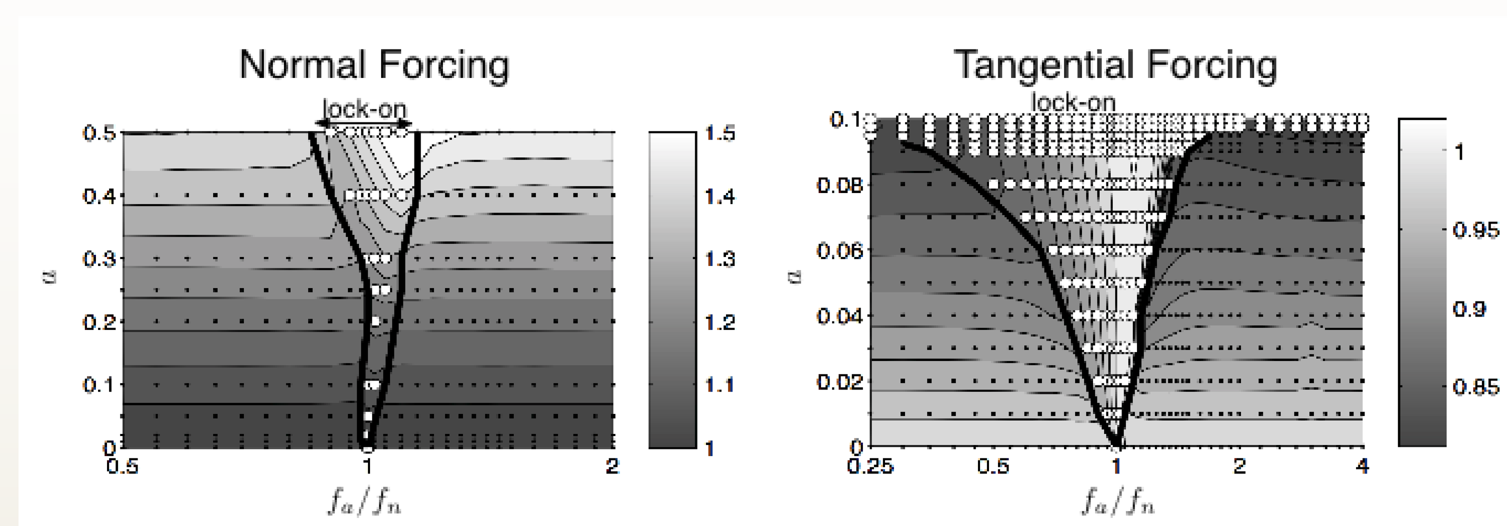

Fig 6: Drag reduction with respect to amplitude and frequency

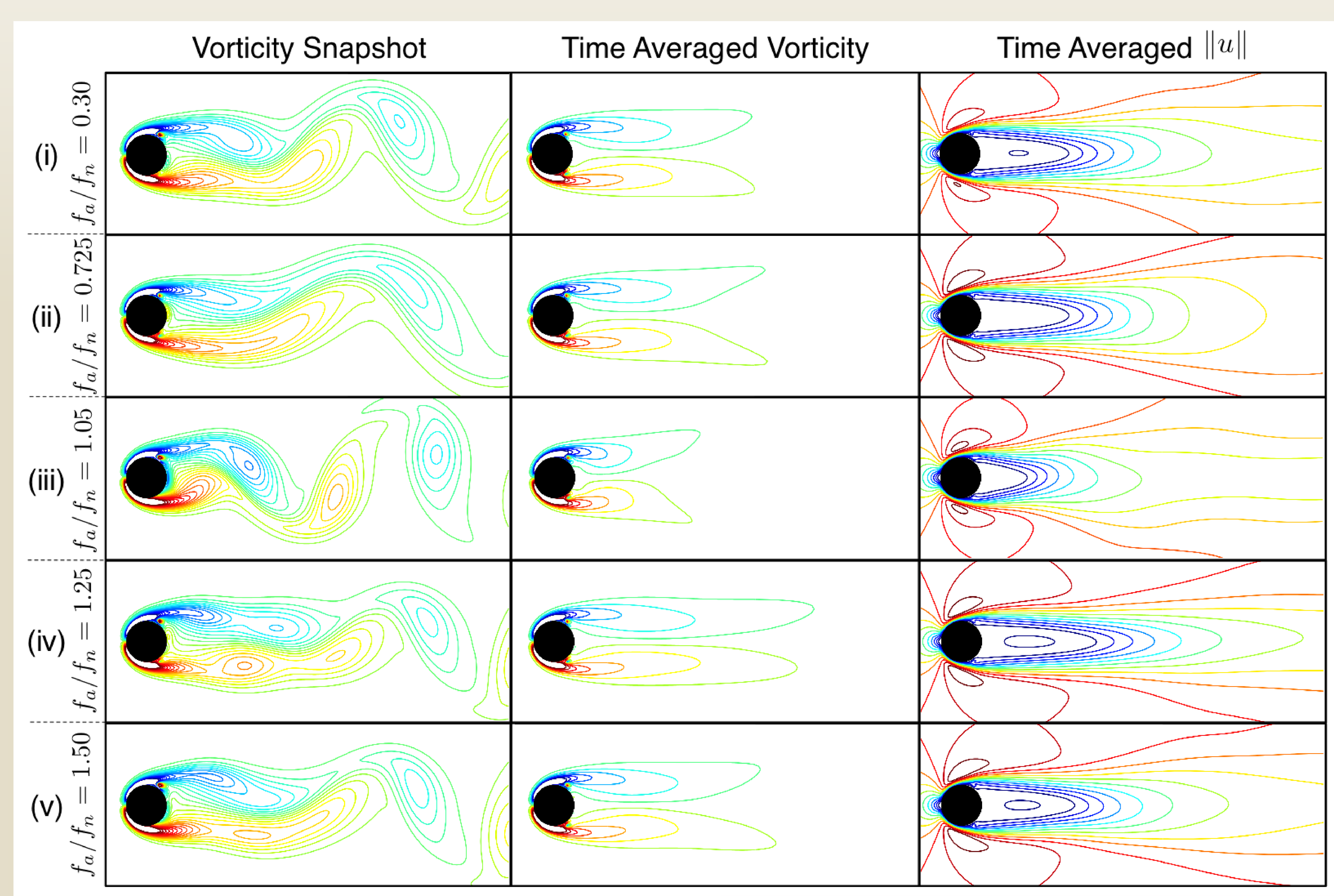

Fig 7: Flow field snapshots from different cases that are locked-on and not locked on (Refer to figure 6 for case information).

Conclusion: The images in Fig. 3 & 4 shows why forcing tangential to the surface is ineffective. As you can see the time average voriticity is shorter for normal actuation which means that the flow is less streamlined than the flow with no control. Different actuation positions were tested (Fig. 5), at the separation of the time average flow field and ten degrees above and below that point. Forcing downstream of the separation point had a slightly higher drag but the change is almost negligible for this case. The actuation frequency and amplitude were the most influential in effecting the lock-on of the simulation (Fig. 6). As the amplitude increase the range of locked on frequencies increased as well, and the drag decreased. In the lock-on region the drag increases but there is a small set of parameters that allows for both predictable flow and reduced drag. Flows for different cases can be seen in Fig. 7 for a = 0.03. Elongated average flow field results in reduced drag, and shorter increases drag.

1) Munday, P., Taira, K ., On the lock-on of vortex shedding to oscillatory actuation around a circular cylinder, Physics of Fluids, 2013