

Low-Dimensional Feedback Control of the von Karman Vortex Street at a Reynolds number of 100

Stefan Siegel, Kelly Cohen, Thomas McLaughlin

US Air Force Academy, Colorado Springs, Colorado

Many fluid–structure interaction problems are caused by unsteady vortex shedding behind bluff bodies. Examples of real life applications subject to these are wakes of submarine turrets and ocean drilling rigs and flame holders in turbine engines. The fluctuating low pressure regions associated with the alternating formation of the vortices causes unsteady loads, mainly in the flow-normal direction, onto the structure. When the frequency of the vortex formation is close to one of the structural modes, large amplitude oscillations and possibly severe structural damage may result. While this problem can be addressed from various directions, our current research is focused on stabilization of the flow using active feedback control. With the fluctuations in the flow reduced, structural loads are diminished a priori.

Our research objective is to stabilize the von Karman vortex street behind a circular cylinder at a Reynolds number of about 100. So far, this has not been demonstrated experimentally or in a Direct Navier Stokes (DNS) simulation. We use both DNS and experiment to test and verify our controller design. The controls approach we use involves low dimensional modeling of the flow field using a modified Proper Orthogonal Decomposition (POD). Sensor information from the flow field is used to obtain an estimate of the POD mode amplitudes characterizing the global flow state. This information is then used as input to the controller, which controls actuation in the form of flow normal translation of the cylinder model.

While controller design and testing is still research in progress, we have some promising preliminary results to report. The influence of the control on flow properties like the wake mean flow distribution and formation are shown on the following page, along with the unsteady lift coefficient during the control run. Using the control approach described above, we were able to reduce the unsteady lift forces on the cylinder by an order of magnitude, and reduce the drag of the cylinder by 15 percent (not shown). At the same time the recirculation region is doubled in length, and the formation length is shifted by 2.5 cylinder diameters downstream. These results were obtained using a variable gain strategy. Gain and phase scheduling depending on the change in the mean flow mode was used to adapt the controller to the varying flow properties as a consequence of the control. While only the most dominant mode was used for feedback, reductions in all global mode amplitudes of more than 75% were observed.

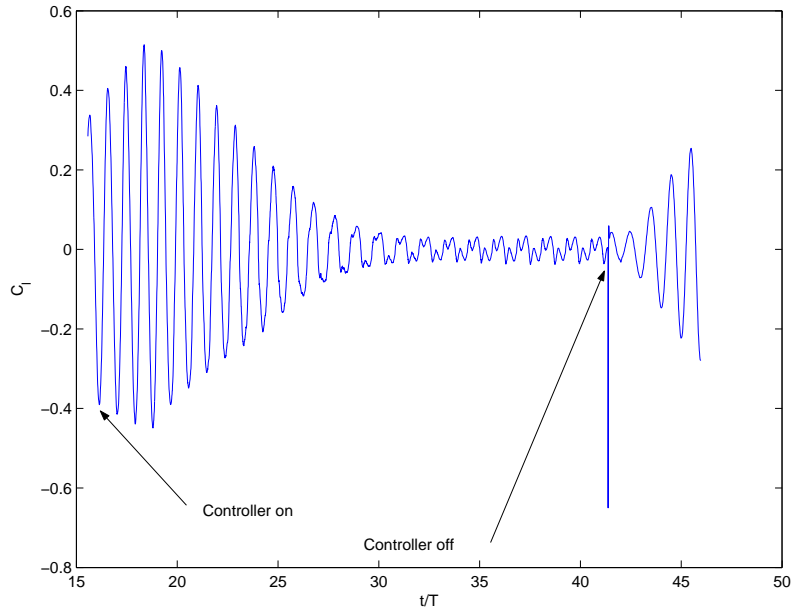


Figure 1. Lift coefficient vs. time after controller turn-on

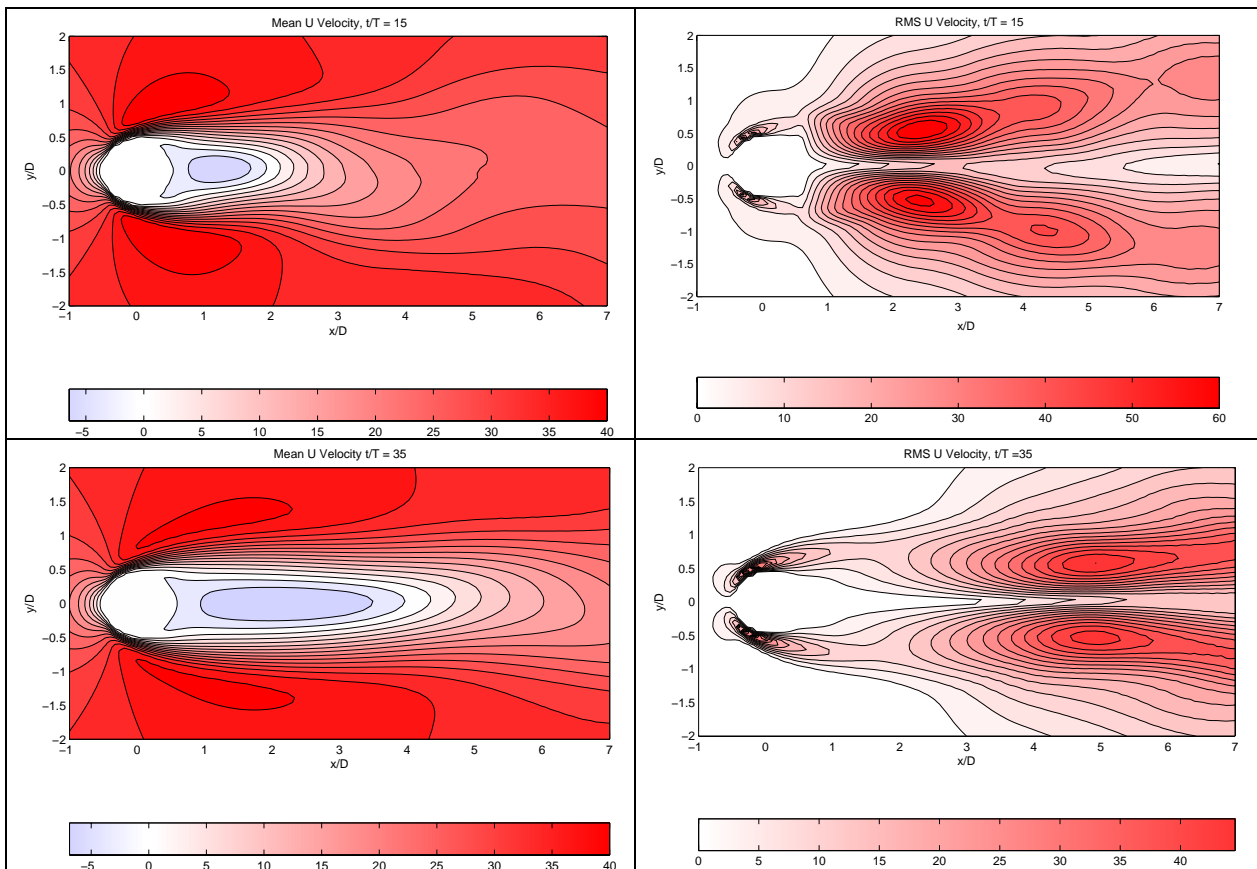


Figure 2. Wake flow distribution showing mean and RMS fluctuation, before and after enabling controller.