Abstract Submitted
for the DFD11 Meeting of
The American Physical Society

Identification of frequency lock-on using Koopman spectral analysis[1] JONATHAN TU, CLARENCE ROWLEY, Princeton University, SHAWN ARAM, RAJAT MITTAL, Johns Hopkins University — The separated flow past an airfoil at a high angle-of-attack is characterized by the frequencies of the wake, shear layer, separation bubble, and zero-net-mass-flux (ZNMF) actuation (if applied). In certain configurations, "lock-on" may occur, in which some or all of these frequencies take on the same value. Previous studies have shown that the presence of lock-on may be related to the effectiveness of ZNMF forcing at a particular frequency. As a model for separated airfoil flows, we analyze the high Reynolds number flow past a finite-thickness flat plate with an elliptical leading edge, inducing separation via a blowing and suction boundary condition rather than angle-of-attack. 3-D large eddy simulations are performed and the resulting data are analyzed using Koopman spectral analysis and proper orthogonal decomposition (POD). Koopman analysis clearly identifies the characteristic flow frequencies and provides corresponding spatial modes. From the spatial support in these modes we determine whether or not lock-on occurs and which structures (wake, shear layer, or separation bubble) are involved. A combination of Koopman and POD analyses shows that ZNMF forcing is most effective when lock-on is achieved in the most energetic modes.

[1]Supported by AFOSR grant FA9550-09-1-0257, NSF GRFP.

Jonathan Tu
Princeton University

Date submitted: 03 Aug 2011 Electronic form version 1.4