From Low-Frequency Oscillations to Markovian Bistable Stall Dynamics

Ivan Kharsansky Atallah*†, Luc Pastur*, Romain Monchaux*, and Laurent Zimmer†

We study experimentally the stall over a thin symmetric airfoil (NACA0012) by focusing on the dynamics from integral quantities such as the lift force. We have found a critical Reynolds number from which the flow transitions from a classical low-frequency oscillations regime [1] [2] to random bistable dynamics. In this regime, the flow switches randomly between a high lift state and a low lift state with residence times orders of magnitude larger than any timescale of the flow. The transitions can thus be considered as rare events. The statistical analysis of the process reveals a memoryless behavior and hence Markovian properties. Going even further, we discovered a super-exponential evolution for the residence times with our control parameter (angle of attack), as in [3] [4]. This result highlights the mathematical equivalence between exponential time statistics (Markov processes) and extreme value laws [5]. Based on this link, we propose a criterion of transition using a variable dynamically linked to our order parameter and we analyze the type of event controlling the transition dynamics. We discuss the physical meaning of these events and their impact on the random bistable dynamics.

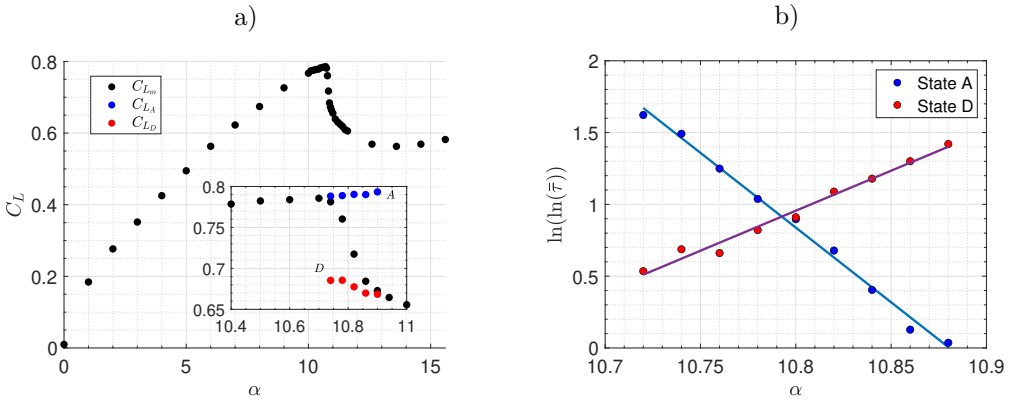

Figure 1: Evolution with the angle of attack α of (a) Lift coefficient C_L showing the bifurcation. (b) Mean residence time $\bar{\tau}$ revealing the super-exponential function.

*Fluid Mechanics Department, ENSTA Paris, Institut Polytechnique de Paris, F-91120 Palaiseau, France

†EM2C Laboratory, CNRS, CentralSupelec, Université Paris-Saclay, 8-10 rue Joliot-Curie, 91190 Gif-sur-Yvette, France

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