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# Near wake of an Ahmed body: analysis of switches and base pressure-velocity relationship

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**Abstract:** We perform the flow behind a squareback Ahmed body using DNS. The dynamics of the flow is analyzed by Proper Orthogonal Decomposition to extract its main characteristics. We focus on the relationship between the base pressure and the near-wake velocity field. The dynamics of the switches due to bimodal behavior of the flow is also considered. The linear stochastic estimation technique [4] is applied to estimate the base pressure modes from the wake flow field and vice-versa. We show that the velocity-based estimator can recover dominant base pressure fluctuations and that the pressure-based estimator can detect velocity deviation and switch mode but fails to capture shedding modes.

*Keywords:* Aerodynamics, Ahmed body, direct numerical simulation, experiments, POD.

## 1 Introduction

In the context of drag reduction associated with environmental issues, we focus on the flow behind an Ahmed body with a square base, mimicking an SUV type profile. It has been observed experimentally [1] that the near wake of this flow is characterized by a bimodal behavior with two symmetrical quasi-stationary states and switches on either side in the spanwise direction. This phenomenon is important to control because it leads to an increase of the drag associated with the base pressure evolution [2,3]. The flow is calculated by DNS at Reynolds number  $Re = 40000$ , based on the incoming fluid velocity and the body height. We first investigate the dynamics of the flow due to these switches. The main topic of this study is to estimate the velocity field from the base pressure data and, conversely, to estimate the base pressure modes from the velocity field.

## 2 Summary of results

The Direct Numerical Simulation code SUNFLUIDH has been used to calculate the flow behind the squareback Ahmed body at  $Re = 40000$ . The Proper Orthogonal Decomposition is applied on numerical data which permits first a fine analysis of the dynamics of the flow from the main energetical modes and highlights deviation, switches and shedding modes characteristics. In previous studies, POD gave a good comparison between numerical and experimental data in the near-wake [5]. The behavior of the switches between the two quasi-stationary states has been also studied and reduced models have been established to reproduce the switches over long periods of time [6].

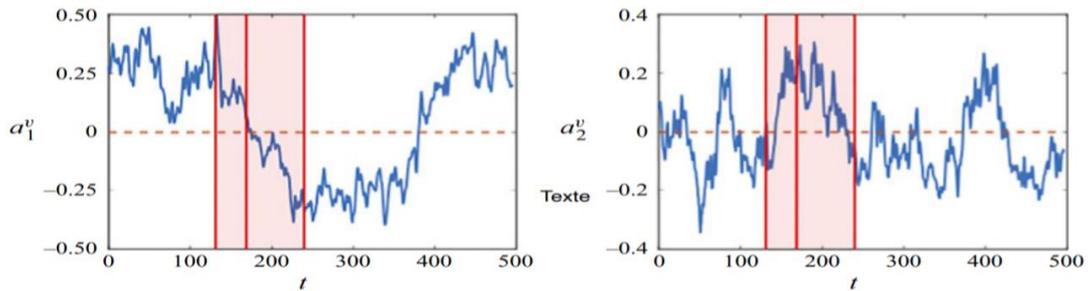


Figure 1: Amplitudes evolution of the velocity modes, POD from DNS data: (left) deviation mode and (right) switch mode.

The figure 1 shows the evolution of deviation and switch modes of the velocity field, over the calculated period with DNS; the switch period is colored. The switch velocity mode (right) is positive during the switch, evidenced on the deviation mode evolution (left). We investigate here what is the footprint of the wake flow on the base pressure. Note that there are two very different kind of data: the pressure field is characterized by one component and two dimensions (1C-2D) while the velocity field is 3C-3D. We apply the POD approach to the pressure field DNS data. We first extract the POD dominant modes of the base pressure (figure 2 left) and obtain a good comparison with experimental data, on spatial modes and temporal evolution of the amplitudes. As we have seen previously studying the velocity field, we find analysing the pressure field that the base pressure also increases during the switches. This increase can be related to edge deformation of separation region.

We then apply the linear stochastic estimation technique of Podvin *et al.* [4] to the both velocity and base pressure fields. Each corresponding transfer function is then calculated. We can then estimate the pressure amplitudes from a velocity-based estimator. The comparison between the true field and the estimation is very correct and recover the dominant base pressure fluctuations (figure 2 right). We then apply the opposite approach to estimate the velocity field amplitudes from a pressure-based estimator. This estimation detects the velocity deviation and the switch mode. However, the shedding modes are not captured by this approach.

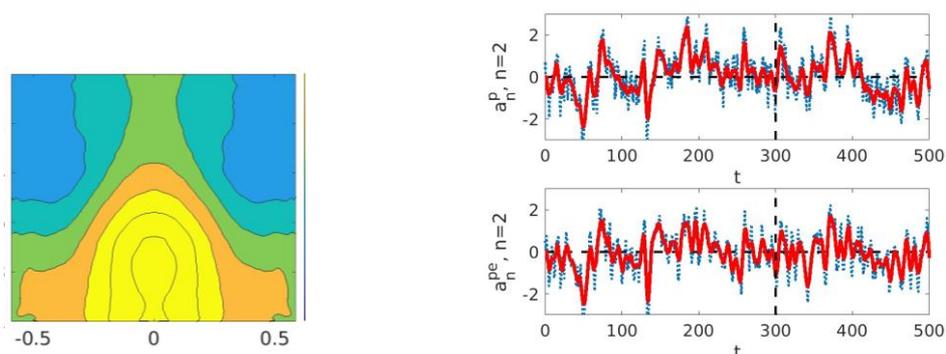


Figure 2: (Left) Mode 2 of the pressure field on the base, POD from DNS data and (right) amplitudes evolution of the pressure mode 2, (top) true field and (bottom) velocity-based estimation field.

## References

- [1] M. Grandemange, M. Gohlke, and O. Cadot. Turbulent wake past a three-dimensional blunt body. part 1 - global modes and bi-stability. *J. Fluid Mech.*, 722:1–26, 2013.
- [2] G. Bonnavion and O. Cadot. Unstable wake dynamics of rectangular flat-backed bluff bodies with inclination and ground proximity. *J. Fluid Mech.*, 854:196–232, 2018.
- [3] Y. Haffner, J. Borée, A. Spohn, and T. Castelain. Mechanics of bluff body drag reduction during transient near-wake reversals. *J. Fluid Mech.*, 894:A14, 2020.
- [4] B. Podvin, S. Nguimatsia, J.-M. Foucaut, C. Cuvier and Y. Fraigneau. On combining linear stochastic estimation and proper orthogonal decomposition for flow reconstruction. *Exp. Fluids*, 59:58, 2018.
- [5] B. Podvin, S. Pellerin, Y. Fraigneau, A. Evrard, and O. Cadot. Proper Orthogonal Decomposition analysis and modelling of the wake deviation behind a squareback Ahmed body. *Phys. Rev. Fluids.*, 6(5):064612, 2020.
- [6] B. Podvin, S. Pellerin, Y. Fraigneau, G. Bonnavion, O. Cadot. Low-order modelling of the wake dynamics of an Ahmed body. *J. Fluids Mech.*, 927: R6, 2021.
- [7] B. Podvin, S. Pellerin, Y. Fraigneau, G. Bonnavion, O. Cadot. Relationship between the base pressure and the velocity in the near-wake of an Ahmed body. *Phys. Rev. Fluids*, 7 (5): 054602, 2022.