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► **To cite this version:**

Bérengère Podvin, Stéphanie Pellerin, Yann Fraigneau, Guillaume Bonnavion, Olivier Cadot. Modelling the dynamics of the wake behind a squareback Ahmed body. Fourth international conference in numerical and experimental aerodynamics of road vehicles and trains (Aerovehicles4), Aug 2020, Berlin, Germany. hal-04406605

**HAL Id: hal-04406605**

**<https://hal.science/hal-04406605>**

Submitted on 19 Jan 2024

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# Modelling the dynamics of the wake behind a squareback Ahmed body

B. Podvin \*, S. Pellerin \*, Y. Fraigneau \*, G. Bonnavion \*\*, O. Cadot +  
Corresponding author: podvin@limsi.fr

\* LISN, Université Paris-Saclay, CNRS

\*\* ENSMA, Université de Poitiers

+ School of Engineering, University of Liverpool, LiverpoolL69 3GH, UK

May 31, 2021

**Abstract:** We use direct numerical simulation of the flow around a squareback Ahmed body at  $Re = 40000$  to characterize changes in the wake dynamics. We focus in particular on the intermittent switches associated with multistability. We use Proper Orthogonal Decomposition to extract the dominant energetic modes for the pressure as well as for the velocity field. A reduced-order model for the amplitudes of the velocity POD modes is constructed in order to reproduce the dynamics of the wake. Comparison with the simulation as well as with experimental results shows that the model is able to predict the key features of the flow.

*Keywords:* Aerodynamics, Proper Orthogonal Decomposition, Reduced-order Model, Direct Numerical Simulation, Experiments.

## 1 Introduction

Drag reduction strategies for aerodynamic bodies require a fine understanding of the physics of flow separation and of the near-wake of the body. The object of the present study is a squareback Ahmed body at a Reynolds number of  $Re = 40000$ , based on the incoming fluid velocity and body height. The wake behind the body is characterized by multistability: the wake is deviated in the spanwise direction two quasi-stationary states exist, each of which is symmetric of the other through spanwise reflection, and corresponds to a wake that is deviated in the spanwise direction. This phenomenon was first identified by [1]. The wake remains near one quasi-stationary state for several thousand of convective time units, then switches abruptly towards the opposite state. Controlling these switches is of interest since it has been shown that they are associated with an increase in the base pressure, and therefore a decrease of the body drag [2, 3, 4, 5]. The purpose of this communication is to report on a numerical investigation of the flow behavior during, and in-between switches.

## 2 Summary of results

Direct numerical simulation of the flow is performed using the second-order, finite-volume solver SUNFLUIDH which has been validated for a variety of configurations ( see <https://datasemeca.limsi.fr> for selected examples). In a previous study [6], the analysis was limited to snapshots corresponding to a near quasi-stationary state - the simulation was not long enough to allow switches. In the present case, we focus on the switches between the quasi-stationary states. Comparison of the simulation with the experimental results of [4] is carried out.

We use Proper Orthogonal Decomposition as an analysis tool to extract the dominant features of the wake dynamics from a basis of flow snapshots, one example of which can be seen in figure 1. Comparison of the

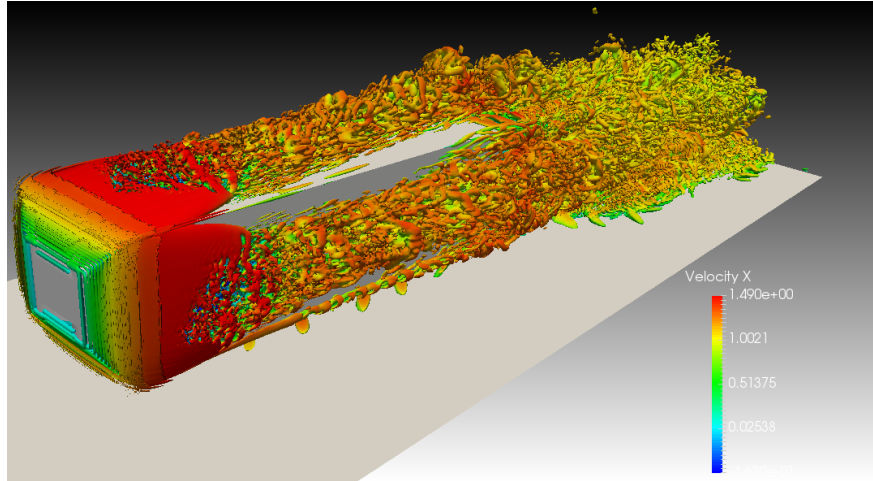


Figure 1: Three-dimensional view of the instantaneous flow around an Ahmed body based on isosurfaces of the Q-criterion, colored by the streamwise velocity. The flow is coming from the left.

decompositions of databases excluding and limited to switching times shows that a mode becomes important during the switch. A description of the switch is given in terms of the spatio-temporal characteristics of the POD modes. Projection of the Navier-Stokes equation onto the spatial modes leads to a reduced-order system of ordinary differential equations. The model is found to reproduce key features of the wake dynamics.

## 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] Y. Fan, X. Chao, S. Chu, Z. Yang, and O. Cadot. Experimental and numerical analysis of the bi-stable turbulent wake of a rectangular flat-backed bluff body. *Phys. Fluids*, 32:105111, 2020.
- [3] Y. Haffner, J. Borée, A. Spohn, and T. Castelain. Mechanics of bluff body drag reduction during transient near-wake reversals. *Journal of Fluid Mechanics*, 894:A14, 2020.
- [4] 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.
- [5] M. Lorite-Diez and J.I. Jimenez-Gonzalez, L. Pastur, C. Martinez-Bazan, and O. Cadot. Experimental analysis of the effect of local base blowing on three-dimensional wake modes. *Journal Fluid Mech.*, 883, 2020.
- [6] 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.