A
BENCHMARK
ON THE
AERODYNAMICS
OF A
RECTANGULAR
5:1
CYLINDER

OVERVIEW DOCUMENT

International Association for Wind Engineering

Associazione Nazionale per l'Ingegneria del Vento

1. PREFACE

The aim of this Benchmark is to provide a contribution to the analysis of the turbulent, separated flow around a fixed rectangular cylinder with chord-to-depth ratio equal to 5. In spite of the simple geometry, it is believed that the problem is of interest not only for the purpose of fundamental research, but also to provide useful information on the aerodynamics of a wide range of bluff bodies of interest in Civil Engineering (e.g. long span bridges decks, high-rise buildings, and so on) and for other Engineering applications. Given the possible interest of Research Institutions and Industries operating in different fields of Engineering, using both computational and experimental tools, the benchmark addresses both the numerical and the experimental approach.

2. AIMS

The aims of the Benchmark are the following:

(1) to deeply investigate one specific problem in the aerodynamics of bluff bodies, with contributions coming from as many researchers as possible worldwide;

(2) to assess the consistency of wind tunnel measurements carried out in different facilities;

(3) to assess the consistency of computational results obtained through different flow models and numerical approaches;

(4) to compare experimental and computational results;

(5) to assess the possibility of developing integrated procedures relying on both experimental and computational outcomes;

(6) to develop Best Practices for experiments and computations.

In addition, the results provided by the participants will create a database to be made available to the Scientific and Technical communities for future reference.

3. ORGANISATION FRAMEWORK

The Benchmark problem is promoted by the Organising Committee, with the support of the Italian National Association for Wind Engineering (ANIV), under the umbrella of the International Association for Wind Engineering (IAWE) and in cooperation with the European Research Community On Flow, Turbulence And Combustion (ERCOFTAC). The activities will be carried out under supervision of the International Advisory Board.

4. ORGANISING COMMITTEE

Gianni BARTOLI	University of Florence
Luca BRUNO	Politecnico di Torino
Andrea CIMARELLI	University of Modena and Reggio Emilia
Claudio MANNINI	University of Florence
Luca PATRUNO	University of Bologna
Francesco RICCIARDELLI	University of Reggio Calabria
Maria Vittoria SALVETTI	University of Pisa

5. INTERNATIONAL ADVISORY BOARD

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Tetsuro TAMURA	Tokyo Institute of Technology (JAP)
Mark THOMPSON	Monash University (AUS)
Alberto ZASSO	Politecnico di Milano (IT)

6. SPONSORS

Public and Private sponsors will be welcome. Funding made available will be used for the organization of Workshops and other dissemination activities.

7. PROBLEM STATEMENT

The Benchmark addresses the high Reynolds number, external, unsteady flow around and past a stationary, sharp-edged rectangular cylinder, and the associated aerodynamic actions. The breadth (B) to depth (D) ratio is set equal to 5.

Participants are invited to submit their original contributions following the formats specified in the requirements. These can include both results already available to the participants and results

specifically obtained for the purpose of participation in the Benchmark. In addition, participants are invited to share with the Scientific and Technical communities the literature and the published results available to them.

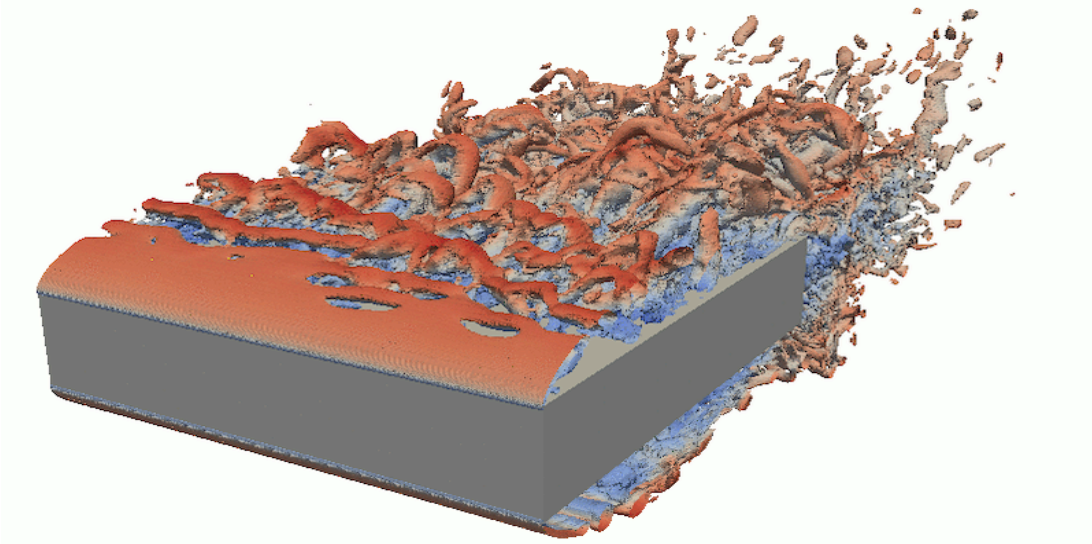

Figure 1 - DNS of the flow around the 5:1 rectangular cylinder (credits: A. Cimarelli, A. Leonforte, D. Angeli)

8. REQUIREMENTS FOR THE MAIN SETUP

The following common requirements are set for both wind tunnel tests and numerical simulations:

(1) *Reynolds number*

The depth-based Reynolds number $\mathrm{Re} = UD/\nu$ has to be in the range 2×10^4 to 8×10^4.

(2) *Incidence*

The oncoming flow has to be set parallel to the base of the rectangle; such angle of attack is termed $\alpha = 0$.

(3) *Intensity of turbulence*

The maximum intensity of the longitudinal component of turbulence is set to $I_u = 0.01$.

(4) *Spanwise length of the cylinder*

The minimum spanwise length of the cylinder is set to $L/D = 15$ for wind tunnel tests, and to $L/D = 3$ for 3D numerical simulations.

(5) *Sharpness of the section*

The maximum radius of curvature of the edges of the cylinder is set to $R/D = 0.025$.

(6) *Sampling frequency*

The minimum sampling frequency f_{sam} is set to 8 times the shedding frequency f_s, i.e. $f_{sam} = 8f_s = 8St_DU/D$.

The following additional requirements are specified for wind tunnel tests:

(7) *Blockage ratio*

The maximum wind tunnel blockage ratio is set to 5%.

(8) *Flow uniformity*

All the points of measurement have to be outside the boundary layers developed at the tunnel floor, roof and side walls. Uniformity of the flow at the locations where measurements are taken must be checked in the wind tunnel prior to installing the model and appropriately documented.

9. SENSITIVITY ANALYSES

In addition to the main setup described in section 8, sensitivity studies are strongly encouraged. The following additional values of the parameters in section 8 are suggested for both wind tunnel tests and numerical simulations:

- Angles of incidence α = 2°, 4°, 6°
- Reynolds number Re = 3×10^3, 1×10^4, 1×10^5, 5×10^5, 1×10^6
- Turbulence intensity I_u = 0.02, 0.05, 0.10
- Radius of curvature of the edges R/D = 0.01, 0.025, 0.05
  (if the main tests/simulations were carried with sharper edges).

10. OUTPUT FOR WIND TUNNEL TESTS AND COMPUTATIONAL SIMULATIONS

For participation in the Benchmark, information concerning the setup and a minimum set of output data must be provided by the participants. These data will be available to all participants for download. This is to allow researchers to compare the results obtained by other researchers.
All the problem quantities must be scaled with respect to the following reference dimensions:

- section depth D;
- fluid density ρ;
- undisturbed flow field velocity U_∞;

Both setup information and output data are classified as “required” (i.e. data that participants are requested to provide) and “encouraged” (i.e. additional data that participants are encouraged to provide). Finally, any further data that can be provided by the participants are denoted as “additional”.

Setup information and output data requested for wind tunnel tests and numerical simulations are set in separate sheets (see *Requests for Computational Simulations* and *Requests for Wind Tunnel Tests*).

All data must be provided following the format described in the requirements above, and sent by e-mail to the BARC Organizing Committee.

The BARC benchmark is included in the ERCOFTAC Knowledge Base Wiki, among the Underlying Flow Regimes as UFR_2-15 (www.kbwiki.ercoftac.org/w/index.php/UFR_2-15_Description).

11. LITERATURE

Reference information can be shared among participants, upgrading the bibliographic database in the Mendeley public group BARC Benchmark (https://www.mendeley.com/community/barc-4/). Published material not restricted by copyright can also be shared there.

12. CONTACTS

All information concerning the Benchmark and registration procedures will be made available at the web page http://www.aniv-iawe.org/barc.

Any questions or comments can be sent to the following e-mail address: barc@aniv-iawe.org.