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

REQUESTS FOR WIND TUNNEL TESTS

International Association for Wind Engineering

Associazione Nazionale per l'Ingegneria del Vento

1. INTRODUCTION

In the following sections, the data are described which are necessary to allow comparisons to be carried out of the results obtained by all the researchers involved in the benchmark.
The data are subdivided in *required* and *encouraged*: while the former are mandatory for all the researchers participating in the benchmark, in order to assure that a minimum amount of information is always available, the latter are strongly recommended to allow the comparison of as many as possible data. Of course, every researcher is free to include any *additional* data that are considered significant from a scientific point of view.

2. WIND TUNNEL CHARACTERISTICS

a. main characteristics of the wind tunnel (required):

Wind tunnel circuit	□ open	□ closed
Test chamber section	□ open	□ closed
Propeller location	□ suction	□ pressure
Uniform section	□ yes	□ no
Tolerant wind tunnel	□ yes	□ no
Adjustable ceiling	□ yes	□ no
Atmospheric pressure	□ yes	□ no
Other relevant characteristics		

b. main dimensions of the wind tunnel test section (according to following Figures 1 and 2) (required);

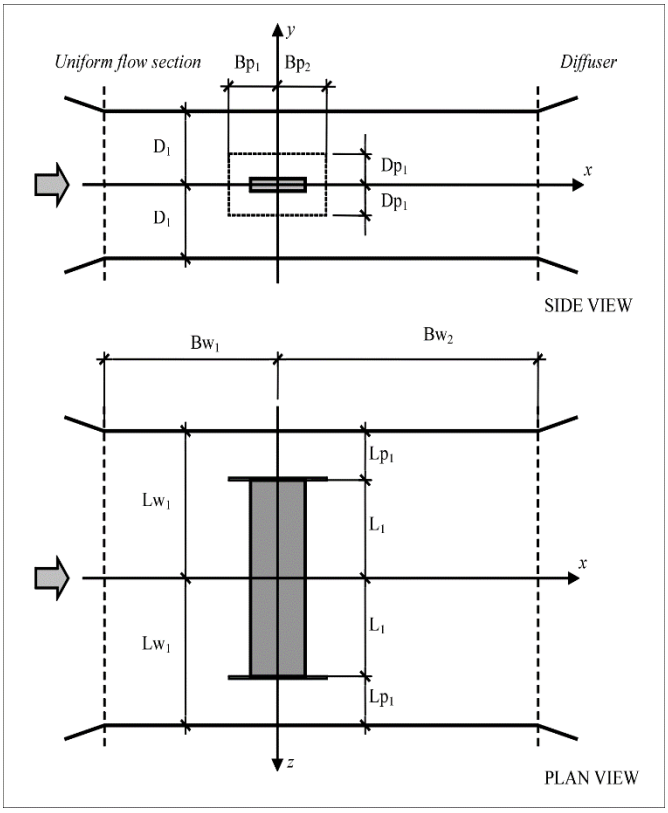

Figure 1 - Model and wind tunnel setup (2D views)

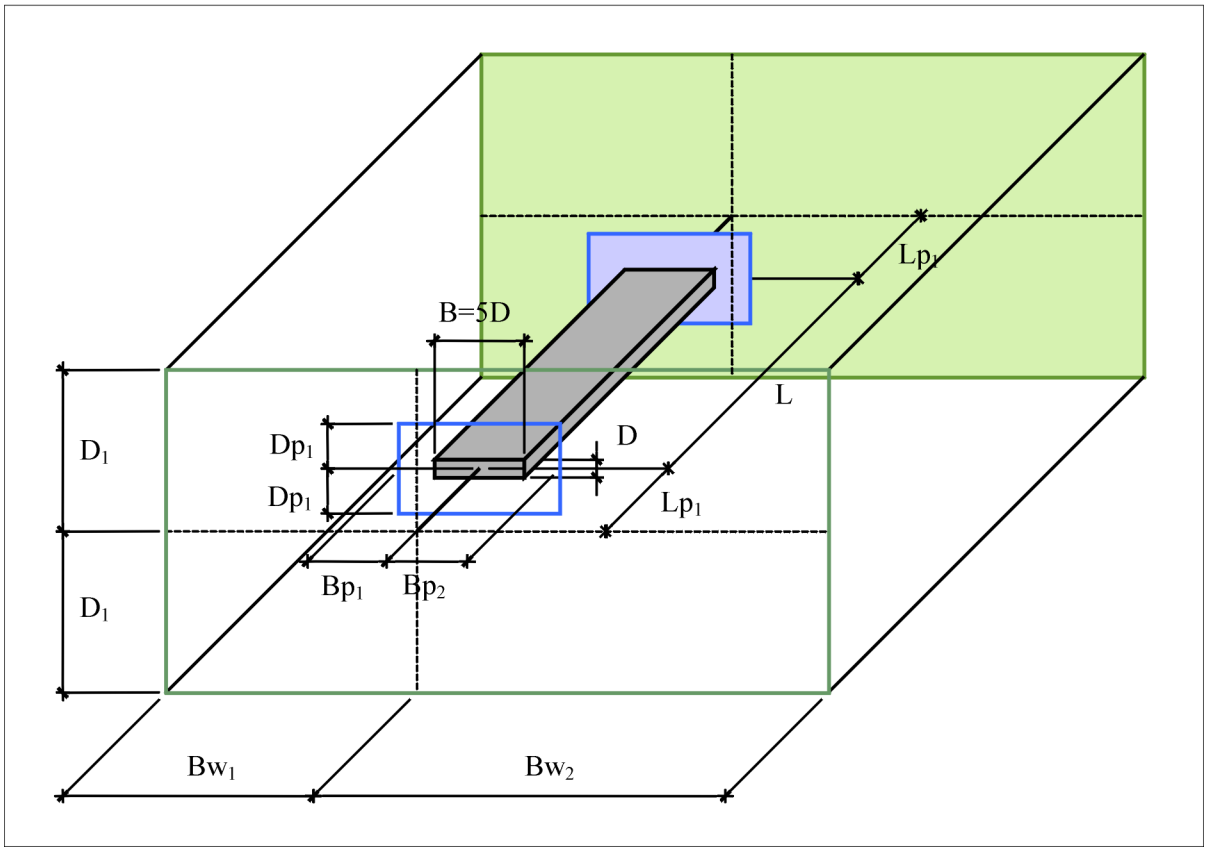

Figure 2 - Model and wind tunnel setup (3D view)

c. ambient parameters (encouraged);

Temperature		
Humidity		
Static Pressure	At a 20*D* distance upwind	
	At a 10*D* distance upwind	
	At the model location	
	At a 10*D* distance downwind	
	At a 20*D* distance downwind	
Other ambient data		

3. WIND TUNNEL SETUP AND INSTRUMENTATION

See Figure 2 for notation

a. distance of the model from the tunnel walls or from the end plates, according to Figures 1 and 2 (required);
b. detailed description of the wind tunnel setup: e.g. model support (whether outside or inside the tunnel), distance of the ends of the model from the tunnel walls (Lp1 in Figure 1), description of the holes in the tunnel walls (if applicable), geometry of the end plates (if applicable) and distance between them (L1 in Figure 1), etc. (required);
c. pictures of the test setup (provide the coordinates of the viewpoints in the reference frame of Figure 1) (required);
d. blockage ratio (including any additional information about its calculation) (required);
e. instrumentation (for each device: description, ranges, accuracy, repeatability, etc.) (required).

4. MODEL CHARACTERISTICS (RIGID MODEL)

a. dimensions of the model (D, L) (required);
b. edge radius of curvature of the model (the model is nominally sharp, but an estimate of R is required; R=0 sharp edges) (required);
c. sketch of the structural characteristics of the model (internal stiffening, etc) (encouraged);
d. external roughness (description of the material, possible estimation of surface roughness) (required);
e. model mass (required);
f. model stiffness (static stiffness and at least first two natural frequencies - bending and torsional - of the mounted model) (required);
g. sketch of the pressure tap locations (required).

5. ONCOMING FLOW CHARACTERISTICS

a. values of the Reynolds (with respect to dimension D) and Mach numbers (required);
b. cross-flow (y-direction) profile of the mean streamwise (x-direction) velocity at model midspan (at least 5 points to be measured before placement of the model, at heights y = -3D, -D, 0, +D, +3D with respect to the centre of the model) (required);
c. spanwise (z-direction) profile of the mean streamwise (x-direction) velocity at the height of the model (at least 5 points to be measured before placement of the model, at coordinates z = -2L/5, -L/5, 0, +L/5, +2L/5 with respect to the centre of the model) (required);
d. cross-flow (y-direction) profile of the streamwise (x-direction) turbulence intensity at model midspan (at least 5 points to be measured before placement of the model, at heights y = -3D, -D, 0, +D, +3D with respect to the centre of the model) (required);
e. cross-flow (y-direction) profile of the cross-flow (y-direction) turbulence intensity at model midspan (at least 5 points to be measured before placement of the model, at heights y = -3D, -D, 0, +D, +3D with respect to the centre of the model) (encouraged);
f. spectrum of the streamwise (x-direction) component of turbulence at model midspan (suggested 5 points to be measured before placement of the model, at heights y = -3D, -D, 0, +D, +3D with respect to the centre of the model) (encouraged);
g. spectrum of the cross-flow (y-direction) component of turbulence at model midspan (suggested 5 points to be measured before placement of the model, at heights y = -3D, -D, 0, +D, +3D with respect to the centre of the model) (encouraged);
h. spanwise (z-direction) coherence function of the streamwise (x-direction) component of turbulence with respect to the centre of the model (at least 5 points to be measured before placement of the model, spaced such to obtain values of the cross-correlation function between 1.0 and 0.1) (encouraged);
i. spanwise (z-direction) coherence function of the cross-flow (y-direction) component of turbulence with respect to the centre of the model (suggested 5 points to be measured before placement of the model, spaced such to obtain values of the cross-correlation function between 1.0 and 0.1) (encouraged).

6. ORGANIZATION OF THE TESTS AND PRELIMINARY DATA TREATMENT

a. organization of the tests (measured quantities, sampling time, sampling frequency, etc.) (required);
b. preliminary data treatment (acquisition methods, use of filters, etc.) (required).

7. RESULTS FOR PRELIMINARY CHECK

a. check that the mean pressure coefficient $\overline{Cp} = 1$ at the stagnation point $m0$ in the central section of the model (z=0) (see Table 1 and Figure 3, required);
b. check of the stationarity of the measured quantities: i.e. mean value, standard deviation and frequency content of the relevant quantities (e.g. drag coefficient, lift coefficient or Cp at point $m1$ in the central section of the model (z=0), see Table 1 and Figure 3) should not vary for increasing sampling time and sampling frequency; indicate the acquisition length over which the statistics are evaluated, in terms of non-dimensional time units and in terms of vortex-shedding cycles (required);

c. check of the local 2D flow features around the central section of the body (z=0): i.e. comparison of the statistics of the pressure coefficients at points $m4$, $m6$, $p7$, $p8$, $p9$, $p10$, $p11$ and $p12$ in Tables 1 and 2, Figures 3 and 4 (required);

d. comparison between statistics of aerodynamic coefficients $C_x(t)$, $C_y(t)$ and $Cm_z(t)$ (torque is meant evaluated with respect to the origin of the reference system), obtained by means of direct force measurements and from integration of pressures in the central section of the body (z=0) (encouraged).

8. RESULTS FOR COMPARISONS

The reference wind velocity used for the evaluation of pressure and force coefficients, as well as for the evaluation of Reynolds and Mach numbers, has to be specified. Usually, this is the free-stream wind velocity at the centre of the model, i.e. velocity at point (x, y, z) = (0, 0, 0,) measured before the placement of the model.

The *required* experimental results have been limited to the minimum, in order to allow the largest number of researchers to contribute to the Benchmark, regardless of the experimental facility available to them. These will form shared platform of results for direct comparison.

a. Integral parameters:
   i. mean value and standard deviation of the aerodynamic coefficients C_x, C_y and Cm_z (torque is meant evaluated with respect to the origin of the reference system) (encouraged);
   ii. Power Spectral Density of the aerodynamic coefficients $C_x(t^*)$, $C_y(t^*)$ and $Cm_z(t^*)$ as a function of the nondimensional frequency fD/U (encouraged, ASCII file with four-column format: fD/U, PSD(C_x), PSD(C_y), PSD(Cm_z));
   iii. sample time histories of the aerodynamic coefficients $C_x(t^*)$, $C_y(t^*)$ and $Cm_z(t^*)$ (encouraged, ASCII file with four-column format: $t^* = tU/D$ (nondimensional), C_x, C_y and Cm_z).

b. Local parameters - statistics:
   i. statistics of the pressure coefficients at points $m0$ through $m9$ in Table 1 and Figure 3, in the central section of the model (z=0) (required, ASCII file with seven-column format: x/D, y/D, s/D, $\overline{Cp}$, Cp_{std}, Cp_{skew}, Cp_{kurt}, where s is the curvilinear abscissa defined in Figure 3);

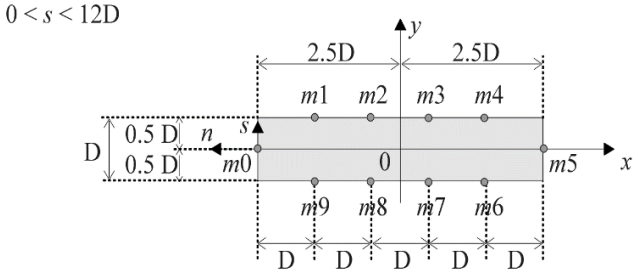

Figure 3 - Location of the points of measurement in the central section

id.	x/D	y/D	z/D	s/D	variable
$m0$	-2.5	0.0	0.0	0.0	Cp
$m1$	-1.5	0.5	0.0	1.5	Cp
$m2$	-0.5	0.5	0.0	2.5	Cp
$m3$	+0.5	0.5	0.0	3.5	Cp
$m4$	+1.5	0.5	0.0	4.5	Cp
$m5$	+2.5	0.0	0.0	6.0	Cp
$m6$	+1.5	-0.5	0.0	7.5	Cp
$m7$	+0.5	-0.5	0.0	8.5	Cp
$m8$	-0.5	-0.5	0.0	9.5	Cp
$m9$	-1.5	-0.5	0.0	10.5	Cp

Table 1 - Required measurement points in the central section

ii. statistics of pressure coefficients in the central section of the model at points other than those required (encouraged, ASCII file with seven-column format: *x/D, y/D, s/D,* $\overline{Cp}$, Cp_{std}, Cp_{skew}, Cp_{kurt});

iii. statistics of pressure coefficients at other instrumented sections of the model ($z \neq 0$) (encouraged, ASCII file with seven-column format: *x/D, y/D, z/D, s/D,* $\overline{Cp}$, Cp_{std}, Cp_{skew}, Cp_{kurt});

iv. statistics of streamwise (*x-direction*) and cross-flow (*y-direction*) flow velocity along the straight line $l1$ (y=0, z=0, see Figure 4) (encouraged, ASCII file with five-column format: *x/D,* $\overline{u}_x$, $u_{x\,std}$, $\overline{u}_y$, $u_{y\,std}$);

v. statistics of streamwise (*x-direction*) and cross-flow (*y-direction*) flow velocity along the straight lines $l2$ (x/D=2.5, z=0), $l3$ (x/D=3.5, z=0), $l4$ (x/D=4.5, z=0) (encouraged, ASCII files with five-column format: *y/D,* $\overline{u}_x$, $u_{x\,std}$, $\overline{u}_y$, $u_{y\,std}$).

c. <u>Local parameters - time histories and coherence functions:</u>

i. sample time histories of the pressure coefficient at points $m1$ through $m9$ (encouraged, ASCII file with nine-column format: s, t^* (non-dimensional), $Cp_i(t^*)$);

ii. sample time histories of the pressure coefficient at points $p1$ through $p18$ (encouraged, ASCII file with twelve-column format: s, t^* (non-dimensional), $Cp_i(t^*)$);

iii. sample time histories of the velocity components at points *mA* and *mB* (encouraged, ASCII files with five-column format: s, t^* (non-dimensional), $u_x(t^*)$, $u_y(t^*)$, $u_z(t^*)$); moreover, the following quantities should be reported for each point: mean value, standard deviation, nondimensional dominant frequency in the spectra;

iv. Coherence functions of surface pressure at positions (x/D=-1.5, y/D=0.5), (x/D=1.5, y/D=0.5) and (x/D=2.5, y/D=0) for $\Delta z_1 = 1/12B$, $\Delta z_2 = 3/12B$, $\Delta z_3 = 5/12B$, $\Delta z_4 = 7/12B$, $\Delta z_5 = 9/12B$ (encouraged, ASCII files with six-column format: *fD/U,* coh(Δz_1), coh(Δz_2), coh(Δz_3), coh(Δz_4), coh(Δz_5)).

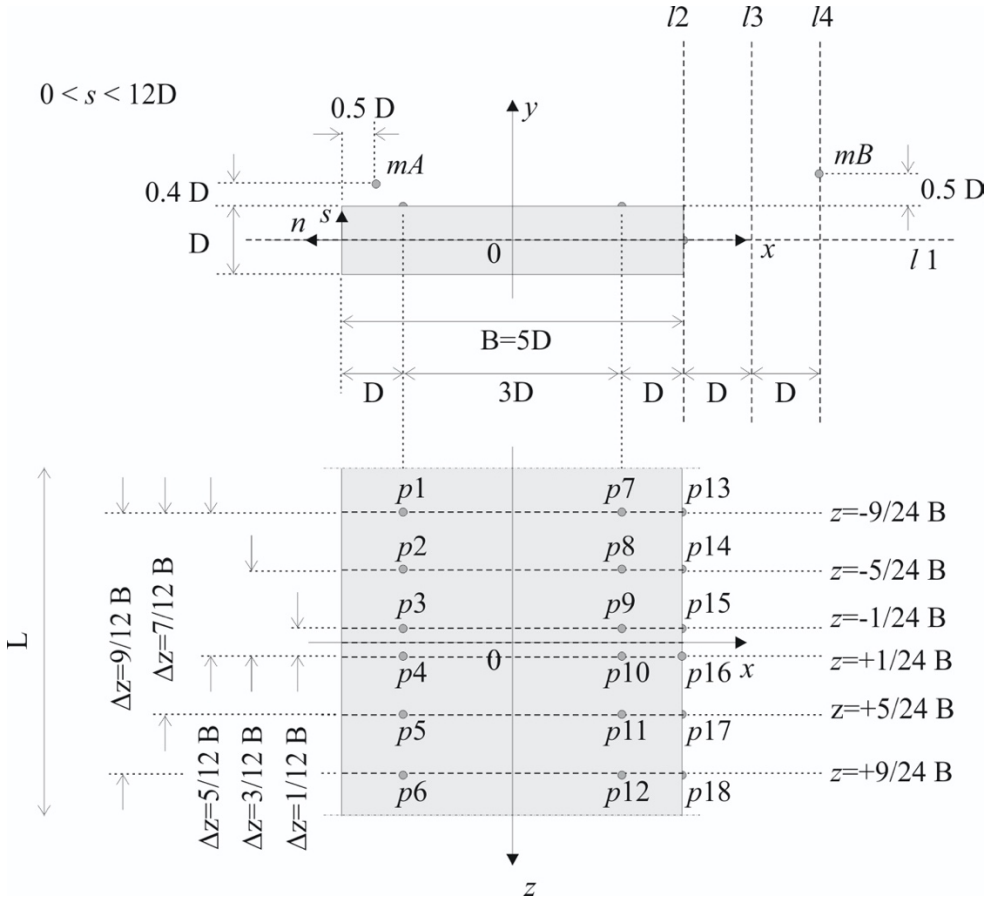

Figure 4 - Location of measurement points

id.	*x/D*	*y/D*	*z/B*	variable	Addressed phenomena
mA	-2.0	0.9	0	u_x, u_y, u_z	shedding mechanism past the leading edge
mB	+4.5	1.0	0	u_x, u_y, u_z	vortex shedding in the wake
*p*1	-1.5	0.5	-9/24	*Cp*	spanwise coherence of the surface pressure field
*p*2	-1.5	0.5	-5/24	*Cp*	
*p*3	-1.5	0.5	-1/24	*Cp*	
*p*4	-1.5	0.5	+1/24	*Cp*	
*p*5	-1.5	0.5	+5/24	*Cp*	
*p*6	-1.5	0.5	+9/24	*Cp*	
*p*7	+1.5	0.5	-9/24	*Cp*	
*p*8	+1.5	0.5	-5/24	*Cp*	
*p*9	+1.5	0.5	-1/24	*Cp*	
*p*10	+1.5	0.5	+1/24	*Cp*	
*p*11	+1.5	0.5	+5/24	*Cp*	
*p*12	+1.5	0.5	+9/24	*Cp*	
*p*13	+2.5	0	-9/24	*Cp*	
*p*14	+2.5	0	-5/24	*Cp*	
*p*15	+2.5	0	-1/24	*Cp*	
*p*16	+2.5	0	+1/24	*Cp*	
*p*17	+2.5	0	+5/24	*Cp*	
*p*18	+2.5	0	+9/24	*Cp*	

Table 2 - Measurement points

9. ADDITIONAL REFERENCES

References cited by the author(s) of the study and not enclosed in the benchmark general database should be listed (required, if any).

10. CONTACT INFORMATION

Complete affiliation, address and e-mail of the author(s) of the study should be enclosed.

11. UPLOAD DATA FILE

The complete set of the set-up data and the required and recommended results should be provided in the tabular-type file, according to the proposed format for download. The ASCII files with space distributions and time histories should be provided in separated, zipped file. The whole data set should be provided in a single archive.