

A  
**B**ENCHMARK  
ON THE  
**A**ERODYNAMICS  
OF A  
**R**ECTANGULAR  
5:1  
**C**YLINDER



REQUESTS FOR  
WIND TUNNEL TESTS





**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 as many data as possible to be compared. 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	<input type="checkbox"/> open	<input type="checkbox"/> closed
Test chamber section	<input type="checkbox"/> open	<input type="checkbox"/> closed
Propeller location	<input type="checkbox"/> suction	<input type="checkbox"/> pressure
Uniform section	<input type="checkbox"/> yes	<input type="checkbox"/> no
Tolerant wind tunnel	<input type="checkbox"/> yes	<input type="checkbox"/> no
Adjustable ceiling	<input type="checkbox"/> yes	<input type="checkbox"/> no
Atmospheric pressure	<input type="checkbox"/> yes	<input type="checkbox"/> no
Other relevant characteristics		

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

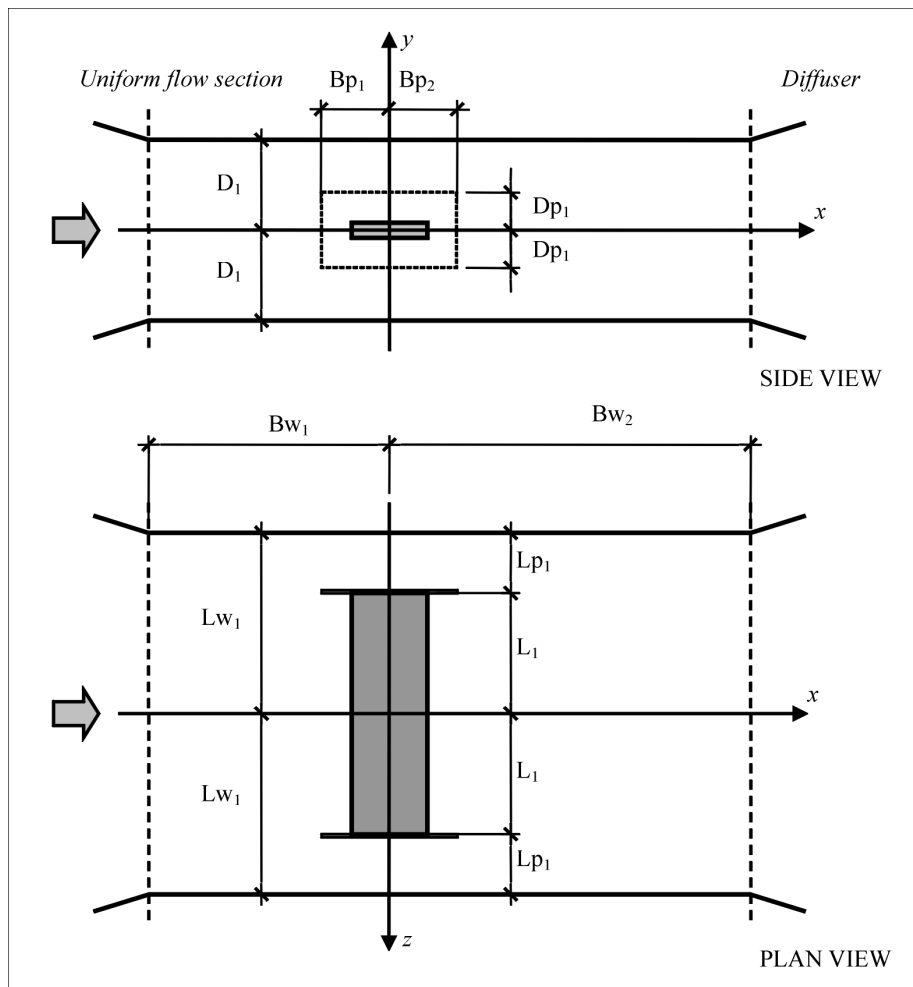


Figure 1 - Model and wind tunnel setup (2D views)

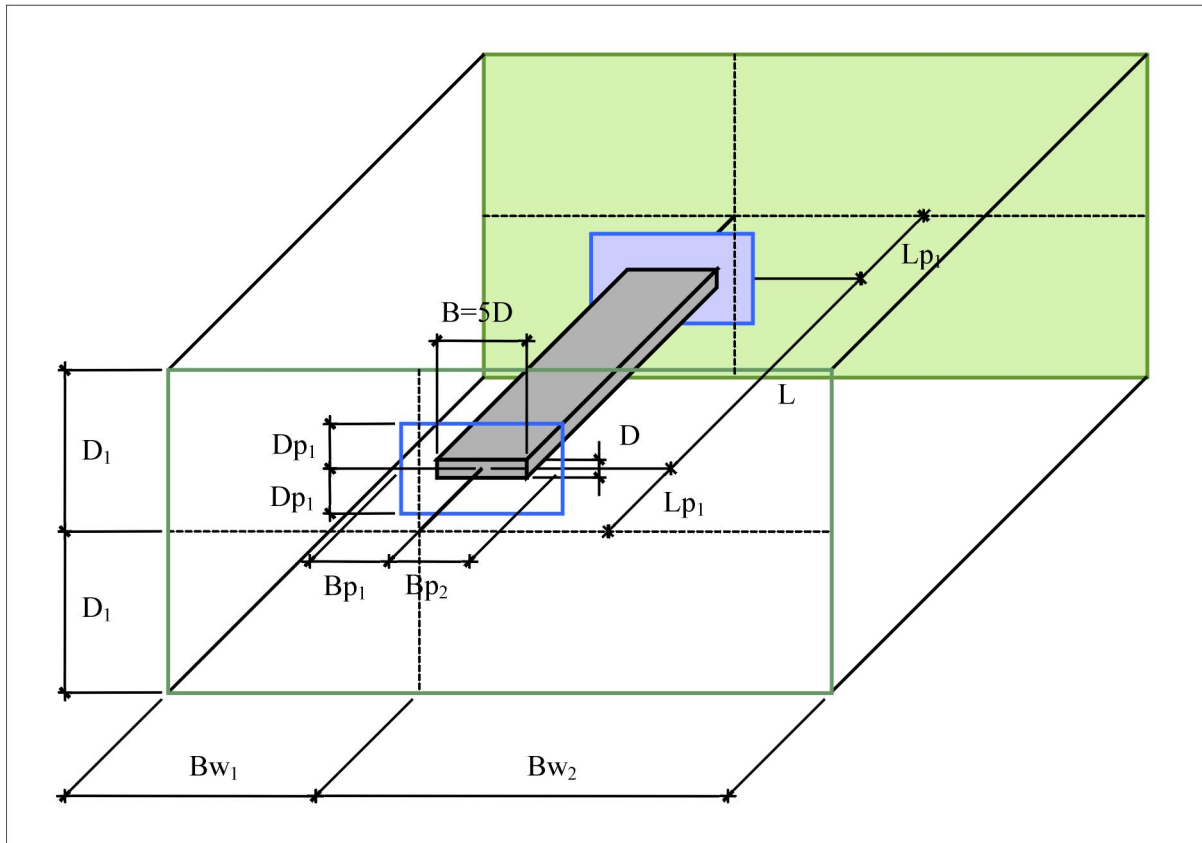


Figure 2 - Model and wind tunnel setup (3D view)

c. ambient parameters (encouraged);

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

**3. Wind tunnel setup and instrumentation** (see Figure 2 for notation):

- distance of the model from the tunnel walls or from the end plates, according to Figures 1 and 2 (required);
- 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 ( $L_{p1}$  in Figure 1), description of the holes in the tunnel walls (if applicable), geometry of the end plates (if applicable) and distance between them ( $L_1$  in Figure 1), etc. (required);
- pictures of the test setup (provide the coordinates of the viewpoints in the reference frame of Figure 1) (required);
- blockage ratio (including any additional information about its calculation) (required);
- instrumentation (for each device: description, ranges, accuracy, repeatability, etc.) (required).

**4. Model characteristics (rigid model):**

- dimensions of the model ( $D, L$ ) (required);
- edge radius of curvature of the model (the model is nominally sharp, but the evaluation 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 - heaving and pitching - 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 the location of the centre of the model (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 the location of the centre of the model (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. spectrum of the streamwise ( $x$ -direction) component of turbulence at the location of the centre of the model (suggested 5 points to be measured before placement of the model, at heights  $y = -3D, -D, 0, +D, +3D$  with respect to the model centre) (encouraged);
- f. spanwise ( $z$ -direction) cross-covariance 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-covariance function between 1.0 and 0.1) (required);
- g. spanwise ( $z$ -direction) cross covariance 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-covariance 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  $\overline{C_p} = 1$  at the stagnation point  $m_0$  on 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 or  $C_p$  at point  $m_1$  on 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  $m_4, m_6, p_2, p_4, p_6, p_8, p_{10}$  and  $p_{12}$  in Tables 1 and 2, Figures 3 and 4 (required);
- d. comparison between 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 on 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 reported. 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 non dimensional frequency  $fD/U$  (encouraged, ASCII file with four columns 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 columns format:  $t^*=tU/D$  (non-dimensional),  $C_x$ ,  $C_y$  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 columns format:  $x/D$ ,  $y/D$ ,  $s/D$ ,  $\overline{C_p}$ ,  $Cp_{std}$ ,  $Cp_{skew}$ ,  $Cp_{kurt}$ , where  $s$  is the curvilinear abscissa defined in Figure 3);

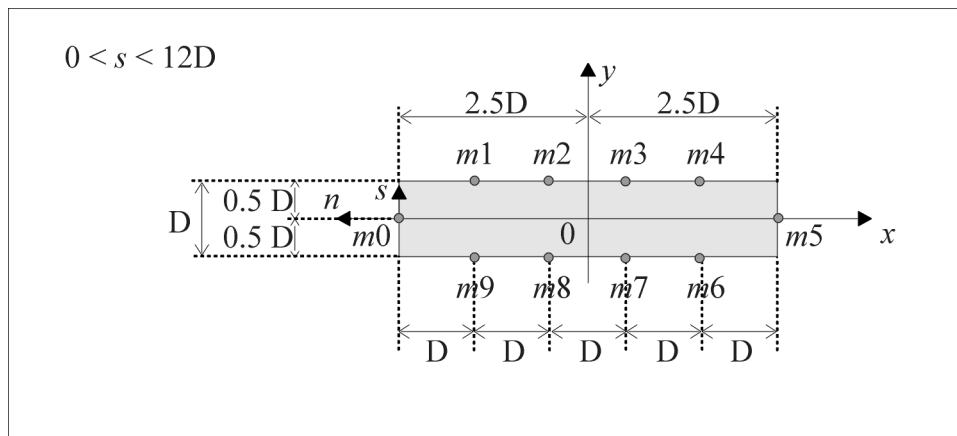


Figure 3 - Location of the points of measurement on the central section

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 on the central section

- ii. statistics of the pressure coefficients at points  $p5$ ,  $p6$ ,  $p7$  and  $p8$  in Table 2 and Figure 4 (required, ASCII file with seven columns format:  $x/D$ ,  $y/D$ ,  $s/D$ ,  $\overline{C_p}$ ,  $Cp_{std}$ ,  $Cp_{skew}$ ,  $Cp_{kurt}$ );
- iii. statistics of pressure coefficients in the central section of the model at points other than those required (encouraged, ASCII file with seven columns format:  $x/D$ ,  $y/D$ ,  $s/D$ ,  $\overline{C_p}$ ,  $Cp_{std}$ ,  $Cp_{skew}$ ,  $Cp_{kurt}$ );
- iv. statistics of pressure coefficients at other instrumented sections of the model ( $z \neq 0$ ) (encouraged, ASCII file with seven columns format:  $x/D$ ,  $y/D$ ,  $z/D$ ,  $s/D$ ,  $\overline{C_p}$ ,  $Cp_{std}$ ,  $Cp_{skew}$ ,  $Cp_{kurt}$ );





id.	$x/D$	$y/D$	$z/B$	variable	phenomena addressed
<i>mA</i>	-2.0	0.8	0	$u_x, u_y, u_z$	shedding mechanism past the leading edge
<i>mB</i>	+4.5	1.0	0	$u_x, u_y, u_z$	vortex shedding in the wake
<i>p1</i>	0.0	0.5	-1/24	$C_p$	spanwise coherence of the surface pressure field
<i>p2</i>	+1.5	0.5	-1/24	$C_p$	
<i>p3</i>	0.0	0.5	+1/24	$C_p$	
<i>p4</i>	+1.5	0.5	+1/24	$C_p$	
<i>p5</i>	0.0	0.5	-5/24	$C_p$	
<i>p6</i>	+1.5	0.5	-5/24	$C_p$	
<i>p7</i>	0.0	0.5	+5/24	$C_p$	
<i>p8</i>	+1.5	0.5	+5/24	$C_p$	
<i>p9</i>	0.0	0.5	-9/24	$C_p$	
<i>p10</i>	+1.5	0.5	-9/24	$C_p$	
<i>p11</i>	0.0	0.5	+9/24	$C_p$	
<i>p12</i>	+1.5	0.5	+9/24	$C_p$	

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 address, fax number, telephone number 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 \*.gz. The whole data set should be provided in an single archive \*.tar.