Course offered for the PhD program
in Civil, Chemical and Environmental Engineering
Curriculum in Wind Science and Engineering
A.Y. 2017/2018 (XXXIII cycle)

(possibility of participation for students in other PhD cycles or other PhD courses)

1. Title

Bluff-body aerodynamics

2. Course description

The main aim of the course is to describe the peculiar aspects of the aerodynamics of bluff bodies, providing the students with the knowledge elements that are necessary to adequately deal with the aerodynamic project in different fields of engineering, with special attention to wind engineering applications. The course consists of lectures and seminars, in which the active involvement of the participants will be required.

3. Course Organization

Recap on fluid dynamics and introduction to the aerodynamics of bluff bodies (2 hours): the fundamental equations of fluid dynamics and meaning of the various terms. Conditions for the validity of the incompressible flow model and corresponding equations. Elaboration on the equations to highlight the role of vorticity. Bernoulli's theorem: derivation and discussion on its conditions of applicability. Irrotational flows. Non-viscous flow assumption and its consequences. Reynolds number and its meaning in terms of forces and vorticity dynamics. Boundary layer: assumptions, link to vorticity, results, laminar and turbulent separation.

General characteristics of bluff-body aerodynamics (4 hours): Definition of aerodynamic and bluff bodies, geometric and flow field differences, different magnitude and methods of prediction of the relevant aerodynamic forces. Example of iterative procedure for aerodynamic bodies. Bluff bodies: "forebody" and "afterbody" and their contribution to the aerodynamic forces. Link between pressure at separation and over the base, influence of the curvature of the streamlines. Free-separation and forced-separation bodies: C_D - Re curves for 2-D and 3-D bodies, and their dependence on surface roughness and turbulence intensity.

Vorticity dynamics and its role (6 hours): Generation and dynamics of vorticity, conservation of total vorticity for incompressible flows, examples of evolution of vorticity, vorticity sources. Role of the energy equation in incompressible flows, energetic interpretation of the aerodynamic drag. Evaluation of dissipation through the Bobyleff-Forsyth formula. Kinetic energy and dissipation of concentrated vortices and link between perturbation energy and vorticity dynamics. Theory of Wu for viscous incompressible flows: expression of the aerodynamic loads as a function of the magnitude, organization and dynamics of the wake vorticity: examples and discussion.

Two-dimensional bluff bodies (4 hours): Alternate vortex-shedding from 2-D bodies: historical outline, Von Karman results, description of the vorticity and velocity fields, Strouhal number and its dependence on the width of the wake. Link between vortex-shedding and forces acting on bodies. Oscillating forces induced by the vortex shedding and their dependence on the body shape and the Reynolds number. Three-dimensionality of the wake and its effects. Conditions for the existence of regular vortex shedding and detailed explanation of the C_D - Re curve of a circular cylinder. Drag reduction by inhibition of alternate vortex shedding. Vortex shedding from rectangular cylinders.

Three-dimensional bluff bodies and flow conditions (4 hours): Generalities, comparison with the 2-D case: similarities and differences. Axisymmetric bodies: characteristics of the wake flow, link between drag and mean velocity field. Boat-tailing: characteristics and mechanism of action. Investigation on the rounding of the rear edges of bluff bodies, examples of application of the results. Effect of the thickness of the boundary layer at separation. Morel bodies: origin, effect and inhibition of concentrated vortexes. Reduction of drag through "base bleed". Methods to delay separation: effect of contoured transverse grooves. Other three-dimensional effects of flow and geometry: finite cylinders and prisms placed vertically on a plane: horseshoe vortices, end effects, influence of the aspect ratio on the existence and characteristics of vortex shedding, mean and oscillating forces.

Interference between bluff bodies (4 hours): Introduction and general considerations: possible changes in flow characteristics and effects on static and dynamic forces. Interference between a cylinder and a plane: flow variation and inhibition of vortex shedding. Cylinders in pairs: in tandem, coupled laterally, staggered. Introduction to the aerodynamics of complex configurations and necessity of dedicated investigations. Reduction of the drag and of the dynamic loads acting on bluff bodies through interference with smaller bodies placed upstream or downstream. Effect of confinement on vortex shedding. Discussion on the importance of fully understanding the physical mechanisms originating the aerodynamic loads.

4. Lecturer

Prof. Guido Buresti
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University of Pisa, Italy
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5. Duration and credits

24 hours (6 credits)

6. Activation mode and teaching period

The course will start on July 9th, 2018. Most of the class hours (around 20) will be held on July 9-12, 2018. The minimum number of participants to activate the course is 3.

7. Deadline for registration

The deadline for applications is July 7th, 2018. Please, send an e-mail confirmation to Giuseppe Piccardo, giuseppe.piccardo@unige.it.

8. Final exam

Test examination at the end of the course

9. Recommended references

- Class slides and scientific articles provided by Prof. Buresti
- Buresti G. - Elements of fluid dynamics, Imperial College Press, 2012.
- Hucho W.-H. – Aerodynamics of road vehicles, Butterworths, 1986.
- Riera I.D., Davenport R.G. (Eds.) - Wind effects on buildings and structures, Balkema, 1998.
- Simiu E., Scanlan R.H. – Wind effects on structures, Wiley, 1986.
- Zdravkovich M.M. - Flow around circular cylinders. Vol. 1: Fundamentals. Oxford Univ. Press, 1997.
- Zdravkovich M.M. - Flow around circular cylinders. Vol. 2: Applications. Oxford Univ. Press, 2003.