GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Wind Turbine Aerodynamics, PG_00070380		
Field of study	Naval Architecture and Offshore Structures		
Date of commencement of studies	February 2026	Academic year of realisation of subject	2026/2027
Education level	second-cycle studies	Subject group	Specialty subject group Subject group related to scientific research in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	1	Language of instruction	Polish
Semester of study	2	ECTS credits	2.0
Learning profile	general academic profile	Assessment form	assessment
Conducting unit	Institute of Naval Architecture -> Faculty of Mechanical Engineering and Ship Technology -> Faculties of Gdańsk University of Technology		
Name and surname of lecturer (lecturers)	Subject supervisor	dr hab. inż. Paweł Dymarski	
	Teachers	Filip Hahs dr hab. inż. Paweł Dymarski	

Lesson types

Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	30.0	0.0	15.0	0.0	0.0	45

E-learning hours included: 0.0

Learning activity and number of study hours

Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	45	2.0	3.0	50

Subject objectives

The aim of the course is to familiarize students with issues related to the aerodynamics of wind turbines. In particular, the student will acquire knowledge in the field of flow around a 2D profile, flow around an airfoil with a finite span and flow around a wind turbine rotor. Students will learn the principle of operation of the turbine and methods for determining aerodynamic forces on its blades. During the laboratory exercises, the student will learn about experimental research methods for vertical axis wind turbines

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K7_W12] identifies and interprets the main developmental trends and significant new achievements in the field of engineering and technical sciences and disciplines relevant to the course of study Naval Architecture and Offshore Structures	The student is aware of the main development trends in the aerodynamics of wind turbines.	[SW3] Assessment of knowledge contained in written work and projects
[K7_W01] explains and describes, based on general knowledge in the field of scientific disciplines forming the theoretical foundations of Naval Architecture and Ocean Engineering, the construction and principles of operation of marine systems, processes and their components, as well as methods and means of their design and operation	The student understands the aerodynamic principles underlying the operation of a wind turbine rotor.	[SW3] Assessment of knowledge contained in written work and projects
[K7_U01] applies acquired analytical, simulation, and experimental methods, as well as mathematical models for analysis and evaluation of shipborne and offshore systems and processes	The student applies analytical, numerical, and experimental methods to analyze wind turbines. The student understands the basic properties of the most important turbine types.	[SU1] Assessment of task fulfilment [SU4] Assessment of ability to use methods and tools

Subject contents

Course content – lecture

1. Fluid mechanics review
1.1 Flow kinematics
- streamlines, stream surface, stream tube
- path (trajectory) of a fluid element, stream surface, stream
1.2 Flow rate: mass flow, volume flow
1.3 Mass conservation principle
1.4 Momentum conservation principle, Bernoulli's equation
1.5 Scalar field, vector field
1.6 Gradient, potential vector field
1.7 Vorticity and divergence of a vector field
1.8 Velocity circulation
1.9 Relationship between circulation and vorticity.

2. Aerodynamic profile theory
2.1 Geometric description
2.2 Lift force, drag force, moment on the profile (2D)
2.3 Pressure coefficient CP, pressure distribution
2.4 Mechanism of lift force generation, Kutta-Zhukovsky equation
2.5 Influence of Reynolds number on Cl, Cd characteristics of the airfoil profile
2.6 Fundamentals of numerical modeling of the flow around the aerodynamic profile

3. Fundamentals of the theory of a finite span airfoil (wing)
3.1 Geometric description of the airfoil
3.2 Lift and drag force on the airfoil (3D)
3.3.1 Helmholtz theorem. The concept of a horseshoe vortex. Bound vortex, free vortices.
3.3.2 System of vortex fibers on and behind the airfoil.
3.3.3 Lift line theory. Calculation of the lift and drag force of the airfoil.

4. Basics of Wind Turbine Aerodynamics
4.1 Ideal Wind Turbine. Momentum Principle for One-Dimensional (1D) Flow
4.1.1 Betz Limit
4.2 Turbine Spinning Effect. Momentum Principle.

4.3 Blade Element Method (BEM) in Stationary Flow
4.4 Unsteady Flow. Turbine Yaw Effect.

5. Wind Modeling
5.1. (Stationary) Wind Speed Profile
5.2. Wind Spectrum (Spectra)
5.3. Determining the Wind Velocity Field in Unsteady Approach

6. Application of Lifting Line Theory to Determining the Flow Around a Turbine Rotor

Course content – laboratory

1. Introduction to the Python programming language and a review of differential calculus
2. Implementation of potential flow equations and analysis of the lift phenomenon
3. Introduction to the Blade Element Method (BEM)
4. Implementation of an iterative solver for the Blade Element Method (BEM)
5. Introduction to turbine blade dynamics – calculation of stiffness matrices

Prerequisites and co-requisites

Basic knowledge of fluid mechanics:
- the concept of mass flow and volume flow
- the principle of flow continuity
- the principle of conservation of momentum
- Bernoulli's equation
- the concept of field vorticity and circulation
- basic solutions of flow (potential flow)
-- Rankine's oval
-- flow around a circular cylinder
- the concept of hydrodynamic reaction

Basics of vector calculus:
- the scalar product of two vectors
- the vector product
- the gradient of a scalar field

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
Labs (reports)	60.0%	33.0%
Lecture (colloquium)	60.0%	67.0%

Recommended reading

Basic literature

1. Snorri Gudmundsson: GENERAL AVIATION AIRCRAFT DESIGN: APPLIED METHODS AND PROCEDURES. Amsterdam, Elsevier 2014
2. Ira H. Abbott, Albert E. Von Doenhoff THEORY OF WING SECTIONS Including a Summary of Airfoil Data. DOVER PUBLICATIONS, INC., NEW YORK 1949, 1959
3. Ryszard Gryboś: Podstawy mechaniki płynów. Warszawa, Wydawnictwo Naukowe PWN, 1998
4. Martin O. L. Hansen: Aerodynamics of Wind Turbines 2nd ed. London * Sterling, Earthscan, 2008
5. John D. Anderson, Jr.: Fundamentals of Aerodynamics Sixth Edition

	Supplementary literature	6. J. Jonkman, S. Butterfield, W. Musial, and G. Scott: Definition of a 5-MW Reference Wind Turbine for Offshore System Development. Technical Report NREL/TP-500-38060, February 2009 7. Gaertner Evan, Jennifer Rinker, Latha Sethuraman, i inni. (2020). Definition of the IEA 15-Megawatt Offshore Reference Wind Turbine. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-75698. https://www.nrel.gov/docs/fy20osti/75698.pdf 8. Sven Schmitz: Aerodynamics of Wind Turbines: A Physical Basis for Analysis and Design, WILEY 2020
	eResources addresses	
Example issues/ example questions/ tasks being completed		
Practical activites within the subject	Not applicable	

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