# GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

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| Subject name and code | Wind turbine aerodynamics, PG_00065623 | | | | | |
| Field of study | Naval Architecture and Offshore Structures | | | | | |
| Date of commencement of studies | February 2025 | | Academic year of realisation of subject | | 2025/2026 | |
| Education level | second-cycle studies | | Subject group | | Specialty subject group<br>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 | | 3.0 | |
| Learning profile | general academic profile | | Assessment form | | exam | |
| Conducting unit | Institute of Naval Architecture -> Faculty of Mechanical Engineering and Ship Technology -> Wydziały Politechniki Gdańskiej | | | | | |
| Name and surname of lecturer (lecturers) | Subject supervisor | | dr hab. inż. Paweł Dymarski | | | |
| | Teachers | | dr hab. inż. Paweł Dymarski | | | |

| Lesson types and methods of instruction | 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 | 8.0 | 22.0 | 75 |

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| 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_U02] formulates and tests hypotheses concerning problems related to shipborne and offshore systems/processes, as well as simple research problems | The student is able to solve basic tasks related to wind turbine design. The student is able to solve simple research problems. | [SU4] Assessment of ability to use methods and tools<br>[SU3] Assessment of ability to use knowledge gained from the subject<br>[SU1] Assessment of task fulfilment |
| [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 | The student identifies and interprets the main development trends and the most important new achievements in the field of wind turbine aerodynamics. | [SW1] Assessment of factual knowledge |
| [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. | [SU4] Assessment of ability to use methods and tools<br>[SU1] Assessment of task fulfilment |

<table>
<tr><td>Subject contents</td><td>1. Fluid mechanics review<br>1.1 Flow kinematics<br>- streamlines, stream surface, stream tube<br>- path (trajectory) of a fluid element, stream surface, stream<br>1.2 Flow rate: mass flow, volume flow<br>1.3 Mass conservation principle<br>1.4 Momentum conservation principle, Bernoulli's equation<br>1.5 Scalar field, vector field<br>1.6 Gradient, potential vector field<br>1.7 Vorticity and divergence of a vector field<br>1.8 Velocity circulation<br>1.9 Relationship between circulation and vorticity.<br><br>2. Aerodynamic profile theory<br>2.1 Geometric description<br>2.2 Lift force, drag force, moment on the profile (2D)<br>2.3 Pressure coefficient CP, pressure distribution<br>2.4 Mechanism of lift force generation, Kutta-Zhukovsky equation<br>2.5 Influence of Reynolds number on Cl, Cd characteristics of the airfoil profile<br>2.6 Fundamentals of numerical modeling of the flow around the aerodynamic profile<br><br>3. Fundamentals of the theory of a finite span airfoil (wing)<br>3.1 Geometric description of the airfoil<br>3.2 Lift and drag force on the airfoil (3D)<br>3.3.1 Helmholtz theorem. The concept of a horseshoe vortex. Bound vortex, free vortices.<br>3.3.2 System of vortex fibers on and behind the airfoil.<br>3.3.3 Lift line theory. Calculation of the lift and drag force of the airfoil.<br><br>4. Basics of Wind Turbine Aerodynamics<br>4.1 Ideal Wind Turbine. Momentum Principle for One-Dimensional (1D) Flow<br>4.1.1 Betz Limit<br>4.2 Turbine Spinning Effect. Momentum Principle.<br><br>4.3 Blade Element Method (BEM) in Stationary Flow<br>4.4 Unsteady Flow. Turbine Yaw Effect.<br><br>5. Wind Modeling<br>5.1. (Stationary) Wind Speed Profile<br>5.2. Wind Spectrum (Spectra)<br>5.3. Determining the Wind Velocity Field in Unsteady Approach<br><br>6. Application of Lifting Line Theory to Determining the Flow Around a Turbine Rotor<br><br>7. Familiarization with the aerodynamics of vertical axis wind turbines during laboratory exercises</td></tr>
<tr><td>Prerequisites and co-requisites</td><td>Basic knowledge of fluid mechanics:<br>- the concept of mass flow and volume flow<br>- the principle of flow continuity<br>- the principle of conservation of momentum<br>- Bernoulli's equation<br>- the concept of field vorticity and circulation<br>- basic solutions of flow (potential flow)<br>-- Rankine's oval<br>-- flow around a circular cylinder<br>- the concept of hydrodynamic reaction<br><br>Basics of vector calculus:<br>- the scalar product of two vectors<br>- the vector product<br>- the gradient of a scalar field</td></tr>
<tr><td>Assessment methods and criteria</td><td><table><tr><th>Subject passing criteria</th><th>Passing threshold</th><th>Percentage of the final grade</th></tr><tr><td>Lecture (colloquium)</td><td>60.0%</td><td>67.0%</td></tr><tr><td>Labs (reports)</td><td>60.0%</td><td>33.0%</td></tr></table></td></tr>
<tr><td>Recommended reading</td><td><table><tr><td>Basic literature</td><td>1. Snorri Gudmundsson: GENERAL AVIATION AIRCRAFT DESIGN: APPLIED METHODS AND PROCEDURES. Amsterdam, Elsevier 2014<br>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<br>3. Ryszard Gryboś: Podstawy mechaniki płynów. Warszawa, Wydawnictwo Naukowe PWN, 1998<br>4. Martin O. L. Hansen: Aerodynamics of Wind Turbines 2nd ed. London * Sterling, Earthscan, 2008<br>5. John D. Anderson, Jr.: Fundamentals of Aerodynamics Sixth Edition</td></tr></table></td></tr>
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| | 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<br>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<br>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 | | |
| Work placement | Not applicable | |

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