GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Aeroelasticity and Durability of Wind Turbines, PG_00062651		
Field of study	Naval Architecture and Offshore Structures		
Date of commencement of studies	February 2024	Academic year of realisation of subject	2024/2025
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 Ocean Engineering and Ship Technology -> Faculty of Mechanical Engineering and Ship Technology		
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	15.0	15.0	0.0	0.0	0.0	30
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	30	4.0	16.0	50

Subject objectives

The aim of the course is to familiarize students with the phenomenon of aeroelasticity of a wind turbine blade, i.e. deformation and / or vibration of a turbine blade due to the action of aerodynamic forces.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K7_U01] Develops innovative strategies to solve complex and dynamic problems by synthesizing information from various sources and utilizing analytical, simulation, and experimental methods, considering environmental variability	The student has the ability to analyze the dynamics of a wind turbine blade: determine the mass matrix, stiffness matrix and damping matrix. The student is able to determine the natural frequencies of the blade.	[SU1] Assessment of task fulfilment [SU4] Assessment of ability to use methods and tools
[K7_W02] Explains the essence and relationships of key components describing systems and processes in ocean engineering, utilizing current knowledge from major scientific fields related to the field of study	The student is able to determine the characteristics of the cross-section of a turbine blade and is able to determine the impact (changes) of these characteristics on the dynamic properties of the turbine blade.	[SW3] Assessment of knowledge contained in written work and projects
[K7_W03] Demonstrates advanced skills in applying analytical methods and problem-solving techniques related to ocean engineering, using appropriate tools	The student knows analytical methods for calculating the aeroelasticity of wind turbines.	[SW3] Assessment of knowledge contained in written work and projects

Subject contents	1. The theory of the aerodynamic profile 1.1 Geometric description 1.2 Lifting force, drag force, profile moment (2D) 1.3 Pressure coefficient CP, pressure distribution 1.4 Mechanism of lift force generation, Kutta-Joukowski equation 2. The theory of the aerofoil (wings) 2.1 Geometric description of the aerofoil 2.2 Lift force on the aerofoil/wing (3D) 3. Numerical analysis of the aerofoil 3.1 Arrangement of the vortex filaments on and behind the wing 3.2 The lifting line theory 4. The blade as a bending beam 4.1 Revision of basic knowledge of the subject 4.1.1 Characteristics of the beam cross-section 4.1.2 Basic solutions for a bending beam. 4.3 Beam stiffness 4.4 Equation of beam deflection 4.5 Stiffness matrix 4.6 Aeroelasticity: static case - blade bending 5. The blade as a twisted beam 5.1.1 Characteristics of the aerofoil cross-section as a closed-profile beam (torsion) 5.1.2 Basic solutions for a twisted beam 5.2 Aeroelasticity: static case - blade twisting 6. Introduction to aerofoil dynamics 6.1 Dynamics of a system with one degree of freedom. Mass spring system 6.2 Dynamics of a system with many degrees of freedom. Model of concentrated (point) masses (lumped mass model) 7. The "real" velocity field of the flowing wind turbine blade. 7.1 Determining the Velocity Field of the Selected Turbine Blade Profile. Stationary case 7.2 Determination of the non-stationary velocity field of the selected turbine blade profile for the stationary wind speed profile. 7.3 The case of a non-stationary wind velocity field. 7.3.1 The spectrum of the wind 7.3.2 Determination of the non-stationary velocity field of the selected turbine blade profile. 8. Basics of blade/foil analysis in the frequency domain 9. Dynamics of the turbine rotor - tower system. Introduction.
Prerequisites and co-requisites	- the student has basic knowledge of fluid mechanics: -- flow continuity equation -- Bernoulli equation -- the concept of lift force and drag force on the aerofoil - the student has a basic knowledge of the strength of materials: -- cross-section characteristics: moments of inertia and strength factors -- basic knowledge of beam bending (statically determinate) -- basic knowledge of screwing closed profiles -- basic knowledge of the theory of vibrations - mass on a spring with a damping element - basic knowledge of general mechanics -- equilibrium equations (statics) -- Newton's laws of motion - basics of numerical methods -- numerical integration -- basic time integration methods

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
Lecture	60.0%	50.0%
Exercises	60.0%	50.0%

Recommended reading

Basic literature	1. Snorri Gudmundsson: GENERAL AVIATION AIRCRAFT DESIGN: APPLIED METHODS AND PROCEDURES. Amsterdam, Elsevier 2014 2. Zbigniew Brzoska: Wytrzymałość materiałów. Warszawa, PWN 1972 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. Srinivasan Chandrasekaran: Dynamic Analysis and Design of Offshore Structures. Springer 2015, 2018
Supplementary literature	6. Ira H. Abbott, Albert E. Von Doenhoff THEORY OF WING SECTIONS Including a Summary of Airfoil Data. DOVER PUBLICATIONS, INC., NEW YORK 1949, 1959 7. Dewey H. Hodges, G. Alvin Pierce: Introduction to Structural Dynamics and Aeroelasticity. Cambridge University Press 2002, 2011 8. James F. Wilson: "Dynamics of Offshore Structures" 2nd ed. John Wiley & Sons 2003
eResources addresses	Adresy na platformie eNauczanie:

Example issues/ example questions/ tasks being completed	Examples of issues: 1.determination of the lift force / drag force / torque on the aerofoil based on the characteristics of the CL, CD, CM coefficients as a function of the angle of attack alpha 2. Explanation of the phenomenon of the formation of lift force. Kutta-Joukowski theorem 3. Lift force on finite span aerofoils. Overview of the carrier line method 4. Characteristics of the cross-section of a bending beam 5. Determination of internal forces in a bending beam and the deflection line. A beam restrained on one side with a constant (or variable) cross-section 6. Characteristics of the cross-section of a closed profile twisted beam 7. Determination of internal forces in a twisted beam and the angle of twist. One-sidedly restrained beam 8. The problem of beam stiffness. Stiffness matrix 9. Overview of the dynamics of a system with one degree of freedom (on the example of a mass on a spring with a damping element). Equation of motion, response to sinusoidal input 10. Overview of the dynamics (equation of motion) of a system with many degrees of freedom (on the example of 2-3 degrees of freedom) 11. Velocity field (velocity components) in the problem of turbine blade flow. 12. Wind modeling - stationary / non-stationary model. The spectrum of the wind
Work placement	Not applicable