GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Numerical modelling of thermal-flow processes, PG_00064849		
Field of study	Mechanical Engineering		
Date of commencement of studies	February 2027	Academic year of realisation of subject	2027/2028
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	4.0
Learning profile	general academic profile	Assessment form	exam
Conducting unit	Division of Thermal Power Systems -> Institute of Energy -> Faculty of Mechanical Engineering and Ship Technology -> Faculties of Gdańsk University of Technology		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Paweł Ziółkowski	
	Teachers		

Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	0.0	0.0	30.0	0.0	60
	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	60	5.0	35.0	100

Subject objectives	The aim of the course is to present the application of numerical modeling software in heat and flow processes. The theoretical component (lecture) is designed to familiarize students with and spark their interest in the subject matter of the mass, momentum, and energy conservation equations in 0D and 3D approaches, taking into account the context of sustainable development. The objective of the practical component (project) is for students to acquire the skills necessary to use numerical analysis tools for heat and flow processes.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K7_W02] demonstrates a structured and theoretically grounded knowledge of the key topics in Mechanical Engineering enabling the analysis and modelling of mechanical systems, processes and devices	The students demonstrate a well-organized and theoretically grounded knowledge of heat and mass transfer issues, enabling the analysis and modeling of heat and mass transfer systems and processes—particularly those that contribute to the development of systems supporting the principles of sustainable development.	[SW3] Assessment of knowledge contained in written work and projects
[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 students are able to identify and interpret the main trends in the development of thermal and industrial energy systems and to identify directions consistent with the concept of sustainable development. The students are able to list the most significant new achievements in both engineering and technical sciences and from a broader interdisciplinary perspective. They highlight the latest implementations and research and development in the context of thermal and fluid flow equipment and machinery, including, in particular, environmentally friendly systems that utilize Renewable Energy Sources (RES) or work in conjunction with them to ensure the security of the power system.	[SW1] Assessment of factual knowledge [SW3] Assessment of knowledge contained in written work and projects
[K7_U15] evaluates the feasibility of advanced methods and tools for solving complex engineering tasks of a practical nature, characteristic of the field of study, and selects and applies appropriate methods and tools for this purpose	Students evaluate the usefulness of advanced numerical methods and tools for solving a complex, practical engineering problem—they model the operation of power generation equipment, such as turbines, compressors, and heat exchangers. To this end, students select and apply appropriate methods, including those that combine an interdisciplinary approach with tools such as 0D or 3D simulations. Students are able to relate to the operating parameters of individual devices and determine whether the results are physically correct.	[SU1] Assessment of task fulfilment [SU4] Assessment of ability to use methods and tools
[K7_U11] communicates and justifies opinions on specialized topics in a manner understandable to diverse audiences, including the use of modern techniques, including information technology	Students are able to communicate and justify their opinions on topics related to thermal and fluid flow machinery in a manner that is understandable to diverse audiences, including through the use of modern interdisciplinary techniques, such as information technology based on software that utilizes 0D and 3D balances.	[SU1] Assessment of task fulfilment [SU2] Assessment of ability to analyse information [SU4] Assessment of ability to use methods and tools

Subject contents

Course content – lecture

The lecture includes a refresher on thermodynamic cycles in the context of their application to support the concept of sustainable development, as well as an expansion on their modeling using numerical tools. During the lecture, the balances, constitutive equations, and methods for specifying boundary conditions in heat and flow problems will be presented, including from an interdisciplinary perspective aimed at improving the general well-being of society. There will also be a discussion of the computational capabilities of FEM and FVM codes, as well as software packages for designing energy systems, including those that integrate with renewable energy sources.

Course content – project

The project-based sessions will focus on modeling a practical example in the context of heat and flow processes.

Prerequisites and co-requisites

Students should be able to solve selected problems in differential and integral calculus. They should be familiar with ordinary and partial differential equations. They should have a basic understanding of fluid mechanics, strength of materials, and thermodynamics.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
Laboratory	56.0%	35.0%
Written exam	56.0%	65.0%

Recommended reading	Basic literature	1. Janusz Badu: Numeryczne modelowanie zrownoważonego spalania w turbinach gazowych. Wydawnictwo IMP PAN (2003): Gdańsk Skrypt dostępny na stronie: https://www.imp.gda.pl/fileadmin/doc/o2/z3/publications/2005_piecwykladow.pdf 2. Magdalena Budziszewska, Aleksandra Kardaś, Zbigniew Bohdanowicz: Klimatyczne ABC. Interdyscyplinarne podstawy współczesnej wiedzy o zmianie klimatu. Warszawa (2021): Wydawnictwa Uniwersytetu Warszawskiego. https://klimatyczneabc.uw.edu.pl/. https://doi.org/10.31338/uw.9788323547303 3. Ziółkowski, P.; Radomski, P.; Koulali, A.; Kreft, D.; Barański, J.; Mikielewicz, D. Numerical Study of Heat Transfer Intensification in a Chamber with Heat Generating by Irradiated Gold Nanorods: One-Way Multiphysics and Multiscale Approach. Energies 2026, 19, 181. https://doi.org/10.3390/en19010181
	Supplementary literature	1.Dariusz Mikielewicz, Jarosław Mikielewicz: Termodynamika we współczesnej nauce i technice; Wydawnictwo Naukowe PWN (2025): Warszawa. 2. Stephen Turns: Thermal-Fluid Sciences an integrated approach. Cambrige University Press, New York 2006. 3. Wolfgang Altmann: Practical process control for engineers and technicians. Newnes, Oxford 2005. 4. Rolf Kehlhofer: Combined-cycle gas & steam turbine power plant. The Fairmont Press, Lilburn, 1991. 5. F. M. White - Fluid Mechanics, McGraw-Hill, 2011 6. Ziółkowski P., Stasiak K., Amiri M., Mikielewicz D. Negative carbon dioxide gas power plant integrated with gasification of sewage sludge. Energy. 2023;262:125496. 7. Janusz Badu: Numeryczne modelowanie zrownoważonego spalania w turbinach gazowych. Wydawnictwo IMP PAN (2003): Gdańsk. 8. Olgierd C. Zienkiewicz (1972): Metoda elementow skończonych. Arkady, Warszawa. 9. Olgierd C. Zienkiewicz, R.L. Taylor, J.Z. Zhu (2005): Finite Element Method vol. I,II,III Elsevier, Amsterdam, Oxford. 10. Ostrowska-Maciejewska J.: Fenomenologiczna machanika ośrodkow ciągłych. Wydawnictwo Instytutu Podstawowych Problemow Techniki PAN, Warszawa 2020 11. Research articles cited in subsequent lectures as examples.
	eResources addresses	

Example issues/ example questions/ tasks being completed	1) Using/drawing a diagram of a channel with one inlet and one outlet, transition from the general differential form of the 3D mass balance to the 0D approach under steady-state conditions. Describe the variables appearing in the equations. (3 points) 2) Using/drawing a diagram of a channel with one inlet and one outlet, transition from the general differential form of the 3D momentum balance to the 0D approach under steady-state conditions. Describe the variables appearing in the equations. (3 points) 3) Using/drawing a diagram of a channel with one inlet and one outlet, as well as a heating wall and a moving blade, derive the 0D steady-state solution from the general 3D differential form of the energy balance equation. Describe the variables appearing in the equations. (3 points) 4) A diagram of the Rankine cycle and p-v, T-s, and h-s graphs, along with equations describing the transformations in the successive devices, distinguishing between mass, momentum, and energy balances. (Mark characteristic points on all graphs and on the diagram of the devices—the equations modeling the physical phenomena should correspond to the mathematical models of the phenomena occurring in the given devices.) (3 points) 5) A diagram of the Joule–Brayton cycle, along with p-v, T-s, and h-s diagrams, including the equations describing the transformations in each device, distinguishing between mass, momentum, and energy balances. (Mark characteristic points on all graphs and on the device diagram—the equations modeling physical phenomena should correspond to the mathematical models of the phenomena occurring in the given devices) (3 points) 6) A flow diagram of a dry-medium ORC cycle, along with p-v, T-s, and h-s diagrams, including the equations describing the transformations in the successive components, distinguishing between mass, momentum, and energy balances. (Mark characteristic points on all diagrams and on the equipment schematic—the equations modeling physical phenomena should correspond to the mathematical models of the phenomena occurring in the given devices). (3 points) 7) A schematic of a combined cycle system with a single-wall boiler, along with T-s, h-s, and T-Q graphs showing the temperature distribution along the flue gas path, including equations describing the transformations in each device, distinguishing between mass, momentum, and energy balances. (Mark characteristic points on all graphs and on the equipment diagram—the equations modeling the physical phenomena should correspond to the mathematical models of the phenomena occurring in the given equipment.) (3 points) 8) A diagram of a counter-current cycle (Linde cycle) and the p-h, T-s, and T-Q graphs showing the temperature distribution in the heat exchangers on both sides of the exchangers, along with equations describing the transformations in each device, distinguishing between mass, momentum, and energy balances. (Mark characteristic points on all graphs and on the device diagram—the equations modeling the physical phenomena should correspond to the mathematical models of the phenomena occurring in the given devices). (3 points) 9) A diagram of the Carnot cycle, along with p-v and T-s graphs, including equations describing the transformations in each device, distinguishing between mass, momentum, and energy balances. (3 points) 10) Diagram of the computational domain with boundary conditions for wind energy extraction. The fundamental CFD equation corresponding to the general mathematical model of this phenomenon. (2 points) 11) An example of a hybrid system, such as a photovoltaic farm or a wind farm combined with a cycle leading to energy storage (CAES), including a system diagram and a description of how the individual devices interact. Provide the definitions of the equations determining the system's efficiency. (2 points) 12) An example of an ORC-VCC hybrid system with a thermal cycle plotted on p-h and T-s diagrams, including a system diagram and a description of how the individual components interact. Equations defining the system's efficiency. (2 points) 13) Draw a diagram illustrating the relationship between conservative and kinematic variables, fluxes, and sources used in thermomechanics (including CFD). (3 points) 14) List examples of constitutive equations characteristic of liquids, gases, and solids. Describe one example for each, specifying all variables, particularly material constants. (3 points)

	15) Discuss the four branches of Computational Thermomechanics of the Continuum. Describe the relationships between these branches using an appropriate diagram as an example. (2 points) 16) Describe the conservative form of the mass balance (equation and variables). Point out the differences between the 0D and 3D mass balances. (2 points) 17) Describe the conservative form of the momentum balance (equation and variables). Identify the differences between the 0D and 3D balances. (2 points) 18) Describe the conservative form of the energy balance (equation and variables). Identify the differences between the 0D and 3D balances. (2 points) 19) Describe the basic k-omega or k-epsilon turbulence evolution equations. Identify their analogies in the system of conservative equations with respect to the momentum balance. Discuss the sources of turbulence and the processes associated with this phenomenon. (3 points) 20) Provide an example of energy storage in a thermodynamic cycle diagram (e.g., a cycle with a steam reservoir) along with the equations describing this phenomenon—in either 3D or 0D. (2 points)
Practical activites within the subject	Not applicable

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