GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

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| Subject name and code | Materials for nuclear engineering, PG_00065879 | | |
| Field of study | Nuclear Engineering | | |
| Date of commencement of studies | February 2026 | Academic year of realisation of subject | 2025/2026 |
| Education level | second-cycle studies | Subject group | Obligatory subject group in the field of study<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 | 1 | ECTS credits | 2.0 |
| Learning profile | general academic profile | Assessment form | assessment |
| Conducting unit | Division of Materials Science and Technology -> Institute of Manufacturing and Materials Technology -> Faculty of Mechanical Engineering and Ship Technology -> Wydziały Politechniki Gdańskiej | | |
| Name and surname of lecturer (lecturers) | Subject supervisor | prof. dr hab. inż. Marek Szkodo | |
| | Teachers | | |

| Lesson types and methods of instruction | Lesson type | Lecture | Tutorial | Laboratory | Project | Seminar | SUM |
|---|---|---|---|---|---|---|---|
| | Number of study hours | 30.0 | 0.0 | 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 |
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| | Number of study hours | 30 | 5.0 | 15.0 | 50 |

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| Subject objectives | Introducing students to the properties, applications, and challenges associated with materials used in nuclear energy. The course aims to discuss the role of materials in ensuring the safety and efficiency of nuclear reactors, as well as in the sustainable management of radioactive waste. |

| Learning outcomes | Course outcome | Subject outcome | Method of verification |
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| | [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 | In terms of knowledge, the learning outcomes assume that the student is familiar with current trends in research and development of materials for nuclear energy, including new technological solutions and their potential applications.<br>The student understands the role of advanced materials in improving the efficiency and safety of nuclear reactors, including the importance of materials resistant to extreme working conditions (high temperature, radiation).<br>The student possesses knowledge of modern methods for studying materials, such as microstructural techniques, computer simulations, and modeling of material properties.<br><br>In terms of skills, the student is able to analyze and interpret research findings and technical reports related to materials for nuclear energy.<br>The student can evaluate the applicability of the latest technological advancements in materials and technologies for the development of nuclear energy.<br>The student is capable of identifying key issues in the field of materials for nuclear energy and proposing innovative solutions based on current research trends.<br>The student can compare and assess alternative materials and technologies in the context of their impact on safety, efficiency, and sustainable development in the nuclear sector.<br><br>In terms of social competences, the student demonstrates openness to technological innovations and is able to make decisions based on an understanding of their social, environmental, and economic consequences.<br>The student understands the importance of an interdisciplinary approach to the development of nuclear technologies and is capable of collaborating with experts from various fields to implement new solutions.<br>The student is aware of the responsibility associated with implementing modern material technologies in nuclear energy, considering their impact on human safety and the environment. | [SW2] Assessment of knowledge contained in presentation |

| Course outcome | Subject outcome | Method of verification |
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| [K7_W01] explains and describes, based on general knowledge in the field of scientific disciplines forming the theoretical foundations of Nuclear Power Technologies, the physics of processes, structure, principle of operation, operation, safety aspects, fuels and materials for reactors, systems, machines and devices of a nuclear power plant | In terms of knowledge, the learning outcomes assume that the student knows the fundamental physical processes occurring in nuclear reactors, including mechanisms of radiation, nuclear fission, and heat transfer.<br>The student understands the structure of nuclear reactors and the role of structural materials in their operation, including the mechanical, thermal, and chemical properties of key materials.<br>The student possesses knowledge about nuclear fuels, their production, properties, and interactions with structural materials in the reactor core.<br>The student knows the principles of selecting materials for systems, machines, and equipment used in nuclear power plants, considering safety and durability criteria.<br><br>In terms of skills, the learning outcomes assume that the student can explain the significance of material properties (e.g., radiation resistance, high-temperature stability, corrosion resistance) in ensuring the safety and efficiency of nuclear reactors.<br>The student is capable of analyzing the impact of operational conditions on material degradation, such as microstructural changes, radiation embrittlement, and corrosion in reactor environments.<br>The student can identify differences between traditional materials and modern solutions in the context of their applications in nuclear reactors.<br>The student is able to correlate the properties of fuel and structural materials with physical and chemical processes in the nuclear reactor.<br><br>In terms of social competences, the learning outcomes assume that the student understands the importance of responsible design and operation of nuclear systems, as well as the role of materials in minimizing risks to people and the environment.<br>The student demonstrates awareness of the importance of an interdisciplinary approach to the selection of materials and technologies for nuclear energy.<br>The student can clearly and substantively communicate issues related to nuclear materials, taking into account aspects of safety and sustainable development. | [SW2] Assessment of knowledge contained in presentation |

| Course outcome | Subject outcome | Method of verification |
|---|---|---|
| [K7_U13] evaluates the feasibility and potential for utilizing new technical and technological achievements in accomplishing tasks characteristic for the field of study | In terms of knowledge, the student knows the physical, chemical, and mechanical properties of materials used in nuclear energy.<br>The student understands the impact of nuclear reactor operating conditions (high temperature, radiation, corrosion) on material properties.<br>The student possesses knowledge about modern technologies and materials developed for nuclear energy (e.g., zirconium alloys, radiation-resistant steels, ceramics, protective coatings).<br><br>In terms of skills, the student is able to assess the suitability of materials for specific applications in nuclear energy, such as reactor shields, fuel rods, and heat exchangers.<br>The student can identify potential problems resulting from material degradation in radioactive environments and propose appropriate solutions.<br>The student is capable of applying acquired knowledge to analyze the potential use of new technologies and materials in the design and operation of nuclear systems.<br><br>In terms of social competences, the student is aware of the role of modern materials in ensuring the safety of nuclear reactors and minimizing the environmental impact of nuclear energy.<br>The student understands the responsibility associated with making decisions regarding the selection of materials in the nuclear energy sector. | [SU3] Assessment of ability to use knowledge gained from the subject |

**Subject contents**

1. Introduction to Nuclear Energy: History, reactor types, importance of materials.2. Fuel Materials: Types of fuels, production, and recycling processes.3. Structural Materials Used in Reactor Construction: Zr alloys.4. Structural Materials Used in Reactor Construction: Stainless steels 304 and 316.5. Structural Materials Used in Reactor Construction: Ferritic-perlitic steels P91, 9Cr-1Mo.6. Ceramic Materials in Reactor Construction: Al2O3, SiC.7. Protective Coating Materials: Anti-corrosion and barrier coatings.8. Material Degradation in Nuclear Power Plants: Effects of radiation on materials: structural damage, radiation-induced embrittlement. 9. Material Safety: Monitoring material condition, failure analysis.10. Nuclear Waste: Materials for waste storage, long-term stability.11. New Trends: Development of new materials for future reactors, sustainable development.

**Prerequisites and co-requisites**

The student should have basic knowledge of Materials Science.

**Assessment methods and criteria**

| Subject passing criteria | Passing threshold | Percentage of the final grade |
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| Students pass the course based on a written exam lasting 45 minutes. During the exam, they answer eight questions in written form. | 50.0% | 100.0% |

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| Recommended reading | Basic literature | 1. Srivastava, D., Kapoor, K. & Amarendra, G. Development of Advanced Nuclear Structural Materials for Sustainable Energy Development. J Indian Inst Sci 102, 391404 (2022). https://doi.org/10.1007/s41745-022-00287-z<br><br>2. Malerba, L.; Al Mazouzi, A.; Bertolus, M.; Cologna, M.; Efsing, P.; Jianu, A.; Kinnunen, P.; Nilsson, K.-F.; Rabung, M.; Tarantino, M. Materials for Sustainable Nuclear Energy: A European Strategic Research and Innovation Agenda for All Reactor Generations. Energies 2022, 15, 1845. https://doi.org/10.3390/en15051845<br><br>3. T. Jayakumar, M. D. Mathew, and K. Laha, "High Temperature Materials for Nuclear Fast Fission and Fusion Reactors and Advanced Fossil Power Plants," Procedia Engineering, vol. 55, pp. 259-270, 2013/01/01/ 2013, doi: https://doi.org/10.1016/j.proeng.2013.03.252 |

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| | Supplementary literature | 1. Ö. Anıl, E. Okay Mutlu, M. Demirhan, and E. Öztorun Köroğlu, "Experimental investigation of material properties of GFRP pipe for numerical simulation of novel nuclear power plant cooling water intake system," Nuclear Engineering and Design, vol. 428, p. 113556, 2024/11/01/ 2024, doi: https://doi.org/10.1016/j.nucengdes.2024.113556.<br><br>2. V. A. Zheltonozhsky, D. E. Myznikov, V. I. Slisenko, M. V. Zheltonozhskaya, and A. P. Chernyaev, "Determination of the long-lived 10Be in construction materials of nuclear power plants using photoactivation method," Journal of Environmental Radioactivity, vol. 227, p. 106509, 2021/02/01/ 2021, doi: https://doi.org/10.1016/j.jenvrad.2020.106509.<br><br>3. S. Hong, J. Kim, M.-W. Kim, H.-D. Kim, B.-S. Lee, and M.-C. Kim, "Evaluation of LBB characteristics of candidate materials for main steam line piping in Korea nuclear power plants," International Journal of Pressure Vessels and Piping, vol. 188, p. 104226, 2020/12/01/ 2020, doi: https://doi.org/10.1016/j.ijpvp.2020.104226.<br><br>4. H. Tukur and L. Yong, "A Review on the Behavior of 308L Cladding Material and Their Corrosion in Nuclear Power Plants," International Journal of Electrochemical Science, vol. 15, no. 1, pp. 1005-1021, 2020/01/01/ 2020, doi: https://doi.org/10.20964/2020.01.67.<br><br>5. J. Toribio, D. Vergara, and M. Lorenzo, "Hydrogen embrittlement of the pressure vessel structural materials in a WWER-440 nuclear power plant," Energy Procedia, vol. 131, pp. 379-385, 2017/12/01/ 2017, doi: https://doi.org/10.1016/j.egypro.2017.09.464.<br><br>6. J. Chen, P. Jung, and W. Hoffelner, "Irradiation creep of candidate materials for advanced nuclear plants," Journal of Nuclear Materials, vol. 441, no. 1, pp. 688-694, 2013/10/01/ 2013, doi: https://doi.org/10.1016/j.jnucmat.2013.04.024.<br><br>7. C. Jang, H. U. N. Jang, J.-D. Hong, H. Cho, T. S. Kim, and J.-G. Lee, "ENVIRONMENTAL FATIGUE OF METALLIC MATERIALS IN NUCLEAR POWER PLANTS A REVIEW OF KOREAN TEST PROGRAMS," Nuclear Engineering and Technology, vol. 45, no. 7, pp. 929-940, 2013/12/01/ 2013, doi: https://doi.org/10.5516/NET.07.2013.040<br><br>8. A. C. Joshi, A. L. Rufus, S. Suresh, P. Chandramohan, S. Rangarajan, and S. Velmurugan, "Characterization of the oxide formed in the presence of poly acrylic acid over the steam generator structural materials of nuclear power plants," Journal of Nuclear Materials, vol. 437, no. 1, pp. 139-148, 2013/06/01/ 2013, doi: https://doi.org/10.1016/j.jnucmat.2013.01.353. |
| | eResources addresses | |
| Example issues/ example questions/ tasks being completed | 1. Describe the basic types of nuclear reactors and the importance of materials in their construction.2. Explain the production process of UO fuel and its role in pressurized water reactors (PWR).3. What are the advantages and disadvantages of using MOX fuel compared to standard uranium fuel?4. Compare the properties of stainless steels 304 and 316 used in reactor construction.5. What are the key features of zirconium alloys (Zr-2, Zr-4) that determine their application as fuel claddings?6. Describe the role of ceramic materials, such as AlO and SiC, in nuclear energy.7. What are the main effects of neutron radiation on structural materials in nuclear reactors?8. Explain the mechanism of radiation-induced embrittlement in ferritic-pearlitic steels.9. What are the functions of anti-corrosion coatings used in reactor components? Provide examples of materials.10. What methods are used to monitor the condition of materials in nuclear reactors?11. Describe new materials being developed for Generation IV reactors. What requirements must they meet?12. How does sustainable development influence the selection of materials for nuclear energy? | |

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| Work placement | Not applicable |

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