MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National Aerospace University
"Kharkov Aviation Institute"

Aircraft Engine Theory department (№ 201)

APPROVED

Guarantor of education program

(signature) M. M. Orlovsky
(first and last name)

«28» August 2023 p.

SYLLABUS OF AN ACADEMIC DISCIPLINE

Theory of Heat Engines
(name of academic discipline)

Field of education 27 «Transport»
(code and name of a field of education)

Field of study 272 «Air transport»
(code and name of a field of study)

Educational program «Engineering Maintenance of Aircraft and Engines»
(name of educational program)

Form of training Full-time studies

Level of higher education First (bachelor)

The syllabus was put into operation on 01.09.2023

Kharkiv – 2023 p.

Person, who developed the syllabus

Mykhailo Shevchenko, Ph.D., assistant
(author, job, academic degree and rank)

(signature)

Working program was approved at the meeting of the department
Aircraft Engines Theory
(department)

Minutes № 1 dated « 24 » August 2023

Head of department *Dr. Sc., Professor* (academic degree and rank) (signature) *Ludmyla Boyko* (first and last name)

Agreed with the representative of education seekers

Monitor of the group 140 OPS (signature) *Kyrylo Hrynkiv* (first and last name)

1. General teacher information

Mykhailo Shevchenko, Ph.D., Assistant, Department of Aircraft Engines Theory. The following disciplines have been taught at the university since 2017:

- Turboexpanders, Compressors and Compressor Station Equipment;
- Theory and Computation of Impeller Machines (course project);
- Theory of air-jet engines;
- Theory of heat engines.

Areas of research: mathematical modeling of air-jet engines for aircraft with supersonic cruise, mathematical modeling of the characteristics of supersonic inlets, the influence of dissociation on the characteristics of aircraft engines, the influence of casing treatment on the shape of flow in the gap and general characteristics of the compressor and gas turbine engine.

2. Description of the discipline

The semester in which the discipline is taught – the 5th semester.

The scope of discipline:

3.5 Credits (105 hours), auditorium – 48 hours, independent work – 57 hours.

Forms of education

Day, distance, dual.

Discipline – obligatory.

Forms of learning: lectures; practical works; individual tasks; independent work; individual consultations.

Form of examination – current, modular and final (semester) control (exam).

Language of instruction – English.

Required prior courses (prerequisites) – mathematics, physics, thermodynamics and heat transfer; theoretical mechanics and theory of machines and mechanisms, mechanics of materials and structures.

Required related subjects (co-requisites) – design and strength of aircraft engines, aerohydrodynamics, aerodrome practice.

3. Goals and purposes of discipline

Goals

Theoretically and practically prepare future specialists for the design and operation of heat engines, in particular gas turbine engines (GTE), which are used on aircraft.

Purposes

Providing knowledge about the main elements of GTE, the principle of operation and their features, the principle of operation of the main schemes of GTE, the characteristics of GTE, and the features of unstable operation of GTE. Expanding the horizons of the specialist and develop the ability to comprehensively analyze of the problems that arise in the design and maintenance of GTE.

After mastering the discipline, the education seeker will acquire the following **competencies**:

1) General competences (GC):

– GC 03. Skills of using information and communication technologies;
– GC 04. Ability to conduct research at the appropriate level;
– GC 05. Ability to develop and manage projects;
– GC 09. Ability to abstract thinking, analysis and synthesis.

2) Special (professional) competencies (SC):

– SC.02. Ability to analyze aircraft facilities and their components, determine the requirements for their design, parameters and characteristics;

– SC.03. Ability to carry out experimental research and measurement of parameters and characteristics of air transport facilities, their units, systems and elements;

– SC.05. Ability to develop and implement in production technological processes of construction, operation, repair and maintenance of aircraft facilities, their systems, to draw up relevant documentation, instructions, rules and methods;

– SC.10. Ability to apply methods and means of technical measurements, technical regulations, standards and other normative documents in technical diagnostics of aircraft facilities, their systems and elements;

– SC.13. Ability to analyze the technical, economic, and maintenance indicators of aviation transport facilities, their systems, and elements in order to identify and eliminate negative factors and increase the efficiency of the production process.

It is expected that after mastering the discipline the education seeker will achieve the **following learning outcomes (LO)** and he can:

– LO 04. Use the principles of formation of labor resources, identify reserves, and ensure the efficiency of the work of aviation transport employees;

– LO 11. Analyze the construction and operation of air transport facilities, their systems, elements, factors influencing their characteristics and parameters;

– LO 12. Determine the parameters of air transport facilities, their systems and elements by conducting and analyzing of measurement experiment;

– LO 14. Develop and implement in production documentation on technological processes of construction, operation, repair and maintenance of aircraft facilities, their systems and other guidelines, rules and methods;

– LO 19. Carry out technical diagnostics of aviation transport objects, their systems, and elements, using effective means, relevant technical regulations, standards, and other regulatory documents;

– LO 22. Calculate technical, economic and operational indicators of aircraft facilities, their systems and elements.

4. Course content

Module 1.

Content module 1.

Topic 1. Introduction to the course «Theory of Heat Engines».

- *Forms of learning: lectures, independent work.*
- *The amount of auditorium workload: 1-2 hours.*
- *Required items and tools (equipment, materials, tools): none.*
- *The amount of independent work of the education seekers: 1-2 hours.*

Subject and content of the discipline. The discipline place in the curriculum and its significance. Features of studying the discipline, educational literature. Brief history of gas turbine plants and engines development. Advantages and disadvantages of one types of heat engines over others in relation to their use as power plants on airplanes.

- *The amount of independent work of the education seekers: 1-2 hours.*

Elaboration of lecture material. Forming questions to the teacher.

Topic 1. Aircraft power plant inlets.

- *Forms of learning: lectures, independent work.*
- *The amount of auditorium workload: 3-4 hours.*
- *Practical work: "Modes of operation of inlet devices AJE".*
- *Required items and tools (equipment, materials, tools): none.*
- *The amount of independent work of the education seekers: 2-3 hours.*

Purpose and principle of inlets operation. Types of inlets and their classification. The main parameters of the inlets and requirements for them. Features of subsonic and transonic inlets.

- *The amount of independent work of the education seekers: 2-3 hours.*

Elaboration of lecture material. Forming questions to the teacher. Familiarization with video materials of the inlets work principle.

Topic 3. GTE Compressors.

- *Forms of learning: lectures, practical works, independent work.*
- *The amount of auditorium workload: 7-8 hours.*
- *Practical work: «Scheme and principle of operation of the axial and centrifugal compressor AJE».*
- *Required items and tools (equipment, materials, tools): visual models (presentation slides at distance learning) of the blades of axial and centrifugal - flow compressors, visual models of GTE.*
- *The amount of independent work of the education seekers: 9-10 hours.*

Purpose of GTE compressors, their types and basic requirements for them. Compressor performance parameters. Compressor stage operation. The distribution of the main parameters of the flow in compressor stage. Energy losses in the axial compressor stage. Working process and functions of main elements of the centrifugal - flow compressor. The distribution of the main parameters of the flow in centrifugal - flow compressor. Advantages and disadvantages of the centrifugal stage. Diagonal compressor stage. Combined compressors. Off-designed regimes of the compressor. Compressor characteristics.

- *The amount of independent work of the education seekers: 9-10 hours.*

Elaboration of lecture material. Forming questions to the teacher. Familiarization with video materials of the GTE compressor work principle. Familiarization with the discrepancy between the modes of operation of the axial compressor stages on off-design modes, the consequences of off-design modes, and ways to regulate the compressor in the literature in way that is more detailed. Preparation for the defense of the laboratory work.

Topic 4. Combustion chamber.

- *Forms of learning: lectures, independent work.*
- *The amount of auditorium workload: 1-2 hours.*
- *Required items and tools (equipment, materials, tools): visual models (presentation slides at distance learning) of GTE combustion chambers.*
- *The amount of independent work of the education seekers: 3-4 hours.*

Purpose of combustion chambers and basic requirements for them. The main parameters of the GTE combustion chambers. The main types of GTEs combustion

chambers. The combustion process organization. The combustion chamber parameters changing. Afterburners and organization of the combustion process in them. Scheme of mixing chambers and flow pattern in them.

- *The amount of independent work of the education seekers: 3-4 hours.*

Elaboration of lecture material. Forming questions to the teacher. Familiarization with video materials of the GTE combustion chambers work principle. Familiarization with the characteristics of combustion chambers and their off-design modes in the literature.

Topic 5. GTE gas turbine.

- *Forms of learning: lectures, practical work, independent work.*
- *The amount of auditorium workload: 5-6 hours.*
- *Practical work: «Scheme and change of gas parameters in AJE turbine stage».*
- *Required items and tools (equipment, materials, tools): visual models (presentation slides at distance learning) of the axial gas turbine blades.*
- *The amount of independent work of the education seekers: 5-6 hours.*

Purpose of GTE turbines, their types and basic requirements for them. Turbine performance parameters. Turbine stage operation. The distribution of the main parameters of the flow in turbine stage. Energy losses in the axial turbine stage. Basic information on the characteristic of a gas turbine. Dimensionless coordinates of turbine characteristics. Typical characteristics of gas turbines.

- *The amount of independent work of the education seekers: 5-6 hours.*

Elaboration of lecture material. Forming questions to the teacher. Familiarization with video materials of the GTE turbine work principle. Familiarization with the energy losses in the axial turbine stage in the literature in way that is more detailed.

Topic 6. GTE exhaust system.

- *Forms of learning: lectures, independent work.*
- *The amount of auditorium workload: 1-2 hours.*
- *Required items and tools (equipment, materials, tools): none.*
- *The amount of independent work of the education seekers: 2-3 hours.*

Purpose of GTE Exhaust nozzle, their types and basic requirements for them. Losses in the outlets and their estimation methods. Characteristics of unregulated supersonic outlets. Tasks and methods of regulating supersonic outlets. Comparative analysis of different types of exhaust nozzle. Thrust reversing and thrust vectoring. Features of the exhaust system of turboshaft GTE of helicopters.

- *The amount of independent work of the education seekers: 2-3 hours.*

Elaboration of lecture material. Forming questions to the teacher. Familiarization with video materials of the GTE exhaust systems work principle. Familiarization with the energy losses in the GTE exhaust systems, their estimation methods and characteristics of unregulated supersonic outlets in the literature in way that is more detailed.

Modular control 1

- *Forms of learning: writing a module in the classroom (by the decision of the lecturer is allowed to conduct in distance form).*
- *The amount of auditorium workload: 2 hours.*
- *Required items and tools (equipment, materials, tools): none.*
- *The amount of independent work of the education seekers – as needed.*

Preparation for module.

Module 2.

Content module 2.

Topic 7. Thrust, power and specific parameters of aircraft engines.

- *Forms of learning: lectures, independent work.*
- *The amount of auditorium workload: 1-2 hours.*
- *Required items and tools (equipment, materials, tools): none.*
- *The amount of independent work of the education seekers: 1-2 hours.*

Jet thrust. Effective thrust of the power plant. External resistance of the power plant at supersonic speeds and its components. Specific parameters of aviation gas turbine engines.

- *The amount of independent work of the education seekers: 1-2 hours.*

Elaboration of lecture material. Forming questions to the teacher.

Topic 8. Power plants with gas turbine engine and their parameters.

- *Forms of learning: lectures, practical works, independent work.*
- *The amount of auditorium workload: 11-12 hours.*
- *Laboratory works: «Schemes of the flow parts of the AJE»; «Familiarization with full-scale models of GTE and air-breathing engines».*
- *Required items and tools (equipment, materials, tools): visual models and posters of aircraft engines (presentation slides at distance learning).*
- *The amount of independent work of the education seekers: 6-7 hours.*

Scheme and working process of turbojet engine. Gas generator part. Scheme and working process of afterburner turbojet engine. Scheme and working process of turbofan engine. Scheme and working process of mixed flow turbofan engine. Scheme and working process of the turboprop engine. Scheme and working process of a turboshaft engine. Scheme and working process of air-breathing engine.

- *The amount of independent work of the education seekers: 6-7 hours.*

Elaboration of lecture material. Forming questions to the teacher. Familiarization with video materials of the different type of aviation engines. Preparation for the defense of the laboratory work.

Topic 9. Performance of power plants with gas turbine engines

- *Forms of learning: lectures, laboratory works, independent work.*
- *The amount of auditorium workload: 11-12 hours.*
- *Required items and tools (equipment, materials, tools): presentation slides at distance learning.*
- *The amount of independent work of the education seekers: 9-10 hours.*

Controlled parameters and controlling factors. Controlling programs of engines and power plants. Nomenclature of aviation AJE's modes. Types of AJE's performances. Ways of obtaining performances of AJE. Altitude and speed characteristics of power plants with turbojet. Restrictions on altitude and speed characteristics of turbojet engines. Features of speed characteristics of power plants with turbofan engines. Speed characteristics of power plants with turboprop engine. Altitude characteristics of power plants with turboshaft engine. Range of altitudes and speeds of the aircraft and the area of modes restrictions of the power plant. Characteristic of thrust curve of power plants with turbojet. Features of characteristic of thrust curves of power plants with turbofan engines. Characteristic of thrust curve of power plants with turboprop and turboshaft engines. Climatic characteristics of GTE.

- *The amount of independent work of the education seekers: 9-10 hours.*

Elaboration of lecture material. Forming questions to the teacher. Familiarization with the engine modes from start to exit on the nominal mode.

Modular control 2

- *Forms of learning: writing a module in the classroom (by the decision of the lecturer is allowed to conduct in distance form).*
- *The amount of auditorium workload: 2 hours.*
- *Required items and tools (equipment, materials, tools): none.*
- *The amount of independent work of education seeker – as needed.*

Preparation for module.

5. Individual tasks

Calculation-graphic work on the topic "Calculation of the Flow Parameters along the GTE Air-Gas Channel"

6. Learning methods

Verbal, visual, practical.

7. Control methods

Conducting current control, defense of laboratory works, written modular controls, and final (semester) control (exam).

8. Evaluation criteria and distribution of the points that the education seekers get

Components of educational work	Points for one lesson (task)	Number of lessons (tasks)	Total number of points
Content Module 1			
Work at lectures	0…1	3	0…3 (the maximum number of points on this indicator)
Execution and defense of laboratory works	0…3	3	0…9
Modular testing	0…20	1	0…20
Content Module 2			
Work at lectures	0…1	3	0…3 (максимальна кількість балів за цим показником)
Execution and defense of laboratory works	0…5	2	0…10
Execution and defense of the calculation work	0…25	1	0…25
Modular testing	0…25	1	0…25
General activity	0…5		0…5
Totally for semester			**0…100**

Accepted evaluation scale

The sum of points for all types of educational activities	Assessment for the exam, calculation work, course project (work), test, practice
90-100	excellent
75-89	good
60-74	satisfactory
01-59	unsatisfactory with the possibility of re-taking the exam

Semester testing (examination) is held in case the student gives up points of modular testing and is permitted to the examination. The permission is given if the student has finished and passed all laboratory works and also successfully defended the individual tasks.

Maximum total score of the examination is 100 points.

The examination card is composed of two theoretical questions, one of which refers to the first module and the other to the second. Each question is rated 0...50 points.

Criteria for evaluating the education seeker's work during the semester

Satisfactory (60-74) – have a minimum of knowledge and skills to ensure learning outcomes. Work out all practical tasks. Perform calculation work.

Good (75-89) – have the basic knowledge and skills provided by the program of the discipline. Performing and defending all practical tasks and calculation work. Knowing the basic principles of the discipline with a deep enough understanding of the logical connections between the parts that make up a single system. It is enough freely use knowledge to analyze typical problems. Knowing the purpose and principle of operation of all elements of GTE, as well as the scheme and principle of operation of aircraft engines.

Excellent (90-100) – have all the knowledge and skills provided by the discipline program. Performing and defending all practical tasks and calculation work. Knowing all the provisions of the discipline while deeply mastering the logical connections between the parts that make up a single system. Freely using knowledge to analyze typical and atypical problems. Freely and reasonably answer any questions about the processes in the aircraft engines. Knowing the dependencies of aviation engines performances.

9. Course policy

Missed classes is worked out in accordance with the schedule of consultations, with the prior consent of the teacher. Issues related to academic integrity are considered by the teacher or according to the procedure specified in the Regulations on Academic Integrity.

10. Methodological support

1. Nezym, V.Yu. Gas Turbines: Design Problem. Lectures synopsis. KhAI Publishing, Kharkov, Ukraine, 2012, 84 pp. Available at: https://library.khai.edu/library/fulltexts/metod/Nezym_Gas_Turbin.pdf

2. Anyutin, A. N. Theory of Turbomachinery: Laboratory Course Manual / A. N. Anyutin, V. Yu. Nezym, G. V. Pavlenko, I. I. Redin – Kh.: Nat. Aerospace Univ. "Kh. Aviation Inst.", 2016. – 48 p. Available at: https://library.khai.edu/library/fulltexts/metod/Anyutin_Theory_Of_Turbomachinery.pdf

3. Nezym, V.Yu., Nikolaenko, Yu.G. Familiarization with Flow Passages and Components of Aviation Gas Turbine Engines. Laboratory work manual. KhAI Publishing, Kharkov, 2015, 16 pp. Available at: https://library.khai.edu/library/fulltexts/metod/Nezyn_Familiarization.pdf

4. Nezym, V.Yu., Polyakov, A.E., Brehov, A.F. et al. Aviation Gas Turbines Theory. Laboratory works manual. KhAI Publishing, Kharkov, 2013, 84 pp. Available at: https://library.khai.edu/library/fulltexts/metod/Aviation_Gas_Turbines_Theory.pdf

• Textbooks, manuals, Methodological book, lecture notes, guidelines for laboratory work, etc., which were published at the University may be found at the following link: https://mentor.khai.edu/course/view.php?id=717

11. Recommended literature for the course

Main

1. Klause, H., Jet Engines Fundamentals of Theory, Design and Operation, 6nd ed., Biddles Ltd, Great Britain, 2003. URL: https://www.academia.edu/6889926/Klaus_Hunecke_Jet_Engines_Fundamentals_of_Theory

Additional

1. Gerasimenko, V., Datsenko, V., Shevchenko, M. Creation of afterburning turbofan engine – history and present// Aerospace Technic and Technology, 2020, 5, 26–40. doi: https://doi.org/10.32620/aktt.2020.5.04

2. Walsh, P.P. and Fletcher, P., Gas Turbine Performance, Blackwell Science, Oxford, 1998. URL: https://sv.20file.org/up1/1043_0.pdf

3. Dixon, S.K., Fluid Mechanics, Thermodynamics of Turbomachinery, 3rd ed., Pergamon Press, Elmsford, N.Y., 1978. URL: http://160592857366.free.fr/joe/ebooks/Mechanical%20Engineering%20Books%20Collection/TURBOMACHINES/Fluid_Mechanics_and_Thermodynamics_of_Turbomachinery_4E.pdf

4. Cohen, H., Rogers, G.F.C., and Saravanamuttoo, H.I.H., Gas Turbine Theory, John Wiley & Sons, New York, 1972. URL: https://soaneemrana.org/onewebmedia/GAS%20TURBINE%20THEORY%20BY%20HIH%20SARAVANAMUTTOO,%20H.%20COHEN%20&%20GFC%20ROGERS.pdf