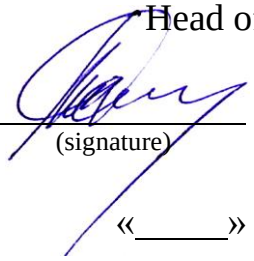
MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National Aerospace University
"Kharkov Aviation Institute"

Aircraft engine design department (№ 203)

APPROVED
Head of project team



_____ *Oleksandr Bilohub*
(signature) (first and last name)

«_____» _____ 2020

SYLLABUS OF AN ACADEMIC DISCIPLINE

DESIGN AND DYNAMICS OF AIRCRAFT ENGINES AND POWER PLANTS

(name of academic discipline)

Field of education *13 «Mechanical Engineering»*
(code and name of a field of education)

Field of study *134 «Aviation and Spacecraft Technologies»*
(code and name of field of study)

Educational program *Aircraft engines and power plants*
(code and name of educational program)

Form of training *Day studies*

Level of higher education *First (bachelor)*

Kharkiv 2020

Working program *Design and dynamics of aircraft engines and power plants*
(name of academic discipline)
for students of a field of study *134 «Aviation and Spacecraft Technologies»*
educational program *Aircraft engines and power plants*

« *1* » June 20*20* *11* *p.*

Person, who developed the syllabus *DSc, Prof. Sergiy Yepifanov*
(author, job, academic degree and rank) (signature)

Working program was approved at the meeting of the department
Aircraft Engine Design
(department)

Minutes № 1 dated « 28 » August 2020

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

1. Description of the discipline

<table>
<tr><td rowspan="2">Characteristics</td><td rowspan="2">Branch of science,
specialization,
academic degree</td><td colspan="2">Description of the discipline
(full-time tuition)</td></tr>
<tr><td colspan="2">Field of education:
13 «Mechanical Engineering»
(cipher and name)</td><td colspan="2">Variable</td></tr>
<tr><td>Modules – 3</td><td rowspan="5">Field of study:
134
«Aviation and spacecraft technologies»
(cipher and name)</td><td colspan="2">Academic year:</td></tr>
<tr><td>Semantic modules – 3</td><td colspan="2">2020 / 2021</td></tr>
<tr><td></td><td colspan="2" rowspan="2">Semester</td></tr>
<tr><td>(title)
Total number of academic hours –
7-th: 72* / 78 ;
8-th: 72* / 78</td></tr>
<tr><td rowspan="11">Number of academic hours for full-time tuition:

auditorium – 4.5

independent work – 5</td><td rowspan="11">Educational program:
Aircraft engines and power plants

Higher education:

First (Bachelor)</td><td>7-th</td><td>8-th</td></tr>
<tr><td colspan="2">Lectures [1)]</td></tr>
<tr><td>40 a.h.</td><td>36 a.h.</td></tr>
<tr><td colspan="2">Practices, seminars [*]</td></tr>
<tr><td>-</td><td>12 a.h.</td></tr>
<tr><td colspan="2">Laboratory activities [*]</td></tr>
<tr><td>32 a.h.</td><td>24 a.h.</td></tr>
<tr><td colspan="2">Independent work</td></tr>
<tr><td>78 a.h.</td><td>78 a.h.</td></tr>
<tr><td colspan="2">Form of examination</td></tr>
<tr><td>Credit</td><td>Examination</td></tr>
</table>

The ratio of hours of classes to independent work is: for full-time education –
7-th, 8-th: 72 / 78

** Auditory load can be reduced or increased by one hour, depending on the schedule of classes.*

2. Goals and purposes of discipline

Goal: knowledge acquisition on aircraft engine design. The task is solved of initial images forming about engine elements and parts dynamics based on the theoretical and engineering disciplined that are studied previously.

Task: study theoretical course, make laboratory and practical works and the course project "Compressor of turbine engine".

According to the requirements of the educational-professional program, students must achieve such **competencies:**

General competencies: *Ability to communicate in the state language both orally and in writing. Ability to communicate in the foreign language. Skills in the use of information and communication technologies. Opportunity to offer new ideas (creativity). Ability to make informed decisions in normal and special situations and implement them correctly. Ability to learn and master modern knowledge.*

Special (professional) competencies: *Ability to use theories of flight dynamics and control in the design of aerospace engineering. Ability to use the propositions of hydraulics, aero- and gas dynamics to describe the interaction of bodies with gaseous and hydraulic environment. Ability to assign optimal materials for structural elements of aerospace engineering. Ability to carry out the strength analysis of elements of aerospace engineering. Ability to design and test elements of aerospace engineering, its equipment, systems and subsystems. Skills in the use of information and communication technologies and specially configured software in studding and professional activities.*

Program learning outcomes: *To explain their decisions and the basis for their adoption to specialists and non-specialists in a clear and unambiguous form. To have the skills of self-study and autonomous work to refreshing professional skills and solve problems in a new or unfamiliar environment. To have the logic and methodology of scientific knowledge, based on an understanding of the current state and methodology of the subject area. To adhere to the requirements of industry regulations on procedures for the design, manufacture, testing and (or) certification of elements and objects of aerospace engineering at all stages of their life cycle. To explain the influence of design parameters of elements of aerospace engineering on its flight performance. Have an idea of the methods of ensuring the stability and controllability of aerospace engineering. To have the skills to determine loads on structural elements of aerospace engineering at all stages of its life cycle. To understand the principles of mechanics of liquid and gas, in particular, hydraulics, aerodynamics (gas dynamics). To describe the structure of metals and non-metals and know the methods of modifying their properties. To assign optimal materials for elements and systems of aerospace and rocket engineering, taking into account their structure, physical, mechanical, chemical and operational properties, as well as economic factors. To describe experimental methods for studying the structural, physical-mechanical and technological properties of materials and structures. To apply modern methods of design, construction and production of elements and systems of aerospace engineering in professional activities. To calculate the stress-strain state, determine stability margins of structural elements and the reliability of aerospace engineering. To understand and justify the sequence of design, manufacturing, testing and (or) certification of elements and systems of aerospace engineering. To understand and justify design features and basic aspects of workflow in systems and elements of aerospace engineering.*

Interdisciplinary links:

Design and Strength of Aircraft Engines and Power Plants, Theory of Blade Machines, Theory of Air-breathing Engines, Engineering Mechanics, Mechanics of Materials and Constructions, Bases of Machine Designing, Material Science, Mathematics.

3. Course content

SEMESTER 7

Module 1
Semantic module 1

TOPIC 1. Subject and tasks of the course. Its place in educational plan. Bibliography. Factors that initiate oscillations of the engine parts. Natural and forced oscillations. Resonance. Types and shape modes of oscillations: bending, torsion, plate oscillations, their combinations. Forced and self-excited oscillations. General order of the engine part oscillation analysis.

TOPIC 2. Oscillations of compressor and turbine blades. Shape modes of blades natural bending oscillations. Calculation of blades natural oscillation frequencies: single-mass model, influence of rotation, model of distributed mass of constant area, general shape model. Dangerous oscillation conditions determining and avoiding.

TOPIC 3. Oscillations of discs of compressors and turbines. Shape modes of discs natural oscillations. Calculation of the disc natural oscillation frequencies. Dangerous oscillation conditions determining and avoiding.

TOPIC 4. Oscillations of shells in aircraft engines. Shape modes of shells natural oscillations. Calculation of the shell natural oscillation frequencies. Dangerous oscillation conditions determining and avoiding.

Modular testing

Module 2
Semantic module 2

TOPIC 1. Critical rotational speed of the weightless rotor with a disc of concentrated mass. Terms “rigid” and “flexible” rotors. Determining frequencies of natural oscillations of non-rotated single-disc shaft.

TOPIC 2. Types of rotors precession. Factors that influence critical rotational speed of rotor. Influence of axial force that acts rotor. Influence of torsion torque. Influence of gyroscopic moment. Determining critical rotational speed considering influence of gyroscopic moment.

TOPIC 3. Determining critical rotational speeds of ponderable shaft and multi-disc rotors. Forced oscillations of rotated rotor. Frequency diagram of rotor and critical rotational speeds determining.

TOPIC 4. Design methods to eliminate critical rotational speeds of rotors. Equivalent design model of real mechanical system. Influence of specific features of a real elastic system on its natural oscillations.

TOPIC 5. Torsional oscillations of shafts. Types and shape modes of oscillations. Resonant modes and natural frequencies analysis.

Modular testing

SEMESTER 8

TOPIC 6. Shaftings of aircraft engines. Power systems of casings. Methods of load transmission in elements of power frames. Engine mounting units. Power systems of engine rotors. Couplings. Bearings of GTE rotors

TOPIC 7. Rotor supports design. Design of bearings. Gas and oil seals. Selection of roller bearings, their fitting to shaft and to a casing. Bearings lubrication and cooling. Bearing thermal state determining.

TOPIC 8. Elastic supports. Oil dampers. Elastic-damper supports. Strength analysis and designing of elastic rings and “squirrel-wheel” elastic elements.

Modular testing

Module 3

Semantic module 3

TOPIC 1. Tasks and main performances of gearboxes. Classification. Kinematic scheme of the gearbox that drives single-row propeller. Kinematic scheme of the gearbox that drives double-row propeller. Arrangement of gearboxes. Strength analysis of the propeller shaft. Torque-meters.

TOPIC 2. Accessory units. Accessory drives. Accessories arrangement. Design of accessory gearbox.

TOPIC 3. Air propellers. Parameters and characteristics. Forces and moments that act propeller blades. Propeller blades strength analysis.

TOPIC 4. Influence of flight conditions on propeller operation characteristic operating modes of air propellers. Negative thrust and methods to prevent it. Design of controlled pitch propeller hubs.

Modular testing

4. Course arrangement

Names of Modules and Topics	Number of hours				
	full-time tuition				
	total	namely			
		lec	pr	lab	i.w.
1	2	3	4	5	6
SEMESTER 7					
Module 1					
Semantic module 1					
TOPIC 1. Subject and tasks of the course. Its place in educational plan. Bibliography.	8	2	-	-	6
TOPIC 2. Oscillations of compressor and turbine blades. Shape modes of blades natural bending oscillations.	30	8	-	8	14
TOPIC 3. Oscillations of discs of compressors and turbines. Shape modes of discs natural oscillations.	24	4	-	6	14
TOPIC 4. Oscillations of shells in aircraft engines. Shape modes of shells natural oscillations.	26	4	-	6	16
Modular testing	2	2	-		
Totally for module 1	**56**	**20**	**-**	**20**	**36**
Module 2					
Semantic module 2					
TOPIC 1. Critical rotational speed of the weightless rotor with a disc of concentrated mass. Terms “rigid” and “flexible” rotors.	13	4	-	4	5
TOPIC 2. Factors that influence critical rotational speed of rotor. Influence of axial force and torsion torque that act a rotor.	11	4	-	2	5
TOPIC 3. Determining critical rotational speeds of ponderable shaft and multi-disc rotors. Forced oscillations of rotated rotor.	10	4	-	-	6
TOPIC 4. Design methods to eliminate critical rotational speeds of rotors. Equivalent design model of real mechanical system. Influence of specific features of a real elastic system on its natural oscillations.	12	4	-	2	6
TOPIC 5. Torsional oscillations of shafts. Types and shape modes of oscillations. Resonant modes and natural frequencies analysis.	14	4	-	4	6
Totally for semester 7	**150**	**40**	**-**	**32**	**78**
SEMESTER 8					
TOPIC 6. Shaftings of aircraft engines. Power systems of casings. Methods of load transmission in elements of power frames. Engine mounting units. Power systems of engine rotors. Couplings. Bearings	45	8	-	8	28

of GTE rotors.					
TOPIC 7. Rotor supports design. Design of bearings. Gas and oil seals. Selection of roller bearings, their fitting to shaft and to a casing.	15	4	6	2	10
TOPIC 8. Elastic supports. Oil dampers. Elastic-damper supports. Strength analysis and designing of elastic rings and "squirrel-wheel" elastic elements.	13	4	-	4	8
Modular testing	2	2			
Totally for module 2	**78**	**38**	**6**	**26**	**54**
Module 3					
Semantic module 3					
TOPIC 1. Tasks and main performances of gearboxes. Classification. Kinematic scheme of the gearbox that drives single-row propeller.	13	4	2	2	8
TOPIC 2. Accessory units. Accessory drives. Accessories arrangement. Design of accessory gearbox.	15	4	2	2	8
TOPIC 3. Air propellers. Parameters and characteristics. Forces and moments that act propeller blades.	16	4	2	2	8
TOPIC 4. Influence of flight conditions on propeller operation characteristic operating modes of air propellers. Negative thrust and methods to prevent it.	13	4	-	4	8
Modular testing	2	2			
Totally for module 3	**77**	**18**	**6**	**10**	**32**
Totally for semester 8	**150**	**36**	**12**	**24**	**78**
Totally for course	**300**	**76**	**12**	**56**	**156**

5. Practical works

№	Name	Hours
1	Elastic and damper supports of engine rotors designing	6
2	Functions and main characteristics of gearboxes	2
3	Design of accessory gearbox of the engine D-36	2
4	Hubs of air propellers	2
Totally		**12**

6. Laboratory works

№	Name	Hours
1	Blades oscillation analysis	8
2	Discs oscillation analysis	6
3	Shells oscillation analysis	6
4	Shaftings of aircraft engines	8
5	Experimental determination of rotor critical rotational speed	4
6	Torsional oscillations of shafts	4
7	Operation of oscillation dampers	2
8	Oil dampers. Strength analysis and designing of elastic rings and "squirrel-wheel" elastic elements	4
9	Selection of roller bearings, their fitting to shaft and to a casing.	2
10	Elasticity of the "squirrel-wheel" elastic element determining	2
11	Gearboxes of turboprop engines	4
12	Design of accessory gearbox	2

13	Design of propeller hub pitch controlling mechanism	2
14	Air propeller operating modes	2
Totally		**56**

7. Independent work

№	Name	Hours
1	Sources of engine vibrations	6
2	Oscillations of compressor and turbine rotor blades. Dangerous blades oscillations controlling.	14
3	Oscillations of compressor and turbine discs. Dangerous discs oscillations controlling.	14
4	Oscillations of turbine engine shells. Dangerous shells oscillations controlling.	16
5	Critical rotational speed of the weightless rotor with a disc of concentrated mass. Terms “rigid” and “flexible” rotors.	5
6	Factors that influence critical rotational speed of rotor. Influence of axial force that acts rotor. Influence of torsion torque.	5
7	Determining frequencies of rotor natural bending oscillations	6
8	Design methods to eliminate critical rotational speeds of rotors. Influence of specific features of a real elastic system on its natural oscillations.	6
9	Torsional oscillations of shafts. Types and shape modes of oscillations. Resonant modes and natural frequencies analysis.	6
10	Shaftings of aircraft engines. Power systems of casings.	28
10	Operating conditions and design of engine rotor supports. Gas and oil seals.	10
11	Operating conditions and design of dampers of engine supports. Strength analysis and designing of elastic rings and “squirrel-wheel” elastic elements.	8
12	Tasks and main performances of gearboxes. Classification. Kinematic scheme.	8
13	Accessory units. Accessory drives. Accessories arrangement. Design of accessory gearbox.	8
14	Air propellers. Parameters and characteristics. Forces and moments that act propeller blades. Propeller blades strength analysis.	8
15	Functions and main characteristics of the controlled pitch propellers. Design of propeller hubs.	8
	Totally	**156**

8. Learning methods

Basic forms of learning:

- lectures;
- practical works;
- laboratory works;
- individual task;
- independent work.

Lecture gives to student basic conceptions, bases of theory, relations which necessary to prepare for laboratory works, practical works and individual task.

Lecture solves one didactic problem only – gives primary knowledge about subject of topic, formulates main problems.

Laboratory and practical works are based on verbal (analytic) description of the object (engine, unit or component) and its material presentation using special didactic materials (mockups, posters, drawings etc.). During laboratory works, team-based approach of students work is applied.

Main form of learning is independent work. It cannot be done without preliminary knowledge given in lecture. During independent work, students study lecture material, prepare to laboratory and practical works, make calculation-graphic task and term project.

9. Questions for independent work

Module 1
Semantic module 1

1. Types and shape modes of blades natural oscillations.
2. Influence of constructive factors on natural oscillation frequency of rotor blades.
3. Turning-out resonant frequencies of rotor blades.
4. Constructive methods of blades resonant oscillation control.
5. Resonant oscillation frequencies of blade determination.
6. Blade frequency diagram plotting.
7. Influence of constructive factors on natural oscillation frequency of discs.
8. Resonant oscillation frequencies of discs determination.
9. Disc frequency diagram plotting.
10. Constructive methods of discs resonant oscillation control.
11. Turning-out resonant frequencies of discs.
12. Shape modes of shells natural oscillations.
13. Influence of constructive factors on natural oscillation frequency of shells.
14. Power schemes of engine casings. Stator power systems. Engine mounting units.
15. Power schemes of engine rotors. Supports type and number choosing.
16. Functions and construction of rotors coupling junctions.
17. Seals of supports.
18. Design of engine mounts.
19. Bearings of aircraft engines.

Module 2
Semantic module 2

1. Critical rotational speed of rotor concept.
2. Experimental determining of rotor critical rotational speeds.
3. Influence of constructive factors on critical rotational speed of rotor.
4. Dependence of rotor flexure on its rotational speed. Terms “rigid” and flexible” rotors. Give examples of “rigid” and “flexible” rotors from engines presented in the classroom.
5. Natural bending oscillations of non-rotated single-disc rotor.
6. Relation between critical rotational speed of rotor and natural frequency of bending oscillations.
7. Precessional motion of rotated single-disc rotor.
8. Direct and retrograde synchronous precession.
9. Motion of rotor and action of gyroscopic moment at direct precession.
10. Motion of rotor and action of gyroscopic moment at retrograde precession.
11. Critical rotational speeds of multi-disc rotors.
12. Resonant conditions and critical rotational speeds of rotor determining.
13. Rotor oscillations in multi-shaft engines. Sliding line of rotors.
14. Using frequency diagram, show influence of supports elasticity on critical rotational speeds of rotor.
15. Design methods to control dangerous bending oscillations of rotors.
16. Elastic elements. Elastic supports.
17. Supports with elastic rings. Strength analysis of elastic ring, rigidity coefficient determining.
18. Supports with rod elastic elements of the “squirrel-wheel” type. Strength analysis of the rod element, rigidity coefficient determining.
19. Hydrodynamic damper support. Specifics of design.

Module 3
Semantic module 3

1. Turboshaft engines advantages and disadvantages. Classification of air propellers. Requirements to propellers.
2. Geometric parameters of the air propeller. Velocity polygon, thrust and power of propeller.
3. Aerodynamic performances of air propellers at fixed and variable pitch angle.
4. Operating modes of air propellers.
5. Forces and moments that act blades of air propellers. Balancing of propellers.
6. Propeller blades position controlling. Propellers of direct, back and double action.
7. Negative thrust of propeller. Conditions of its origination and methods that prevent it.
8. Blades fixing.
9. Intermediate stop of blades.
10. Propeller feathering.

10. Testing

The course is divided into three semantic modules:

1. Oscillations of blades, discs and shell.
2. Oscillations of rotors and supports design.
3. Gearboxes/
4. Air propellers.

Module 1 is passed during 10-th week of 7-th semester (one attempt), module 2 is passed during 6-th week of 8-th semester (one attempt), module 3 is passed during 12-th week of 8-th semester (one attempt).

Before passing modulus, student must finish and submit all laboratory and practical works of this modulus.

Reports on laboratory works – in writing form, defense – orally.

Semester 7 – *test (credit).*
Semester 8 – *differential test (defense of term project), examination.*

11. Evaluation criteria and distribution of the points that the students get

11.1 Distribution of the points that the students get (quantitative evaluation criteria)

Components of educational work	Points for one lesson (task)	Number of lessons (tasks)	Total number of points
Module 1 **Semantic module 1**			
Work at lectures	0…0.5	10	0…5
Execution and defense of laboratory (practical) works	1…2	3	3…6
Modular testing	14…23	1	14…23
Module 2 **Semantic module 2**			
Work at lectures	0…0.3	18	0…6
Execution and defense of laboratory (practical) works	0.5…1	7	4…7
Modular testing	14…23	1	14…23
Module 3			

Semantic module 3			
Work at lectures	0…0,3	12	0…4
Execution and defense of laboratory (practical) works	0.5…1	7	4…7
Modular testing	12…19	1	12…19
Total for semester			**60…100**

7-th semester testing (credit) 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 and practical works.

Maximum total score of the credit testing is 34 points.

The credit testing card is composed of two theoretical questions and 13 practical test questions (the student must choose the correct answers of some proposed answers).

Number of points for each theoretical question is 4, number of points for each test question is 1.

8-th 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 and practical works.

The examination card is composed of three theoretical questions and one practical task. The theoretical questions are distributed as follows:

the first question is on rotor dynamics (Module 2);

the second question is on rotor support design (Module 2);

the third question is on gearbox or propeller design (Module 3).

The practical task concerns the engine rotor and casing composition and power structure. Student must identify some asked features of this structure for one of engines represented in the classroom.

Maximum number of points for each question is 25.

12.2 Qualitative evaluation criteria

To get positive mark, the student must

know:

- what is natural oscillation frequency and resonance;
- factors that excite oscillations of blades, discs and shells;
- types of blades, discs and shells oscillations;
- single-mass model of a rotor blade;
- how rotation influences natural oscillation frequency;
- what is the oscillation shape mode;
- types of disc oscillations;
- frequency diagram of the single-mass rotor;
- what is critical rotation speed of rotor;
- influence of support elasticity on critical rotation speed of rotor;
- what is the rotor bending oscillation shape mode;
- scheme of elastic support;
- types of gearboxes that are applied in turboprop engines;
- scheme of planetary gearbox;
- purpose of the engine accessory drives;
- velocity polygon of propeller;
- purpose and main elements of propeller hub;

know how:

- determine natural oscillation frequency of the engine part experimentally;
- change blade natural oscillation frequency by design methods;
- draw the Bode diagram and find resonant points;

– make digital analysis of rotor oscillations;
– identify type of gearbox;
– propeller pitch is controlled;
– propeller blade is protected from icing.

12.2 Criteria of the student evaluation during semester

Satisfactory (60-74). The student must have the required minimum of knowledge. He must finish and pass all laboratory and practical works, pass modular testing with positive mark. He must know main reasons of oscillations in turbine engines, types and shape modes of blade, disk and shell oscillations, single-mass model of a rotor blade, how to draw and analyze the Bode diagram, scheme of elastic support, rotor clutch purpose, principles of rotor supports disposition, scheme of planetary gearbox, propeller operation modes, functions of propeller hub.

Good (75-89). The student must be proficient in minimum knowledge. He must finish and pass all laboratory and practical works, defend the individual task with good mark, pass modular testing with positive mark. Know main factors that excite oscillations in engine parts and influence natural oscillation frequency. Draw the Bode diagram and explain how to find resonant modes of the engine operation. Derive equation of a blade natural oscillation frequency using a single-mass model, explain how to improve the blade oscillation properties. Explain disk and shell oscillation shape modes. Derive and draw a single-mass rotor frequency diagram. Explain a rotor precession. Identify types of rotor and casing power scheme using the engine drawing or mockup. Draw schemes of elastic-damper supports. Know propeller operation modes, thrust and power performances. Identify type of gearbox, explain design of a propeller hub and name main elements that prevent negative thrust origination.

Excellent (90-100). He must finish and pass all laboratory and practical works with good or excellent mark, pass modular testing with excellent mark (one or two modules with "good" mark and minimum 80 points are permitted). Know main and additional material in full scale. Explain influence of temperature and rotation speed on a blade natural oscillation frequency, explain main models of blade dynamics (single-mass model, distributed mass model with constant area, distributed mass model with variable area and temperature). Know general order of a blade oscillation analysis using Railey-Ritz method. Know experimental equipment for engine parts oscillation testing. Know types and shape model of shells oscillations and factors that influence the natural oscillation frequency. Know methods of rotor oscillations damping and how to change a rotor critical rotation speed. Identify a type of gearbox, know a difference between conventional and differential schemes of the planetary gearbox. Know methods and devices for torsion torque measurement. Know structure of accessory drives and what accessory units are driven. Know main types and parameters of propellers, draw velocity polygon and explain modes of propeller operation and its thrust and torque performances. Know main functions of a propeller hub and explain methods of negative thrust elimination and devices that implement these methods.

Grade scales: national and ECTS

Grade scale	National scale	
	For exam, course project (work), practice	For test
90-100	"excellent"	Passed
75-89	"good"	
60-74	"satisfactory"	
0-59	"non-satisfactory"	Not passed t

12. Methodological support

1. Didactic materials (manuals, Power point presentations, posters etc.).
2. Mockups of TJEs, TFEs, TPEs, TShEs in 103 and 124 rooms.
3. Tutorials for different topics of the course.

4. Laboratory equipment for natural frequencies of blades, discs, shells and rotors researching.

13. Recommended literature for the course

Main

1. Yepifanov, S. Major units of aircraft gas turbine engines: Tutorial [Text] / S. Yepifanov, Y. Shoshin, Y. Gusev. – Kharkov : National Aerospace University “Kharkov Aviation Institute”, 2013. – 101 p.

2. Aircraft Propellers. Tutorial / I. Kravchenko, S. Yepifanov, A. Garkusha. - Kharkiv: National Aerospace University “Kharkiv Aviation Institute”, 2020, 64 p.

3. Yepifanov, S. Blade Bending Oscillation Analysis [Text] : tutorial / S. Yepifanov, Y. Shoshin, R. Zelenskyi. – Kharkiv : National Aerospace University “Kharkiv Aviation Institute”, 2014. – 24 p.

4. The Jet engine [Text] // The Technical Publications Department of RR plc. – Derby, England. – 1996. – 278 p.

5. Treager, I. E. Aircraft gas turbine engine technology [Text] / I. E. Treager. – 3-rd ed. – Glencoe/McGraw-Hill, 2001. – 677 p.

6. Hunecke, K. Jet engines. Fundamentals of theory, design and operation [Text] / K. Hunecke. – 6-th impression – Osceola : Motorbooks IP&W, 2003. – 241 p.

7. Boyce, M. P. Gas turbine engineering handbook [Text] / M. P. Boyce. - 3-rd ed. – Gulf Professional Publishing. – 2006. – 936 p.

8. Чигрин, В.С. Конструкция и прочность авиационных двигателей (конспект лекций). Харьков, Нац. аэрокосм. ун-т, 2017. – 420 с.

9. Скубачевский, Г. С. Авиационные газотурбинные двигатели, конструкция и расчет деталей [Текст] / Г. С. Скубачевский. - М. : Машиностроение, 1981. - 552 с.

10. Конструкция и проектирование авиационных газотурбинных двигателей. [Текст] : учебник для вузов ; под ред. Д. В. Хронина.– М. : Машиностроение, 1989. – 368 с.

11. Иноземцев, А. А. Газотурбинные двигатели [Текст] : в 5 кн. / А. А. Иноземцев, М. А. Нихамкин, В. П. Сандрацкий. – М. : Машиностроение, 2008. – Кн. 2 : Компрессоры. Камеры сгорания. Турбины. Выходные устройства. – 367 с.

12. Чигрин, В. С. Колебания [Текст] : учеб. пособие по лаб. практикуму / В. С. Чигрин, А. И. Скрипка. – Х., ХАИ, 1999. – 35 с.

13. Гаркуша, А. И. Редукторы силовых установок вертолетов и турбовинтовых двигателей [Текст] : учеб. пособие / А. И. Гаркуша, В. С. Чигрин. – Х., Нац. аэрокосм. ун-т «Харьк. авиац. ин-т», 2010. – 56 с.

Additional

1. Shoshin, Yu. Basic technical data of Soviet, Ukrainian and Russian cruise engines of aircraft [Text] / Yu. Shoshin, F. Sirenko. – Kharkov : National Aerospace University “Kharkov Aviation Institute”, 2015. – 65 p.

2. Никитин, Ю. М. Конструирование элементов деталей и узлов авиадвигателей [Текст] / Ю. М. Никитин. - М. : Машиностроение, 1968. - 324 с.

3. Локай, В. И. Газовые турбины двигателей летательных аппаратов [Текст] / В. И. Локай, М. К. Максутова, В. А. Струнки. – М. : Машиностроение, 1979. – 477 с.

4. Technical descriptions of aircraft engines.

14. Information sources

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