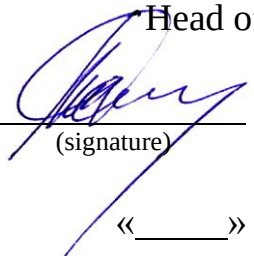
MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National Aerospace University
"Kharkov Aviation Institute"

Aircraft engine design department (№ 203)

APPROVED
Head of project team



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

«_____» _____ 2020

SYLLABUS OF AN ACADEMIC DISCIPLINE

AIRCRAFT PISTON ENGINES
(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 *Aircraft piston engines*
(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* *9* *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>Characteristics</td><td>Branch of science, specialization, academic degree</td><td>Description of the discipline (full-time tuition)</td></tr>
<tr><td>Credits – 5.5</td><td>Field of education:
13 «Mechanical Engineering»
(шифр і назва)</td><td>Variable</td></tr>
<tr><td>Modules – 2</td><td rowspan="4">Field of study:

134
«Aviation and Spacecraft Technologies»

(cipher and name)</td><td>Academic year:</td></tr>
<tr><td>Semantic modules – 2</td><td>2018 / 2019</td></tr>
<tr><td>Individual research task
«Calculation of the working process of the four-stroke aircraft piston engine»
(назва)</td><td>Semester</td></tr>
<tr><td>Total number of academic hours – 72*/165</td><td>8-th</td></tr>
<tr><td rowspan="9">Number of academic hours for full-time tuition:

auditorium – 6

independent work – 7,5</td><td rowspan="9">Educational program:
Aircraft engines and power plants

Higher education:
First (Bachelor)</td><td>Lectures *</td></tr>
<tr><td>36 a.h.</td></tr>
<tr><td>Practices, seminars *</td></tr>
<tr><td>24 a.h.</td></tr>
<tr><td>Laboratory activities *</td></tr>
<tr><td>12 a.h.</td></tr>
<tr><td>Independent work</td></tr>
<tr><td>93 a.h.</td></tr>
<tr><td>Type of control</td></tr>
<tr><td>credit</td></tr>
</table>

The ratio of hours of classes to independent work is: for full-time education – 72 / 93.

[1)] Auditory load can be reduced or increased by one hour, depending on the schedule of classes.

2. Goal and tasks of the discipline

Goal: knowledge acquisition about aircraft piston engine working process and design.

Task: study principles of the piston engine arrangement and operation, classification, working process and dynamics analysis.

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

General competencies: *Skills to carry out safe activities, the desire to preserve the environment. Skills in the use of information and communication technologies. Ability to work both independently and in a team with representatives of other professional groups. Ability to make informed decisions in normal and special situations and implement them correctly. Ability to learn and master modern knowledge. Ability to preserve and multiply moral, cultural, scientific values and achievements of society based on understanding the history and patterns of development of the subject area, its place in the general system of knowledge about nature and society, and place in the development of society, engineering and technology; ability to use different types and forms of physical activity to relax and lead a healthy lifestyle.*

Special (professional) competencies: *Ability to assign optimal materials for structural elements of aerospace engineering. Ability to carry out the strength analysis of elements of aerospace engineering. Skills in the use of information and communication technologies and specially configured software in studding and professional activities.*

Program learning outcomes: *To have the means of modern information and communication technologies to the extent sufficient for studding and professional activities. 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 skills to determine loads on structural elements of aerospace engineering at all stages of its life cycle. 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 understand features of workflow in hydraulic, pneumatic, electrical and electronic systems used in aerospace engineering. 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 design features and basic aspects of workflow in systems and elements of aerospace engineering.*

Interdisciplinary links:

Theory of Mechanisms and Machines, Hydraulics, Hydro-gas-dynamics, Thermodynamics, Heat Transfer, Design and Strength of Aircraft Engines and Power Plants, Design and Dynamics of Aircraft Engines and Power Plants, Computer Aided Design.

3. Course content

SEMESTER 8

Module 1
Semantic module 1

TOPIC 1. Subject and tasks of the course. Its place in educational plan. Bibliography.

Operational principle of four-stroke and two-stroke piston engines. Definition of strokes, processes, compression ratio and other terms. PE classification by processes, structure and other features.

TOPIC 2. PE working process.

Fuels used in PE. Elementary content of fuel. Chemical reactions of combustion. Composition of fresh charge and exhaust gas. Intake process. Coefficient of admission. Factors that influence the intake process. Compression process. Factors that influence the compression process. Combustion process. Velocity of laminar and turbulent flame propagation. Toxic components generation. Combustion stability. Processes of expansion and exhaust. Factors that influence them. Indicator factors of the working process. Indicator efficiency and indicator specific fuel consumption. Factors that influence indicator parameters of the working process. Effective parameters of the working process. Power of mechanical losses. Effective and mechanical efficiency. Specific fuel consumption. Factors that influence effective parameters of the engine.

TOPIC 3. PE performances and heat balance.

Speed performances (external and partial). Loading performances. Propeller and generator performances. Partial throttle performance. Multi-parameter (combined) performance. Idle performance. Knocking performance. Heat balance and thermal load of the PE.

TOPIC 4. Construction of the PE parts.

Construction of pistons, crankshafts, cylinders and cylinder blocks.

Module 2

Semantic module 2

TOPIC 5. PE kinematics and dynamics.

Kinematics of the crank mechanism. Piston position, velocity and acceleration. The link rod PE kinematics. PE dynamics. Gas and inertia forces. Forces and reactions that act in main and link cylinders. Piston rod mass distribution. PE balancing. Rotating mass balancing. Reciprocating mass balancing. Lanchester mechanism. Multi-cylinder engines balancing. Strength analysis of PE main parts.

TOPIC 6. PE fuel systems.

Fuel system of the spark ignition PE. Carburetor system. Carburetor operation and performances. Altitude correction. Mechanical fuel spraying system. Electronic intake duct injection fuel system. Electronic cylinder injection fuel system. Construction of the fuel system components. Fuel system of a diesel engine. Mechanical fuel spraying system. Electronic fuel spraying system. Construction of high-pressure fuel pumps. Construction of fuel nozzles, including nozzles with electric and piezoelectric hydraulic control.

TOPIC 7. Other systems of PE.

Cooling system. Lubrication system. Ignition system.

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	7
Module 1					
Semantic module 1					
TOPIC 1. Subject and tasks of the course. Its place in educational plan. Bibliography	10	2	-	2	6
TOPIC 2. PE working process	26	10	6	-	10
TOPIC 3. PE performances and heat balance	15	6	-	-	9
TOPIC 4. Construction of the engine parts	20	2	8	-	10
Modular testing	2		2		
Totally for module 1	**71**	**18**	**16**	**2**	**35**
Module 2					
Semantic module 2					

TOPIC 5. PE kinematics and dynamics	28	8	-	6	14
TOPIC 6. PE fuel systems	21	5	4	-	12
TOPIC 7. Other systems	23	5	2	4	12
Modular testing	2		2		
Totally for module 2	**74**	**18**	**8**	**10**	**38**
Individual task *«Calculation of the four-stroke aircraft piston engine working process»*	**20**	**-**	**-**	**-**	**20**
Totally for course	**165**	**36**	**24**	**12**	**93**

5. Practical works

№	Name	Hours
1	Calculation of the PE working process	6
2	Pistons	4
3	Piston rods	4
4	Crankshafts	2
5	Cylinders and blocks	4
6	Fuel system	2
6	Lubrication system	2
	Together	**24**

6. Laboratory works

№	Name	Hours
1	Acknowledging aircraft piston engines in the laboratory classroom	2
2	Analysis of forces that act in a crank mechanism (PE dynamics)	2
3	PE dynamics simulation	2
4	Engine parts strength analysis	2
5	Starting system	2
6	Valve control mechanism	2
	Together	**12**

7. Independent work

№	Name	Hours
1	Examples of aircraft, automotive, stationary and marine piston engines studying	6
2	PE ideal cycles	10
3	PE thermal intensity	9
4	Selected PE parts construction: heads of cylinders, cylinder spacers, superchargers etc.	10
5	Link rod PE kinematics and dynamics	14
6	Fuel supply systems COMMON RAIL, GDI etc.	12
7	Valve control system. Cooling system. Lubrication system. Ignition system.	12
8	Calculation and graphic work	20
	Total	**93**

8. Individual task

1. Calculation and graphic work «Calculation of the four-stroke aircraft piston engine working process».
2. Stages of work:

- analysis of initial data; type of piston engine selection, prototype engine finding and studying;
- suction stroke parameters calculation;
- compression stroke parameters calculation;
- working stroke parameters calculation;
- exhaust stroke parameters calculation;
- indicator diagram drawing;
- indicator and effective work, efficiency and pressure determination;
- report preparation;
- defense of work

9. Learning methods

Basic forms of learning:

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

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

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

Laboratory 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 works, make calculation-graphic task.

10. Questions for independent work

Questions for Module 1

“Working process”

1. Processes that compose the piston engine cycle.
2. Structure and principle of operation of the four-stroke piston engine.
3. Structure and principle of operation of the two-stroke piston engine.
4. Classification of the piston engines.
5. Fuels for the piston engines. Requirements to them.
6. Composition of fuels for piston engines. Chemical reactions at combustion. The air/fuel excess ratio.
7. Main parameters that characterize fuels for piston engines.
8. Toxic emissions and reasons of their formation.
9. Intake process. Residual gas coefficient. Coefficient of admission. Factors that influence these coefficients.
10. Indicator diagram of the intake process for naturally-aspirated and supercharged engines. Temperature and pressure and the end of intake stroke determining.
11. Compression process. Indicator diagram.
12. Compression process. Polytrophic index and factors that influence it. Temperature and pressure and the end of compression stroke determining.
13. General features of combustion in piston engines. Chemical and diffusion combustion. Flame propagation velocity. Phases of combustion.

14. Combustion in engines with spark ignition. Ignition dwell angle. Influence of different factors on the combustion.
15. Difference between combustion in the spark-ignited and diesel engines. Indicator diagram.
16. Knocking, preignition and misfiring and how to prevent them.
17. Thermodynamic analysis of combustion in the four-stroke spark-ignited engine. Temperature and pressure at the end of combustion determining.
18. Expansion process. Indicator diagram.
19. Expansion process. Polytrophic index and factors that influence it. Temperature and pressure and the end of expansion stroke determining.
20. Exhaust process. Stages of exhaust. Influence of the exhaust valve opening.
21. Exhaust process. Indicator diagram for naturally aspirated and supercharged engines.
22. The indicator diagram of the four-stroke spark-ignited engine. Consequence of valves operation and influence of valve lead and lag on indicator diagram.
23. Indicated indexes of the piston engine and factors that influence them.
24. Effective (brake) indexes of the piston engine and factors that influence them.
25. Performances of the piston engines.
26. Thermal balance in the piston engine.

Questions for Module 2

“Kinematics and Dynamics of Piston Engines”

1. Types of the crank mechanism: normal, offset, and master-and-articulated rod.
2. Piston position as a function of a crank angle.
3. Piston velocity as a function of a crank angle.
4. Piston acceleration as a function of a crank angle.
5. Kinematics of the piston rod in a single-cylinder engine.
6. Kinematics of the articulated rod in a radial-type engine.
7. Kinematics of the articulated rod in a V-type engine.
8. Choice of geometrical parameters of a crank mechanism.
9. Forces that act in a crank mechanism. Gas force.
10. Forces that act in a crank mechanism. Inertia force of a piston.
11. Forces that act in a crank mechanism. Inertia force of a piston rod.
12. Forces that act in a crank mechanism. Inertia force of a link rod.
13. Total inertia forces in a crank mechanism.
14. Order of ignition in a multi-cylinder engine.
15. Summing up forces of gas pressure and inertia. Resolutions of forces by elements of a crank mechanism.
16. Summing up forces that act one crank from several cylinders.
17. Purpose methods of the piston engine balancing.
18. Balancing of the rotated mass inertia force.
19. Balancing of the inertia force of the reciprocating mass of a first order.
20. Balancing of a second order inertia force of a reciprocating mass.
21. Balancing of the row-type engines.
22. Balancing of the radial-type single-row engines.
23. Balancing of the two-row radial-type engines.

11. Testing

The course is divided into two modules:

1. Working process.
2. Kinematics and dynamics.

Module 1 is passed during 6-th week (one attempt), module 2 is passed during 12-th week (one attempt).

Before passing modulus, student must make all laboratory works, individual task and independent work of this modulus.

Term of the home task defense – *10-th* week. Delay of defense on one week – 2 points minus; 2 weeks – 4 points minus.

Semester 8 – *credit.*

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

12.1 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…1	9	0…9
Execution and defense of laboratory (practical) works	1…2	4	4…8
Modular testing	15…25	1	15…25
Module 2 Semantic module 2			
Work at lectures	0…1	9	0…9
Execution and defense of laboratory (practical) works	1…2	4	4…8
Modular testing	15…25	1	15…25
Execution and defense of individual task	10…16	1	10…16
Total for semester			**60…100**

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 and also successfully defended the home task.

Maximum total score of the examination is 100 points.

The examination card is composed of two theoretical questions and two practical tests. The theoretical questions are distributed as follows:

- the first question is on the piston engine working process (Module 1);
- the second question is on the piston engine kinematics and dynamics (Module 2).

The first practical test contains 10 test questions on module 1. The student must choose one or some of proposed answers.

The first practical test contains 10 test questions on module 2. The student must choose one or some of proposed answers.

Maximum number of points for each question is 25.

12.2 Qualitative evaluation criteria

To get positive mark, the student must

know:

- structure and principle of operation of the four-stroke piston engine;
- classification of the piston engines;
- fuels for piston engines;
- indicator diagram of four-strike piston engine;
- main features of compression and power strokes;
- indicated and effective work and efficiency;
- types of crank mechanism;
- kinematics of piston;

- kinematics of piston-rod in a single-cylinder engine;
- forces that act the elements of the crank-piston mechanism;
- purpose methods of the piston engine balancing;

know how:

- identify four-stroke and two-stroke engines;
- calculate main parameters of the piston engine working process;
- draw the indicator diagram and determine main indicator and effective parameters;
- arrange cylinders in row-type and radial-type engines;
- determine gas and inertia forces that act piston and are transmitted to the crankshaft;
- sum forces that act different cylinders;
- is the inertia force of rotated mass balanced;
- is the inertia force of reciprocating mass balanced.

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, defend the individual task, pass modular testing with positive mark. He must know difference between spark-ignition and diesel engine, between four-stroke and two-stroke engines. He must know main requirements to fuels and main parameters of fuels, composition of row-type and radial-type engines, main strokes of four-stroke engine, draw the indicator diagram. He must explain variation of the gas force and inertia force of crank angle, explain total radial and circumferential forces that act the crankshaft and main elements of the engine balancing.

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 all stages of the working process, draw the indicator diagram and explain how it depends on engine parameters and operation conditions. Know a difference between indicator and effective parameters (work, efficiency and pressure). Explain a shape and operation conditions of piston, piston rod, crankshaft and cylinder. Draw a diagram of gas and inertia forces, know how they are summarized on common crankshaft. Identify and explain types of balancing using drawing or mockup of the engine. Know main elements and operation of the fuel system, valve control mechanism and lubrication system.

Excellent (90-100). He must finish and pass all laboratory and practical works, defend the individual task with good or excellent mark, pass modular testing with excellent mark (one module with "good" mark and minimum 80 points are permitted). Know structure and operation processes of four-stroke and two-stroke, spark ignition and diesel engines. Draw the indicator diagram of four-stroke spark ignition engine, explain a difference between ideal and real diagrams. Know main indicator and effective parameters, explain a difference between them. Know heat balance diagram of the piston engine. Know chemical composition of fuels for piston engines and main properties of fuels. Draw a diagram of forces distribution between main elements of the piston engine. Know how these forces are summarized in a crankshaft. Know main principles of the piston engine balancing, identify type of balancing using drawing or mockup of the engine. Know main features of the valve controlling, fuel supplying, lubrication and starting of the piston engine.

Grade scales: national and ECTS

<table>
<tr><td rowspan="2">Grade scale</td><td colspan="2">National scale</td></tr>
<tr><td>For exam, course project (work), practice</td><td>For test</td></tr>
<tr><td>90-100</td><td>“excellent”</td><td rowspan="3">Passed</td></tr>
<tr><td>75-89</td><td>“good”</td></tr>
<tr><td>60-74</td><td>“satisfactory”</td></tr>
<tr><td>0-59</td><td>“non-satisfactory”</td><td>Not passed t</td></tr>
</table>

12. Methodological support

1. Lecture notes.
2. Manuals for laboratory and practical works.
3. Mockups of aircraft piston engines in 107 room and hall of Motor building.
4. Posters and Power point presentations.

13. Recommended literature for the course

Main

1. Heiwood, J. B. Internal combustion engines fundamentals. – McGraw-Hill series in mechanical engineering. 2-nd edition. – 2018. – 1056 p.

Additional

1. Mike Bush. What every aircraft owner needs to know about the design, operation, condition monitoring, maintenance and troubleshooting of piston aircraft engines. 1-st edition. – 2019. – 408 p.
2. Масленников, М. М. Авиационные поршневые двигатели [Текст] : учебное пособие для авиационных вузов / М. М. Масленников, М. С. Рапипорт. – М., Госуд. издательство оборонной промышленности. – 1951. – 847 с
3. Масленников, М. М. Авиационные двигатели. Общий курс. [Текст] / М. М. Масленников, М. С. Рапипорт. // Книга 2-ая. Конструкция и расчет на прочность. – М «Оборонгиз», 1946. – 406 с.
4. Двигатели внутреннего сгорания. Устройство и работа [Текст] : учебник для студентов вузов специальности “Двигатели внутреннего сгорания”. – Т. 1. - М. : Машиностроение, 1980.
5. Двигатели внутреннего сгорания : Теория поршневых и комбинированных двигателей. Изд. 4-е, переработанное и дополненное [Текст] ; под ред. А. С. Орлина, М. Г. Круглова. Учебник для вузов по специальности “Двигатели внутреннего сгорания”. - М. : Машиностроение, 1983. - 372 с.
6. Двигатели внутреннего сгорания : Конструирование и расчет на прочность поршневых и комбинированных двигателей. Изд. 4-е, переработанное и дополненное [Текст] ; под ред. А. С. Орлина, М. Г. Круглова. Учебник для втузов по специальности “Двигатели внутреннего сгорания”. – М. : Машиностроение, 1984. - 384 с.
7. Двигатели внутреннего сгорания : Системы поршневых и комбинированных двигателей. Изд. 4-е переработанное и дополненное [Текст] ; под ред. А. С. Орлина, М. Г. Круглова. Учебник для вузов по специальности “Двигатели внутреннего сгорания”. - М. : Машиностроение, 1985. - 456 с.
8. Авиационные поршневые двигатели. Кинематика, динамика и расчет на прочность [Текст] : пособие для инженеров. / И. А. Биргер, Н. И. Дружинин, В. К. Житомирский и др.— М. : Оборонгиз, 1950. – 871 с.
9. Колчин, А. И. Расчет автомобильных и тракторных двигателей [Текст] / А. И. Колчин, В. П. Демидов. – М., Транспорт, 2008. – 496с.
10. Тареев В.М. Справочник по тепловому расчету рабочего процесса двигателей внутреннего сгорания [Текст] / В. М. Тареев. – М. : Машиностроение, 2009. – 402 с.
11. Автомобильные двигатели [Текст] ; под ред. М. С. Ховаха. – М. : Машиностроение, 1977. - 591 с.
12. Грехов, Л. В. Топливная аппаратура и системы управления дизелей [Текст] : учебник для вузов / Л. В. Грехов, Н. А. Иващенко, В. А. Марков. - М. : Легион-Автодата, 2005. – 2-е изд. – 344 с.

14. Information sources

Electronic manuals on PE strength analysis, drawings of PE, Internet-resources.