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

Aircraft engine design department (№ 203)

APPROVED
Head of project team

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

« » _____ 2020

SYLLABUS OF AN ACADEMIC DISCIPLINE

DESIGN AND STRENGTH OF AIRCRAFT ENGINES

(name of academic discipline)

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

Field of study *272 «Aviation Transport»*
(code and name of field of study)

Educational program *Maintenance and repair of aircraft and aviation engines*
(code and name of educational program)

Form of training *Day studies*

Level of higher education *First (bachelor)*

Kharkiv 2020

Working program *Design and Strength of Aircraft Engines*
(name of academic discipline)

for students of a field of study *272 «Aviation Transport»*

educational program *Maintenance and repair of aircraft and aviation engines*

« *1* » June 20*20* *10* *p.*

Person, who developed the syllabus *PhD, ass. Prof. Garkusha Alexander* _____
(author, job, academic degree and rank) (signature)

PhD, assoc. Prof. Bezuglyi Sergey _____
(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)

Working program was approved at the meeting of the department
Aircrafts and helicopters Designing

Minutes № ____ dated « ____ » August 2020

Head of department *DSc., Professor* _____ *Aleksandr Grebenikov*
(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 – 4</td><td>Field of education:
27 «Transport»
(cipher and name)</td><td>Variable</td></tr>
<tr><td>Modules – 2</td><td rowspan="3">Field of study:

272 «Aviation transport»
(cipher and name)</td><td>Academic year:</td></tr>
<tr><td>Semantic modules – 2</td><td>2020 / 2021</td></tr>
<tr><td>Individual task
-
(title)</td><td>Semester</td></tr>
<tr><td>Total number of academic hours – 56*/120</td><td rowspan="2">Educational program:
Maintenance and repair of aircraft and aviation engines

Higher education:
First (Bachelor)</td><td>7-th</td></tr>
<tr><td rowspan="2">Number of academic hours for full-time tuition:

auditorium – 3.5

independent work – 4</td><td>Lectures *</td></tr>
<tr><td>32 a.h.</td></tr>
<tr><td></td><td>Practices, seminars *</td></tr>
<tr><td></td><td>24 a.h.</td></tr>
<tr><td></td><td>Laboratory activities *</td></tr>
<tr><td></td><td>-</td></tr>
<tr><td></td><td>Independent work</td></tr>
<tr><td></td><td>64 a.h.</td></tr>
<tr><td></td><td>Form of examination</td></tr>
<tr><td></td><td>exam</td></tr>
</table>

The ratio of hours of classes to independent work is: for full-time education - 56 / 64.

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

2. Goals and purposes of discipline

Goal: to give students knowledge about the structural elements of the aircraft glider, about ways to reduce the weight of the structure, to ensure strength during design and operation.

Task: to provide knowledge about the structural elements of the aircraft glider, about ways to reduce the weight of the structure, to ensure strength during design and operation.

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

General competencies: *Ability to abstract thinking, analysis and synthesis. Knowledge and understanding of the subject area and understanding of professional activity. Ability to make informed decisions in normal and special situations and implement them correctly.*

Special (professional) competencies: *Skills to work with regulations, reference books and other sources of information governing the activities of air transport.*

Program learning outcomes: *Summarize information on regulatory documentation, reference literature and other sources of information governing the activities of air transport.*

Interdisciplinary links: The course of aircraft power plants and units design is based on knowledge that is previously acquired from courses of blade machines, theory of air-breathing engines, theoretical mechanics, strength of materials, material science, gas dynamics, heat transfer, machine designing etc.

3. Course content

Module 1
Semantic module 1

TOPIC 1. Studying subject and discipline purposes. Power plant – as element of "Aircraft" system. Aircraft power plants types. Criteria to choose power plant for aircraft, which is under development. Aircraft power plants classification according to the way of propelling force creation and working processes carrying out. Aircraft engines` application range.

TOPIC 2. General structure and working process of different aircraft engine types. Main specific parameters of aircraft engines.

TOPIC 3. Inlet units of GTE: operation principle, efficiency, means to improve the operation efficiency.

TOPIC 4. Compressors of GTE: operation principle, efficiency, operation stability, structure, means to expand the frame of efficient and stable operation.

TOPIC 5. GTE turbines: operation principle, efficiency, structure, means to improve the operation efficiency, cooling.

TOPIC 6. GTE combustion chambers (main and afterburning). Operation principle, structure and means to improve the operation efficiency.

TOPIC 7. Exhaust system of GTE. Operation principle and structure.

Modular testing

Module 2
Semantic module 2

TOPIC 8. *General information about aircraft PPs.* The composition of PP. Main systems. Requirements to PP. Weight indicators of PP. Stages of PP designing.

TOPIC 9. *Fuel supply system of an aircraft* (FSA). Functions and application of FSA. Requirements made to FSA. Fuels and their properties. The compositions of FSA. Schemes of FSA. The analyses of FSA. Altitude performance of FSA. Venting and supercharging FSA. Designing the scheme of emergent jettisoning and its analysis. Fuelling system. Constructive elements of FSA.

TOPIC 10. *Fuel supply system of an engine* (FSE). General information about FSE, the structure of the system. Transfer pumps. High pressure pumps of main and afterburning fuel: gear, plunger, centrifugal. Fuel nozzles. Fuel-metering sensors. Fuel filters. Tubing of fuel supplying systems.

TOPIC 11. *Lubrication system of PPs* (*oil systems OS*). Lubrication system application and requirements made for it. Aviation oils. General characteristic of OS. Structural schemes of OS: normal, reverse, normal with centrifugal air separator, short-circuited, two flow. Air separator, breather. Cooling oil, radiators. Oil tanks. Tubing, oil nozzles.

TOPIC 12. *Starting system* (SS). Starting the GTE. Requirements to starting system of GTE. The variation of driving torque moment and antitorque moment during starting. Calculating starting time and required power of starter. Composition of SS. The classification of SS: electric, air, gas, gas-turbine. Ignition.

Modular testing

4. Course arrangement

Names of Modules and Topics	Number of hours				
	full-time tuition				
	total	including			
		lec	lab	pr	indp
1	2	3	4	5	6
Module 1 Semantic module 1					
TOPIC 1. Studying subject and discipline purposes. Power plant – as element of "Aircraft" system. Aircraft power plants types.	7	2	-	1	4
TOPIC 2. General structure and working process of different aircraft engine types. Main specific parameters of aircraft engines.	12	3	-	2	4
TOPIC 3. Inlet units of GTE: operation principle, efficiency, means to improve the operation efficiency.	12	2	-	2	4
TOPIC 4. Compressors of GTE: operation principle, efficiency, operation stability, structure, means to expand the frame of efficient and stable operation.	14	2	-	2	6
TOPIC 5. GTE turbines: operation principle, efficiency, structure, means to improve the operation efficiency, cooling.	14	2	-	2	6
TOPIC 6. GTE combustion chambers (main and afterburning). Operation principle, structure and means to improve the operation efficiency.	12	2	-	2	4
TOPIC 7. Exhaust system of GTE. Operation principle and structure.	11	2	-	1	4
Modular testing	1	1			
Totally for the module No 1	**60**	**16**	**-**	**12**	**32**
Module 2 Semantic module 2					
TOPIC 8. General information about aircraft PPs.	6	2		-	6
TOPIC 9. Fuel supply system of an aircraft.	14	4		4	6
TOPIC 10. Fuel supply system of an engine.	13	3		2	6
TOPIC 11. Lubrication system of PPs (oil systems OS).	14	4		4	8
TOPIC 12. Starting system.	12	2	-	2	6
Modular testing	1	1			
Totally for the module No 2	**60**	**16**	**-**	**12**	**32**
Totally for the course	**120**	**32**	**-**	**32**	**56**

5. Practical activities

№	Topic of the activity	Hours
1	Aircraft engines` application range	1
2	Working process of different aircraft engine types	2
3	Inlet units of GTE	2
4	Compressors of GTE	2
5	GTE turbines	2
6	GTE combustion chambers	2
7	Exhaust system of GTE	1
8	Fuel system of an aircraft	4
9	Fuel system of an engine	2
10	Oil system of an engine	4
11	Auxiliary power units and starters	2
	Together	**24**

6. Independent work

№	Topic	Hours
1	Aircraft power plant classification according to the way of propelling force creation and working processes carrying out	7
2	Criteria to choose power plant for aircraft, which is under development	7
3	Aircraft power plant composition. Requirements to power plant	9
4	Discharge units, means for noise reduction	9
5	General information about aircraft PPs.	6
6	Fuel supply system of an aircraft	6
7	Fuel supply system of an engine	6
8	Lubrication system of PPs	8
9	Starting system	6
	Together	**64**

7. Learning methods

Basic forms of learning:

- lectures;
- practical activities;
- laboratory activities;
- independent work.

Student familiarizes with basic notions and regularities, theoretical bases at lectures. They are needed when performing laboratory activities, independent task and during individual learning.

Lecture deals with single didactic problem, i.e. gives a prima facie on a problem, provides prior understanding of the presented information and states main sub problems.

The laboratory activities are based on a verbal (analytical) description of an object (systems and assemblies of GTE) and its physical representation by the special didactic materials (prepared mockups, posters, etc.). Students work in groups.

8. Questions for independent work

Module 1

Semantic module 1

1. When was the first GTE tested?

2. What is the name of English scientist, who patented the first TJE in 1930?
3. What aircraft engines belong to air-breathing engines?
4. Mark all engine types, which belong to air breathing compressor less engines.
5. What is the flight speed limit for TPE?
6. What was maximum turbine inlet temperature of engines of the first generation?
7. What engine generation was in 1960s.
8. What generation do turbofans with high bypass (more than four) ratio belong to?
9. Engines of what generation are currently used for modern aircrafts?
10. Mark main reasons of aircraft jet engines development in early 40s.
11. Mark the first jet airplane, which first flight happened in 1939.
12. Mark all gas turbine engine types of direct reaction.
13. Choose engine type for airplane with maximum flight speed is 1,8...2,2 Mach's.
14. How does engine specific weight change form generation to generation.
15. Mark all engine types, which operate by periodical working cycle.
16. Specify all engine types of indirect reaction.
17. Choose the correct statements to describe a power plants.
18. What physical law the thrust creation principle is based on for GTE?
19. What units are occupied in air compression in gas turbine engine?
20. Is turbine inlet temperature limited? In case it is limited than choose the parameters that limit.
21. Choose the correct statement to describe the operation of TFE.
22. Choose the statement that describes the way ramjet compresses air before delivering it to combustion chamber.
23. Choose the statements that describe the operation of ramjet
24. What is the airflow speed in combustion chamber of hypersonic ramjets?
25. Choose the statement that does not concern liquid propellant engines.
26. Specify wrong requirement that does not concern the liquid propellant engine operation.
27. Specify main components of solid fuel rocket engine.
28. Specify the correct statements to describe the burning of charge is combustion chamber of solid fuel rocket engine.
29. Choose the ways thrust rate of SFRE is controlled.
30. What are main functions of air-breathing engine intake?
31. What are main sources of pressure losses in supersonic intakes.
32. What is the main compressor purpose?
33. What type of compressor is mostly applied for gas turbine engines?
34. What compressor part transforms mechanical work, taken from turbine, to potential energy of air flow.
35. What lock is the most widely used to mount compressor blades in the disk?
36. Choose the correct statements to describe the requirements to radial clearance between impeller blades and facing them casing.
37. Choose the equation for determining the pressure ratio of multistage compressor.
38. Choose the correct statements to describe work distribution between stages of multistage compressor.
39. Choose the way blades of impeller are fastened to the disk in centrifugal compressors.
40. Specify wrong statement to describe the combustion chamber operation.
41. Where preliminary fuel atomization and mixing happens in modern GTEs.
42. function of a turbine?
43. What lock is the Choose correct statements to describe annular combustion chambers
44. Choose correct statements to describe tube-annular combustion chambers.
45. What is the main most used to fit turbine blades in the disk?
46. What substance is used to cool turbine blades?
47. Choose the correct statements to describe the way parameters change in the stage of the turbine.

48. What “Fir-tree" lock has the advantages comparing to the other locks?
49. What to describe propelling nozzle structure.
50. Fixed subsonic nozzles have apex angle less than
51. What for diffuser is used main function of propelling nozzle?
52. Mark all statements in afterburners?

Module 2

Semantic module 1

1. What are application purposes of aircraft PP?
2. What is an aircraft PP?
3. What elements form the aircraft PP?
4. What is fuel supplying system?
5. Enumerate the main requirements made to fuel supplying system.
6. What components does fuel supplying system consist of?
7. What is two-stage pumping system? What are the reasons it became so abundant?
8. What are the functions of relief valve in fuel supplying manifolds?
9. What are functions of the fuel accumulator?
10. Name the advantages and disadvantages of parallel and sequential tanks arrangement?
11. Characterize fuel supplying systems.
12. What is altitude capacity?
13. What is excessive pressure in tank? How is it used?
14. What sources of total pressure losses do you know?
15. What arrangements can be done to improve the altitude capacity of fuel system?
16. What is the application of draining and supercharging in fuel supplying system?
17. What sources of gas in closed draining system do you know?
18. What fuelling methods do you know?
19. Name advantages and disadvantages of closed fuelling, its application range.
20. Name types of fuel pump drives. Characterize briefly each drive.
21. What are functions of fuel in aircraft GTE?
22. What is the application of fuel pump?
23. What pump types are used as booster pumps?
24. What pump types are used as main pumps?
25. Operating principle of centrifugal pump.
26. Operating principle of plunger pump.
27. Operating principle of gear pump.
28. Name application purposes of oil system of an engine.
29. Name the requirements that are made to lubrication system of AEs.
30. Name the key properties of oil that make them suitable for being applied in AEs.
31. What is the difference between lubrication systems of TJE (TFE) and TPE?
32. Make an analysis of normal and reverse scheme of LS.
33. Name the advantages of short-circuited and two flow LS.
34. Name methods you know to reduce the air portion in oil.
35. Why the total capacity of scavenge pumps is few times higher than capacity of supply pump?
36. What material is used to manufacture the filtering elements of oil filter?
37. Describe the operating principle of deaerator and centrifugal breather.
38. How oil delivered from the engine is cooled?
39. What is the difference between in-flight and ground starting?
40. What for is rotor accelerated before lighting the combustion chamber during the starting?
41. Explain the way torque moments change during starting.
42. What rotor of multi-rotor engine is accelerated by the starter? Why?
43. Name types of starting systems.
44. What are advantages of air starting system?

45. Which starting system is of the lowest weight?
46. How is combustion chamber started? Why does chamber need external power source for this?
47. Draw the scheme of high-voltage plug. What voltage is required to provide its operation?
48. Draw the scheme of surface discharging plug. Compare it with high-voltage plug.

9. Testing

The course is divided into two modules:

1. General structure and working process of different aircraft engine types. Main specific parameters of aircraft engines. Compressors, turbines and combustion chambers of GTE.

2. Fuel, oil, and starting systems.

Module 1 is passed during 8-th week (one attempt), module 2 – 16-th week (one attempt).

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

Execution of laboratory works – in writing form, defense – orally.

Semester 7 – examination.

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

10.1 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			
Work at lectures	0…0.5	12	0…6
Execution and defense of laboratory (practical) works	1…2	8	8…16
Modular testing	24…32	1	24…32
Module 2			
Work at lectures	0…0.5	12	0…6
Execution and defense of laboratory (practical) works	1…2	4	4…8
Modular testing	24…32	1	24…32
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 four theoretical questions. The theoretical questions are distributed as follows:

the first question is on working process of different aircraft engine types (Module 1);

the second question is on compressors, turbines and combustion chambers of GTE (Module 1);

the third question is on fuel system (Module 2);

the fourth question is on oil + starting system (Module 2);

Maximum number of points for each question is 25.

10.2 Qualitive evaluation criteria

To get positive mark, the student must

know:

- types of aircraft propulsion systems by way of engine propulsion and engine workflows;
- scope of their application;

- basic specific parameters of aviation engines;
- input devices. Structure, means of increase of efficiency of work .;
- GTD air blade compressors: principle, efficiency, sustainability;
- gas turbines GTD: principle, efficiency, structure, means of increasing the efficiency of work;
- combustion chambers of the GTD. Principle of work, structure, means of increase of efficiency of work;
- GTD output devices. Principle of work, structure;
- systems that provide engine performance;
- purpose of main PP systems (fuel, oil, starting) and requirements to them;
- purpose and components of an aircraft fuel system;
- purpose and components of an engine fuel system;
- ways of fuel supply from fuel tanks;
- fuelling methods;
- types an structure of pumps used;
- structure of oil systems;
- used oils;
- types and structure of starting systems;
- the way torque moments change during starting;

know how to:

- to determine the overall structure and workflows of varieties of aviation heat engines;
- to evaluate the purpose, structure and efficiency of the GTD units;
- perform comparative assessment of existing structures, suggest ways to improve them;
- choose type of fuel supply system;
- choose type and parameters of oil and fuel pumps;
- choose type and parameters of oil system depending on engine type;

10.3 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. Be able to determine the type of engine by its model or drawing, the type of compressor, turbine and output device. Determine the number of compressor and turbine stages.

He must know purpose and structure of fuel, oil, and starting, deicing and firefighting systems. He must identify systems components and methods of their efficiency improvement, explain main functions of accessories, their structure, name main parts of an accessories and explain its shape.

Good (75-89). The student must be proficient in minimum knowledge. He must finish and pass all laboratory and practical works, pass modular testing with positive mark. Be able to determine the type of engine by its model or drawing, the type of compressor, turbine and output device. Determine the number of compressor and turbine stages. Be able to determine the type of compressor rotor type of combustion chamber. Know main trends in turbine engine power plants development, confidently identify type of accessory. He must explain principles and methods of power plant systems operation improving, accessory parts unloading, and choosing optimal operational and design parameters of components; explain altitude performances off aircraft systems and methods of their analysis.

Excellent (90-100). He must finish and pass all laboratory and practical works, pass modular testing with excellent mark (one or two modules with “good” mark and minimum 80 points are permitted). Full knowledge of basic and additional material. Be able to determine the type of engine by its model or drawing, the type of compressor, turbine and output device. Determine the number of compressor and turbine stages. Be able to determine the type of compressor rotor type of combustion chamber. Explain conditions and mechanism of occurrence of temperature stresses. Know main and additional material in full scale. Explain influence of flight altitude, flight velocity on systems efficiency. Know influence of the operational mode and flight conditions on the system efficiency. Successfully identify type of component, name its parts and methods of their junction using a drawing or mockup. Explain the problem of fuel and

oil stability (absence of cavitation) and methods of this problem solution. Name loads that act impellers, plungers, gears and casings at different operation conditions; explain loads and torques applied to rotor at starting process. Know basic materials which the main engine units' parts are made from.

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

11. Methodological support

1. Didactic materials (manuals, Power point presentations, posters etc.).
2. Mockups of pumps, fuel nozzles, starters in 103, 124, 122 rooms and hall of Motor building.
3. Tutorials for different topics of the course.

12. Recommended literature for the course

Main

1. Авиационные силовые установки. Системы и устройства / Н. Т. Домотенко, А. С. Кравец, Г. А. Никитин и др. – М. : Транспорт, 1976. – 312 с.

2. Скубачевский, Г. С. Авиационные газотурбинные двигатели. Конструкция и расчет деталей / Г. С. Скубачевский. – М. : Машиностроение, 1981. – 552 с.

3. Конструкция и проектирование авиационных газотурбинных двигателей ; под ред. Д. В. Хронина. – М. : Машиностроение, 1989. – 368 с.

4. Лещинер, Л. Б. Проектирование топливных систем самолетов / Л. Б. Лещинер, И. Е. Ульянов. – М. : Машиностроение, 1975. – 394 с.

5. Кац, Б. М. Пусковые системы авиационных ГТД / Б. М. Кац, Э. С. Жаров, В. К. Винокуров. – М. : Машиностроение, 1976. – 220 с.

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12. Агрегаты систем авиационных двигателей / С. В. Безуглый, А. И. Скрипка, Б. Г. Нехорошев и др. – Х. : ХАИ, 2007.- 90 с.

13. Bezuglyi, S. Systems and Units of Aircraft Power Plants / S. Bezuglyi, S. Yepifanov, R. Tzukanov. – Kh. : KhAI, 2015. - 100 p.

14. Безуглый, С. В. Центробежные насосы авиационных двигателей : учеб. пособие / С. В. Безуглый. – Х. : Нац. аэрокосм. ун-т «Харьк. авиац. ин-т», 2006. - 27 с.

15. Безуглый, С. В. Шестеренные насосы. Конструкция и проектирование : учеб. пособие / С. В. Безуглый, А. И. Гаркуша, В. С. Чигрин. – Х. : Нац. аэрокосм. ун-т «Харьк. авиац. ин-т», 2009. – 48 с.

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18. Bezuglyi, S. Components of Aircraft Power Plant Systems [Text]: lect. summary /

S. Bezuglyi, F. Sirenko, M. Shevchenko. – Kharkov: National Aerospace University «Kharkov Aviation Institute», 2016. – 104 p.

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2. Башта Т. М. Объемные насосы и гидродвигатели гидросистем / Т. М. Башта. – М. : Машиностроение, 1976. - 606 с.

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