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

COMPONENTS OF AIRCRAFT POWER PLANTS DESIGNING
(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 *Components of aircraft power plants designing*
(name of academic discipline)
for students of a field of study *134 «Aviation and Spacecraft Technologies»*
educational program *Aircraft engines and power plants*

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Person, who developed the syllabus *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)

1. Description of the discipline

Characteristics	Branch of science, specialization, academic degree	Description of the discipline *(full-time tuition)*
Credits – *5*	**Field of education:** *13 «Mechanical Engineering»* (cipher and name)	*Variable*
Modules – *2*	**Field of study:**	**Academic year:**
Semantic modules – *2*		*2020 / 2021*
Individual task ***Calculation-graphic work*** *«Designing of Engine Main Fuel Pump»* (title)	*134* *«Aviation and spacecraft technologies»* (cipher and name)	**Semester**
Total number of academic hours – *64*/150*		*7*-th
		Lectures *
Number of academic hours for full-time tuition: auditorium – *4* independent work – *5.4*	**Higher education:** *First (Bachelor)*	*32 a.h.*
		Practices, seminars *
		-
		Laboratory activities *
		32 a.h.
		Independent work
		86 a.h.
		Form of examination
		exam

The ratio of hours of classes to independent work is: for full-time education - 64 / 86.

* *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 the knowledge necessary for the development of structures, design and manufacture of systems and units that are part of the aircraft power plant.

Task: development of designs of fuel pumps and injectors that are part of the aircraft power plant.

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. 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. 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. Ability to design and test elements of aerospace engineering, its equipment, systems and subsystems.*

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 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 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 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: 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

TOPIC 1. *General information about aircraft PP components*. The composition of PP components. Requirements to PP components. Main components of hydraulic systems. Weight indicators of PP components. Calculations and designing of PP systems and components.

TOPIC 2. *Pumps of aircraft systems*. General characteristics of pumps. Types of the pumps used in aircraft power plants. The pump basic elements. The positive-displacement pumps capacity. Displacement pump efficiency. Power consumed by the pump.

TOPIC 3. *Gear-type pumps* (GP). General information about GP. Structure and operation principle of the GP. The gear-type pumps design schemes. Pressure head provision. Capacity provision. The basis for calculation of gear-type pump sizes. Definition of forces acting on gear pump supports. The gear -type pumps design and materials used.

TOPIC 4. *Plunger pumps* (*PlP*). Structure and operation principle of PlP. Provision of pressure by the plunger pump. Kinematics of the drum-type PlP with a parallel arrangement of plungers and flat swash plate. Capacity of the PlP. Uniformity of fluid supply by PlP and features of the cylinder filling. Forces and moments in plunger pumps. Calculation on durability of elements of plunger pumps. Designing of distributive valve and calculation of the forces in it. Lubrication system application and requirements made for it. Designing of the plunger shoe.

Module 2

TOPIC 5. *Centrifugal pumps* (CP). General information about CP. Schemes of centrifugal pumps. The basic parameters of the pump. Classification of centrifugal pumps. Velocity diagram at the inlet of the impeller and the location of the blades. Velocity diagram at the outlet of the impeller. Theoretical pump head. Cavitation in centrifugal pumps.

TOPIC 6. *Fuel and oil nozzles*. General information. Basis of calculation and design of the fuel and oil nozzles. Jet injectors. Designing of centrifugal nozzles. Dual centrifugal nozzles. The fuel atomization by nozzles.

TOPIC 7. *Designing of starting system (SS).* Requirements to starting system of GTE. Calculating starting time and required power of starter. Composition of SS. Designing of electric, air, gas, gas-turbine starters. Components of ignition system.

4. Course arrangement

Names of Modules and Topics	Number of hours				
	full-time tuition				
	total	including			
		lec	pr	lab	indp
1	2	3	4	5	6
Module 1 **Semantic module 1**					
TOPIC 1. General information about aircraft PP components.	6	2	-	-	4
TOPIC 2. Pumps of aircraft systems.	12	2	-	2	8
TOPIC 3. Gear-type pumps (GP).	28	6	-	6	16
TOPIC 4. Plunger pumps (PlP).	29	5	-	8	16
Modular testing	1	1	-	-	-
Totally for the module No 1	**76**	**16**	**-**	**16**	**44**
Module 2 **Semantic module 2**					
TOPIC 5. Centrifugal pumps (CP).	24	6	-	6	12
TOPIC 6. Fuel and oil nozzles.	26	6	-	8	12
TOPIC 7. Designing of starting system (SS).	13	3	-	2	8
Modular testing	1	1	-	-	
Totally for the module No 2	**64**	**16**	**-**	**16**	**32**
Individual task **Calculation-graphic work on the topic of:** *«Designing of Engine Main Fuel Pump»*	**10**	**-**	**-**	**-**	**10**
Totally for the course	**150**	**32**	**-**	**32**	**86**

5. Laboratory activities

№	Topic of the activity	Hours
1	Gear pumps constructions	8
2	Plunger pump constructions	8
3	Construction of centrifugal pumps	4
4	Construction of de-aerators and air breathers	6
5	Fuel nozzles constructions	4
6	Construction of auxiliary power units and starters	4
	Together	**32**

7. Independent work

№	Topic	Hours
1	General information about aircraft PPs	4
2	Pumps of aircraft systems	8
3	Gear-type pumps (GP)	16
4	Plunger pumps (PlP)	16
5	Centrifugal pumps (CP)	12
6	Fuel and oil nozzles	12
7	Designing of starting system	8
8	Calculation-graphic work	10
	Together	**86**

8. Individual task

Calculation-graphical work *«Designing of Engine Main Fuel Pump»*.

Stages of work:

– choosing the type of pump;
– calculations of main parameters of the pump;
– pump scheme designing bearings types and displacement choosing;
– making 3D model of the pump;
– explanatory report drawing-up;
– defense of work.

9. Learning methods

Basic forms of learning:

- lectures;
- practical activities;
- laboratory activities;
- individual task;
- 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.

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

Module 1

01. Types of the pumps used in the aircraft power plant systems.
02. The positive displacement pumps (PDP) capacity.
03. The positive displacement pumps volumetric efficiency.
04. The influence of gap values on PDP volumetric efficiency.
05. The influence of rotational speed on PDP volumetric efficiency.
06. Power consumed by the pump.
07. Pressure head provision by gear pumps (GP).
08. Capacity provision by gear pumps.
09. The influence of teeth number on GP capacity.
10. The influence of gear width on GP capacity
11. The influence of rotational speed on GP capacity.
12. Definition of lateral forces applied to GP supports.
13. Definition of reaction forces from a torsion torque applied to GP supports.
14. Structure and operation principle of the plunger pump (PlP).
15. Pressure head provision by plunger pumps.
16. Kinematics of the drum-type PP with a parallel arrangement of plungers and flat swash plate?
17. Capacity of the plunger pump.
18. Uniformity of fluid supply by plunger pumps and features of filling of the cylinder.
19. The forces and the moments are applied to a plunger.
20. Force of a spring applied to a plunger.
21. Hydraulic force applied to a plunger.
22. Centrifugal force applied to a plunger.
23. Force of inertia in relative motion applied to a plunger.
24. Force of reaction of a PIP swash plate.
25. Spherical heads of plunger calculations on bearing strains (crumple) from contact stresses.
26. Methods of contact pressure reduction in pair “plunger – swash plate”.
27. The lateral surface of plunger calculations on action of forces, perpendicular to axis of plunger.
28. The sizes and position of holes of a distributive valve of a PIP.

Module 2

29. The main elements of the centrifugal pump (CFP)
30. The positive suction head (cavitation margin) of a CFP.
31. The necessary boost CFP pressure head.
32. The CFP volumetric efficiency.
33. The CFP hydraulic efficiency.
34. The CFP mechanical efficiency.
35. The CFP full efficiency.
36. The CFP useful power.
37. The power required for a CFP drive.
38. Velocity diagram at the inlet of the impeller.
39. The location of the blades at the inlet of the impeller.
40. The expression for the equivalent inlet diameter which provides the minimal pressure difference.
41. Velocity diagram at the outlet of the impeller.
42. Theoretical centrifugal pump pressure head.

43. Cavitation in the centrifugal pumps.
44. Fuel and oil nozzles. General information.
45. Basis of calculation and design of the fuel and oil nozzles.
46. Jet injectors.
47 Designing of centrifugal nozzles.
48. Duplex centrifugal nozzles.
49 The fuel atomization by nozzles.
50. Designing of starting system (SS).
51. Calculating starting time and required power of starter.
52. Designing of gas-turbine starters.
53. Designing of air starters.
54. Components of ignition system.

11. Testing

The course is divided into two modules:

1. Positive displacement pumps.
2. Centrifugal pumps, spray nozzles, 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 works, individual task and independent work of this modulus.

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

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

Semester 7 – examination.

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			
Work at lectures	0…0.5	8	0…4
Execution and defense of laboratory (practical) works	1…2	8	8…16
Modular testing	25…30	1	25…30
Module 2			
Work at lectures	0…0.5	8	0…4
Execution and defense of laboratory (practical) works	1…2	8	8…16
Modular testing	15…25	1	15…25
Execution and defense of individual task	4…5	1	4…5
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 gear pump (Module 1);
- the second question is on plunger pump (Module 1);

– the third question is on centrifugal pump (Module 2);
– the fourth question is on fuel nozzle or starting system (Module 2).

Maximum number of points for each question is 25.

12.2 Qualitive evaluation criteria

To get positive mark, the student must

know:

– purpose of main engine system components (boost pump, main fuel pump, oil pumps, starters, heat exchangers, fuel/oil nozzles) and requirements to them;
– advantages and disadvantages of plunger, gear and centrifugal pumps;
– loads that act impeller of centrifugal pump and methods of impeller unloading;
– loads that act supports of gear pump;
– loads that act cylinder barrel and plunger of plunger pump;
– structure of plunger pump;
– structure of gear pump;
– structure of centrifugal pump;
– structure of duplex centrifugal fuel nozzles;
– structure of air and turbo starters;
– methods of plunger and swash plate contacting;
– methods of gear supports unloading;
– methods of gear plunger unloading;
– main elements of pumps;
– main elements of duplex centrifugal nozzle
– types of starting systems;
– main loads that act casings of pumps;

know how to:

– calculate main parameters and sizes of gear pump;
– calculate main parameters and sizes of plunger pump;
– calculate main parameters and sizes of centrifugal pump
– calculate main parameters and sizes of duplex centrifugal fuel nozzle;
– join gears between themselves;
– join a drive gear to a shaft;
– press plunger to a swash plate;
– distribute fuel flow at the outlet of plunger pump;
– join an impeller a drive shaft;
– improve anti-cavitation characteristics of the pump.

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 purpose and structure of pumps, fuel an oil nozzles, starters. He must identify parts of units and methods of efficiency improvement, explain main loads that act parts of pumps and what stresses do they initiate, name main parts of a pump 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, defend the individual task with good mark, pass modular testing with positive mark. Know main trends in turbine engine units' development, confidently identify type of pump, nozzle, starter, type of the plunger connection with swash plate. He must explain principles and methods of pump parts unloading and identify unloading cavities using drawings; name main stresses that originate in pump parts and explain their distribution by radius; explain main loads that act casings of pumps and methods of their analysis.

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 or two modules with “good” mark and minimum 80 points are permitted). Know main and additional material in full scale. Explain influence of rotational speed, temperature of liquid, pressure difference on pump efficiency. Know influence of the pressure difference on the unit perfection and sizes. Successfully identify type of pump, spray nozzle, starter, name their parts and methods of their junction using a drawing or mockup, explain main loads and how are they transmitted between parts, between modules and engine components and finally to the unit casings. Explain the problem of pump stability (absence of cavitation) and methods of this problem solution. Name loads that act impellers, plungers, gears and casings at different operation conditions; explain which conditions are selected for strength analysis and why. 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

13. 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.

14. Recommended literature for the course

Main

1. Авиационные силовые установки / Н. Т. Домотенко, А. С. Кравец, Г. А. Никитин и др. – М. : Транспорт, 1976. - 3122 с.

2. Раздолин, М. В. Агрегаты воздушно-реактивных двигателей / М. В. Раздолин, Д. Н. Сурнов. – М. : Машиностроение, 1973. - 352 с.

3. Башта, Т. М. Гидравлические приводы летательных аппаратов / Т. М. Башта. – М. : Машиностроение, 1967. - 495 с.

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

5. Системы авиационных двигателей / С. В. Безуглый, С. В. Епифанов, А. И. Скрипка и др. – Х. : ХАИ, 2008. - 74 с.

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

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

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

9. 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.

10. Безуглый С. В. Плунжерные насосы. Конструкция и проектирование : учеб. пособие / С. В. Безуглый, А. И. Скрипка. - Х. : Нац. аэрокосм. ун-т «Харьк. авиац. ин-т», 2010. - 80 с.

11. Безуглый С. В. Конструкция топливных форсунок авиационных двигателей : учеб. пособие / С. В. Безуглый, В. Е. Костюк, И. Ф. Кравченко. – Х. : Нац. аэрокосм. ун-т «Харьк. авиац. ин-т», 2008. - 49 с.

12. 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.

Additional

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

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

3. Авиационные центробежные насосные агрегаты / Л. С. Аринушкин, Р. Б. Абрамович, А. Ф. Поликовский и др. – М. : Машиностроение, 1967. - 255 с.