Ministry of Education and Science of Ukraine
National Aerospace University
"Kharkiv Aviation Institute"

Department of Aircraft Control Systems (Dep. 301)

APPROVED:
Guarantor of Educational Program
_____ A. S. Kulik
«27» 08 2021

WORK PROGRAM OF THE COMPULSORY DISCIPLINE

Fundamentals of Avionics System Simulation

(name of the discipline)

Field of Study: 17 "Electronics and Telecommunication"

Program Subject Area: 173 "Avionics"

Educational Program: Systems of Autonomous Navigation and Adaptive Control of Aircrafts
(code number and the name of specialization)

Level of Qualification: 1st (bachelor degree)

Kharkiv 2021

Work program of compulsory discipline "Fundamentals of Avionics System Simulation" is for English-speaking students of training direction 173 "Avionics".

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Developer:
I.V. Bychkova, senior lecturer of dep. 301 _____ (sign)

The work program has been examined at the meeting of dep. 301 "Aircraft Control Systems".

Record of proceeding: No. "01" from «27» 04 2021

Head of the department
PhD (Engineering), Candidate of Science _____ (sign) K. Yu. Dergachov

1. Course description

<table>
<tr><td colspan="2" rowspan="2">Indices</td><td colspan="2" rowspan="2">Field of study, Program subject area, Educational program</td><td colspan="2">Course specification</td></tr>
<tr><td colspan="2">Full-time study</td></tr>
<tr><td colspan="2">ECTS credits – 10.5</td><td colspan="2" rowspan="3">Branch of Education:
17 – Electronics and Telecommunication</td><td colspan="2">Optionally discipline</td></tr>
<tr><td colspan="2">Modules – 2</td><td colspan="2" rowspan="2">Calendar year</td></tr>
<tr><td colspan="2">Semantic modules – 5</td></tr>
<tr><td colspan="2" rowspan="2">Individual assignment
1. "Construction of models of control objects" - 4 semester.
2. "Building aircraft models as object management" - 5 semester.</td><td colspan="2" rowspan="2">Program subject area:
173 – Avionics</td><td colspan="2">2021-2022</td></tr>
<tr><td colspan="2">Semester</td></tr>
<tr><td colspan="2" rowspan="2">Total hours – 315</td><td colspan="2" rowspan="12">Educational Program:
Systems of Autonomous Navigation and Adaptive Control of Aircrafts</td><td>4</td><td>5</td></tr>
<tr><td colspan="2">Lectures</td></tr>
<tr><td colspan="2">Academic hours per day for full-time study</td><td>32</td><td>38</td></tr>
<tr><td colspan="2">Semester 4</td><td colspan="2">Tutorials</td></tr>
<tr><td>contact (classroom)
5.5 hrs.</td><td>self-study
5 hrs.</td><td>24</td><td>24</td></tr>
<tr><td colspan="2">Semester 5</td><td colspan="2">Lab classes</td></tr>
<tr><td>contact (classroom)
5 hrs.</td><td>self-study
4 hrs.</td><td>32</td><td>24</td></tr>
<tr><td colspan="2" rowspan="3"></td><td colspan="2">Self-study (unaided) work</td></tr>
<tr><td>80</td><td>64</td></tr>
<tr><td colspan="2" rowspan="3">Level of qualification:
1st (bachelor degree)</td></tr>
<tr><td colspan="2">Assessment form</td></tr>
<tr><td colspan="2">Pass</td><td>Exam</td></tr>
</table>

Note: ratio of tutorial work and unaided (independent) work makes: 160/155 (under full-time education).

2. Purpose and objectives of academic discipline

Learning Aims – familiarization with the basic concepts, definitions, ideas, principles and methods of modeling, model train control systems to form and carry through with their investigation of dynamic properties of Automatic Control Objects (ACO).

Learning Objectives – acquiring skills for constructing verbal, graphic, mathematical, machine models and experimental study of the functional properties of the object of automatic control, solving the problem of structural and parametric identification of mathematical models in the time and frequency domain.

Learning Outcomes

By the end of the course, students

should know

- principles of construction of verbal, graphic and mathematical models ACO;
- the main characteristics of the models ACO;
- methods used in the development of mathematical models ACO;
- tools for constructing linear mathematical models;
- general requirements for automatic control facilities;
- basic coordinate system forces and moments acting on the aircraft as an object of control;
- basic theory, principles and features of mathematical models of aircraft and their subsystems;

should be able

- verbal form, graphic, mathematical and computer models ACO;
- lessons use mathematical tools to study the ACO;
- taking an aircraft model t and their subsystems;
- simplifying and using mathematical models of the aircraft and its subsystems.

Interdisciplinary connections:

In order to study this discipline:

Physics: Newton's laws, Ohm's law, Faraday's law, power, energy, energy conservation. Higher Mathematics: differential and integral calculations; actions with complex numbers in algebraic and exponential form; research functions and their construction schedules; Vector algebra. Technical mechanics, kinematics and dynamics of complex rigid body motion, Lagrange equation of the 2nd kind.

The course supports the following courses:

Automatic Control Theory. Servo control systems. Control Systems aircraft.

3. Content of the course

Module 1. Fundamentals of design objects.

Content module 1. The main provisions of modeling of dynamic objects.

Theme 1. The object of study and objectives of the course "Fundamentals of

modeling ACO". Place discipline in the curriculum.

Theme 2. History of model concepts. Milestones formation model concepts and their characteristics. Formation of model representations regarding automated systems. The theory of knowledge. The logical structure of the cognitive process.

Theme 3. Basic concepts of modeling ACO. The concept model features models, their classification. Defining the object Control object automatic control, automatic control system.

Theme 4. Measurements modeling. Place dimensions in modeling, measuring scale.

Theme 5. Modeling languages. Classification, features and characteristics of modeling languages. Obtaining information. The graphical modeling language. Natural language modeling. Mathematical modeling language approach to designing automated systems using models. Consistency as generalized properties of matter. The concept of the system.

Modular control.

Content module 2. Modeling in the design of control systems.

Theme 6. Models automatic control facility. Verbal, graphic, mathematical models of automatic systems, their properties and characteristics. Display performance management systems using models. Visual and verbal models as tools for building linear mathematical models.

Theme 7. Instrumental means for constructing linear mathematical models. Linearization nonlinearities (graphical and analytical) form linear mathematical equations, transfer function. Direct and inverse Laplace transform of continuous and discrete systems. The classic method of modeling time characteristics of continuous systems. Operational Methods of modeling time characteristics of continuous systems.

Subject 8. Modeling objects with linear mathematical models. Attributes model ACO, research ACO response to input effects with differential equations using the method of state space modeling with ACO, identification of parameters of mathematical models and examples.

Subject 9. Modeling as an experimental process of obtaining information. Features of digital control systems. Models ADC and DAC scheme of automation of experimental tests.

Modular control.

Module 2. Simulation aircraft as a control object.

Content module 3. Features design of the aircraft as a control object.

Subject 10. The overall structure of control system aircraft. Appointment links, connections, incoming influences.

Subject 11. Aircraft as objects of automatic control. Global and local objects.

Subject 12. Vector equation of spatial movement of the aircraft. Translational motion. rotational movement.

Subject 13. Basic coordinate system in the dynamics of flight. Inertial and terrestrial coordinate system. Moving coordinate system.

Subject 14. The main aeronautical flight parameters of the aircraft. Coordinates and speed. viewing angle and speed.

Modular control.

Content module 4. The dynamics of the aircraft as a solid.

Subject 15. Dynamic equations of translational motion of the aircraft as a solid. Projections impulse to bound axis coordinates, variables, control and disturbing effect.

Subject 16. The equation of kinematics forward movement of the aircraft as a solid. Kinematics equation as bound, high-speed and Trajectory frames.

Subject 17. The equation of the dynamics of rotational motion of the aircraft as a solid. Projections momentum on the axis bound coordinate system, variables, control and disturbing moments.

Subject 18. Kinematics equation of rotational motion of the aircraft as a solid. Euler equations, Poisson equation.

Modular control.

Content module 5. Linearized model aircraft movement.

Subject 19. Classification of aircraft movement. Series short-and long-period motion. Lateral movement is isolated to roll and yawing.

Subject 20. Methods of linearization of the equations of motion of the aircraft. The choice of the reference motion equations decomposition Taylor.

Subject 21. Linear equations longitudinal movement. The system of differential equations longitudinal movement operated, control and disturbing variables.

Subject 22. Equation short-longitudinal movement. Struktukturni circuit, the transfer function of the aircraft to control actions.

Subject 23. Linear equations lateral movement. Struktukturni circuit, the transfer function of the aircraft to control actions.

Subject 24. Mathematical models of isolated movements of roll and yawing. Struktukturni circuit, the transfer function of the aircraft to control actions. Manageability to roll and yawing.

Modular control.

4. Structure of discipline

Names of content modules and topics	Number of hours				
	Full-time				
	all	including			
		lec	tut	lab	indep
1	2	3	4	5	6
Module 1 (4 semesters) Basic modeling objects					
Content module 1. Key provisions of modeling of dynamic objects.					
Theme 1. The object of study and objectives of the subject "Fundamentals of modeling ACO".	2	2	-	-	-

1	2	3	4	5	6
Subject 2. History of model concepts.	9	2	-	-	7
Topic 3. Basic concepts of modeling ACO.	14	4	-	-	10
Topic 4: Measurements modeling.	15	4	-	-	11
Theme 5. Modeling languages.	23	4	4	4	11
Modular control.	5				5
Together for the content modules 1	**68**	**16**	**4**	**4**	**44**
Content module 2. Modeling in the design of control systems.					
6. Subject object model automatic control.	27	4	8	4	11
Theme 7. Instrumental means for constructing linear mathematical models.	27	4	4	8	11
Theme 8. Modeling systems using linear mathematical models.	27	4	4	8	11
Theme 9. Modeling as an experimental process of obtaining information.	27	4	4	8	11
Modular control.	4				4
Together for the content modules 2	**112**	**16**	**20**	**28**	**48**
Total for module 1	**180**	**32**	**24**	**32**	**92**
Module 2 (5 semester) Simulation aircraft as property management.					
Content module 3. Features of the aircraft design as an object of control.					
Subject 10. The overall structure of the control system of the aircraft.	4	1	-	-	3
Theme 11. Aircraft as objects of automatic control.	4	1	-	-	3
Subject 12. The vector equation of spatial movement of the aircraft.	4	1	-	-	3
13. The main theme of the coordinate system in the dynamics of flight.	9	1	2	2	4
Subject 14. The main aeronautical flight parameters of the aircraft.	9	1	2	2	4
Modular control.	5				5
1	2	3	4	5	6
Total for 3 content modules	**35**	**5**	**4**	**4**	**22**
Content module 4. The dynamics of the aircraft as a solid.					
Subject 15. The dynamic equations of translational motion of the aircraft as a solid.	9	1	2	2	4
16. Subject kinematics equation of translational motion of the aircraft as a solid.	9	1	2	2	4
Subject 17. The dynamic equations of rotational motion of the aircraft as a solid.	9	1	2	2	4
18. Subject kinematics equation of rotational motion of the aircraft as a solid.	9	1	2	2	4
Modular control.	4				4
Total for 4 content modules	**40**	**4**	**8**	**8**	**20**

Content module 5. Linearized model aircraft movement.					
1	2	3	4	5	6
19. Subject Classification of aircraft movement.	4	1	-	-	3
Subject 20. The method of linearization of the equations of motion of the aircraft.	13	1	4	4	4
Theme 21. Linear equations longitudinal movement.	9	1	2	2	4
Subject 22. Equation short-slitting motion.	9	1	2	2	4
Subject 23. Linear equations lateral movement.	9	1	2	2	4
Subject 24. Mathematical model of isolated movements roll and yaw.	10	2	2	2	4
Modular control.	6				6
Together for the content modules 5	**60**	**7**	**12**	**12**	**29**
Total modulo 2	**135**	**16**	**24**	**24**	**71**
Total hours	**315**	**48**	**48**	**56**	**163**

5. Topics of seminars

Number s / n	topic	Number of hours
1	not scheduled	

6. Topics of practical classes

Number s / n	topic	Several. h.
1	2	3
Module 1: Fundamentals of modeling objects.		
1	Graphic linearization of static characteristics ACO.	4
2	Analytic linearization of nonlinear equations of mathematical model ACO.	4
3	Form of the mathematical model of the dynamics of the ACO.	4
4	Solution linearized mathematical model equations ACO in the time domain.	4
5	Solution linearized mathematical model equations ACO in the frequency domain.	4
6	Construction of analog models ACO bench.	4
	Total for module 1	**24**
Module 2: Modeling of aircraft as property management.		
7	The transformation of coordinates using matrices direction co-sines.	4
8	Building a verbal model aircraft as an object of control.	4
9	Graphical models of aircraft as object management.	4
10	Construction of mathematical model aircraft movement isolated using the equations of conservation laws.	4

1	2	3
11	Construction of mathematical model aircraft isolated motion using Lagrange equations of the second kind.	4
12	Getting a linearized mathematical model of longitudinal and lateral movement of the aircraft.	4
	Total for module 1	**24**
	Together	**48**

7. Topics laboratory classes

Number s / n	topic	Several. h.
1	2	3
	Module 1: Fundamentals of modeling objects.	
1	Learning functionality of laboratory stand.	4
2	Modeling of dynamic links using operational amplifiers.	4
3	Experimental study of static characteristics ACO bench.	4
4	Experimental study of temporal characteristics ACO bench.	4
5	Experimental study of frequency characteristics ACO bench.	4
6	Experimental study of analog models ACO bench by sequential integration.	4
7	Experimental study of analog models ACO bench by block integration.	4
8	Modeling executive bodies of ACO motor using SL-267.	4
	Total for module 1	**32**
	Module 2: Modeling of aircraft as property management.	
9	Experimental research body drag force of different configurations by changing the angle of attack.	4
10	Experimental research body drag force of different configurations for different airflow.	4
11	Experimental research airfoil aerodynamic forces by changing the angle of attack.	4
12	Experimental study analog model aircraft longitudinal movement.	4
thirteen	Experimental study of lateral movement analog model aircraft.	4
14	Experimental study analog model aircraft as an object of Automatic Control.	4
	Total for module 2	**24**
	Together	**56**

8. Independent work

Number s / n	topic	Number of hours
1	2	3
Module 1: Fundamentals of modeling objects.		
1	History of model concepts.	7
2	Basic concepts of modeling ACO.	10
3	Measurements modeling.	11
4	modeling languages.	11
5	Models automatic control facility.	11
6	Instrumental means for constructing linear mathematical models.	11
7	Modeling systems using linear mathematical models.	11
8	Modeling as an experimental process of obtaining information.	11
	Total for module 1	**83**
Module 2: Modeling of aircraft as property management.		
9	The overall structure of control system aircraft.	3
10	Aircraft as objects of automatic control.	3
11	Vector equation of spatial movement of the aircraft.	3
12	Basic coordinate system in the dynamics of flight.	4
thirteen	The main aeronautical flight parameters of the aircraft.	4
14	Dynamic equations of translational motion of the aircraft as a solid.	4
15	The equation of kinematics forward movement of the aircraft as a solid.	4
16	The equation of the dynamics of rotational motion of the aircraft as a solid.	4
17	Kinematics equation of rotational motion of the aircraft as a solid.	4
18	Classification of aircraft movement.	3
19	Methods of linearization of the equations of motion of the aircraft.	4
20	Linear equations longitudinal movement.	4
21	Equation short-longitudinal movement.	4
22	Linear equations lateral movement.	4
23	Mathematical models of isolated movements roll and yaw.	4
	Total for module 2	**56**
	Together	**139**

9. Individual task

1. "Construction of models of control objects" - 4 semester.
2. "Building aircraft models as object management" - 5 semester.

10. Teaching methods

Verbal - visual lectures, practical, laboratory and practical work, individual counseling (if necessary), independent work of students on materials published by the Department (guides).

11. Methods of control

Current control - according to structural modules and themes in the form of a written survey, oral questioning, testing.

Semester control - in the form of a written exam and test.

12.1. Evaluation criteria and distribution points that receive students

12.1. Distribution points that receive students

4 semester

Components of training of	Score one for over-mak (task)	number over-notions (tasks)	The total number of points
1	2	3	4
Content module 1			
Work in class	0 ... 1	8	0 ... 8
Performance and Protection laboratory work	1 ... 5	1	1 ... 5
1	2	3	4
Performance and Protection practical work	1 ... 5	1	1 ... 5
Modular control	1 ... 5	1	1 ... 5
Content module 2			
Work in class	0 ... 1	8	0 ... 8
Performance and Protection laboratory work	2 ... 5	7	12 ... 35
Performance and Protection practical work	2 ... 5	5	6 ... 25
Modular control	1 ... 5	1	1 ... 5
Performance and protection work	1 ... 4	1	1 ... 4
Total per semester 60 ... 100			

5 semester

Components of training of	Score one for over-mak (task)	number over-notions (tasks)	The total number of points
Content module 3			
Work in class	0 ... 1	2.5	0 ... 2.5
Performance and Protection laboratory work	1 ... 6	1	1 ... 6
Performance and Protection practical work	1 ... 6	1	1 ... 6
Modular control	1 ... 5	1	1 ... 5
Content module 4			
Work in class	0 ... 1	2	0 ... 2
Performance and Protection laboratory work	1 ... 6	2	2 ... 12
Performance and Protection practical work	1 ... 6	2	2 ... 12
Modular control	1 ... 5	1	1 ... 5
Content module 5			
Work in class	0 ... 1	3.5	0 ... 3.5
Performance and Protection laboratory work	1 ... 6	3	3 ... 18
Performance and Protection practical work	1 ... 6	3	3 ... 18
Modular control	1 ... 5	1	1 ... 5
Performance and protection PP	1 ... 5	1	1 ... 5
Total per semester 60 ... 100			

Ticket exam consists of theoretical and practical questions. Example. Theoretical question:

1. Mathematical models of helicopter isolated movement in height.
2. Forces and moments acting on the helicopter.
3. Mathematical models of isolated movements on roll .
4. Linear equations lateral movement.

Practical issues:

1. Absorb circuit simulation longitudinal movement maneuverable aircraft.

Provide value pitch angular velocity $\omega_z = 20$ rad / s.

2. Get direction cosines matrix for the transition from the normal moving frame bound to the coordinate system of the aircraft. Calculate the matrix components, given Euler angles: $\psi = 15$ degrees; $\upsilon = 20$ degrees; $\gamma = 8$ degrees.

3. Scaling equations of mathematical model of short-longitudinal movement of aircraft:

$$W_{Л}(s) = \frac{\Omega_z(s)}{\Delta_в(s)} = \frac{к_{Л}(T_1 s + 1)}{T_2^2 s + 2\xi T_2 s + 1},$$

where $\Omega_z(s)$ - the image of the angular velocity of the pitch; $\Delta_в(s)$ - Image rudder deflection height; $к_{Л} = 0{,}5\ с^{-1}$; $T_1 = 1{,}3$ с; $T_2 = 0{,}8$ с; $\xi = 0{,}6$; $\Delta\omega_z = 25$ рад/с; $\Delta\delta_в = 0{,}52$ рад; $\Delta u_{вх} = 100$ В; $\Delta u_{вих} = 100$ В.

4. Construct a schematic diagram of a set of analog models of long longitudinal movement UAV

$$W_{М}(s) = \frac{U_{вих}(s)}{U_{вх}(s)} = \frac{0{,}74(0{,}5s + 1)}{(1{,}5s + 1)\left(0{,}12s^2 + 1{,}2s + 1\right)},$$

using the block method of integration.

12.2. Qualitative evaluation criteria

The necessary knowledge to obtain a positive assessment:

- principles of construction of verbal, graphic and mathematical models ACO;
- the main characteristics of the models ACO;
- methods used in the development of mathematical models ACO;
- tools for constructing linear mathematical models;
- General requirements for automatic control facilities;
- Basic coordinate system forces and moments acting on the aircraft as an object of management;
- basic theory, principles and features of mathematical models of aircraft and their subsystems;

The required amount of skills to obtain a positive assessment:

Be able:

- work with: equipment and measuring methods used in laboratory work;
- verbal form, graphic, mathematical and computer models ACO;
- Lessons use mathematical tools to study the ACO;
- design model aircraft and their subsystems;
- simplifying and using mathematical models of the aircraft and its subsystems.

12.3. Evaluating criteria of the student work during the semester

1. Excellent (90 ÷ 100 points):

1.1 Student knows the basic concepts and principles pertaining to the discipline "Fundamentals of avionics system simulation". Student has defended all practical,

laboratory and individual tasks, completed all modular tasks with an "excellent" mark, has excellent practical skills in circuit design. Freely uses the educational and scientific literature on the discipline subject. Student can logically and clearly form his answer, solve practical and laboratory tasks. An excellent performance, clearly outstanding. Student demonstrates excellent judgement and a very high degree of independent thinking.

1.2 A reduction in the number of the mark points is possible with inaccurate wording in the answers to the additional questions posed to student.

2. Good (75 ÷ 89 points):

2.1 Student has sufficient knowledge of the theoretical part of the discipline. Defended all practical, laboratory and individual tasks, completed all modular tasks with a "good" mark, has practical skills in circuit design. Correctly solves practical tasks, student's answers are not clear. A good performance in most areas. Student demonstrates a reasonable degree of judgement and independent thinking in the most important areas.

2.2 A reduction in the number of the mark points is possible if the theoretical or practical questions are not fully answered.

3. Satisfactory (60 ÷ 74 points):

3.1 Student has weak theoretical knowledge, has a minimum of knowledge and skills, makes mistakes in solving practical problems. Has defended all practical, laboratory and individual tasks, completed all modular tasks, has unsure practical skills in circuit design. A satisfactory performance, but with significant shortcomings. Student demonstrates a limited degree of judgement and independent thinking.

3.2 A reduction in the number of the mark points is possible due to inaccurate and incomplete answers to theoretical and practical questions.

Grading scale: national assessments

Total marks	National validation grade	
	Exam	Pass-fail exam
90 – 100	excellent	pass
83 – 89	good	
75 – 82		
68 – 74	satisfactory	
60 – 67		
0 – 59	unsatisfactory	failure

13. Methodical aids

1. Summary of lectures on discipline " Fundamentals of Avionics System Simulation ".
2. Slides with presentations of lecture materials
3. Instructions and assignment for laboratory course
4. Learning aids for tutorial classes
5. Learning aid for the calculation-and-graphics assignment performance

14. Recommended reading

Basic sources

1. Gordin A.G. Aircraft as the controlled object: educational supply / A.G. Gordin. - Kharkiv.: National Aerospace University «Khark. Aviat. Inst», 2010. - 60 p.

2. Ian Moir, Allan Seabridge. Aircraft Systems Mechanical, electrical, and avionics subsystems integration / Ian Moir.- John Wiley & Sons Ltd, 2008. – 456 p.

Complementary reading

1. John S. Duncan. Pilot's Handbook of Aeronautical Knowledge / John S. Duncan - Oklahoma City: United States Department of Transportation, Federal Aviation Administration, 2016. – 524 p.

14. Інформаційні ресурси/ Information Resources

https://mentor.khai.edu/course/view.php?id=754&notifyeditingon=1

https://mentor.khai.edu/course/view.php?id=4449