Міністерство освіти і науки України

Національний аерокосмічний університет ім. М.Є. Жуковського
«Харківський авіаційний інститут»

Кафедра № 103 «Проектування літаків і вертольотів»

ЗАТВЕРДЖУЮ

Керівник проектної групи
(назва факультету)
_____ О.Г. Гребеніков
(підпис) (ініціали та прізвище)

«_1_» _____ 2020 р.

РОБОЧА ПРОГРАМА ВИБІРКОВОЇ НАВЧАЛЬНОЇ ДИСЦИПЛІНИ

Інженерний аналіз елементів АТ

(назва навчальної дисципліни)

Галузі знань: 13 «Механічна інженерія»
(шифр і найменування галузі знань)

Спеціальність: 134«Авіаційна та ракетно-космічна техніка»
(код та найменування спеціальності)

Освітня програма: «Літаки і вертольоти»
(найменування спеціалізації)

Рівень вищої освіти: другий (магістерський)

Харків 2020 рік

Робоча програма **Інженерний аналіз елементів АТ**
(назва дисципліни)
для студентів за спеціальністю 134 «Авіаційна та ракетно-космічна техніка»
освітньою програмою «Літаки і вертольоти»

«30» Червня 2020 р., - 12 с.

Розробники: к.т.н., доц. Гуменний А.М. _____
(прізвище та ініціали, посада, наукова ступінь та вчене звання) (підпис)
д.т.н., проф. Филіпковський С.В. _____
(прізвище та ініціали, посада, наукова ступінь та вчене звання) (підпис)
ст. викл. Чумак А.С. _____
(прізвище та ініціали, посада, наукова ступінь та вчене звання) (підпис)

Робочу програму розглянуто на засіданні кафедри
Проектування літаків та вертольотів
(назва кафедри)
Протокол № 1 від «31» 08 2020 р.

Завідувач кафедри д.т.н., професор _____ Гребеніков О.Г.
(наукова ступінь та вчене звання) (підпис) (ініціали та прізвище)

1. The purpose and objectives of the discipline

The purpose of teaching the discipline "Engineering analysis of JSC elements" is to provide a basic idea of performing engineering analysis of VAT elements of aircraft construction under static loading using the finite element method implemented in computer integrated CAD / CAE system ANSYS and ANSYS Workbench

objective of the study subjects'pre-graduation course "isto get the students knowledge of modern engineering analysis implementation of the NDS design elements aviation technology using finite element method implemented in a computer integrated CAD / CAE system ANSYS APDL and ANSYS Workbench

requires educational and professional programs students must achieve the following **competencies:**

Integral competence:

The ability to solve complex problems and problems in the field of maintenance and repair of aircraft and aircraft engines or in the learning process that involves research and / or innovation and is characterized by uncertain conditions and requirements.

General competences (LC)

LC1 - Ability to abstract thinking, analysis and synthesis
LC2 - Ability to apply knowledge in practical situations
LC5 - Ability to make informed decisions
LC8 - Ability to evaluate and ensure the quality of work
LC9 - Ability to conduct research at the appropriate level
LC10 - Ability to identify , pose and solve problems

Professional competencies of the specialty (FC)

FC1 - Ability to formulate the purpose and objectives of the study, identify priorities for solving problems, select and create evaluation criteria
FC2 - Ability to apply modern research methods, evaluate and present the results of work
FC4 - Knowledge and ability to use the achievements of science and technology in professional activities
FC5 - Ability to prepare reviews, publications on the results of research
FC10 - Ability to conduct technological calculations of the enterprise to determine the need for personnel, production and technical base, materials, spare parts x.
FC14 - Ability to develop models that predict changes in the technical condition of aircraft, to monitor the parameters of the effectiveness of its technical operation on the basis of modern analytical methods and complex models.
FC15 - Ability to develop plans, programs and research methods, practical recommendations for the use of research results.

Program learning

outcomes PRN1 - Formulate the purpose and objectives of the study, identify priorities for solving problems, select and create evaluation criteria.
PRN2 - Apply modern research methods, evaluate and present the results of work performed.
PRN3 - Use the laws and methods of mathematics, natural sciences, humanities and economics in solving professional problems, including the solution of non-standard problems that require in-depth analysis of their essence from a natural science standpoint.
PRN6 - Use the achievements of science and technology in professional activities.
PRN17 - To develop models that allow to predict changes in the technical condition of aircraft, to monitor the parameters of the efficiency of its technical operation on the basis of modern analytical methods and complex models.

As a result of studying the discipline, the student must

***know*: the**

- basic provisions of the finite element method to perform engineering analysis of VAT elements of aircraft construction at their static load;
- basics of work in CAD / CAE system ANSYS APDL and ANSYS Workbench;
- methods of modeling elements of aviation equipment in CAD / CAE system ANSYS APDL and ANSYS Workbench;
- methods of creating finite-element models of aircraft objects in the CAD / CAE system ANSYS

APDL and ANSYS Workbench;
- methods of VAT analysis of aircraft construction elements at their static loading in CAD / CAE system ANSYS APDL and ANSYS Workbench

***be able to*:**
- work in computer integrated system CAD / CAE ANSYS APDL and ANSYS Workbench to
- create computer models of aircraft construction elements;
- create finite-element models of aircraft objects;
- perform VAT calculations of aircraft objects at their static load;
- to carry out the engineering analysis of the results received during calculation of the VAT of objects of aviation equipment at their static loading to

***have idea*:**
- about modern computer systems which are used for performance of calculations of the VAT by means of a finite element method;
- about modern methods of engineering analysis of aircraft elements.

Interdisciplinary links: the discipline is based on the knowledge gained in the study of Physics, Mathematics, Descriptive Geometry and Engineering Graphics, Theoretical Mechanics, Theory of Mechanisms and Machines, Machine Parts, Material Resistance, Materials Science, Aerohydrogasematics, , COMPASS-3D computer system, Ineric design of airplanes and helicopters and Design of power plants.

2. Curriculum

Content module 1.

Creation of CAD models of aircraft design elements and finite-element grid based on them. Analysis of the results of calculations of individual models

INTRODUCTION

The purpose and objectives of the course. Summary of the course. List of recommended reading. Fundamentals of the finite element method. An overview of computer integrated CAD / CAE systems and their capabilities for computing problems in various fields of science.

TOPIC 1. General information about CAD / CAE system ANSYS APDL and ANSYS Workbench

General information about ANSYS CAD / CAE system. Structure and main modules. Assignment of basic modules. A brief description of the program's capabilities for all types of analysis: structural, thermal, electromagnetic, CFD and various types of related tasks.

TOPIC 2. Basics of work in CAD / CAE system ANSYS APDL and ANSYS Workbench

Start of ANSYS system. Description of the structure of thedialog box *ANSYS Product Launcher*. Login. Graphical user interface. Graphics and selection of objects. Assigning mouse keys. The structure of the database in the ANSYS system. List and description of ANSYS system file types.

TOPIC 3. The main stages of structural analysis in the CAD / CAE system ANSYS APDL and ANSYS Workbench

Description of the stages for performing linear structural analysis of elements of aircraft structures. PREPROCESSOR. SOLUTION. POSTPROCESSOR. Analysis of the results of the decision.

TOPIC 4. Stage of previous decisions

Choosing the type of analysis. Detailing of the calculation model. Symmetry properties of the computational model. Select the type of item. The order of the finite element. The density of a finite element grid.

TOPIC 5. Import of geometric objects in CAD / CAE system ANSYS APDL and ANSYS Workbench

Description of the main types of files that can be used to import geometric models. Configure import settings in the ANSYS system.

TOPIC 6. Fundamentals of modeling in CAD / CAE system ANSYS and ANSYS Workbench

Description of the hierarchical structure of geometric elements in the ANSYS system. Description of modeling methods: "top-down" and "bottom-up". Primitives. Working plane. Boolean operations. Types of coordinate systems. Construction of points, lines, surfaces, volumes. Operations of transformation of geometric objects. Construction of CAD model of bearing support. Construction of a CAD model of a connecting rod.

TOPIC 7. Basics of creating a finite element grid in CAD / CAE system ANSYS and ANSYS Workbench

Assign attributes to CAD model objects. Grid density control. SmartSizing option. Global item size management. The default finite element size. Local control of finite element size. Modify and delete finished element grid. Description of models of materials.

TOPIC 8. Methods of creating finite element grids in CAD / CAE system ANSYS and ANSYS Workbench

Method of free grid creation. The method of orderly grid creation. Hex-to-tet grid method. Creation of a grid by an extrusion method. Creating a grid using the Sweep method. Creating a finite element grid model of the bearing support. Creating a finite-element grid of the connecting rod model. Creating a finite-element grid of the cotter pin model. Creating a finite-element grid of the wheel model.

TOPIC 9. Fundamentals of logical selection of objects in CAD / CAE system ANSYS and ANSYS Workbench

The structure of logical selection of objects in the ANSYS system. Methods of logical selection of objects in the ANSYS system.

TOPIC 10. Basics of setting boundary conditions and application of load to the model for different types of solvable problems in CAD / CAE system ANSYS and ANSYS Workbench

Description of the boundary conditions available in the system for different types of tasks to be solved. Tasks of boundary conditions. Symmetric and asymmetric boundary conditions. Concentrated load. Load on the surface. Mass (volume) load. Inertial loads. Load for related tasks.

TOPIC 11. Basic information about the Solution module in the CAD / CAE system ANSYS and ANSYS Workbench

Description to the SOLUTION module. Setting solver options. Stages of loading, substeps and number of iterations. Output control options. Getting a solution.

TOPIC 12. Analysis of the results of the solution using the postprocessor module (POSTPROCESSOR) in the CAD / CAE system ANSYS and ANSYS Workbench

Description of the main postprocessor. Reading the results of the decision. Graphical representation of results. Presentation of results in the form of tables. Presentation of results on the selected path. Working with element tables.

TOPIC 13. Calculation of VAT of the bracket of the hinge of the unit

Application of external load to the design of the bracket and setting boundary conditions. VAT analysis of a bracket loaded with a distributed load.

TOPIC 14. Calculation of the connecting rod VAT Application of
external load to the connecting rod structure and setting boundary conditions under the conditions of geometric and force symmetry of the connecting rod model. VAT analysis of the connecting rod loaded with a distributed load.

TOPIC 15. Determination of the coefficient of stress concentration in a plate with a hole
Analysis of a plate with a hole loaded with tensile force. Determination of stress concentration factor based on the analysis of the obtained VAT results of the plate with the hole.

TOPIC 16. Calculation of VAT of a thick-walled cylinder
Analysis of the classical problem of calculation of a thick-walled cylinder loaded with internal pressure and temperature.

TOPIC 17. Calculation of VAT flat farm
Analysis of VAT design of flat farm.

TOPIC 18. Analysis of the total VAT of the nose rack of the chassis
Calculation and analysis of the total VAT of the nose rack of the truss-beam structural power scheme, loaded with concentrated forces.

TOPIC 19. Analysis of the total VAT of the caisson of the swept wing
Analysis of the total VAT in the power elements of the caisson arrow-shaped wing loaded with transverse force.

Content module 2.

VAT analysis of typical elements of aviation equipment

TOPIC 20. Calculation of the passenger seat mounting unit
Analysis of general and local VAT in the passenger seat mounting unit.

TOPIC 21. Simulation of pre-tightening in a bolted connection
Methods of modeling pre-tightening in a bolted connection are given.

TOPIC 22. Hertz problem. Contact of the cylinder with the plane
The solution of the Hertz problem is carried out

TOPIC 23. Materials testingof stretching
demonstrated the possibilitythe example of a nonlinear problem of stretching a cylindrical sample

4. Structure of discipline

Names content modules and topics	Number ofhours					
	full-time					
	total	including				
		l	n	lab	ind	SR
1	2	3	4	5	6	7
Content module 1. ***Creation of CAD models of aircraft design elements and finite element grid based on them. Analysis of the results of calculations of individual models.***						
1. Introduction. The purpose and objectives of the course. Summary of the course. References	1	1		1		2
2. General information about CAD / CAE system ANSYS	7	1		1		2
3. Basics of work in CAD / CAE system ANSYS	5	1		1		2

4. Basic stages of structural analysis in CAD / CAE system ANSYS	2	1		1		2
5. Preliminary decision stage	1	1		1		2
6. Import of geometric objects into CAD / CAE ANSYS system	2	1		1		2
7. Basics of modeling in CAD / CAE system ANSYS	12	1		1		2
8. Basics of creating a finite element grid in CAD / CAE system ANSYS	3	1		1		2
9. Methods of creating finite element grids in CAD / CAE system ANSYS	4	2		2		2
10. Fundamentals of logical selection of objects in CAD / CAE system ANSYS	2	1		1		2
11. Fundamentals of setting boundary conditions and application of load to the model for different types of solvable problems in CAD / CAE system ANSYS	8	2		2		4
12. Basic information about the Solution module in the CAD / CAE system ANSYS	4	1		1		2
13. Analysis of the results of the solution using the postprocessor module (Postprocessor) in the CAD / CAE system ANSYS и ANSYS Workbench	6	1		1		2
14. Calculation of VAT of the bracket of the hinge unit	4	1		1		2
15. Calculation of VAT of the connecting rod	3	1		1		2
16. Determination of the stress concentration factor in the plate with the hole	4	1		1		2
17. Calculation of VAT of the thick-walled cylinder	5	1		1		2
18. Calculation of VAT of a flat truss	4	1		1		2
19. Analysis of the general VAT of a nasal riser of the chassis	4	2		2	24	4
20. Analysis of the general VAT of a caisson of an arrow-shaped wing	9	2		2	24	4
Together on the semantic module 1	**142**	**24**	**-**	**24**	**48**	**46**
Content module 2. ***VAT analysis of typical elements of aviation equipment.***						
21. Calculation of the fastening unit of the passenger seat		2		2		8
22. Simulation of the pre-tightening in the bolted connection		2		2		10
23. Hertz problem. Contact of the cylinder with the plane		2		2		18
24. Testing of tensile materials		2		2		16
Total for the content module 2	**68**	**8**		**8**		**52**
Total hours	**210**	**32**		**32**	**48**	**92**

5. Topics of seminars

№ з / п	Name of the topic	Number of hours
	Not provided by the program	

6. Topics of practical classes

№ s / n	Name of topic	Number of hours
	Not provided by the program	

7. Topics of laboratory classes

№ s / n	Name of topic	Number of hours
1.	Basics of work in CAD / CAE system ANSYS and ANSYS Workbench. Preparation of geometric models.	4
2.	Creation of finite element models in ANSYS and ANSYS Workbench	2
3.	Calculation of the total VAT of the truss	2
4.	Calculation of the local VAT of the structural elements	4
5.	Determination of the stress concentration factor in the plate with the hole	2
6.	Calculation of the VAT taking into account the contact interaction. Hertz's task.	4
7.	Calculation of VAT taking into account nonlinear properties of material	2
8.	Calculation of VAT taking into account temperature stresses	4

8. Independent work

№ s / n	Topic title	Number of hours
	Content module 1.	
1	Study of the main menus of the interactive interface of ANSYS	2
2	Adjustment of visualization and model orientation in ANSY	2
3	Mastering the graphical selection of model objects	4
4	Learning the main features of the PREPROCESSOR module	12
5	Learning the main features of the SOLUTION module	10
6	Learning the models of materials available in ANSYS	2
7	Learning the basic features of the POSTPROCESSOR module	12
Content module 2.		

	Learning the main menus of the interactive interface systemANSYS Workbench	12
	Development ofgraphical object selection ANSYS Workbench model	12
	models Study materials available in the ANSYS Workbench	14
	Study of the main features of the module Static Structural	14
	total	**98**

9individual tasks

numbe r of/ n	topic	hours
1	*Analysis of the total VAT Quezon arrow-shaped cree la*	24
2	*Analysis of the general VAT of the chassis riser*	24

10. Teaching methods

Conducting practical classes, individual consultations (if necessary), independent work of students on materials published by the department (manuals) and leading aviation organizations, use of Internet materials and electronic materials posted on website of the department.

11. Methods of control

Carrying out current control, written modular control, final control in the form of offset.

12.1. Distribution points that get students (quantitative assessment criteria)

Routine testing and self-study			Final Test (test) in the case of refusal marks the current test and admission to the offset	amount
Content module 1	Content module 2	laboratory works		
T1 - T20	T20 - T-26			
0 ... 25	0… 25	0… 50	0… 100	0… 100

T1, T2 ... T12 - topics of content modules.

12.2. Qualitative evaluation criteria

Required amount of knowledge to obtain a positive assessment:

Satisfactory (60-74). Show the set minimum of knowledge. Defend all individual tasks and pass the test.

Good (75-89). Firmly know the minimum, protect all individual tasks, perform all CDs.

Excellent (90-100). Pass all checkpoints with a grade of "excellent". Thoroughly know all the topics.

The required amount of skills to obtain a positive assessment:

Satisfactory (60-74). Show the set minimum of knowledge and skills. Defend all individual tasks and pass the test.

Good (75-89). Firmly know the minimum, protect all individual tasks, perform all CDs.

Excellent (90-100). Pass all checkpoints with a grade of "excellent". Thoroughly know all the topics and be able to apply them.

12.3 Criteria for evaluating student work during the semester

Satisfactory (60-74). Have a minimum of knowledge and skills. Work out and defend all laboratory work and homework.

Good (75 - 89). Firmly know the minimum knowledge, perform all tasks. Demonstrate the ability to perform and defend all laboratory work within the period specified by the teacher with a justification of the decisions and measures proposed in the work.

Excellent (90 - 100). Fully know the basic and additional material. Know all topics. Navigate in textbooks and manuals. Unmistakably perform and defend all laboratory work within the period specified by the teacher with a detailed justification of the decisions and measures proposed in the work.

scale: point and traditional

Sum of points	GradingGrade according to the traditional scale	
	Exam, differentiated test	Credit
90 - 100	Excellent	Credited
75 - 89	Good	
60 - 74	Satisfactory	
0 - 59	Unsatisfactory	Not credited

13. Methodical support

Lecture notes and literature in the library, методичному кабінеті та в електронному вигляді на сервері кафедри проектування літаків та вертольотів (перелік приводиться нижче у розділі 14 даної програми).

14. Рекомендована література

Базова:

1. Анализ напряженно-деформированного состояния авиационных конструкций с помощью системы ANSYS [текст] / В.Н. Анпилов, А.Г. Гребеников, Д.Ю. Дмитренко и др. – Х. Нац. Аэрокосм. Ун-т “ХАИ”, АНТО “КНК”, ANSYS INC., 2008. – 410 с.
2. Методология интегрированного проектирования и моделирования сборных самолетных конструкций [текст] / А.Г. Гребеников. - Н .: Nat. aerospace XAI University, 2006. - 532 p.
3. Анализ напряженно-деформированного состояния авиационных конструкций с помощью системы ANSYS: Учеб. пособие в 2 ч. [текст] / А.Г. Гребеников, С.П. Светличный, В.Н. King, W.N. Анпилов – Х.: Нац. aerospace ун-т «ХАИ», CADFEM GmbH, АНТО «КНК», 2002. – Ч.1 – 310 с.
4. Метод конечных элементов в задачах строительной механики летательных аппаратов: учеб. пособие для вузов [текст] / И.Ф. Образцов, Л.М. Савельев, Х.С.Хазанов– М.: Высш. шк., 1985. – С. 325 – 328.
5. Проектирование самолетов: Учебник для вузов [текст] / С.М. Егер, В.Ф. Mishin, NK Liseytsev and others; Under. ed. S.M. Eger. - 3rd ed., Reworked. and ext. - M .: Mashinostroenie, 1983. - 616 s.
6. Проектирование вертолетов [текст] / В.С. Кривцов, Я.С. Karpov, LI Losev. - Textbook. - Kharkiv: Nat. aerospace Kharkiv Aviation Institute, 2003. - 344 p.
7. Fundamentals of general design of aircraft with gas turbine engines: Textbook. пособие в 2 ч. [текст] / Балабуев П.В., Бычков С.А., Гребеников А.Г., Желдоченко В.Н., Кобылянский А.А., Мялица А.К., Рябков В.И., Цепляева Т.П. - Н .: Nat. aerospace XAI University, 2003. - Part 1 - 454 p. - Part 2 - 390 p.
8. CALS (Continuous Acquisition and Life cycle Support – непрерывная информационная поддержка жизненного цикла изделия) в авиастроении [текст] / Братухин А.Г., Давыдов Ю.В., Елисеев Ю.С., Павлов Ю.Б., Суров В.И.; Ed. A.G. Bratukhina - M .: Izd-vo MAI, 2000. - 304 p.
9. Сопротивление усталости элементов конструкций [текст] / А.З. Воробьев, Б.И. Olkin, VN Stebenev et al. - M .: Mechanical Engineering, 1990. - 240 p.
10. Справочник по сопротивлению материалов [текст] / Писаренко Г.С., Яковлев А.П., Матвеев В.В. – 2-е изд., перераб. and ext. – К.: Наук. думка, 1988. – 736с.
11. Коэффициенты концентрации напряжений. Графики и формулы для расчета конструктивных

элементов на прочность [текст] / Петерсон Р. – М.: Мир, 1977. – 302 с.
12. Crawford, John. Guidelines for good Analysis: A step-by-step process for obtaining meaningful results // ANSYS Solutions. – Fall 2003. – p. 69-74.
13. Crawford, John. Interpreting Your Analysis Results: Spend time reviewing the answers to understand what they really mean // ANSYS Solutions. – Spring 2004. – P. 36-38.
14. Release 14.0 Documentation for ANSYS. Element Reference. Element Library, ANSYS Inc., 2011.
15. Release 14.0 Documentation for ANSYS. Basic Analysis Guide. Loading. Defining Pretension in a Joint Fastener, ANSYS Inc., 2011.
16. Release 14.0 Documentation for ANSYS. Basic Analysis Guide. The General Postprocessor (POST1). Reading Result Data into the Database. 5.1.3. Creating an Element Table

Допоміжна:

1. Проектирование легких самолетов [текст] / Бадягин А.А, Мухамедов Ф.А. - М .: Mashinostroenie, 1978. - 208 s.
2. Проектирование гражданских самолетов: Теории и методы [текст] / И.Я. Katyrev, MS Neymark, W.M. Sheinin et al .; Ed. G.V. Новожилова. - М .: Машиностроение, 1991. - 672 с.
3. Авиастроение: Летательные аппараты, двигатели, системы, технологи [текст] / Колл. A20 authors; под ред. A.G. Bratukhina. - М .: Машиностроение, 2000. - 536 с .: ил.
4. Материалы конференции пользователей ANSYS. – М., 2005
5. Справочник по концентрации напряжений [текст] / Савин Г.Н., Тульчий В.И. – К.: Вища школа, 1976. – 412 с

15. Інформаційні ресурси

1. Сайт кафедри проектування літаків та вертольотів **k103.khai.edu**.
2. Сервер кафедри проектування літаків та вертольотів.
3. Ресурси мережі Internet