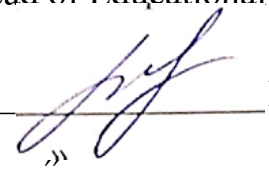
Ministry of Education and Science of Ukraine
National Aerospace University "Kharkiv Aviation Institute"

Department of composite structures and aviation materials (№ 403)

APPROVED
Head of Educational program



_____M. Shevtsova
«___» _____2020

# GRADUATING PROGRAM OF THE DISCIPLINE

Finite Element Method in Analysis of Composite Structures
(title of discipline)

Field of Study: 13 «Mechanical Engineering»
(code and title of the field of study)

Program Subject Area: 134 «Aerospace Engineering»
(code and title of the program subject area)

Educational Program: Design and Manufacturing of Composite Structures
(title of educational program)

Mode of study: Full-time

Degree: Bachelor

Kharkiv 2020

Graduating program of the discipline «**Finite Element Method in Analysis of Composite Structures**» for students by program subject area **134 «Aerospace Engineering»**, educational program **«Design and Manufacturing of Composite Structures»**.

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Prepared by:
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Head of Department of composite structures and aviation materials  M. Shevtsova

## 1. Description of educational discipline

<table>
<tr><td rowspan="2">Indicators</td><td rowspan="2">Field of Study,<br>Program Subject Area,<br>Educational Program,<br>Degree</td><td colspan="2">Characteristics<br>of the discipline</td></tr>
<tr><td colspan="2">Daily form of studying</td></tr>
<tr><td>ECTS – 8.5</td><td rowspan="15">Field of Study<br>13 Mechanical Engineering<br>(code and title)<br><br>Program Subject Area<br>134 Aerospace Engineering<br>(code and title)<br><br>Educational Program<br>«Design and Manufacturing of Composite Structures»<br><br>Degree<br>Bachelor</td><td colspan="2">Cycle of professional training (variative)</td></tr>
<tr><td>Modules – 3</td><td colspan="2">Years of studying</td></tr>
<tr><td>Substantial modules – 6</td><td colspan="2">2020 / 2021</td></tr>
<tr><td rowspan="3">Individual S&R task<br>_____<br>_____<br>(title)</td><td colspan="2">Semester</td></tr>
<tr><td>7-th</td><td>8-th</td></tr>
<tr><td colspan="2">Lectures</td></tr>
<tr><td rowspan="2">Total hours – 255</td><td>32 hrs</td><td>32 hrs</td></tr>
<tr><td colspan="2">Practical, seminar classes</td></tr>
<tr><td rowspan="2">Weekly rate for daily form of studying:<br>semester 7:<br>- auditoria – 4<br>- self-studying – 4.4<br>semester 8:<br>- auditoria – 4<br>- self-studying – 6</td><td>32 hrs</td><td>24 hrs</td></tr>
<tr><td colspan="2">Laboratory classes</td></tr>
<tr><td>-</td><td>-</td></tr>
<tr><td colspan="2">Self-studying</td></tr>
<tr><td>71 hrs</td><td>72 hrs</td></tr>
<tr><td colspan="2">Individual studying</td></tr>
<tr><td>–</td><td>–</td></tr>
<tr><td colspan="2">Control</td></tr>
<tr><td>exam</td><td>exam</td></tr>
</table>

**Notes:**
Ratio between auditoria classes to self-studying and individual studying (hours): 56/64.
in 7-th semester – 64 / 71;
in 8-th semester – 48 / 72.

## 2. Objective and aims of the discipline

**Objectives:** formation of students' professional profile knowledge and practical skills to calculate the strength and stability of composite structures, in particular by the finite element method.

**Aims:** study of modern numerical methods for calculating the strength and stability of composites and the acquisition of skills in modeling elements of aircraft structures using the system of engineering analysis MSC.Patran / Nastran.

As a result of studying the discipline the student must be able to:

- to calculate the elements of aviation and rocket and space technology, including composite materials using knowledge in the field of mechanics and strength of materials and structures;
- use the appropriate software (programming languages, packages) for physical and mathematical calculations in the field of design and manufacture of composite structures;
- to calculate the stress-strain state, to determine the bearing capacity of structural elements of aviation and rocket and space technology, including composite materials.

## 3. Content of the discipline

**Module 1. Introduction to the finite element method.**

**Substantial module 1. Variation methods.**

**Topic 1.** Basic equations of the linear theory of elasticity.

**Topic 2.** Variational principles of mechanics of a deformable solid. Variation methods.

**Topic 3.** Examples of solving problems of structural mechanics by the Rayleigh-Ritz variational method

**Module control №1.**

**Substantial module 2. Introduction to the finite element method.**

**Topic 4.** Theoretical basis of finite element method.

**Topic 5.** Construction of a stiffness matrix of a one-dimensional element of the beam type.

**Topic 6.** Application of the finite element method for calculation of one-dimensional systems.

**Topic 7.** Construction of stiffness matrices of two-dimensional finite elements.

**Module control №2.**

**Module 2. The main features of MSC.PATRAN / NASTRAN.**

**Substantial module 3. Basic tools MSC.PATRAN / NASTRAN.**

**Topic 8.** Introduction to MSC.PATRAN / NASTRAN. Construction of geometric models**.**

**Topic 9.** Creating a finite element grid**.**

**Topic 10.** Boundary conditions and external loads**.**

**Topic 11.** Types of analysis. Display of calculation results.

**Topic 12.** Calculation of structural elements in MSC.PATRAN / NASTRAN

**Module control №3.**

**Module 3. Solving dynamics problems by means of MSC.PATRAN / NASTRAN.**

**Substantial module 4. Advanced functions MSC.PATRAN / NASTRAN.**

**Topic 13.** Application of the Laminate Modeler module for modeling and calculation of the strength of composite structures**.**

**Topic 14.** Modelling of special conditions of interaction of nodes and finite elements**.**

**Topic 15.** Modelling of contact conditions.

**Topic 16.** Additional tools MSC.PATRAN for creating finite-element models of structures.

**Module control №1.**

**Substantial module 5. Fundamentals of nonlinear analysis of structures.**

**Topic 17.** Methods of nonlinear analysis of structures**.**

**Topic 18.** Solving nonlinear problems in MSC.PATRAN / NASTRAN**.**

**Module control №2.**

**Substantial module 6. Fundamentals of dynamic analysis of structures.**

**Topic 19.** Equation of motion of dynamical systems.
**Topic 20.** Damping.
**Topic 21.** Analysis of natural frequencies and forms of oscillations of structures.
**Topic 22.** Introduction to the theory of vibration.
**Topic 23.** Analysis of transients.
**Topic 24.** Frequency analysis of structures.
**Module control №3.**

## 4. Arrangement of the discipline

| Substantial modules and topics | Hours | | | | | |
|---|---|---|---|---|---|---|
| | Total | including | | | | |
| | | Lectures | Practical works | Labs. | Ind. work | Self-studying |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **Module 1. Introduction to the finite element method** | | | | | | |
| **Substantial module 1. Variation methods** | | | | | | |
| Topic 1. Basic equations of the linear theory of elasticity | 5 | 2 | – | – | – | 3 |
| Topic 2. Variational principles of mechanics of a deformable solid. Variation methods | 6 | 4 | – | – | – | 2 |
| Topic 3. Examples of solving problems of structural mechanics by the Rayleigh-Ritz variational method | 6 | 2 | 2 | – | – | 2 |
| Module control №1 | 4 | – | 2 | – | – | 2 |
| Total in substantial module 1 | **21** | **8** | **4** | **0** | **0** | **9** |
| **Substantial module 2. Introduction to the finite element method** | | | | | | |
| Topic 4. Theoretical basis of finite element method | 6 | 2 | – | – | – | 4 |
| Topic 5. Construction of a stiffness matrix of a one-dimensional element of the beam type | 4 | 2 | – | – | – | 2 |
| Topic 6. Application of the finite element method for calculation of one-dimensional systems | 10 | 4 | 2 | – | – | 4 |
| Topic 7. Construction of stiffness matrices of two-dimensional finite elements | 8 | 4 | – | – | – | 4 |
| Module control №2 | 6 | – | 2 | – | – | 4 |
| Total in substantial module 2 | **34** | **12** | **4** | **0** | **0** | **18** |
| **Module 2. The main features of MSC.PATRAN / NASTRAN** | | | | | | |
| **Substantial module 3. Basic tools MSC.PATRAN / NASTRAN** | | | | | | |
| Topic 8. Introduction to MSC.PATRAN / NASTRAN. Construction of geometric models | 8 | 2 | 2 | – | – | 4 |
| Topic 9. Creating a finite element grid | 8 | 2 | 2 | – | – | 4 |
| Topic 10. Boundary conditions and external loads | 10 | 4 | 2 | – | – | 4 |
| Topic 11. Types of analysis. Display of calculation results | 10 | 4 | 2 | – | – | 4 |
| Topic 12. Calculation of structural elements in MSC.PATRAN / NASTRAN | 38 | – | 14 | – | – | 24 |
| Module control №3 | 6 | – | 2 | – | – | 4 |
| Total in substantial module 3 | **80** | **12** | **24** | **0** | **0** | **44** |
| **Total in 7-th semester** | **135** | **32** | **32** | **–** | **–** | **71** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Module 3. Solving dynamics problems by means of MSC.PATRAN / NASTRAN** | | | | | | |
| **Substantial module 4. Advanced functions MSC.PATRAN / NASTRAN** | | | | | | |
| Topic 13. Application of the Laminate Modeler module for modeling and calculation of the strength of composite structures | 8 | 2 | 2 | – | – | 4 |
| Topic 14. Modelling of special conditions of interaction of nodes and finite elements | 12 | 2 | 4 | – | – | 6 |
| Topic 15. Modelling of contact conditions | 8 | 2 | 2 | – | – | 4 |
| Topic 16. Additional tools MSC.PATRAN for creating finite-element models of structures | 8 | 2 | 2 | – | – | 4 |
| Module control №1 | 6 | – | 2 | – | – | 4 |
| Total in substantial module 4 | **42** | **8** | **12** | **0** | **0** | **22** |
| **Substantial module 5. Fundamentals of nonlinear analysis of structures** | | | | | | |
| Topic 17. Methods of nonlinear analysis of structures | 6 | 2 | – | – | – | 4 |
| Topic 18. Solving nonlinear problems in MSC.PATRAN / NASTRAN | 12 | 2 | 2 | – | – | 8 |
| Module control №2 | 6 | – | 2 | – | – | 4 |
| Total in substantial module 5 | **24** | **4** | **4** | **0** | **0** | **16** |
| **Substantial module 6. Fundamentals of dynamic analysis of structures** | | | | | | |
| Topic 19. Equation of motion of dynamical systems | 6 | 2 | – | – | – | 4 |
| Topic 20. Damping | 6 | 2 | – | – | – | 4 |
| Topic 21. Analysis of natural frequencies and forms of oscillations of structures | 10 | 2 | 2 | – | – | 6 |
| Topic 22. Introduction to the theory of vibration | 6 | 2 | – | – | – | 4 |
| Topic 23. Analysis of transients | 10 | 2 | 2 | – | – | 6 |
| Topic 24. Frequency analysis of structures | 10 | 2 | 2 | – | – | 6 |
| Module control №3 | 6 | – | 2 | – | – | 4 |
| Total in substantial module 6 | **54** | **12** | **8** | **0** | **0** | **34** |
| **Total in 8-th semester** | **120** | **24** | **24** | **–** | **–** | **72** |
| **Total hours** | **255** | **56** | **56** | **–** | **–** | **143** |

## 5. Topics of practical classes

| № | Topics | Hours |
|---|---|---|
| **1** | **2** | **3** |
| 1 | Calculation of statically determined beams by Rayleigh - Ritz method | 2 |
| 2 | Modular control №1. Selection of the approximating function and recording of the variational functional for the calculation of beams by the Rayleigh - Ritz method | 2 |
| 3 | Solving the problem of transverse bending of the ITU beam using one finite element | 2 |
| 4 | Modular control №2. Construction of a stiffness matrix for rectangular and triangular two-dimensional elements from orthotropic materials | 2 |
| 5 | Construction of one-dimensional and two-dimensional geometric models | 2 |
| 6 | Construction of a grid of finite elements based on one-dimensional and two-dimensional geometric models | 2 |
| 7 | Imposition of boundary conditions and external loads based on geometric and finite element primitives | 2 |

| 1 | 2 | 3 |
|---|---|---|
| 8 | Performing static analysis of the frame and plotting force factors, stresses and displacements | 2 |
| 9 | Static calculation of the beam based on a one-dimensional geometric model in several calculation cases | 2 |
| 10 | Static calculation and analysis of the stability of a smooth panel of composite material | 2 |
| 11 | Static calculation and analysis of the stability of the composite panel with aggregate | 2 |
| 12 | Static calculation and analysis of the stability of the panel with a hole made of composite material | 2 |
| 13 | Static calculation and analysis of the stability of a composite beam based on a two-dimensional geometric model in several calculation cases | 3 |
| 14 | Static calculation and stability analysis of a composite reinforced panel | 3 |
| 15 | Modular control №3. Analysis of strength and stability of structures in the software package MSC.PATRAN / NASTRAN | 2 |
| | Total in 7-th semester | 32 |
| 1 | Analysis of the strength of the composite panel by different criteria | 2 |
| 2 | Static calculation and analysis of the stability of the shaped structure | 2 |
| 3 | Static calculation and analysis of the stability of a composite beam with a strut | 2 |
| 4 | Static calculation of single-bolt connection of composite and metal parts | 2 |
| 5 | Static calculation of a simplified model of a multi-row bolted connection | 2 |
| 6 | Modular control №1. Analysis of the strength and stability of the composite shell rotation | 2 |
| 7 | Nonlinear static analysis of supercritical behavior of a composite panel | 2 |
| 8 | Modular control №2. Nonlinear static analysis of the beam | 2 |
| 9 | Analysis of the natural frequencies of the composite shell | 2 |
| 10 | Analysis of the stress-strain state of a composite beam under impact | 2 |
| 11 | Analysis of the amplitude-frequency characteristics of the composite beam under the influence of sinusoidal vibration | 2 |
| 12 | Modular control №3. Analysis of natural frequencies of elements of composite structures | 2 |
| | Total in 8-th semester | 24 |
| | Total hours | 56 |

## 6. Self-studying topics

| № | Topics | Hours |
|---|---|---|
| **1** | **2** | **3** |
| 1 | Recording the stiffness matrix of isotropic, orthotropic and anisotropic materials | 3 |
| 2 | Variational methods for solving problems of structural mechanics. Bubnov-Galerkin principle | 2 |
| 3 | Solving problems of structural mechanics by the variation method of Rayleigh - Ritz | 2 |
| 4 | Preparation for modular control №1 | 2 |
| 5 | Theoretical foundations of the finite element method | 4 |
| 6 | Construction of a stiffness matrix of a one-dimensional element of the rod type | 2 |
| 7 | Calculation of the ITU beam using two 2-node finite elements. Calculation of the ITU beam using one 3-node finite element | 4 |
| 8 | Construction of stiffness matrices of two-dimensional triangular finite elements | 4 |

| 1 | 2 | 3 |
|---|---|---|
| 9 | Preparation for modular control №2 | 4 |
| 10 | The basic structure of the software environment MSC.PATRAN / NASTRAN | 4 |
| 11 | Creating a grid of finite elements | 4 |
| 12 | Boundary conditions and external loads | 4 |
| 13 | Types of analysis. Display of calculation results | 4 |
| 14 | Calculation of structural elements in MSC.PATRAN / NASTRAN | 24 |
| 15 | Preparation for modular control №3 | 4 |
| | Total in 7-th semester | 71 |
| 1 | Features of modeling and calculation of the strength of composite structures | 4 |
| 2 | Modeling of special conditions of interaction of nodes and finite elements | 6 |
| 3 | Modeling of contact conditions | 4 |
| 4 | Additional tools for creating finite-element models of structures | 4 |
| 5 | Preparation for modular control №1 | 4 |
| 6 | Methods of nonlinear analysis of structures | 4 |
| 7 | Solving nonlinear problems in MSC.PATRAN / NASTRAN | 8 |
| 8 | Preparation for modular control №2 | 4 |
| 9 | Equations of motion of dynamical systems | 4 |
| 10 | Damping | 4 |
| 11 | Analysis of natural frequencies and forms of oscillations of structures | 6 |
| 12 | Introduction to the theory of vibration | 4 |
| 13 | Analysis of transients | 6 |
| 14 | Frequency analysis of structures | 6 |
| 15 | Preparation for modular control №3 | 4 |
| | Total in 8-th semester | 72 |
| | Total hours | 143 |

## 7. Methods of studying

Conduction of auditoria lectures, practical classes, individual consultation (if necessary), students self-studying by materials published by department (workbooks and textbooks).

## 8. Methods of control

Current control in the form grading the practical works, module controls in the form of testing, final exam (if required).

## 9. Score points distribution

| Components of educational work | Scores for one entity | | Number of classes | Total scores | |
|---|---|---|---|---|---|
| | min | max | | min | min |
| Module control №1 | 12 | 20 | 1 | 12 | 20 |
| Practical classes | 3 | 5 | 1 | 3 | 5 |
| Total in substantial module | | | | **15** | **25** |
| Module control №2 | 12 | 20 | 1 | 12 | 20 |
| Practical classes | 3 | 5 | 1 | 3 | 5 |
| Total in substantial module | | | | **15** | **25** |
| Module control №3 | 12 | 20 | 1 | 12 | 20 |
| Practical classes | 3 | 5 | 6 | 18 | 30 |
| Total in substantial module | | | | **30** | **50** |
| Total in 7-th semester | | | | **60** | **100** |

| | | | | | |
|---|---|---|---|---|---|
| Module control №1 | 6 | 10 | 1 | 6 | 10 |
| Practical classes | 6 | 10 | 4 | 24 | 40 |
| Total in substantial module | | | | **30** | **50** |
| Module control №2 | 6 | 10 | 1 | 6 | 10 |
| Total in substantial module | | | | **6** | **10** |
| Module control №3 | 6 | 10 | 1 | 6 | 10 |
| Practical classes | 6 | 10 | 3 | 18 | 30 |
| Total in substantial module | | | | **24** | **40** |
| Total in 8-th semester | | | | **60** | **100** |

## Estimation scale: national and ECTS

| **Total score by all studying activities** | **ECTS scale** | **Mark by national scale** |
|---|---|---|
| 90 – 100 | A | excellent |
| 83 – 89 | B | good |
| 75 – 82 | C | |
| 68 – 74 | D | satisfactory |
| 60 – 67 | E | |
| 1 – 59 | FX | not passed (repassing is allowed) |

## 10. Methodological support

Methodical instructions for performing practical work, as well as for settlement work.