БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ /
BELARUSIAN STATE UNIVERSITY

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МНОГОПАРАМЕТРИЧЕСКОЕ МОДЕЛИРОВАНИЕ И АНАЛИЗ СЛОЖНЫХ ТЕХНИЧЕСКИХ СИСТЕМ И ПРОЦЕССОВ/ MULTI-PARAMETER MODELING AND ANALYSIS OF COMPLEX TECHNICAL SYSTEMS AND PROCESSES

Учебная программа учреждения образования по учебной дисциплине для специальности:
The program of the educational institution of the discipline for the speciality:

Специальность / Speciality: 7-06-0533-06 Механика и математическое моделирование/ 7-06-0533-06 Mechanics and Mathematical Modelling

Профилизация / Profilization: Теоретическая и прикладная механика/Theoretical and Applied Mechanics

2024

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ПОЯСНИТЕЛЬНАЯ ЗАПИСКА

Цели и задачи учебной дисциплины

Цель учебной дисциплины – повышение уровня профессиональной компетентности в решении проблем многопараметрического моделирования и анализа сложных технических систем и процессов. Формирование у студентов навыков и умений, связанных с основными методами компьютерного моделирования сложных технических систем, процессов, механизмов и машин. Формирование установки на творческую профессиональную деятельность; развитие профессионального мышления, которое обеспечило бы будущему специалисту возможность свободно оперировать профессиональными знаниями, видеть проблемы и оптимальные пути их решения в самостоятельной практической деятельности.

Задачами учебной дисциплины «Многопараметрическое моделирование и анализ сложных технических систем и процессов» являются:

1. развитие навыков проектирования, моделирования, построения и анализа инженерных проектов;
2. ознакомление магистрантов с основами численных методов моделирования и оптимизации проектов и их компьютерной реализации в современных пакетах программ;
3. обучение магистрантов корректной постановке задач многопараметрического моделирования и анализа сложных технических систем и процессов;
4. формирование навыков практического решения задач компьютерного анализа сложных технических систем, процессов, механизмов и машин.

Место учебной дисциплины в системе подготовки специалиста с углубленным высшим образованием (магистра).

Дисциплина «Многопараметрическое моделирование и анализ сложных технических систем и процессов» посвящена изучению изучению математических подходов и методов, направленных на решение задач многопараметрического моделирования сложных технических систем, описанию напряженно-деформированного состояния твердых тел.

Учебная дисциплина входит **в модуль** «Математическое моделирование в машиностроении» компонента учреждения образования.

Рассматриваются конкретные приложения и примеры решения задач механики деформируемого твердого тела и механики стержневых систем с постановкой граничных задач и использованием прикладных математических методов.

Учебная программа составлена с учетом межпредметных связей и программ по дисциплинам: «Конечно-элементные методы», «Механика сплошных сред» и «Механика современных материалов».

Требования к компетенциям

Освоение учебной дисциплины «Многопараметрическое моделирование и анализ сложных технических систем и процессов» должно обеспечить формирование следующей **специализированной компетенции:**

СК-1. Овладеть методами математического моделирования при анализе сложных технических систем и процессов, многофазных сред, при решении задач механики.

В результате изучения дисциплины «Многопараметрическое моделирование и анализ сложных технических систем и процессов » магистрант должен:

знать:

- проблематику многопараметрического аналитического и компьютерного моделирования элементов, узлов машин и механизмов;
- общую постановку задач оптимизации, этапы постановки и решения оптимизационных задач, стратегию оптимизационных исследований;
- методику составления математической модели, целевой функции;
- математические методы решения задач многопараметрического моделирования элементов, узлов машин и механизмов.

уметь:

- рассчитывать и визуализировать с помощью компьютерных средств процессы многопараметрического моделирования элементов и узлов машин и механизмов с учетом их механических характеристик, начальных и граничных условий;
- выполнять проектировочные расчеты основных типов деталей и узлов машин в основных пакетах компьютерного моделирования и проводить анализ полученных результатов.

иметь навык:

- компьютерными методами моделирования и решения типичных задач многопараметрического моделирования;
- методами проведения компьютерной симуляции основных типов деталей и узлов машин с учетом многопараметрического анализа;
- методами компьютерного моделирования, проектирования и оптимизации основных типов деталей и узлов машин (в пакете SolidWorks и ANSYS).

Структура учебной дисциплины

Дисциплина изучается в 3 семестре. Всего на изучение учебной дисциплины «Многопараметрическое моделирование и анализ сложных технических систем и процессов» отведено:

– для очной формы получения углубленного высшего образования: 90 часов, в том числе 36 аудиторных часа, из них: лекции – 18 часов, практические занятия – 18 часов.

Трудоемкость учебной дисциплины составляет 3 зачетные единицы.

Форма промежуточной аттестации по учебной дисциплине – зачет.

EXPLANATORY NOTE

Aim and tasks of the discipline

Aim of the discipline – to increase the level of professional competence in solving problems of multi-parameter modeling and analysis of complex technical systems and processes. Formation of students' skills and abilities related to the basic methods of computer modeling of complex technical systems, processes, mechanisms and machines. Formation of the attitude to creative professional activity; development of professional thinking, which would provide the future specialist with the ability to operate freely with professional knowledge, to see problems and optimal ways of their solution in independent practical activity.

The tasks of the educational discipline “Multi-parameter modeling and analysis of complex technical systems and processes” are:

1. development of skills of designing, modeling, construction and analysis of engineering projects;
2. acquaint master students with the basics of numerical methods of modeling and optimization of projects and their computer implementation in modern software packages;
3. training of undergraduates in correct formulation of problems of multi-parametric modeling and analysis of complex technical systems and processes;
4. formation of skills of practical solution of problems of computer analysis of complex technical systems, processes, mechanisms and machines.

Place of the academic discipline in the system of training a specialist with advanced higher education.

The academic discipline is part of the module “Mathematical modeling in Engineering”.

The program is designed taking into account the interdisciplinary connections and programs for the disciplines: “Finite element methods”, “Continuum mechanics” and “Mechanics of advanced materials”.

Requirements for competences

Mastering of the academic discipline “Multi-parameter modeling and analysis of complex technical systems and processes” should provide the formation of the following special competences*:*

to master the methods of mathematical modeling in the analysis of complex technical systems and processes, multiphase environments, when solving mechanics problems.

As a result of mastering the academic discipline, the student is expected to:

know:

– problems of multi-parameter analytical and computer modeling of elements, units of machines and mechanisms;

– general formulation of optimization problems, stages of formulation and solution of optimization problems, strategy of optimization studies;

– methodology of compiling a mathematical model, target function;

– mathematical methods of solving problems of multi-parameter modeling of elements, units of machines and mechanisms;

– calculate and visualize with the help of computer means the processes of multi-parameter modeling of elements and units of machines and mechanisms taking into account their mechanical characteristics, initial and boundary conditions;

– perform design calculations of the main types of parts and units of machines in the main packages of computer modeling and analyze the obtained results;

have skills in:

– computer methods of modeling and solving typical problems of multi-parameter modeling;

– methods of computer simulation of the main types of parts and assemblies of machines taking into account multi-parameter analysis;

– methods of computer modeling, design and optimization of the main types of parts and assemblies of machines (in SolidWorks and ANSYS).

Structure of the academic discipline

The discipline is studied in the 3rd semester. In total for the study of the discipline «Multi-parameter modeling and analysis of complex technical systems and processes» is allocated:

– for full-time advanced higher education – 90 hours, including 36 in-class hours, of them: lectures – 18 hours, practical classes – 18 hours.

The labour intensity of the discipline is 3 credit units. Form of certification – end-of-term test.

CONTENT OF THE STUDY MATERIAL

Section 1 Theoretical information

Topic 1.1 Mathematical methods for solving optimization problems

The general formulation of the optimization problem. Mathematical optimization problem. Limited application of the differentiation method to solve the optimization problem. The stages of formulation and solving optimization problems. Strategy of optimization research. Composition of mathematical model. The target function. Criteria for optimization of mode problems. Limitations on variables.

Topic 1.2 Optimization concepts

Optimization objectives. Design parameters. One-dimensional optimization. The target function. An example of Example of optimization problem formulation. Local and global minima. The Weierstrass theorem. Search methods. The interval of uncertainty. The golden ratio method. Unconditional and conditional optimization. Analytical and numerical methods for solving the problem of unconditional one-dimensional optimization. An analytical method for finding a local minimum. Search methods. Sequential search methods. Scanning methods (direct iteration). The method of dividing a segment in half. Unimodal functions.

Topic 1.3 Methods for solving linear programming problems

Formation of a mathematical model based on a meaningful statement of the problem. Mathematical assumptions for the linear programming problem. The basic problem of linear programming. The first standard form of a linear programming problem. The second standard form of the linear programming problem. The canonical form. Rules of reduction. Geometric method for solving the linear programming problem. The theorem on optimal extreme points. Simplex algorithm. The canonical maximization (minimization) problem. Equivalent transformations. The basic solution of a system of linear equations. Classification of simplex tables. The algorithm of the direct simplex method (maximization). Linear programming. Nonlinear programming. Stochastic programming. Dynamic programming. Multi-criteria optimization.

Topic 1.4 Multiparametric optimization

Mathematical models for the implementation of optimal choice problems. Methods of multiparametric optimization. A classic linear programming problem. The method of successive concessions. An example of a multiparametric optimization problem. Method of finding a compromise target function. The formula for calculating compromise coefficients. An example of a multiparametric optimization problem.

Section 2. Practical examples of multiparametric modeling

Topic 2.1 Topological optimization in ANSYS ADJOINT SOLVER

Topological optimization in Ansys - beam. Topological optimization in Ansys - lever. Topological optimization in Ansys - bracket. Topological optimization in Ansys - pillar. Topological optimization in Ansys APDL. Parametric optimization in Ansys Workbench. Parameter Optimization in Ansys APDL.

Topic 2.1 Multi-parameter optimization using SOLIDWORKS computer system

Topology study: non-parametric optimization in Solidworks Simulation of beams. Parameter configuration in SolidWorks package. Topological optimization in Solidworks. Topological optimization: reverse engineer meshes produced by Solidworks. Topology study: nonparametric optimization in Solidworks Simulation of beams. Topology study: non-parametric optimization in Solidworks Simulation of a bracket. Solidworks Parametric Compression Spring.

TEACHING AND METHODOLOGICAL MAP OF THE DISCIPLINE

Full-time form of higher education with the use of distance learning technologies (DLT)

Title of section, topic	Title of section, topic	In-class hours					Independent work	Form of control
		Lectures	Practical classes	Seminar classes	Laboratory classes	Other		
1	2	3	4	5	6	7	8	9
1.1	Mathematical methods for solving optimization problems	4						interview
1.2	Optimization concepts	4						interview
1.3	Methods for solving linear programming problems	6						interview
1.4	Multiparametric optimization	4						interview
2.1	Topological optimization in ANSYS ADJOINT SOLVER				10			problem solutions, laboratory reports
2.2	Multi-parameter optimization using SOLIDWORKS computer system				8			problem solutions, laboratory reports

INFORMATION AND METHODOLOGICAL PART

List of basic literature

1. Ray M. Bowen. Introduction to Continuum Mechanics for Engineers. Published By Plenum Press. 2007. (Revised Edition).
2. Zhuravkov M., Lyu Y., Starovoitov E. Mechanics of Solid Deformable Body. Springer. 2023. 317p. 2.
3. Горлач Б.А. Математическое моделирование. Построение моделей и численная реализация: учебное пособие для студентов вузов, обучающихся по программам высшего образования в областях: "Инженерное дело, технологии и технологические науки" и "Науки об обществе" / Б. А. Горлач, В. Г. Шахов. - Изд. 5-е, стер. - Санкт-Петербург ; Москва ; Краснодар : Лань, 2023. - 291 с. URL: https://e.lanbook.com/book/305219.

List of additional literature

1. Lyu Y. Finite Element Method Element Solutions. – Springer, 2022. – 191 p
2. Jamshid Ghaboussi, Xiping Steven Wu. Numerical Methods in Computational Mechanics. Published 2019 by CRC Press. 332 p.
3. Zienkiewicz O.C., Taylor R.L., Zhu J.Z. The Finite Element Method: Its Basis and Fundamentals. Sixth edition. Elsevier Butterworth Heinemann, 2005. – 719 p.

Approximate list of assignments for controlled self-study

The object of diagnostics of Master's students' competences is the knowledge and skills acquired by them as a result of studying the academic discipline. Diagnostics of Master's students' educational achievements is carried out by means of current control and interim certification.

Diagnostics of the results of learning activities in the discipline “Multi-parameter modeling and analysis of complex technical systems and processes” is carried out, as a rule, during classroom training. For diagnostics are used:

- questions for self-checking;
- oral questioning;
- reports on laboratory works.

Assessment for answers at lectures (questioning) and laboratory classes includes the completeness of the answer, the presence of arguments, examples from practice.

Control activities are carried out in accordance with the educational-methodical map of the discipline.

For undergraduates who missed the control events or received an unsatisfactory mark, the decision to repeat the control event is made in accordance with the Regulations on the rating system of assessment of knowledge of students in the academic discipline at the Belarusian State University.

The form of intermediate certification in the discipline “Multi-parameter modeling and analysis of complex technical systems and processes” the curriculum provides credit.

Approximate list of laboratory classes

Laboratory work Nº 1. Topological optimization in Ansys - beam, pillar.

Laboratory work Nº 2. Topological optimization in Ansys - lever, bracket.

Laboratory work Nº 3. Topological optimization in Ansys APDL.

Laboratory work Nº 4. Parametric optimization in Ansys Work-bench.

Laboratory work Nº 5. Parameter Optimization in Ansys APDL.

Laboratory work Nº 6. Topology study: non-parametric optimization in Solidworks Simulation of beams.

Laboratory work Nº 7. Parameter configuration in SolidWorks package. Topological optimization in Solidworks.

Laboratory work Nº 8. Topology study: non-parametric optimization in Solidworks Simulation of a bracket.

Laboratory work Nº 9. Solidworks Parametric Compression Spring.

Form of control - lab report.

Description of innovative approaches and methods for teaching the discipline

When organizing the educational process the practice-oriented approach is used, which implies:

- mastering the content of education through solving practical problems;
- acquiring skills to effectively perform different types of professional activities;
- using procedures, methods of evaluation, fixing the formation of professional competencies.

Methodological recommendations for the organization of independent work

1. Self-work while working through the literature.

Review the lecture notes immediately after class. Mark the material in the lecture notes that is difficult to understand.

Try to find answers to difficult questions, using the proposed literature.

If you are unable to understand the material on your own, formulate questions and ask the instructor for help at the next lecture.

It is recommended to set aside time each week to review the material you have learned by testing your knowledge, skills, and abilities by completing the test questions.

2. Independent work on making an outline.

1. Collect literature on the topic. Study the source where it is presented in the most complete and up-to-date manner.

2. Based on this source, make a detailed outline, indicating the pages of the book that relate to a particular point of the outline.

3. Study other sources. If they contain material on the already existing point of the plan, write down in the plan and the new source, indicating the pages. If the material in the other source reveals the topic from a different perspective, add another paragraph to the outline.
4. Having analyzed all the literature collected on the topic, you will get a final plan, on which you can write an outline, combining the material from different sources.
5. Edit your outline, read it carefully and think: - whether you are satisfied with its general plan; - whether the semantic, logical connection between the individual elements of the content is well perceived; - whether the quotations are successfully used, whether the connection between turns of speech and phrases is correctly established; - whether the punctuation marks in the quotations are correctly placed.

3. Preparation for laboratory classes

The purpose of laboratory classes is to deepen and elaborate the theoretical material of the subject through regular and systematic independent work of students throughout the course. Directly conducting a laboratory class involves: solving problems and exercises according to the sample; analyzing the results; systematizing the material and preparing a report on the work done.

Instruction:

Study normative documents, obligatory and additional literature on the issue under consideration.

read the lecture notes on the topic.

Carefully study the order of execution of individual practical work or the algorithm presented by the teacher.

4. Preparing for credit

Carefully read the material on the outline prepared at the training session.

Read the same material from the textbook, study guide.

Try to understand the unclear, in particular new terms. Often ignorance of terminology prevents students from perceiving the material in the classroom at the proper level.

Answer the self-check questions in the textbook.

Briefly retell the content of the studied material “in your own words”.

Memorize “working definitions” of basic concepts and laws.

Having mastered the theoretical material, proceed to the performance of tasks, exercises, solving problems, calculations on individual tasks, etc.

Approximate list of questions for the end-of-term test

1. Mathematical optimization problem.
2. Limited application of the differentiation method to solve the optimization problem.
3. The stages of setting and solving optimization problems.
4. Optimization research strategy.
5. Composition a mathematical model.
6. Objective function. Constraints on variables.
7. Optimization problems. Design parameters.

8. One-dimensional optimization.
9. An example of setting an optimization problem.
10. Local and global minima.
11. Search methods. The Golden Ratio method.
12. Unconditional and conditional optimization.
13. Analytical and numerical methods for solving the problem of unconditional one-dimensional optimization.
14. Analytical method of finding a local minimum.
15. Sequential search methods. Scanning methods (direct search).
16. The method of dividing a segment in half.
17. Formation of a mathematical model based on a meaningful statement of the problem.
18. Mathematical assumptions for linear programming problem.
19. The second standard form of the linear programming problem.
20. Geometric method for solving the linear programming problem.
21. The theorem on optimal extreme points.
22. Simplex method for solving the linear programming problem.
23. The canonical problem of maximizing (minimizing).
24. Equivalent transformations.
25. Basic solution of a system of linear equations.
26. Classification of simplex tables.
27. The algorithm of the direct simplex method (maximization).
28. Linear programming. Nonlinear programming.
29. Stochastic programming. Dynamic programming.
30. Multi-criteria optimization.
31. Mathematical models for the implementation of optimal choice tasks.
32. Methods of multiparametric optimization.
33. The classical linear programming problem.
34. The method of successive concessions.
35. An example of a multiparametric optimization problem.
36. A method for finding a compromise objective function.
37. The formula for calculating compromise coefficients.

ПРОТОКОЛ СОГЛАСОВАНИЯ УЧЕБНОЙ ПРОГРАММЫ УО

Название учебной дисциплины, с которой требуется согласование	Название кафедры	Предложения об изменениях в содержании учебной программы учреждения высшего образования по учебной дисциплине	Решение, принятое кафедрой, разработавшей учебную программу (с указанием даты и номера протокола)
Учебная дисциплина не требует согласования			

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28.05.2024

ДОПОЛНЕНИЯ И ИЗМЕНЕНИЯ К УЧЕБНОЙ ПРОГРАММЕ
ПО ИЗУЧАЕМОЙ УЧЕБНОЙ ДИСЦИПЛИНЕ

на _____/_____ учебный год

№ п/п	Дополнения и изменения	Основание

Учебная программа пересмотрена и одобрена на заседании кафедры
_____(протокол № ____ от _____ 202_ г.)

Заведующий кафедрой
_____ _____

УТВЕРЖДАЮ
Декан факультета
_____ _____