National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

Department of Chemical Engineering and Oil Refining Industry

COMPUTER DESIGN OF ROTATING ELEMENTS OF CHEMICAL EQUIPMENT

Working program of the academic discipline (Syllabus)

Level of higher education	***Second (master's)***
Branch of knowledge	*G Engineering, Production and Building*
Specialty	*G11 Machinery Engineering (by specialization)*
Educational program	*Process and Equipment Engineerings*
Discipline status	*Selective*
Form of education	*Full-time (day/distance/mixed)*
Year of training, semester	*1st year, spring semester, ЛМ-51мп*
Scope of the discipline	*5 ECTS credits, 150 hours*
Semester control/ control measures	*examination, current control*
Lessons schedule	*Lectures - 2 hours every week, practical – 1,07 hours week*
Language of teaching	*Ukrainian*
Information about the lector / teachers	***Lector:*** *Ph.D. Husarova O.V.* *contact details: phone +380663120701, O.V.Husarova@nas.gov.ua* ***Practical:*** *Ph.D. Husarova O.V.* *contact details: phone +380663120701,O.V.Husarova@nas.gov.ua* ***Laboratory:*** *not provided for in the curriculum*
Placement of the course	https://classroom.google.com

Program of educational discipline

1. Description of the educational discipline, its purpose, subject of study and learning outcomes

The discipline "Computer design of rotating elements of chemical equipment" considers the issue of ensuring strength, stability, rigidity, tightness, corrosion resistance, structural perfection and manufacturability, as well as other requirements for the given basic technological equipment of chemical industries.

The subject of the academic discipline

The discipline considers the issue of ensuring strength, stability, rigidity, tightness, corrosion resistance, structural perfection and manufacturability, as well as other requirements for the given basic technological equipment of chemical industries with the use of computer-integrated calculation and design technologies.

The discipline contributes to the development of professional self-awareness, the culture of communication, the formation of theoretical, practical and personal motivational components of professional competence.

1.1. The purpose of the educational discipline

The purpose of the educational discipline is to form students' competence:

- *ability to design activities in the field of engineering and technology;*
- *the ability to apply industry standards within the framework of one's professional tasks;*
- *the ability to present technical documentation in accordance with the requirements of current systems and design documentation standards;*
- *the ability to analyze scientific and technical information, domestic and foreign experience in chemical engineering techniques and technology;*
- *ability to design technological equipment of chemical industries;*
- *the ability to work independently, individually, to make decisions within the framework of one's professional tasks;*
- *the ability to implement advanced engineering developments to obtain practical results.*

1.2. The main tasks of the academic discipline

According to the requirements of the educational and professional program, students, after mastering the academic discipline, must demonstrate the following learning outcomes:

KNOWLEDGE:

- *modern approaches, methods and techniques for solving problems in equipment design;*
- *modern approaches, methods and techniques for solving problems during maintenance, modernization and operation throughout the entire life cycle of technological equipment;*
- *methods of computer engineering, well-known packages of applied computer programs for calculation and design of equipment.*

***SKILL**:*

- *using scientific and technical information, normative documents, professional knowledge, perform calculation and design of new technological equipment;*
- *using scientific and technical information, regulatory documents, professional knowledge, perform calculations and design documentation during modernization and operation throughout the entire life cycle of technological equipment;*
- *perform computer design of equipment. Apply computer engineering methods using well-known packages of applied computer programs.*

2. Pre-requisites and post-requisites of the discipline (place in the structural and logical scheme of training according to the relevant educational program

The list of disciplines that the student needs to master (requirements for the level of training):

- *mechanics of materials and structures-1. Basics of resistance of materials;*
- *mechanics of materials and structures-2. Resistance of materials under complex loading;*
- *structural materials and basics of metallurgy;*
- *processes and equipment of chemical technologies;*
- *calculation and design of typical equipment.*

The list of disciplines provided by this educational discipline:

- *computer-integrated technologies of technological equipment design;*
- *high pressure processes and equipment;*
- *innovative technologies for cleaning and processing materials;*
- *course work on engineering of innovative technologies and equipment;*
- *scientific work on the topic of the master's thesis-2. Research work on the topic of the master's thesis.*

3. Content of the academic discipline

Chapter 1. CENTRIFUGES AND SEPARATORS

Topic 1.1. *Centrifuges and separators. Appointment. Basic terms and definitions. Classification, main designs, materials, permissible stresses. The shape of the liquid surface in the centrifuge rotor.*

Basic terms and definitions of non-homogeneous liquid mixtures, methods of their separation and classification of relevant processes are given; the definition of the separation factor and the performance index is given. The main designs of centrifuges and separators and areas of their use are considered. The geometric characteristics of the space in which the separation process takes place and the shape of the internal surface of the liquid in the centrifuge rotor are determined.

Topic 1.2. *Load on drum parts. Calculation of normals in the momentless zone. Calculation of customs in the marginal zone. Calculation of assemblies and parts of centrifuges for strength, stiffness and stability.*

Concepts of strength, rigidity and stability of parts and assemblies of centrifuges and separators are given. Active loads distributed over the surface and volume of the drum are considered. Equations are given for determining the internal forces and stresses in the moment-free and boundary zone of cylindrical, conical solid and perforated casings of the centrifuge drum and separator. The calculation of cylindrical and conical curves in the momentless zone is given. Normative dependencies are given.

The loads on the edges of the drum of the centrifuge are considered. Differential equations of equilibrium, deformations and their solutions are presented. Edge stresses and strength conditions are determined.

Topic 1.3. *Calculation of the bottom and sides of centrifuge drums*

Designs of bottoms, covers and sides of centrifuges and separators are given. The simplest geometric models of them are given.

Stresses in a disk of constant thickness, which rotates rapidly, are considered; internal forces and stresses in an axisymmetric plate loaded with moment and transverse force uniformly distributed along the edge. Stresses in the plate under the combined action of centrifugal and edge loads, strength conditions are determined.

Topic 1.4. *Critical speed of rotors of centrifuges and separators*

The concept of frequency of natural oscillations of an elastic system is explained. The phenomenon of resonance. Concept of critical speed. Active loads.

Derivation of the deflection equation. Determination of the critical speed of the rotor. Analysis of the received decision.

Chapter 2. DRUM ROTATING APPARATUS

Topic 2.1. *Drum rotating devices. Appointment. Terms and definitions. Classification. Constructions.*

Purposes of drum rotating devices are considered; basic terms and definitions; classification, basic designs of devices and individual components and parts.

Topic 2.2. *Loads on nodes and parts. Calculation of strength, stiffness and stability.*

The concepts of strength, stiffness and stability of parts and assemblies are given.

The calculation of loads on the hull is presented and analyzed. Inspection of the case for strength and rigidity is given. The forces acting on the brace are determined. Calculation of the bending moment in the section of the bandage. The calculation of the bandage for endurance is given.

Topic 2.3. *Contact strength of rims and rollers*

The concepts of contact strength and examples of contact strength of parts in engineering are given; features of the destruction of parts in case of violation of contact strength. The contact stresses in the tire and rollers are determined, stress plots are shown; the stress state is analyzed and strength conditions are outlined.

Section 3. STIRRING EQUIPMENT

Topic 3.1. *Appointment. Terms and definitions. Classification. Constructions*

Purposes of mixing devices are considered; basic terms and definitions; classification, basic designs of mechanical mixing devices and their individual units and parts.

Topic 3.2. *Calculation of blade strength*

The calculation of the equivalent resistance force and the coordinate of the point of its application to the blade of a paddle mixer, inclined blade, elliptical blade, and the relationship between force and power are explained. Bending and torque moments are determined. The algorithm for calculating the blade strength is given.

Topic 3.3. *Calculation of mixing devices. Calculation of shafts for vibration resistance, strength and stiffness*

The concept of the resistance force when moving a body in a liquid medium, the calculation of the power spent on mixing is given.

Calculation of shafts for vibration resistance, strength and stiffness. The concept of frequency of natural oscillations of an elastic system is explained. The phenomenon of resonance. Concept of critical shaft speed. Calculation schemes of shafts and determination of critical speed are given. The method of calculating shafts for strength and stiffness is taught.

4. Educational materials and resources

Basic

1. Комп'ютерне проєктування обертових елементів обладнання хімічної технології: курс лекцій [Електронний ресурс] : навч. посіб. для здобувачів ступеня магістра за освіт. програмою «Інжиніринг та комп'ютерно-інтегровані технології проєктування інноваційного галузевого обладнання» спец. 133 Галузеве машинобудування / КПІ ім. Ігоря Сікорського ; уклад.: О. В. Гусарова. – 2-ге вид., перероб. і допов. – Електрон. текст. дані (1 файл: 8,78 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2024. – 288 с. – Назва з екрана. URI https://ela.kpi.ua/handle/123456789/70834

2. Комп'ютерно-інтегровані технології проєктування та виготовлення обладнання хімічної технології: курс лекцій [Електронний ресурс] : навч. посіб. для здобувачів ступеня магістра за освіт. програмою «Інжиніринг та комп'ютерно-інтегровані технології проєктування інноваційного галузевого обладнання» спец. 133 Галузеве машинобудування / КПІ ім. Ігоря Сікорського ; уклад.: О. В. Гусарова. – Електронні текстові дані (1 файл: 7,91 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2023. – 249 с. – Назва з екрана. URI: https://ela.kpi.ua/handle/123456789/66735

3. Розрахунок центрифуг: Методичні вказівки до проведення практичних занять з дисциплін «Конструкторське проектування обладнання хімічних виробництв» та «Комп'ютерне проектування обладнання ЦПВ» для студентів спеціальностей «Обладнання хімічних виробництв і підприємств будівельних матеріалів і «Обладнання лісового комплексу» / Укл.: О.Г. Зубрій, О.О. Семінський – Київ: НУТУ «КПІ», 2010. – 62с.

4. Смагін П.В. Міцністні розрахунки барабанів сушарок. – Херсон: Редакційно-видавничий відділ ХНТУ. – 72 с.

5. Стороженко, В. Я. Реактори об'ємного типу з перемішувальними пристроями (розрахунок та конструювання) [Текст] : навч. посіб. / В. Я. Стороженко, В. А. Смирнов. - Суми : СумДУ, 2011. - 283 с.

Auxiliary

6. Устаткування галузі та основи проектування: Підручник для студентів хіміко-технологічних спеціальностей вищих навчальних закладів / Волошин М.Д., Шестозуб А.Б., Гуляєв В.М. – Дніпродзержинськ (Кам'янське): ДДТУ, 2004, – 371 с. (розділи 1-3).

7. Михайліченко В. П. Розрахунок і конструювання посудин і апаратів хімічної та харчової промисловості: підручник / В. П. Михайліченко, Д. І. Нечипоренко, Т. Б. Новожилова, В. В. Себко, І. В. Пітак, О. Я. Пітак – Харків: НТУ «ХПІ», 2020. – 280 с. doi: http://doi.org/10.15587/978-617-7319-28-2

8. Основи розрахунку та конструювання обладнання переробних і харчових виробництв [Текст]: підручник / Самойчук К. О. [та ін.] ; [за ред. Самойчука К. О.] - Київ : ПрофКнига, 2020. - 427 с. ISBN 978-617-7762-05-7.

9. Атаманюк В.М. Конспект лекцій з курсу «Розрахунок і конструювання машин та апаратів хімічних та силікатних виробництв. Розрахунок ємнісних апаратів» / В.М. Атаманюк. – Львів : вид-во НУ «Львівська політехніка», 2001. –99 с.

10. Ружинська Л.І. Проектування реакторів біотехнологічних та фармацевтичних виробництв. Навч. посібник/ Укладачі: Л.І. Ружинська, І А Буртна, В.М. Поводзинський, В.Ю. Шибецький – К.: НТУУ «КПІ», 2014 – 130 с.

11. Бабко Є.М., Даценко М.М., Житнецький І.В. Основи розрахунків конструктивних елементів обладнання. Курс лекцій для студ.спец. 6090221 "Обладнання переробних і харчових виробництв" ден. та заоч. форм навчання – К.: НУХТ, 2007. - 56 с.

12. Писаренко Г.С. та ін. Опір матеріалів: підручник / Г.С. Писаренко, О.Л. Квітка, Е.С. Уманський; За ред. Г.С. Писаренка –2-е вид. допов. і перероб. – Київ: Вища школа, 2004. 655 с.

13. Андреєв І.А., Зубрій О.Г., Мікуленок І.О. Застосування матеріалів у хімічному машинобудуванні. Сталі і чавуни. Навч. посібник.- Київ: 1999.-148 с.

14. Андреєв І.А., Мікульонок І.О. Розрахунок, конструювання та надійність обладнання хімічних виробництв: Термінологічний словник. – К.: ІВЦ "Видавництво «Політехніка» , 2002. – 216 с.

Normative

15. НПАОП 0.00-1.81-18 Правила охорони праці під час експлуатації обладнання, що працює під тиском.

16. ДСТУ EN 12547:2014 «Центрифуги. Загальні вимоги щодо безпеки» (EN 12547:2014, IDT).

17. ДСТУ 2432-94 Розділення рідких неоднорідних систем методами фільтрування та центрифугування. Терміни та визначення.

18. Наказ від 20.03.2012 № 352 Про затвердження переліку галузевих нормативних документів, якими користуються промислові підприємства та організації України .

Educational content

5. Methods of mastering an educational discipline (educational component)

Lecture classes

Lectures are aimed at:

– *provision of modern, comprehensive in-depth knowledge of the discipline, the level of which is determined by the target attitude to each specific topic;*

– *provision of critical creative work together with the teacher in the process of work;*

– *education of students' professional qualities and development of their independent creative thinking;*

– *awareness of global trends in the development of science in the area of equipment calculation and design;*

– *awareness of the methods of processing information resources and determining the main directions for solving specific scientific and technical problems;*

– *teaching development materials in a clear and high-quality language in compliance with structural and logical connections, explaining all the given terms and concepts available for perception by the audience.*

No	***The name of the topic of the lecture and a list of the main questions (a list of didactic tools, references to the literature and tasks on independent processing)***	***Number hours***
	Chapter 1. Centrifuges and separators	
	Topic 1.1. *Centrifuges and separators. Appointment. Basic terms and definitions. Classification, main designs, materials, permissible stresses. The shape of the liquid surface in the centrifuge rotor.*	
1	***Lecture 1.*** *Centrifuges and separators. Appointment. Basic terms and definitions. Classification.* *Basic terms and definitions of non-homogeneous liquid mixtures, methods of their separation and classification of relevant processes are given; the definition of the separation factor and the performance index is given. Classification of centrifuges and separators. Designation of centrifuges.* ***Literature*** *[1-2, 16, 17]* ***Tasks on student's independent work (SIW)****. Classification of centrifuges and separators. Learn the designation of centrifuges.* ***Literature*** *[1-2, 16, 17]*	***2***
2	***Lecture 2.*** *Basic designs of centrifuges and separators. The shape of the liquid surface in the centrifuge rotor.* *The main designs of centrifuges and separators and areas of their use are considered.* *The differential equation of the surface shape is derived.* ***Literature*** *[1-2]* ***Tasks on SIW****. The differential equation of the surface shape is derived. The solution of the equation. Analysis of the result.* ***Literature*** *[1-2]*	***1***
	Topic 1.2. *Load on drum parts. Calculation of normals in the momentless zone.*	
3	***Lecture 2.*** *Active loads on the drum core. Calculation of the normal in the momentless zone.* *Values of active loads – pressure, equivalent pressure and inertial load component – are derived. Calculation of the normal in the momentless zone. The main provisions of the momentless theory are explained. Internal forces and stresses are determined, stress state analysis is performed.* *The calculated and operational wall thickness, the permissible frequency of rotation of the cylindrical bushing are determined. Thin-walled condition.* ***Literature*** *[1-3]* ***Tasks on SIW****. Determination of active loads.* ***Literature*** *[1-3]*	***1***
4	***Lecture 3.*** *Calculation of the shell in the moment-free zone. Supercentrifuges. Calculation of the cylindrical rotor shell of a supercentrifuge.* ***3.1 Calculation of the shell in the moment-free zone.*** *Internal forces and stresses are determined, and the stress state of the conical and perforated shells is analyzed. The design and actual wall thicknesses of the conical and perforated shells and the permissible rotational speed are determined.* ***References*** *[1-3]* ***Tasks for SIW.*** *Determination of active loads. Determination of stresses in the wall of conical and perforated casings.* ***References*** *[1-3]* ***3.2 Supercentrifuges.***	***1***

	Supercentrifuges. Designs. Features of calculations of supercentrifuge drums. Stresses in the shell are caused by liquid pressure. Stresses in the shell caused by inertial forces. Total stresses. The condition of strength. ***References** [1, 2]* ***Tasks for SIW.** Design of supercentrifuges.* ***Literature** [1, 2].*	***1***
	***Topic 1.3.** Calculation of shells in the edge zone*	
5	***Lecture 4.** Calculation of shells in the edge zone* *The reasons for the occurrence of edge loads are explained. The sequence of calculation of a cylindrical shell of a centrifuge drum in the edge zone is presented. The basic equation of deformation compatibility is given and the rule of signs is explained. A method for calculating unit displacements is given. The differential equation of deflection is presented.* *Edge loads on the cylindrical shell of a centrifuge drum are determined. The method of calculating the forces, moments, and stresses acting on the cylindrical shell element is carried out.* ***References** [1-2].* ***Task for SIW**. An example of calculating the shell in the edge zone.* ***References** [1-2].*	***2***
	***Topic 1.4** Calculation of the bottoms of centrifuge drums, separators*	
6	***Lecture 5. Calculation of the bottom of the centrifuge drum.*** *Designs of centrifuge drum bottoms and separators. The calculation models of the bottom or side of the centrifuge drum are explained.* ***5.1 Calculation of the bottom by the model of a rapidly rotating disk.*** *The model of a thin-walled rapidly rotating disk is substantiated. General dependences for the stresses in a thin-walled disk are derived. The integration constants are determined from the conditions at the edges. The dependencies for stresses in a solid and annular disk are written down. From the strength conditions, the radial dimensions and permissible rotational speed are determined.* ***5.2 Calculate a bottom loaded with distributed load, edge moment, and edge force using a plate model.*** *The design model of the plate is explained. The general dependencies for internal forces acting on a selected element are derived.* *Their calculation by the method of initial forces is explained. Determination of stresses due to internal forces. The condition of strength.* ***References** [1- 3]* ***Tasks for the SIW.** Get acquainted with the method of initial forces.* ***References** [1- 3].*	***1*** ***1***
	Topic 1.5 Critical speed of rotors of centrifuges and separators	
7	***Lecture 6.** Shafts. Main provisions. Critical speed of centrifuge and separator rotors.* *Shafts. The main provisions. The phenomenon of resonance. The concept of critical speed. The use of resonance in technology. Critical speed of centrifuge and separator rotors. Effective loads. Deflection equation. Determination of the critical rotor speed. Influence of the gyroscopic moment of the drum and the value of the drum center of mass overhang on the value of the critical angular frequency of rotation of the shaft* *Calculation of the centrifuge rotor in accordance with DSTU EN 12547:2016.* ***References** [1, 2, 16, 18].* ***Tasks for the SIW**. Critical speed of rotors.* ***References** [1-2].*	***2***

	Chapter 2. Design and calculation of rotary drum machines	
	Topic 2.1*. Drum rotating devices. Purpose Terms and definitions. Classification. Constructions.*	
8	***Lecture 7.*** *Drum rotating devices. Appointment. Terms and definitions. Classification. Designs of rotary drum machines and their constituent parts.* *The definition of "Rotary drum apparatus" is given. Signs of classification are given, classification is given. The choice of the device, the material of the parts is explained. The requirements for the design of the casing of the rotary drum apparatus are substantiated. Designs of rotary drum machines and their constituent parts.* ***Literature*** *[1,2, 4].* ***Tasks on SIW.*** *Designs of drum rotary devices.* ***Literature*** *[1,2, 4].*	***2***
	Topic 2.2. *Loads on nodes and parts. Calculation of the body for strength, rigidity and stability*	
9	***Lecture 8.*** *Calculation of the load on the body. Calculation of the body for strength, rigidity and stability.* *The calculation of the active loads on the housing of the drum rotating apparatus and the reactions of the supports is explained. Calculation of strength, stiffness and stability.* ***Literature*** *[1, 2, 4, 12]* ***Tasks on SIW****. To study the issue of determining active loads and reactions in resistances. To study the question of determining the moment and transverse force in the cross-sections of the hull.* ***Literature*** *[1, 2, 4, 12].*	***2***
10	***Lecture 9.*** *Determination of the forces acting on the bandage fixed on the shoes. Calculation of forces in a key section, Castigliano's theorem.* *Designs of bandages and methods of connection with the body of the apparatus. Determination of the forces acting on the bandage fixed on the shoes. Determination of the bending moment in the section of the bandage. Calculation of forces in a key section, Castigliano's theorem.* ***Literature*** *[1, 2, 4, 18].* ***Tasks on SIW****. Designs of bandages and methods of connection with the body of the apparatus.* ***Literature*** *[1, 2, 4].*	***2***
	Topic 2.3*. Contact strength of rims and rollers.*	
11	***Lecture 10.*** *Contact pressure and contact stresses in the tire and roller material. Calculation of the bandage and rollers from the conditions of contact strength.* *The geometric dimensions of the contact strip, the contact pressure and its distribution over the width of the contact strip are calculated. Stresses in the contact zone are defined. A stress analysis is performed and a strength conclusion is drawn.* *Inspection of the bandage, support and thrust rollers for contact strength. Calculation of the support roller taking into account the thermal elongation of the drum.* ***Literature*** *[1, 2, 4, 12].* ***Tasks on SIW****. Structures of support and support-support stations. Prepare the topic of contact strength.* ***Literature*** *[1, 2, 4].*	***2***
	Chapter 3. Stirring devices	

	***Topic 3.1**. Appointment. Terms and definitions. Classification. Constructions. Calculation of mixing devices.*	
12	***Lecture 11.** Purpose. Terms and definitions. Classification. Designs. Structural calculation of the reactor. Body resistance when moving in a liquid.* *The term mixing, methods of mixing, classification of mixing devices are defined. The designs of the main types of stirrers are given. The general layout of the apparatus with a stirrer.* *The basic calculation dependencies for determining the size of the vessel and mixing devices are given.* *The concept of resistance force when moving a body in a liquid medium is given. The Bernoulli's law is presented.* ***Literature** [1, 2, 5, 9, 10]* ***Tasks for SIW**. Classification and design of stirring devices. Body resistance when moving in a liquid. Bernoulli's law.* ***References** [1, 2, 5].*	**2**
	***Topic 3.2.** Calculation of mixing devices.*	
13	***Lecture 12.** Calculation of power for a given type of stirrer. Calculation of the resistance force, coordinates of force application for different types of agitators, dependencies for calculating torque and bending moments, checking the strength of the blades.* *The algorithm for calculating the power for a given type of agitator is presented and explained.* *The dependencies for finding the resistance force, the coordinates of the point of force application for the blade, inclined and anchor blades are derived. Dependencies for calculating the torque and bending moments, an algorithm for checking the strength of the blades are provided.* ***References** [1, 2, 9, 10].* ***Tasks for SIW.** Algorithm for checking the strength of blades.* ***References** [1].*	**2**
	***Topic 3.3.** Calculation of shafts for vibration resistance, strength and stiffness.*	
14	***Lecture 13.** Determination of the frequency of natural oscillations of the shafts and the critical frequency.* *The frequency of natural oscillations of the shafts and the critical frequency are defined. Rigid and flexible shafts. Vibration resistance condition. Determination of the frequency of natural oscillations of shafts with one concentrated mass. Determination of the frequency of natural oscillations of shafts with several concentrated masses. Determination of the natural oscillation frequency of shafts with distributed mass.* ***Literature** [1, 2, 5, 18]* ***Tasks on SIW.** Study the material on the topic of natural shaft frequency and forced oscillations. Resonance phenomenon and critical frequency.* ***Literature** [1, 2, 5]*	**2**
15	***Lecture 14.** Calculation of shafts for stiffness and strength. Systems for strength calculation.* *Determination of the movement of the shaft according to the accepted geometric dimensions and known forces. Rigidity condition.* *Rules and dependencies for determining active and reactive forces acting on a shaft. Calculation of moments and stresses in dangerous sections. Strength conditions.* *An overview of strength calculation systems is given.* ***Literature** [1, 2, 5, 18]*	**2**

	***Tasks on SIW**. Study the material on the topic "Calculation of shafts for stiffness and strength".* ***Literature** [1, 2, 5]*	
16	***Lecture 15.** Module test* *Written MCW.* ***Literature [1-18]*** ***Tasks for SIW.** Study the independent material on topics 1-3.*	***2***

Practical training

The main goals of practical classes are to systematize and consolidate the knowledge gained at lectures and during independent work with theoretical material; acquired skills and experience in using calculation models for calculations of details for strength, stiffness, stability, skills and experience in using reference literature, normative documents; skills and experience in creating sketches of details and nodes.

No	*Name of the subject of the lesson and list of main questions (list of didactic support, references to the literature and tasks on the independent processing)*	*Number of hours*
	Chapter 1. Centrifuges and separators	
	***Topic 1.1.** Centrifuges and separators. Appointment. Basic terms and definitions. Classification, main designs. The shape of the liquid surface in the centrifuge rotor.*	
1	***Practical lesson 1.** Centrifuges. Selection of a centrifuge. Selection of material. Determination of physical properties of the material and allowable stresses in non-moment and moment zones. The thin-wall condition of the centrifuge rotor core is checked*	***1***
	***Topic 1.2.** Load on drum parts. Calculation of normals in the momentless zone*	
2	***Practical lesson 1.** Calculation of active loads for a cylindrical drum sleeve. Determination of stresses, analysis of the stress state. Determination of the calculated and operational thickness of the wall of the cylindrical bushing, the allowable frequency of rotation from the conditions of strength.*	***0.5***
3	***Practical lesson 1.** Calculation of active loads for a conical drum ring. Determination of stresses, analysis of the stress state is performed. Determination of the calculated and executive thickness of the wall of the conical joint, the permissible rotation frequency.*	***0.5***
4	***Practical lesson 2.** Calculation of active loads for a perforated drum liner. Determination of stresses, analysis of the stress state is carried out. Determination of the calculated and executive wall thickness, permissible rotation frequency.*	***1***
5	***Practical lesson 2.** Calculation of ultracentrifuges. The thick-wall condition of the supercentrifuge rotor core is checked. Checking the strength of the cylindrical wall of the tubular centrifuge rotor.*	***1***
	***Topic 1.3.** Calculation of customs in the marginal zone*	
	***Topic 1.4**Calculation of the bottom and side of drums of centrifuges and separators*	
6	***Practical lesson 3.** Calculation of the bottom (or side) as a rapidly rotating disc.* *Stresses are calculated depending on the current radius. Construction of stress plots is performed depending on the current radius.*	***1***

7	***Practical lesson 3***. *Calculation of the bottom as a plate loaded with pressure, end force and moment.* *Stresses are calculated depending on the current radius. The results are summarized in graphs. Analysis of results. Calculation of the total stresses is carried out depending on the current radius. A stress graph is being built. An analysis is performed and a conclusion is made regarding strength.*	***1***
	Chapter 2. Drum rotating devices.	
	Topic 2.1. *Drum rotating devices. Appointment. Terms and definitions. Classification. Constructions.*	
8	***Practical lesson 4.*** *Drum rotating devices.* *Determination of the mass of the device, material. Active and reactive loads on the body of the drum rotating apparatus. The resistance reactions are calculated. The reactions in the supports are determined separately from the distributed load and concentrated forces.*	***1***
	Topic 2.2. *Loads on nodes and parts. Calculation of strength, stiffness and stability.*	
9	***Practical lesson 4.*** *Checking the strength of the body of the drum apparatus. The moment and transverse force in the cross-sections of the hull are determined. A plot of total moments is being built. Checking the strength condition.*	***1***
10	***Practical lesson 5.*** *Calculation of the drum body for stability and rigidity.* *Executed calculation of the drum body for stability.* *The drum body is calculated for rigidity. Conclusions are made.*	***2***
11	***Practical lesson 6.*** *Calculation of the drum bandage* *Determination of the geometric dimensions of the bandage, which is loosely put on the body of the drum dryer from the condition of its operation for bending and contact strength. The force N0 and the moment M0 acting on the truss in the key section are determined.* *Determination of the moment in the sections of the truss. An analysis is performed and a conclusion is made regarding the dangerous section. The bandage is tested for strength.* *Structural calculation of the bandage and the roller. Calculation of active loads on the truss with continuous contact with the body and contact at individual points.*	***2***
	Topic 2.3. *Contact strength*	
12	***Practical lesson 7.*** *Contact strength. Inspection of the bandage and support roller for contact strength.* *The geometric dimensions of the contact strip, the contact pressure in the middle of the contact strip and its distribution along the width of the maximum stress are calculated. An analysis is performed and a conclusion is made regarding strength.*	***2***
	Chapter 3. Stirring devices	
	Topic 3.1. *Appointment. Terms and definitions. Classification. Constructions.*	
	Topic 3.2. Calculation of blade strength	
13	***Practical lesson 8.*** *Choice of stirrer. Determination of power, torque and bending moments.* *According to normative materials, the type of mixer is adopted and its dimensions are determined. Calculation of power for the adopted type of mixer, calculation of torque and bending moments is carried out. The strength of the*	***1***

	stirrer blade is checked. An analysis is performed and a conclusion is made regarding strength.	
	***Topic 3.3**. Calculation of mixing devices. Calculation of shafts for vibration resistance, strength and stiffness*	
14	***Practical lesson 8.** Calculation of shaft strength, stiffness and vibration resistance.* *According to the accepted geometric dimensions, active and reactive forces acting on the shaft are determined. Moments and stresses in dangerous sections. The strength condition is checked.* *Checking the smooth weightless shaft of the mixing device for vibration resistance (with one degree of freedom)* *According to normative materials, coefficients and values necessary for determining the frequency of natural oscillations are calculated.* *Inspection of cantilever and single-run shafts is carried out for compliance with the condition of vibration resistance.*	***1***

6. Independent work of student

The student's independent work is 96 hours, of which 30 hours are for exam preparation.

The main task of students' independent work is mastering the knowledge of the material of the discipline, mastering the methods of calculations and design developments; development of problem formulation skills and ways to solve them; mastering knowledge about constructions and calculations, through personal search for information, formation of active interest and creative approach in educational work.

Independent work includes determining the properties of materials and calculated values according to standards; development of schemes, tables, graphs that explain the performance of individual tasks; drawings nodes and parts according to an individual task. Work is performed using computer equipment.

No	*The name of the topic submitted for independent processing*	*Number of hours*
	Chapter 1. Centrifuges and separators	
1	*Topic 1.1 Centrifuges and separators. Appointment. Basic terms and definitions. Classification, main designs. The shape of the liquid surface in the centrifuge rotor [1, 2].* *Graph of the shape of the surface, calculation of the volume of liquid in the rotor.*	*8*
	Topic 1.2. Load on drum parts. Calculation of normals in the momentless zone. Load schedule. Drawings of cylindrical, conical, and perforated slats [1, 2, 3].	*14*
	Topic 1.3. Calculation of customs in the marginal zone. Load schemes. Graphs of the change in effort along the length of the rod. Drawing of a cylindrical border on the edge [1, 2].	*10*
	Topic 1.4. Calculation of the bottoms of centrifuge drums, separators. Sketches for calculation schemes. Stress graphs depending on the current radius [1, 2, 3].	*6*
	Chapter 2. Drum rotating devices	
2	*Topic 2.1. Drum rotating devices. Appointment. Terms and definitions. Classification. Designs of devices and their nodes, namely, designs of the drum (body), nozzles, seals, bandages and methods of*	*6*

	their fastening, support and support-support stations, loading and unloading chambers, mechanisms for introducing a loose medium [1, 2, 4]. *Topic 2.2. Loads on nodes and parts. Calculation of strength, stiffness and stability.* *Loads on nodes and parts, graph of internal forces and stresses. Calculation of strength, stiffness and stability [1, 2, 4].* *Topic 2.3. Contact strength* *Load schemes, load and stress graphs [1, 2, 4, 12].*	*12* *6*
	Chapter 3. Stirring devices	
3	*Topic 3.1. Appointment. Terms and definitions. Classification. Designs of mechanical mixing devices [1, 2, 5].* *Designs of mechanical mixing devices, graphic illustrations of calculation schemes. Graphs of load and stress diagrams.* *Topic 3.2. Calculation of blade strength* *Calculation of mixing devices [1, 5, 2].*	*6* *6*
4	*Preparation for the exam*	*30*

Policy and control

7. Policy of educational discipline

The system of requirements that the teacher sets before the student

Rules for attending lectures and practical classes:

- *attending classes is mandatory;*
- *not to be late for classes and not miss them without good reasons.*

Rules of behavior in classes:

- *students are obliged to actively participate in the educational process;*
- *do not interfere with the teacher conducting classes;*
- *not to be distracted by actions unrelated to the educational process;*
- *turn off phones during class;*
- *use means of communication only to search for information on the teacher's Google Drive or on the Internet, etc.;*

Rules for the protection of individual practical tasks.

In the practical lesson, the necessary calculations are performed, the teacher checks their validity, the student completes the work. Works designed in accordance with the requirements for textual and design documents are submitted for protection. Requirements are announced by the teacher at the first practical session.

The work must be protected and credited no later than the next practical session.

Rules for assigning incentive and penalty points

Incentive points can be awarded by the teacher for active and honest performance of work and for creative works and working hypotheses.

The sum of incentive points cannot exceed 10% of the rating scale.

Penalty points are applied for untimely completion and defense of practical work and untimely writing of a module work.

Policy of deadlines and rescheduling

In the event of academic debts arising from the academic discipline or any force majeure circumstances, students should contact the teacher to coordinate actions related to solving the existing problems.

Policy of academic integrity

Plagiarism and other forms of dishonest work are unacceptable. Plagiarism refers to the absence of references when using printed and electronic materials, quotes, opinions of other authors. Inadmissible tips and write-offs during writing tests, conducting classes, tests, exams.

The policy and principles of academic integrity are defined in Chapter 3 of the Code of Honor of the National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute". More details: https://kpi.ua/code

Policy of academic behavior and ethics

Students should be tolerant, respect the opinion of others, formulate objections in the correct form, adequately support feedback during classes.

Standards of ethical behavior of students and employees are defined in Chapter 2 of the Code of Honor of the National Technical University of Ukraine "Ihor Sikorskyi Kyiv Polytechnic Institute". More details: https://kpi.ua/code

8. Types of control and rating system for evaluating learning outcomes (RSO)

Distribution of study time by types of classes and tasks in the discipline according to the working schedule curriculum:

Semester	Training time		Distribution of study hours				Control measures	
	Credits	Acad. hours	audio hour	Lectures	Practical	SIW	MCW	Semester control
2	5	150	46	30	16	104	1	exam

The student's rating in the discipline is 100 points (maximum value) and has two components:

1. starting 60 points;
2. exam answer 40 points.

The starting rating (during the semester) consists of points that the student receives for: work in practical classes (8 classes), answers to the teacher's questions in lectures or a report on the design of the equipment being studied (1 report), *module control work (MCW).*

System of rating points

1. Practical training.

- "excellent", creative disclosure of the question, fluency in the material - 5 points.
- "good", deep disclosure of the question - 4 points.
- "enough", disclosure of the main provisions of the question - 3 points.
- "unsatisfactory", unsolved question - 0 points.

2. **Report on the designs of the equipment being studied:**

- creative presentation, fluency in the material - 5 points;
- in-depth disclosure of the topic of the report - 4 points;
- disclosure of the main issues of the report - 3 points.

or

- answers to questions at lectures - 0.5-1 point (5 points in total).

3. ***Module control work (MCW).***

The weighted score is 15.

Answers on the exam: 40 points.

Penalty points: untimely completion of practical work (later than the next practical lesson) - minus 1 point; submission of practical work at the end of the semester - minus 2 points, untimely writing of the ICR without a valid reason - minus 1 point

The condition of the first attestation is the completion of 50% of practical work (at the time of attestation). The condition of the second attestation is the completion of 75% of practical work (at the time of attestation).

A condition for admission to the exam is the completion of all assignments in practical classes and MCW, and attendance at least 60% of lectures. Starting rating of at least 30 points.

At the exam, students submit written work. Each paper contains four tasks (questions). The first two are theoretical questions, the third is a theoretical problem, and the fourth question is a description of the design. The maximum score of questions is 10 points.

The maximum value of the rating semester scale:

$$R_D = R_{pc}+R_p+R_{MCW}+ R_{exam} = 5.0 \cdot 8+5+15+40=60+40=100 \text{ points}$$

The condition of the first attestation is the completion of 50% of practical work (at the time of attestation). The condition of the second attestation is the completion of 75% of practical work (at the time of attestation).

Students perform written work on the exam. Each paper contains four tasks (questions). The first two theoretical questions, the third theoretical or task, the fourth question is a description of the structure. The maximum score for questions is 10 points.

Question evaluation system:

- "excellent", complete answer (at least 90% of the required information) - 10 points
- "good", sufficiently complete answer (at least 75% of the required information or minor inaccuracies) - 8 points;
- "enough", incomplete answer (at least 60% of the required information and some errors) - 6-7 points;
- "unsatisfactory", unsatisfactory answer - 0 points.

The sum of the starting points and the points for the examination work is transferred to the examination grade according to the table:

R=rC+rE	**Rating**
100...95	Perfectly
94...85	Very good
84...75	Fine
74...65	Satisfactorily
64...60	Enough
Less than 60	Unsatisfactorily
There are not included practical works or starting rating is less than 30 points	Not allowed

9. Additional information on the discipline (educational component)

- *a list of questions submitted for semester control (as an appendix to the syllabus);*

Main questions of examination tickets

Centrifuges. Separators

Analyze designs of centrifuges.

To analyze the designs of centrifuges with knife discharge of sediment.

To analyze the designs of centrifuges with auger sediment discharge.

Analyze the design of centrifuges with pulsating sediment discharge.

The shape of the inner surface of the liquid in the centrifuge rotor.

Justify the calculation of the pressure in the liquid layer of the cylindrical sleeve of the centrifuge drum.

To substantiate the calculation of the load P_i from the action of the inertial force in the cylindrical shaft of the centrifuge rotor

Justify the calculation of the net pressure on the bottom of the centrifuge drum.

Internal forces and stresses in the moment-free zone of the cylindrical sleeve of the centrifuge drum.

To substantiate the determination of internal forces and stresses in the moment-free zone of the cylindrical shaft of the centrifuge rotor.

Perform an analysis of the stress state in the moment-free zone of the cylindrical shaft of the centrifuge rotor.

Calculation of the wall thickness of the cylindrical solid liner of the centrifuge drum.

Justify the calculation of the permissible speed for the cylindrical hub of the centrifuge drum.

Checking the condition of the thin-walled cylindrical continuous sleeve of the centrifuge drum.

Internal forces and stresses in the perforated cylindrical casing of the centrifuge drum.

To justify the calculation of the wall thickness of the perforated cylindrical sleeve of the centrifuge rotor.

Explain the sequence of calculation of the cylindrical shell of the centrifuge drum in the edge zone.

Determination of limit loads on the cylindrical hub of the centrifuge drum.

The differential equation of the deflection of the cylindrical shaft of the centrifuge drum.

The equation of the deflection of the cylindrical sleeve of the centrifuge drum.

Checking the strength of the cylindrical sleeve of the centrifuge drum on the edge.

Ultracentrifuges. Constructions.

To substantiate the calculation of the cylindrical barrel of the supercentrifuge drum.

Structures of bottoms of centrifuges.

To substantiate the determination of stresses in a rapidly rotating disk.

Calculation of the strength of a rapidly rotating annular disk.

Calculation of the strength of a solid, rapidly rotating disk.

Calculation of the bottom (side) of the centrifuge drum loaded with extreme moment.

Analyze the calculation of the critical speed of the supercentrifuge rotor.

To substantiate the determination of the critical speed of the centrifuge rotor.

Drum machines

Fields of application of drum rotary devices.

Designs of drum rotary devices.

Analyze the structure of the body of the drum rotary apparatus.

To analyze the methods of fastening bandages on the body of the drum rotary apparatus.

Analyze the design of the nozzles of drum machines.

Analyze the design of loading chambers.

Analyze the design of unloading chambers.

Analyze the structure of the support station of the drum rotary apparatus.

Analyze the calculation of the loads on the body of the drum rotating apparatus.

Calculation of the bending moment in the cross-sections of the casing of the drum rotary apparatus.

Calculation of the torque on the body of the drum rotating apparatus.

Calculation of the body of the drum rotary apparatus for strength.

To substantiate the calculation of the body of the drum rotary apparatus for stiffness.

Calculation of the housing of the drum rotating apparatus for stability.

Calculation of the forces acting on the bandage of the drum rotating apparatus.

To substantiate the calculation of the bending moment in an arbitrary section of the bandage of the drum rotating apparatus.

Determination of forces in the key section of the truss.

To substantiate the inspection of the bandage for strength from the action of the bending moment.

Calculation of the geometric dimensions of the support rollers of the drum rotating apparatus.

Explain the contact pressure in the bandage-support roller pair.

Contact stresses in bandage (roller) materials.

Justify the calculation of the bandage (roller) on the contact strength.

Stirring devices

Classification of mixing devices.

Designs of paddle mixers.

To evaluate the designs of anchor stirrers.

To evaluate the designs of turbine mixers.

To evaluate the designs of screw mixers.

General layout of the apparatus with a stirring device.

The force of resistance of a body moving in a liquid.

To substantiate the calculation of the net resistance force of the blade of the paddle mixer.

To substantiate the calculation of the coordinate of the point of application of the net resistance force to the blade of the paddle mixer.

Justify the strength calculation of the blade of the paddle mixer.

To substantiate the calculation of the net resistance force of the blade of the anchor (elliptical) stirrer.

Coordinates of the point of application of the equivalent resistance force to the blade of the inclined stirrer.

To substantiate the calculation of the critical speed of a cantilever shaft with one concentrated mass. Rigid and flexible shaft.

To substantiate the determination of the frequency of natural oscillations of a single-run shaft with one concentrated mass.

To substantiate the determination of the frequency of natural oscillations of a cantilever shaft with one concentrated mass.

Working program of the academic discipline (syllabus):

Compiled by Ph.D, Olena Husarova

Approved by the Department of Chemical Engineering and Oil Refining Industry (protocol No. 20 dated June 12, 2025)

Agreed by the Methodical commission of the faculty[1] *(protocol No. 11 dated June 27, 2025)*

[1] Methodical council of the university – for general university disciplines.