# MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
## National Aviation University
Aerospace Faculty
Department of Applied Mechanics and Materials Engineering

AGREED
Dean of the Aerospace Faculty
_____ Mykola KULYK

«_15_» _09_____2022

APPROVED
Vice-rector for Academics
_____ Anatolii POLUKHIN

«_da_» _09_____2022

Quality Management System

## COURSE TRAINING PROGRAM
### on
## "Theory of Mechanisms and Machines"

Educational and Professional Program: «Aircraft Equipment »
Field of study:                     13 «Mechanical Engineering»
Specialty:                          134 «Aviation and Rocket-Space Engineering»

| Form of training | Semes-ter | Total (hours / ECTS credits) | Lectures | Labs | Self-study | Home works | Term Paper | Form of se-mester control |
|---|---|---|---|---|---|---|---|---|
| Full-time: | 3 | 105/3,5 | 34 | 17 | 54 | CGP-1 | - | Graded Test 3s |

Index: CB–1-134-2/22-2.1.10

The Course Training Program on "Theory of Mechanisms and Machines" was developed on the basis of Educational and Professional Program «Aircraft Equipment», Curriculum CB–1-134-2/22-2.1, Extended Curriculum ECB–1-134-2/22-2.1; for the "Bachelor" educational degree specialists training for the Specialty 134 «Aviation and Rocket-Space Engineering» and corresponding normative documents.

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Discussed and approved by Department of Applied Mechanics and Materials Engineering, Minutes № 8 of "26" 09 2022.
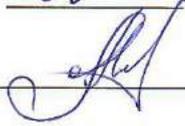
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Discussed and approved by the Graduate Department for the Speciality 134 «Aviation and Rocket-Space Engineering», Educational and Professional Program «Aircraft Equipment» - Department of Aircraft Design,

Minutes № 9 of "14" 09 2022.

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« 16» 09 2022

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# Contents:

## INTRODUCTION

The Course Training Program on "Theory of Mechanisms and Machines" is developed based on the "Methodical guidance for the subject course training program", approved by the order № 249/од, of 29.04.2021 and corresponding normative documents, international training programs for aviation professionals, in particular those coordinated by ICAO (International Civil Aviation Organization), EASA (European Aviation Safety Agency) and corresponding regulatory documents.

## 1. EXPLANATORY NOTE

### 1.1. Place, objectives, tasks of the subject

The discipline is intended for the formation of competencies that form the aviation profile of a specialist in the field of kinematics and dynamics of mechanisms and machines, and the basics of designing diagrams of mechanisms for a given kinematic and dynamic parameters.

**Main target** is the formation of future specialists' knowledge of the structure, kinematics and dynamics of modern mechanisms and machines, as well as methods of their design. The acquired knowledge is the basis for the study of modern aviation technology at special departments and is needed by specialists working in the fields of aircraft and helicopter construction.

**The tasks of the discipline**:

- mastering the general principles of analysis and synthesis of lever, cam and gear mechanisms, acquiring practical skills in determining the structure, performing kinematic and force calculation of mechanisms, acquaintance with the method of determining the law of motion and methods of balancing the movement of mechanisms and machines.

- ability to analyze the results and features of the design and calculation of lever, gear and cam mechanisms;

- mastering the methods of kinematic research of different types of mechanisms; determination of the law of motion of the mechanism under the action of given forces; balancing and regulating the movement of mechanisms and machines.

### 1.2. Program learning outcomes

As a result of studying the discipline the student must acquire the following skills:

- the ability to independently divide the mechanisms into separate simpler kinematic chains (groups of links);

- ability to independently perform kinematic study of lever, gear and cam mechanisms;

- the ability to independently determine the forces acting on the links of mechanisms and machines, as well as reactions in the moving joints of the links of mechanisms;

- ability to independently analyze and solve individual problems of designing mechanisms under given initial conditions.

### 1.3. Acquired competences

Ability to solve complex specialized tasks and practical problems in a particular field of professional activity or in the learning process, which requires knowledge and application of certain theories and practical methods of relevant science.

Ability to apply knowledge and skills in practice.

Ability to apply knowledge of legislation and state standards of Ukraine.

Ability to organize work in accordance with the requirements of life safety and labor protection.

Ability to use knowledge and actual skills in the operation, maintenance and repair of aircraft, its systems and its aircraft engines.

### 1.4. Interdisciplinary Connections

The discipline "Theory of Machines and Mechanisms" is based on knowledge of such disciplines as: "Descriptive Geometry and Engineering Graphics", "Physics", "Computer Science", "Higher Mathematics", "Theoretical Mechanics" and is the basis for study of such disciplines as: "Machine Elements", "Design and strength of aircraft engines", "Design and strength of aircraft ", "Design of power installations of aviation ground equipment", "Technical operation of aviation ground equipment".

## 2. COURSE TRAINING PROGRAM ON THE SUBJECT

### 2.1. The subject content

The training material of the subject is structured in a modular manner and consists of two training modules, namely:

- training module № 1 "Structure, kinematics and dynamics of mechanisms and machines";
- training module № 2 "Mechanisms with higher pairs", each of which is a logically complete, relatively independent, integral part of the discipline, the assimilation of which involves a modular test and analysis of the results of its implementation.

### 2.2. Modular structuring and integrated requirements for each module

**Module № 1 "Structure, kinematics and dynamics of mechanisms and machines";**

**Know**:
- the principle of construction of lever mechanisms;
- methods of kinematic research of lever mechanisms;
- features of design and calculation of lever mechanisms;
- the method of determining the law of motion of the mechanism under the action of given forces;
- methods of balancing and regulating the movement of mechanisms and machines.

**Learning outcomes**:
- to divide the mechanisms into separate simpler kinematic chains (groups of links);
- to perform kinematic study of levers;
- to determine the forces acting on the links of mechanisms and machines, as well as the reactions in the movable joints of the links of mechanisms;
- to reduce the masses and moments of inertia of the links, as well as the forces and moments of the pairs of forces acting on the links of the mechanisms to the reduced link;
- to solve separate problems of designing of mechanisms under the set initial conditions.

**Topic 1. Main terms and definitions.**

Machine-building as the leading branch of the national economy. Theory of mechanisms and machines as a science. Interrelation of TMM with other related disciplines. The role of TMM in the preparation of specialists in aircraft and helicopter engineering. Definition of mechanism, machine, link, kinematic pair. Classification of kinematic pairs. Degree of freedom of a mechanism.

**Topic 2. Structural analyses of mechanisms.**

Structural analyses and synthesis of mechanisms. Groups of links. Group of initial links. Assours groups and their classification. Replacement of higher pairs by lower. Replaced mechanisms. Parasitic links in mechanisms and their exclusion. Determining mechanism structure.

**Topic 3. Kinematic analysis of mechanisms**.

Main tasks and methods of kinematic analysis. Construction mechanism plans and paths of individual points. Scale. Standardization of the scale. Vector equation for the velocity and acceleration. Velocity and acceleration diagrams. Theorem for sequences of velocities and accelerations.

**Topic 4. Kinetostatics of mechanisms**.

Kinetostatic method of mechanisms force analysis. Main tasks. Classification of acting forces. The forces of inertia. The order of the force analysis of the Assours groups. Determination of balancing moment which is applied at the initial link. Method of Zhukovsky's rigid lever.

**Topic 5. Balancing of rotating links**.

The tasks of mechanisms balancing. The static, dynamic and total balancing of rotating links. Determination of balances magnitude and position by graphical and analytical methods. Balancing of aircraft mechanisms.

**Topic 6. The motion of mechanism**.

Reducing forces and masses to the reduced link. Dynamic model of mechanisms. Reduced force. Reduced moment

**Module №2 "Mechanisms with higher pairs"**

**Know**:
- design features of gears;
- principles of construction of gear and cam mechanisms, their application;
- methods of kinematic study of gear and cam mechanisms;
- features of design and calculation of gear and cam mechanisms;
- features of application of mechanisms of intermittent movement;
- types of friction, the use of lubrication to reduce friction losses, determining the efficiency of mechanisms.

**Learning outcomes:**
- to perform the calculation of the geometric parameters of the gears;
- to perform a kinematic study of gear and cam mechanisms;
- to determine the parameters of gears and cam mechanisms in accordance with the specified initial conditions
- to perform the calculation of the characteristics that characterize the friction.
- to solve separate problems of designing of mechanisms under the set initial conditions.

**Topic 1. Gear trains. The parameters of involute spur gear.**
Gear trains. Velocity ratio. Involute and its properties. The main parameters of normal gears. Standardization of basic concepts, definitions, parameters of gears. Module. Pitch. Types of circles.

**Topic 2. Modified gearing.**
Methods of production of gears. Modified gearing. Offset factor. Interference and undercutting of gears. The phenomenon of wedge gear.

**Topic 3. Determination of the velocity ratio of gear trains**. **Theory of gearing.**
Determination of the velocity ratio of gear trains. Multistage gearings and gearings with intermediate gears. Mechanisms with movable axes of gears. The types of planetary gearings. The method of reversal of motion. Use in aviation engines gearboxes. Theory of gearing

**Topic 4. Analysis and synthesis of planetary gearings.**
Analytical and graphical methods for kinematic analysis. Differential gear train. Closed differential transmission. Conditions for selection of numbers of teeth of planetary gears. Selection of numbers of teeth.

**Topic 5. Mechanisms of intermittent action**.
The main types of mechanisms of intermittent action. Analysis and synthesis of Maltese, ratchet and other mechanisms with given duration of stopping.

**Topic 6. Cam mechanisms. Plotting the graphs of the follower paths**.
Cam mechanisms. Plotting the graphs of the follower paths. Types of plane cam mechanisms. Method of reversed motion.

**Topic 7. Profiling plane cam mechanisms.**
Plotting the cam profile for different types of cam mechanisms. Designing cam mechanisms taking into account pressure angle. Laws of motion of the follower

**Topic 8. Friction in kinematic pairs. The efficiency**.
Types of friction. Types of lubrication. Sliding friction. The coefficient of sliding friction. Friction in translational kinematic pair. Friction on an inclined plane. Condition of self-braking. Friction in rotational kinematic pair. Rolling friction. The efficiency as the main characteristic of the machine. Efficiency at serial and parallel connection of mechanisms.

### 2.3. Training schedule of the subject

| № | Topic | Academic Hours | | | |
|---|---|---|---|---|---|
| | | All | Lectures | Labs | Self-study |
| 1 | 2 | 3 | 4 | 5 | 6 |
| **Module № 1 "Mechanisms with higher pairs"** | | | | | |
| 1.1 | Main terms and definitions. Determination of degree of freedom of a mechanism. | 7,5 | 2 | 2 | 3,5 |
| 1.2 | Structural analysis of mechanisms. Determination of a mechanism structure | 7,5 | 2 | 2 | 3,5 |
| 1.3 | Kinematic analysis of mechanisms. Velocity diagram. | 7,5 | 2 | 2 | 3,5 |
| 1.4 | Kinematic analysis of mechanisms. Acceleration diagram. | 4 | 2 | – | 2 |
| 1.5 | Kinetostatics of mechanisms | 4 | 2 | – | 2 |
| 1.6 | Balancing of mechanisms and machines | 7,5 | 2 | 2 | 3,5 |
| 1.7 | The movement of mechanisms links under the action of given forces | 4 | 2 | – | 2 |
| 1.8 | Розрахунково-графічна робота | 10 | – | – | 10 |
| 1.9 | Module test №1 | 4 | 2 | – | 2 |
| **Total for Module №1** | | **56** | **16** | **8** | **32** |
| | | | | | |
| 2.1 | Gearings | 7,5 | 2 | 2 | 3,5 |
| 2.2 | Parameters of involute spur gear. | 7,5 | 2 | 2 | 3,5 |
| 2.3 | Modified gearings | 7,5 | 2 | 2 | 3,5 |
| 2.4 | Determination of the velocity ratio of gear trains | 3 | 2 | – | 1 |
| 2.5 | Planetary mechanisms | 3 | 2 | – | 1 |
| 2.6 | Analysis and synthesis of planetary gearings | 3 | 2 | – | 1 |
| 2.7 | Mechanisms of intermittent action | 3 | 2 | – | 1 |
| 2.8 | Cam mechanisms. Plotting the graphs of the follower paths and profiling of plane cam mechanisms | 7,5 | 2 | 2 | 3,5 |
| 2.9 | Friction in kinematic pairs of mechanisms | 4 | 2 | – | 2 |
| 2.10 | Module test №2 | 3 | – | 1 | 2 |
| **Total for Module №2** | | **49** | **18** | **9** | **22** |
| **Total for the academic discipline** | | **105** | **34** | **17** | **54** |

### 2.4. Calculation and graphic paper

Calculation and graphic paper (CGP) is performed in the third semester, in accordance with the approved guidelines, in order to consolidate and deepen the theoretical knowledge and skills of students and is an important step in mastering the material taught in the third semester.

Calculation and graphic work is performed on the basis of educational material submitted for independent study by students, and is part of the module №1 "Structure, kinematics and dynamics of mechanisms and machines."

The time required to perform calculation and graphic paper - 10 hours of self- study.

### 3. BASIC CONCEPTS OF GUIDANCE ON THE SUBJECT
### 3.1. Teaching methods

To intensify the educational and cognitive activities of students during the study of the discipline, such educational technologies are used as work in small groups, solving situational problems, lectures using multimedia presentations

### 3.2. List of references
#### Basic literature

3.2.1. Воронкін М.Ф., Цимбалюк А.А. Основи теорії механізмів і машин: Конспект лекцій. –К.: КМУЦА, 2000.-208 с.

3.2.2 Кіницький Я.Т. Теорія механізмів і машин. – К.: Наукова думка, 2002. –660 с.

3.2.3 Теория механизмов и машин. Механизмы с высшими кинематическими парами: учеб. пособие/ А.О. Корниенко, С.В. Федорчук, А.С. Крыжановский, О.В. Тисов. – К.: НАУ, 2017. – 170с.

3.2.4. Теорія механізмів та машин. Механізми з вищими кінематичними парами: навч. посібник / А.О. Корнієнко, С.В. Федорчук, О.В. Радько, О.В. Тісов. – К. : НАУ, 2018. – 135 с.

#### Additional literature

3.2.5. Теорія механізмів і машин. Лабораторний практикум / Уклад.: Воронкін М. Ф., Бабенко Є.М. – К.: НАУ, 2002. – 78 с.

3.2.6. Теорія механізмів і машин. Лабораторний практикум / Корнієнко А.О., Федорчук С.В., Радько О.В. – К.: НАУ, 2018. – 36 с.

3.2.7. Теорія механізмів і машин. Розв'язання задач. Навчальний посібник / Уклад.: Бабенко Є.М., Корнієнко А.О., Башта О.В. – К.: Вид-во Нац. авіац. ун-ту "НАУ-друк", 2011. – 120 с.

3.2.8. The Theory of Mechanisms and Machines. Guide to Laboratory Work / A. Kornienko, O. Bashta, O. Tisov. – K.: NAU, 2018. – 35 p.

3.2.9. Theory of mechanisms and machines. Gear trains: A method guide / Authors: A. Kryzhanovskyi, E.Babenko, A. Kornienko. – K.: National aviation university publishing house «NAU-druk», 2009. – 44 p.

3.2.10. Theory of mechanisms and machines: Kinematic and force analyses of leverages Authors: Kryzhanovsky A., Kononykhin Y. – K.: NAU, 2003. – 48 p.

### 3.3. Internet information resources

3.3.1. https://drive.google.com/file/d/1MexZIgzwcFWEqlI-YR0XhkoZU8vkmFKD/view

3.3.2. http://internal.khntusg.com.ua/fulltext/PAZK/UCHEBNIKI/TMM09_kurs_lekcii.pdf

3.3.3. https://books.google.com.ua/books?id=N-f5f-CytUIC&printsec=frontcover#v=onepage&q&f=false

## 4. RATING SYSTEM OF KNOWLEDGE AND SKILLS GRADE
4.1. Grading of individual types of student work done in points in accordance with table 4.1.

Table 4.1.

| Kind of Academic Activities | Max Grade | Kind of Academic Activities | Max Grade |
|---|---|---|---|
| 3ᵈ semester | | | |
| Module № 1 "Structure, kinematics and dynamics of mechanisms and machines » | | Module № 2 "Mechanisms with higher pairs" | |
| Performing and defense of laboratory works | 45 (total) | Performing and defense of laboratory works | 25 (total) |
| *For carrying out module test 1 a student must receive not less* | 27 | Performing of control work (homework) | – |
| | | *For carrying out module test 1 a student must receive not less* | 15 |
| | | Final semester test | – |
| Module Test №1 | 15 | Module Test №2 | 15 |
| **Total for module №1** | **60** | **Total for module №2** | **40** |
| **Total for modules №1, №2** | | | **100** |

| **Total Semester Grade** | **100** |
|---|---|

     4.2. Completed types of educational work are credited to the student, if he received a positive rating for them.

     4.3. The sum of rating assessments received by the student for certain types of completed academic work is the current modular rating assessment, which is recorded in the module control.

     4.4. The final modular rating obtained by the student based on the results of the course defense and defense in points, on the national scale and ECTS scale is entered in the module control, as well as in the study card, individual student curriculum and Diploma Supplement, for example, as follows: *92 / Excellent / A, 87 / Good / B, 79 / Good / C, 68 / Sat./D, 65 / Sat./E, etc.*

     4.5. The final semester rating is converted into a grade on the national scale and the ECTS scale.

     4.6. The final semester rating in points, on the national scale and the ECTS scale is entered in the test report, study card and individual curriculum of the student (record book), for example, as follows: *92 / Excellent / A, 87 / Good / B, 79 / Good / C, 68 / Sat./D, 65 / Sat./E, etc.*

     4.7. The Total Grade for the subject is equal to the average grade from Total Semester Grades with its further transformation into national scale and ECTS system.

     The Total Grade is recorded to the Diploma Appendix

(Ф 03.02 – 01)

## АРКУШ ПОШИРЕННЯ ДОКУМЕНТА

| №<br>прим. | Куди<br>передано<br>(підрозділ) | Дата<br>видачі | П.І.Б. отримувача | Підпис<br>отримувача | Примітки |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

(Ф 03.02 – 02)

## АРКУШ ОЗНАЙОМЛЕННЯ З ДОКУМЕНТОМ

| №<br>пор. | Прізвище ім'я по-батькові | Підпис<br>ознайомленої<br>особи | Дата ознайом-<br>лення | Примітки |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

(Ф 03.02 – 04)

## АРКУШ РЕЄСТРАЦІЇ РЕВІЗІЇ

| №<br>пор. | Прізвище ім'я по-батькові | Дата ревізії | Підпис | Висновок щодо<br>адекватності |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

(Ф 03.02 – 03)

## АРКУШ ОБЛІКУ ЗМІН

| №<br>зміни | № листа (сторінки) | | | | Підпис особи,<br>яка<br>внесла зміну | Дата<br>внесення<br>зміни | Дата<br>введення<br>зміни |
|---|---|---|---|---|---|---|---|
| | Зміненого | Заміненого | Нового | Анульо-<br>ваного | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

(Ф 03.02 – 32)

## УЗГОДЖЕННЯ ЗМІН

| | Підпис | Ініціали, прізвище | Посада | Дата |
|---|---|---|---|---|
| Розробник | | | | |
| Узгоджено | | | | |
| Узгоджено | | | | |
| Узгоджено | | | | |