Syllabus of the educational component
Program of educational discipline

Computer Numerical Control of Mechatronic Systems

Code and name of specialty
141 – Power engineering, electrical engineering and electromechanics

Institute
NNI Educational and Scientific Institute of Energy, Electronics and Electromechanics.

Educational program
Electric drive, mechatronics and robotics

Department
Automated electromechanical systems (129)

Educational level
Master's degree

Type of discipline
Professional profile training

Semester
1, 2

Language of teaching
English

Lecturers and course developers

Serhii Pohasii

Serhii.Pohasii@khpi.edu.ua
Candidate of economic sciences, associate professor of the department of cybersecurity of National Technical University "Kharkiv Polytechnic Institute".

The number of scientific publications: more than 95, including 2 utility model patents, 6 monographs, of which 4 are collective monographs, 4 teaching aids, 4 of which bear the seal of the Ministry of Education and Science of Ukraine, 65 articles in foreign publications and specialized publications of Ukraine, with 11 of them are in the Scopus scientometric database. Leading lecturer in the disciplines: "Analog and digital electronic devices", "Internet of things and services", "Security of cloud technologies", "Fundamentals of construction and protection of modern operating systems", "Modeling of critical infrastructure systems", "Fundamentals of construction and protection of microprocessor systems ", "Security of smart technologies and Internet of things", "Information and communication systems in the field of national security" for undergraduate and graduate students, Section "Information security of cloud services", "Modern methods of protection of socio-cyber-physical systems", "Modeling of mechanisms cyber security" for graduate students.

More about the lecturer on the department's website

general information

Abstract

The course is aimed at mastering the theoretical foundations and practical skills in the field of design and operation of modern numerical software control devices and electric drives of metal cutting machines and industrial robots. The principle is considered
organizations and types of industrial networks for automatic control of technological equipment.

Purpose and objectives of the discipline

To form students' concepts and provide knowledge about the methods of building numerical software control systems, the basics of preparing control programs, the structure of numerical software control systems, the principles of building electric drives of metal cutting machines and industrial robots and the organization of industrial networks for the exchange of information between devices of automated control systems.

Format of classes

Lectures, practical work, calculation tasks, consultations. Final control: 1st semester – exam, 2nd semester – credit.

Competences

K01. Ability to abstract thinking, analysis and synthesis.
K02. Ability to use a foreign language for professional, scientific and technical activities and communication.
K03. Ability to search, process and analyze information from various sources. K04.
Ability to use information and communication technologies.
K05. Ability to apply knowledge in practical situations, work independently and in a team.
K13. Awareness of the need to constantly expand one's own knowledge of new technologies in electric power, electrical engineering and electromechanics.
K14. Knowledge and understanding of modern technological processes and systems of technological preparation of production, technical characteristics, design features, purpose and rules of operation of electric power, electrotechnical and electromechanical equipment and equipment.
K15. Ability to apply acquired theoretical knowledge, scientific and technical methods and appropriate software to solve scientific and technical problems and conduct scientific research in the field of electric power engineering, electrical engineering and electromechanics.
K16. Ability to apply existing and develop new methods, techniques, technologies and procedures for solving engineering tasks, including in the design and operation of power engineering, electrical engineering and electromechanics facilities.
K17. Ability to apply analytical methods of analysis, mathematical modeling and perform physical, mathematical and computational experiments to solve engineering problems and when conducting scientific research.
K18. Ability to apply information and communication technologies and programming skills to solve typical tasks of engineering and scientific activities in electric power, electrical engineering and electromechanics.
K 22. The ability to analyze the current state and determine trends in the development of electric drive systems and the theory of automatic control, numerical control systems of mechatronic systems, metal cutting machines, industrial and mobile robots.
K 23. Ability to use modern methods of mathematical apparatus in the design of electromechanical and mechatronic systems and microprocessor control systems of electric drives.
K 25. The ability to develop and calculate schemes of electrical installations for various purposes, determine the composition of their equipment and calculate their operating modes.
K 26. The ability to use modern means of computer technology, communication and communication in carrying out technical calculations of means of automation of enterprises and designing mechatronic systems and modules.
K 27. Ability to use modern methods of design and calculation of individual mechatronic systems and modules and methods of mathematical and computer modeling to study the dynamic characteristics of mechatronic and robotic systems.

Learning outcomes

PR02. Reproduce processes in electric power, electrotechnical and electromechanical systems during their computer simulation.
PR03. Master new versions or new software designed for computer modeling of objects and processes in electric power, electrical engineering and electromechanical systems.
PR05. Analyze processes in electric power, electrotechnical and electromechanical equipment and

corresponding complexes and systems.
PR06. To have the methods of mathematical and physical modeling of objects and processes in electric power, electrotechnical and electromechanical systems.
PR08. Search for sources of resource support for additional training, scientific and innovative activities.
PR10. Adhere to the principles and rules of academic integrity in educational and scientific activities.
PR12. Communicate freely orally and in writing in national and foreign languages on modern scientific and technical problems of electric power, electrical engineering and electromechanics.

PR14. Reconstruct existing electrical networks, stations and substations, electrotechnical and electromechanical complexes and systems in order to increase their reliability, efficiency of operation and extension of the resource.
PR15. To solve professional problems in the design, installation and operation of electric power, electrotechnical, electromechanical complexes and systems.
PR16. To master new methods of synthesis of electric power, electrotechnical and electromechanical installations and systems with specified indicators.
PR18. To analyze the current state and determine trends in the development of electric drive systems and the theory of automatic control, numerical control systems, mechatronic systems, metal cutting machines, mobile and industrial robots.
PR19. Be able to use modern methods of mathematical apparatus in designing electromechanical systems, microprocessor control systems for electric drives of mechatronic systems.
PR21. To be able to use modern means of computer technology, communication and communication in carrying out technical calculations of enterprise automation and designing mechatronic systems and modules.
PR22. Be able to use modern methods of design and calculation of individual mechatronic systems and modules and methods of mathematical and computer modeling for research dynamic characteristics of mechatronic and robotic systems.

Scope of the discipline

The total scope of the discipline is 180 hours. (6 ECTS credits): lectures – 64 hours, practical classes – 16 h., independent work - 100 h.

Prerequisites for studying the discipline (prerequisites)

To successfully complete the course, you must have a 1st (bachelor's) level qualification preparation of the educational program "Electric drive, mechatronics and robotics" or other educational programs of the specialty "Electric power engineering, electrical engineering and electromechanics".

Features of the discipline, methods and technologies of education

Verbal, visual and practical teaching methods are used during classes. Lectures are conducted interactively using multimedia technologies. Lectures are conducted using lecture texts prepared and distributed to students in advance. At this makes it possible to review some sections of the lecture material in more detail and conduct current and test control.
Practical classes are related to the preparation of control programs manually and with using the automated programming system. The developed programs are processed on personal computers with emulators of a real numerical software device management. This allows you to familiarize yourself with programming and the principle of operation of CHPC devices.

Program of educational discipline

Topics of lectures

1 semester, part 1

Topic 1. Modern methods of controlling mechatronic modules and systems
Setting the problem of controlling mechatronic systems. Control hierarchy in mechatronic systems. Management systems of executive, tactical and strategic levels.

Topic 2. General information about ChPK systems
Basic definitions of CHPC systems. The structure of the technological process and technological documentation.Topic 3. Coordinate systems. Calculation of tool path elements
Coordinate systems of the machine, part and tool. Connection of coordinate systems. Calculation of elements of the contour of the part and the trajectory of the tool. Interpolation and features of tool trajectory calculation.
Topic 4. Control program. Code ISO-7 bit

Code ISO-7 bit. The structure of the control program. Control program frame format. Types of software carriers.
Topic 5. Programming automation systems
Classification and overview of SAP. SAP structure. SAP programming languages. Robot programming methods and languages.
Topic 6. Structure and classification of CHPC systems. 1st generation ChPK microprocessor devicesStructure and classification of CNC systems by machines. NC, SNC classes of CNC systems. ChPK systems classes CNC, DNC, HNC. Architecture of microprocessor-based PCs. ChPK device model 2S42. ChPK device model "Electronics NTS-31". ChPK device model "Electronics NC 80-31" (MS-2101). ChPK device model "Sphere-36".
Topic 7. Classification and structural diagrams of modern systems of CHPC
Classification of modern CHPC devices. CNC and PCNC-1 CNC devices. PCNC-1 type WL4 device. PCNC-1 type NC-230 type CNC device. PCNC-2 type CNC device. PCNC-3 type CNC device. PCNC-4 type CNC devices. PCNC device type PCNC-4 model WinPCNC.
Topic 8. Operating systems of control microprocessor systems
Operating Systems. Real time systems. Overview of real-time operating systems. A real-time problem in CNC systems of the PCNC type.
Topic 9. The principle of construction of PCNC-type CNC systems
Modular open architecture of CHPC systems. The principle of open management. Building an intermodular communication environment.
Topic 10. Software and interfaces of control microprocessor systems
Software of MP PCHPK. Features of the software of PCNC type CNC systems. Types of MP system interfaces.
Topic 11. Terminal management problem
Dialog interpreter in the Windows interface. Construction of KP editor in ISO-7bit code and high-level language. Principles of building remote terminals.
Topic 12. Diagnostic management problem
Diagnostic systems of technical condition. Diagnostics of CPC devices. The structure of the PCNC type PCNC diagnosis subsystem. Implementation of a logic analyzer. Oscilloscope implementation.Topic 13. Logical management problem
The essence of the logical control problem. Controller of electrical automation MP PCHPK of the 1st generation.
Control of electrical automation by PLC type controllers. Graphical editor of the logic of operation of the controller of electro-automatic devices of the WL series. Control of electrical automation using the SOFTPLC virtual controller.
Topic 14. Technological task of the ChPK
Quality control of part processing. Adaptive control of processing efficiency. Adaptive control systems.
Topic 15. Implementation of a geometric problem
Interpreter of control programs. The essence of interpolation. Interpolator in CNC systems of the PCNC type.Topic 16. Interpolation methods
Interpolation by the estimation function method. Interpolation by the method of digital differential converters. Polynomial interpolation.

2 semester, part 2

Topic 1. Classification of electric drives of machines and robots. Electric drive of the main movement
Classification of electric drives of machines and robots. Electric drive of the main movement. Functional diagram. Complete drive of the main drive "Kemtor". Complete Fanuc asynchronous electric drive. Complete electric spindles
Topic 2. Complete electric feed drives

The structure of the tracking electric drive. Complete electric drive of direct current supply. Complete asynchronous electric feed drive. Valve electric drive of supply.Topic 3. Stepping electric drive of systems with CNC
Stepper motors. Stepper motor control systems. Complete control units for stepper motors.
Topic 4. Position feedback sensors
Inductive position feedback sensors. Magnetostrictive sensors.
Photoelectric angle converters (FPK). Incremental optical encoders. Absolute optical encoders. Absolute sensors with SSI interface. Optical linear position sensors.
Topic 5. Organization of the outline of the position in the MP of the PCHPK
Organization of the outline of the position in the "Electronics NC-31" PChPK. Outline of the position in the CNC-type CNC "Electronics NTS80-31". Organization of the contour of the position in the CNC 2C42 PCP. PCNC JNC type PCNC axis position module. Position contour of PCNC type FMS-3200.
Topic 6. Follow-up electric drive of systems with CHPK
Purpose and characteristics of the tracking electric drive. Correction of SEP control systems. Follow-up EP with the standard setting of the regulators. Features of choosing an electric motor for the feed mechanism.
Topic 7. Non-standard settings of the regulators of the tracking electric drive
Formulation of the problem. Approximation by the Butterworth polynomial. Approximation by the Chebyshev polynomial. Adjusting the SEP according to the Pozdeev method.
Topic 8. Systems of combined control of SEP
The principle of combined control. A system with compensation of the error by the control influence. A system with error compensation for disturbance effects. The structure of the combined control system.
Topic 9. The influence of the errors of the tracking electric drive on the quality of processing
Quality indicators of details processing. The speed component of the contour error. Static component of contour error. Communication of the electric drive with the CHPK system.
Topic 10. Characteristics and features of the construction of digital tracking electric drivesCharacteristics of digital control systems. Digital position control system.
The structure of the tracking electric drive with a servo controller. Construction of digital drives with SERCOS interface.
Topic 11. Industrial networks and interfaces
General information about industrial networks. The principle of interaction of open systems. Technical and software support of industrial networks. Classification of industrial networks.
Topic 12. Physical data transmission channels
Physical data transmission environment. Wireless data transmission channels. Wired data transmission channels.
Topic 13. Topology of industrial networks
Data transmission technology. Topology of industrial networks. Exchange management methods.Topic 14. Standards and interfaces of levels 1 and 2 of the OSI model
RS-485 interface. RS-422 and RS-232 interfaces. Interface "current loop". Standards of wireless networks.
Topic 15. Sensorbus-type industrial networks
SERCOS is an interface. AS-interface. HART standard. Industrial CAN networks.Topic 16. Fieldbus type industrial networks
Modbus industrial networks. Profibus industrial networks. Ethernet network technology. Industrial networks based on Ethernet.

Topics of practical classes

Topic 1. Calculation of tool trajectory elements
Introduction to product processing programming using the example of milling processing. Programming of part contour and equidistant contour.
Topic 2. Preparation of control programs for the WL4 PDA device
General issues of preparation of control programs for the WL4 control device. Programming of movements. Examples of preparation of the KP of the WL4 CHPK device in the ISO-bit code for various details.
Topic 3. Systems of automation of programming of CPC devices
Preparation of control programs using the programming automation system "INTERSAP-4". Examples of programming in the input language of INTERSAP-4

SAP.Topic 4. Practical work on the WL4 CNC device
Familiarization with the WL4 PCP. Modes of operation. Programming of movements, feeds and technological commands. Work with the WL4 PCP. Entering and editing KP. Learning the visualizer. Execution of individual tasks.

Topics of laboratory works

Laboratory work within the discipline is not provided

Independent work

The course involves the completion of two (one in each semester) individual calculation tasks.
1 semester: Development of a control program for milling processing of a complex part using the "INTERSAP-4" programming automation system.
2 semester: Calculation of the two-zone speed regulation system of the electric drive of the main motion of the metal-cutting machine.
Based on the results of calculations and modeling, a written report is drawn up. After checking the report, the student must defend the calculation task.

Literature and educational materials

Basic literature

1 Anishchenko M.V. Numerical software control systems: study guide/ Kharkiv: "Textbook of NTU "KhPI", 2012. - 312 p.
2 Onofreychuk N.V. Basics of processing and programming on numerically controlled machines / Kyiv: "Svit", 2019. - 352 p.
3 The fate of V.M. Programming, introduction and testing of control programs for machinesfrom CNC and RTK: Study guide. Kharkiv: NTU "KhPI", 2003.169 p.
4 Innovative equipment of automated production. Design features and fundamentals of programming machines with numerical program control [Electronic resource]: study guide for students of specialty 131 "Applied mechanics" specialization "Technologies computer design of machines, robots and machines" / KPI named after Igor Sikorskyi; comp.: Kovalev V.A., Havrushkevich A.Yu., Havrushkevich N.V. – Electronic text data (1 file: 21.8 Mbytes) – Kyiv: KPI named after Igor Sikorskyi, 2020. – 158s https://ela.kpi.ua/bitstream/123456789/36433/1/IOAV_versaty_ChPK.pdf
5 Mirantsov S. L. Systems of automated programming of machines with CNC: training manual / S. L. Mirantsov, V. I. Tulupov, S. G. Onyshchuk, Yu. B. Borysenko, E. V. Mishura, O. S. Kovalevska – Kramatorsk: DDMA, 2011. – 152 p.http://www.dgma.donetsk.ua/docs/kafedry/kmsit/metod.pdf
6 Shulga A.A. Automated electric drive of metal-cutting machines: study guide: for students of the specialty "Electromechanical systems of automation and electric drive" / A. A. Shulga, I. I. Polupan, A. A. Tkachenko. – Kramatorsk: DDMA 2010. – 124 p.http://www.dgma.donetsk.ua/docs/kafedry/kmsit/metod.pdf
7 Preparation of control programs on the example of milling on a 6P13F machine with a device ЧПК 2С42: Methodological instructions for practical classes from the course "Software control of mechanisms" for students of the specialty 7.092203 - Electromechanical automation systems and electric drives/ Layout. M. V. Anishchenko – Kh.: NTU "KhPI", 2011. - 60 p.
8 Synthesis of the two-zone frequency control system of the electric drive of the main drive of metal-cutting machines [Electronic resource]: method. instructions for execution calculation task for the course "Numerical program management of mechatronic systems": for students. specialization 141.09 – Electromechanical systems of automation and electric drive 141.10 – Mechatronics and robotics / comp. N.V. Anishchenko; National technical Kharkiv Polytechnic Institute. - Electron. text. data - Kharkiv, 2019. - 29 p. – URI:http://repository.kpi.kharkov.ua/handle/KhPI-Press/39464.
9 Calculation of electric drives of machines with numerical software control: Methodical instructions for course and diploma design for students of specialty 7.05070204 Electromechanical systems of automation and electric drive / Layout. M.M. Kazachkovsky - Dnipropetrovsk: National Mining University, 2013. - 50 p. https://elprivod.nmu.org.ua/ua/student/disciplines/pdpdp/%D0%95%D0%9F_%D0%A7%D0%9F%D

0%A3.pdf.
10 Pupena O.M. Industrial networks and integration technologies in automated systems:
Study guide / O.M. Pupena, I.V. Elperin, N.M. Lutska, A.P. Ladanyuk – K.: Publishing house "Lira-K", 2011. – 552 p.

Additional literature

1 Methodical instructions for independent work "Numerical software control of technological equipment" from the discipline "Metal cutting machine control systems" and "Automation of production processes" For students of the training direction 6.050502 "Engineering mechanics" and 6.050503 "Mechanical engineering". Inc.: Korotkov V.S. Dniprodzerzhynsk, DDTU, 2016, 12 pages.http://www.dstu.dp.ua/Portal/Data/1/1/1-1-mzs10.pdf
2 Mulyar Yu. I., Deribo O. V. Programming of lathe processing on CNC machines. Educational manual. – Vinnytsia: VNTU, 2004. – 91 p.http://pdf.lib.vntu.edu.ua/books/2016/Mulyar_2004_91.pdf3 Technical documentation of the WL4M CNC device

Evaluation system

Criteria for evaluating student performance and distribution of points

1 semester: 100% of the final grade consists of assessment results in the form of an exam (40%) and ongoing assessment (60%). Exam: 2 questions on theory +
performance of the task, oral report.
Current assessment: online tests, performance of individual tasks in practical classes and calculation task (20% each).
2 semester: 100% of the final grade consists of the results of the current assessment. current assessment: online tests, and a calculation task (50% each).

Rating scale

Total points	National assessment	ECTS
90–100	Perfectly	A
82–89	Fine	B
75–81	Fine	C
64–74	Satisfactorily	D
60–63	Satisfactorily	E
35–59	Unsatisfactorily (further study required)	FX
1–34	Unsatisfactorily (re-study required)	F

Norms of academic ethics and policy of the course

The student must adhere to the Code of Ethics of Academic Relations and Integrity of NTU "KhPI": show discipline, education, benevolence, honesty, responsibility.
Conflict situations should be openly discussed in study groups with the teacher, and if it is impossible to resolve the conflict, it should be brought to the attention of the employees of the institute's directorate. Regulatory and legal support for the implementation of the principles of academic integrity of NTU
"KhPI" is located on the website:http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

Coordination

Syllabus approved	Date of approval, signature 21/09/2023	Head of Department Bohdan VOROBYOV
	Date of approval, signature 21/09/2023	Guarantor OP Vera SHAMARDINA