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CHAPTER 3. PRINCIPLES DEVELOPMENT OF MODULES MECHATRONIC SYSTEMS

3.1. Construction Principles and Levels of Integration Electromechatronic Systems

General trends in the development of technology and features of mechatronics, as well as robotics, directly determine the main principles that have a systematic approach in accordance with the law of degree 3/2, step-by-step miniaturization, unification, integration, intellectualization.

In view of the development of mechatronic systems and robotics, some general principles on which their work is based are defined [1–4].

The first principle is system design (that is, the synthesis of mechatronics products) based on system-wide criteria without decomposition into individual functional components. The implementation of this principle became possible only at a certain stage of the development of science and on the way to its further improvement. At the same time, there are still many problems in terms of the formation of system-wide criteria and the development of synthesis methods based on them.

The second principle is the step-by-step miniaturization of elements through the successive mastering of different dimensions of products in the form of separate generations of technology. Each such generation requires new, appropriate technologies. At the same time, technological equipment based on the technique of preliminary dimensioning is necessary for the implementation of ideas.

For example, the implementation of this principle in micromechatronics involves the development of 3D mechatronic and microsystem technologies based on 2D microelectronics technologies. The development of nanotechnology, for its part, involves the use of microtechnology (for example, micromanipulators, etc.).

The third principle is the unification of functional components. In the course of miniaturization for systems down to decimeter dimensions, this principle is implemented in the form of modular construction of systems from the type of dimensional series. They have structurally unified functional components, such as: power supply, sensor, information and control, executive (drive).

Considering the main requirements for components, they can be divided into two groups: informational and power.

With the reduction of overall dimensions of product elements to the level of centimeter dimensions, system-wide optimization leads to mutual penetration (convergence) of these functional components. This leads to a reduction in weight and size parameters, an increase in speed and reliability (primarily by reducing intercomponent connections).

The first mastered stage of the process is the dissemination of artificial intelligence methods with informational and control components that affect other functional components from sensory to executive.

A similar trend exists in energy supply and energy consumption through its decentralization and the introduction of secondary energy sources into separate functional components. The basis of these processes, as before, is system-wide optimization.

The fourth principle is the integration of functions on the basis of homogeneous structures. The principle of building systems is replaced by the modular one when moving to millimeter dimensions. This is preceded by the above-mentioned gradual mutual penetration of functional components, which ends with the transition to a qualitatively new type. Such a transition includes two stages.

The first stage covers informational components (sensory, informational and control, communication), and the second - power (executive, power supply).

Currently, the first stage is implemented on the basis of neuro-like structures. Each function is performed by separate sections of such structures with the possibility of their operational redistribution and boundary changes. Such an organization is similar to a multi-agent system in computer networks. Individual components lose their constructive independence and turn into a software product, namely into software agents-modules functioning in a homogeneous material environment.

The second stage of mastering homogeneous structures is the implementation of this principle in power functional components. This task requires the search for new physical principles and ways of their technical implementation. Research is being conducted on the creation of "artificial muscle" actuators. They consist of hundreds of elementary microactuators based on electroactive polymers and have energy sources (nanobatteries or nanofuel cells). This contributes to the improvement of the weight and size parameters of the drives and allows to dramatically increase the reliability of their components and modules in general.

The fifth principle is the intellectualization of both individual functional components and system-wide functions. The further development of this principle will be the technical development of creative (creative) human abilities.

The sixth principle is the so-called power law of 3/2. It belongs to miniaturization and consists in the fact that due to the different order of dimensions of the volume (3) and surface (2) of the objects, when they are miniaturized, the significance of surface phenomena increases. For example, heat exchange with the external environment compared to volumetric phenomena (inertia, etc.). As a result, the principles of construction, methods of calculation and design of mechatronic systems in the process of their miniaturization are subject to revision.

Considering the construction structure and levels of integration of electromechatronic systems, we must define a mechatronic device.

Mechatronic devices are a class of machines or assemblies based on the use of advances in precision mechanics, electric drive, electronics, and computer control. All these elements can be found in a huge number of traditional techniques.

Mechatronic devices are generally defined by a number of features:

1. Availability of integration of the following functional elements:

– the output mechanical link, which performs the external functions of the mechatronic device;

– engine of the output link with a mechanism for transmitting motion to the output mechanical link;

– amplifier-converter of engine power supply energy;

– device for digital program control of the drive;

– an information system that monitors the state of the external environment and the internal parameters of the mechatronic device.

2. A minimum of information and energy transformations (for example, direct digital control of a gearless drive).

3. Using one and the same element of a mechatronic device to implement several functions (for example, motor parameters: current, EMF resistance), which are used to measure its moment and speed (principle of combining functions).

4. Designing the functions of various elements of the mechatronic device in such a way that the purpose of the service purpose of the product is achieved by joint performance of these functions without their duplication and with maximum effect (principle of synergy).

5. Combining the housings of mechatronic device nodes (principle of combining housings).

The computer control device performs the following functions:

– control of the process of mechanical movement of a mechatronic module or multidimensional system in real time with processing of sensory information;

– organization of control of functional movements of a mechatronic system, which involves coordination of control of its mechanical movement and accompanying external processes. Usually, discrete inputs/outputs of the device are used to implement the control function of external processes;

– interaction with the "man-operator" system through the machine interface in autonomous programming modes (off-line mode) and directly during the movement of the mechatronic system (on-line mode);

– organization of data exchange with peripheral devices, sensors and other devices of the system.

Qualitatively new properties of mechatronic modules, compared to traditional drives, are achieved by synergistic integration of constituent elements.

Synergistic integration is not simply the connection of separate parts into a system using interface blocks, but the construction of a single drive module through the constructive combination and even interpenetration of elements that usually have different physical origins.

The purpose of mechatronic modules is the implementation of a given controlled movement, usually by one controlled coordinate.

Mechatronic motion modules are the functional "cubes" from which complex multi-coordinated mechatronic systems can then be assembled.

The essence of the mechatronic design approach is to combine components into a single drive module.

The application of the mechatronic approach to the design of the motion module is based on the determination of possible points of integration of elements in the drive structure. On this basis and taking into account technical, economic and technological analysis, it is necessary to make specific engineering decisions on the design and manufacture of the movement module.

For example, the input of the mechatronic module receives information about the purpose of movement, which is formed by the upper level of the control system. The output is a purposeful mechatronic movement of the final link (movement of the output shaft of the module).

So, for the physical implementation of an electromechanical mechatronic module, four functional blocks are theoretically necessary, which are connected in series. For example, informational-electrical and electromechanical, functional converter in a direct circuit and electrical-informational and mechanical-informational converters in a feedback circuit.

3.2. Structure and Means of Diagnostics Mechatronic Systems

The construction of a diagnostic forecast, the development of transport, mechanical engineering, etc., as well as the selection of the main trends and strategies, focuses on the following:

– integration of technologies and knowledge;
– intellectualization of production technologies;
– mechatronic technologies of machines and robots;
– end-to-end information systems.

The system approach dictates new requirements for built-in mechanical and hybrid components, defining their parameters and characteristics. This, in turn, leads to the development of new technologies and design solutions in the field of energy and mechanics.

There are test and functional diagnostic systems.

In test diagnostics systems, specially organized test effects from diagnostic tools are applied to the object. In this case, the diagnostic object is usually not used for its main purpose, but works only for diagnostic tasks.

In the systems of functional diagnosis, the object receives working influences, which are provided by its algorithm of functioning according to the purpose.

In systems of both types, the diagnostic equipment perceives and analyzes the feedback of the object to the input (test or working) influences (stimuli) and issues the diagnostic result.

So, the diagnostic system consists of active visual (diagnostic installation) and measuring (diagnostic device) parts.

Diagnostic systems, depending on the level of control, can be performed as non-automatic, automated (process control) or automatic (system control). Computerized or computer diagnostic systems are usually used to implement an automated or automatic diagnostic process [5–7].

A non-computer diagnostic system does not exclude the use of a personal computer by the operator for the purpose of obtaining reference diagnostic information about the object of diagnosis, as well as entering and processing the results of diagnostics. At the same time, the personal computer does not have a direct information connection with the means and objects of diagnostics.

In general, a computerized system is created on the basis of a conventional electromechanical diagnostic system by computerizing it and completely falls under the category of "diagnostic equipment".

Digital-to-analog converters are used to match the digital signals of the diagnostic computer with the electromechanical converters of the diagnostic unit.

Analog-to-digital converters are used to measure analog signals of electrical devices of the measuring part of the system by a diagnostic computer.

The computer diagnostic system provides for the exchange of information between the diagnostic computer of an external connection and the on-board computer, on the basis of which the on-board diagnostic system is integrated. In such systems, the main diagnostic functions are implemented on the basis of elements, for example, the standard equipment of the car.

In this case, the diagnostic system is divided into "diagnostic equipment" and "diagnostic equipment" according to the category of means. At the same time, the diagnostic computer (device) connected to the on-board computer usually performs only the functions of the operator's peripherals (keyboard and monitor). The adjustment of digital signal levels of the local computer network formed in this way is carried out using an adapter.

Integrated diagnostic systems belong to the class of embedded diagnostic tools, which are built into mechatronic systems at the software and hardware levels. Such systems perform several passive (observation, informing) and active (reservation, adoption) functions, the implementation of which is based on the use of an expert program.

An expert system is a program that uses expert knowledge (knowledge of specialists) to provide an effective solution to informal problems in an interactive mode [6–10].

Informal problems are characterized by certain characteristics:

– tasks cannot be given in numerical form;

– the goal cannot be expressed in terms of a precisely defined objective function;

– there is no algorithmic solution to the problem;

– the presence of signs of error, ambiguity and contradiction of the original data.

The functioning of the expert system is based on the use of knowledge, and its manipulation is carried out on the basis of heuristic rules formed by the expert. Expert systems provide advice, analysis, classification, consultation and diagnosis.

Unlike conventional programs that use procedural analysis, expert systems solve problems in a narrow subject area based on deductive reasoning.

In addition to the functional purpose, expert systems are classified according to several structural features [7,8]:

– the method of decision formation (analytical or synthetic);

– time accounting (static or dynamic);

– types of data and knowledge (deterministic or indeterminate);

– the number of sources of knowledge.

During the development of expert systems for certain subject areas, existing software shells are used:

1) SHELL – a basic element of the operating system that determines the interpretation of user commands and actions;

2) CLIPS – a system that uses the conclusion from facts to the goal;

3) DYNACLIPS – includes a bulletin board, a mechanism for dynamic knowledge exchange, and tools for CLIPS;

4) FuzzyCLIPS – used to represent and manage fuzzy facts and rules, has two basic concepts of inaccuracy, vagueness and uncertainty;

5) OPS5 – contains knowledge presentation and management mechanisms, enables the programmer to use symbols and represent relationships between symbols, according to the rules proposed by the programmer;

6) WindExS – a fully functional Windows-based expert system; contains a logical inference engine, a file manager, a user interface, a message manager, and knowledge base modules; supports fact-to-goal inference and graphical representation of the knowledge base;

7) RT-EXPERT is a general-purpose expert system that enables programmers to integrate expert system rules into application programs.

The basis of the expert system is a knowledge base (formalized empirical knowledge), which is designed to store long-term data describing the object field and the rules for appropriate data transformations of this field.

The analysis of the object sphere in the expert system is carried out by selecting an adequate solution from the knowledge base upon receiving the database, which determines individual facts characterizing objects, processes and phenomena in the subject sphere.

For example, in relation to car diagnostics, the mechatronic system is considered as an object field, and its technical condition is considered as an object field. In this case, the admissible (reference) values of diagnostic parameters and the algorithms of functioning of a working system are considered as a knowledge base (hereinafter referred to as the database), and as a database – the current (actual) values of diagnostic parameters and algorithms of the functioning of the system based on the fact of their implementation (hereinafter according to the test - current data).

Therefore, all the current information about the state of the mechatronic system, which is received and stored in the expert system, is the parameters of electrical quantities (signals), which are analyzed in an interpreted (coded) form by comparison.

Depending on the purpose and mode of operation, integrated diagnostic systems have a different structure and are divided into informational and self-diagnostic systems, as well as adaptation and backup systems.

The information diagnostic system is an integrated system built on the basis of an expert system and designed to control the diagnostic parameter of the control object. Such a system performs passive diagnostic functions (for example, registration of deviations of diagnostic parameters beyond acceptable values).

Signals from sensors of the information system are not used to implement the object management process and are considered only as diagnostic parameters. The database of the expert system stores the permissible values of the signal parameters of the list of sensors of the information system.

The self-diagnosis system is an integrated diagnostic system built on the basis of an expert system. It is designed for diagnostics of control system elements (transducers, actuators) and performs passive diagnostic functions (fact registration and fault localization). The information signals of sensors and the control signals of executive devices of the self-diagnosis system are used to implement the object control process. Therefore, mode (working) signals of the control system (bulky connection arrows) are simultaneously considered as diagnostic parameters (thin connection arrows).

The redundancy system is an integrated diagnostic system built on the basis of an expert system designed to maintain the operability of the mechatronic system in case of failure of its individual elements and performs active diagnostic functions (hardware element replacement or software signal replacement).

The redundancy system, like the self-diagnosis system, is based on the analysis of current information coming from the operating signals of the control system.

The adaptation system is an integrated diagnostic system built on the basis of an expert system. It is designed to support optimal control of the object in case of impact on the mechatronic system by destabilizing factors (external, structural) and performs active diagnostic functions.

The adaptation system reproduces the functions of the automatic control system (stabilization of the output parameter), where the transmitter of the output signal (parameter) is used in the feedback loop. An exemplary value of this parameter stored in the database of the expert system is considered as a resistance level.

The reliability of the operation of electromechatronic systems is determined by means of diagnosis using diagnostic methods implemented for a specific object.

System diagnostic tools have several features, which consist of the following:

– checks of the technical system;
– determining the diagnosis of damage;
– building a diagnostic system;
– locations and conditions of diagnostic operations;
– the diagnostic tool used.

The methods of diagnosing technical systems by the type of checks can be classified according to the following characteristics: the nature of human participation in the diagnosis process; a means of detecting a malfunction; as a means of reproduction during inspections by substitution methods; search type; the flexibility of implementation of diagnosis algorithms; depth of fault localization [7,8].

According to the nature of human participation in the diagnosis process, organoleptic (subjective assessment based on signs and symptoms of malfunctions), statistical (analysis of accumulated information about failures), and instrumental or hardware (using diagnostic tools) methods of determining the technical condition of the object are distinguished.

Instrumental means methods that use non-electrical means of control (measuring tools, mechanical equipment, direct assessment devices), and hardware means methods that use electrical measuring devices that control electrical and non-electrical parameters.

Modern diagnostic hardware methods involve the use of special test stands and complexes, the structure of which consists of electromechanical drives (actuators), sensors of non-electric quantities, electrical means of displaying information (measuring devices) and devices for converting measured signals into information ones.

The selected parameter determines the diagnosis method (principle of building a diagnostic system) and, accordingly, the diagnostic tool in which these functions are implemented. In addition, all these positions regarding the object of diagnosis can be alternative.

According to the structural feature, complex diagnostics based on the initial characteristics of vehicles (functional parameters), system and aggregate diagnostics, and diagnostics of nodes and assembly units based on structural parameters are distinguished. Depending on this, the place and conditions for conducting diagnostic operations are determined.

Usually, complex diagnostics is carried out at the post, system – on board the vehicle, aggregate – in the conditions of the electrical section or car repair company. Test diagnosis is carried out under static conditions, and functional - during system tests. Inspections can be carried out with working (activated) or non-working units and systems.

Considerable attention is paid to the undercarriage systems of the vehicle, which depend on the safety of the vehicle (brakes, steering wheel, suspension). The overall technical condition of the braking system is assessed using decelerometers (vehicle deceleration meters) and decelerographs (deceleration recorders). At diagnostic posts, roller stands (with running drums) are common, which use the forces of adhesion of the vehicle wheel to the supporting surface, and stands where the braking moment is transmitted directly through the wheel or through the hub [7, 8, 9].

Diagnostics of control bodies consists in checking the degree of wear and backlash of connected parts, deformation of levers and rods, violation of adjustments. For example, diagnostics of vehicle steering is carried out by evaluating the total circumferential backlash (according to the scale of the backlash gauge) and the value of the friction force (according to the readings of the dynamometer).

Diagnostic parameters of electrical and electronic devices and systems can be conditionally divided into several groups: parameters of constant values, parameters of actual values, time parameters, shape parameters.

For electrical systems, the consumption current, the electrical resistance of the supply circuit, and the voltage on the circuit sections are mostly alternative parameters. Universal measuring devices are used to control these parameters on board any electromechanical system.

The devices for evaluating parameters of constant values include meters of electrical resistance R (ohmmeters), constant voltage U (voltmeters) and current I (ammeters). Ohmmeters are used for "cold" testing of circuits and discrete circuit elements. Voltmeters and ammeters are used to evaluate diagnostic parameters when the diagnostic object is turned on. Diagnostic parameters of operating values, which include alternating current voltage and alternating current, are measured with alternating current ammeters and voltmeters.

The functions of the listed measuring devices are usually implemented in combined devices of universal (multimeters) or, for example, automotive (auto testers) application.

The time parameters of electric signals (frequency f, pulse duration t and their frequency q) make it possible to evaluate the operation of setting, forming and relaxation circuits, as well as cascades of electronic devices of control systems and are measured using frequency meters and oscilloscopes.

The parameters of the waveform (amplitude, steepness of the fronts, unevenness of the pulse peak) are used to estimate the values of the distributed reactive parameters of pulse circuits (electronic units, ignition systems, etc.) and are measured using oscilloscopes.

The phase shift between periodic harmonic signals of the same frequency (voltage and noise) characterizes the reactive component resistance of an alternating current circuit and is measured using oscilloscopes.

In pulse devices, the phase shift of periodic signals is generally considered as a functional parameter.

Electric energy converters for various purposes are used in the vehicle's electrical systems (lighting devices, heaters, actuators, etc.).

Non-electrical parameters can also be added to the list of diagnostic parameters: strength and direction of the light beam of headlights, temperature of heating elements, working clearances, etc. In this case, optoelectric, thermoelectric, tensometric, etc. should be added to the list of measurement methods, and regloscope, thermometer, dynamometer, etc. to the list of diagnostic devices.

After localization of a faulty system, device or unit in a vehicle or under static conditions, they are sent to the electrical section for troubleshooting (maintenance and replacement of structural elements) or for unit restoration (rewinding of windings, boring of anchors).

In the first case, special stands and specialized aggregate diagnostics devices are used, in the second case, stationary industrial equipment. Computer diagnostics of mechatronic systems during driving and testing of the vehicle is carried out using portable diagnostic scanners.

3.3. Development Trends and Principles of Building Modules Mechatronic Systems

The process of miniaturization is based on the implementation of this trend in the basic components of any equipment - sensor, information and control, executive (power), power supply.

Classic solutions in the field of design and construction of technical modular systems are based on the possibility of decomposition of general technical requirements for the system at the stage of design of the technical task, which is widely used for machines and complexes at the macro level.

An example of convergence in a different sense (the process of convergence, reaching compromises) or interpenetration of functional subsystems are MEMS devices, in which sensor, information-control and executive components are placed on a single micro-platform.

At the same time, for example, photo sensors are integrated with microprocessors, and piezo elements are simultaneously executive devices.

Acceleration of the convergence process is dictated not only by the need for miniaturization, but also by the wide opportunities that open up with each new level of interpenetration of subsystems. At certain stages of integration, real opportunities appear for self-organization and self-reproduction processes.

The latest complex components have already become examples:

– energy sources are miniature chemical current sources in which polymer membranes with a nanoporous structure are used as effective electrolyte fillers;

– information and control – radiation-resistant microanalogues of electronic lamps, as well as micromechanotronics, in which the cold cathode is formed from carbon nanotubes;

– sensors are chemical sensors based on transistor structures with pre-formed chemisorption centers;

– distributed tactile sensors, the sensitive elements of which are made of nanocomposite materials;

– encoders of angular velocities and linear accelerations for orientation and navigation systems, in which moving elements are manufactured by growing methods in the process of creating the module component as a whole.

When building mechatronic modules, robotics and mechatronics are inextricably linked. If progress in modern robotics is determined mainly by the success of mechatronics, which ensures the miniaturization and integration of functional components, then the process of robotization of technical means is one of the most important stimulators and catalysts of the development of mechatronic technologies. Robotization involves steadily increasing requirements in the field of intellectualization and complex automation of complex systems. Mechatronic technologies ensure this process by creating a design and technological base.

Robotics technologies are based on the same principles as mechatronic technologies. In addition to intellectualization and miniaturization, they include a number of macro-level technologies: unification of components and their interface interconnection, integration of functions and mutual penetration (convergence) of heterogeneous functional subsystems [10, 11].

Let's consider each functional subsystem in more detail.

The sensory subsystem is represented by transducers that implement the functions of hearing, touch, technical vision, orientation and geometric parameters of the control object, its position in space for the purpose of navigation, etc.

The executive subsystem makes it possible to move the platform (locomotion), as well as functional movements - fixing, grabbing, folding, positioning, etc. Manipulation of systems takes place through the use of drives, mechanical gears, grippers and other elements of influence.

The information and control subsystem provides collection, processing and storage of information, generation of control signals, static and dynamic feedback, as well as interaction with the operator or an external control system of a higher level by means of receiving and transmitting information by means of communication.

The energy subsystem regulates the supply and distribution of energy of other subsystems, as well as the accumulation of energy from external sources and its storage during the operation of the machine. Internal energy components can be represented by chemical, electrical, nuclear, micro-explosive, pneumatic and other similar energy sources.

Critical from the point of view of the need for fundamentally new approaches to development are the executive and energy components, which require the organization of conditions for basic innovations in these areas.

Sensor and information-control components are widely adopted, which improves further innovation and emphasizes the development of new subsystems. For example, the development of modern means of global navigation ensured their widespread use at the household level. This makes it possible to predict the equipping of vehicles with navigation equipment and to use them as integral requirements for such systems already in the near future.

The given analysis of the objective development trend of approaches to the construction of technical systems shows the need for large-scale measures regarding the system development and software implementation of mechatronic technologies, as well as for the realization of the needs of industry today and in the perspective of the next 5-10 years.

On the basis of the forecast and systematic analysis of the prospective needs of all branches of the country's economy, it is necessary at the state level to undertake the anticipatory development of the above-mentioned components in the form of a system of unified mechatronic modules, covering the entire standard size range of machine-building products, based on promising production technologies.

As the first steps in this direction, it is advisable in the near future on the basis of large scientific centers that have the necessary experience in the development of the systems in question, to launch the production of micro-robotic systems of the new generation, which are built using mechatronic design technologies. At the same time, it is necessary to use modern MEMS components as a technological basis.

Thus, the use of micron-sized mechatronic modules makes it possible to talk about the development of distributed component systems based on multiplexing and on the basis of microchips with a high level of intellectualization.

This ensures the reliability and stability of the received data and information. Such an approach increases the level of system reliability many times due to the possibility of transferring part of the functions of failed components to others without significantly reducing technical characteristics during critical operations.

The complex nature of the approach to the development of mechatronic modules requires a systematic integration of all the work carried out, which is confirmed by the experience of developing and creating foreign analogues. A typical example is integrated computer production complexes of domestic and foreign systems.

The scientific and technical relevance of this problem logically follows from the advantages of a technical modular system built according to the mechatronic principle: intelligence, adaptability, reliability, miniaturization.

The principles of robotics and mechatronics are interconnected and have a common theoretical basis [1, 10, 11].

Only the principle of unification, which determines the peculiarities of the use of robotics, has significant specificity:

– wide nomenclature;

– the complexity of the technical requirements for the means of robotics, which is often at the limit of the capabilities of modern technology;

– insignificant needs of elements in certain types of robotic systems.

These features are the basis for solving the task of unifying robotics tools by building them from functionally and constructively unified components - mechatronic modules in the form of their standard size series with a modular software system.

The advantages of the modular construction principle are as follows:

– shortening the terms of creation, development in production and operation of technical modular systems;

– system design, which comes down to assembling from standard components, and their production - to assembly from them, which can be organized at almost any machine-building enterprise;

– the possibility of practically unlimited expansion of the range of technical systems, in particular, the operational composition of their various modifications for specific one-time applications;

– reducing the cost of systems by several times due to the cheaper parts of them when switching to unified serial modules and reducing structural and parametric redundancy;

– reduction of costs for the development, operation and repair of technical modular systems;

– the growth of their technical level, in particular reliability, the use of proven standard modules.

The effectiveness of the modular principle does not exclude the use of other engineering principles in robotics. For example, the experience of industrial robotics shows that when designing transport and loading and unloading robots, the optimal principle of their construction is the creation of such systems based on previously developed basic structures. When creating technological robots to perform such operations as welding, cutting, assembling, the aggregate design principle often turns out to be the most effective.

It is also necessary to take into account the fact that the modular construction of equipment has its own disadvantages, which are caused by the inevitable overestimation of weight and size characteristics and the number of intermediate mechanical and electrical connections.

Organizational principles. The development of mechatronics and robotics as a complex interdisciplinary scientific and technical direction requires an adequate state organization. This is how the development of robotics began.

For example, in Japan, which is recognized as a leader in this field, all the achievements were obtained precisely because the anticipatory development of robotics was recognized as a strategic state task. A similar approach was implemented in a number of European countries.

The main state tasks include:

– determination of the nomenclature of functional components and technical requirements for mechatronics and robotics (with the selection of priority needs) based on the analysis of financial needs.

– unification of these components, their development and organization of industrial production. This will make it possible to reduce the range of products by 2-3 times, and, accordingly, the development costs, increase the serial production, reduce the cost and increase the quality;

– development of primary basic mechatronic and robotic systems and complexes on this basis;

– their industrial production and testing in operation.

According to the tasks, the following works are provided:

- creation of priority systems of mechatronics and robotics of the new generation;

- organization of training and retraining of personnel, in particular organizers and managers.

In general, the development program should be focused on the solution of the most important state tasks (security, technological independence, technical support, development of critical technologies and types of equipment according to priority areas of development). In the future, these solutions should be replicated and developed to meet other needs in mechatronics and robotics funds.

When developing and organizing the production of relevant products, it is necessary to be guided by the following:

– creating products that are guaranteed to be competitive on the world market;

– a solution to the problems of import substitution and organization of the production of the best examples of this technology in the world, but at a significantly lower cost.

As mentioned above, the solution to this problem is based on the further development of the following critical technologies:

– mechatronics technologies and creation of microsystem equipment;

– technologies for creating intelligent systems;

– bioinformation technology;

– information processing and protection;

– biosensor technology.

So, the considered complex problem immediately belongs to several priority areas of development of science and technology. First of all, this is the industry of nanosystems and materials, living systems, information and telecommunication systems. The proposed approach is of particular importance in the creation and implementation of technical means for ensuring security and countering terrorism.

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production in the world – 2023 : collective monograph. (Series of monographs Slovak publishing house NES Nová Dubnica s.r.o. Monograph 1). Nová Dubnica : NES Nová Dubnica s.r.o., 2023. P. 70–88. https://dspace.bdpu.org.ua/handle/123456789/732

natural science is formed, and the level of educational achievements increases. The project method forms the basis of project-based learning, the purpose of which is to create conditions for independent assimilation of educational natural scientific material by pupils in the process of project implementation.

Keywords: project, cognitive interest, primary school, studying, primary school pupils, natural science.

2.2. Borys Shevel FORMATION OF ECONOMIC COMPETENCE OF FUTURE TEACHERS OF VOCATIONAL EDUCATION AND TECHNOLOGY AS A SCIENTIFIC AND PEDAGOGICAL ISSUE

An analysis of the problem of economic training for future teachers of vocational education and technology has been conducted. Based on the research, it has been observed that the formation of economic competence is relevant and strategically significant for students in this specialty, contributing to the socio-economic development of the Ukrainian state. The main approaches to interpreting the given definition have been considered, and our own vision of it has been proposed.

Keywords: future teachers of vocational education and technology, technological education sector, economic competence.

CHAPTER 3. Serhii Onyshchenko PRINCIPLES DEVELOPMENT OF MODULES MECHATRONIC SYSTEMS

The main concept of electromechatronic systems is to harmonize the design principles of physically disparate components of mechanical and electrical systems. The joint functioning of such systems and their subsystems makes it possible to ensure the necessary parameters and characteristics of machines and mechanisms already at the early stages of design.

This approach requires a developed system of automated design and control and consists of software modules of automated formation, the study of mathematical models of the dynamics of both machines in general and their individual functional parts.

On the basis of the created electromechatronic systems and subsystems, promising methods of their diagnosis are being developed, which contribute to the creation of modern automated structures that have wide possibilities and interchangeability of elements.

In general, mechatronics is related to practice and technical progress, which is due to the knowledge and skills of specialists and their engineering intuition.

Keywords: mechatronics, system, complex, module, electromechatronics.

ABOUT THE AUTHORS

CHAPTER 1. MODERN BASICS OF ECONOMICS, MANAGEMENT AND TOURISM

1.1. Andrii Kalynovskyi – PhD in Economics, Associate Professor, Associate Professor of the Foreign Trade and Customs Department, Lviv Polytechnic National University, Ukraine

1.2. Nataliya Synyutka – PhD (Economics), Associate Professor, Associate Professor Department of Finance, Lviv Polytechnic National University, Ukraine

1.3. Olena Shandrivska – Ph.D., Assoc.Prof., Assoc.Prof. Department of Modern Foundations of Economics, Management and Tourism, Lviv Polytechnic National University, Ukraine

Nataliya Hryniv – Ph.D., Assoc.Prof., Assoc.Prof. Department of Modern Foundations of Economics, Management and Tourism, Lviv Polytechnic National University, Ukraine

CHAPTER 2. INNOVATIVE AND MODERN FOUNDATIONS OF PEDAGOGY AND PSYCHOLOGY

2.1. Iryna Mozul – Candidate of Pedagogical Sciences, Senior Lecturer of Theory and Methods of Primary Education Department, Educational and Scientific Institute of Pedagogy and Psychology Oleksandr Dovzhenko Hlukhiv National Pedagogical University, Ukraine

2.2. Borys Shevel – PhD in Education, Associate Professor, Associate Professor of the Department of Technological and Vocational Education, Oleksandr Dovzhenko Hlukhiv National Pedagogical University, Ukraine

CHAPTER 3. PRINCIPLES DEVELOPMENT OF MODULES MECHATRONIC SYSTEMS

3.1., 3.2., 3.3. Serhii Onyshchenko – PhD, Associate Professor, Associate Professor of the Department of Professional Education, Labor Training and Technologies, Berdyansk State Pedagogical University, Ukraine