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Modular Design of Electromagnetic Mechatronic Multi-axis Modules

NazarovKH.N., MatyokubovN.R.

Associate Professor, Department of mechatronics and robotics, Tashkent State Technical University,
Senior lecturer of the department automation of manufacturing processes, Tashkent State Technical University

ABSTRACT: The article discusses the principles of modular construction of manipulators of intelligent robots based on multi-coordinate mechatronic modules, classification of mechatronic modules by design features, structural, kinematic, and analytical descriptions of multi-coordinate mechatronic modules of intelligent robot robots.

KEYWORDS*:* intelligent robot, multi-coordinate mechatronic module, robot manipulator, classification of mechatronic modules.

I. INTRODUCTION

During creation of the intelligent robot as well as when developing some other machines, two main directions connected with attempts of finding of the most rational method of their creation in terms of reduction of cost of the robot and increasing reliability. One of these directions — creation of the universal robots having broad functionality, and another — creation of specialized robots with smaller opportunities, but simpler on construction.
The first of these areas involves the development of a number of robots with wide capabilities, which allows them to be used in various areas of production, therefore, the production of each of the models can reach significant sizes, which, as is known, helps to reduce costs. The disadvantage of this method is the relatively high cost of an intelligent robot due to its complexity. At the same time, the capabilities of an intelligent robot are underutilized in many cases.
A feature of the modern stage of development of electromagnetic multicoordinate mechatronic modules (EMMM) of robotic systems is the intellectualization of the management processes of their functional movements. The main attention is paid to the development of a fundamentally new generation of multi-axis modules, in which the integration of three components - electromechanical, electronic and computer - is carried out and it is possible to obtain a set of coordinates of the module. The technical realization of intelligent EMMM movements became possible due to the rapid development in recent years of microprocessor-based systems focused on motion control tasks. Electromagnetic multicoordinate mechatronic motion modules allow one to obtain a set of linear and angular motions at the output.

II. MATERIAL AND METHODS

The second direction in creating an intelligent robot, on the one hand, leads to an increase in the nomenclature of the robot, which adversely affects the serial production of their production and, consequently, the cost, and on the other hand, simplifying the design of the intelligent robot arm reduces the cost of manufacturing the robot.
One of the ways to facilitate the resolution of these contradictions is the construction of an intelligent robot arm on an aggregate-modular basis.

The aggregate-modular method of building an intelligent robot, that is, creating manipulator structures based on a limited group of normalized nodes, has several advantages, which basically boil down to the following [1]:

• the possibility of obtaining specialized machines that best meet the requirements of solving a specific technological problem and do not have redundant functions and therefore are cheaper than universal robots. At the same time, specialized robots are not carried out on individual projects, but are separate representatives of a previously developed range;

• reducing the time and complexity of designing specialized robots, since the aggregate construction of the structure allows for a more complete use of previously developed designs and expanding the range of products by adding new nodes and their combinations based on previously developed nodes;

• an increase in the reliability of the robot due to the sophistication of its components and the greatest compliance of

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this design with the problem to be solved;

• improving operating conditions and improving the maintainability of the robot park by reducing the number of options for the construction of components and parts;

• Cheaper production by reducing the range of parts in production and increasing the serial production of them;

• Reduction of time for training staff.

The disadvantages of the aggregate-modular approach include the need to develop a mechanical system of specific models of manipulators of intelligent robots from parts, assemblies and kinematic modules of a limited range, which sometimes can lead to an unjustified (technologically) reduction in the functionality of the machine. Obtaining a given trajectory of the executive bodies of the manipulator using the existing set of simple functional units, each of which provides one or two types of movements, can cause an increase in the number of joints, weighting the structure, reducing its rigidity, deterioration of dynamic characteristics and accuracy parameters. In some cases, it is necessary to make decisions that are less expedient from a design point of view, but more in keeping with the chosen principles of aggregate construction.

The techniques and principles laid down by individual designers when creating aggregate-modular structures are different [2].

One of the varieties of the aggregate principle of building manipulators of intelligent robots is a modular principle. This usually means creating a robot based on functional modules (nodes) that have all the necessary elements, including drives, feedback sensors, etc., necessary to provide the module with its functional purpose. When building a robot arm, the modules are interconnected in the required order, and the power and control communications are connected.

• The modular construction principle of robot manipulators as compared with the method of construction on the basis of smaller normalized nodes has an advantage in terms of greater convenience in creating and rebuilding a manipulator and reducing the number of nodes included in a particular robot. The disadvantages of this construction principle are:
• an increase in the range of modules, due to the fact that the same nodes with different drives or feedback sensors turn into different modules;
• complexity and, in some cases, functional redundancy of modules;
• the complexity of using the same modules with different control systems.
• In connection with this, the following main directions in the creation of an intelligent robot arm can be identified:
• when creating a robot for performing complex movements in space (welding, painting, cleaning castings, etc.), it is most appropriate to recognize the creation of original designs of a universal robot with wide capabilities based on mechatronic modules;
• when creating a robot to perform simpler operations, such as loading machines, presses, casting machines, etc., it is advisable to create a specialized type of robot on an aggregate-modular construction principle. At the same time, only those mechatronic modules in which are located on the base of the robot should be included in the nomenclature of normalized nodes.
In figure 1 shows the classification of mechatronic modules (MM) according to their design features. In this classification, 3 features are sufficiently fully characterizing the design of mechatronic modules (level of integration, number of degrees of mobility and type of movements), as well as a set of features (technical characteristics) determining the functionality of the modules.
Classification of mechatronic modules provides for the level of integration: motion modules, mechatronic motion modules and intelligent mechatronic modules. According to the number of coordinates of the degrees of mobility - one-coordinate and multi-coordinate. By type of movement - translational and rotational.
The complex of attributes of technical characteristics includes: developed force and torque; magnitude, speed and accuracy of the stroke (linear and angular).
Consider the mechatronic modules according to the presented classification.

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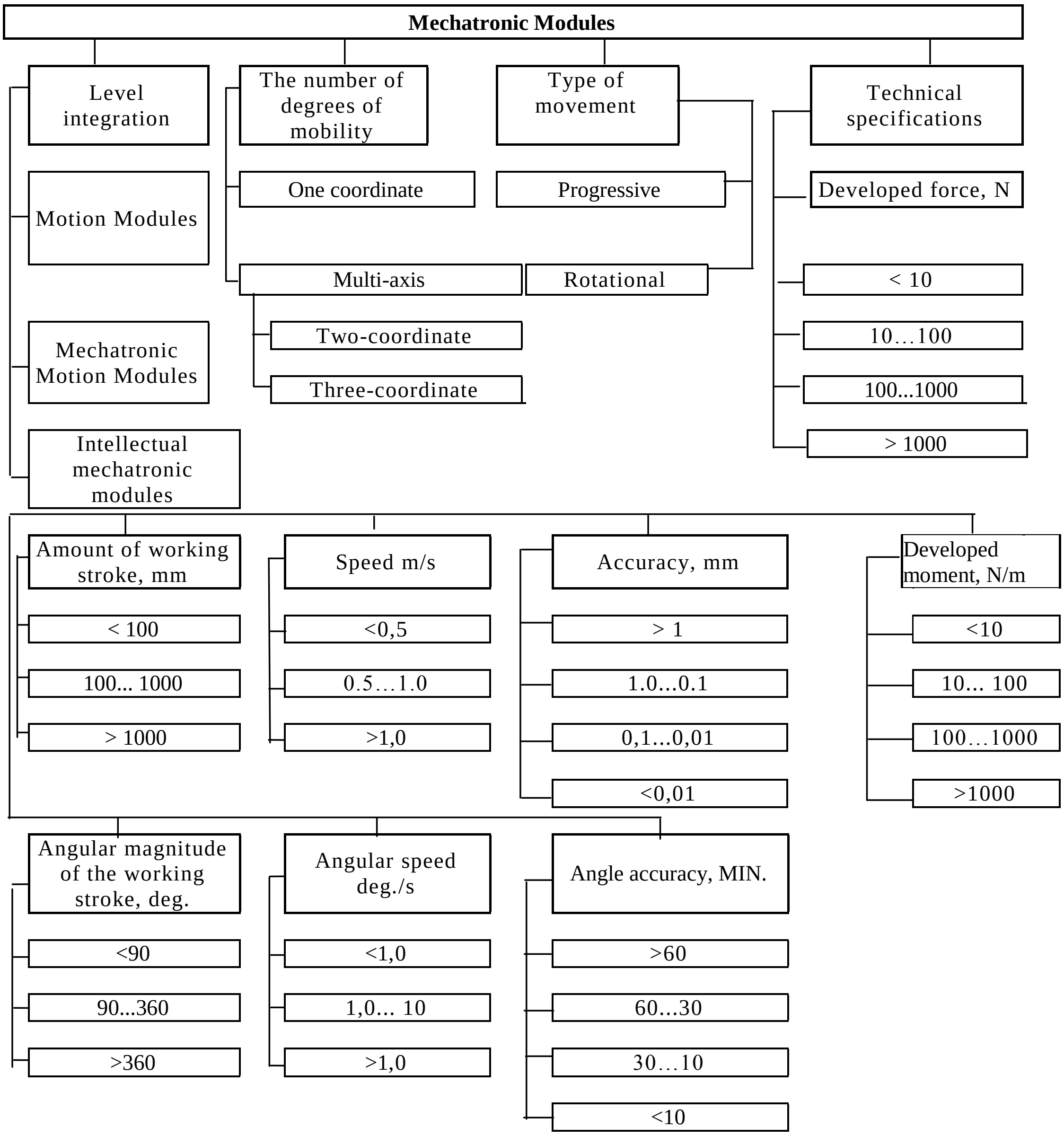

Figure 1. Classification of mechatronic modules by design features

Table 1 shows the structural, kinematic schemes and analytical description of the set of electromagnetic multi-coordinate modules of intelligent robot manipulators [3, 4].

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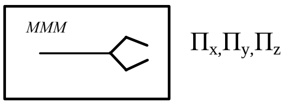
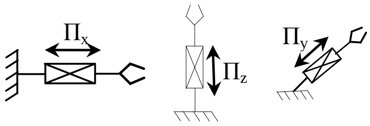
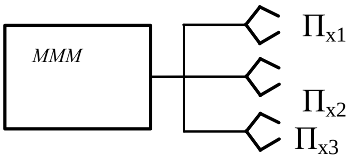
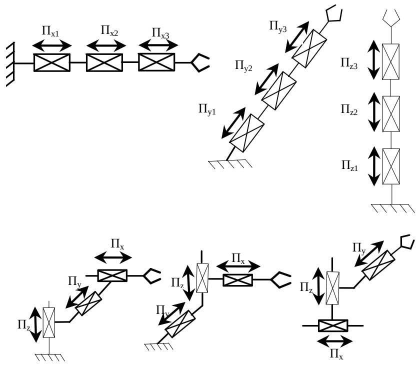
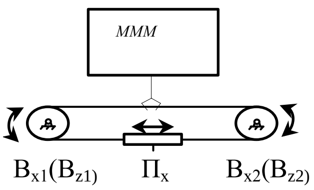
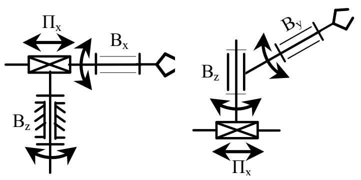
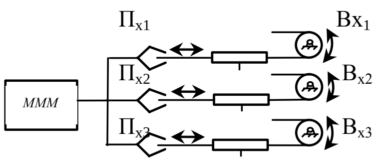
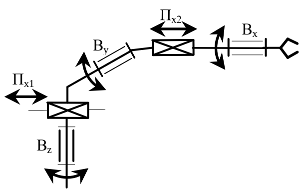
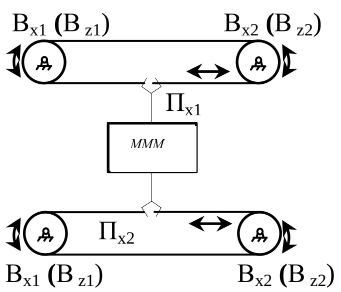
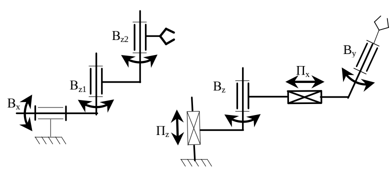
Table 1 Structural scheme MM

№	Structural schemes of MM	Kinematic scheme	Analytical description of schemes
1.			$П_x \wedge П_y \wedge П_z$
2.			$(П_{x1} \vee П_{x2} \vee П_{x3}) \wedge (П_{y1} \vee П_{y2} \vee П_{y3}) \wedge (П_{z1} \vee П_{z2} \vee П$
3.			$(B_{z1} \wedge B_{z2} \wedge П_x)$ $(B_{x1} \wedge B_{x2} \wedge П_x)$
4.			$(П_{x1} \wedge B_{x1}) \vee (П_{x2} \wedge B_{x2}) \vee (П_{x3} \wedge B_{x3})$; $(B_{z1} \vee B_{z2} \vee B_{z3}) \wedge 3П_x$
5.			$(B_{x1} \wedge B_{x2}) \wedge (B_{x3} \wedge B_{x4}) \wedge П_{x1} \wedge П_{x2}$ $(B_{z1} \wedge B_{z2}) \wedge (B_{z3} \wedge B_{z4})$

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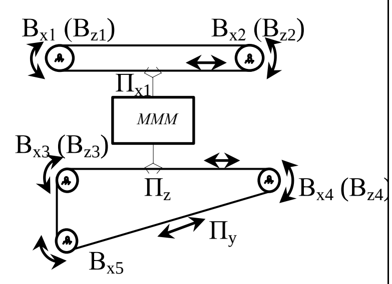
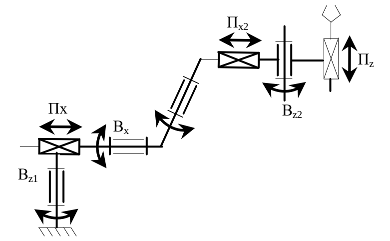
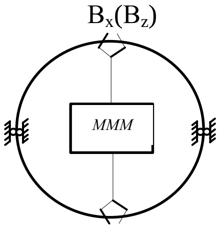
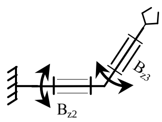
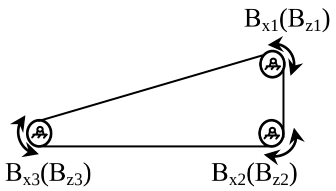
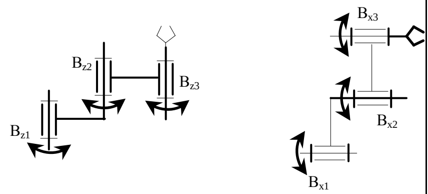
6.			$(B_{x1} \vee B_{x2}) \vee (B_{x3} \vee B_{x4} \vee B_{x5}) \vee (\Pi_{x1} \wedge \Pi_{x2} \wedge \Pi_z \wedge \Pi_y) \vee (B_{z1} \vee B_{z2}) \vee (B_{z3} \vee B_{z4} \vee B_{z5})$
7.			$B_x \vee B_z$
8.			$(B_{x1} \wedge B_{x2} \wedge B_{x3}) \vee (B_{z1} \wedge B_{z2} \wedge B_{z3})$

III. CONCLUSION

The developed multi-coordinate mechatronic module provides for obtaining a multitude of linear and rotational movements of the links of the manipulator and is located on the base of the robot. At the same time, the movements of the module outputs are transmitted to the links with the help of various mechanical gears, which allows simplifying the design of the manipulator and reducing weight and dimensional parameters and improving the dynamic characteristics of the intelligent robot arm.

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