Prospects for the Development of Educational Programs in Mechatronic and Electric Drive Systems for Agriculture

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Abstract— The article is devoted to the development of approaches to the formation of a curriculum for the master’s program in agrarian mechatronics, corresponding to the requirements of the Russian and European higher education standards. The concept of "mechatronics" is considered. The analysis of input disciplines in technical university Ilmenau (TU Ilmenau) and Platov South-Russian State Polytechnic University (NPI) (Platov SRSPU(NPI)) which produce master classes in this direction is made. Their correspondence and the possibility of integrating the curricula are established. The relevance of the introduction of mechatronic systems in agriculture and the need for training of specialized specialists is presented. The structure of the curriculum on the direction of 15.04.06 "Mechatronics and Robotics" the orientation "Agrarian mechatronics" is proposed. The interrelation of the introduced disciplines is shown.

Keywords— mechatronics, agriculture, curriculum, master’s program

I. INTRODUCTION

With the advent of the term "mechatronics" in the 70s of the last century, the branch of science and technology that creates aggregates, computer-controlled machines, complicated automated systems, is increasingly gaining popularity and significance throughout the world. Therefore, educational programs in mechatronics and robotics, as a component of mechatronics, become popular among students, as well as in demand on the world labor market. According to UNESCO specialists in mechatronics are among the five most demanded and promising specialties in the world [1, 2].

Mechatronics is often treated as science and technology direction dealing with computer control of the exact movement of mechanisms. However, in its essence this is a new philosophy of design and operation of machines and systems with intelligent control of their functional movements based on the synergetic combination of precision mechanics nodes with electronic, electrical and computer components (fig. 1).

Based on the definition of mechatronics training of the specialists in mechatronics in the Russian Federation is conducted on the basis of the departments of production processes automation, precision mechanics, electronics and computer science, electro- and hydraulic drives [3, 4]. In our opinion, the basic departments with the experience of educational, scientific and practical activities in automated electric drives, electromechanics and automation of technological processes and manufactures are in the best degree prepared for the Master program in mechatronics and robotics realization.

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Fig. 1. Schematic representation of the term "Mechatronics"
At the electromechanical faculty of the Platov SRSPU (NPI) in close co-operation with the departments "Mechatronics and hydropneumatics", "Electric power supply and electric drive" and "Electromechanics and electrical devices" is currently creating a new master's educational program in "Mechatronics and Robotics technology" with the academic orientation "Agro-industrial mechatronics" within the framework of the Erasmus + project 585596-EPP-1-2017-1-DE-EPPKA2-CBHE-JP Promoting internationalization in the agro-industrial complex in Iran and Russia.

The implementation of this program in accordance with European Commission requirements allows Russia and Iran to integrate into the European education structure to increase the academic mobility of the students and bring the education to the European level.

II. STRUCTURE OF THE CURRICULUM "AGRO-INDUSTRIAL MECHATRONICS"

To develop a unified curriculum for master's program in agro-industrial mechatronics it is necessary to make a detailed analysis of the structure of the curriculum of Russian and European Union universities to determine the list of basic and variable disciplines reflecting the training profile

Master's training is the second stage of higher education. Students enrolled to the Master course must previously learn the basic disciplines of bachelor's training in this direction.

Table 1 shows the comparison of the entrance bachelor's disciplines in "Mechatronics" curricula at the TU Ilmenau (Germany) and Platov SRSPU (NPI) (Russia).

<table>
<thead>
<tr>
<th>Entrance disciplines according the curriculum of TU Ilmenau</th>
<th>Entrance disciplines according the curriculum of Platov SRSPU (NPI)</th>
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<tbody>
<tr>
<td>Mathematics</td>
<td>Mathematics</td>
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<tr>
<td>Physics</td>
<td>Physics</td>
</tr>
<tr>
<td>Electrical and Electronics</td>
<td>Electrical</td>
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<tr>
<td>Measuring system technologies</td>
<td>Metrology, standardization and certification</td>
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<tr>
<td>Mechanics and design</td>
<td>Mechanics of controlled machines</td>
</tr>
<tr>
<td>Theory of systems</td>
<td>Theory of automatic control</td>
</tr>
</tbody>
</table>

As can be seen from Table 1, the curricula of the TU Ilmenau and Platov SRSPU(NPI) are homogeneous and fully meet the requirements for ensuring academic mobility of the two universities.

The four-year experience in the preparation of masters students in "Mechatronics and Robotics" at the Platov SRSPU(NPI) shows that the graduates of the direction "Electric Power Engineering and Electrical Engineering" with the orientation to "Electric Drive and Automation" are more suited to the requirements of internal academic mobility.

Taking into account that modern electric drive increasingly relies on mechatronic approaches with intellectual control in the new educational program, these features and perspective possibilities of the modern electric drive should be reflected.

To understand the structure of the educational program in agro-industrial mechatronics, let us consider the main problems in agriculture related to the insufficient amount of machinery with its negative impact on the quality of agricultural products.

Currently, the world's farms give about 360 million tons of food per year. By 2050, it is required to provide no less than 1.2 billion tons of food per year [5-12]. These indicators can not be achieved with the use of existing agricultural machinery and the traditional approach to farming. At present, the use of a large amount of heavy machinery in agriculture has led to the fact that more than 25% of the earth suitable for agriculture has been largely eroded, water degraded and lost biodiversity. Up to 96% of the treated fields are now subjected to tire compaction due to the movement along the field of heavy agricultural machinery, so up to 90% of the energy that is currently spent on cultivation is used to restore the soil condition.

In crop production, unreliable information about the process of growing products leads to harmful consequences. Applied modern technology often damages crops even with small deviations of agricultural machines from the course. During planting and harvesting, farmers need considerable labor resources. Hiring seasonal workers is a big problem for modern farmers [13-15]. Up to 60% of the harvested crop does not reach the quality required for its successful sale. Collected vegetables and fruits require sorting by size and quality, which increases the time and labor costs, leading to an increase in the cost of the harvest. Traditional approaches to agriculture require the use of a large amount of water and pesticides, both introduced into the ground, and sprayed from the air for pest control. Pesticides have a significant effect on the soil, leading to a decrease in yields, and are the cause of water and air pollution. Therefore, in addition to increasing the quantity and quality of agricultural products and reducing its cost, the problem of environmental protection is topical.

Solve these problems by developing fundamentally new classes of automated and robotic agricultural machines. Transport agricultural robots by reducing the size and increasing maneuverability will optimize the traffic routes in terms of achieving maximum efficiency and minimum soil damage [16, 17]. Flying drones equipped with vision systems can solve a wide variety of tasks (analysis of plant condition, flooding, salinization, fertilizer imbalance, etc.) on the field without exposing the soil to any impact. Robots with micro drop sprayers will reduce the use of pesticides by 99.9% using the system of sighting plants, when the chemical is applied only to the leaves. Robots specialized for harvesting will make it possible to work without attracting seasonal workers, which will greatly simplify the logistics processes on the farm. The use of swarms of autonomous micro-robots will make it possible to surpass man's productivity by about 20 times, increasing the speed and quality of work.
Robots will be able to carry out an independent evaluation of the crop in an autonomous mode, which will allow collecting fruits in the required volume and quality at a given time. The harvesting robot is able to sort and pack the collected crop directly at the collection point, speeding up the process by improving the quality of products and reducing the labor costs of people [18-20].

In view of the foregoing, the main areas and objects of the agro-industrial complex where it is possible to use mechatronic modules and systems are presented in fig. 2. To successfully introduce mechatronic systems into the agro-industrial complex, specialists with knowledge in both agriculture and mechatronics are needed.

A key element of any agricultural mechatronic equipment is an electric drive. Its characteristics must be selected in accordance with the functions performed. For agricultural machinery, it is dust and waterproof execution, stability in a wide range of temperatures, high overload capacity and easy operation.

Another important element is information systems allowing to determine the state of both the external environment and the parameters of the equipment itself. Also relevant are the issues of providing agricultural machines with vision systems and algorithms for processing visual information that will be used both for navigation and for the care of agricultural products both at the stage of cultivation and at the stage of processing and storage.

Agricultural mechatronic equipment must have high reliability and fault tolerance. Therefore, a specialist designing such a technique should have knowledge of methods to improve the reliability and efficiency of the equipment.

Proceeding from the foregoing, the curriculum of the master's training with the direction "Agro-industrial mechatronics" should contain the following main modules (fig. 3).

1. Basic module "Technological processes of agro-industrial productions"

The module is designed for two semesters. Disciplines begin with the first semester.

The first part of the module includes the study of the basic technologies of agriculture. Taking into account the peculiarities of the Erasmus+ project, special attention should be given to the technological processes of the agro-complex inherent in the southern countries and characterized by a special status of melioration requiring maximum efficiency with minimum water costs. Also, technological processes and technologies of multiple yielding of crops specific for southern countries and their needs should be considered.

The second part of the module relies on the technologies studied in the first part of this module, and is associated with agro-industrial machinery, technological machines and apparatus used in agro-industry. Here, special attention should be paid to the study of foreign models of technology, their specifics, features in comparison with similar domestic equipment.

2. Module "Mechanics of mechatronic systems"

The module is designed for two semesters. Disciplines begin with the first semester. It can consist of two disciplines (or two submodules) "Mechanics of controlled machines" and "Applied robotics mechanics". The first discipline should contain the basic principles of building machinery mechanisms that provide the main types and types of movement, their relationship with the problems of managing aggregates and machines. The second discipline examines the problems of analysis of the kinematics and dynamics of manipulation mechanisms with several degrees of mobility, based on the matrix and vector mathematical apparatus.
3. Module "Mechatronic systems control"

The module is designed for three semesters starting from the first semester.

Here the discipline "Automatic control theory" is studied in depth and competence is created to control the trajectory movement and in unknown environment moving which typical for a number of technologies of the agrarian industry.

4. Module "Electronics and microprocessor technology of mechatronic systems"

The module is designed for two semesters and begin from the first.

It includes the disciplines "Modern electronics mechatronic systems" and "Microprocessor technology mechatronic systems" which reflect the modern base of electronics and microprocessor technology and the trend for its development. A special assessment should be made of the applicability of electronic equipment for the specificity of the agro-industrial complex (reliability, energy consumption, etc.).

5. Module "Information Technologies and Systems"

The module is designed for three semesters from the first. It includes the disciplines "Mechatronic system sensors", "Artificial intelligence methods" and "Software and programming of mechatronic systems". The first discipline generalizes the principles of the formation of measurement devices and processing of information flows. The second discipline is specific for all mechatronics and includes the study of neural networks, fuzzy logic and the foundations of artificial intelligence. The third discipline forms the competence of programming systems of the mechatronic type (systems with numerical program control, robotic systems, etc.).

6. The module "Electromechanical drives of mechatronic systems"

The module is implemented two semesters starting from the second. Specificity of forming the competencies of a specialist in mechatronics is their inseparable connection with the study and application of mechatronic motion modules that are associated with automated electric drives and electromechanical systems based on them. Therefore, this module is logically connected with all other modules of the curriculum, is based on them and is the
basis for building the entire mechatronic system. When forming the knowledge base of this module in the field of agro-industrial mechatronics, it is necessary to take into account the specifics of the agro complex, regions and regions of the use of electromagnetic and electric drive systems in it. In addition to these six modules, the structure of the curriculum. A number of disciplines aimed at general education, general scientific and general technical training have been introduced, which will be included in elective disciplines, elective disciplines and the general curricular part of the curriculum.

One of such general scientific disciplines that components are present in most technical disciplines and whose knowledge is necessary for the training of a complex specialist in agrarian mechatronics for development and testing of new technology is the "Experiment theory."

In addition, the curriculum contains the integrative disciplines "Microprocessor control of mechatronic modules and systems" which is studied in the 2nd semester and integrates 1, 3, 4 and 6 modules of the curriculum. The final discipline "Design of mechatronic systems" (3 semester) combines all the main modules for the preparation of the Master of Mechatronic and Robotic Systems. Here, all stages of designing agro-industrial mechatronic systems from the technical task to the working documentation for the new equipment are considered. Supposes the study of unified system for design documentation as well as foreign normative project documentation.

The curriculum will contain course work on the discipline "Microprocessor control of mechatronic modules and systems" and a course project on the discipline "Design of mechatronic systems".

**CONCLUSION**

The article substantiates the urgency of the introduction of mechatronics resources in agriculture and the need to train specialized specialists to solve this problem. The structure of the curriculum for master’s program "Mechatronics and Robotics" orientation "Agrarian mechatronics", taking into account the requirements of the Russian federal state educational standard and the European standard. The description of each module of disciplines is given, their interrelation is shown.

**REFERENCES**


