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Peter Tuleja[1], Tomáš Danilo[2]

[1] Assistant Professor, Assistant Professor of the Department of Production Systems and Robotics, Technical University of Košice, (Košice, Slovakia)
E-mail: peter.tuleja@tuke.sk**. ORCID:** https://orcid.org/0000-0001-6390-3109
Scopus Author ID: 55570858300

[2]Student of the Department of Industrial Automation and Mechatronics, Technical University of Košice (Košice, Slovakia)
E-mail: tomas.danilo@student.tuke.sk

RECONSTRUCTION OF ELECTRO-PNEUMATIC MECHANISM AS PART OF A LABORATORY ENVIRONMENT FOR TEACHING NEEDS

The paper discusses the proposal of a mechanism forming part of the training environment for the practical preparation of faculty students for the needs of industry. The training environment serves as an educational and practical workplace enabling the improvement of students in PLC programming as well as in describing the functions and design solutions of the represented components from the field of pneumatics, sensors, electrical safety devices and their combinations.

The design of the described mechanism was implemented as an upgrade of the existing solution, which showed some imperfections during operation. The article presents the original solution and the proposal for a new one, while at the end a comparison of the pros and cons of both solutions is made.

Both described solutions were created as outputs from the diploma solution, respectively. Bachelor thesis of our students. The article has an educational and descriptive character.

Keywords: *pneumatics; training workplace; reconstruction, electro-pneumatic, programming, PLC.*
Fig.: 11. Tables: 0. References: 6.

Relevance of the research. The Slovak labour market, especially in the engineering sector, has been struggling with a lack of skilled labour for a long time. With the disappearance of company training centres before 1989, the "exodus" of secondary and elementary school students in Slovakia began from industrial schools and apprenticeship schools to gymnasiums and humanitarian-oriented schools. In addition, the transformed industrial schools introduced more and more subjects unilaterally focused on IT support into the curriculum, while successfully creating a "vacuum" in professionally prepared high school students who would like to continue their training at technical universities. If they were found, there were and still are few inquiries in the field of automation means and equipment.

Problem statement. Around the middle of the second decade of the 21st century, companies established on the Slovak market began to urgently demand a qualified workforce, whose recruitment still lagged behind the needs of the development of these companies. Some companies started to build their own training centres and "in their own image" there they started to educate the "teenage" workforce. Since there is a relatively high turnover of the workforce in the Slovak labour market, this model was not entirely successful. Companies began to "pressure the state" in an attempt to transfer this responsibility to it. The state accepted the challenge in the form of introducing the so-called of dual education in secondary schools. The universities remained slightly aside.

Analysis of recent research and publications. The current state of preparation of university graduates meeting the criterion of "immediate use in practice" is still not at the required level. That is also why we at the department (also in the form of published grant tasks) started the process of practical teaching in such a way that, in the form of training on equipment used in technical practice and by involving students in the practical form of teaching in the form of building equipment based on the assignments set by the teachers, the output of these assignments is then a real laboratory a facility that can often be used for practical training of the next generation of students.

Uninvestigated parts of a common problem. The socio-professional problem of the practical preparation of technical youth for companies is still as if on the periphery of the state's interest. It is necessary to look for alternative ways to ensure the real start of the university training of graduates, especially of technical schools and universities, because only a practically prepared graduate can hold a position in the research field, even if it does not necessarily have to be basic research.

Research objective. We have therefore based the issue of the practical training of our students on the construction of laboratory spaces equipped with the necessary technical and component equipment so that, when solving semester or bachelor's or diploma theses, the student can produce technical equipment not only from the design side but also from the implementation side (finished product from design to implementation concept with the revival and fulfillment of the simulated task).

The statement of basic materials. In the sense of what has been said, the project of a training workplace designed for practical training in the field of pneumatics and electro-pneumatics is implemented in the form of continuous improvement. Within the solution of the diploma thesis [6], the basis for the possibility of implementing new mechanisms was created. The very basis contained in the solution of this diploma thesis contained a mechanism (workingly designated as Workplace 4) based on a combination of pneumatic and electric drives, Fig. 1.

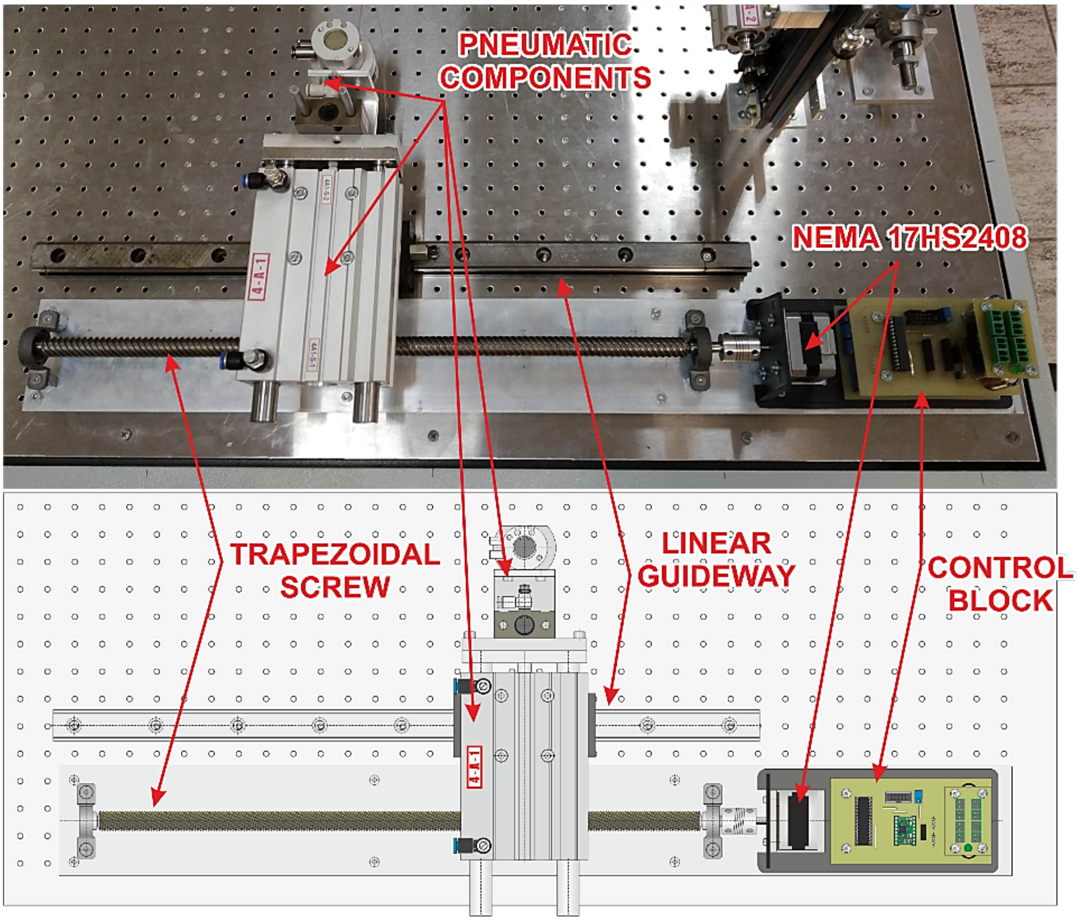

Fig. 1 Mechanism with trapezoidal screw (original version)
Source: photo created by the authors

It is a mechanism, one of whose linear movements is provided by a NEMA 17HS2408 electric stepper motor [6] controlled via PLC outputs to precisely programmed positions within its movement ranges. The stepper motor was controlled by a control block consisting of an A4988 driver with an ATMEL Atmega 186a microcontroller, Fig. 2.

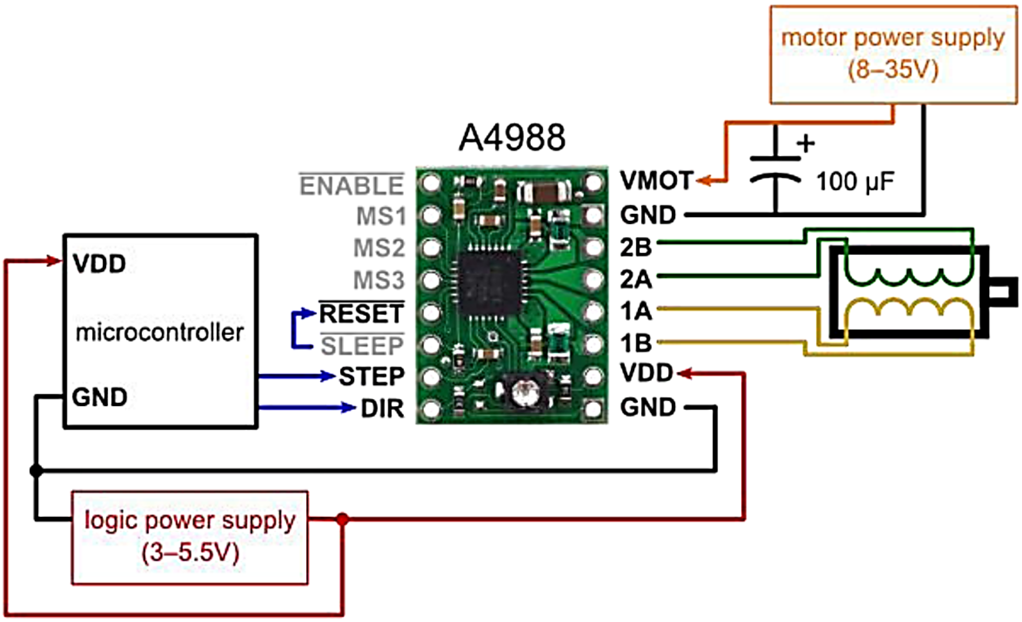

Fig. 2 Microcontroller and driver wiring diagram.

Source: [5]

The control process was solved by uploading a permanent program to the microcontroller, which sent a set number of pulses to the driver, which then generated the corresponding number of motor steps. The request for this process itself was generated from the connected PLC (based on a specific output signal).

Since this solution showed some problematic properties (overheating of the control module, problem with reprogramming the system to a new position), we proceeded to modify it, while at the same time we integrated it into a single unit with the workplace previously marked as Workplace 9, Fig. 3.

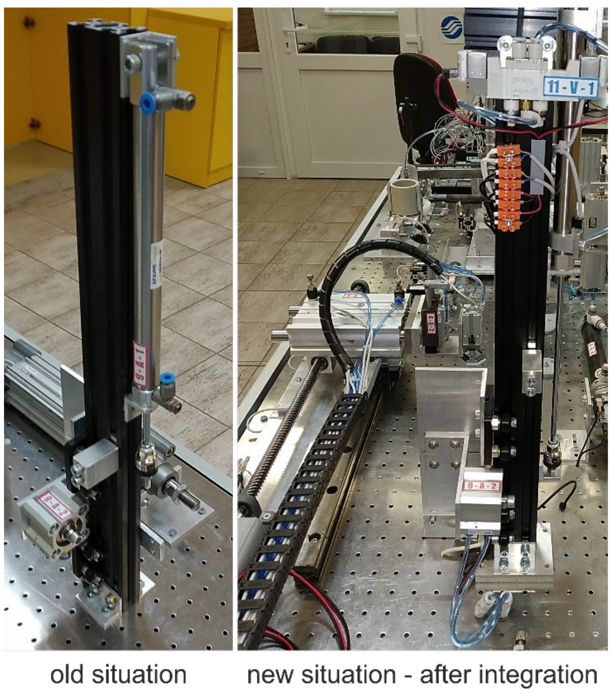

Fig. 3 The process of integrating two workplaces.

Source: photo created by the authors

The entire reconstruction process with the integration of two workplaces was designed and implemented by a bachelor's student as the output of his bachelor's thesis [1].

To a certain extent, it was necessary to proceed with fundamental changes in the organization of the workplace. The author of the project suggested replacing the NEMA stepper motor (including its control unit) with a DC motor with an integrated gearbox [4], Fig. 4.

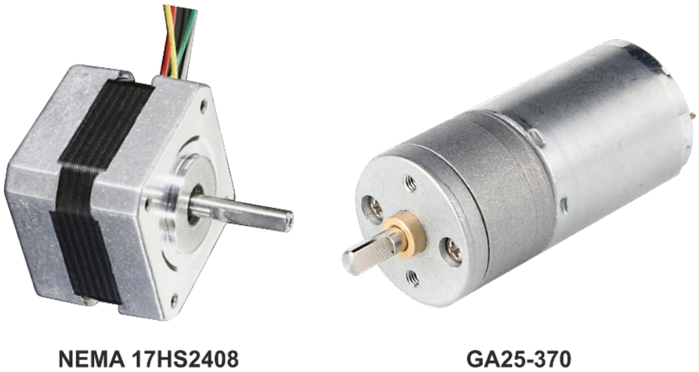

Fig. 4 Original and new electric drive (motor).

Source: by editing the catalog data of [6, 4] - created by the author

On the one hand, we thus eliminated the problem of complicated control and overheating of the power member (driver) of the unit, on the other hand, we lost higher accuracy when positioning the mechanical unit. It happened because of the need to use magnetic switches as a signal for the desired position (sensor hysteresis - a magnetic reed sensor from SMC was used). The problem with hysteresis caused by the "unstable" interpretation of the position is partially compensated by the high gear ratio of the new engine's gearbox, which guarantees a nominal output speed of 62 rpm. The easy "reconfiguration" of the motor activity of the electric motor unit can be considered as a positive.

Thanks to the fact that the author of the project of the training workplace [5] remembered to ensure two DC voltages (24V DC and 12V DC), it facilitated the integration of the new motor into the control chain in the form of a cross arrangement of the control signal from the PLC with a pair of relays, Fig. 5.

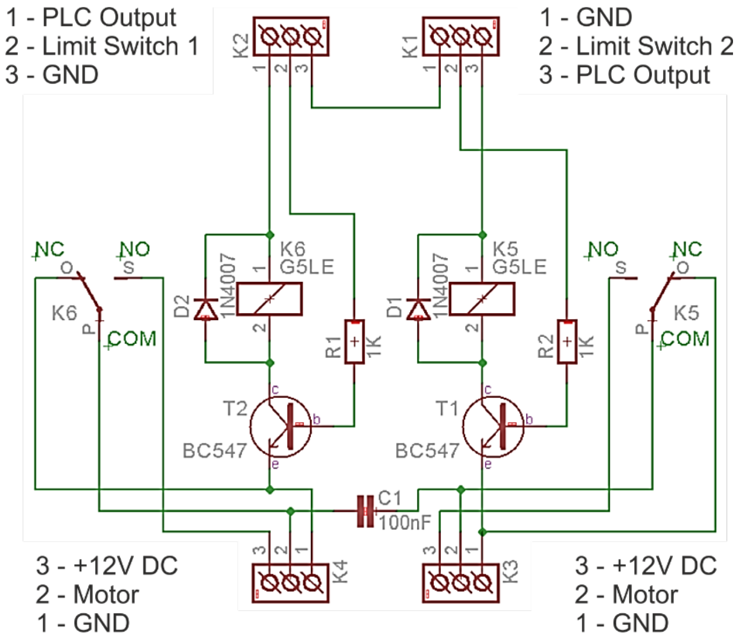

Fig. 5 Control circuit for controlling the new motor [1]

Thus, through this electronics, it was possible to ensure the reversal of the movement of the motor during steering and at the same time treat the end positions of the movement unit.

The entire block of electronics together with the motor is covered by the 3D printed lid and together with the pneumatic valves was placed on the base on which the entire linear electric movement unit is placed, Fig. 6.

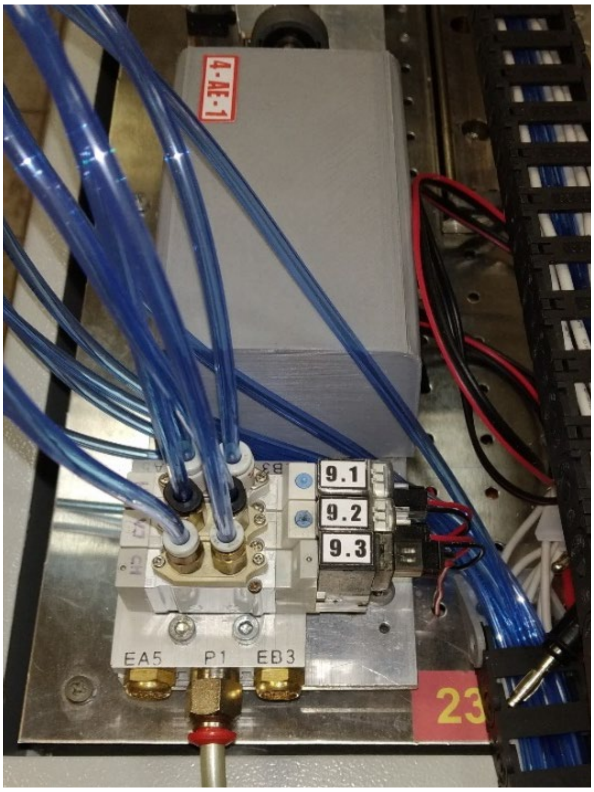

Fig. 6 Control electronic unit and valve unit.

Source: photo created by the authors

The overall view of the rebuilt linear module (workplace 4) of the solved project is shown in Fig. 7.

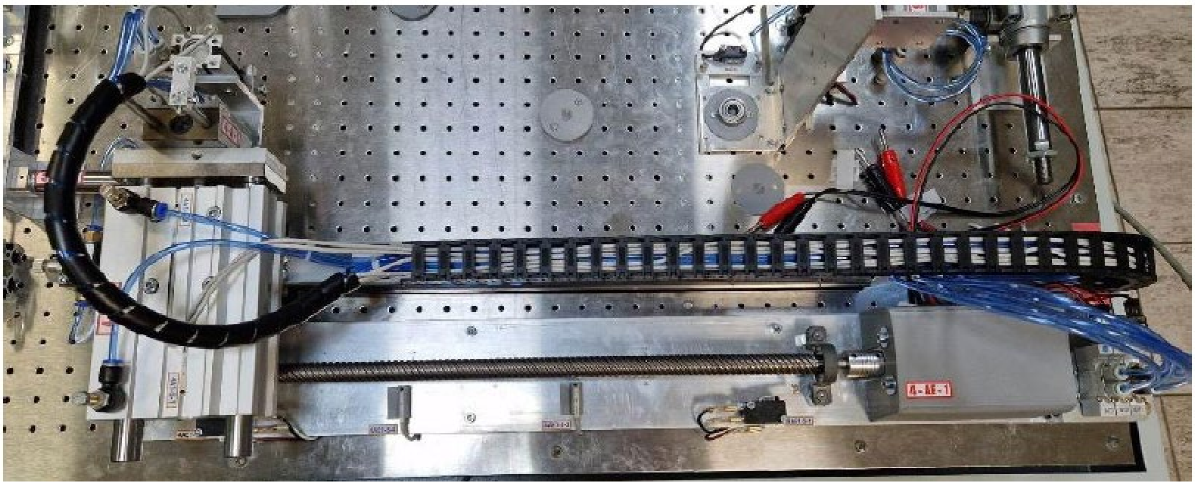

Fig. 7. A view of the linear motion unit and the pneumatic superstructure of the mechanism with 3 DOF (degrees of freedom) [1]

In order to be able to meaningfully manipulate the object for which we chose the 6082Z ball rolling bearing, it was necessary to establish a suitable handling cycle. In the first step, the latter consisted of manually placing the object of manipulation on the platform of the lifting platform, which in its upper position awaits the entry of the object.

The lifting platform is part of an integrated mechanism (referred to as Workplace 9). It is made up exclusively of pneumatic drives and guides used in 3D printing technology (aluminium profile with V-groove), Fig. 8.

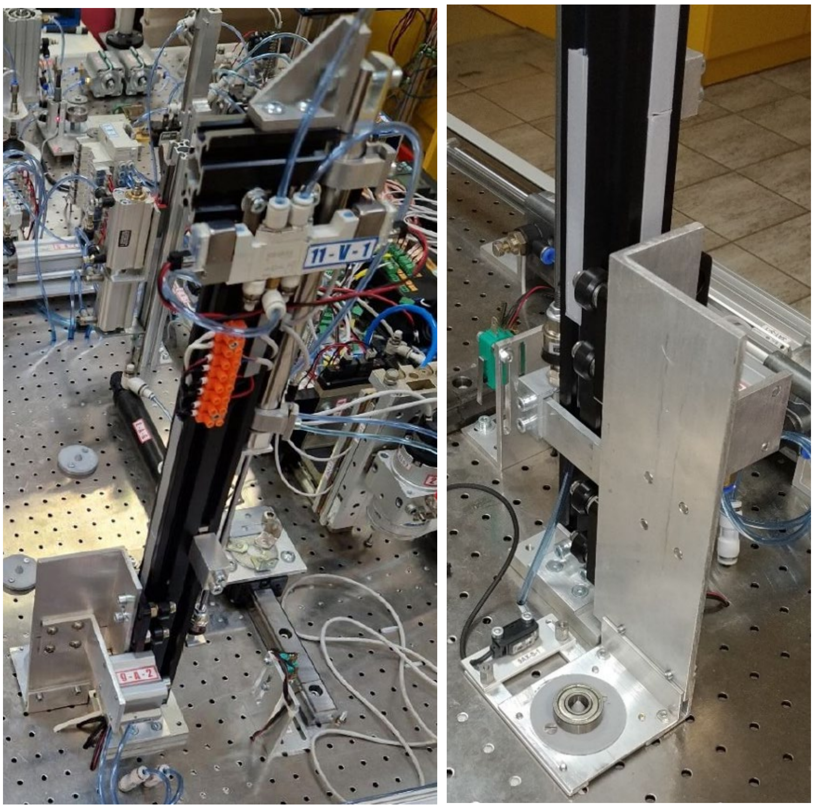

Fig. 8 View of the lifting mechanism (Workplace 9).

Source: photo created by the authors

The manipulation cycle starts with a short delay (provided by the program) after inserting the bearing on the 3D-printed pad with a centering cone, Fig. 9.

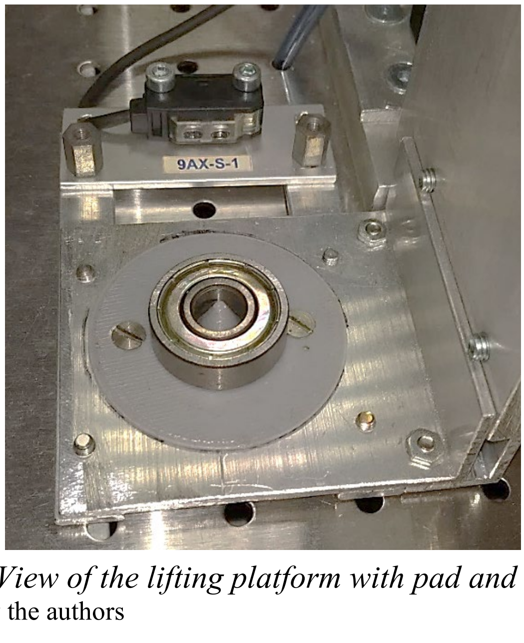

Fig. 9 View of the lifting platform with pad and sensor.

Source: photo created by the authors

Presence is indicated by the used photoelectronic presence sensor 9AX-S-1 (EX-28B series photoelectric sensor by PANASONIC [2]). Once the presence is detected, the handling task cycle is started. The linear electric unit starts moving from the limit switch 4AE1-S-2 (Honeywell V15H22-CZ100A06) to the lifting platform until it reaches the position of the limit switch 4AE1-S-1. At the same time, the platform will move downwards (to the sensor marked 9A1-S-2. The lifting unit of the manipulator 4-A-2 by moving to the sensor 4A2-S-2 reaches the lower level necessary to grasp the object. Subsequently, the gripper 4-A- 3, Fig. 10, grasps the object of manipulation and the unit 4-A-2 again moves to its upper position. The electric linear unit then travels with the grasped object successively to individual storage positions, where it alternately deposits and immediately removes the same object. after storing the object in the last storage position, the manipulator returns to the basic setting on the limit switch 4AE1-S-2.

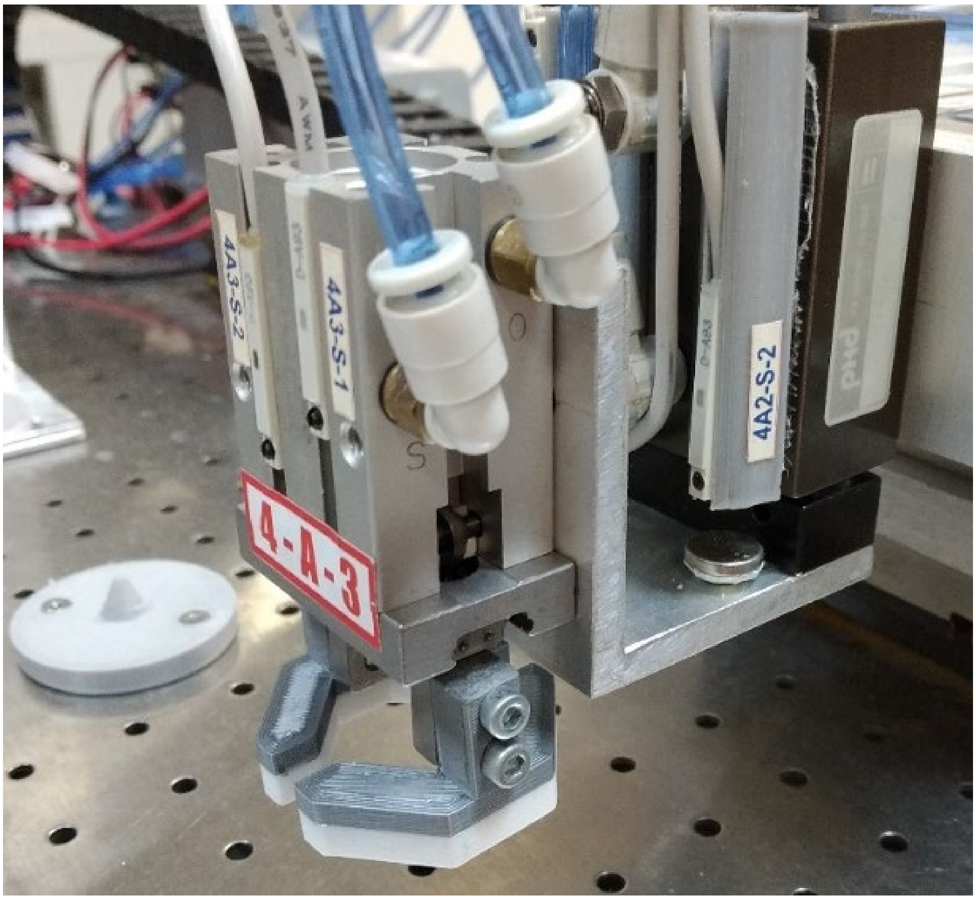

Fig. 10 A view of the grasping effector with 3D printed fingers (4-A-3 gripper).
Source: photo created by the authors

The handling cycle can be changed almost arbitrarily by reconfiguring the storage places, but a new adjustment of the positions of the sensors of the electric linear module is necessary (there are two marked 4AE1-S-3, 4AE1-S-4 and they are reed magnetic D-A93 switches from SMC, see Fig. 7, [3]).

To illustrate the manipulation cycle, we also present the pneumatic connection diagram of the manipulator (Workplace 4), Fig. 11.

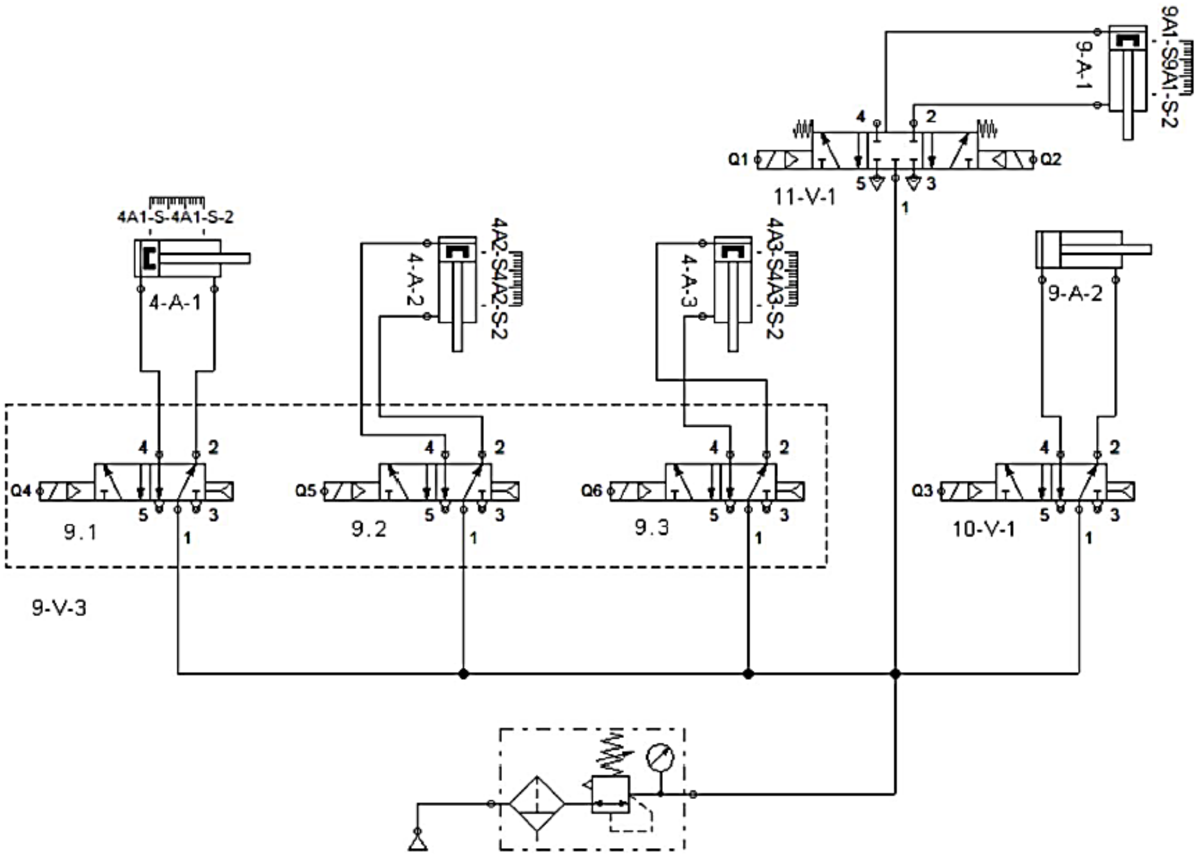

Fig. 11 Wiring diagram of the pneumatic part of the integrated workplace [1]

The whole modification fulfilled the expectations, although, as with any modification, it is possible to find many subjects for improvement. However, it is a laboratory training facility, therefore the identified shortcomings can be understood positively, as they give room for new ideas in the implementation of our students. Even from the mistakes of others, it is possible to gain new experience and discover new challenges for solving in yourself.

Conclusions.

The described procedure for rebuilding the existing grouping of automation components into a new form more accessible for use in laboratory conditions reflects our idea of how to initiate in students the finding of solutions in imperfect or inappropriately solved applications and thus better prepare them for practical application in industrial operations. If the students' interest in such a form of preparation persists, we will continue it (an example of which is the past semester, in which students solved the assigned task from the design of the solution to handing over the mechanism, including the demonstration of the manipulation task after it was revived and programmed via PLC).

Acknowledgements

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Петер Тулея[1], Томаш Данило[2]

[1] Доцент, доцент кафедри виробничих систем і робототехніки,
Технічний університет Кошице, (Кошице, Словакія)
E-mail: peter.tuleja@tuke.sk. **ORCID:** https://orcid.org/0000-0001-6390-3109
Scopus Author ID: 55570858300

[2] Студент кафедри промислової автоматизації та мехатроніки,
Технічний університет Кошице, (Кошице, Словакія)
E-mail: tomas.danilo@student.tuke.sk

РЕКОНСТРУКЦІЯ ЕЛЕКТРОПНЕВМАТИЧНОГО МЕХАНІЗМУ ЯК ЧАСТИНИ ЛАБОРАТОРНОГО СЕРЕДОВИЩА ДЛЯ ПОТРЕБ НАВЧАННЯ

У роботі розглядається впровадження реконструкції механізму, що входить до складу навчального середовища, призначеного для практичної підготовки студентів нашого факультету, для потреб реальної промисловості. Це навчальне середовище вже тривалий час служить освітнім і практичним робочим місцем, що дозволяє нашим студентам вдосконалюватися в набутті знань в області теоретичних і практичних навичок використання пневматичних і електропневматичних компонентів, а також в PLC. програмування. Тут вони отримують практичний досвід у вигляді опису функцій і конструктивних рішень представлених компонентів з області пневматики, датчиків, електричних пристроїв безпеки, включаючи їх комбінації.

Запропонована реконструкція описаного механізму була реалізована як модернізація вже існуючого рішення, яке, на жаль, показало деякі неприємні недоліки в процесі експлуатації. У статті коротко представлено оригінальне рішення та хід реконструкції від проектування нового рішення до циклу обробки, а також порівнюються плюси та мінуси обох рішень.

Обидва описані рішення були створені як результати розв'язання студентських випускних робіт (дипломних чи бакалаврських) наших студентів (випускників).

Стаття має навчально-описовий характер.

Ключові слова: *пневматика; навчальне робоче місце; електропневматика, програмування, ПЛК.*

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