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INNOVATIVE LABORATORY OF HYDROTRONICS AND AUTOMATIC CONTROL OF MOBILE ROBOT DRIVES

Key words

Hydrotronics, laboratory, hydraulic systems.

Abstract

The assimilation of practical knowledge by pupils and students of technical education institutions requires those institutions to have the necessary laboratory facilities. Practical discovery of phenomena allows them to confront theoretical knowledge with practice. The article presents an innovative laboratory of hydrotronics and automatic control of mobile robot drives, which has been founded at the Institute of Mechanical Engineering of the Mechanical Faculty of the Military University of Technology. The laboratory conducts classes on the design and operation of hydrotronic drive systems, which are used as drive systems for mobile robots.

Introduction

Implementation of hydrostatic drive systems as drive systems for modern machinery and equipment has led to a rapid increase in the demand for engineers qualified in the operation and maintenance of these systems [3, 4, 5].

This problem applies to both training of future engineering personnel as well as continued professional development of engineers working in the hydraulic drive industry.

Many discussions with representatives of educational institutions and centres indicate that one of the main barriers to the implementation and maintenance of high quality practical training is the lack of appropriate laboratory equipment at these institutions and centres, both at secondary school and university level [9].

Repeated budget cuts, reduced spending on the development of educational institutions, combined with the relatively high prices of professional stations make running practical classes more and more difficult, while presenting these issues in the form of virtual presentations distorts the elementary effect of vocational training.

The negligence of recent years, the under-funding of vocational education in the era of the reconstruction of the teaching potential of vocational schools and technical universities require radical measures aimed at financing the development of laboratory base of these institutions.

The paper presents an innovative laboratory of hydrotronics and automatic control of mobile robot drives, which has been developed at the Institute of Mechanical Engineering of the Mechanical Faculty of the Military University of Technology, thanks to a grant from the Ministry of National Defence for the expansion of the laboratory base for the purposes of training future personnel of Polish Armed Forces and continued vocational training of personnel responsible for the maintenance and operation of weapons and military equipment equipped with hydrostatic drive systems, with particular emphasis on the latest design solutions in remotely controlled unmanned land platforms – mobile robots. The laboratory consists of 8 teaching and research stations for the hydrotronics of mobile robot drives and an integrated hydrotronics station with elements of industrial automatic control.

1. Teaching and research stations at the laboratory of mobile hydrotronics of robot drives

Getting to know the design of hydrostatic drive systems, the principles of their operation and phenomena occurring within them is a very important element in the process of designing those systems. Classes in this subject are conducted at eight teaching and research stations for mobile hydrotronics of robot drives – four from Bosch Rexroth (Figure 1) [7] and four from RDL Hydraulics (Figure 2) [8].

All the stations meet the following requirements:

– They are bilateral and enable the performance of teaching exercises by four students at a time (2 on each side).
– They are mobile, meaning that they can move on their own wheels with brakes.

Fig. 1. Teaching and research stations for mobile hydrotronics of robot drives from Bosch Rexroth at the laboratory of hydrotronics and automatic control of mobile robot drives

Fig. 2. Teaching and research stations for mobile hydrotronics of robot drives from RDL Hydraulics at the laboratory of hydrotronics and automatic control of mobile robot drives

- They have a hydraulic power unit, consisting of two independent hydraulic pumps with variable speed, driven by a common electric motor with a power of 3kW.
- They have maximum pressure valves with setting lock.
- They have two glass measuring tanks (one on each side of the station).
- They have sensors and components for measuring hydraulic values (pressure, flow rate), incorporated into the system by means of hydraulic quick couplers, for the full range of the measured values.
- They have sensors and components for measuring physical values (speed of travel, rotational speed), for the full range of the measured values.
- They are equipped with devices for reading the measured hydraulic and physical values (multimeters, timers, gauges).
- They have elements for the direct reading of the parameters of the hydraulic system (pressure gauges).

- They are fitted with components for the visualization of flow.
- They have oil tanks with the capacity of min. 40 dm^3.
- They have a set of frames and grilles for mounting hydraulic components.
- They have a connection block for hydraulic components for the purposes of branching the hydraulic main and supplying several receivers at the same time, taking into account the main drain.
- They are powered with 3xAC 400 V, 50 Hz.
- They have an electrical supply box that can be connected to equipment powered by DC 12 V and 24 V.
- They have two independent emergency stop switches for the power supply.

A very important feature of the laboratory stations is that the components of the hydrostatic drive systems are typical industrial components, used for the construction of hydrostatic drive systems of machines and equipment (Fig. 3). This means that students engaged in practical activities on these stations will find the same components on the machines in the future.

Fig. 3. Components for the construction of hydrostatic drive systems for machines and devices

For the purpose of developing procedures for the control of hydrotronic drive systems, two positions have been equipped with hydraulic actuators, controlled using a CAN bus, programmable CAN-bus controllers, an application for developing control procedures, their compilations, and an interface for sending to the controller (software, hardware).

At the teaching and research stations for mobile hydrotronics of mobile robot drives, the students practically build hydraulic systems that they had designed, starting from a diagram of the hydraulic system, through the selection of main units and actuators, to their control systems. A very valuable tool to support the process of building hydrotronic drive systems is the Automation Studio environment, which allows one to build virtual drive systems and simulate their correct operation.

2. Integrated hydrotronic station with elements of industrial automatic control

One of the important issues related to the design of hydrotronic drive systems for mobile platforms is the development of their control systems. These systems are increasingly built using microprocessors and programmable controllers communicating via a CAN bus. Being able to discover phenomena occurring in such control systems in practice is necessary to be able to design such systems in future. Therefore, for the purposes of building unmanned mobile platforms (robots), the laboratory has been equipped with an integrated hydrotronics station with elements of industrial automatic control (Fig. 4). At this station, students can program controllers, in this case for the processes of transport, assembly, and storage of selected components, in the form of cubes made of various materials.

The station is a complete transport and assembly mechatronics system, consisting of the following:

1) A station acting as a reservoir for parts fed by a manipulator from a conveyor belt (Fig. 4a);
2) A station with a hydraulic press (Fig. 4b); and,
3) A station acting as static storage of finished products (Fig. 4c).

The station acting as a reservoir (Fig. 4a) can work autonomously and consists of the following components:

- Two separating reservoirs,
- A conveyor belt,
- A measurement system,
- A control panel,
- A maintenance unit,
- An electric unit with signal processing, and
- A programmable controller with software.

Each of the two separating reservoirs has space for no less than 8 workpieces. To measure the properties of material at the station, there are 4 sensors: optical, capacitive, inductive, and pneumatic. At this station, students program the process of picking components with specific material properties from the reservoirs.

a) b) c)

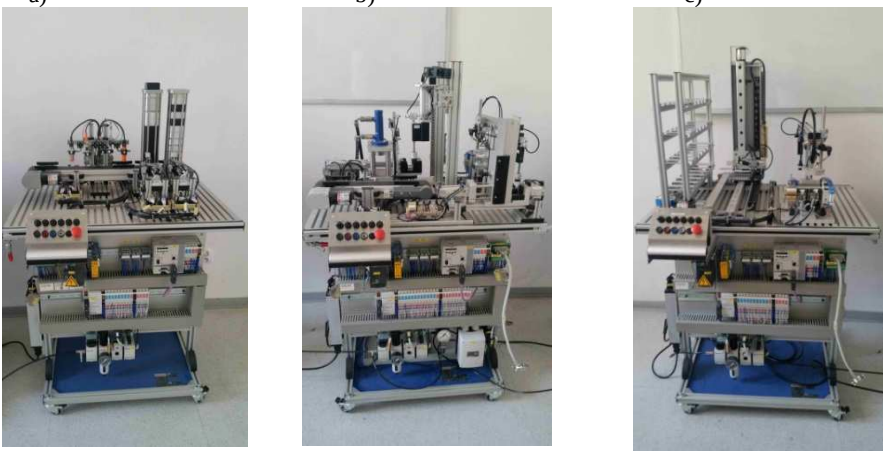

Fig. 4. Integrated hydrotronic station with elements of industrial automatic control: a) station acting as a reservoir for parts fed by a manipulator from a conveyor belt, b) station with a hydraulic press, c) station acting as static storage of finished products

Components selected in this way go to the second station (Fig. 4b), where a hydraulic press is used to carry out the assembly of two selected components. Before going into the hydraulic press, the cubes are armed with appropriate connection elements.

The hydraulic press, as the most important component of the second station, provides maximum operating pressure in the hydraulic system – no less than 45 bar, and the minimum flow rate of the working medium in the hydraulic system is 0.8 dm^3/min. The press is controlled using a microprocessor controller, and the assembly process is carried out behind a shield made from a transparent plastic, ensuring safety and the ability to watch the assembly process.

The station acting as a static reservoir of finished products (Fig. 4c) can work autonomously and consists of the following components:

– A static internal high bay warehouse in the form of a high rack with dividers,
– Cartesian robot,
– Manipulator,
– Control panel,
– Electric unit with signal processing, and
– Programmable controller with software.

The station is equipped with a static high-bay warehouse with a capacity of 25 parts. The Cartesian robot moves assembled products to their storage locations and the pneumatic manipulator arm puts them in the warehouse.

Summary

The innovative laboratory of hydrotronics and the automatic control of mobile robot drives presented in the paper is one of the largest laboratories in Europe. It allows one to conduct practical classes with 32 students at a time. The components of hydrostatic drive systems from which the stations are built are typical components used in the design of hydrostatic drive systems for machines and devices. With this laboratory equipment, classes in power hydraulics at all levels of advancement can be conducted, ranging from the construction of elementary hydraulic systems, controlled manually, to proportional systems controlled with the load sensing technology [1], to the most modern hydraulic systems controlled using programmable microprocessor controllers, communicating with actuators via a CAN bus [2]. This laboratory setup makes it possible to carry out practical classes for several teaching subjects at different levels, ensuring the highest quality of education.

In addition to study classes, students conduct research at the laboratory as part of Student Science Clubs, thus expanding their knowledge, and improving skills in the use and operation of hydrotronic drive systems [6].

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Innowacyjne laboratorium hydrotroniki i automatyki napędów robotów mobilnych

Słowa kluczowe

Hydrotronika, laboratorium, układy hydrauliczne.

Streszczenie

Przyswajanie wiedzy praktycznej przez uczniów i studentów placówek dydaktycznych o profilu technicznym wymaga posiadania niezbędnego zaplecza laboratoryjnego. Praktyczne poznanie zjawisk pozwala skonfrontować wiedzę teoretyczną z praktyką. W artykule zaprezentowano innowacyjne laboratorium hydrotroniki i automatyki napędów robotów mobilnych, które powstało w Instytucie Budowy Maszyn Wydziału Mechanicznego WAT. W laboratorium prowadzone są zajęcia z zakresu budowy i eksploatacji hydrotronicznych układów napędowych, które wykorzystywane są w charakterze układów napędowych robotów mobilnych.