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THE DIDACTIC AND SCIENTIFIC RESEARCH CAPABILITIES OF THE LABORATORY OF HYDRAULIC DRIVES & VIBROACOUSTICS OF MACHINES

MOŻLIWOŚCI NAUKOWO-DYDAKTYCZNE LABORATORIUM NAPĘDÓW HYDRAULICZNYCH I WIBROAKUSTYKI MASZYN

Abstract

This article presents a description of the equipment and the didactic and scientific research capabilities of the Laboratory of Hydraulic Drives & Vibroacoustics of Machines located at the Faculty of Mechanical Engineering of Wrocław University of Technology. In the article, the main areas of the laboratory activity are indicated as well as didactic offer including presentation of currently available test rigs.

Keywords: hydraulic drives, pneumatic drives, vibroacoustics of machines

Streszczenie

W artykule przedstawiono opis wyposażenia i możliwości dydaktyczne oraz naukowo-badawcze Laboratorium Napędów Hydraulicznych i Wibroakustyki Maszyn Wydziału Mechanicznego Politechniki Wrocławskiej. W artykule wskazano obszary działań Laboratorium, przedstawiono ofertę dydaktyczną, a także opisano stanowiska dydaktyczne i pomiarowe.

Słowa kluczowe: napędy hydrauliczne, napędy pneumatyczne, wibroakustyka maszyn

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1. Introduction

The Laboratory of Hydraulic Drives & Vibroacoustics of Machines is one of the most advanced laboratories in the field of hydraulics and vibroacoustic diagnostics on the national and continental level. In addition to delivering a wide range of courses dedicated to students of the Faculty of Mechanical Engineering of Wrocław University of Technology, much research is also conducted in the laboratory. This research is connected with master's theses, doctoral dissertations and projects as well as professional research from external orders including commissions from industry. The Laboratory is the only one in the country authorised for the attestation of hydraulic components and systems in terms of radiated noise. The laboratory equipment is mainly based on apparatus for testing vibration, noise, and mechanical and hydraulic parameters. A complete list of research equipment in the laboratory includes a total of over 200 entries. The acoustic reverberation chamber for NVH testing complies with the ANSI standard S1.21-1972 and PN-85/N-01334 and provides the ability to attest machines and devices for vibration and noise. In addition, the laboratory has a unique set of apparatus for measuring noise emission with energy methods – an acoustic probe and acoustic holography (STSF method) allow for the identification of sources of noise and sound power measurements according to ISO 9614. On a global scale, there is a total of approximately 50 systems for acoustic holography and this is the only facility of its kind in Poland. The interdisciplinary research team consists of experienced academics from Wrocław University of Technology who have been conducting scientific and development research in the field of hydrostatic drives for decades. As a result of numerous projects, the research team of the laboratory has done a lot of industrial implementations and has won important prizes and awards. The laboratory team continues to develop didactic and research offers, attempting to demonstrate the highest possible professionalism in the performance of tasks. One of the many activities of the laboratory is also conducting training sessions in hydraulic drives and control systems for the engineering staff of enterprises through the implementation of proprietary training programs.

2. A brief historical note

The research and didactic team in the field of hydraulics and pneumatics was established in 1964 under the leadership of Professor Stefan Stryczek. Since the year 1978, the head of the department was Associate Professor Wacław Kollek until his retirement in 2011, already as a professor organized all forms of research and didactics in the field of hydraulic drives as well as vibroacoustics of machines, ranging from the design stage to the industrial implementations of new solutions. In 2011 and 2012, the leadership of the Department of Hydraulic Drives & Automation was entrusted to Ph.D. Eng. Michał Stosiak, who continued to organise and coordinate the research and teaching activities of the department. The Department of Hydraulic Drives & Automation was included in the structures of the Department of Hydraulic Machines & Systems headed by Professor Jan Kulczyk in 2012 as a result of restructuring, and then in 2014, it became part of the Department of Maintenance & Operation of Logistics, Transportation & Hydraulic Systems managed by Professor

Tomasz Nowakowski. Currently, the activities of the department are being continued and developed in the Laboratory of Hydraulic Drives & Vibroacoustics of Machines, led by Ph.D. Eng. Piotr Osiński. Today, the laboratory is one of the leading research institutes in the field of vibroacoustic diagnostics of machinery and equipment, hydraulic drives and microhydraulics in the country and also acknowledged in Europe [6].

3. Fields of laboratory activities

In the field of hydraulic systems and vibroacoustics, the following research are carried out [6]:

- analysis and synthesis of hydraulic, microhydraulic and pneumatic structures;
- design and modernisation of hydraulic and electro-hydraulic systems;
- design and modernisation of hydraulic components;
- miniaturisation of hydraulic component design;
- automation of hydraulic systems control;
- durability testing of hydraulic components;
- identification of vibroacoustic energy propagation in the environment;
- use of vibroacoustic signals for diagnostic purposes;
- synthesis of vibroacoustic machinery and signals;
- location of vibration and noise sources in hydraulic components and systems, and noise reduction;
- passive and active methods to reduce noise and vibration of machines and equipment with hydraulic systems;
- simulation of dynamic phenomena in hydraulic components and systems;
- optimisation of hydraulic components and systems;
- identification of phenomena associated with the flow of fluid in hydraulic systems;
- modelling of viscous and compressible fluid flow with thermodynamic changes;
- calculation of multiphase flows, e.g. cavitation.

4. Equipment of the Laboratory

The laboratory is equipped with: a stand for testing hydraulic systems Hydro-Prax (Rexroth), a new generation of components controlled by electromagnetic coils, proportional elements – directional valves, throttle valves, pressure control valves, check valves, load-sensing valve, and actuators-hydraulic motors and cylinders [2]. Furthermore, pressure switches or inductive proximity sensors can be used in the system timers to implement sequential hydraulic circuits (Fig. 1).

The laboratory has extensive facilities for the design, construction and testing of components, pneumatic systems and controls enabling the creation of many individual hydraulic and pneumatic circuits for teaching and research in the field of pneumatic and electric automation, such as systems with timers, limit switches, pressure and logic elements (Fig. 2).

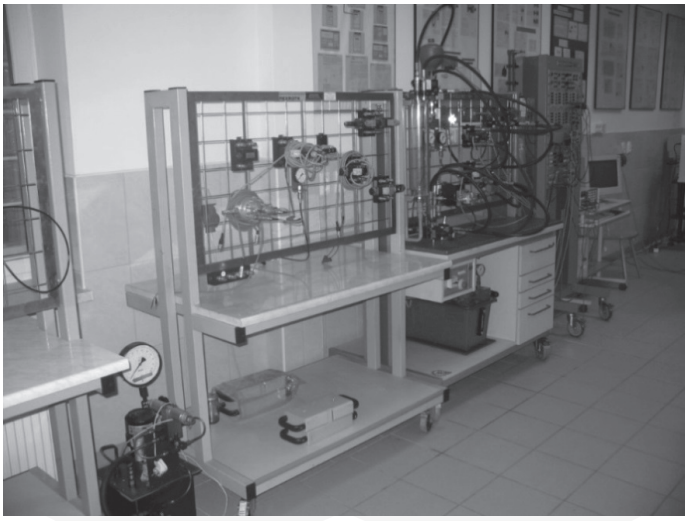

Fig. 1. Training stand with hydraulic components and electrical and proportional control panel

Fig. 2. Test rigs with the elements for pneumatic control systems

Additionally, in the laboratory of high powers, unique test rigs are dedicated for testing the following elements: seals, cylinders, valves, including proportional spool valves and servos. The test rigs enable studying various phenomena such as: cavitation, obliteration and to determine the type of flow. Moreover, a dedicated test rig enables dynamic testing of hydraulic components and systems. The acoustic reverberation chamber for vibroacoustic tests meets the requirements of ISO 9000 and enables attestation of machines and devices for vibration and noise, while a set of instruments for measuring noise emission with the use of energetic methods with a probe and acoustic holography allow the identification of the noise source and the measurement of sound power by ISO 9614 (Figs. 3, 4).

The Hydropax ZY25 linear hydrostatic drive simulator should also be described. It is a research unit of the propulsion system with reciprocating movement, which meets the actual conditions of devices with this kind of drive. The simulator consists of a hydraulic unit, control unit and the control program (Fig. 5).

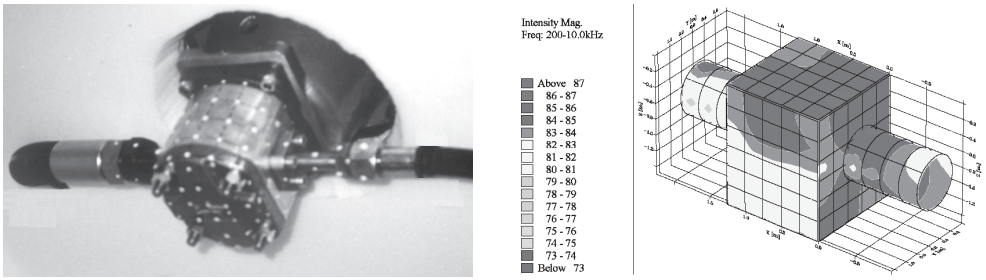

Fig. 3. Localisation of noise sources in the external gear pump (acoustic probe) [3]

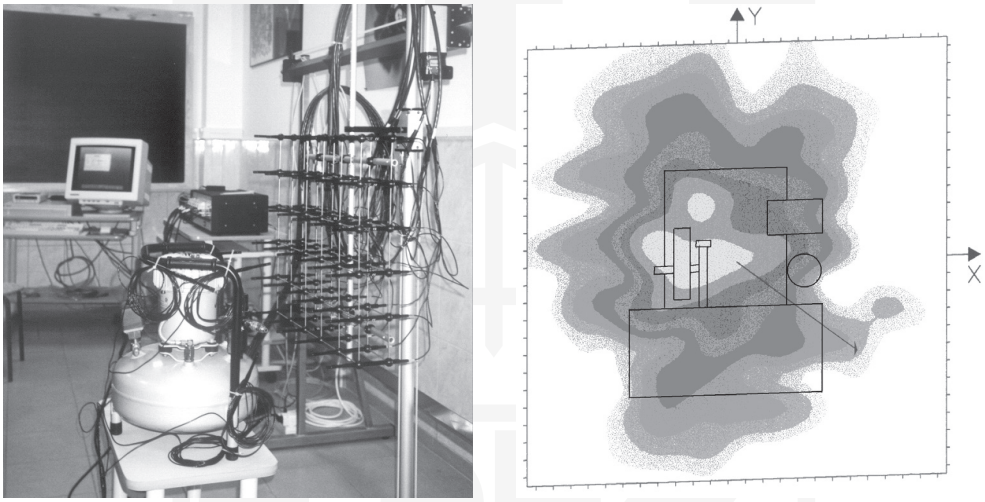

Fig. 4. Localisation of noise sources in the compressor (acoustic holography)

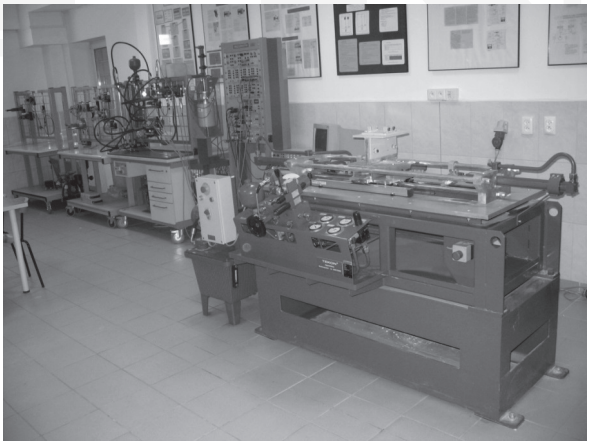

Fig. 5. Linear hydrostatic drive simulator

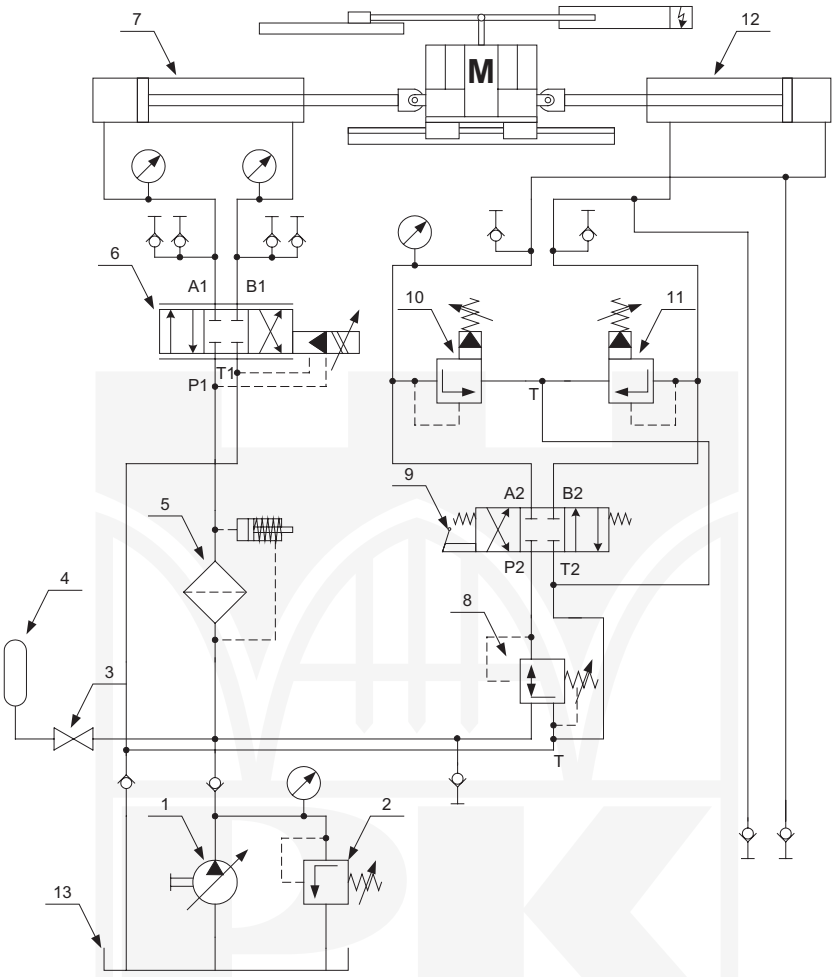

Fig. 6. Diagram of the HYDROPAX ZY25 hydraulic system simulator: 1 – displacement pump; 2 – safety valve; 3 – shut-off valve; 4 – accumulator; 5 – oil filter; 6 – electro-hydraulic amplifier; 7 – cylinder; 8 – differential valve; 9 – directional valve 4/3; 10, 11 – overflow valve; 12 – opposed acting cylinder; 13 – tank [5]

The hydraulic unit has the following specifications [1, 4, 5]:

- variable displacement vane pump PV7-16/20 with parameters p_{max} = 16 MPa, Q_{max} = = 29 dm^3/min, $n_{min} – n_{max}$ = 900 – 1800 rpm;
- electro-hydraulic amplifier 4WSE2EM10-45 – two-stage with integrated electronics in which the first stage is a flapper-nozzle type system, and the second stage is a control slider. This amplifier also has mechanical feedback;
- hydraulic cylinder CDE 160-32/22-500 – double-acting with single rod and cushioning on both sides. The diameters of the piston and rod are 32 mm and 22 mm respectively, the piston stroke is 500 mm;

– double-acting opposed cylinder CDE 160-32/22 – 400, the purpose of which is to produce forces resulting from movement resistances – friction etc. This force counteracts the force generated in the working cylinder;
– directional valve 4WMM 6 E53 – manually operated, 4 ways, 3 positions, for controlling the operation of the opposed cylinder;
– pressure reducing valve ZDR6DP1 – used to reduce the pressure in the chambers of the opposed cylinder, and thus determine the value of such forces as movement resistance.

A hydraulic schematic of the simulator is shown in Fig. 6.

The control device simulator (SYHCE 1) can be used to control, monitor and adjust the linear drives. It consists of the following elements [1, 4, 5]:

– BK1 measuring card for connecting external devices, e.g. an oscilloscope to observe (and registrate) analysed values, inputs and outputs;
– FERN1 remote control card and an FBOX transmitter allowing remote adjustment of the simulator. The FBOX transmitter is a potentiometer, which allows setting the position of the cylinder;
– BAS1 control device allowing the manual operation of the simulator, and choosing the type of operation by selecting the appropriate button;
– VR3D controller card, along with the BAS1 control device, allows access control to the electrohydraulic amplifier. This card is closely linked to the control program. Control parameters selected by VR3D are sent to the electrohydraulic amplifier, which performs specified tasks. The real value of the actual potentiometric sensor displacement is sent to the card in the form of an analogue signal. On this basis, it may be compared to the reference value of the input.

The HCE 1 control program allows choosing the type and parameter of regulation. The selection can be made between two main types of control – displacement and force regulation. After selecting the type of regulation, the parameters may be chosen from three controllers – proportional (P), integral (I) and derivative (D) [1, 4, 5].

5. Classes

Laboratory didactic equipment enables dozens of exercises taking into account electrohydraulic control, electropneumatic control and the proportional technique. Students carry out exercises based on laboratory instructions containing the theoretical basis. After every class, students prepare the short report with the results of measurements. The students assemble hydraulic or pneumatic circuits of the elements available at the test rig and connect the electrical circuit necessary for the proper control of previously assembled hydraulic or pneumatic circuit. The advantages of the module for hydraulic systems include the easy assembly of hydraulic elements with the use of hoses with quick release couplings, the quiet operation of the hydraulic power unit and the safety levels resulting from the low control voltage (24 V), insulated electrical wires and the presence of check valves and pressure relief valves.

In the case of hydraulic systems, after the assembly of the circuit and determining the measurement path, it is possible to perform measurements of hydraulic losses in the system, the flow rates, temperatures and linear or angular velocities, as well as voltage and current.

Some of the topics of exercises carried out during classes include topics related to volumetric and throttle control, sequential control, proportional technique, including load-sensing, as well as the realisation of measurements of pressure pulsation and other topics.

Students have the opportunity to use Automation Studio software intended for the design and simulation of complex mechatronic systems during the classes, which includes extensive groups of elements from the area of pneumatics, hydraulics, proportional hydraulics, electrical engineering and digital technology in its libraries. The program allows the simulation of processes by means of electrically controlled contactor-relay circuits, or programmable logic controllers (PLC). The program enables entering the parameters of individual hydraulic components and their characteristics, making the simulated system behave like a real one – composed of elements selected from manufacturers' catalogs. During the simulation, the plotting of specified variables in time is possible, e.g. pressure at the desired location of the system or flow through a particular element. The advantage of using the Automation Studio software is the ability to create documentation and carry out simulations and animations of system operation. With the software, it is possible to build a hydraulic system with different types of control, then test the operation of the system before proceeding with practical tasks.

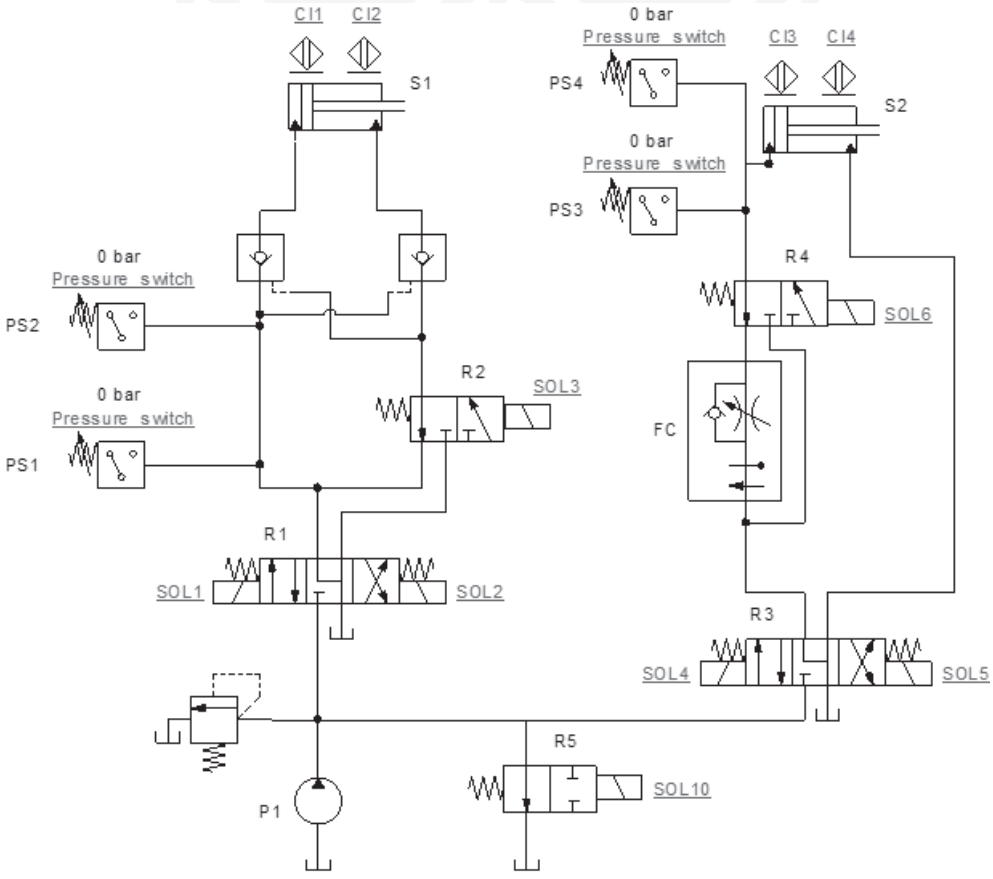

Fig. 7. A hydraulic circuit designed in the Automation Studio software

The design of the circuit in the Automation Studio program is made by dragging the specific symbols of desired elements from libraries to the project window and join them together in the desired way. The ability to use included symbols and the intuitive operation of the program greatly simplifies the complicated process of design; moreover, the option of monitoring the actual operation of the proposed system still allows finding errors in the design phase. Fig. 7 illustrates an exemplary hydraulic system made in the Automation Studio.

During the classes taking place in the laboratory, students acquire competences that are particularly relevant and sought after in the labour market. The most important of these include: the ability to draw appropriate conclusions; the ability to work in a group; the ability to achieve specified tasks; the ability to perform concise reporting.

6. Didactic offer

Currently, the Laboratory of Hydraulic Drives & Vibroacoustics of Machines hold classes for students of the Faculty of Mechanical Engineering, in the fields of automation and robotics (AIR), mechatronics (MTR), mechanical engineering (MBM). The teaching offer includes a range of bachelor's and master's courses, diversified in terms of the advancement of the participants, fields of study and specialisations. In addition, courses are conducted in Polish and English for foreign students.

The courses in the winter semester are: Hydrostatic Drive Systems (MBM, I level); Hydraulic, Hydrotronic & Pneumatic Systems (MBM, I level) – course conducted in English; Seals & Sealing Technique (MBM, specialisation in Construction and Operation of Machinery *KE*, II level); Hydraulic & Pneumatic Drive Systems, (AiR, I level); Drive Systems, Hydraulic & Pneumatic Components (MTR, I level), Dynamics of Electromechanical Systems (MTR, specialisation in Mechatronics in Factory Systems *MSP* and Mechatronics of Machines & Vehicles *MMP*, II level); Electrohydraulic Control (MTR – MMP, II level).

Moreover, in the summer semester the following courses are conducted: Hydraulic Drive (MBM, I level) in Polish and English; Machinery & Equipment Control (MBM, specialisation in Construction & Operation of Machinery *KE,* Engineering of Construction Materials *IMK*, Processes, Machines & Production Systems *PMS*, II level); Vibro-acoustic Diagnosis of Machinery & Equipment (MBM – KE, II level) – in Polish and English; Vibrations & Noise in Mechanical Engineering (AiR, specialisation in Automation of Machines & Processes *AMP*, II level), Systems of Hydrotronics & Pneumotronics (AiR – *AMP*, II level); Hydrotronic & Pneumotronic Systems (MTR – *MMP*, II level). The classes of hydraulic drive are also held for MBM students at the Faculty of Engineering & Natural Sciences in Legnica and the Faculty of Technology & Engineering in Wałbrzych.

7. Summary

The equipment and wide range of educational offers of the Laboratory of Hydraulic Drives & Vibroacoustics of Machines makes it the perfect base to put into practice the knowledge acquired during the academic lectures. The didactic offer is addressed to students

of various courses and specialisations in not only the field of vibroacoustics, hydraulic and pneumatic drive and control, but can also successfully serve the students of other fields such as those related to electronics. In addition, the laboratory provides the opportunity to conduct advanced research and measurements at the request of the industry. In the future, it is planned to further expand the laboratory with modern hydrotronic elements and systems, in particular controlled in proportional technique, load-sensing systems and systems controlled wirelessly. It is also planned to acquire new dedicated simulation programs for the purposes of teaching and training. Laboratory employees strive to continually improve the didactic and research offers in order to provide services at the highest possible level.

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