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EDUCATION IN THE FIELD OF FLUID POWER TECHNOLOGY - CHALLENGES, OPPORTUNITIES AND POSSIBILITIES

Darko LOVREC[1]

[1]University of Maribor, Faculty of Mechanical Engineering, Slovenia, darko.lovrec@um.si

Abstract: *Education in the field of Fluid Power technology presents a huge challenge in terms of equipment, place, as well as adequate installed power, which enables the knowledge transfer under real operating conditions. In addition to this, it is necessary to add constant updating of the subject contents and adaptation to international guidelines and teaching approaches.*
The contribution presents the experiences gained over the years in providing knowledge within this field, for both regular full-time and part-time students, as well as for participants from industry at various courses and skills trainings. Various aspects were taken into account in the education process: Fundaments of knowledge, combining knowledge from different fields, integration into R&D and industrial practice, globalisation and internationalisation, as well as new methods and approaches, e.g. flipped, combined and project based learning in the field of Fluid Power technology and Systems.

Keywords*: Fluid power, education, practical work, equipment, approach, challenges*

1. Introduction

Teaching of Hydraulics and Pneumatics as a special branch of Technology in some countries dates back to the early 1950s of the last century. Most countries around the world are still engaged very intensively in transforming educational systems and learning content. Different views and experiences can serve as an incentive for the general public to begin to intensify their education, as well as to find appropriate methods and ways of educating professionals capable of meeting the challenges of today, including the digitisation of industry and society.
Countries with more and better potential for engineering and technical personnel in the future will clearly have the advantage. On the other hand, there is still not enough (desired) interest in the study of Engineering, which is not only a Slovenian specialty. It is a global phenomenon, reflecting the transition from industrial to post-industrial society, the age of Informatics, including Virtualisation and Virtual Reality.
Surveys among engineering students indicate that they complain of a "hard", tedious and old-fashioned study approach and poor teaching, often conditioned by equipment in practical work. In the list of shortcomings found by industry representatives, they draw attention to the modest ability to communicate, both written and oral, and insufficient practical experience, especially in design, which is more alarming. Additionally, they are worried that many graduates are unable to connect seemingly unrelated fields such as Politics, Social Sciences and Technology.
In the field of Higher Education of technology-related subjects, for example, Mechanical Engineering, we are faced with numerous challenges. This is especially true for the subjects concerning the operating principles of power drive systems and devices. Transmission of forces and motion based on the hydraulic principle definitely falls within this specific area: Fluid Power Drives and Systems.

How to satisfy different conditions, limitation and specifics in the knowledge transfer of these contents, where we are faced with:

- High energy density and realistic operating conditions,
- The interdisciplinarity of knowledge and skills,
- Diversity of equipment,
- Internationalisation of content,
- Integration into development technology trends like Industry 4.0,

Bearing in mind:

- The proposed, necessary and prescribed learning/teaching content, the pedagogical approach, industry needs on one side, and those suggested by the umbrella professional associations which relate to the subject matter, for example CETOP,
- The existing situation in the field of Higher Education at the national level,
- to ensure the safety within practical tests and experiments when using suchtype of equipment.

2. Forms of knowledge transfer and guidelines

Typically used forms of knowledge transfer in the field of Fluid Power engineering is shown in principle in Figure 1. They range from giving theoretical background in the oral way and in the form of equations and diagrams, which is, according the students' opinion, tedious and exhausting, but understanding the theoretical background is extremely important. Students prefer learning through simulation and visualisation (the so-called “click generation”) and independent practical work and experimentation (but not in the form of a demonstration and, of course, in a safe way).

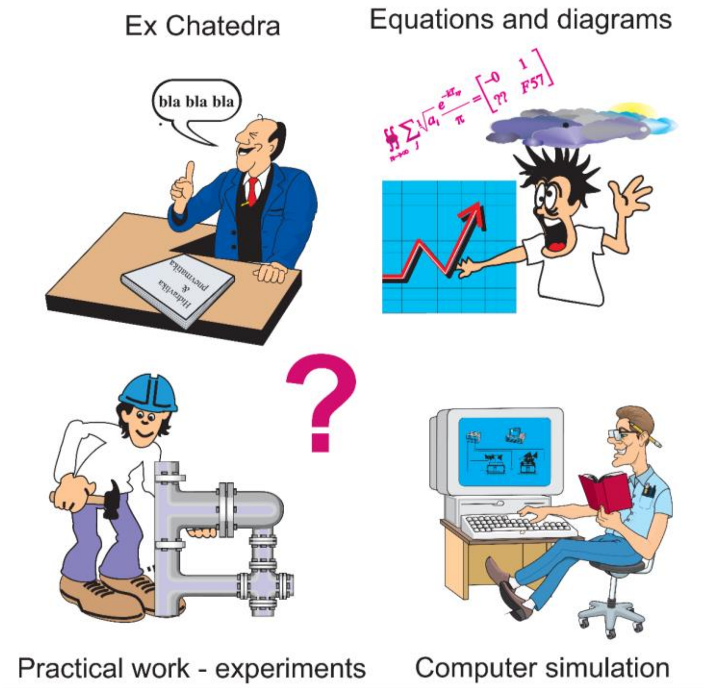


Fig. 1. Typical forms of knowledge transfer in the field of Fluid Power

In addition to all the methods and aspects mentioned, it is necessary to bear in mind (and of course also implement) the renovation, modernisation and adapting of learning contents to the education profile. The focus should be on use of newer approaches in the field of Education, taking into account the integration into the Bologna education system and internationalisation at the same time (e.g. Erasmus).
One of the tasks in order to stimulate and implement reforms of Study Programmes in Engineering effectively is undoubtedly a need for modernisation, introducing and testing new teaching methods and approaches.

These guidelines should also apply to the field of Fluid Power technology education process:

- *Emphasis on learning the basics (fundamentalisation of knowledge).* A modern engineer will have a good mastery of the basics, among which we consider, in addition to mathematics, computing, etc. The Natural Sciences and Social Sciences will contribute substantially to the effective management of rapidly changing technologies in terms of the rapid obsolescence of knowledge and shorter time transfer of research results into industrial practice. *Understanding the physical interdependencies in the operation of hydraulic and pneumatic systems is a necessary starting point for the selection and sizing of components, commissioning these devices, maintenance and condition monitoring of these devices, including fault finding as one of the more difficult tasks – "hydraulic forensics".*

- *Combining the knowledge from different fields (synthesis).* It is of great importance to acquire and upgrade the ability to work with experts from other fields and teamwork, as well as the ability to integrate their work into larger systems. Today, Fluid Power technicians are closely associated with experts in Automation (control concepts, sensors, informatics, maintenance and remote control). Today, experts in the field of Fluid technology are closely associated with professionals engaged in automation (management concepts, sensors, information technology, maintenance and condition monitoring at a distance).
- *Integration into R&D and industrial practice (integration).* The focus of the education system only on classroom lectures and calculation exercises, without significant practical work and experiments in the laboratory, must be redirected to the integration of students into industrial practice and in Research and Development activities. Practical work can be in the form of student projects within a Study Programme (e.g. Mechanical Engineering, Mechatronics), in the form of students` projects on the national level in cooperation with an industrial partner, involving students in market-based applied projects for industry, topics for Bachelor's and Master's theses for industry, and a month long practice in the industry as a compulsory part of the educational programme.
- *Education as a "life-long" learning process.* Due to the increasing obsolescence of knowledge and professional skills, the term "life cycle of education" is, increasingly, being transformed into "education as a life process". Accordingly, universities, colleges (as well as secondary schools) are also expected to offer more continuing education programmes. In this sense, engineers who are already working under "pressure" in the field of Fluid Power engineering, or who have retrained in this field, should be offered longer or shorter seminars or training courses, whether of a general nature, or in-depth and thematically focused on a specific area of the technique (e.g. Tribology and Hydraulic Fluids, Servo Hydraulics, Hydraulic Safety Regulations, Hydraulic Pumps and the like, fluid power control circuits etc.).
- *Personality* development and ethics. In terms of personality development, a modern engineer must also, in a moral and ethical perspective, be brought up into a mature personality with a sense of responsibility to the environment – nature, society and the public, and to manifest himself with sacrificial work, e. g. knowledge and use of energy-saving components and drive concepts, use of environmentally friendly and sustainable hydraulic fluids.
- *Globalisation and internationalisation.* With the emergence of unified global markets and international cooperation, there are also needs for harmonisation of education systems that can no longer be restricted to individual countries or regions. As engineers and technicians, we need to possess internationally comparable professional qualifications and be familiar with the languages, (cultures and mentality, as well the circumstances and specificities) of other nations and areas, as well as the political, social and judicial systems of other countries.
- *Teaching with technology; new methods and approaches.* Implementing of ICT in flipped, combined and project-based learning, within the subject of Fluid Power technology, as well as e-learning and "forensic-case like learning".

The field of Technology, ranging from manufacturing and mobile machinery all the way to space technology, where hydraulic and pneumatic drive systems are used, is increasingly intertwined with knowledge of the control and monitoring of these systems, taking into account autonomous operation, far away from maintenance staff, and also the energy and environmental aspects – Automate-Monitor-Predict.

2.1 Introduction of changes and new approaches

How already today to accede to the changes in the field of Fluid Power technology education? What to preserve? What to improve? What to discard? The answers to these questions will be reached most quickly if we first determine the goals, work tasks, content and aids needed for education, and the population or target group at whom we are targeting the education. In order to formulate some general guidelines, it is necessary first to determine for whom the education is intended, and who are the populations in a country which will need essential knowledge in the field of Fluid Power engineering in their professional work. Are they countries that are more manufacturers of fluid power components and systems, or are they countries where they are mostly used?

Approximately 90 % of all those who are professionals in the field of Fluid Power are operators of already finished machinery. They should always intervene when the machine is no longer functioning properly. Their job is to find the causes of the disorders, to identify and correct them. Those who deal with the installation of hydraulic equipment are estimated roughly at around 10 %, but are faced with the same problem when commissioning the machine.
In the field of Research, Development, Construction and Design of fluid engineering components and devices, a relatively small percentage of experts are involved in the total number of all those involved in Fluid Power engineering.
Depending on their educational profile, they can be divided into:
- Maintenance profile or the fluid power machine operator and
- Engineer profile.

2.2 Necessary knowledge and skills of different professional profiles

Let us first turn to the profile of the maintainer, who represents the broadest interest group in the field of Education, with emphasis on practical instruction. In the event of a malfunction, they are forced to find the causes, to identify and remedy them, or to take preventative measures to prevent them from occurring at all.
Regarding the machines and appliances, it is crucial to know how they operate, how to find defects with the help of the available documentation (wiring diagram, technical data...) the functions of the individual components and the whole system. The operating functions of the individual components are generally valid, while the construction details vary from manufacturer to manufacturer. The maintainer must be able to understand the desired normal operation from the documentation, and then verify the actual status by means of measurements. Knowledge of appropriate measuring procedures and measuring equipment is certainly important. Based on the above, it is necessary to know basic expertise such as:
- The physical background,
- Knowledge of the control functions and performance of individual components and the system as whole, and
- As a continuation of these, in-depth – specialist training focused on user areas.

2.3 Scope of the Fluid Power professional

Depending on the activity area of a maintainer, his tasks can be extended to the in-depth phase of troubleshooting or fault finding. This phase, however, is usually followed by the phase of elimination of a malfunction. The following knowledge and skills required for the maintenance profile can be summarised in the following notes:
- Based on the real circuit, to design the circuit diagram of the hydraulic or pneumatic system properly, in accordance with the given technical requirements,
- Select the appropriate components optimally from the manufacturer's catalogue,
- Identify and localise the fault,
- Identify the causes of the fault reliably,

- Eliminate the fault in accordance with professional measures, and
- Select replacement components correctly from the manufacturers' data sheets.

Based on the above, we can go immediately to the educational profile of the engineer, and find that most of the skills described above can serve an engineer as a basis. This, however, must be supplemented with in-depth knowledge of the control techniques, as the increasing degree of automation of controlling and monitoring of modern machines is becoming more demanding and complex – Industry 4.0.
Without going into detail, it should be noted that, in addition to knowledge of the structure, function and operational properties of fluid power devices and measuring equipment, an engineer must also have an insight into the dynamic behaviour of fluid power systems, which is not only intended for development and design, but increasingly serves for efficient and prompt preparation of Tender documentation. In addition to this, it is necessary to have certain knowledge in other fields of engineering.
In the case of a general education programme that does not specify exactly where the future engineer will work, specialisation in a certain direction of the Fluid Power technology area is, on the one hand, due to over-specialisation too narrow for the general engineer profile, and, on the other hand , unfair to other areas. Each of the specific, narrow areas of the profession requires its own additional specialist knowledge. That's why it's more important and necessary to place emphasis on matters of general character/knowledge and importance. Undoubtedly, these are the physical basics of how the systems work, different types of components and their purpose, particularly of fluid power systems, the ability to interpret hydraulic or pneumatic circuits, and to identify the operation of the device on that basis.

2.4 Forms of knowledge transfer

The verbal way of imparting knowledge – especially theory, as the most widespread method of knowledge, cannot be avoided. The transfer of knowledge and topics should, of course, be adapted to the educational profile and level of education. Special care must be taken when the transfer of knowledge is underpinned or supplemented with equations and diagrams. Both methods provide a huge opportunity to adapt and keep up with changes in the technical field.
Nowadays, the theoretical application of the theory in this field – the so-called two-dimensional technique "on paper" – is a very widespread, practical education in teaching or training. Real hydraulic and pneumatic systems and assemblies (so-called three-dimensional technics), are, in many cases, due to barriers in the form of available equipment and a place for it, pushed more into the background. This is especially evident in areas where theoretical education is at the forefront, and the practical application of theoretically acquired knowledge usually draws the shorter end. Practical work is very important within the field of Fluid Power Engineering.
Practical training – learning about the control functions and performance characteristics of components and systems on learning devices (setups) is important, both in terms of educating the engineer, as well the maintainer. For the latter, the importance of practical work and experimentation is particularly important.
When selecting and designing the equipment and testing facilities for the practical part of the training, it is reasonable to select such devices that are, as much as possible, suited to real-world performance in industry in terms of actual pressures, fluid flows, circuit design...
Here, we must emphasise the possibility of using computers and appropriate software. For many years, computerised simulation of dynamic systems, designed primarily to educate the engineer profile, is an important tool for designing electrohydraulic and -pneumatic drives. Numerous insights into the physics of fluid power circuits` structures and innumerable technical improvements have made software more precise through extensive research in computer models. Nevertheless, many computer software packages are slowly making their way onto desks of Project and Development Departments. The reason for this may lie in the excessive scientific orientation and the long duration from learning about such a programme to its effective implementation in practice.

The real reason for this is probably the relatively high price of complex software packages. There are not so many lecturers who think they have no money so that "students could play". The money that they earn through research and projects for industry is invested in the necessary equipment for the further research, and the State, as the "official trustee" of official Study Programmes, has "no ear" for it. Thus, this aspect is often left to the individual holder of the object, often his ingenuity.
It is a misconception that most of the conditions for the effective use of a simulation programme are fulfilled only when colleagues or entire departments that prioritise this technique are nearby. The simulation technique can be used very effectively in daily design, except that the programmes must meet certain requirements:

- Flexibility in designing models,
- Simple use of the programme and usefulness of the simulation results,
- The appropriatemanageable amount of theoretical knowledge required to design the models.

When these requirements are met, the benefits offered by the simulation technique can be very effective, and, above all, because the "comfortable" simulation programmes allow for a significant reduction in both the time required for testing on the test sites and the time spent on developing components or systems, first start-up, or systems design. The development of user-friendly programmes and the reduction of fear of use, were some of the tasks of modernising educational systems years ago. Nowadays, such programmes are well adapted to the user, so, especially the young generation, is growing up in the age of Informatics and smart devices, so using them has no problems.
Thus, only the problem remains – their procurement. A Fluid Power engineering Institute or Laboratory requires quite a few different software packages: A programme or software package for drawing circuits using appropriate symbols, for simulating circuit operation including component dimensions and operating parameters, for drawing electrical control circuits, for programming controllers, and visualisation of operation, to simulate the dynamic behaviour of servo systems and some extras.

3. Spatial arrangement of topics

In principle, we can say that there are only two problems in the field of Fluid Power education: “Where to place / Where would I put it?” and “Where to take / Where would I get it from?” This is the space available to place the equipment and the financial means to purchase the equipment.
Real-world practical and experimenting equipment is expensive, heavy and large, and requires a fixed layout – fixed working places. As these are usually larger pieces of equipment, it is not sensible to re-install, re-connect and check operation before each lab work. In such a way, the constant setting and storing equipment again, equipment will definitely degrade, or a piece of equipment can be misplaced, or even lost. On the other hand, the appropriate time and staff – the “equipment-keeper”, is not available for such an approach. A further problem is a suitable equipment warehouse. A fixed layout is the only sensible solution from these points of view, and not just from that point of view. Hydraulic equipment also needs a proper power connection – a central pipe network distributed throughout the hydraulic part of the laboratory.
Such an approach, topic-dependent layout and installation of the equipment, is adhered to in accordance with CETOP recommendations related to hydraulic and pneumatic education (e.g. [1]). Unfortunately, the recommendations, no doubt this make sense, are one thing, and the reality another. The problem of spatial arrangement is always, and usually, present at universities and colleges, since there are a lot of other topics and subjects that also include lab work. The buildings are usually old and have their own spatial limitations, and there are only a few new buildings. Adequate space is a particular problem for hydraulics, since, apart from the easily accessible room (due to relatively heavy and large equipment), the available electricity is required for the hydraulic power trains. According to the CETOP recommendations, we should have separate rooms, sorted

by individual topics. Taking into account, or at least following this recommendation, we tried to implement it at the Faculty of Mechanical Engineering at the University of Maribor. Figure 2 shows the layout of the spatial arrangement of laboratory facilities intended for practical work, for a specific segment of Fluid Power and Automation, and Figure 3 shows the pipeline system for hydraulic and for pneumatic energy transfer.

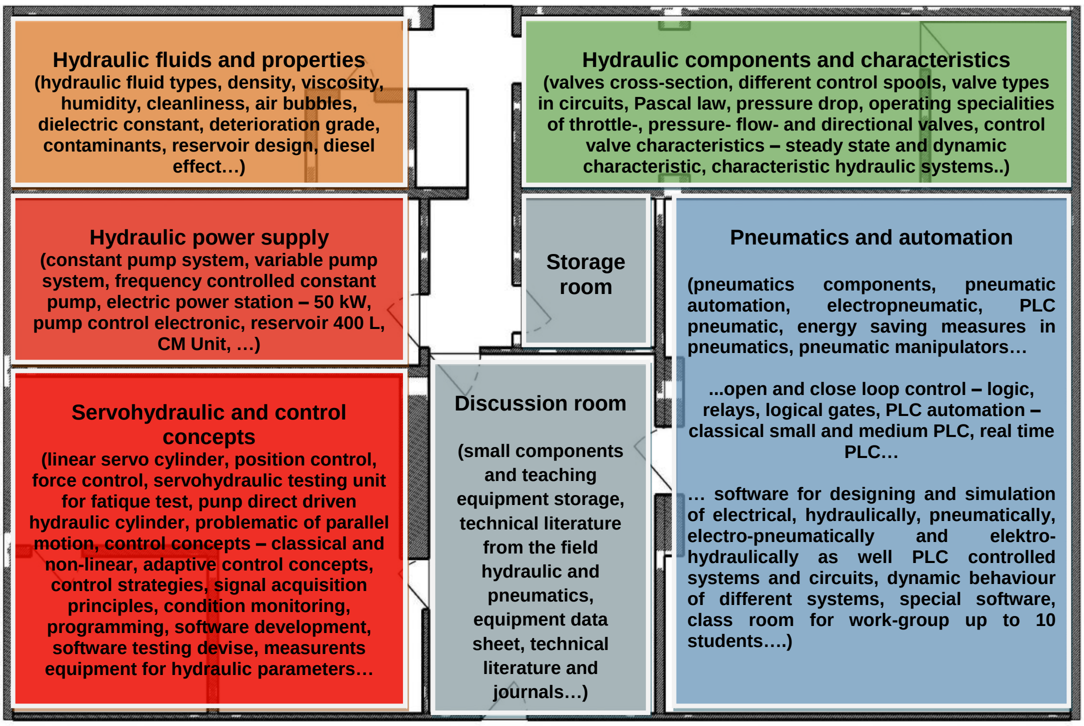


Fig. 2. Spatial arrangement of the laboratory facilities

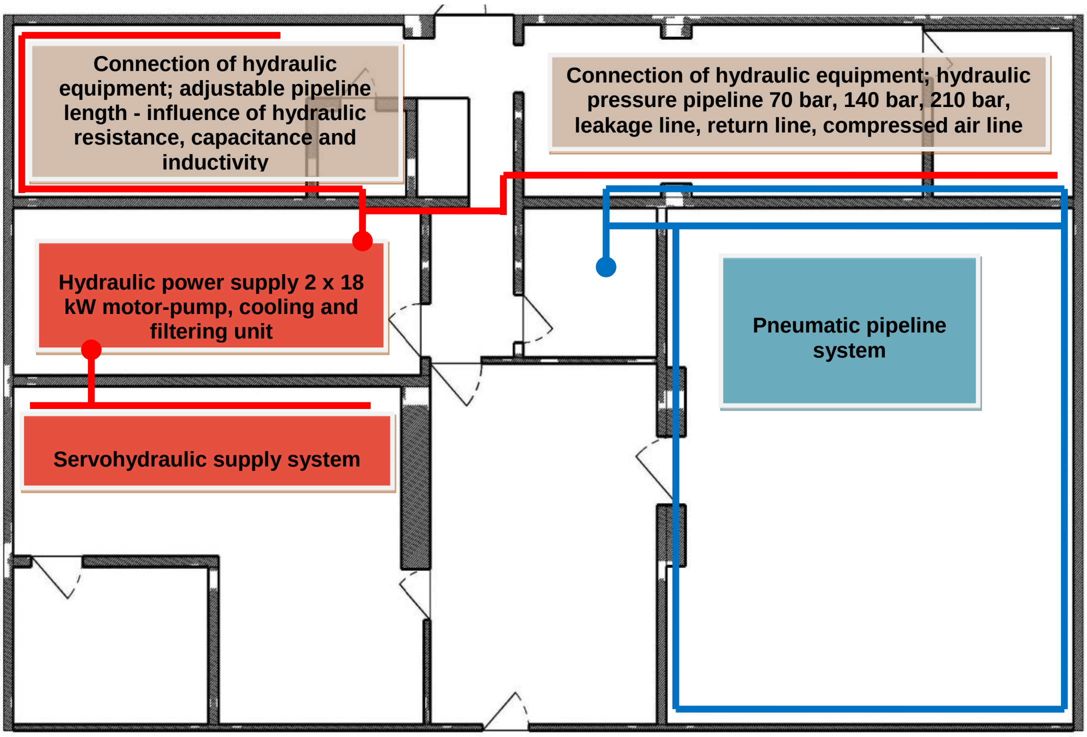


Fig. 3. Pipeline system arrangement

4. Contents related to the learning of hydraulic basics

According to the recommendations, for each topic, preferably in its own room, we also carry out individual sets of practical exercises and experiments. Exercises related to the determination of the density and viscosity of the hydraulic fluid is carried out in a place intended for the knowledge of the basic physicochemical properties of hydraulic fluids. Viscosity of a sample is measured at different rates, taking into account the influence of temperature, and understanding the viscosity values given by different Standards. Furthermore, the influence examination of different oil viscosity`s degree to resistances when the component parts move in the fluid.
The cleanliness level measurement is intended to understand the importance of cleanliness of a hydraulic fluid, the manner in which it is given in the literature, including search for information regarding the required cleanliness level of a particular hydraulic component, given in the component manufacturer's datasheets in the form of different Standards. Furthermore, the degree of chemical, thermal degradation (acidification) of the oil is determined by use of simple instruments, as well as by precision laboratory ones. Of great importance is also the issue of air bubbles inside hydraulic fluid, as well as the proper design of the inside of the tank – layout of the suction and return pipes, and measures for the better functioning of the tank (partition wall, diffuser on the return line etc.). Hydraulic oil compressibility is also discussed in relation to air issues - measuring the compressibility modulus for different types of hydraulic fluid inside different pipes (steel tube and hose). The effect of air (dissolved in oil or present in the form of air bubbles) is also visualised by a diesel effect test. One part of the space for learning about the properties of hydraulic fluids is shown in Figure 4.

Fig. 4. Basic properties of hydraulic fluid – detail from the experimental room

In this part of the laboratory, pressure drops at different fluid temperatures (cold start and operating temperature) are also measured, as well as the influence of the length of the pipeline on the size of the pressure drop (hydraulic resistance), and the effect of the pump flow size on the pressure drop (the latter can be achieved by an adjustable pump). Thus, it is also possible to determine the hydraulic capacitance and inductance of the pipe network.
In fact, this set of experiments is already related to the next set of experiments, to learn about the specificities of hydraulic power transfer. Part of this second set of experiments is conducted in the next laboratory room – Hydraulic components and characteristics. It is intended for experimenting about different types of valves (throttling valves, pressure valves, flow valves and directional valves), different designs of real hydraulic circuits, pressure drops on components and circuits, as well as experimenting regarding the operating specialities of individual valve designs. Each of the valve types is mounted at its own workstation. Two examples of experimental layout for this group of experiments are shown in Figure 5.

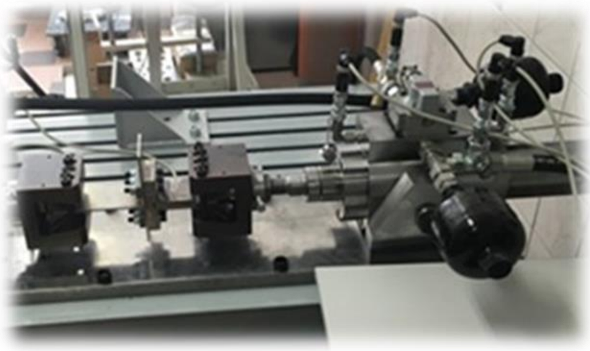
Experiments: Throttle vs. orifice, serial and parallel connection of hydraulic resistors and pressure drops, heat generation, Pascal Law, influence of pipeline design and the pressure drops, influence of flow amount on the pressure drop…

Experiments: Design form of pressure valves – one-stage pressure valve with and without damping piston, flow depended operational instabilities, pressure shock valve two-stage pressure valve, influence of back-pressure, adjusting principle…

Fig. 5. Setup for hydraulic basics and components experiments – pressure drops (left) and pressure valves (right)

Similarly configured are a test rig for the measurement of static and dynamic characteristics of the valves and a test stand for servo drives. The latter is located in its own part of the laboratory (see Figure 2). Figure 6 shows a part of the test setup for measuring the (control) valve characteristics and a linear servo drive.

Steady-state experiments: Δp-Q characteristic, flow-input signal, flow capacity, leakage, valve linearity, threshold, rated flow, flow gain, limiting power etc.



Experiments: Position control, force control – force sensor, pressure sensors, adaptive control concepts development, influence of accumulators and pipeline system etc.

Fig. 6. Setup for valve steady-state characteristic measurement (left) and linear servodrive (right)

As shown in Figure 3, the power supply to all rooms dedicated to the hydraulics is derived from the central power unit – see Figure 7). It is also used for many experiments at the same time: Except for the basic task of powering hydraulic working places, various types of pump control (variable pump, speed controlled constant pump), to know the importance of sensors for monitoring the condition of the power unit, CM of built oil, remote control and adjustment of all operating parameters, visualisation of operating parameters etc. as well as of special operating situations e.g. aeration of the system through a loose pipe connector and, consequently, noise and foaming.

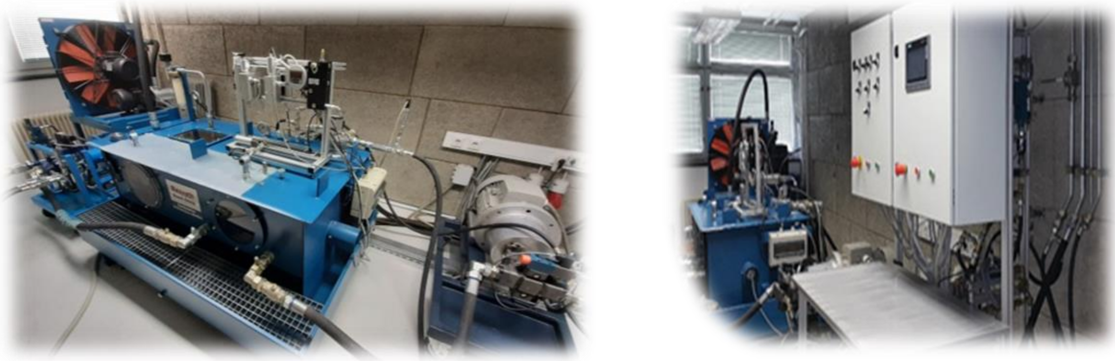


Fig. 7. Central hydraulic power unit with control cabinet

5. Contents related to learning of Pneumatics and Automation

Pneumatic-related exercises are performed in a separate laboratory room – Figure 2. In contrast to the hydraulics experiments, the pneumatics has less emphasis on the physical background of the operation of the pneumatic systems. More emphasis is on the use of the pneumatics as a technique for products` manipulating – automation (handling and assembly). In this sense, the various pneumatic control circuits, from basic cases, through the electropneumatic to the PLC pneumatic, are at the forefront. Students build and test pneumatic controls or circuits at five workstations, where the exercises are upgraded, from simple ones to the more advanced. Workstations can be rearranged quickly and easily according to the subject under consideration – pneumatic controls or electrical controls, in various implementations and techniques (relay technology, semiconductor technology or PLC-programmable technique). Figure 8 shows the aforementioned multifunctional workstations for pneumatic circuits, and for automation basics with electrical components.

Fig. 8. Modular laboratory equipment – pneumatic and automation basics

A more advanced approach is to build pneumatic manipulators with the ability to reprogramme in terms of performing different sequence of actuator motions – automation of production processes.
Automation of production processes is the driving force of development of production-oriented companies. Thus, it is important that future technical personnel acquire specific skills in designing, implementing and managing automated devices and processes. Unfortunately, the didactic equipment used in educational institutions is usually of a simple nature (operation and control of individual components), so the transition of the trained technical personnel into a real industrial environment can be very demanding [2, 3]. A lot of related work was found in this field, yet the

work is more focused on developing single components, adding vision control [4], or developing higher level SCADA and manufacturing systems. However, closely related work on didactic pneumatic workstations was also found [5], which presents a more simple solution. We attempted to fill this gap with design and construction of a more complex didactic station, which is based entirely on real industrial components, and represents an automated workstation based on the use of pneumatic systems.

The workstation is based on a pre-designed work cycle. Workpieces are loaded into a container, from where a two-way cylinder pushes them to the pick-up point. The transfer of the workpiece from the pick-up point to the workplace is carried out by a 3-axis pneumatic manipulator, which can perform different movements of the workpiece – Figure 9.

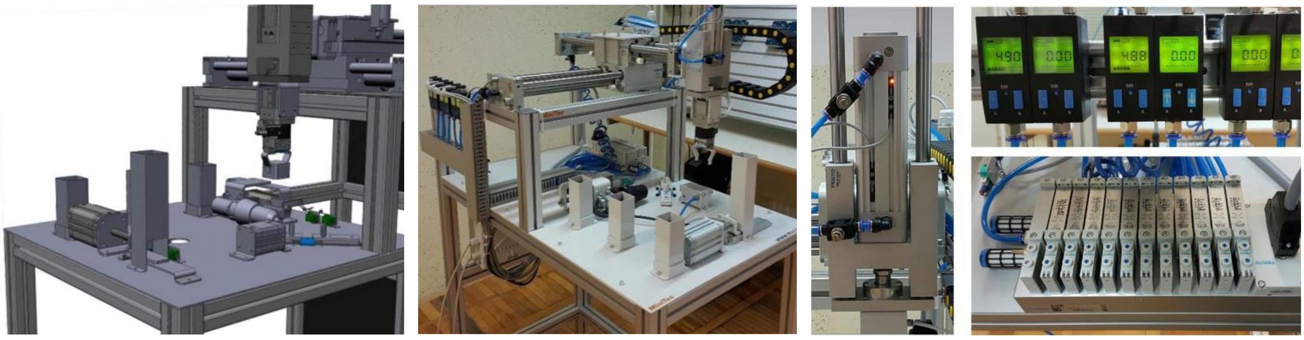


Fig. 9. Didactic workstation – 3D design (left), real appearance (middle), detail – industrial components (right)

The designed workstation provides a high level of flexibility in design using a PLC programmable pneumatic control system; from the simplest control cycles, where only three axes are managed; the user inserts the workpiece into the workplace manually, followed by clamping, drilling, stamping, un-clamping and manual removal of the workpiece; to very complex control cycles, where all 9 available axes are operated: Ejection of the workpiece from the container, pick-up and transfer to the workplace, both machining operations, clamping and turning of the workpiece by 180°, re-clamping and repeating the machining operations, and transfer to an appropriate container in respect to its current fill capacity.

The basic concept of the station and its operation was developed further and conceived in SolidWorks, where we created a simulation of movement through the work process, making it easier to reconcile the individual movements of all 9 axes. On the basis of the final 3D model, the drawings and plans were made for manufacturing and assembly.

Conclusions

In higher education courses that relate to the automation of individual machines, systems or entire industrial plants, including hydraulic and pneumatic components, we are faced constantly with rapid development of new technologies. The main challenges are not the basics, the basic background and concepts of industrial automation, but rather a vast number of technical innovations related to the design and use of automation building blocks: Sensors, programmable logic controllers and corresponding programming languages, as well as new fluid power components.

Students who complete a certain degree of education should not only have an appropriate basic knowledge, but they should also have an insight into the equipment used most commonly by their potential employers in the local and international areas. Since we are experiencing rapid technological advancement, we need to find a way to use the limited resources allocated for equipment, while following the development of new technologies, and providing students with the new, ever more powerful, flexible and versatile equipment that they will use tomorrow in industry. This problem began to stand out with the implementation of the internationally comparable Bologna

Process, and became even more demanding with the introduction of Industry 4.0 in our companies. In addition to theoretical and practical exercises the problem also involves mainly student projects.
We have been dealing with this problem successfully for more than two decades. As an example of good practices in teaching, we conform to the following principles – approaches:

- The main emphasis is on obtaining the basic knowledge.
- Concepts of exercises and content delivered is according to the principle: "Start with basics and add functions". In this manner, we cover the minimal skills that everyone should understand fully. For those more interested students we have the possibility to upgrade the basic exercise. We use this well-proven and accepted concept for both full-time and part-time students, for student project work, as well as for participants from industry in various trainings and courses.
- The next approach is to teach how to use different equipment to solve the same problem.
- Solving the given task in various ways, including thinking "out of the box", where the creativity of students is particularly evident and leads to the desired target – an intelligent student or an expert. We also encourage students by enhancing common tasks and existing controls with hidden errors that they have to find, diagnose and repair.
- In parallel to the practical work, the students have to use modern e-tools for industrial automation planning and design, and, later, they have to switch from the virtual world to the real world.
- We incorporate the "self-service" concept, whereby students search for the necessary equipment in a box, as when purchasing it in a company. Then they have to read the instructions, install it, wire it and use it;
- Within the practical work, both in the field of Hydraulics and Pneumatics, we use real industrial components, and realistic operating conditions.

This approach also provides insight into the specificities of the operation of these systems. In addition, it provides a variety of already established and newer approaches to learning: Implementing of ICT in flipped, combined and project based learning, within the subject of Fluid Power Technology, as well as e-learning and "forensic-case like learning".

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