

THE IMPLEMENTATION OF AN ULTRASONIC DETECTOR IN THE EDUCATION OF VOCATIONAL STUDIES STUDENTS

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Abstract: The primary role of higher education institutions in the technical field is to ensure that vocational engineers they educate are equipped with practical skills and knowledge that enable them to effectively and efficiently meet the demands of the labor market. Achieving this goal requires the integration of modern equipment into laboratory work and practical training as one of the key requirements. A constant obstacle in the realization of this requirement is the lack of financial resources, which higher education institutions try to overcome through projects and by seeking alternative sources of financial support. This paper presents an example of equipment that is highly applicable in a wide range of study programs and corresponding courses, for which the acquisition did not require significant financial resources. The multifunctional mobile device called the ultrasonic leak detector was purchased in mid-2024 by the Technical College of Applied Sciences in Zrenjanin, and its characteristics and potential applications in teaching and practice are presented.

Key words: experimental equipment, ultrasonic detection, compressed air leakage, energy efficiency

1. INTRODUCTION

In the modern economy higher education institutions are treated equally like any other companies across various industries - their task is to generate human capital [1]. The need for these institutions to continuously improve the quality of education they offer to their students is obvious. This can be achieved by innovating and upgrading equipment for practical and laboratory work, developing modern teaching materials, teaching methods, and assessment, providing various forms of student support, enhancing physical infrastructure, and continuously improving the teaching staff [2].

With the continuous progress of science and technology, the application of educational technology and equipment in higher education institutions has been continuously expanded and deepened [3]. The higher education institutions in the Republic of Serbia that educate future vocational engineers make continuous efforts to provide their students with a high level of practical work, thus promoting the development of their skills. The goal is to raise students' competencies to a level that meets the diverse needs of both domestic and foreign labor markets, which are in continuous expansion.

The successful implementation of these efforts by higher education institutions is very challenging, as it is inevitably conditioned by the constant lack of financial resources. In addition to the necessary search for various funding sources, the activities of these institutions could, in parallel, be directed towards researching and acquiring equipment that does not require significant financial resources but can be applied in multiple subjects and/or across various study programs. This paper presents such a device – an ultrasonic leak detector, as well as numerous possibilities for its application in teaching subjects across various study programs.

2. ULTRASOUND LEAK DETECTOR AND APPLICATION CAPABILITIES

As part of the project titled "Improving the energy efficiency of machines, devices, and systems using ultrasonic detectors," which was funded in 2024 by the Provincial Secretariat for Higher Education and Scientific Research, the Technical College of Applied Sciences in Zrenjanin acquired a device called an ultrasonic leak detector. As shown below, the application possibilities of this device in teaching are significant. On the other hand, its implementation in practice is diverse and provides significant insights into the behavior of various machine and system components, enabling timely response from maintenance services in the field of preventive actions.

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2.1. Theoretical background

Compressed air is one of the most energy-intensive and expensive forms of energy, making it crucial to identify and address areas of energy loss, as it powers a wide range of industrial devices and machines. This energy source is particularly critical in automated manufacturing systems, where there are high demands for maintaining constant pressure at the required levels, along with the need for air of consistent quality, to ensure optimal and reliable system performance [4]. Leaks are a common occurrence in pneumatic systems, especially at components such as regulators, valves, and fittings, and they lead to a pressure drop within the system.

However, the allowable range for these losses is $\Delta p = 0.1 - 0.5$ bar, measured from the point of production to the most distant point of compressed air consumption. [4], [5]. If the pressure drop exceeds the allowable range, it indicates uncontrolled air leaks within the system, which results in a loss of optimal performance. Therefore, it is necessary to detect the locations where losses occur and assess the severity of the leaks. Following this, it is important to recommend to the system user the replacement of the problematic component with a new one. In this way, through preventive action, not only is the probability of system failure reduced, but the energy efficiency of the compressed air system is also maintained and improved [5].

When air leakage occurs through small unwanted openings with sharp, rough edges, the fluid flow contains a high level of ultrasonic waves resulting from friction in the turbulent fluid flow. This sound is above the range of human hearing (> 20 kHz), but it can be detected using an ultrasonic detector and then traced to its source.

2.2. Device selection

For the purpose of gas leak identification, numerous devices have been developed, which vary widely in price ranges (≤ 15000 €) as well as in application complexity, but also come with certain limitations. Since the first gas sensors were invented, researchers have been developing instruments that measure gas concentration and there are different types of concentration-based methods [6]. For example, a "sniffer" is a device specialized in "sensing" only one type of gas (such as freon, methane, acetone, etc.) and cannot be used for other gases. Nevertheless, there are detection technologies that do not depend on gas concentration, but rely on certain gas properties to identify the onset of a hazard. One that has emerged as a viable means of detecting gas leaks is aptly named ultrasonic gas leak detection. Therefore, an ultrasonic leak detector was chosen as the appropriate device for detecting compressed air leaks. During the hardware selection project phase, four criteria had to be aligned:

- the highest possible device quality to ensure its application in teaching over a longer period of time,
- optimal price, considering the very limited financial resources,
- compactness and mobility, and
- versatility, as it would then be applicable in various fields, i.e., in multiple teaching subjects.

The project team selected the AccuTrak® ultrasonic leak detector, version VPE, by Superior Signal Company LLC, as the optimal device, which fulfilled all the specified requirements [7]. The selected device and accompanying equipment are shown in Fig. 1.



Figure 1 – Ultrasound leak detector AccuTrak® VPE with equipment

The accompanying equipment of the device includes a contact probe, an attachment for accessing remote and hard-to-reach detection positions, headphones converting the detected ultrasound into sound audible to the human ear, a battery, a manual, and a case for device storage and transport.

In Fig. 2, it can be seen that the ultrasonic sensor is located below the "cone-shaped nose", which, in addition to protecting the sensor, serves to collect the ultrasonic waves generated in the surrounding area and direct them towards the sensor. The ultrasound detected by the device is displayed as LED indicators, with the number of glowing LEDs indicating the intensity of the compressed gas leak. The device is also equipped with a side slider that allows sensitivity adjustment and features a peak hold option designed to eliminate irrelevant ultrasonic signals from surrounding sources.

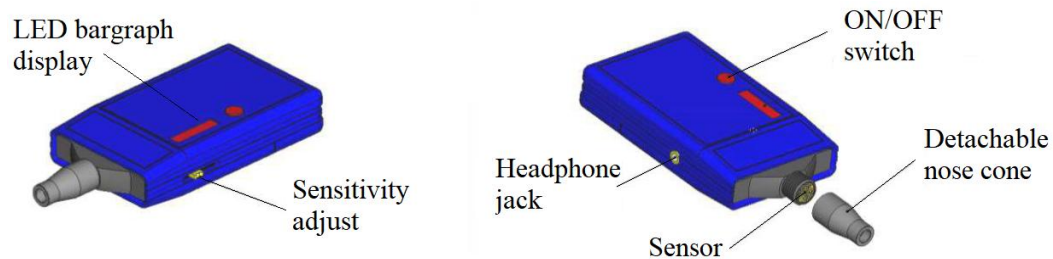


Figure 2 – Characteristic parts of ultrasound leak detector AccuTrak® VPE

The device is compact (housing dimensions 150×100×15 mm), and has a very low weight (~ 120 g including the battery). It fits in one hand, which allows easy handling, and its price is (including additional costs such as supplier fees, import duties, customs, and international shipping) approximately 1700 €. The AccuTrak® VPE ultrasonic leak detector successfully detects generated ultrasound from a distance of up to 12 m, but for more reliable leak location, it is always better to perform the detection with zigzag movements near the areas suspected of gas leakage.

2.3. Ultrasound leak detector like multipurpose device

In addition to the previously described application, the AccuTrak® VPE ultrasound leak detector can also be successfully used for detection in the following areas [7]:

- in vacuum systems,
- detecting leaks in air conditioning and refrigeration systems,
- detecting friction and wear in rotating machine parts,
- detecting internal leaks in liquid systems (e.g., valve seats), and
- locating electrical failures that cause power quality degradation, circuit breakers, buss bars, relays, corrosion in contacts, or poor insulation.

The principle is the same in all cases: the intake of air from the surrounding environment into a vacuum system through damage in the form of small cracks with sharp edges, as well as gas leakage from air conditioning and refrigeration systems through similar cracks, create turbulent flows in which ultrasound is generated. Also, the formation of an electrical arc or sparking creates a crackling, sizzling, or buzzing sound in the ultrasonic range.

It is necessary to specifically explain the potential application of this device for detecting friction and wear in rotating machine parts. Due to the fact that ultrasound propagates through solid materials and is generated when rotating machine parts (e.g., rolling bearings) are worn and/or inadequately lubricated, it is possible to identify such components well before their failure. In order to apply the ultrasonic detector in this way, it is necessary to unscrew the conical "nose" from the ultrasonic sensor (see Fig. 2) and replace it with a touch probe (taking care not to damage the thread), as shown in Fig. 3. The contact probe tip should be pressed against the outer surface of the housing containing the rotating machine part. The pressure should be strong enough to ensure a stable contact, but not so

strong as to damage the probe or the device. In addition, in the case of wear and inadequate lubrication of rolling bearings, the display shows glowing LED diodes and the sound in the headphones is characteristic. Specifically, gas leaks under pressure emitting ultrasound in the device's headphones sound like "hissing" or "water noise", while rotating machine parts produce a rhythmic mechanical sound. Since uncontrolled air leaks under pressure and mechanically generated ultrasound (for example, due to wear of rolling bearings) can occur on the same device (e.g., compressor), it is essential for the user to learn to distinguish between these two types of sound [8].

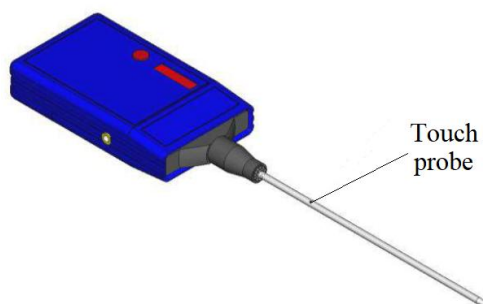


Figure 3 – Ultrasound leak detector AccuTrak® VPE with touch probe

Only if this is confirmed by the glowing LED diodes and the corresponding sound in the headphones, will the person conducting the monitoring be certain that the issue is a worn and/or inadequately lubricated rotating machine part.

As can be seen from the above, the AccuTrak® VPE ultrasound leak detector is truly a multipurpose device that can be applied in various areas of machine and system monitoring.

3. APPLICATION OF ULTRASOUND DETECTOR IN DIFFERENT STUDY PROGRAMS AND SUBJECTS

The research has shown that the purchased multifunctional portable AccuTrak® VPE ultrasonic leak detector can be implemented in practical classes and practical lab work within as many as 12 different courses across 7 study programs at the Technical College of Applied Sciences in Zrenjanin. As shown in Table 1, this device will be applied to 4 study programs and 8 corresponding courses in the undergraduate vocational studies.

Table 1 – Bachelor's vocational studies - Study programs and courses where the ULD is used

Bachelor's vocational studies - Study programs			
Mechanical Engineering	Engineering Technology	Electrical Engineering and Computing	Safety Engineering
Courses			
Hydraulics and Pneumatics	Environmental Protection	Electrical Engineering Materials and Components	Pressure Plants and Installations
Machine Elements	/	Electrical Installations and Lighting	/
Engineering Materials		/	Engineering Materials
Energy efficiency			/

The research also showed that the ultrasonic detector will be applicable to 3 study programs and 4 different courses offered within the master's professional study programs (Table 2).

These data demonstrate the exceptional applicability of the AccuTrak® VPE ultrasonic leak detector in teaching. Part of the implementation has already begun in the winter semester. In the courses Hydraulics and Pneumatics at the bachelor vocational studies and in the course Material and

Structure Testing at the master's vocational studies, students had the opportunity to familiarize with the characteristics of the acquired device (Fig. 4) and practice its application in real scenarios (Fig. 5).

Table 2 – Master's vocational studies - Study programs and courses where the ULD is used

Master's vocational studies - Study programs		
Mechanical Engineering	Safety Engineering	Engineering Technology
Courses		
Material and Structure Testing		/
/	Monitoring of the Environment and Working Conditions	
/	Pressure Equipment	/
Measuring Techniques		



Figure 4 – Students study the setup of the contact probe

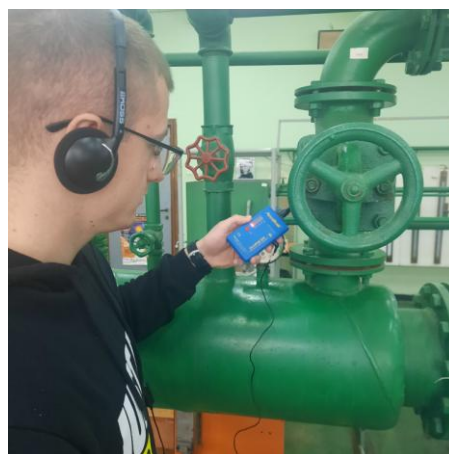


Figure 5 – The student practices testing internal leaks in valves

It is important to highlight that one of the activities within the mentioned project involved demonstrating the capabilities of the device in production facilities (Fig. 6 and Fig. 7). The activity was carried out in three industrial companies in the city of Zrenjanin, of which the first has a gas installation, the second a cooling system, and the third a compressed air system.



Figure 6 – Checking the wear of rotating pump parts in the gas boiler room



Figure 7 – The detection of gas leaks at the pressure regulator connection "UNIS" 1892 b

Employees who attended the demonstration expressed a clear opinion that the device is extremely useful and that its application is one of the skills that is desirable for vocational engineers to possess, especially those who conduct continuous system monitoring in their companies.

4. CONCLUSION

A device with such capabilities significantly enhances the reliability of the systems it is used to monitor, reduces the likelihood of failures, contributes to maintaining and improving the energy efficiency of the system, and thus positively impacts potential financial losses due to reduced energy delivered by compressed air to actuators. Additionally, due to its multifunctionality, the device is also applicable in detecting various adverse phenomena that generate ultrasound in numerous machine and system components, thereby positively impacting their safety and improving their energy efficiency.

Testing pressurized air systems with this ultrasonic detector results in identifying leak locations and their approximate intensity, as the device is straightforward and does not provide precise information about the intensity of air leakage or intake. However, calibration can be performed by conducting simultaneous parallel testing with this device and a more expensive model of the same type equipped with a precise scale. This would make the results obtained from testing pneumatic systems with the AccuTrak® VPE more accurate and provide numerical interpretation, allowing them to be used for estimating flow rates at leakage points and subsequently for more accurate financial loss calculations. The calibration of this ultrasonic detector is part of the project team's future plans.

As demonstrated in this paper, the AccuTrak® VPE device is highly applicable in educating technical students across various study programs and numerous courses. This example strongly supports the claim that, through effective ideation and active, professional research, it is possible to identify devices and equipment that do not require significant financial investments yet substantially enhance students' competencies and practical training. Of course, this fact does not imply that vocational colleges and academies should disregard their continuous pursuit of funding sources to obtain more financially demanding and structurally complex equipment that offers far greater opportunities for aligning students' technical competencies with labor market needs.

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