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Using of remote controlled pneumatic spring in teaching[1]

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Abstract: *The paper presents application of a new didactic resource - the remote controlled pneumatic spring in teaching at the Faculty of Technical Sciences Novi Sad in studies of Mechatronics and Industrial engineering. The paper provides basic theoretical background and description of the developed experiment as well as results of the student evaluation related to design, quality of use and application results of the presented remote experiment.*

Keywords: *remote experiments;pneumatic spring; evaluation*

1. INTRODUCTION

Remote laboratories become very important for a large number of higher education institutions, especially those that teach students in the field of Mechatronics [1] and Industrial engineering. Access to the modern laboratory equipment is a necessary prerequisite for quality of teaching and scientific research. Remote access is particularly important for institutions that are not able to independently provide the adequate equipment or, in terms of utilization, can not justify investment in expensive laboratory equipment. Remote access to laboratories is very important for the frequently marginalized group of people with special needs and for some it is the only means of access. The Faculty of Technical Sciences in Novi Sad, through participation in the Nerela Tempus project [2], provided the necessary equipment and installed the several experimental facilities with possibility of remote access. One of the developed experiments is shown in the next chapter.

2. DESCRIPTION OF EXPERIMENT

Remote controlled pneumatic spring is designed to simulate operation of mechanical springs under compression load, under different conditions using double acting pneumatic cylinders.

[1] *This paper presents the outcome of the NeReLa project "Building Network of Remote Labs for strengthening university-secondary vocational schools collaboration", No. 543667-TEMPUS-1-2013-1-RS-TEMPUS-JPHES, supported by The Education, Audiovisual and Culture Executive Agency (EACEA).*

Different conditions are obtained by changing the parameters which describe operation of spring. It is necessary to possess certain theoretical knowledge in order to achieve this.

2.1. Theoretical background

The force needed to extend or compress a spring by some distance is proportional to that distance (Hooke's law). It is stated with formula 1:

$$F = k \cdot x \ \ [N], \tag{1}$$

where is k coefficient of spring stiffness and x elongationor distance from balance. Coefficient of spring stiffness is calculated from spring's geometry and shear modulus using formula 2:

$$k = \frac{G \cdot d^4}{8 \cdot n \cdot D^3} \ \ \left[\frac{N}{m}\right], \tag{2}$$

where is G shear modulus of material, D mean diametar of spring, d spring wire diametar and n number of active coils.On the other side, a force which is created by compressed air in pneumatic cylindersis calculated using formula 3:

$$F = p \cdot A \ \ [N], \tag{3}$$

where is p pressure in pneumatic system and A cross sectional area, which is calculated using formula 4:

$$A = \frac{d_1^{\,2} \cdot \pi}{4} \ \ \left[m^2\right]. \tag{4}$$

Diametar of pneumatic cylinderis marked with d_1. At the end, with the combination of the previous formulas (it's necessary to say that frictional force is neglected), the compressed air pressure in the piston side of pneumatic cylinder, in the transformation of forces in the pressure, or mechanical energy to pneumatic energy, can be easily calculated according to the formula 5:

$$p = \frac{G \cdot d^4 \cdot x}{2 \cdot \pi \cdot d_1^2 \cdot D^3 \cdot n} \ \ [Pa]. \tag{5}$$

2.2. Description of experiment and activities for execution of the experiment

Practical implementation of remote controlled pneumatic spring is shown in Fig.1a. Programmable logic controller (PLC) is used for control of spring. PLC controls the operation of double acting pneumatic cylinders according to the predefined algorithm (it is based on electropneumatic control scheme which is shown in Fig. 1b) and thereby allows the simulation of spring.

As can be seen on control scheme, in initial moment, both monostable electrical actuated valve 3/2 (1V1 and 1V2) are actuated. Compressed air (a value of pressure is 6 bar) is brought from source to piston rod side of cylinder B and it is in a retracted position. On same way, compressed air (a value of pressure is equal value of secondary pressure from electrical pressure regulator and it lower than 6 bar) is brought to piston side of cylinder A, through electrical pressure regulator, and it is in a drawn position. When PLC deactives valve 1V2, cylinder B performs work stroke and pushes cylinder A by compressing air in its piston side. On that way, cylinder B simulates a force whish is needed to move the spring from its equilibrium position. The air in the piston side of the cylinder A is compressed (there is no possibility that the air released into the atmosphere because there is a non-return valve between the valve 1V1 and the pressure regulator 1V3). On that way, cylinder A simulates a mechanical spring. When PLC reactives valve 1V2 after defined time, cyilinder A pushes cylinder B which performs return stroke and returns in its retracted position. This is one cycle of simulation operation of mechanical springs.

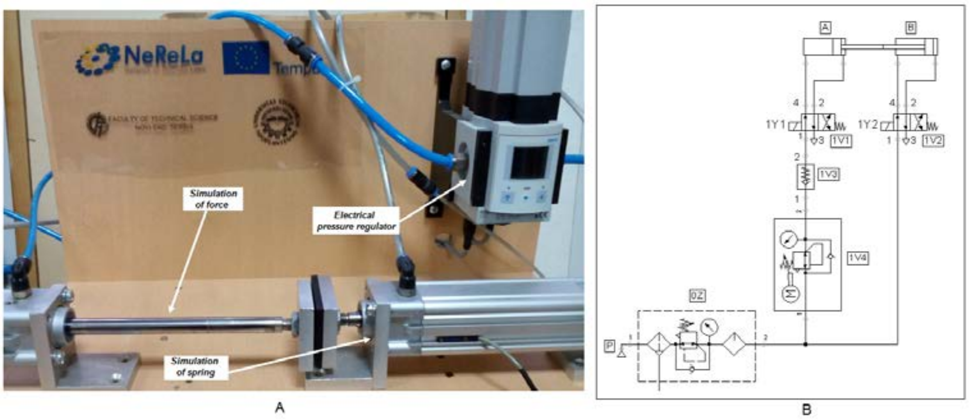

Figure 1. A) *Practical implementation of pneumatic spring* **B)** *Electropneumatic control scheme*

Remote control of pneumatic spring is enabled using applications which is made in object-oriented programmable language called LabVIEW. All users (clients) have to install client's application, which is shown if Fig. 2, on their computer. Clients must have username and password which is obtained by sending a request on the e-mail, too. After entering the parameters that describe the characteristics of the spring, clients is obtained a calculated value of secondary pressure of electrical pressure regulator and it is shown in application. This value forwarded to the server computer via the Internet. Server serves as a link between the client and the PLC. If it is correct, server forwards the received data to the PLC via serial communication. After receiving data, PLC controls the operation of pneumatic cylinders according to the previously described algorithm, and thus executes the process of remote control. Clients can monitor what is happening in system in live because web camera is placed near the system.

3. EVALUATION OF TEACHING MODULE

At the Faculty of Technical Sciences in Novi Sad, the remote-controlled pneumatic spring was used as a remote experiment in teaching of Mechatronics and Industrial engineering in courses Components of technological systems and Automation of work processes, respectively, in teaching modul Fundamentals of pneumatic systems. Before the experiment, the teacher presented basic theoretical background and necessary explanations to the students. The remote experiment set up was in the lab and students accessed it remotely, over the Internet, individually or in pairs. Upon completion of the experiment, each student completed the evaluation questionnaire. A total of the 60 students completed the questionnaire, 37 students of Mechatronics and 23 students of Industrial engineering.

Evaluation questionnaire consists of the 15 questions and the space provided for comments [5-6]. Questions are answered by numbers from 1 to 5 that must be entered on the appropriate place, where: 5 represents strongly agree and 1 represents strongly disagree. Questions in the questionnaire can be divided into three categories. Questions in first category are related to the design of the experiment, that is, whether the experiment is prepared at the appropriate technical level, whether it is easy for understanding and using, how useful and understandable attached instructions are and whether the experiment allows collection and storage of necessary experimental results.

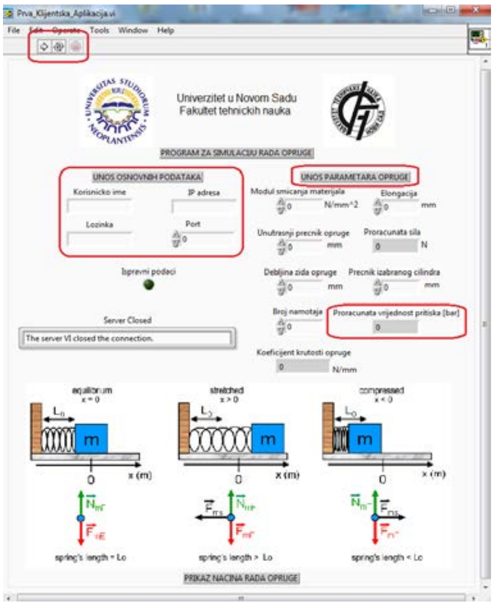

Figure 2. *Clients' application*

Second group of questions is related to the experience and usage quality of the remote experiment. It includes questions about the simplicity of user interface, the speed of response to commands, the quality of visual display and the appearance of problems and delays in execution of the experiment. The third group of questions is focused on the results of application, that is, whether the experiment help students to better understand the theoretical fundamentals, goals and outcomes of the teaching modules, whether it help them to better understand and use laboratory equipment and would they like to use remote experiments in other teaching modules.

Summary score for design of the experiment was 4.69 out of 5. Students of Mechatronics evaluated design with 4.72 out of 5, and students of Industrial engineering evaluated it with 4.65 out of 5. By examination of individual questions it can be noted that students of Industrial engineering evaluated question about simplicity and usage of the experiment and question on clarity of written instructions significantly worse than students of Mechatronics, which implies the lack of adequate knowledge in the field.

Summary score on quality of use for the remote experiment is 4.75 out of 5. Students of Mechatronics evaluated it with 4.83 out of 5, and students of Industrial engineering evaluated it with 4.67 out of 5. Students of Industrial engineering significantly worse evaluated the question about simplicity of user interface and two Industrial engineering students experienced some technical problems in the execution of remote experiment.

Summary score for application results of the remote experiment is 4.63 out of 5. Mechatronics students expressed a greater desire than Industrial engineering students to use remote experiments, while Industrial engineering students, probably because of the lower prior knowledge, demonstrated that remote experiment helped them more in understanding of the theoretical foundations.

Overall results of student evaluations are shown in Table 1.

Table 2. *Summary results of student evaluation*

Design of the experiment	II	ME
The remote experiment is easy to understand and use.	4.57	4.76
The remote experiment is prepared at the appropriate technical level.	4.70	4.73
The written manual is understandable and helpful.	4.39	4.76
Before starting I received an adequate explanation from the teacher	4.96	4.97
The experiment allows collection and memorization of the results.	4.65	4.41
Quality of use		
User interface of the remote experiment is easy to use.	4.70	4.95
Response speed to user actions in the experiment is satisfactory.	4.61	4.73
Quality of the visual display during the experiment is satisfactory.	4.74	4.68
During the work with the remote experiment there was no problems either stoppages.	4.65	4.97
Application results		
The remote experiment enabled me to better understand theoretical basis, objectives and outcomes of teaching modules.	4.70	4.65
The remote experiment helps me to better understand and use laboratory equipment.	4.52	4.57
I would like to use the remote experiments in other lessons.	4.61	4.73

Most common positive comments of the students are related to the possibility of remote access to the experiment and aid in understanding of the theory, while the negative comments are directed at the impossibility of simultaneous access to the experiment by a multiple users and inability of the experiment executor to independently eliminate the eventual malfunction. Several students proposed development of an mobile applications for the control of remote experiments.

4. CONCLUSION

Remote-controlled pneumatic spring is an experiment designed for the high school students and the students of technical universities, primarily to those that are dealing with automation. It is expected that by implementation of this experiment a pupil or a student is able to better understand the fundamentals of pneumatic systems, the basics of automatic control systems, the basics of programming and application of the programmable logic controllers and the basics of springs theory, as well as to understand the concept of transformation of forces to pressure or mechanical to pneumatic energy.

Based on the positive assessment of the experiment by the students, the positive comments about the possibility of remote access and help in understanding the theory, it can be concluded that the experiment has fully met the expectations and, as such, it became a important didactic tool for teaching at the Faculty of Technical Sciences in Novi Sad. This experiment can also be used by the students of Automation and control systems, Manufacturing and Design engineering, etc.

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