The 19th INTERNATIONAL DAAAM SYMPOSIUM
"Intelligent Manufacturing & Automation: Focus on Next Generation of Intelligent Systems and Solutions"
22-25th October 2008

EDUCATIONAL SYSTEM FOR WATER LEVEL REGULATION: DESIGN AND IDENTIFICATION

PETRLIĆ, D[ario]; MAJETIĆ, D[ubravko]; NOVAKOVIĆ, B[ranko] & BREZAK, D[anko]

Abstract: *This paper presents a student research work on modeling and identification of an experimental setup for educational purposes of control system demonstration and implementation. A brief description of the experimental setup is given with the emphasis on modeling and system identification. Both, mechanical and electrical parts of the setup have been realized in the Laboratory for automation and robotics. The communication with PC was established through serial port using MatLab software. The model parameters have been experimentally obtained based on various identification experiments which are in detail described in the paper.*
Key words: *Identification, Modeling, Liquid Level Control, Educational Experimental Setup*

1. INTRODUCTION

A laboratory setup for the purpose of education and analyzing of different control algorithms has been recently developed and implemented in the Laboratory for automation and robotics of the Faculty of Mechanical Engineering and Naval Architecture in Zagreb (Petrlic, 2005). The concept of the setup is selected in order to provide possibility of liquid level control. Generally, it comprises an open liquid container, a centrifugal pump, and various electronically controlled valves which provide possibility of disturbance simulation. This paper outlines the modeling and experimental identification of the setup. The results of the experimental validation are given. The work considered in the paper presents a basis for the future research which will include the methods of liquid level control.

2. SETUP DESCRIPTION

The experimental level regulation (LR) setup consists of eleven essential parts which are presented in the figure 1.

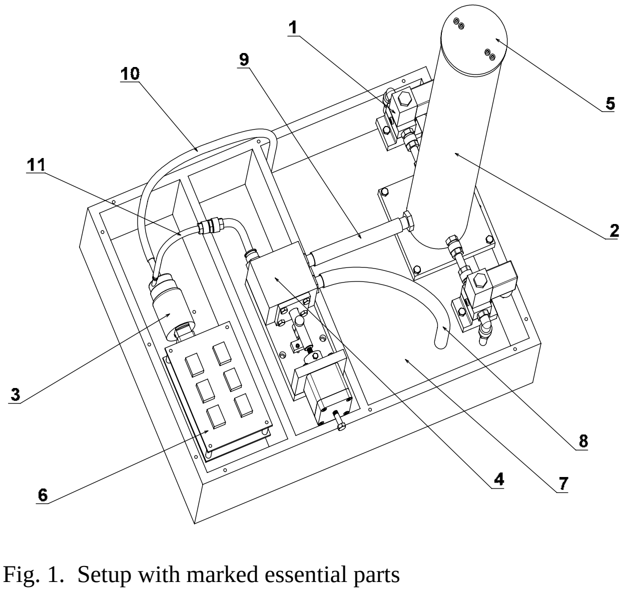

Fig. 1. Setup with marked essential parts

These parts are as follows: *1. solenoid 2/2 valve, 2. gauge glass, 3. the water pump which is activated by DC motor, 4. two-way valve with motor step drive, 5. sensor, 6. control unit, 7. water tank, 8. - 11. connective hoses*. Among all these parts, control unit and two-way value module were developed in the laboratory.

All these elements are located into the casing which is made from transparent plastic / perspex, so the system changes are easy to note. Construction of casing is realized as the union of three chambers. In first chamber the electronic elements are located. Function of second chamber is isolation of electronics from water. Finaly, all volume of liquid is stored in third chamber which represents the water tank from where the pump takes water and, distributes it through the system (it is circular process). DC motor is used to drives the water pump and with pulse-width modulation (PWM) of voltage signal the pump-power is regulated. By changing the voltage signal at the DC motor, regulation or control of liquid-level in gauge glass is performed. Main characteristic of the two-way valve is that it has one input and two outputs as it shown in figure 2. The two-way valve module is made from polished transparent plastic / perspex, so that separation of flow is visible and easy to note.

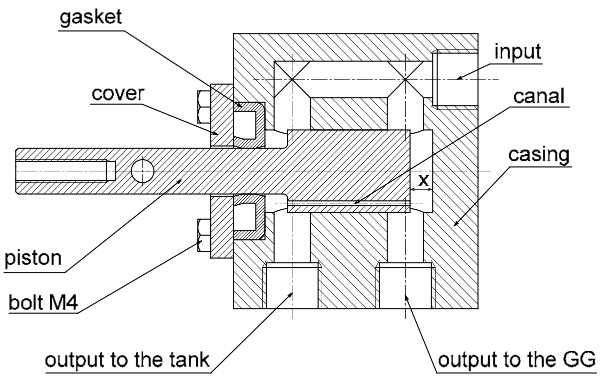

Fig. 2 Section view of two-way valve module

By shifting the piston which is located inside the valve, the total volume of liquid that flows into the valve distributes in different rates at two outputs. The stepper motor is used for shifting the piston. The gauge glass (GG) represents the tank in which the fluid level is controlled. It is calibrated (from 100 mm to 300 mm with spacing of 5 mm) and it has four leaks: at the front of the GG there is a supply of liquid and at the bottom there is a drain which is always active, independently of the system state. On the left and right side, there are two leaks directly connected with solenoid valves. Solenoid valves are used to simulate disturbances (they have two states – on and off). Level of liquid is measured by sensor which is implemented into the gauge glass. The control unit enables the connection and control of main system parts (water pump, two-way valve, solenoid valves and sensor). By RS232 protocol control unit communicates with PC and the drivers are written as an M-functions using MatLab software.

3. MATHEMATICAL MODEL

Existence of an accurate model of object dynamics is of crucial importance for the object control-related purposes (Isermann, 1996). In order to define the mathematical model of LR system, static and dynamic characteristics of system parts are defined (Lenart, 1995). On the basis of extensive measurements for every system part the mathematical equations are defined for each one. Structure of the mathematical model is given in figure 3, where the *Simulink* model is presented (Matlab help, 1999). It consists of power input, pump, two-way valve module, solenoid valves (left and right) and gauge glass with leak and height output. Two transformations of signal exist in this system. First, power input is transformed into the flow and second one, flow is transformed into the height.

This model presents the control of liquid level through the pump (control can be realized using the pump, two-way valve or in the combination). System input is power of the pump and the output is height of the liquid level in the gauge glass which is measured by sensor implemented into the gauge glass. Signal of the pump-power must also be sent as an input of the two-way valve module since it depends on the pump power and the piston shift. After the power signal is carried out through the pump and two-way valve, it is transformed into the flow-signal. Most system parts of LR setup can be identified as a simple dynamic elements (P0 or I0), as it shown in figure 3 (Kuo & Golnaraghi, 2003).

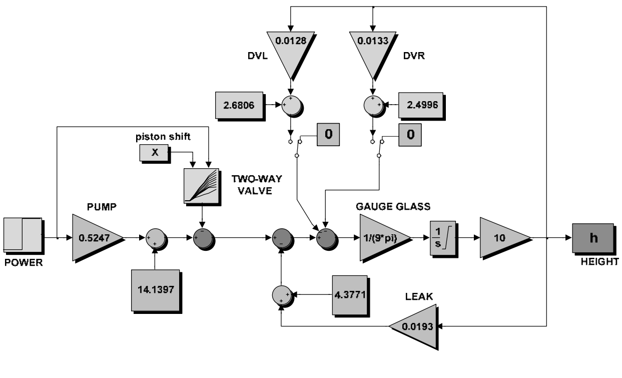

Fig. 3 Mathematical model described in *Simulink*

Identification of gauge glass required a different approach, because the parameters of constantly active drain could not be measured with existing sensor. Appling the Bernoulli's equation at the gauge glass the following relation is given:

$$q_{GG} = A_i \cdot \sqrt{\frac{1}{1+\xi_i}} \cdot \sqrt{2g} \cdot \sqrt{h(t)} + \left(\frac{dh}{dt}\right) A_m \quad , \quad (1)$$

where q_{GG} is total GG flow, A_i is area of the GG drain cross-section, A_m is area of the GG cross-section, *h(t)* is height of liquid level in GG (from the drain), ξ_i is lost at the drain of the GG and *g* is gravitational constant. Coefficients of the first part of equation are measured with experimental method and approximate as a straight line ($q_{is}=0.0193*h+4.3771$, where q_{is} is leak flow from GG). The second part of equation can be expressed as:

$$h = \frac{1}{A_m} \int q_{mz}(t)dt \quad , \quad (2)$$

where q_{mz} is input flow in GG. The GG without leak flow is determinate as an I0 dynamic element with gain $K_i=1/Am=1/9*\pi = 0.0354\ cm^{-1}$, as it shown at figure 3. For more authenticity of the model, initial condition for gauge glass is set up (i.e. the height is measured from 100 mm up to 300 mm).

Mathematical description of two-way valve in *Simulink* is realized with the look-up table where different values of pump-power and piston shift are entered into the table. Thereby, the interpolation of output flow is accomplished. Solenoid 2/2 valves which simulate disturbances are P0 dynamic elements which are also approximated with straight line equation.

4. SIMULATION RESULTS

After the comparison of obtained results from the conducted simulations with the results obtained by measure at the LR setup, it turns out that mathematical model of LR system has shown a very good behavior and a minor deviation from the real model. Variation of system input (signal of pump-power) was the key-element for the conducted experiments. The results of one experiment are presented by the figure 4. In this case, power signal was variable in amplitude and the cycle aspect. Additional disturbance was the active left solenoid valve. From figure 4 high accuracy of mathematical model can be determinate regardless the irregularity of some objects in LR system (the pump show the most influence anomaly).

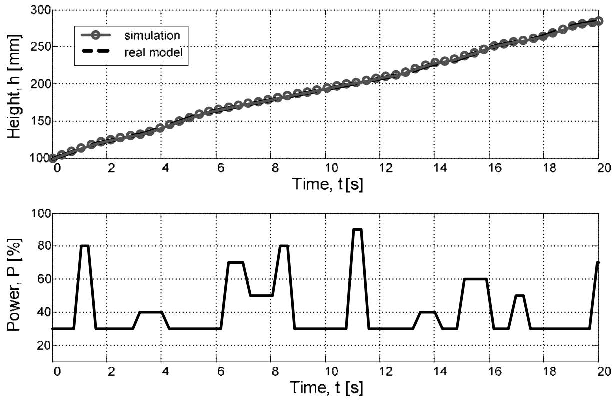

Fig. 4 Simulation results with variable power input

Besides, the other additional tests were made and all of them gave the similar results. Maximum height deviation between simulated and real LR model was *1.5 mm*. Obtained results tell us that the regulation of liquid level will be possible.

5. CONCLUSION

An experimentally supported work on identification and modeling of an educational level regulation system is given in the paper. A mathematical model of the system is derived. The model comprises dynamics of all crucial elements such as water pump, two-way valve, solenoid valves and gauge glass. The model has been experimentally identified and validated. A good correlation has been found. In the next phase of this project graphical user interface of the LR system is going to be developed in which basic PID and intelligent control algorithms will be integrated.

6. REFERENCE

Isermann, R. (1996) Modeling and Design Methodology for Mechatronic Systems, *IEEE/ASME Transaction on Mechatronics*, Vol. 1, No. 1, March 1996, pp. 16-28, ISSN 1083 – 4435

Kuo, C. B. & Golnaraghi, F. (2003) *Automatic Control System*, John Wiley & Sons, Inc., ISBN 0-471-13476-7, New York, USA

Lenart, Lj. (1995) *System identification Toolbox – For Use with MatLab*, The MathWorks, Inc., Natick, USA

Matlab help (1999) *Simulink – Dynamic System Simulation for MatLab*, The MathWorks, Inc., Natick, USA

Petrlic, D. (2005) Bsc. Thesis: *Level regulation of liquid in open container with disturbances*, Zagreb, Croatia