Acta Mechanica Slovaca **26 (1): 52 - 56,** March **2022**
https://doi.org/10.21496/ams.2022.022

Acta Mechanica Slovaca
ISSN 1335-2393
www.actamechanica.sk

Educational Model Layout Design

Maksym Danyliuk[1]

1 Nadvirna College of National Transport University, Nadvirna, Ivano-Frankivsk, Ukraine

Abstract: The article deals with the design of an educational training device for solving control systems for regulating the water level in the reservoir. The system allows several options for operation with different control algorithms. The device can be connected to the control system for practical training activities in the educational process.

Keywords: control; sensor; level, pump, valve.

1. Introduction

The goal of this work is the creation of an educational stand to support the practical part of the teaching process. The stand represents a reduced model of a real system, which contains the same components as the system used in practice. It is an application of sensors and actuators that are implemented in a model with a process that needs to be controlled. In this case, a tank and tank system is designed where it is possible to implement the process of pumping and mixing liquids according to the chosen algorithm. This process can be solved as a simulation, but this simulation does not take into account some phenomena of the real process, and students may encounter these problems when working with such practical models. The model is also intended to support innovativeness and creativity in proposing improvements and solving some problems related to the implementation of the management process [1-6].

2. Process description - system layout design

The system consists of transparent cylinder A, B, C, master cylinder (fig. 1) and transparent tank (fig. 2). Each cylinder contains liquid level sensors for detecting the height of the liquid level, which detect the state when the cylinder is empty and the state when the cylinder is full (fig. 3). The master cylinder contains sensors for 4 liquid levels to detect the gradual filling and mixing of liquid from individual cylinders A, B, C (fig. 3).

Cylinders A, B, C are connected by pipes to the master cylinder through electronically controlled solenoid valves. With the solenoid valves, it is then possible to fill the master cylinder from the individual cylinders A, B, C. The master cylinder is connected by means of another solenoid valve to the tank into which the liquid from the master cylinder can flow. There is a separate pump for each cylinder A, B, C, which can be used to refill the empty cylinders A, B, C.

For Cylinder (A, B, C) have been selected transparent measuring cylinder made from plastic. Maximum water level in the cylinder is h_1 = 265 mm. The height of the outlet hole is h_2 = 10 mm. Cylinder diameter is d_1 = 49 mm. Outlet hole diameter is d_2 = 7 mm.

Water level height h_1 of (A, B, C) cylinder can be obtained from volume of cylinder V:

$$V = \pi r_1^2 h_1 \tag{1}$$

$$h_1 = \frac{V}{\left(\pi r_1^2\right)} \tag{2}$$

*** Corresponding author:** Maksym Dalnyliuk, ***E-mail address:*** *danyliuk.maxym@gmail.com*

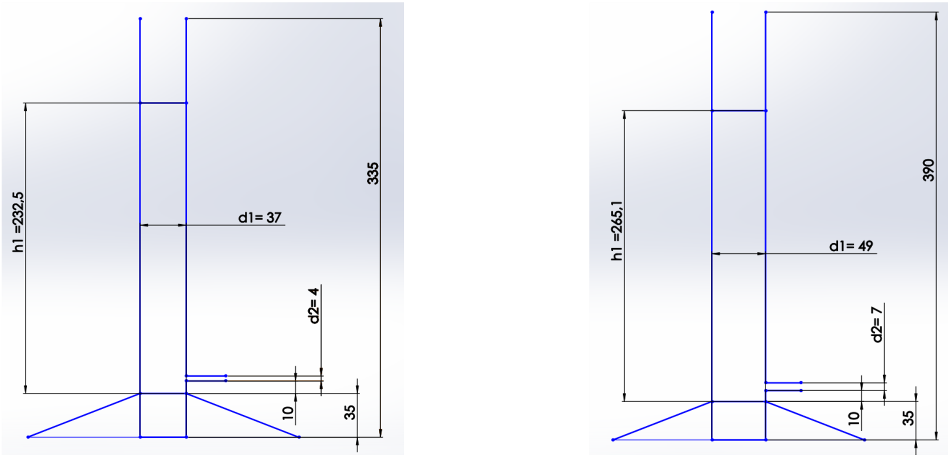

Figure 1: Cylinder (A, B, C are shown on left figure) and master cylinder (is shown on right figure).

The relation for the flow rate of liquid through the hole of small cross-section is:

$$v = \sqrt{(h_1 - h_2) \cdot 2g} \tag{3}$$

Incompressible flow equation is:

$$h + \frac{v^2}{2g} + \frac{p}{\rho g} = const \tag{4}$$

$$h_1 + \frac{p}{\rho g} + 0 = h_2 + \frac{p}{\rho g} + \frac{v^2}{2g} \tag{5}$$

The size of the drain hole is:

$$S_2 = \frac{\pi d_2^2}{4} \tag{6}$$

Volumetric flow rate is:

$$Q = S_2 \cdot v \tag{7}$$

Time of emptying cylinders:

$$t = \frac{V}{Q} \tag{8}$$

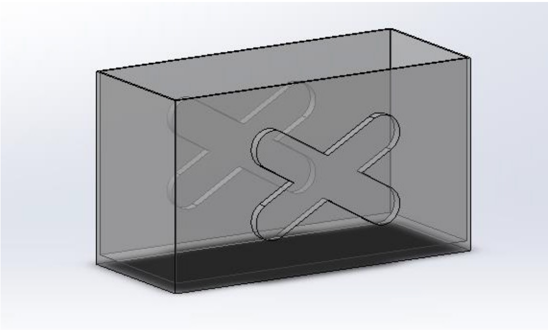

Figure 2: Collection tank for liquid emptying from master cylinder.

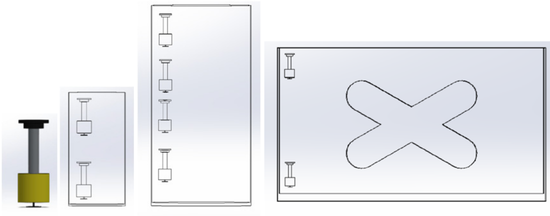

Figure 3: Liquid level sensor and its placements in the system.

The proposed model is intended exclusively for educational purposes to demonstrate the technical process as it happens in a real system. In the actual system, three different fluids will be placed in cylinders A, B, C, which will be infused and mixed in the master cylinder in some proportion. However, for the sake of simplicity, in this model we will use only one liquid of coloured demineralized water, and the system will thus form a closed cycle, in which the liquid will be discharged from cylinders A, B, C to the master cylinder or according to another selected algorithm, and then the mixed liquid will be discharged gradually from the master cylinder to the tank and finally it will be pumped back to cylinders A, B, C.

The cycle starts when cylinders A, B and C are full. Then water is poured from cylinder A into the master cylinder and fills it until the level in the master cylinder reaches the second sensor, after which the first electric valve closes and the second electric valve opens, which is responsible for the liquid in cylinder B. Liquid from cylinder B flows into the master cylinder until the level reaches the third sensor in the master cylinder. Similarly, the valve in the last cylinder is opened and the liquid is drained into the master cylinder so that the level reaches the last sensor (fig. 4).

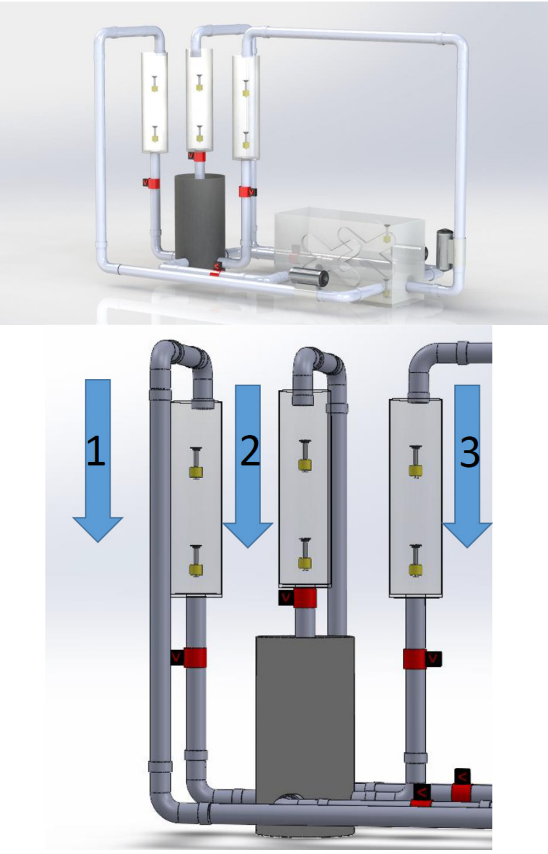

Figure 4: Finished educational model layout design.

When the master cylinder is full (up to 4 sensors), a timer will start, simulating the mixing of liquids. When the timer runs out, the liquid will enter the tank, which also has 2 sensors. Sensors in the tank detect when there is no fluid in the system or when there is too much fluid. These fault conditions are evaluated in the control system and the necessary measures are subsequently taken (fig. 5).

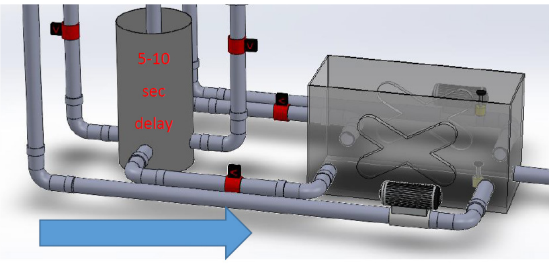

Figure 5: Simulation of fluid mixing and discharge of fluid into the tank.

After draining the liquid from the master cylinder, the process of pumping the liquid back into cylinders A, B, C will begin so that these cylinders are filled up to the level of the sensors detecting the full state of cylinders A, B, C (fig. 6).

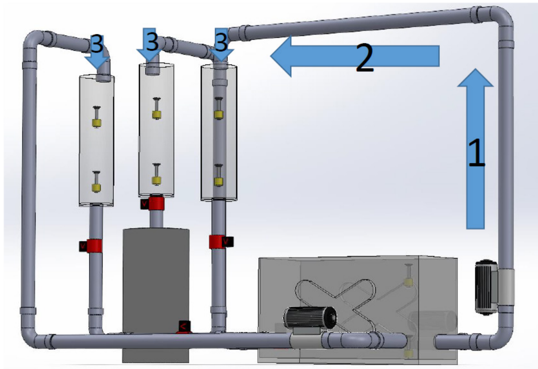

Figure 6: The process of pumping the liquid back into cylinders A, B, C.

3. Diagram of the system

After approving the concept of the system, it is necessary to make calculations for more accurate operation of the system and to prevent problems in its operation. Figure 7 shows a diagram of the system. The arrows in this diagram symbolize the tubes with which the components will be connected.

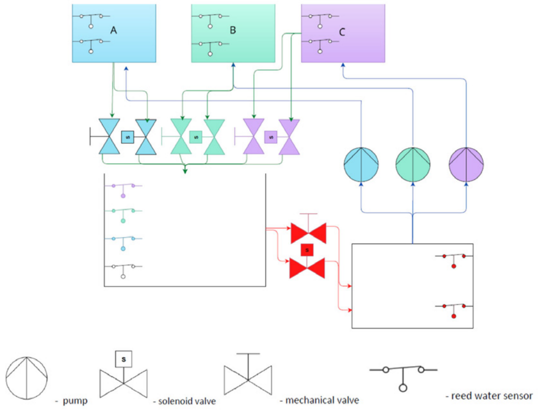

Figure 7: The diagram of the system.

All working components in the system are divided into 4 groups:

– *Group A contains the components associated with cylinder A (the left cylinder that is denoted by the letter A). This group is assigned a marking color - blue.*

– *Accordingly, group B belongs to cylinder B. The marking color of* *group B is light green.*

– *Group C is created on the same principle. It was assigned a purple color.*

– *The last group is the group belonging to the tank, it is marked in red.*

4. Arrangement of concept

For the system to work properly, there is a need to design a tripod on which you can put the cylinders, the junction box, attach the pumps and tie the wires. The structure must be strong enough to withstand the load of water-filled cylinders, not very heavy and mobile. A model was designed that could be used for a real layout. Figure 8 shows the assembled model of educational model layout design.

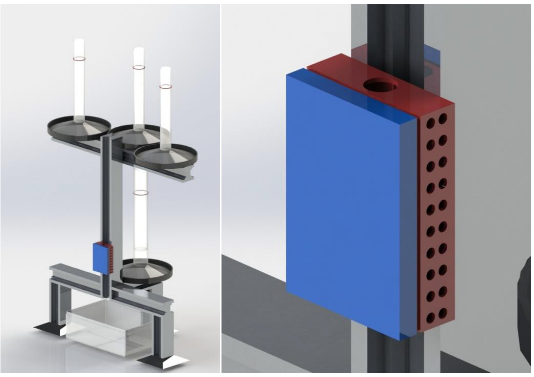

Figure 8: Tripod concept and Junction box with cover.

The tripod is a 6 aluminium profiles of different lengths fastened with self-tapping screws together. An aluminium profile with a thickness of 55 mm was chosen. Due to the properties of aluminium, the profile of this width is able to withstand possible loads on it in the system and still remains quite light, so the layout will be easy to transfer if necessary. In the upper part you can see three cylinders A, B, C that are fixed in specially designated places where plastic profiles for placing cylinders are screwed to the profile. The same stand is screwed into the base to accommodate the main cylinder.

The junction box is attached to the tripod with self-tapping screws. The junction box has 20 holes on both sides and one large hole where all the wires will converge. Wires from all electrical appliances will go inside the profile restrained by a screed and come together in a junction box through a large hole. Inside the box they will be distributed: inputs to the left, outputs to the right.

The sensor mounting inside the cylinder was also designed (fig. 9). A 10 mm wide plastic profile was used for it. The metal ring fastens to the profile by screws to which it is possible to attach the sensor by means of factory fastening. The sensor mounting inside the cylinder was also designed. A 7 mm wide plastic profile was used for it. With the help of self-tapping screws, a metal ring will be attached to the profile to which the sensor can be attached with the help of factory fastening. This structure will be placed in a cylinder where it will fit snugly against the walls and therefore does not need to be fastened inside. A longer profile with 4 rings was used for the master cylinder. The finished design can be seen in the image below (fig. 9).

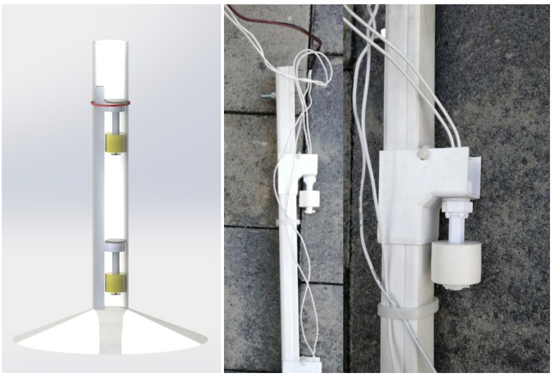

Figure 9: Mounting of sensors inside the cylinder.

6. Conclusions

Currently, there is a shortage of qualified employees who are able to be creative and innovative. For these abilities, the educational process must also be prepared so that several practical tasks are available, which will significantly support the students' creativity. Scale models with real sensors and actuators are an ideal solution for teaching practical tasks with the application of control systems. Such practical lessons usually ended only with a simulation, but this stand will allow students to connect a real model with real properties to the control system.

References and Notes

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