

VIRTUAL MODELS IN MATLAB

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Abstract

The paper describes several simulink models with virtual reality of systems that were created by students at Department of Control Engineering, Faculty of Electrical Engineering, Czech Technical University in Prague within their bachelor thesis.

1 Introduction

Even though there is a lot of nice and interesting textbooks in the field of control theory, for example [5, 6, 4, 3], many students think that control theory is very boring because what they usually see is just a lot of “difficult” mathematical equations. On the other hand, even a very difficult study can be taught in an interesting way.

In education, it is standard to use Matlab/Simulink [2, 1] to model said difficult mathematical equations. The mathematical equations are used to create a Simulink model of a real system. The usual results of the Simulink model are time responses of the system inputs and outputs. But the time responses (graphs) do not need to demonstrate the model behaviour clearly. They do not need to give students a good idea about the system behaviour.

Matlab/Simulink contains the Virtual Reality Toolbox [2] that allows us to illustrate the behaviour of the Simulink model by virtual world more clearly. The toolbox uses the Virtual Reality Modelling Language (VRML) technology [2]. First, we create a virtual world in V-Realm Builder [2] and set the properties of particular objects such as: translation, scale, rotation etc. Then we connect the signals of the Simulink model to the *VR Sink* block [2]. The procedure is very easy and intuitive.

Because the opinion of our students is very important for us, we created together with them several Simulink models of real systems with virtual worlds: water tank with a gear-pump or rotary-pump, coupled tanks with a gear-pump or rotary-pump, mass on spring, double mass on springs. Similar systems can be found in our laboratory at Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Control Engineering. Unfortunately, the capacity of the laboratory is limited, so students cannot make the experiments on the systems whenever they want. But the Simulink models can be download from the Internet [7] and every student can work with those models as long as he likes. The Simulink models have masks that allow the users to change system parameters easily and have virtual worlds that illustrate the system behaviour more clearly than mere Simulink models.

The paper is organized as follows. In section 2, the model of water tank is developed. In section 3, the model of mass on spring is developed. In section 4, the model of double masses on springs are described.

2 Water Station with a Gear-pump

In this section, creating of the simulink model with virtual reality of the water station is shortly described. More details with the simulink file can be found at [7].

The model of the water tank consists of a gear-pump, tank, inflow and outflow pipes and an output valve. The tank is filled with the fluid by the gear-pump and the fluid drains away through the output valve. The system input is the voltage u [V] of the motor of the gear-pump. The system output is the level h [m] of the fluid in the tank. The dynamics of the gear-pump is neglected. The static transfer characteristic between the voltage of the motor of the gear-pump and the flow rate of the fluid on the output of the gear-pump $u \rightarrow q_i$ is shown in Figure 2.

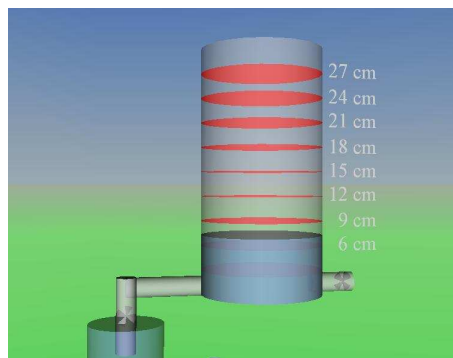


Figure 1: Water tank system

The dynamical model of the water tank can be described by the following differential equation

$$\frac{dh(t)}{dt} = -k_o \frac{S_{o_{\max}}}{S} \sqrt{2g} \sqrt{h(t)} + \frac{S_i}{S} v_i(t), \quad (1)$$

where the constants can be set in the mask of the simulink model [7]. Several time responses of the system are shown in Figure 3 and Figure 4.

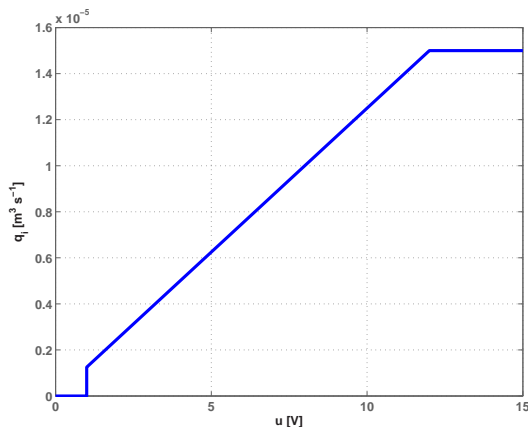
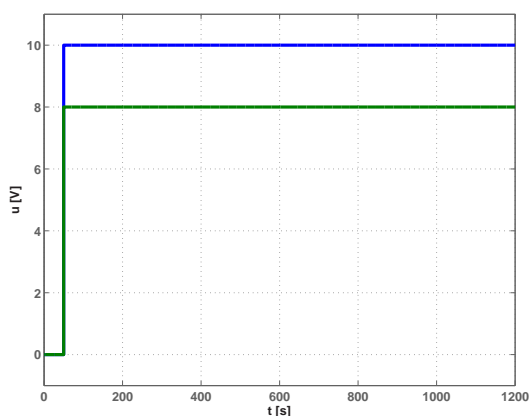
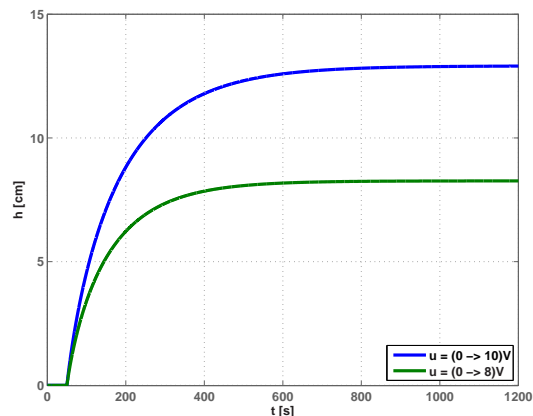


Figure 2: Transfer static characteristic of the gear-pump $u \rightarrow q_i$

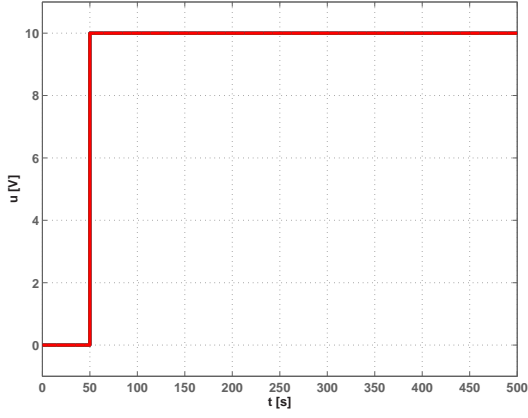


(a) input voltage $u(t)$

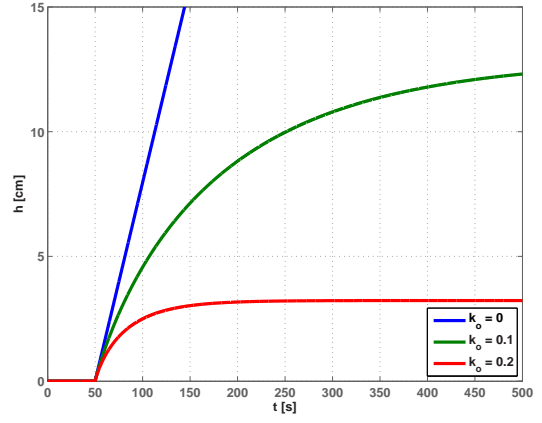


(b) level in the tank $h(t)$

Figure 3: Time responses of the system for different system input u



(a) input voltage $u(t)$



(b) level in the tank $h(t)$

Figure 4: Time responses of the system for different valve opening k_o

3 Mass on Spring

In this section, creating of the simulink model with virtual reality of the mass on spring system is shortly described. More details with the simulink file can be found at [7].

The model of the mass on spring system consists of a mass on the spring on movable suspension. The input of the system can be the force acting on the suspension F [N] or the position of the suspension y [m]. The output is the position of the mass y_1 [m], eventually the position of the suspension y [m].

The dynamical model of the mass on spring system can be described by the following differential equations

$$m\ddot{y}(t) + b\dot{y}(t) = F_u(t) - mg - m_1g, \quad (2)$$

$$m_1\ddot{y}_1(t) + b_1\dot{y}_1(t) + k_1y_1(t) = b_1\dot{y}(t) + k_1y(t) - m_1g, \quad (3)$$

where the constants can be set in the mask of the simulink model. Several time responses of the system are shown in Figure 6 and Figure 7.

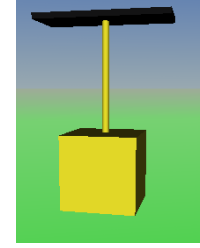
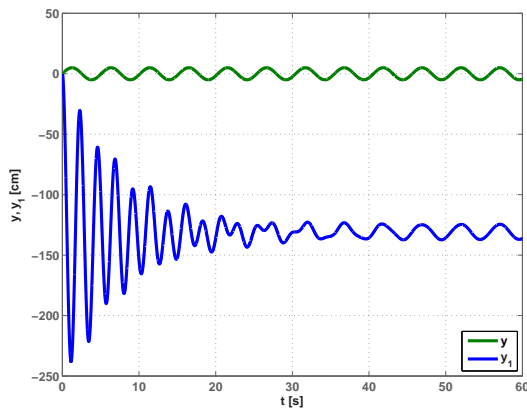
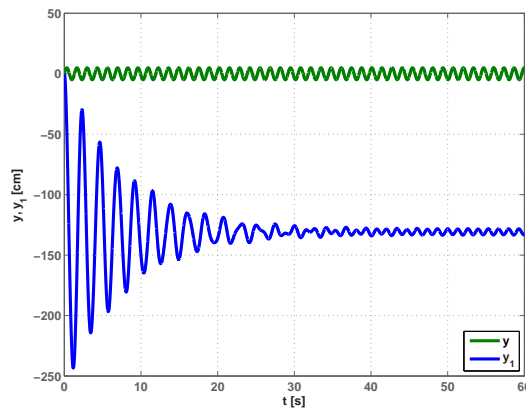


Figure 5: Mass on Spring



(a) $\omega < \omega_v$



(b) $\omega > \omega_v$

Figure 6: Time responses of the system for system input $y(t) = \sin(\omega t)$

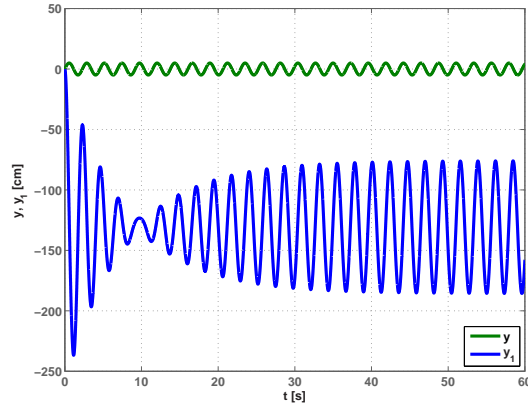


Figure 7: Time responses of the system for system input $y(t) = \sin(\omega t)$, $\omega = \omega_v$

4 Double Masses on Springs

In this section, creating of the simulink model with virtual reality of the double masses on springs system is shortly described. More details with the simulink file can be found at [7].

The model of the double masses on springs system consists of two masses on the springs on movable suspension. The input of the system can be the force acting on the suspension F [N] or the position of the suspension y [m]. The outputs are the positions of the masses y_1 , y_2 [m], eventually the position of the suspension.

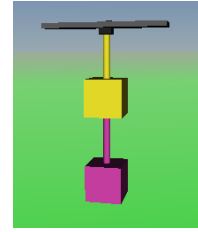


Figure 8: Double masses on springs

The dynamical model of the masses on springs system can be described by the following differential equations

$$m\ddot{y}(t) + b\dot{y}(t) = F_u(t) - b_1(\dot{y}(t) - \dot{y}_1(t)) - k_1(y(t) - y_1(t)) - mg, \quad (4)$$

$$m_1\ddot{y}_1(t) + (b_1 + b_2)\dot{y}_1(t) + (k_1 + k_2)y_1(t) = b_1\dot{y}(t) + k_1y(t) + b_2\dot{y}_2(t) + k_2y_2(t) - m_1g, \quad (5)$$

$$m_2\ddot{y}_2(t) + b_2\dot{y}_2(t) + k_2y_2(t) = b_2\dot{y}_1(t) + k_2y_1(t) - m_2g, \quad (6)$$

where the constants can be set in the mask of the simulink model. Several time responses of the system are shown in Figure 9 and Figure 10.

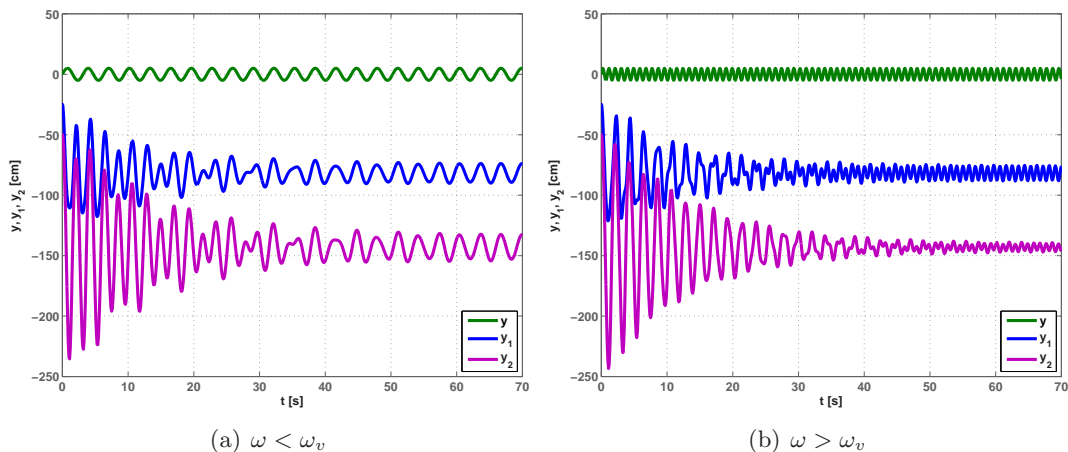


Figure 9: Time responses of the system for system input $y(t) = \sin(\omega t)$

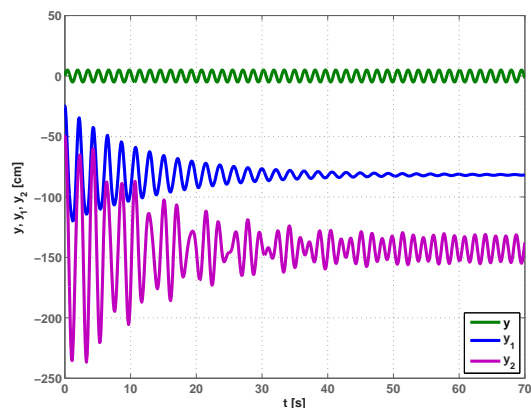


Figure 10: Time responses of the system for system input $y(t) = \sin(\omega t)$

5 CONCLUSION

In this paper, several simulink models with virtual reality of systems were shortly described. The simulink files were created by students at Department of Control Engineering within their bachelor thesis. The simulink models should be helped to students who are beginning to study the control theory.

Acknowledgements

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