Modeling and identification of a system with pulleys, fluid, and position measurement with Hall effect sensor.

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ABSTRACT

In laboratory 2, the modeling of a mass-spring system will be carried out first, in which the mass is driven by a DC motor and it is inserted inside the of a fluid. The operation of the described plant will be through a push-pull circuit for the movement of the motor. For the second part of the laboratory, the identification of the plant was developed, for this it was necessary to introduce a hall effect sensor in order to measure the position of the mass that in this case contains a magnet. The data delivered by the sensor is voltage, so the behavior of the plant is plotted using the oscilloscope in order to carry out the identification using the graphic method and also using MATLAB with "ident".

Abstract---

In the laboratory 2, the modeling of a mass-spring system in which the mass is driven by a DC motor is introduced and is introduced into a fluid. The operation of the described plant will be through a push-pull circuit for the movement of the motor. For the second part of the laboratory the identification of the plant was developed, for this it was necessary to introduce a hall effect sensor in order to measure the position of the mass that in this case contains a magnet. The data that the sensor delivers are voltage, then the oscilloscope graphs the behavior of the plant in order to be able to perform the identification through the graphical method and also through MATLAB with ident..

Keywords--- .Identification, modeling, ident, graphic method

OBJECTIVES

General Objective--- Identify and simulate a mass-spring plant.

Specific objectives--

* Identifyand model a mass-spring plant.

* Simulate the response of each of the identified models and compare it, in addition to identifying the corresponding correlations of the model with the measured input and output data.

INTRODUCTION

Identification of systems is understood as the experimental obtaining of a model that reproduces with sufficient accuracy, for the desired purposes, the dynamic characteristics of the process under study.

In general terms, the identification process comprises the following steps:

Obtaining input-output data: To do this, the system must be excited by applying an input signal and recording the evolution of its inputs and outputs during a time interval .

Pre-treatment of the recorded data: The recorded data is generally accompanied by unwanted noise or other types of imperfections that may need to be corrected before starting the identification of the model. It is, therefore, about 'preparing' the data to facilitate and improve the identification process.

Choice of model structure: If the model to be obtained is a parametric model, the first step is to determine the desired structure for said model. This point is greatly facilitated if you have some knowledge of the physical laws that govern the process.

Obtaining the parameters of the model: Next, we proceed to estimate the parameters of the structure that best fit the response of the model to the input-output data obtained experimentally.

THEORETICAL FRAMEWORK

Strejc method.

This method is used for the identification of multiple pole systems, by means of the parameters Tu and Ta obtained from the response of the system. It uses a straight line of maximum slope superimposed on the slope area, so that the value of the parameter Tu is obtained by cutting the abscissa axis and the value of the parameter Ta is obtained by cutting a line parallel to the abscissa axis in the point where the response is stable. [1]

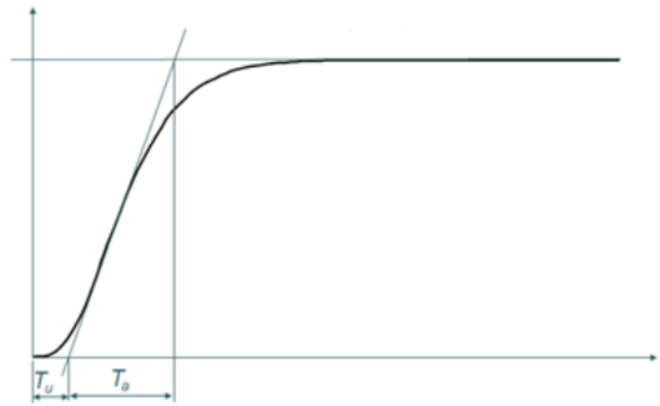


***Figure 1**: Strejc parameters.*

After obtaining the value of the variables Tu and Ta, the value of Tu/Ta is obtained. With this value, we go to the Strejc table and take the closest value, which determines the number of multiple poles "n".

***Table 1**: Number of multiple poles.*

n	Ta/τ	Tu/τ	Tu/Ta
1	1	0	0
2	2.7	0.28	0.104
3	3.7	0.8	0.22
4	4.46	1.42	0.32
5	5.12	2.1	0.41

1. MATERIALS

* Software: MATLAB ®

* White coat.

* DC motor

* Fluid (Coconut oil)

* Mass (Fragment of platen)

* Spring

* Assembly (MDF) with pulleys

* Hall effect sensor

2. PROCEDURE

The plant illustrated in figure 2 must be modeled and then built.

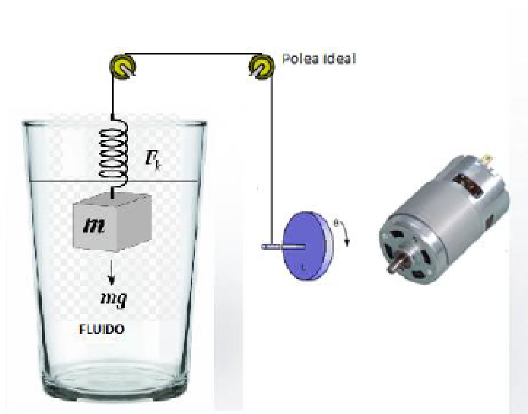
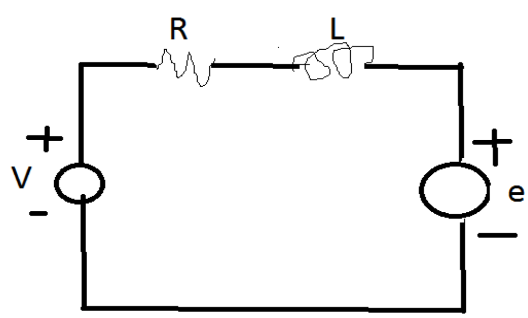


Figure 2: *System mass-guide spring.*

2.1 Modeling

For the modeling, a model for the motor and another model for the mass-spring system are taken into account. The input is the source voltage displayed on the motor mesh, and the output is the ground position. Gravity is considered as a disturbance.

2.1.1 Motor model



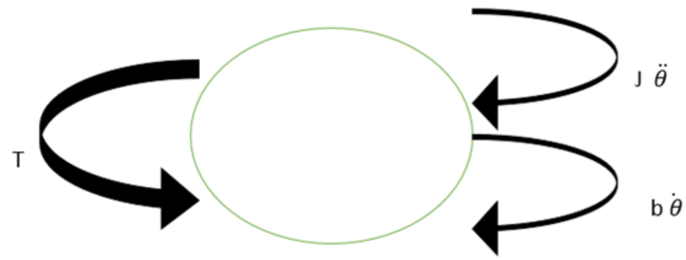


Figure 3: *Mesh and DCL of torques for the motor.*

$$T=j\,\theta+b\,\theta$$
$$T=i.kt$$
$$j\,\ddot{\theta}=i.kt-b\,\dot{\theta}$$
$$\ddot{\theta}=i\left(\frac{kt}{j}\right)-\dot{\theta}\left(\frac{b}{j}\right) \quad (1)$$
$$V=Ri+L\,\dot{i}+e$$
$$e=ke\,\dot{\theta}$$
$$L\,\dot{i}=V-Ri-ke\,\dot{\theta}$$
$$\dot{i}=V\left(\frac{1}{L}\right)-i\left(\frac{R}{L}\right)-\dot{\theta}\left(\frac{ke}{L}\right) \quad (2)$$

2.1.2 Model of the mass

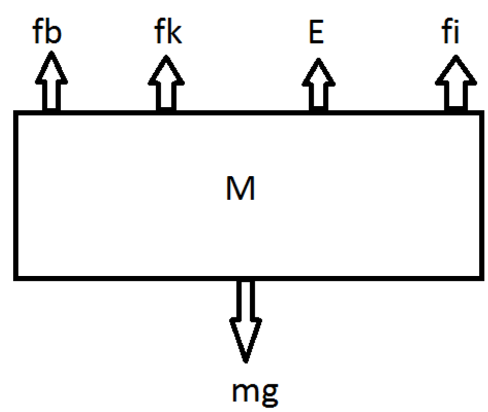


Figure 4: *FBD of the mass.*

$$kx + b\dot{x} + m\ddot{x} + \rho g Vsum = mg$$

$$m\ddot{x} = mg - b\dot{x} - kx - \rho g Vsum$$

$$\ddot{x} = -\dot{x}\left(\frac{b}{m}\right) - x\left(\frac{k}{m}\right) + g\left(1 - \frac{\rho Vsum}{m}\right) \qquad (3)$$

$$v = \dot{x} \qquad (4)$$

Now we are going to show the state space representation.

$$\begin{bmatrix} \ddot{\theta} \\ \dot{i} \\ \ddot{x} \\ \dot{x} \end{bmatrix} = \begin{bmatrix} \frac{-b}{j} & \frac{kt}{j} & 0 & 0 \\ \frac{-ke}{L} & \frac{-R}{L} & 0 & 0 \\ 0 & 0 & \frac{-b}{m} & \frac{-k}{m} \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ i \\ \dot{x} \\ x \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{L} \\ 0 \\ 0 \end{bmatrix} V + \begin{bmatrix} 0 \\ 0 \\ 1 - \frac{\rho Vsum}{m} \\ 0 \end{bmatrix} g$$

$$y = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ i \\ \dot{x} \\ x \end{bmatrix}$$

2.2 Construction of the plant

A solidworks assembly is first carried out, which allows a motor to be supported and the 2 pulleys to be located as indicated in figure 5.

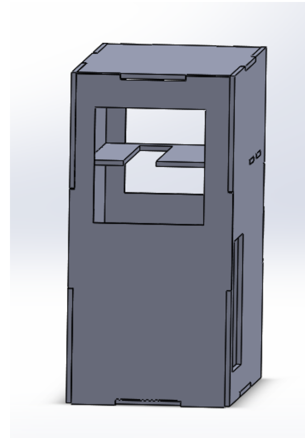


***Figure 5**: Assembly of the plant to be built.*

It is decided to create a plant with a height of approximately 20 cm so that the mass can move approximately 6 cm up or down, apart from that it is taken into account that the spring must not be submerged and that the pulley must be kept in the highest above the container containing the fluid. Two pulleys, coconut oil, DC motor and the push pull DC circuit are used for the motor, since it allows better control of the motor current and the direction to both sides.

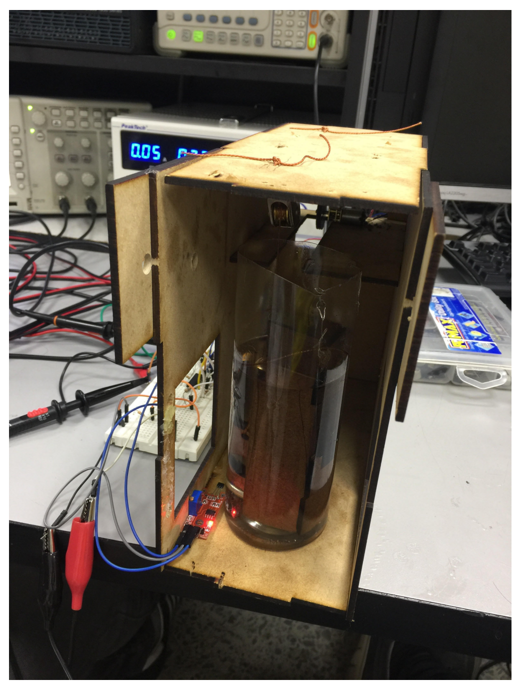


Figure 6: Physical assembly of the plant.

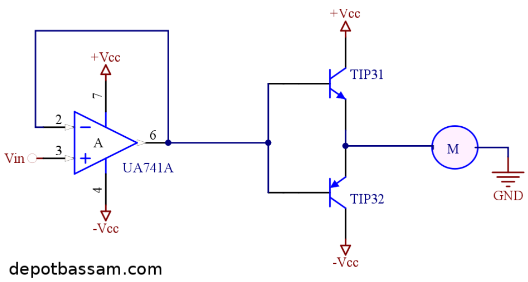


***Figure** 7: Push-pull*

circuit This push-pull circuit allows the motor to better control the current needed to move the mass within the fluid.

The sensor that was decided to use is a hall effect sensor which, when tested with the displacement of the mass, varies between 2.5v and 4v. Therefore, it had to be conditioned by means of a circuit which allows a measurement from 0v to a positive voltage. , which in this case is taken as 2v.

Using the ident software, the signal obtained from the oscilloscope is taken and modifications can be made to the signal, such as filtering and clipping to obtain the most optimal data.

Following this, different identifications are tested with the system of different order to see with which a better similarity is obtained. In addition to the graphic method with which it can be compared.

3. ANALYSIS OF RESULTS

After using the matlab ident tool, the input and output data are entered to start the identification.

From the oscilloscope a response is obtained as shown in figure 8.

***Figure 8**: Response in the real oscilloscope*

In figure 8 the yellow signal represents the input, obtained by the generator, and the blue signal is the output signal, or the position of the mass obtained thanks to the hall effect sensor. It can also be seen that the output signal is stabilized at the end of the step and this is in open loop, so the system is stable, due to factors such as mass, motor torque and the thrust force of the viscous fluid.

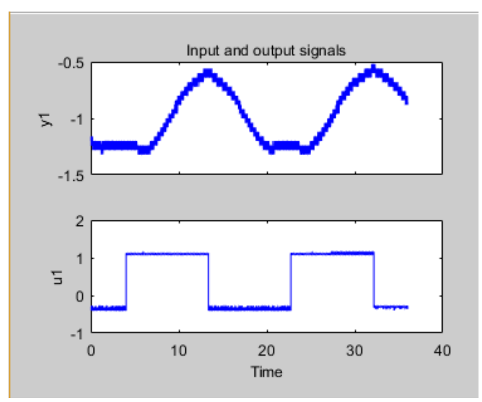


***Figure 9**: Oscilloscope signals as variables in matlab.*

The entire segment of the signal obtained from the oscilloscope is entered, to then select a time range which, when analyzed, would have a better response.

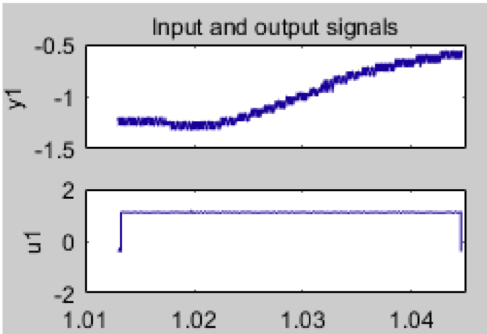


Figure 10*: Selected segment.*

Based on the segment in Figure 10, all plant estimates are made, observing the different responses and which one is closest to the experimental one.

First, analyzing in first order, it is clearly seen that the system cannot be estimated with an order of 1, as can be seen in figure 11.

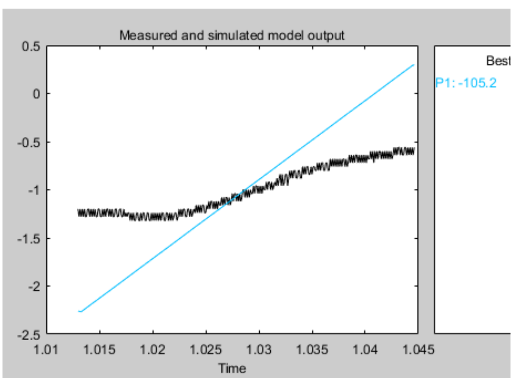


Figure 11*: First order system estimation.*

Then, in view of not having similarity with a first-order estimate, a second-order estimate is followed.

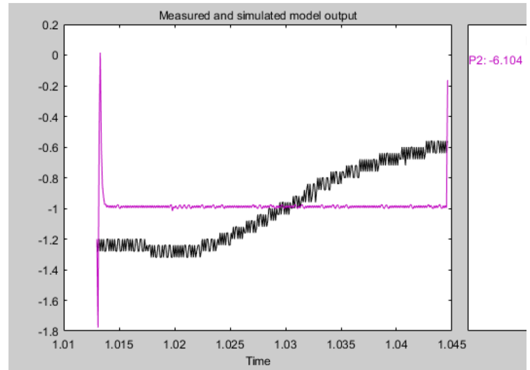


Figure 12*: Second order system estimation.*

In the estimation of the second order, the similarity with the data obtained is not observed either, therefore a third order plant is estimated.

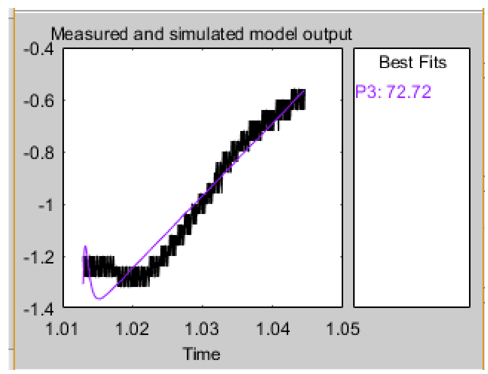


Figure 13*: Estimation of the third order system.*

With a 3rd order estimate, the plant achieves a similarity of 72.72% with respect to the experimental one, however a better fit is desired.

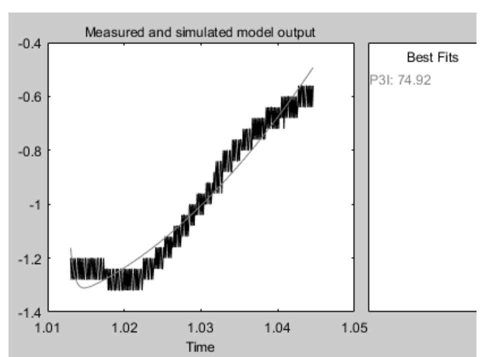


Figure 14*: Estimation of third order system with integrator.*

The representation of a type 1 third order system, in order to obtain a better similarity of the experimental signal.

```
              -0.0008023
---------------------------------------
s^4 + 1795 s^3 + 0.1891 s^2 + 9.6e-07 s
```

This being the transfer function that is closest to the experimental response

Graphic method:

The measured establishment time is 1.044 seconds, and it is known that tao is 63% of the time it takes for a signal to stabilize, then:

$$\tau = 0.63(4s)$$
$$\tau = 2.52s$$
$$Tu = 1s$$
$$Ta = 3.05s$$
$$\frac{Tu}{Ta} = \frac{1}{3.05} = 0.327$$

According to the table 1, we have a fourth order system, which is as follows:

$$G(s) = \frac{K}{(1+\tau s)^n} = \frac{K}{(1+2.52s)^4}$$
$$G(s) = \frac{K}{40.33s^4 + 64.01s^3 38.1s^2 + 10.08s + 1}$$

4. CONCLUSIONS

After estimating different plant models to get closer to the experimental one, we arrive at a 3rd order plant and a 3rd order type 1 plant that are similar to the desired one, however it is necessary to filter the signal to obtain a signal without so much noise, since the sensor is linear but does not have a filter against noise due to the frictional movements of the mass when ascending or when descend.

The graphic method generated a good approximation of the system since graphically a fourth order system was obtained and the best estimated model in ident was fourth order.

5. REFERENCES

[1] Experimental identification of systems, Ángel Martínez Bueno, University of Alicante, Strejc method.

[2] System Identification Toolbox Matlab. Available at:

https://www.mathworks.com/products/sysid/features.html#linear-model-identification