Effect of Dynamics Loading on a PID controlled Two-Wheeled Vehicle of Wheelchair-Based Inverted Pendulum

Christanto Dwicahyo Putro Nugroho [1], Endra Pitowano[2]
Department of Mechatronics Engineering[2]
Electronics Engineering Polyechnic Institute of Surabaya *(EEPIS),*
Phone: (+62)31-5947280 Fax (+62) 31-5946114
Email: antok240888@gmail.com[1], epit@eepis-its.edu[2]

Abstract

This paper present a simulation investigastion of a PID-controlled Two-Wheeled Vehicle (Wheelchair-based Inverted Pendulum) namely ESG2 (EEPIS Segway Generation 2) with a variety of loading between 10 to 100 kg. this represents the effects of changing the weight of driver that ride on the vehicle although the control applied is a PID (proportional-integral-derivative) method with only one tuning process. The simulation result show the simple application that can be run in the real implementation. This is proofed in the experiments also expose that the control will be more stable when the weight of driver is heavier with some limitation of simulation of maximum loading.

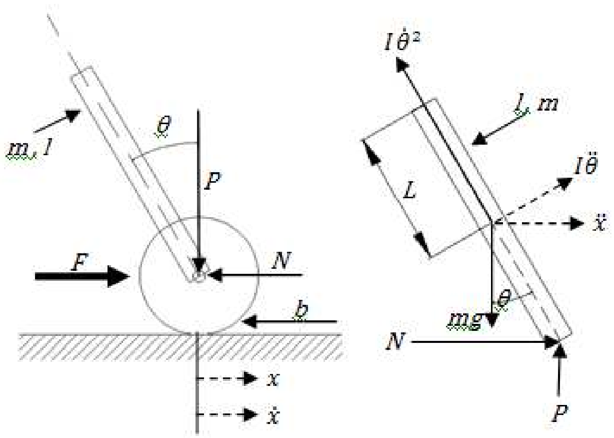
Keywords: *ESG2*, inverted pendulum, inverted pendulum vehicle

1. Introduction

The main problem from inverted pendulum vehicle is how to make it balance. There are many control methods have been introduced, such as Proportional-Integral-Derivative (PID) control, Resolve Acceleration Control (RAC), adaptive control, active force control (AFC), intelligent control, Iterative Learning Control (ILC), etc. Almost all the methods contains the clasic element (PID) that gives better results on the entire system reliability. In this research used PID as a control system, and then used MATLAB® dan Simulink® to simulate the system.

2. System Modeling

The inverted pendulum vehicle that discussed in this paper is modeled from side view. The free body diagram is shown in **fig.1.**



(a) **(b)**

Figure 1: (a) free body diagram of *ESG2*
(b) free body diagram of pendulum

This system is hard to model in Simulink because of the physical constraint (the pin joint) between the cart and pendulum which reduces the degrees of freedom in the system. Both the cart and the pendulum have one degree of freedom (X and theta, respectively). We will then model Newton's equation for these two degrees of freedom.

Equation for cart:

$$F = M\ddot{x} \tag{1}$$

$$\ddot{x} = \frac{F}{M} \tag{2}$$

$$\frac{d^2x}{dt^2} = \frac{1}{M}\sum_{ESG2} F_x = \frac{1}{M}\left(F - N - b\frac{dx}{dt}\right) \tag{3}$$

Equation for pendulum:

$$\tau = I\ddot{\theta} \tag{4}$$

$$\ddot{\theta} = \frac{\tau}{I} \tag{5}$$

$$\frac{d^2\theta}{dt^2} = \frac{1}{I}\sum_{\substack{driver\\and\\ESG2}} \tau = \frac{1}{I}(NL\cos(\theta) + PL\sin(\theta)) \tag{6}$$

It is necessary, however, to include the interaction forces N and P between the cart (*ESG2*) and the pendulum (driver and ESG2) in order to model the dynamics. The inclusion of these forces requires modeling the x and y dynamics of the pendulum in addition to its theta dynamics. This is the model of x and y equations for the pendulum:

$$m\frac{d^2x_p}{dt^2} = \sum_{\substack{driver\\and\\ESG2}} F_x = N \tag{7}$$

$$\Rightarrow N = m\frac{d^2x_p}{dt^2} \tag{8}$$

$$m\frac{d^2y_p}{dt^2} = \sum_{\substack{driver\\and\\ESG2}} F_y = P - mg \tag{9}$$

$$\Rightarrow P = m\left(\frac{d^2y_p}{dt^2} + g\right) \tag{10}$$

However, xp and yp are exact functions of theta. Therefore, we can represent their derivatives in terms of the derivatives of theta.

$$x_p = x - L\sin(\theta) \tag{11}$$

(12)

$$\frac{dx_p}{dt} = \frac{dx}{dt} - L\cos\theta\frac{d\theta}{dt}$$

$$\frac{d^2x_p}{dt^2} = \frac{d^2x}{dt^2} + L\sin\theta\left(\frac{d\theta}{dt}\right)^2 - L\cos\theta\frac{d^2\theta}{dt^2} \tag{13}$$

$$y_p = L\cos(\theta) \tag{14}$$

$$\frac{dy_p}{dt} = -L\sin\theta\frac{d\theta}{dt} \tag{15}$$

$$\frac{d^2y_p}{dt^2} = -L\cos\theta\left(\frac{d\theta}{dt}\right)^2 - L\sin\theta\left(\frac{d^2\theta}{dt^2}\right) \tag{16}$$

3. Simulation

Model of *ESG2* will be simulated using MATLAB® dan Simulink®. The simulation related to the dynamic system and the control system that will be used in the system. The simulation using PID for the control system. The dynamic system of *ESG2* will be made in simulation block with assume the disturbance. There are five variables that can be changed, mass of *ESG2* (M), mass of driver (m), friction of *ESG2* (b), length to *COG* of driver (L), radius of wheel (r). The block diagram will be shown in **fig.2.**

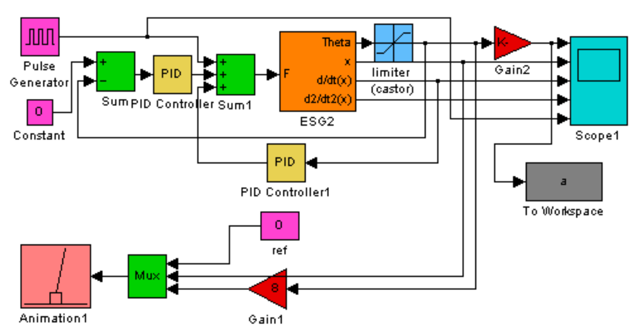


Figure 2: Block of simulation of *ESG2*

4. Data

First, the controller have to be tuned and then run the simulation. To know the respons of the system from the disturbance, plot the result. The simulation performed to determine the effect of loading to the balance of *ESG2* especially for (θ). For the simulation, variable M = 46.5 ; b = 0.1 ; L = 0.4 ; r = 0.27, fourth of them are constant.

First simulation:
m = 100, the result is shown in **fig.3**.

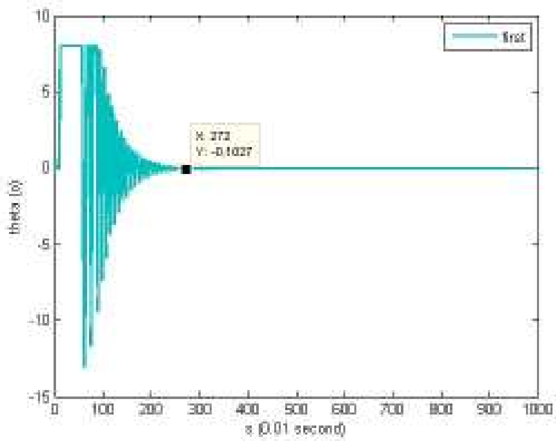


Figure 3: First simulation

The system become steady before 20 second and the theta is about 7.9 degrees.

Second simulation:
m = 70, the result is shown in **fig.4**.

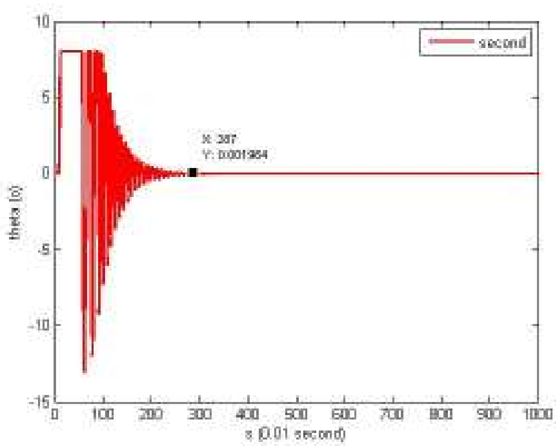


Figure 4: Second simulation

The system become steady after 20 second and the theta is about 7.9 degrees.

Third simulation:
m = 40, the result is shown in **fig.5**.

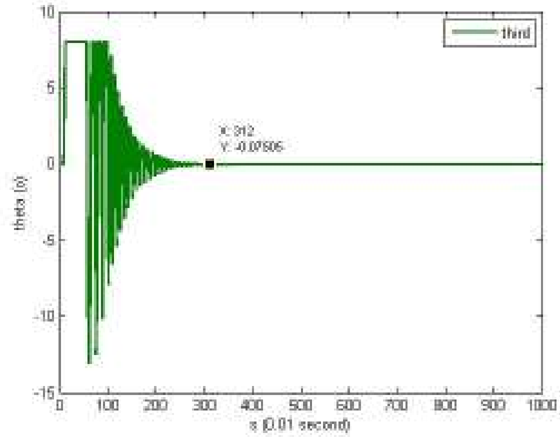


Figure 5: Third simulation

The system become steady after 20 second and the theta is lower than the first and second simulation is about 7.8 degrees.

fourth simulation:
m = 10, the result is shown in **fig.6**.

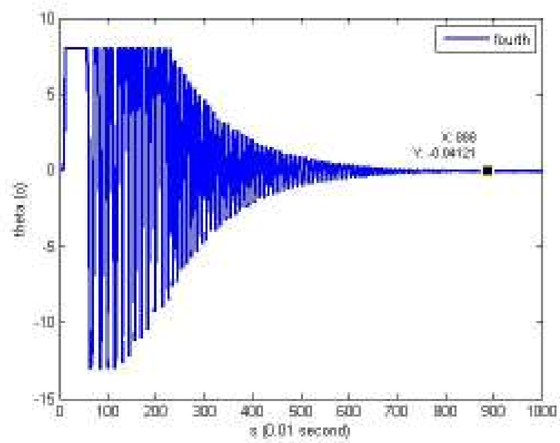


Figure 6: Fourth simulation

The system become steady after about 40 second and the theta is about 7 degrees. To make it easy to compare each other, in **Fig.7** will be shown all of the simulation.

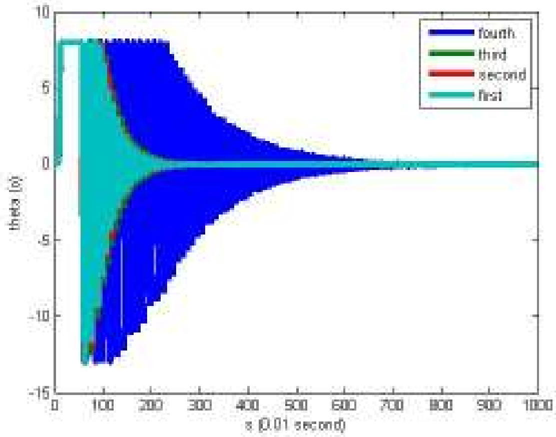


Figure 7: All simulation result

5. Conclusion

From all discussed above, can be concluded that if the rider is getting heavier, the system will be easier to balance. Otherwise, if the weight of the rider is getting lighter, the system is more difficult to balance.

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