Ball On The Plate Model Based on PID Tuning Methods*

Narong Aphiratsakun$^1$ and Nane Otaryan$^2$

Abstract—Controller design is one of the important steps during the modelling of various systems, starting with constructing an electric kettle to an aircraft system. To achieve a good controller it is needed to define suitable values for the controller coefficients. This paper describes the research practices of the tuning technique by using MATLAB/Simulink compared with manually PID tuning based on the trial and error process, as well as, PID tuning methods from Ziegler-Nichols and Tyreus-Luyben (closed-loop proportional gain control or P-Control tests). The paper can be useful for readers who want to have a basic knowledge of research assignments based on PID tuning.

I. INTRODUCTION

Finding the proper mathematical model description and good coefficients for the controller can save time on trying to define the controller coefficients, which ones are more accurate. This paper is dedicated analysing the efficiency of Ziegler-Nichols, Tyreus-Luyben PID tuning methods and through MATLAB/Simulink obtained coefficients on Ball On The Plate system, comparing the results with the values that were obtained through trial and error.

The report is based on the AU Ball On The Plate Balancing Robot, which is a non-linear system [1]. PID Tuning Methods require the transfer function and thus, the mathematical equation of the model. To find the transfer function is not easy because of the complexity and non-linearity of the system. In this case, the transfer function is based on linearized mathematical equations of the ball motion [2],[3],[10]. After obtaining the transfer function, PID Tuning experiments can be performed according to the methods mentioned above.

This report is divided into three main sections. Chapter II gives an introduction of the model and tuning methods. The mechanical and mathematical descriptions of the AU Ball On The Plate Balancing Robot are considered: knowledge about mechanical construction makes it possible to get the mathematical equations of ball motion, and the transfer function for the system is obtained due to the non-linear equations.

II. BALL ON THE PLATE MODEL AND TUNING METHODS

A. AU Ball On The Plate Balancing Robot

Figure 1 shows the mechanical construction of the AU Ball On The Plate Balancing Robot. The model contains two microcontrollers - Raspberry Pi 2 and STM32F0407 board, a camera on top of the plant, two DC motors attached to cables and pulleys and servo motors attached to arms, which are responsible for plate inclination. The camera on the top detects the position of the ball in real time and sends it to Raspberry Pi. The received coordinates’ data is sent to the STM board. STM32F0407 calculates pulses that will be sent to servo motors, which are connected beneath the plate through arms and ball-sphere joints, and controlled with the PID algorithm. Therefore, the inclination angle depends not only on detected error, but also on the values of the PID controller [1].

B. Mathematical Model and Transfer Function

The angles of servo arms $\theta_x$ and $\theta_y$ are assumed to be the inputs, the ball position on x and y axis are assumed to be the output. Having the input and the output, the transfer function can be obtained. Thus, the mathematical model is needed and the linearization of the system is to be obtained due to the non-linear equations.

1) For the Ball On The Plate Model the following mathematical descriptions for the ball motion are considered with the parameters in Table I [2],[10]:

\[
\dot{x} = m \dot{\alpha}^2 + y \dot{\beta} \dot{\gamma} + mgsina \alpha = 0 \quad (1)
\]

\[
\dot{y} = m \dot{\beta}^2 + x \dot{\alpha} \dot{\gamma} + mgsin\beta = 0 \quad (2)
\]

Since there was a slow rate of change, for the plate it is assumed [3]:

---

*This work was supported by Assumption University of Thailand

$^1$Narong Aphiratsakun with Faculty of Mechatronics Engineering, Assumption University, Thailand nott.notty@gmail.com

$^2$Nane Otaryan with Faculty of Computer Sciences, Clausthal University of Technology, Germany nane.otaryan@tu-clausthal.de