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DESIGN OF SURGE AND ROLL MOTION CONTROL SYSTEM OF ITSUNUSA AUV USING PID CONTROLLER

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ABSTRACT

This paper is about designing motion control system with 2-DOF motion equation to be applied to an Autonomous Underwater Vehicle (AUV) system. The 2-DOF motion equation which consists of surge and roll motion in the form of equations of nonlinear motion. The control system design applied to the ITSUNUSA AUV system uses the Proportional Integral Derivative (PID) method. The simulation results of the PID control system with the motion equation with 2-DOF on the ITSUNUSA AUV system show that the system proves to be stable at a predetermined set-point with an error of 0.01% for surge motion and that with an error of 4.2% for roll motion.

Keywords: *AUV, motion control, PID*

1. INTRODUCTION.

Technology of underwater vehicles has a very important role for Indonesia as a maritime country. Since the water territory of Indonesia is wider than the land, underwater technology is needed to explore and maintain the natural resources of the country, or it requires an underwater vehicle (Herlambang et al,2014). Underwater vehicles widely developed by many countries nowadays are underwater robots without crew or unmanned submarines (Herlambang, 2017). This robot is known as the Autonomous Underwater Vehicle (AUV) which is one of unmanned vehicles operating automatically without a direct human control. The benefits of AUV are not only for exploring marine resources but also for subsea mapping and underwater defense system equipment (Herlambang et al, 2015). In fact, underwater monitoring has to be carried out periodically to get complete and accurate data and information. With the human resources and technology available today, it remains difficult to achieve and consequently results in lack of information and data produced in both quality and quantity (Ermayanti et al, 2015).

This paper is initiated with the preparation of the 2-DOF motion model, that is, for surge and roll motions. Surge motion and roll motion are translational and rotational motions on the x-axis. Then a motion control system design is developed using Proportional Derivative Integrator (PID) to be applied to ITSUNUSA AUV. Next, the stability, error, and settling time can be observed, generated by PID method by analyzing the simulation results with the specified set-point values.

2. MATERIALS AND METHODS

1. Autonomous Underwater Vehicle (AUV) Model

To analyze the AUV system requires two important things, namely the axis system consisting of Earth Fixed Frame (EFF) and Body Fixed Frame (BFF) as represented in Figure 1 (Ansari and Bojadah, 2017). The EFF is used to describe the position and orientation of AUV, whereas the position of the x-axis leads to the north, the y-axis to the east and the z-axis towards the center of the earth. Whereas the BFF defines the positive x-axis leading to the direction of the vehicle, the positive y-axis points to the right side of the vehicle, and the positive z-axis points down (Oktafianto et, 2015). This study uses the equation of motion with 2-DOF namely surge and roll by ignoring the motion of sway, heave, pitch and yaw. Here is the equation of motion with 2-DOF:

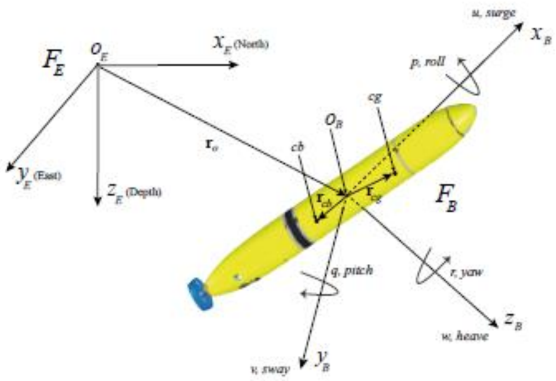

Fig. 1 Six degrees of motion freedom of AUV (Ansari and Bojadah, 2017)

$$\dot{u} = \frac{X_{res}+X_{|u|u}u|u|+X_{prop}}{m-X_{\dot{u}}} \quad (1)$$

$$\dot{p} = \frac{K_{res}+K_{p|p|}p|p|+K_{prop}}{I_x-K_{\dot{p}}} \quad (2)$$

Where X_{res} and K_{res} are hydrostatic forces and moments in x-axis direction, and X_{prop} and K_{prop} are as force and moment of thrust. The profile and specifications of ITSUNUSA AUV are as shown in Figure 2 and Table 1.

Fig. 2 Profile of ITSUNUSA AUV

Table 1. Specifications of ITSUNUSA AUV

Weight	16 Kg
Overall Length	2000 mm
Beam	300 mm
Controller	Ardupilot Mega 2.0
Communication	Wireless Xbee 2.4 GHz
Camera	TTL Camera
Battery	Li-Pro 11.8 V
Propulsion	12V motor DC
Propeller	3 Blades OD : 40 mm
Speed	1.94 knots (1m/s)
Operation Depth	8 m

2. Proportional - Integral - Derivative (PID) Conttroller

Utilizing the PID Control for process control system is very common. For one thing, the PID Controller has relatively simple structure. Besides, its performance is good enough. The combination of controllers can cover the weakness and emphasize the strengths of each controller. Figure 2 represents the block diagram of the PID Controller.

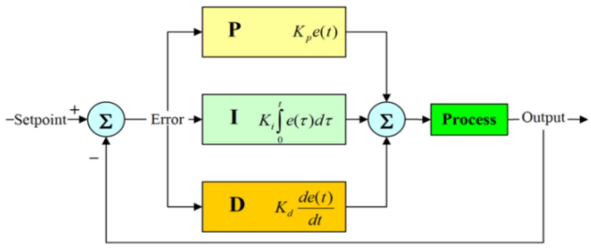

Fig. 3 Block diagram of PID Controller

The characteristics of the PID controller are strongly influenced by the large contribution of the three parameters P, I and D. Setting the constants Kp, Ti, and Td will result in the prominence of the properties of each element. One or two of these three constants can be set more prominently than others. These prominent constants will contribute influence to the overall system. The parameters Kp, Ki, and Kd must be rearranged to have better performance. In controlling the PID controller requires precision and tenacity to gain the optimal value.

3. Designing PID Control System of Non-linear Model with 2-DOF

In this part a PID control system is designed to get control inputs for surges and roll motions with Kp, Ki and Kd values as shown in Table 2. While the Close loop block diagram of PID with 2-DOF nonlinear model is shown in Figure 4.

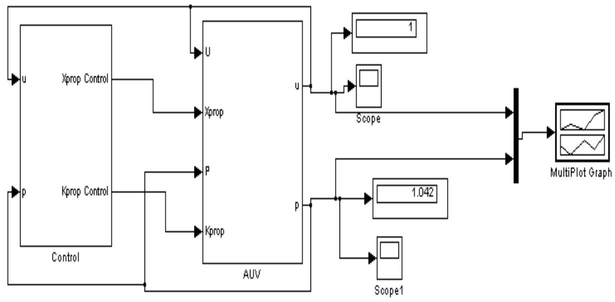

Fig 4. Block Diagram of AUV Nonlinear Model with 2-DOF using PID Control system

Table 2. *proportional, integral* dan *derivative* values of PID controller

	PID		
	Proportional	**Integral**	**Derivative**
Surge	10	1.5	2
Roll	2	1	0.01

3. DISCUSSION.

Once the SMC conttrol system design of nonlinear model with 2-DOF is done, then it is simulated in Simulink Matlab as shown in Figure 3. After the simulation of SMC control system dan AUV is done, it generates responses for translational as shown in Figure 5.

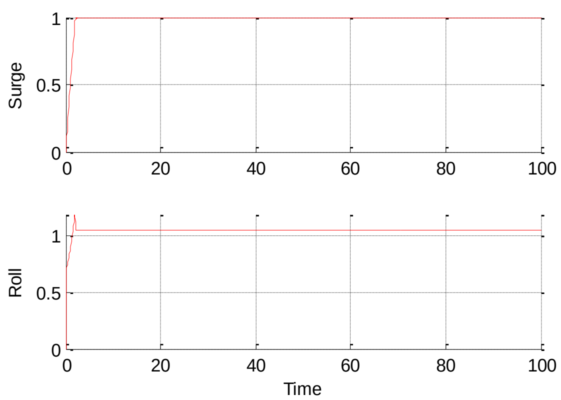

Fig. 5 Responses of Surge and Roll Motion by PID Control System

In Figure 5 is the result of the PID response to surge motion. It appears that the response of the surge motion is stable at set-point of 1 m / s and can reach settling time of 0.3 seconds and has an error of 0.01%. Whereas in Figure 5 is the result of PID response for roll motion. It can be seen that the roll motion response at set-point is 1 rad / s and can reach a settling time of 0.5 seconds and has an error of 4.2% and reaches a maximum overshoot of -2.8 rad / s.

4. CONCLUSION.

Based on the results and discussion, it can be concluded that the Proportional Integral Derivative (PID) method. can be applied as a surge and roll motion control system by generating an error of 0.01% for surge motion with a settling time of 0.3 second and a motion error of 4.2% and a settling time of 0.5 second.

5. ACKNOWLEDGEMENTS.

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