Available online at:
Al-Fiziya: Journal of Materials Science, Geophysics, Instrumentation and Theoretical Physics
Website: http://journal.uinjkt.ac.id/index.php/al-fiziya
Vol. 4 No. 2 Tahun 2021, 115 - 123

Design And Build Underwater Robot Control System Based On PID (Proportional Integral Derivative)

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Submitted : November 2021; Revised : December 2021; Approved : December 2021; Available Online : December 2021

Abstrak. Indonesia memiliki perairan yang luas dan didalamnya terdapat potensi perikanan yang sangat melimpah seperti berbagai spesies ikan air tawar dan biota perairan lainnya. Besarnya peranan perairan Indonesia ini tentu perlu didukung dengan adanya sistem monitoring yang mampu mengontrol dan memantau kondisi di dalam air, seperti underwater robot. Pada penelitian ini dilakukan rancang bangun underwater robot berbasis PID (Proportional Integral Derivative). Kestabilan robot dikontrol menggunakan PID dengan feedback dari IMU MPU6050 untuk kontrol kemiringan dan feedback dari sensor tekanan MS5803 untuk kontrol posisi kedalaman. Underwater robot ini dilengkapi dengan enam buah motor DC, dimana empat buah motor DC digunakan sebagai penggerak robot pada arah vertical (ke atas dan ke bawah) sedangkan dua buah motor DC lainnya digunakan untuk menggerakn robot pada arah horizontal (maju, mundur dan berbelok). Selain itu, robot juga dilengkapi dengan dua buah lampu sebagai penerangan robot. Dalam penelitian ini, underwater robot dapat menjaga kestabilan ketika nilai parameter PID yang diberikan adalah Kp_{roll} sebesar 0.001, Ki_{roll} sebesar 0.001, Kd_{roll} sebesar 1, Kp_{pitch} sebesar 0.001, Ki_{pitch} sebesar 0.001, Kd_{pitch} sebesar 1, Kp_{depth} sebesar 5, $Ki_{depth,}$ sebesar 1 dan Kd_{depth} sebesar 1.

***Kata Kunci**: MPU6050, MS5803, PID, Underwater Robot*

Abstract. Indonesia has wide waters and in it there is very abundant fishery potential such as various species of freshwater and other aquatic biota. The large role of Indonesian waters certainly needs to be supported by a monitoring system that is able to control and monitor conditions underwater, like underwater robot. In this research, the design of an underwater robot based on PID (Proportional Integral Derivative). Robot stability is controlled using PID with feedback from IMU MPU6050 for tilt angle control and feedback from MS5803 pressure sensor for depth position control. This underwater robot is requipped with six DC motors, four DC motors are used to drive the robot in a horizontal direction (forward, backward and turn). In addition, the robot is also equipped with two lamps for lighting the robot. In this research, the underwater robot can maintain stability when given PID parameter values are 0.001 for Kp_{roll}, 0.001 for Ki_{roll}, 1 for Kd_{roll}, 0.001 for Kp_{pitch}, 0.001 for Ki_{pitch}, 1 for Kd_{pitch}, 5 for Kp_{depth}, 1 for Ki_{depth} and 1 Kd_{depth}.

***Keywords**: MPU6050, MS5803, PID, Underwater Robot*

DOI : *10.15408/fiziya.v4i2. 23173*

P-ISSN: 2621-0215, E-ISSN: 2621-489X

Vol. 4 No. 2 Tahun 2021, 115 - 123
P-ISSN: 2621-0215, E-ISSN: 2621-489X

INTRODUCTION

Indonesia is one of the largest archipelagic countries in the world which has a strategic location. Where the area of inland waters and Indonesian archipelagic waters reaches more than 3000000 km^2, one of the types is lakes [1]. The lake is one of the waters in Indonesia which is located in a basin area and is surrounded by land. Besides having beautiful view, the lake also has abundant fishery potential such as various species of freshwater fish and other freshwater biota. The role of Indonesian waters is so large, of course it needs to be supported by a well it grated monitoring system in order to maintain the underwater ecosystem. One solution is to use an underwater robot to find out how the conditions and situations of the underwater environment area.

Underwater robot is a robot that can maneuver in water. Where this robot is usually used to make observations of underwater environmental conditions. Based on working system, underwater robots consist of two types, namely ROV (Remotely Operated Vehicle) and AUV (Autonomous Underwater Vehicle). Remotely Operated System (ROV) is an unmanned underwater robot that can maneuver in water controlled by an operator above the water surface [2]. ROVs are usually equipped with underwater positioning systems, video cameras and others according to the needs and engineering activities in the water, such as laying pipes and cables under the sea and surveying coral reefs and other marine biota [3]. Autonomous Underwater Vehicle (AUV) is an underwater robot that is autonomous, where this robot can move and carry out all activities under its own water sensors to support the work of the robot [4]. The autonomous system applied to the AUV can make it easier for users to operate, such as maneuvering the robot, avoiding other objects, taking pictures and videos and sending data to users wirelessly [5].

METHODOLOGY

Hardware Design

The following is the design of the entire hardware circuit on the underwater robot

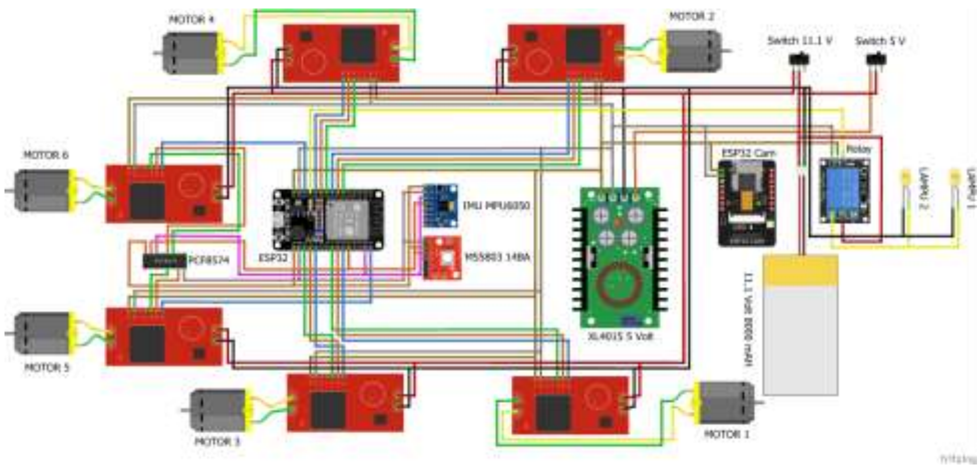

Figure. 1 The Overall Circuit of Underwater Robot Hardware

The explanation of the components contained in **Figure. 1**, including:

1. DOIT ESP32 DEVKIT is used as the main controller of the control system.

2. ESP32 Cam and OV2640 cam are used as image and video image data capture.
3. PCF8574 IO module is used as an additional GPIO pin.
4. MS5803 pressure sensor is used to measure the depth position of the robot.
5. IMPU MPU6050 sensor is used to measure the tilt of the robot and maintain the stability of the robot.
6. VNH2SP30 motor driver is used as a DC motor driver.
7. A 1100gph bilge pump DC motor is used to drive the robot.
8. Relay is used as a regulator of the condition of the lamp.
9. Lamp is used as a robot lighting.
10. Buck converter XL4015 is used to lower the voltage from 11.1 V to 5 V.
11. On-off switch is used to disconnect and connect electric current.
12. LiPo (Lithium Ion Polymer) battery is used as a voltage source for the robot.

Flowchart Design System

The following is a flow diagram of the underwater robot as shown in **Figure. 2**.

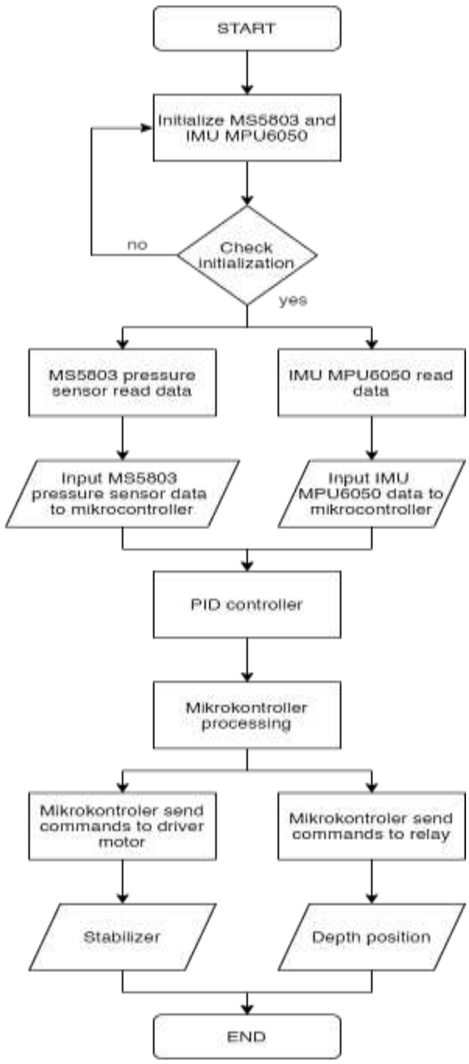

Figure. 2 Flowchart Design System Underwater Robot

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P-ISSN: 2621-0215, E-ISSN: 2621-489X

Robot Motion Design

In designing the motion of the robot, six motors are used which are equipped with a propeller of 60 mm for each motor.

Table 1. Direction of Rotation of The Propeller to The Motor Thrust Force

Position Propeller	Motor Thrust Style	
	Clockwise	Anti-Clockwise
Motor 1	Down	Up
Motor 2	Up	Down
Motor 3	Up	Down
Motor 4	Down	Up
Motor 5	Forward	Backward
Motor 6	Backward	Forward

The formulation of the input function of each DC motor can be seen in **Table 2**.

Table 2. DC Motor Input Function

DC Motor	PID			Joystick
	Roll	Pitch	Depth	
1	+	+	+	
2	-	+	+	
3	+	-	+	
4	-	-	+	
5				+
6				+

RESULTS AND DISCUSSIONS

Underwater Robot Design Results

In designing the robot,1/2 inch PVC pipe and several pipe connections are used which are to form a robot frame. To protect the robot components that are not waterproof a watertight control box is used which has dimensions of 27 cm x 18.4 cm x 9.4 cm.

Figure. 3 Underwater Robot Design Result

PID Control Test Results

In the PID roll control test, it is done by providing different PID parameter values. Where this test was carried out five times. PID roll control testing is done by tilting the robot on a roll slope until it reaches a slope of about 30˚ then released and the resulting response system is seen. The data on the characteristic of the response system from each experiment in this test can be seen in **Table 3**.

Table 3. Characteristics of Roll PID Control Response System

No	PID Parameters	Rise Time	Peak Time	Settling Time	Overshoot
1	Kp 0.5, Ki 1, Kd 1	0.9702 s	1.34 s	6.7 s	17˚
2	Kp 0.001, Ki 0.01, Kd 0.5	1.0086 s	1.34 s	6.365 s	14˚
3	Kp 1, Ki 0.05, Kd 0.1	1.927 s	2.345 s	5.695 s	13˚
4	Kp 1, Ki 0.001, Kd 1	1.046 s	1.675 s	4.69 s	10˚
5	Kp 0.001, Ki 0.001, Kd 1	0.932 s	1.005 s	4.02 s	5˚

Based on **Table 3** above, it can be seen that in the PID roll test, the robot can maintain stability when given a PID parameter value of Kp 0.001, Ki 0.001 and Kd 1. Where the value of this parameter has obtained data on the characteristics of a good response system with a rise time value of 0.932 s, peak time of 1.005, settling time of 4.02 s and overshoot of 5˚.

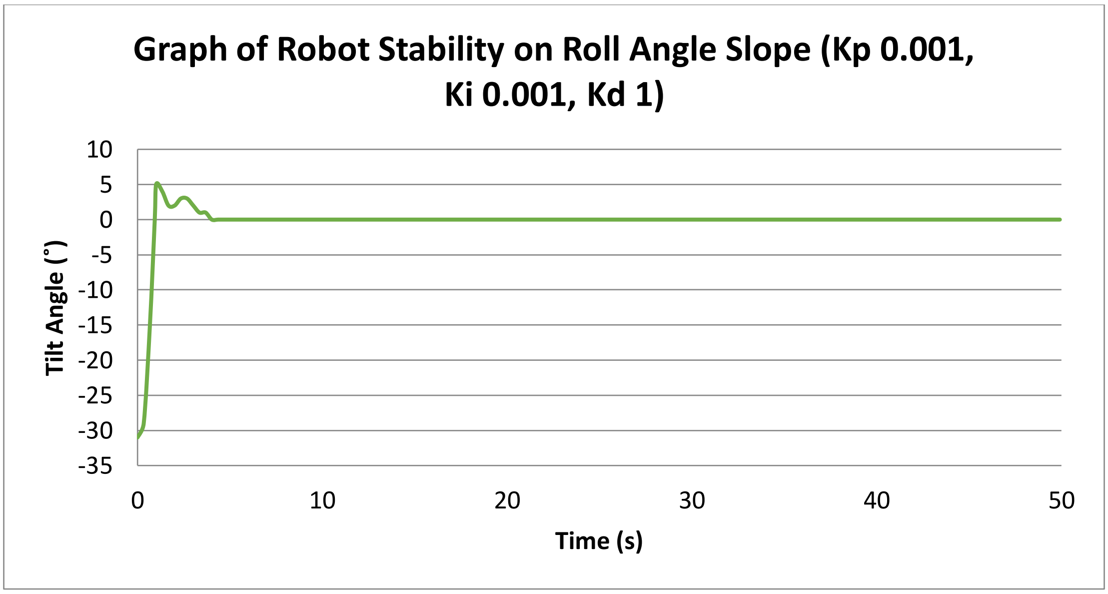

Figure. 4 Graph of Response System on Roll Slope

In the PID pitch control test, it is done by giving different PID parameter values. Where this test was carried out five times. PID pitch control testing is done by tilting the robot on a pitch slope until it reaches a slope of about 30˚ then released and the resulting response system is seen. The data on the characteristics of the response system for each PID pitch parameter are given as shown **Table 4**.

Table 4. Characteristics of Pitch PID Control Response System

No	PID Parameters	Rise Time	Peak Time	Settling Time	Overshoot
1	Kp 0.5, Ki 1, Kd 1	0.472 s	1.34 s	5.36 s	12˚
2	Kp 0.001, Ki 0.01, Kd 0.5	0.9703 s	1.34 s	5.695 s	16˚
3	Kp 1, Ki 0.05, Kd 0.1	0.5108 s	1.005 s	4.02 s	9˚
4	Kp 1, Ki 0.001, Kd 1	1.046 s	1.34 s	3.015 s	5˚
5	Kp 0.001, Ki 0.001, Kd 1	0.855 s	1.005 s	3.35 s	4˚

Based on **Table 4**, the robot can maintain stability very well when given a PID parameter value of Kp 0.001, Ki 0.001 and Kd 1. Where the value of this parameter has obtained data on the characteristics of a good response system with a fast rise time of 0.855 s, peak time of 1.005 s, settling time of 3.35 s and overshoot of 4˚. So that the PID value is applied to the system.

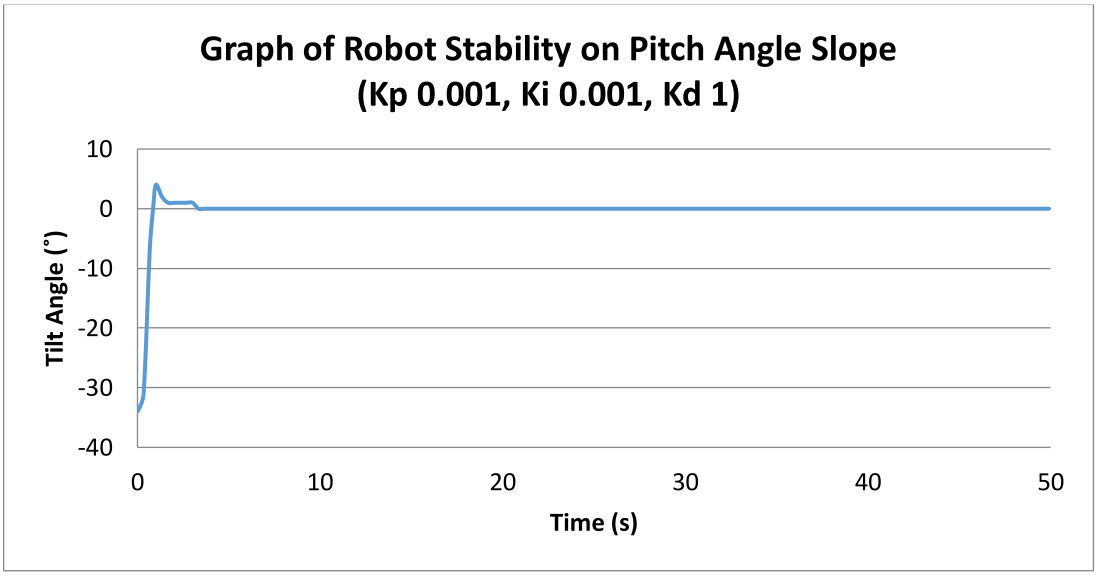

Figure. 5 Graph of Response System on Pitch Slope

In the PID control test, the depth position is carried out by providing different PID parameter values. Where this test was carried out five times. PID control testing for depth position is carried out when the robot is in a floating condition (0 cm depth) then gives a command in the form of a set point value for a depth of 5 cm by moving the slider widget on the blynk until it reaches number 5 and the resulting response system is seen. The data on the characteristics of the response system from each experiment in this test can be seen in **Table 5**.

Table 5. Characteristics of Depth Position PID Control Response System

No	PID Parameters	Rise Time	Peak Time	Settling Time	Overshoot
1	Kp 4, Ki 3, Kd 2	2.0938 s	7.705 s	49.8715 s	20% (1 cm)
2	Kp 3, Ki 2, Kd 2	2.0100 s	2.68 s	49.5365 s	20% (1 cm)
3	Kp 3, Ki 3, Kd 1	1.0888 s	2.68 s	49.5465 s	40% (2 cm)
4	Kp 5, Ki 1, Kd 3	0.2233 s	0.67 s	49.8815 s	40% (2 cm)
5	Kp 5, Ki 1, Kd 1	0.3769 s	0.67 s	49.2115 s	20% (1 cm)

PID control testing at the depth position is carried out by giving 5 cm depth position command using the slider widget on the blynk application on the smartphone. in the depth position PID test, the robot can maintain stability when given the PID parameter values Kp 5, Ki 1 and Kd 1. Where the value of this parameter has obtained good response system characteristic data worth a rise time of 0.3769 s, peak time of 0.67 s, settling time 49.2115 s and overshoot by 20% (1 cm).

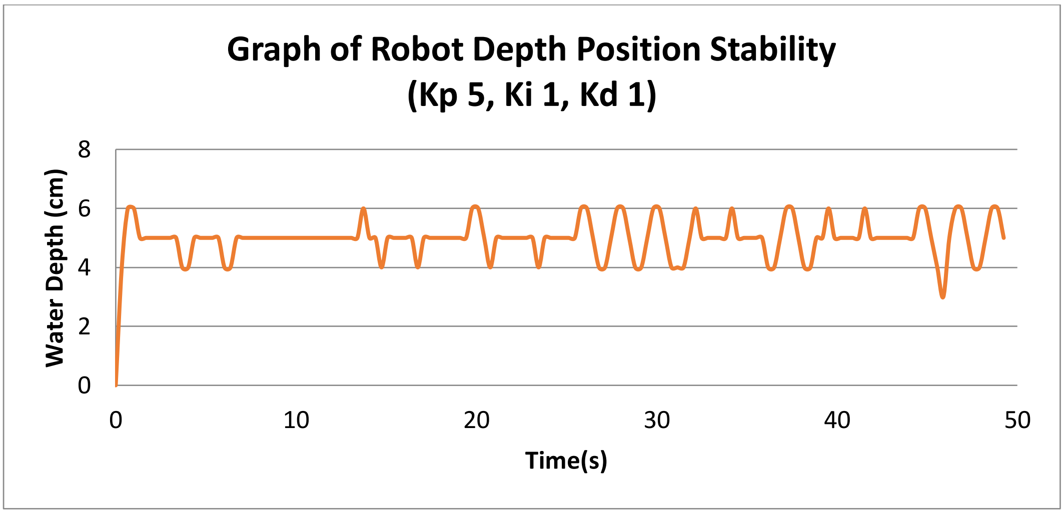

Figure. 6 Graph of Response System on Robot Depth Position

Stability Test Result Against Random Disturbance

Stability testing against random disturbances is carried out to determine the speed of the system response in maintaining the stability of the robot when there is a disturbance. Where the disturbance is given in the form of water waves generated by a DC motor. The value of the PID parameter used is the value that produces the best response in this control system, namely Kp_{roll} of 0.001, Ki_{roll} of 0.001, Kd_{roll} 1, Kp_{pitch} of 0.001, Ki_{pitch} of 0.001, Kd_{pitch} 1, Kp_{depth} of 5, Ki_{depth} of 1 and Kd_{depth} of 1.

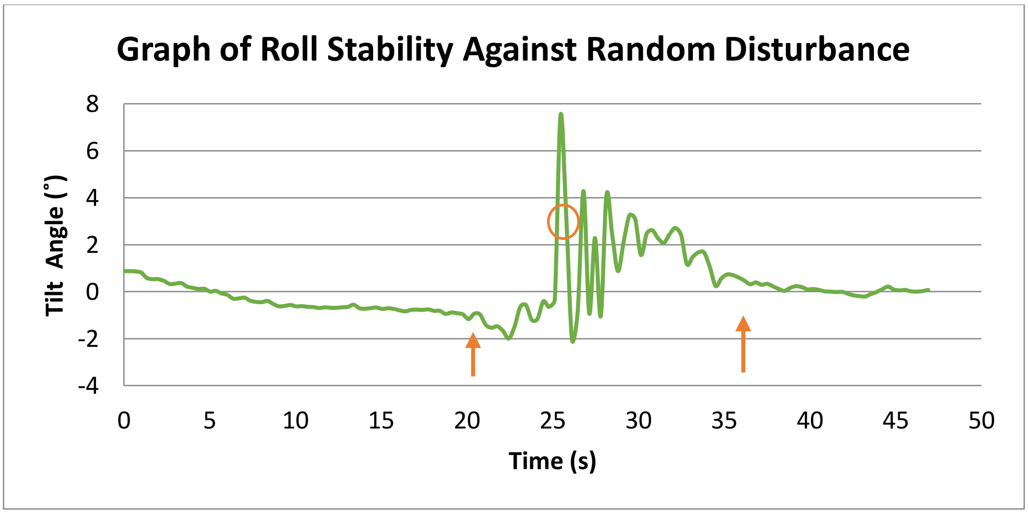

Figure. 7 Graph of Roll Stability Against Random Disturbance

In **Figure. 7**, it can be seen that in the second to 19.43 the robot is still in a stable condition and has not been disturbed. Then at the second to 19.765 the robot experienced instability due to the disturbance given until the second to 35.845 as indicated by the arrow, which resulted in a maximum slope error of 7.5˚. This error occurs because the disturbance given to the robot is greater than the robot's thrust, so the robot difficulty maintaining stability. Then the robot can be stable again at the second to 36.18.

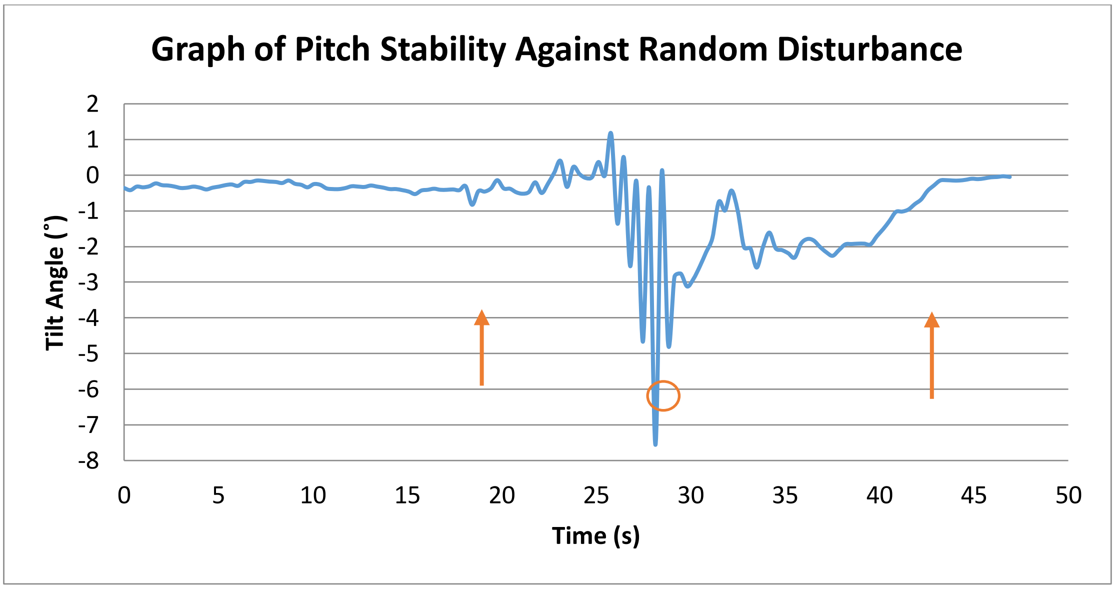

Figure. 8 Graph of Pitch Stability Against Random Disturbance

In the pitch stability graph as shown in **Figure. 8**, the robot is still stable and has not experienced disturbances until the second to 17.42. At the second 17.755 to 42.545 the robot experienced instability due to random disturbance given. Where in this condition the robot has a pitch slope error of 7.56˚. Then the robot can stabilize again at the second to 42.88.

CONCLUSION

The outcome of the number of layers study can be concluded that there are significant differences in the mechanical properties result. Tensile strength and bend ability of the welded metal show optimal when the layers increased. The results for tensile test shows that the highest point recorded is 460,831 MPa for 4 layers, while bend test without any defects recorded was 919.544 MPa for 4 layers, both using electrode ER70S-6. Based on the response optimizer done by this research, electrode ER70S-6 is the ideal electrode used in this study for tensile and bend.

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