

# AUTONOMOUS QUADCOPTER STABILITY WITH PID CONTROL

Sri Wahyuni<sup>1</sup>, M. Izar Bahroni<sup>2</sup>, Faikul Umam<sup>3</sup>

University of Trunojoyo Madura  
Mechatronics Department of Engineering Faculty  
Engineering Faculty  
Bangkalan, East Java, Indonesia

<sup>1</sup>s.wahyuni@trunojoyo.ac.id, <sup>2</sup>Ijhar.osd@gmail.com, <sup>3</sup>faikul@trunojoyo.ac.id

**Abstract**— *Unmanned Aerial Vehicle (UAV) has many uses, including aerial photography, aerial mapping and monitoring activities. Quadcopter is a type of UAV that uses four rotors. The speed of each rotor has a considerable influence on the movement. The quadcopter movement can be done in this research, namely the process of arming, taking off, hover, and landing on decisions made by the system (autonomous). How the quadcopter achieves a balance in its movement to be stable and responsive requires a method. One method that is suitable for processing stability is the method (PID). The PID method has three main parameters, namely Proportional (Kp), Integral (Ki), Derivatives (Kd), with the determination of the constant through the trial and error process to obtain the optimal stability value as the purpose of this study. But the load of the quadcopter and the wind tightness around it is very influential to get the quadcopter movement to survive in stable conditions. Through a series of experimental processes carried out to produce the best constant values, at  $K_p = 1.3$ ,  $K_i = 0.04$ , and  $K_d = 18$ , where the quadcopter is able to survive for 20 sec at the same relative point from the time of departure. The addition of GPS sensors in advanced research will be able to make this quadcopter move stable with the monitored position.*

**Keywords**—UAV; Quadcopter; PID; Autonomous

## I. INTRODUCTION

Quadcopter / quadrotor is one type of UAV (Unmanned Aerial Vehicle) which has a manual or automatic control system. The development of this UAV has been used in various aspects. For example in agriculture. The Center for Agricultural Land Resources Research and Development began developing unmanned aircraft with the aim of analyzing the condition of plants / vegetation or agricultural land using VNIR, SWIR, thermal, radar or SAR bands [1]. Another example in the military field, the reconnaissance process in hard-to-reach areas is the background of the development of drones / UAVs by the National Aeronautics and Space Agency (LAPAN) [2].

Aerial footage Photography, Aerial footage Videography, Aerial mapping including activities that require drones / UAVs in the implementation. In addition to the skills of the user users, the stability and the surrounding natural conditions also have a considerable influence. A good drone is a drone / UAV that can maintain stability from outside interference, for example wind

speed and frequency interference. Quadcopter is one type of UAV with four rotor drives. Each rotating rotor has a lift force and has the same distance to the center of gravity. This type of quadcopter is one type of drone that is quite easy to maneuver.

The method used to be able to adjust the rotational speed of a quadcopter motor is the PID method. The method that uses proportional (Kp), integral (Ki), derivative (Kd) elements aims to accelerate the reaction of a system, eliminate offsets and produce large initial changes. Literatur Review

Researchers of Gembong ES examined the height control on a quadcopter. In controlling the quadcopter, the PID method was used to obtain stability. Researchers are more likely to do testing in the form of simulations [3]. Likewise with Panca AK researchers, the method used is the Fuzzy PID in stabilizing the height of the quadcopter. This research only focuses on pitch and roll angle movements [4]. Guneshwor Singh menjelaskan tentang navigasi otomatis pada quadcopter.

There are two types of propellers in the test. Propellers with a 10 inch size and a pitch of 4.5 can produce a greater total thrust than the use of an 8 inch size propeller with the same pitch size. This also affects flight time which tends to be longer when using a 10 inch propeller [5].

Analysis of the stability of diagonal motion has been carried out by Salmaa. The analysis includes the combination of lateral motion and longitudinal motion in a quadcopter. Based on the analysis, the stability of the diagonal motion model is obtained that all diagonal motion models are unstable. Therefore PID control is needed by determining the gain of Kp, Ki, and Kd [6].

Determination of the combination of PID constants is very influential on the control of stability of the quadcopter. The PID constant generated from the research conducted by Wili Kumara is  $K_p = 40$ ,  $K_i = 40$ ,  $K_d = 60$  for roll motion while  $K_p = 40$ ,  $K_i = 60$ , and  $K_i = 60$  for pitch movement. However, the value of this constant has a fluctuation of  $1^\circ$  to  $(-5^\circ)$  slope [7].

## II. PID METHOD

The PID method is a control system consisting of three types of controllers, namely Proportional, Integral and

Derivative controllers. PID controller is one of the control methods that is often used in industrial control systems [8].

**A. Proportional Controller**

The proportional controller has an output proportional to the magnitude of the error signal (the difference between the desired amount and the actual price). More simply it can be said that proportional controller output is a multiplication between proportional constants with input. Changes to the input signal will immediately cause the system to directly change its output by its constants.

**B. Integral Controller**

The integral controller functions to produce a system response that has a steady state error (zero steady state error). If a plant does not have an integrator element, the proportional controller will not be able to guarantee the system output with a zero steady state error. The use of an integral controller, the system response can be corrected, which has a zero steady state error.

An integral controller has characteristics as well as an integral. The controller output is greatly affected by changes that are proportional to the error value. If the error signal does not change, the output will maintain the state as before the input changes.

**C. Derivative Controller**

Intuitively, the oscillating system response is caused by several things. The dynamic process of a plant causes the response of a plant to not change immediately with a change in the control signal, but requires processing time. This time will make the control system experience delays to correct errors. This requires a controller that can predict errors from a system.

Derivative controllers are generally used to speed up the initial response of a system, but do not minimize errors in the steady state. Derivative controller work is only effective in a narrow scope, namely in the transition period. Therefore the derivative controller is never used without any other controller of a system [8].

**III. BLOCK DIAGRAM SYSTEM**

The block diagram in Fig. 1 is a system diagram consisting of several inputs which include the MPY-6050 type GY module in which there is an MPU-6050 sensor. Input in the form of slope data (gyrometer) and acceleration (accelerometer) becomes a reference for quadcopter balancing movements. The output of the system in the form of the speed value converted into a voltage value by ESC will drive a brushless motor that amounts to four. Brushless motor speed will be fully controlled using the PID method calculation. The ESC specification and brushless motor are adjusted to the load of the quadcopter.

Input in the form of height sensor / wind pressure is a barometer and receiver from 2.4GHz radio control in the process on a different microcontroller. This section is as a medium for information on the height of the quadcopter when the quadcopter airs. Quadcopter communication with ground

station uses a bluetooth / wireless network module. The ground station receives altitude data from bluetooth to be able to control the 2.4GHz transmitter radio control and provide information on the current mode status and height data on the personal computer.

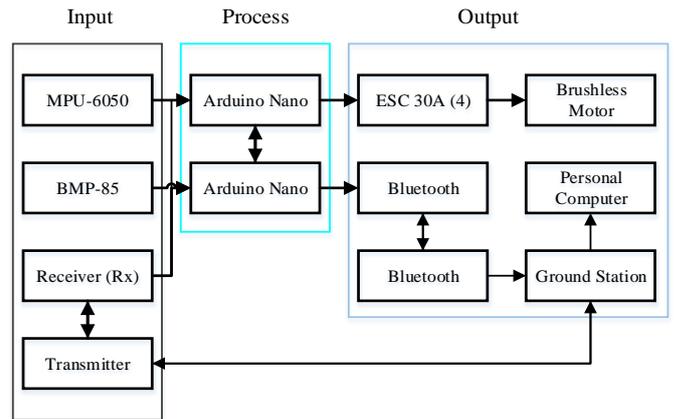


Fig. 1. Block Diagram System

**IV. FLOWCHART**

**A. General Flowchart Autonomous System**

In Fig. 2 and Fig. 3 are general autonomous system flowcharts. Overall testing is done if the constant  $K_p$ ,  $K_i$ ,  $K_d$  is found to be optimal. This process is the whole process of moving the system on a quadcopter.

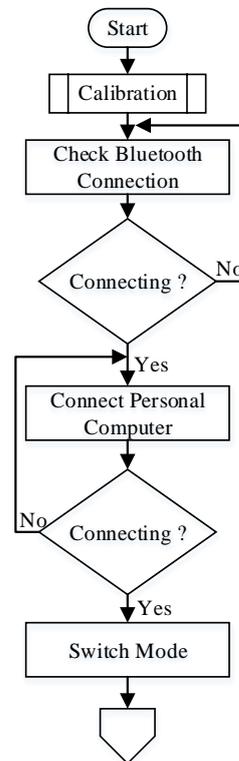


Fig. 2. General flowchart of autonomous systems part 1

Two bluetooth (master / slave) auto-pairing, both have ID identifiers, so bluetooth will be connected to bluetooth whose identification ID has been aligned. After the Bluetooth connection process is complete, the next step is to connect the personal computer to the system using a USB cable. Users can choose to use autonomous mode (automatic) or manual mode. When using autonomous mode, the system will run automatically according to the system design that has been made. The command to turn on the brushless motor is done by using a radio control transmitter. In the aeromodeling field, the process is often known as the Arming process. Then Take off is a quadcopter process to take off. Take off is done until it reaches a height of five meters. If the height has reached ten meters, the quadcopter will maintain height and stability for 30 seconds. Then the quadcopter will land / land slowly until it reaches the surface. But if the user uses manual mode. The manual program will be activated, all control systems are carried out manually by the user with a radio control device. Flowchart PID.

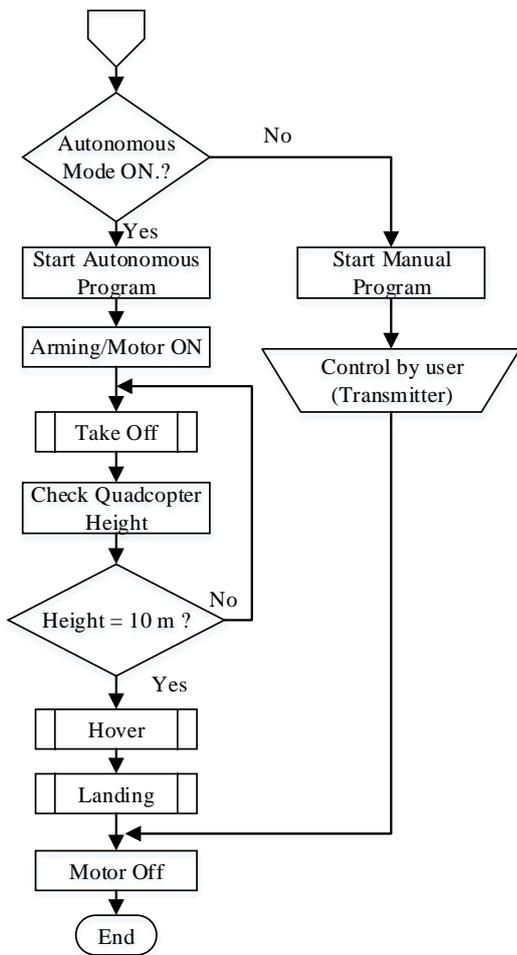


Fig. 3. General flowchart of autonomous systems part 2

In Fig. 4 is a flowchart from the PID method. The PID method is used to maintain the stability of the quadcopter when moving. This method requires the main constants, Kp, Ki, Kd and Set point. The constant will be used to obtain an optimal

system response. Determination of the value of Kp, Ki and Kd based on experiments by adjusting specifications on hardware. Starting with the reading of the gyro quadcopter value on the pitch, roll and yaw axis. The gyro data will be used as input for the calculation of the PID method. The output from the PID calculation will produce a PWM value for each brushless motor. The process will repeat the process until the error value is 0. The PID calculation is applied to the manual mode or autonomous mode.

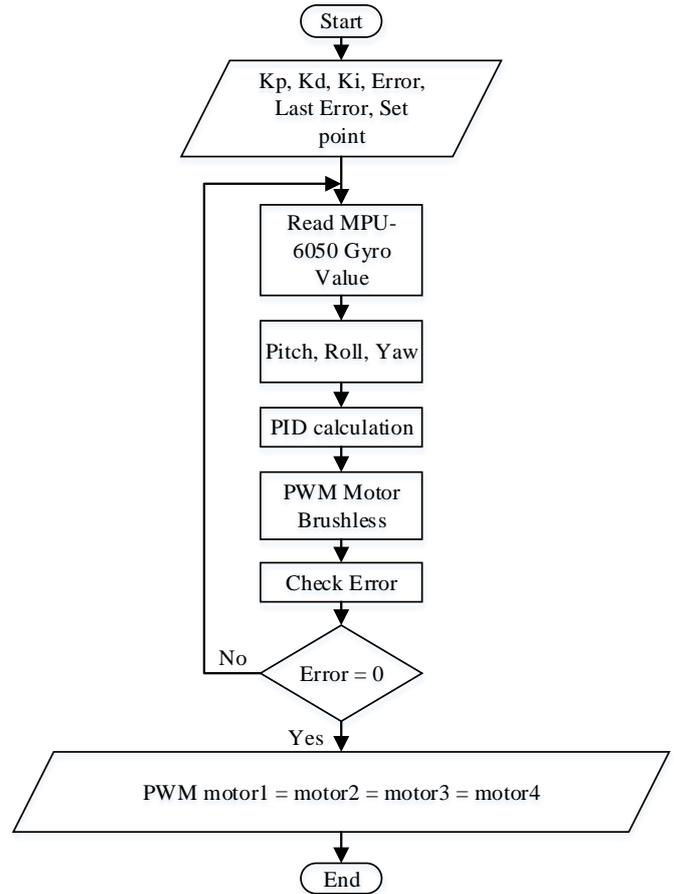


Fig. 4. Flowchart PID

**V. TESTING**

**A. Bluetooth Distance Testing**

Testing is done in the open. This test aims to determine the range of the second Bluetooth communication. Because bluetooth communication is very important, the installation of the bluetooth module and the direction of the antenna on the bluetooth module must be considered very carefully. shown in Table 1.

TABLE I. REACH TESTING DATA

No	Trial	Communication Range
1	Trial 1	21 meter
2	Trial 2	23 meter

No	Trial	Communication Range
3	Trial 3	23 meter
4	Trial 4	19 meter
Average reach		21.5 meter

From the results of the experiment in testing four times bluetooth communication, the average value of the range was 21.5 meters. If the Bluetooth range exceeds the range that has been entered in the test, the data communication will not be sent to the maximum or even the communication will be interrupted.

**B. Testing of Motor Lifting Power (Thrust)**

Lifting (thrust) testing is carried out on each brushless motor used on a quadcopter. Figure 5 is a graph of testing the lift using a 9540 (9 inch) propeller.

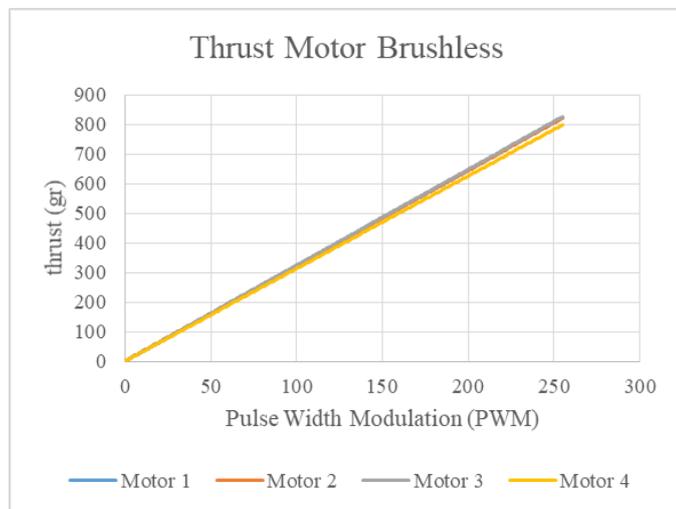


Fig. 5. Motor Lift Power Chart

**C. Testing the PID Method**

PID method is the main method used for quadcopter stabilization process. In testing this method, to get proportional ( $K_p$ ), integral ( $K_i$ ) and derivative ( $K_d$ ) constants is done by trial and error. When the system is given a constant  $K_p$ ,  $K_i$ ,  $K_d$  is observed for quadcopter behavior. Testing the PID method is done in the test box. The test box is shown in Fig. 6.

Testing to find a good system response is repeated. By observing the movement of the quadcopter in the stabilization process there will be some differences, including the response of the quadcopter stability to time. Here are some test results using  $K_p$ ,  $K_i$ ,  $K_d$  that have been done.



Fig. 6. Stability Test

Fig. 7 is a test with a constant value of  $K_p = 1.3$ ,  $K_i = 0.04$   $K_d = 5$ . The value of this constant is used continuously by the system. In addition to the response to steadystate fast enough, the response is not too visible to perform large oscillations. When testing, 200 sensor reading samples were taken with the assumption of data retrieval for four seconds.

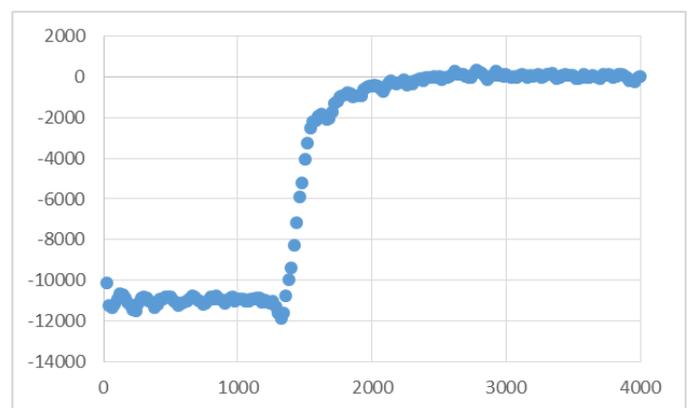


Fig. 7. Results of Testing the PID Method

**VI. CONCLUSION AND FURTHER RESEARCH**

Based on the testing and analysis results that have been carried out in the research, the following conclusions are obtained:

1. Quadcopter can perform optimal stability movements using the PID method. With a constant value of  $K_p = 1.3$ ,  $K_i = 0.04$  and  $K_d = 18$ .
2. Delivery of altitude data sent via bluetooth communication can work well up to a distance of 21.5 meters.
3. The initial position of the quadcopter during take off will affect the shift of movement during flight.
4. The type of propeller 1045 has a fairly large lift, but the temperature of the motor when used is faster heat.
5. The type of propeller 9450 tends to be more stable in movement.
6. Quadcopter tends to stay away from the initial coordinate point if the flight time is increased.

From the results of the research conducted, for the next development, it is suggested that the following:

1. Pay attention to the specifications of the quadcopter part used, especially in the specifications of the motor for lift strength and propeller type.

2. Communication for quadcopter and ground station should use telemetry. So that the data transmission range can be carried out with a considerable distance and minimize frequency interference from outside.
3. Adding GPS components, to determine the position / location when flying.
4. Provides an electronic shock damper component that is in the quadcopter to minimize the vibration generated by the four brushless rotors.
5. Better mechanical design, to make it easier to implement the control algorithm used.
6. Pay attention to security factors during implementation. Addition of propeller protectors so that the propeller is safe when experiencing a system experiencing errors / crashes.
7. When testing, you must first consider the state of the wind speed, this is to reduce the potential of the quadcopter carried by the wind (flyaway).

#### ACKNOWLEDGMENT

We would like to show our gratitude to all our college and student in Mechatronics Department for sharing their wisdom during our research. This research was supported by Basic Mechatronic Laboratory.

#### REFERENCES

- [1] R. Shofiyanti, "Teknologi Pesawat Tanpa Awak untuk Pemetaan dan Pemantauan Tanaman dan Lahan Pertanian", *Informatika Pertanian*, Vol.20, No.2, pp 58-64, 2011.
- [2] Aerostar TUAV : Drone Intai Andalan Skadron Udara 51 TNI AU. <<http://www.indomiliter.com/aerostar-tuav-drone-intai-andalan-skadron-udara-51-tni-au/>> accessed on September 12<sup>th</sup> 2017.
- [3] G.E. Setyawan, E. Setiawan, W. Kurniawan, "Sistem Kendali Ketinggian *Quadcopter* Menggunakan PID," **JTIK**, vol 2, no 2, pp 125-131, 2015.
- [4] P.A. Kusuma, A. Dharmawan, April, "Pengendalian Kestabilan Ketinggian pada Penerbangan *Quadrotor* dengan Metode PID Fuzzy," **IJEIS**, Vol.7, No.1, pp 61-70, 2017.
- [5] I.O.G. Singh, "Self-Navigating *Quadcopter*," *Int. J. Computer Sci. and Information Technologies (IJCSIT)*, vol 6(3), pp 2761-2765, 2015.
- [6] Salmaa, "Analisa Kestabilan Gerak Diagonal pada *Quadrotor* menggunakan Kontrol PID," *Jurnal Ilmiah Matematika (MATH unesa)*, vol 3, no 6, 2017.
- [7] W.K. Juang, and L.L. Tung, "Pembuatan *Model Quadcopter* yang Dapat Mempertahankan Ketinggian Tertentu," *Jurnal Teknik Elektro*, vol 9, no 2, 2016.
- [8] W.K. Juang, and L.L. Tung, "Pembuatan *Model Quadcopter* yang Dapat Mempertahankan Ketinggian Tertentu," *Jurnal Teknik Elektro*, vol 9, no 2, 2016.