Development of the Test Platform for Rotary Wing Unmanned Air Vehicle

Uğur YÜZGEÇ[1*], İrfan ÖKTEN, Hakan ÜÇGÜN, Ali Rıza GÜN, Telat TÜRKYILMAZ, Metin KESLER, Cihan KARAKUZU, Gökhan UÇAR

Abstract-**In this study, a new test platform was developed for rotary wing unmanned air vehicle (UAV) with the multi-rotors. This platform basically includes three different sized circles. Before the flight of UAV, all tests such as yaw, pitch, roll, elevation, etc., are done by the proposed test platform, so the problem or crash in flight of UAV will be prevented. The developed test platform is more superior to the existing test platforms. In this work, the detailed developing process of test platform is presented and some pre-flight tests done by this test platform are represented for the rotary wing UAV with six rotors.**

Keywords- **UAV, Test Platform, Rotary Wing.**

I. INTRODUCTION

In the last years, there have been important developments on multi-rotor unmanned air vehicles (UAV). These vehicles can perform the tasks which are too dangerous for human life. Therefore, there is a rising demand for these UAV vehicles in civilian and military applications such as traffic monitoring, security mission, monitor of pipeline [1]. A rotary-wing unmanned air vehicle, which is capable of VTOL (vertical takeoff and landing) has got high maneuver capability. This air vehicle hovers, takes off, flies, and lands vertically in small areas, and it can have complex control platforms according to the flight missions. To avoid the UAV flight crash, some tests have to be done before the flight. For the stable flight, it must be adjusted the suitable control parameters [2].

Due to a small error in anywhere of the rotary wing UAV, it may induce failure or crash during the flights. Therefore, the parameters in the flight controller of UAV need to be tuned well. In general, the simulation results are different from real time experiments for UAV, so ranges for control parameters obtained by simulation are adjusted by the test bench. In the past years, there have been several test benches for rotary wing UAVs to tune the control parameters of UAV. In the work presented by Grzonka et. al, one axis control tests were realized for a quadrotor [8]. Azfar et. al was proposed the single axis based test bench platform to tune the parameters of the PID controller [9].

By Ömürlü and his friends, variable DOF flight control system was designed for an unmanned quadrotor. In order to modify the proposed structure, some of the connection parts, such as universal joints and roller bearings, are set to be lockable. Pitch, yaw, roll and elevation motions were tested separately by the proposed test system [10]. In the work done by Baran et. al., a test platform was designed for flight control of unmanned helicopter [11]. There is a disadvantage in these test platforms. During flight tests, rotary wing UAVs can move in limit ranges of test platforms. For that reason, the tests done with these platforms don't reflect the flight of UAV completely.

In this study, a new test platform that is based on the gyroscope circles, was proposed for the pre-flight tests. This prototype can be used for the UAV with multi-rotors. There are fundamental pre-flight tests for rotary wing UAVs. These tests are given name as attitude test, such as pitch, roll and yaw movement tests. For sending the test commands and receiving values of the sensors, a GUI was designed and all data were sent and received by wireless communication modules. The results obtained by the proposed test platform were presented for a rotary wing UAV with six rotors.

II. ROTARY WING UAV WITH MULTI ROTORS

In general, there are two different UAV design: fixed wing and rotary wing. Both have some advantages and disadvantages according to each other. In Figure 1, different kinds of rotary wing UAVs are shown. A quadcopter or quadrotor has four motors that are placed at the front, back, left, and right ends of a cross frame. The motion of the quadrotor is controlled by changing the velocity of rotation of each motor. The two reciprocal rotors rotate in a counter-clockwise direction while the other reciprocal rotors rotate in a

[1*] Corresponding Author: ugur.yuzgec@bilecik.edu.tr
Computer Engineering, Bilecik Şeyh Edebali University, Gülümbe, BİLECİK

clockwise direction to hover and fly. For controlling the roll and pitch rate of quadrotor, the relative speed of the reciprocal rotors is varied [3].

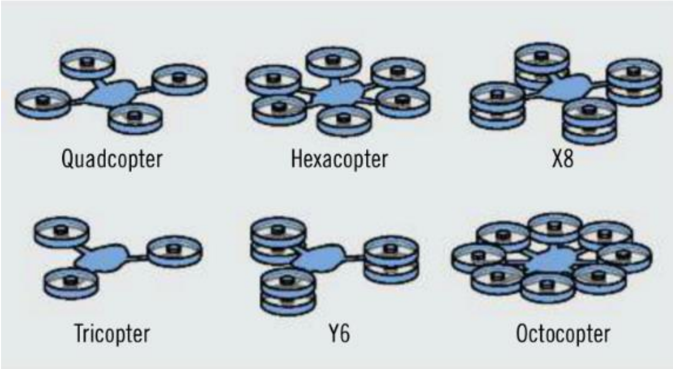
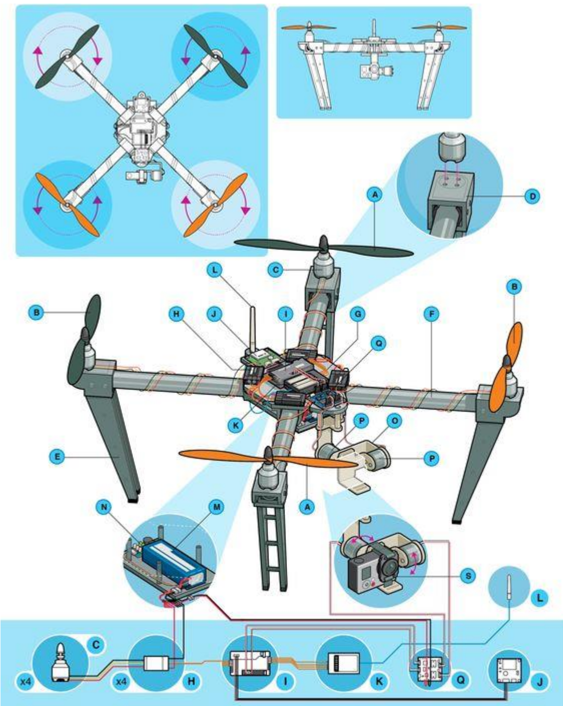


Figure 1. Different kinds of rotary wing UAVs [4].

By varying the relative speed of the clockwise and counter-clockwise rotors, the yaw motion of the quadrotor is realized. The elevation motion is controlled by varying the speed of all the rotors simultaneously. The other rotary wing UAV designs such as octocopter, hexacopter, etc., work similarly. The rotary wing UAVs consist of IMU (inertial measurement unit) sensors, flight board, batteries, dc motors, propellers, gears, electric speed controllers (ESC), RC transmitter and receiver. In Figure 2, the fundamental pieces of a quadrotor model are presented.



A. propeller
B. contra-rotating propeller
C. motor
D. motor mount
E. landing gear
F. bar
G. main body
H. electronic speed controller (ESC)
I. flight controller board
J. GPS module
K. receiver
L. antenna
M. battery
N. battery monitor
O. gimbal system
P. gimbal motor
Q. gimbal controller board
S. camera

Figure 2. Rotary wing UAV with four rotors (Quadcopter) [5].

In this study, a rotary wing UAV with six rotors known as hexacopter was used to evaluate the proposed test platform. The general schematic structure of the hexacopter is shown in Figure 3. In this figure, f_i denotes the force of each motor, w_i represents the angular velocity of each motor, τ_i stands for the torque values of each motor.

For stable flight of rotary wing UAV, two PID controllers per axis (yaw, pitch and roll) were used in its software. By the first PID controller the hexacopter was tried to hold as stable at the desired angle from the pilot. The second controller produces the motor torque using the rotational rate from gyro sensor and desired rotational rate that is produced by first controller [6]. To adjust the suitable PID parameters, basic motion tests have to be done before flight. By developing the proposed test platform, all of the pre-flight tests can be done for the rotary wing UAV with multi rotors.

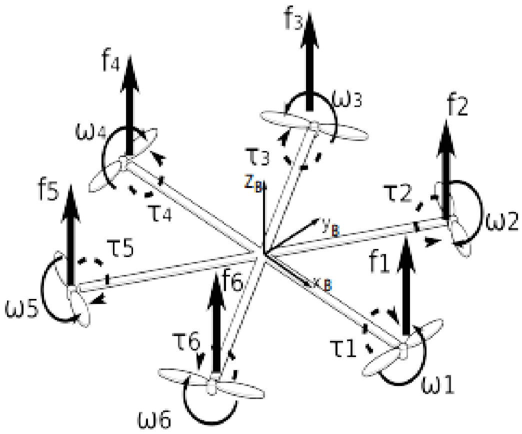
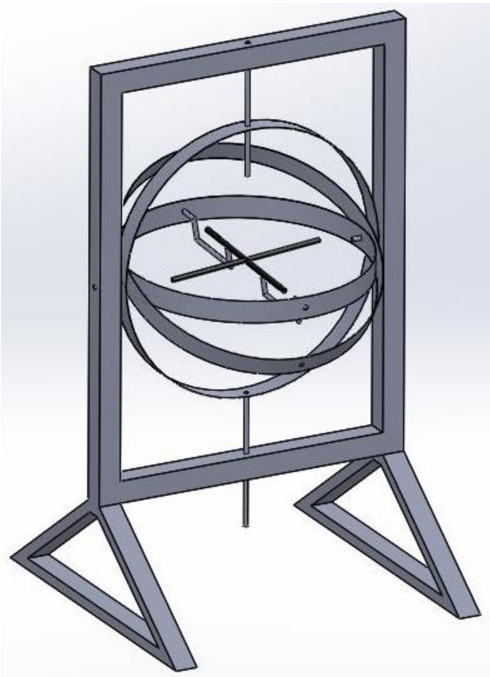


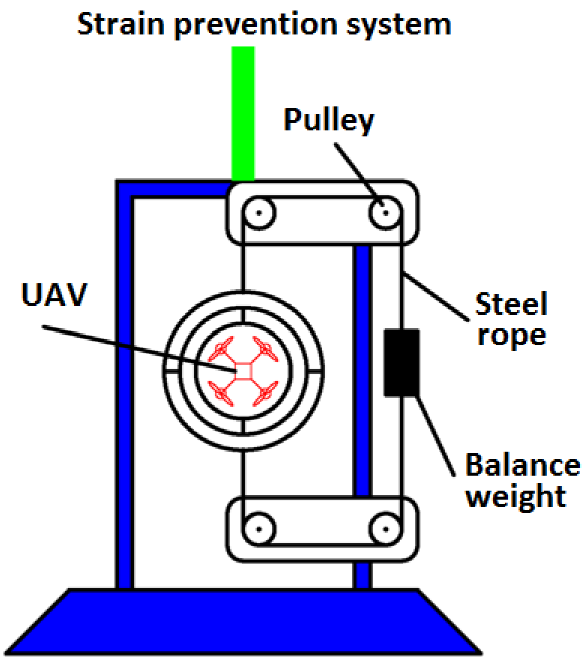
Figure 3. Rotary wing UAV with six rotors (Hexacopter) [7].

III. DEVELOPMENT OF UAV TEST PLATFORM

In this study, a test platform for rotary wing UAVs with multi-rotors is presented. This platform is inspired by gyroscope. The proposed test platform draft done by Solid Works is presented in Figure 4a. As can be seen from this figure, the rotary wing UAV that is hanged on to the test platform can move easily at all axis on the contrary the other test platforms presented in the literature. It consists of the balance weight, steel rope, pulleys, strain prevention system and three circles as shown in Figure 4b. These three-circles have entered into each other, in this way, the rotary wing UAV that is assembled onto the test platform, is easily able to move at all axis. For the elevation test, the circles are connected to the balance weight using steel rope and four pulleys as shown in Figure 4b to eliminate the extra weight of the circles of the test platform. By using this platform, the pre-flight tests, such as pitch, roll, yaw and elevation will be realized.



(a)



(b)

Figure 4. (a) UAV Test Platform draft done by Solid Works software (b) Components of UAV Test Platform

The last condition of the proposed test platform was presented in Figure 5. During flight tests, the rotary wing UAV with multi rotors is placed tightly at the center of the test platform. To get the values of the sensors from the microcontroller board on the UAV and to send the motor command, the control parameter to the rotary wing UAV, a graphical user interface was developed as shown in Figure 6. In this interface, the measurement values of all sensors, such as gyroscope, accelerometer, magnetometer, barometer, etc., can be seen on the graphical figures. At the same time, all control parameters can be sent to the UAV on the test platform via wireless transmission. From the menu on the interface, the desired pre-flight test can be selected, then obtained test results are presented on the figures.

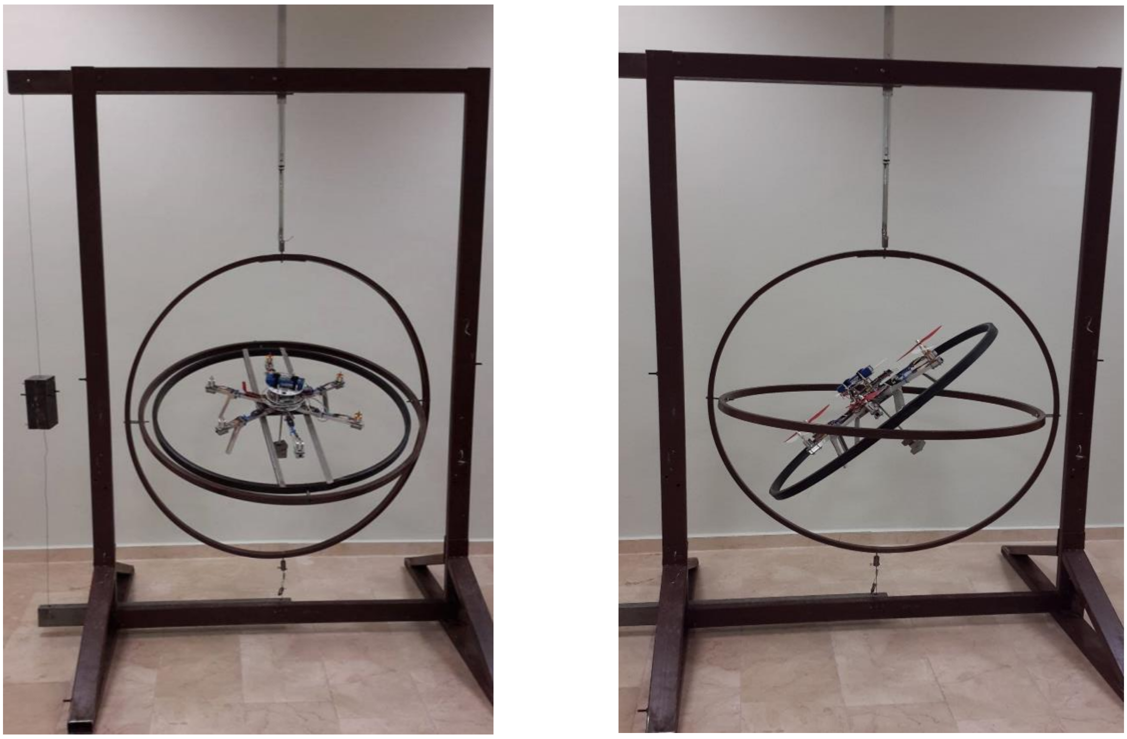


Figure 5. View of Rotary wing UAV Test Platform

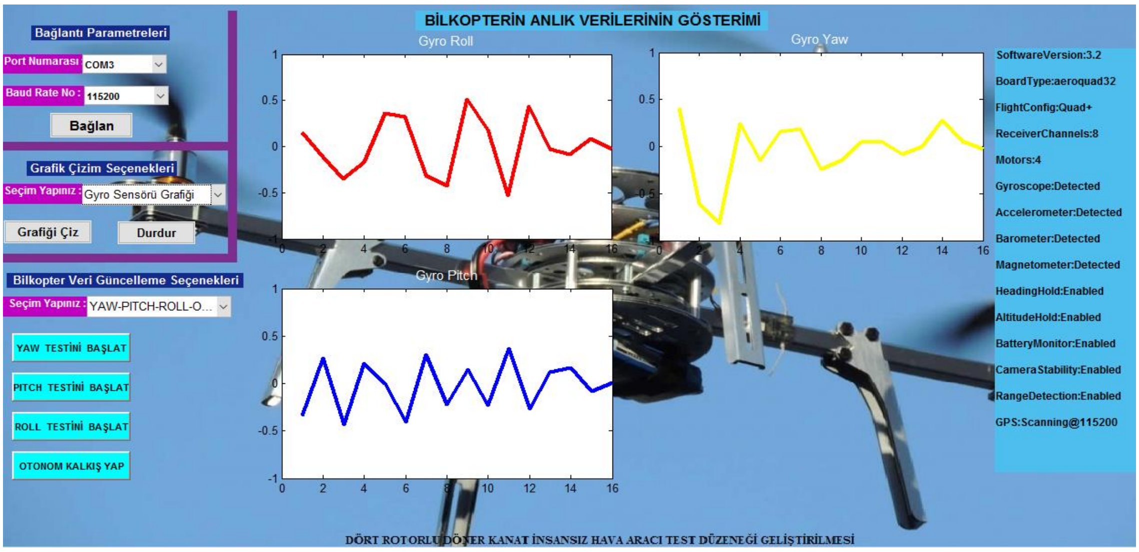


Figure 6. UAV Test Platform GUI (In Turkish)

IV. EXPERIMENTAL RESULTS

In this section, a rotary wing UAV with six rotors (hexacopter) was set on to the test platform to observe the performances of the proposed test platform. By the graphical interface, different set angle values were sent to the rotary wing UAV on the test platform via wireless transmission. In Figure 7, the experiment setup including UAV on the test platform, wireless communication modules and computer is illustrated. Three set angle signals, $x(t)$ were used as below:

$$x_1(t) = 20[u(t) - u(t - 100)] \quad (1)$$

$$x_2(t) = 20.u(t) - 40u(t - 50) + 20u(t - 100) \quad (2)$$

$$x_3(t) = 30.\sin(2\pi t/100) \quad (3)$$

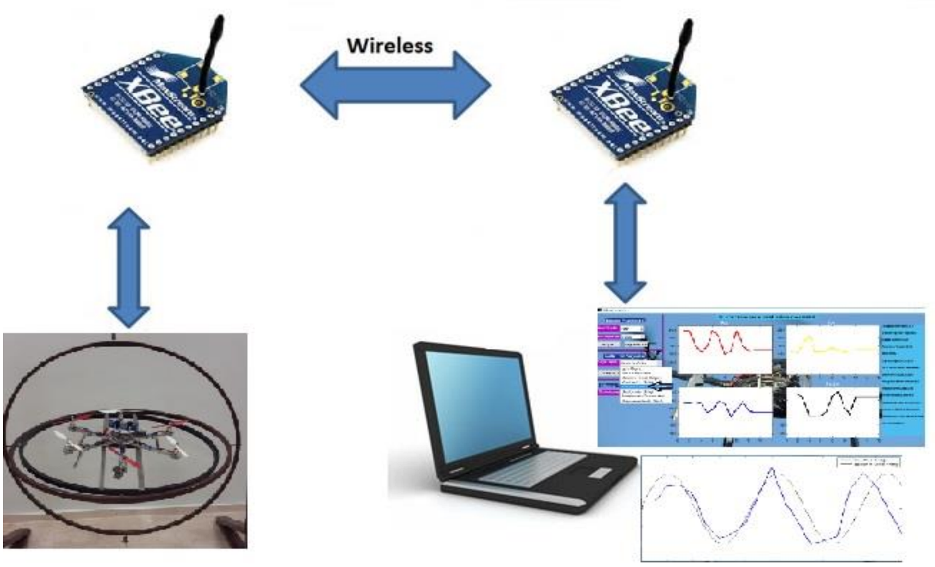


Figure 7. Experimental setup

For the pitch angle tests, the parameters of PID controller were selected as $K_p = 5.5, K_i = 0.5, K_d = 1.5$. During the pitch tests, the rotary wing UAV was set tightly at the center of the test platform. For set angle signal given in Eq.(1), the obtained experimental result is presented in Figure 8. As can be seen from this figure, it is shown that the pitch angle that is taken from the kinematic angle calculated by the sensors on the UAV follows the set angle signal and the squared error is decreased by PID controller with selected control parameter. The response on this figure with PID includes a little steady state error, but this can be eliminated by adjusting the K_i parameter as more sensitive.

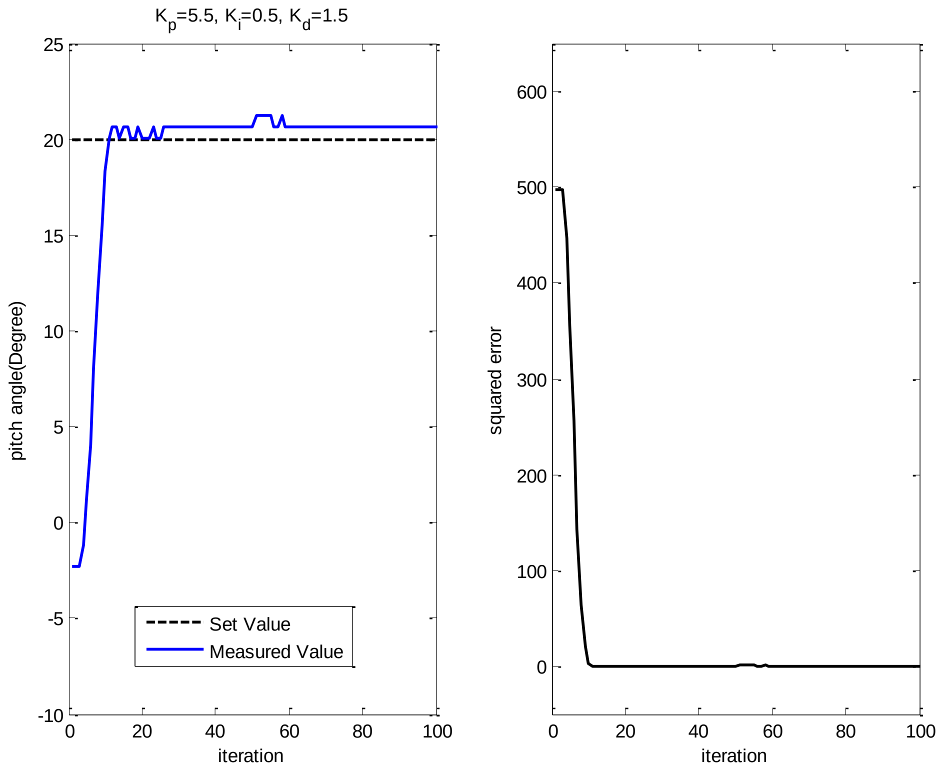


Figure 8. The result of the pitch test for set angle signal given in Eq. (1)

In Figure 9, the result of the pitch test for the second set angle signal is shown. The set signal consists of 20 degree value in range of [0 50] and -20 degree value in range of [51 100]. In this test process, the same PID controller parameters were used. The response of the UAV for the first interval consists of the a little steady state error, but in the second interval, the response includes an excessive overshoot and oscillation. By adjusting the parameters of the PID controller using the graphical interface, this response has got no steady error and no overshoot. Figure 10 shows the result of the pitch test for the third set angle signal given in Eq. (3). The set angle is a sinusoidal signal. In this test process, the same PID controller parameters were used. The results show that the response of the UAV follows the sinusoidal test signal successfully. This response includes only little phase difference.

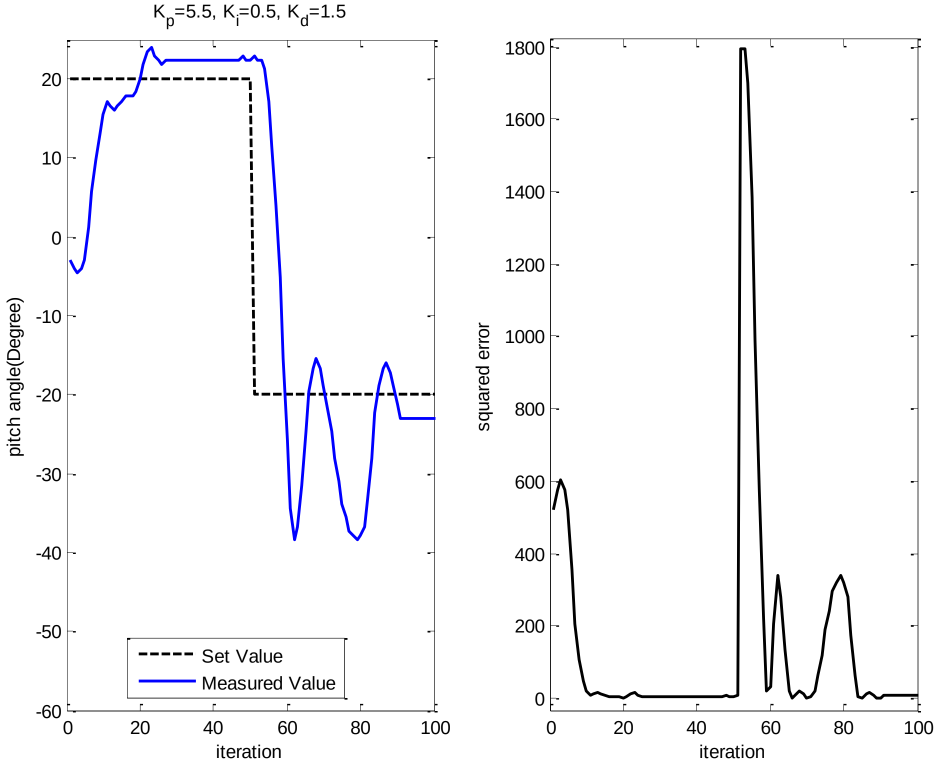


Figure 9. The result of the pitch test for set angle signal given in Eq. (2)

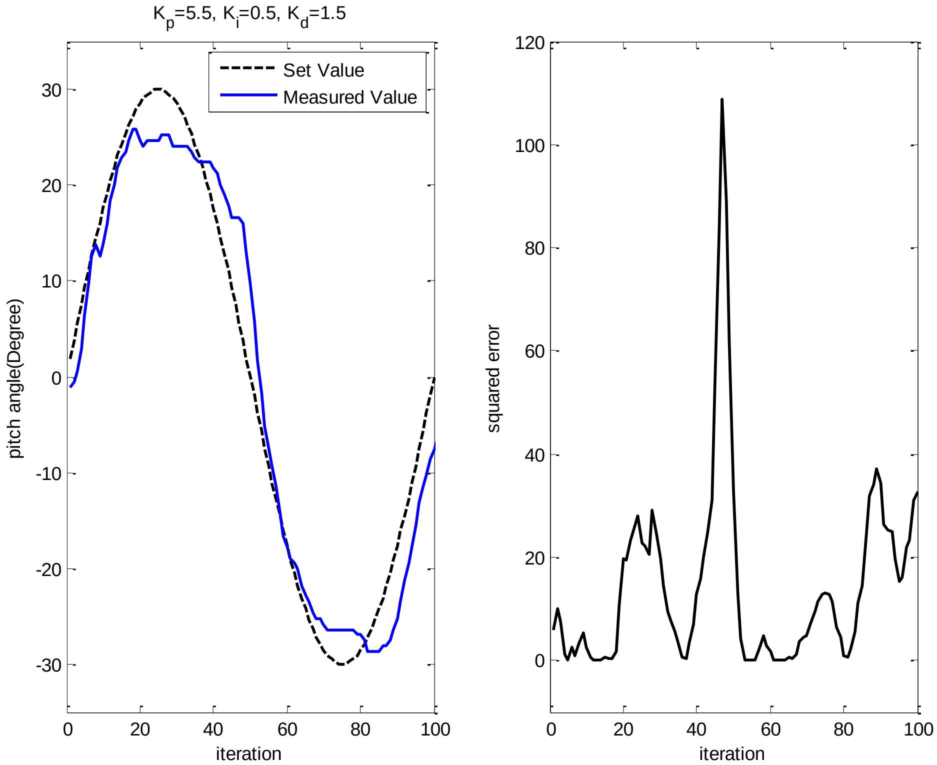


Figure10. The result of the pitch test for set angle signal given in Eq. (3)

V. CONCLUSION

In this study, a new test platform was designed and developed for the different rotary wing UAV with the multi-rotors. This test platform is based on the gyroscope motion and it consists of the three different sized circles that lies one inside the other, the balance weight, steel rope, pulleys and strain prevention system. The aim of the proposed test platform is to do the axis motion tests, such as yaw, pitch, roll and elevation, before the flight of rotary wing UAV. The advantage of this proposed test platform is that it has no motion limitation along all axis without elevation motion in comparison with the other existing test platforms. The experimental results show that the response of the rotary wing UAV follows the set signal with a little overshoot and steady state error. In the future works, the pitch, roll, yaw, elevation tests will be done by this test platform for quadcopter, hexacopter and octocopter UAVs.

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REFERENCES

[1] How, J. P., Bethke, B., Frank, a., Dale, D., & Vian, J., "Real-time Indoor Autonomous Vehicle Test Environment", *IEEE Control Systems*, vol. 28(2), pp. 51–64, 2008.

[2] Ömürlü V. E., Kirli, A., Büyükşahin, U., Engin, Ş. N., & Kurtoğlu, S., "A Stationary, Variable DOF Flight Control System for An Unmanned Quadrocopter." *Turkish Journal of Electrical Engineering and Computer Sciences*, vol. 19(6), pp. 891–899, 2011.

[3] Hanford, S. D., Long, L. N., & Horn, J. F., "A Small Semi-Autonomous Rotary-Wing Unmanned Air Vehicle (UAV)", *American Institute of Aeronautics and Astronautics Conference 2005*, pp.1–10.

[4] Volkmann, O., "Multirotor 101" published in Drone 360 on the website. [Online]. Available: https://www.habanaavenue.com/2015/05/14/multirotor-101

[5] Ragan, S.M., "Anatomy of a Drone" makezine homepage. [Online]. Available: http://makezine.com/2014/01/07/anatomy-of-a-drone/ (date: 02.06.2016, 16.09)

[6] Yu, Y., & Ding, X., "A Quadrotor Test Bench for Six Degree of Freedom Flight. *Journal of Intelligent and Robotic Systems: Theory and Applications*, vol. 68(3-4), pp. 323–338, 2012.

[7] Artale, V., Milazzo, C. L. R., & Riccardello, a., "Mathematical Modeling of Hexacopter". *Applied Mathematical Sciences*, vol. 7(97), pp. 4805–481, 2013.

[8] Grzonka, S., Grisetti, G., Burgard, W., A Fully Autonomous Indoor Quadrotor, *IEEE Transactions On Robotics*, vol. 28, pp. 90-100, 2011.

[9] Azfar, Z.A., Hazry, D., A Simple Approach On Implementing Imu Sensor Fusion in PID Controller for Stabilizing Quadrotor Flight Control, 2011 IEEE 7th International Colloquium on Signal Processing and its Applications, 7: pp. 28-32, 2011.

[10] Ömürlü, V. E., Kirli, A., Büyükşahin, U., Engin, Şeref Naci, & Kurtoglu, S., A stationary, variable DOF flight control system for an unmanned quadrocopter. *Turkish Journal of Electrical Engineering and Computer Sciences*, vol. 19(6), pp. 891–899. 2011.

[11] Baran, E.A., Hançer, C., Çalıkoğlu, E., Duman, E., Çetinsoy, E., Ünel, M., Akşit, M.F., Baran, Insansiz Hava Araçlari için Test Düzeneği Tasarimi ve Üretimi, Otomatik Kontrol Türk Milli Komitesi, Otomatik Kontrol Ulusal Toplantısı TOK'08, İstanbul, Türkiye, 2008.