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Review Article

Properties of Novel Tricopter And Comparision of Other Unmanned Aerial Vehicles

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Abstract

With the development of technology, the usage rates of unmanned aerial vehicles have increased. Although unmanned aerial vehicles were first used as counter-attack in army, they were also used for surveillance, reconnaissance, mapping and defence. In addition to this, have begun to be used for various purposes such as taking images from the air in the film industry, carrying cargo, traffic control, natural disaster search and rescue, fire warning and extinguishing, illegal building control. While the advantages of fixed wing unmanned aerial vehicles are that they can move quickly, the disadvantages is that long runways for take-off and landing. Rotary wing unmanned aerial vehicles have the advantage that they do not need runways because they can take off and landing in the same place, but they are disadvantageous because of their low flight time. The general name of the rotating wing unmanned aerial vehicle is drone. 4 propelled quadcopter and other multi-propelled multicopters are inefficient in energy management, 2 propelled bicopters are less manoeuvrable, tricopter is more advantageous than others. The tricopters have better maneuverability than other rotary wing aircraft thanks to the servo mechanism used in the tail motor. Tricopter's fixed body (moment arm of the rotor) which are endurance, ease of control, ease of to-downstream keeps constant the air vibrations and like many features stable flight. By using innovative tricopter aerodynamic mechanism, the moment arm of the rotors is provided with variability and performance/stability parameters are planned to be stabilized and kept in the air for a long time.
Key words: Rotating Wing Unmanned Aerial Vehicle, Tricopter, Drone.

Özgün Trikopterin Özellikleri ve Diğer İnsansız Hava Araçları ile Karşılaştırılması

Öz

Teknolojinin gelişmesiyle insansız hava araçlarının kullanım oranları artmıştır. İnsansız hava araçları ilk önceleri orduda karşı saldırı olarak kullanılsa da, gelişmeler ile birlikte gözetleme, keşif, haritalama ve savunma gibi amaçlar için de kullanıldı. Buna ek olarak, sinema endüstrisinde havadan görüntü çekimi, kargo taşıma, trafik kontrolü, doğal afet arama ve kurtarma, yangın ihbar ve söndürme, kaçak yapı kontrolü gibi çeşitli amaçlar için de kullanılmaktadır. Sabit kanatlı insansız hava taşıtlarının avantajları hızlı hareket edebilmeleri olsa da, dezavantajları kalkış ve iniş için uzun pistlerin olmasıdır. Döner kanatlı insansız hava araçları, kalkış ve iniş için uzun pistlere ihtiyaç duymama avantajına sahiptir, küçük düz bir alandan kalkış yapabilecekleri gibi iniş de yapabilirler, fakat kısa uçuş süreleri nedeniyle dezavantajlıdırlar. Dönen kanatlı insansız hava aracının genel adı drondur. 4 pervaneli dron quadcopter ve diğer çok pervanleli multikopterler enerji yönetimi konusunda yetersizdir. 2 tahrikli bikopter stabilite ve manevra kabiliyeti dezavantajlıdır, tricopter ise döner kanatlı insansız hava araçlarına göre daha avantajlı. Kuyruk motorlarında kullanılan servo mekanizması sayesinde, Trikopterler diğer döner kanatlı hava araçlarına göre daha iyi manevra kabiliyetine sahip. Başkalaşabilen özgün trikopter aerodinamik yapısnı kullanılarak, rotorların tork kollarının hareket etmesi sağlanır ve performans/stabilite parametrelerinin optimize edilmesi ve uzun süre havada tutulması planlanır.
Keywords: Döner kanatlı insansız hava aracı, Trikopter, Drone.

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1. Introduction

Unmanned aerial vehicles, which have been used in defense systems for the past 60 years and then used for different tasks such as surveillance and defense in the civilian sector, have become a popular topic today. Along with the developing technology and the ease of accessing materials, different tasks have been gained with the introduction of civil use. The cheaper cost of production, operation and maintenance than aeroplane or helicopter may be at the head of reasons for the unmanned aerial vehicles becoming the focus of attention. Other advantages of UAV can be easily adapted to user requests and the operator who controls the UAV is not in the vehicle so pilot does not have a vital danger in difficult tasks. Various UAV designs have been made to improve performance with developing technology. UAVs that are less vulnerable to human life can be seen as the reason for its popularity. On the other hand, they are more suited to flexible designs according to the tasks assigned to them. They can be used comfortably for tasks that are dangerous for human life with the reason that they need less human resources.It is also being used as a hobby by the users because of the easy of use.

Unmanned aerial vehicles are divided into two for wing. First of these are the fixed-wing unmanned aerial vehicles and other is rotating wings unmanned aerial vehicles. Fixed-wing unmanned aerial vehicles formally like an airplanes and require long runways to take off.

Rotating wings unmanned aerial vehicles dont need long runways to take off and land in opposed of fixed wings unmanned aerial vehicles. Rotary wing unmanned aerial vehicles of different forms, obtained by changing the number of rotors of the multicopter, have all been named differently. The name of rotary-wing unmanned aerial vehicles which has six propeller is hexacopter, optocopter has eight propeller and tricopter has three propeller.

The most popular rotating wing unmanned aerial vehicles are quadrocopter and helicopter. But tricopter has many advantage such as the longer battery life and longer maneuverability with the same battery than others. Rotary wing unmanned aerial vehicles generally consist of propeller, brushless motors, electronic speed control circuits, microcontroller, sensor unit and battery.

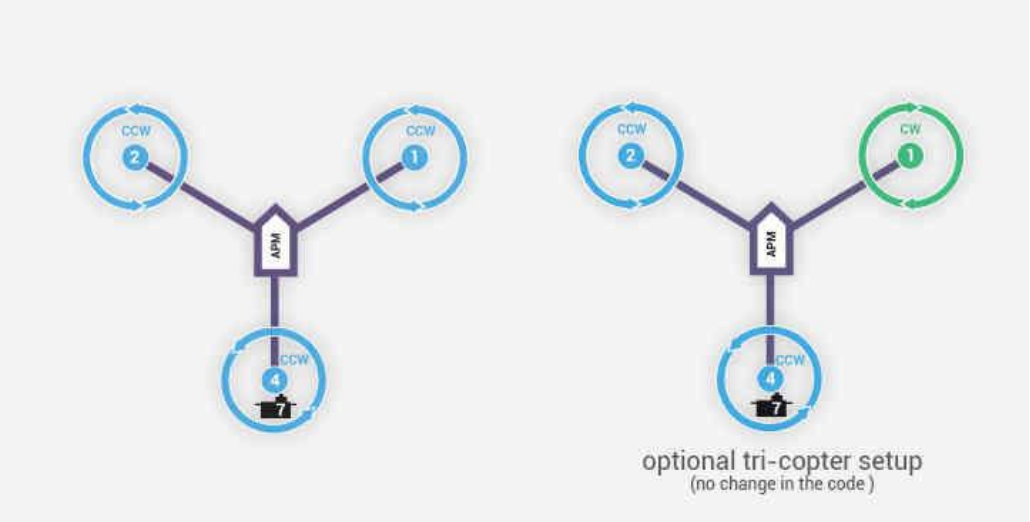
Unmanned aerial vehicles can be produced at low cost and started to be used in different areas. Thats why it has a popular especially with surveillance and defense applications. This development can be explained by the autonomous use of unmanned aerial vehicles and their ease of use. UAVs are sensitivity with the GPS and other sensors. The most important role in the development of unmanned aerial vehicles is the development of engine and battery technology and the cheapening of materials.

The balance, which is a common problem of rotating-wing UAV, also applies to tricopters. Tricopter requires a variety of sensors and servo in order to remain stable and fly stable or easy maneuverability. The basic sensors used in tricopter are gyro and accelometer. In addition, special sensors such as a magnetometer, a barometric pressure sensor or an ultrasonic distance sensor can be used in tricopter applications. These sensors can be used independently or with the help of a control card.

Compared to other unmanned aerial vehicles, the tricopter has a complicated structure and has several advantages, such as maneuverability and flight time.

As can be understood from the names of the tricopter is an unmanned aerial vehicle with 3 propellers. The tricopter, which have different designs, "Y" and "T" forms are highly preferred. It can be named in different names because it can be in different structures ("YCopter", "Tcopter"). Generally, they have 3 propellers, 3 brushless motors, 1 servo motor, 3 ESC (Motor Speed Control Card) and a control card. Servo motor is used in order to be able to easily maneuverable. Provides energy efficiency by using less energy than quadrocopter using 1 motor.

Figure 1: Formal Structuring of Tricopter



Referance: Ardupilot.org

Unmanned aerial vehicles need to be classified when considering performance characteristics. Some of these characteristics are weight, durability, flight time, maximum height, useful load carrying capacity, engine type and propulsion power.

Unmanned aerial vehicles can be operated with various energy sources such as gasoline, nitrous, fuel cell and electric battery. Less vibrations is desirable in aircraft because it is required for tasks such as camera shooting from the air, mapping, defense, and surveillance. Engines that use fuels such as gasoline or nitro are work more vibrant like they produce more power. Therefore, when unmanned aerial vehicles use sensitive equipment such as a camera, electricity is selected as an energy source.

The innovations of this study is morphing moment arm. Thanks to movable moment arm unmanned aerial vehicle is more stable and more economic. In bad weather, all aircraft cannot withstand wind force and cannot flight stable. Therefore autopilot systems have been developed and tried to flight wind resistant. This method is often useful for high-powered aircraft, but it is aerodynamically inadequate. The system made in this study allows the moment arm on which the motors are operated to extend and shorten.

Moment is directly proportional to the distance of the motors from the center. that is, the greater the distance of the applied position from the center, the greater the moment. The fact that the length of the moment arms increases the moment as well as the maneuver speed is disadvantageous in terms of features. Therefore, it is advantageous if the moment arms are short in smooth and windless weather, while the moment arms are long in case of flight in windy weather.

The morphism moment arm system is used in this study. It has active and passive morphing properties. When the autopilot senses windy air, it automatically activates the morphing system and extends the moment arms. Thus, the distance from the engines to the center increases and the flight becomes stable. In the case of passive morphing moment arm system, the user can optionally reduce flight vibration by extending the moment arms.

2. Material and Method

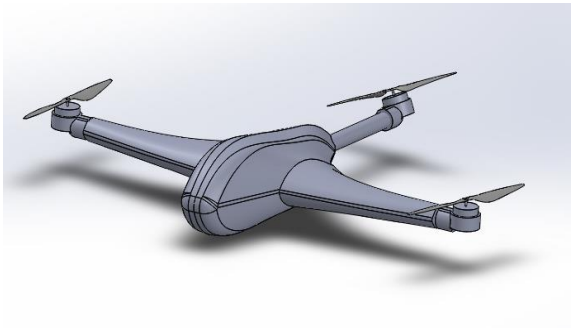
Our novel tricopter is aerodynamically efficient because it has moment arms and body in the form of a wing profile. In addition, it has the advantage of having the active and passive morphing mechanism and using energy efficiently. With the use of electricity sources not emitting greenhouse gases, produced less noise and pollution are reduced. Thanks to its transparent part in its body, it has a more esthetic appearance and it can carry camera is inside of the body. Thus it creates less drag resistance aerodynamically. With the autopilot system, it can reduces the risk of accidents.

Table 1: General characteristics of novel tricopter

Total weight	1.5 kg.
Useful load	0.5 kg.
Passive morphose	Used
Active morphose	Used
Range	10 km.
Flying time	30 min.
Max. Altitude	3000 m.
Transparent body	Used
Autonomus flying	Used
Airfoil	Used
Energy source	Electric battery

Novel tricopter is able to stay in the air for a longer time with less aerodynamic effect and less energy on cruise flights. Furthermore, the active and passive morphose mechanism provides a more stable flight by irregular weather conditions with the movement of the moment arms when the rolling control is not provided by the differential control of the main rotors.

Figure-2: Solid modeling of novel tricopter



2.1 Propulsion System of Novel Tricopter

Since the novel tricopter is planned to be used in scientific research, the power required by the tricopter engines should be at least multiple the total weight of the tricopter. The total weight of the novel tricopter is planned to be 1000gr. The tricopter needs to produce at least 3000 gr of thrust for the aircraft to be carry of 500 gr useful load. The 3,000gr thrust will share 3 engines on the tricopter. Therefore, each motor must be capable of producing at least 1000 gr drives. Based on these calculations, thrust system design is applied. Factors of affecting thrust system are propeller shape, engine speed, air density and speed of air in front of the propeller. When the air density is assumed to be 1,225 kg/m3 on a standard day at sea level, the thrust can be determined by the following formul;

$$F = 1.225\frac{\pi(0.0254*d)^2}{4}*\left[\left(rpm*0.0254*pitch*\frac{1\min}{60}\right)-\left(rpm*0.0254*pitch*\frac{1\min}{60}\right)*v_0\right]*\left(\frac{d}{3.29546*pitch}\right)^{1.5} \quad (1)$$

Staples G. (2013)

Expressions in the form;

- F is the force given in "Newton".
- rpm is the speed of rotation of the motor and is accepted as "rpm".
- The pitch is displayed in the form of the pitch angle "inch".
- V0 is the speed of air in front of the propeller and must be written in "m / s".

Simplified form of the formul;

$$F = 4.3924*10^{-8}*rpm*\frac{d^{3.5}}{\sqrt{pitch}}\left(4.2333*10^{-4}*rpm*pitch-V_0\right)$$

(2)

Staples, G. (2013)

When the values are placed on the formula, the thrust is given by the "Newton" unit.

2.1.1 Selection of Propeller

One of the most important steps in designing the thrust system in the novel tricopter is propeller selection. The propellers move the air using the cyclic motion that take motors. The surface must be smooth so that the propeler can be efficient. The selection of propeller also affects the all thrust system. In selecting the propeller, the diameter and pitch of the propeller is important. The diameter of propeller should be shorter than the distance between the motors. The diameter of the propeller indicates the distance between the two ends of the propeller. The propeller is manufactured as inclined to move the air. The propeller pitch is the distance taken on a tour of the propeller rotation. The last value to be considered when selecting propeller is CW and CCW propeller. Some of propellers turns clockwise (CW) while the other propellers turn counter-clockwise (CCW) while the tricopter shows its formal configuration.

According to the information we have obtained as a result of the experiments, when the propeller diameter increases and the propeller pitch does not change, the static thrust increases and the maximum speed does not change. The propeller diameter and pitch must be large enough to generate more thrust. More thrust allows for more load carrying. On the other hand, if other parts of the thrust system are insufficient, the system can cause major damage. In order to system to generate sufficient power, other units such as engine, ESC, battery must be compatible.

Figure-3: Solid Model Drawing of the Propeller Used in Tricopter

2.1.2 Selection of Motor

The most important part of the thrust system is motor. In the production or maintenance of the tricopter, the motors and motor drivers must be the same. It's decided to use electricity as the power source of the tricopter, electric motors must be use. Electric motors are divided into brushed and brushless motors. Although the brushed motors are simple to use, their torque and RPM values are low. Therefore, brushed engines are suitable for use in small-size unmanned aerial vehicles.

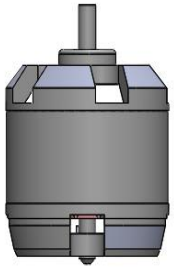


Figure-4: Solid Model of Brushless Motor Used in Tricopter

When choosing an motor, the motor KV value should be carefully selected. Motor KV value; is the unit of the cyclic speed when a 1V voltage is applied to the motor. When a 750 KV motor is supplied with 10 V, the motor will rotate at 7500 RPM. 7500 RPM is the data of the motor shaft rotates 7500 times in a minute. High current is used when the motor is at load or acceleration. The maximum current value is affects ESC selection at the same time. A thrust system designed without considering these values can cause overheating and fire.

2.1.3 Selection of ESC

After the engine selection, next step is choosing the ESC. One of the disadvantages of brushless DC motors is the need to have a controller for use. ESC is the part of the thrust system that controls the speed of the motor, that adjusts the voltage given to the motor. ESC is part of the thrust system that helps to control the speed of the motor. When ESC is selected, it is necessary to select 30% increase of the maximum current value of the motor or at least 10A more. For example, it is recommended to use an ESC of 40A in a motor where the maximum current value of the motor is 30A. The ESC can brake the motor.

Brushless ESC basically provides 3-phase AC power. There are 3 types of cables in ESCs used in brushless motors. The first of these is the battery power cable which consists of 2 cables. This cable is connected directly to the battery. The battery should also be compatible with the ESC. The latter is a control cable consisting of 3 thin cables. The control cable is connected to the control board and receives information about how fast the motor should turn. The last cable is connected to the motor. Motor connection is made from the 3 cable. If the direction of rotation of the motor is different from the designed direction, you should be replace any two of the motor connection cables.

Changing the propeller dimensions may cause the motor to overheat, or it may cause permanent damage if it exceeds the ESCnin values that give the motor power.

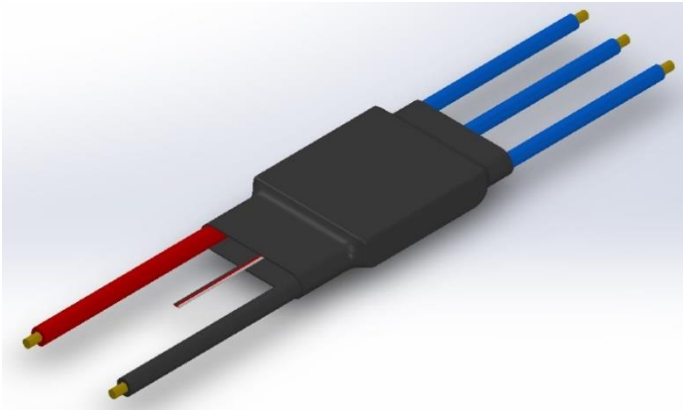


Figure-5: Solid Model Drawing of ESC Used in Tricopter

2.1.4 Selection of Battery

Lithium-polymer (Li-Po) batteries are chosen for unmanned aerial vehicles that use electricity as an energy source because they can deliver high current. Lipo batteries are the most popular source of energy in UAV due to their high power, light weight and long use. Lipo batteries have some disadvantages as they have advantages. The advantages and disadvantages of lipo batteries compare ni-mh and ni-cd batteries from rechargeable batteries are as follows;

Table 2: Advantages and disadvantages of using a Lipo battery

Advantage	Disadvantage
Lipo batteries are more light.	Lipo batteries have less life.
Lipo batteries have high capacities.	The sensitive chemical structures of lipo battarias are available to burn.
They may allow high discharge currents.	

There are 3 basic units to consider when choosing a Lipo battery. These units are number of cells, electric capacity and discharge current.

A cell in a Lipo battery usually has a 3.7V rating. We can find the voltage value of a battery that we know the cell number by multiplying by 3.7. The "S" on the battery reports the number of cells means cell. The "3S" battery can produce 3X3.7 = 11.1V. Some batteries have "S" and "P" values like "2S2P". This battery has 4 cells but 2 of them are connected in parallel and 2 of them are serial.

Figure-6: Lipo battery used in tricopter

Another important parameter of the Lipo battery is the capacity of the battery. The unit of capacitance is milliamper/hour (mAh). Although a high-capacity battery allows long flight, the battery should be well chosen as it will increase in weight. Assuming that the tricopter uses 9A on average, a 3000mAh battery can provide 20 minutes of flight.

Discharge rate is an important parameter especially in electric air vehicles. The unit of this parameter which is able to calculate the maximum current intensity that the battery can give is indicated by the unit "C". The current that the battery can safely deliver can be found by multiplying the amper/hour (Ah) by the discharge rate (C). For example, if the discharge rate of 3000mAh or 3Ah battery is 50C, this battery can deliver a maximum of 50X3 = 150A.

2.2 Avionic System of Novel Tricopter

Avionics; all electronic system used for communication and control. The general purposes of avionic systems include tasks such as communication, control and navigation for the aircraft. Avionic system must be used for the novel tricopter to fly safely. If the tricopter is to be used in special tasks such as security or search and rescue, it must have lighting systems to be easily recognizable. These lighting systems can also be called avionic systems.

2.2.1 Control System

The esc and servo motors are controlled using the information received from the sensors so that the tricopter can fly with stable.

2.2.1.1 Remote Control System

The control systems consist of receiver and transmitter modules. The transmitter module of the control system is located in the ground station and the commands given by the pilot are transmitted to the UAV. The control system must have a receiver module operating at the same frequency as the transmitter module. The receiver modul converts the radio signals, given from transmitter control movements into electrical power. Bandwidth of channel that receiver and transmitter modules use to operate the same radio frequency is a factor affecting the performance of the tricopter. One of the important parameters of the control system is the control distance. Control range and range of aircraft; the communication receiver and transmitter modules without disconnect the work area. Control distance is influenced by the environment of the air vehicle.

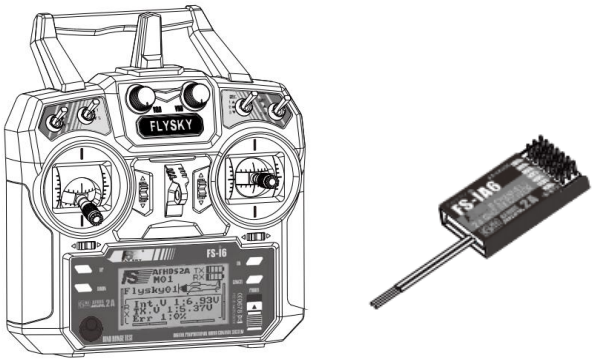


Figure-7: Transmitter and Receiver Used in Tricopter

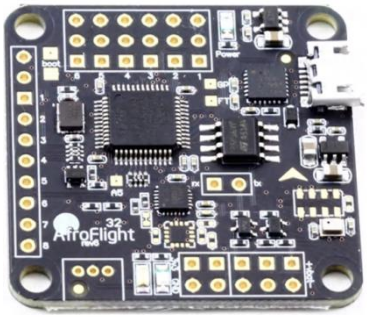
Referance: FS-i6 manual

2.2.1.2 Flight Control Card

Signals from the control system are processed on a flight control card. This flight control card allows autonomous flight thanks to a number of sensors and software in advance. The control card that works with the computer software specified by the flight control card manufacturer is set. The flight control card is connected to this program and settings can be made. The sensors that the flight control card has are:

- Accelerometer / gyroscope
-Magnetometer (magnetic compass)
-Barometric pressure sensor
-GPS connection

Figure-8: Flight Control Card used in Tricopter



2.2.1.2.1 Accelometer-Gyroscope

The use of a 3-axis gyro for inertial measurement can measure the novel tricopter speed. Allows the UAV's direction and position to be measured using gravitational force and processed at the flight control card. This sensor is also used in smartphones, tablets and wearable technology. It is easy to use with devices such as arduino with low energy usage. Sensor working with 3 accelerometers placed in 3 axes. In addition, the size of the sensor is small and the weight of the sensor is less influenced by the flight of the UAV.

2.2.1.2.2 Magnetometer

They are used to calculate the position of the UAV using the earth's magnetic field, which is used to calculate the magnetic field density. The magnetometer measures the magnetic forces of the medium in which the UAV is located. The measured value is processed on the flight control card to control of tricopter. It is used for navigating in tricopter. It is used in GPS systems, vehicle braking systems, mining and geological investigations, maritime and smart devices besides aviation.

2.2.1.2.3 Barometric Pressure

The barometric pressure sensor used to hold the altitude in the novel tricopter operates with high precision. The sensor, which calculates the static pressure of the medium by means of a tube, provides high precision and stability. Due to the UAV operating at low altitudes on high altitude flights, some sensors are difficult to operate. But the barometric pressure sensor is suitable for working between -40 and +85 degrees. It is also suitable for use in air vehicles with low energy consumption, small size and light weight.

2.2.1.2.4 GPS connection

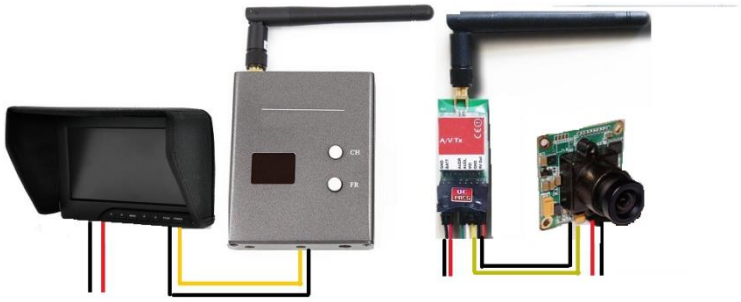
Despite not having a GPS system in flight control card structure, the device which can be connected to the control card depending on demand, is widely used in military and civil systems with usage convenience everywhere in the world. The GPS system needs to connect with 4 or more GPS satellites to work smoothly. The novel tricopter equipped with a GPS system is used to determine the precise location on earth.

Figure-9: Gps

2.2.2 FPV system

The First Person View (FPV) system is widely used in unmanned aerial vehicles. It operates by transmitting the image taken from the camera located on the air vehicle to the ground station. The system consists of a camera, a battery, a monitor, a transceiver radio module and a recorder. In addition, the OSD device is used to provide information such as speed, position, battery status of the UAV along with camera information to the ground station. Some FPV systems are equipped with a gimbal system that works with a gyroscope to capture images smoothly.

Figure-10: FPV System Schematic a) ground station b) UAV configuration



a b

2.2.2.1 Camera

It is preferred that the camera placed on the airplane is light enough to not affect the flight. In addition, the camera can be fixed on a servo to change the direction of the camera while the vehicle is in the air, and the servo mechanism can be fitted with spare channels on the flight control board. For the servos of such cameras to be available, the number of channels of the air vehicle control system must be suitable. Also available with Go-Pro-style lightweight cameras are systems that do not have telemetry requirements and are available with higher quality images.

2.2.2.2 OSD

On Screen Display (OSD) is a system that transmits parameters such as battery level to the ground station with the FPV system. In this way, the UAV control personnel can see that the battery level or attitude of UAV. In addition to the battery level, the OSD system can also add information such as position, status, and speed of the aircraft to the camera image.

2.2.2.3 Telemetry

Used to monitor and control a system remotely. The telemetry system is used in the FPV system when the video from the camera is transmitted to the ground control station. The operation of the telemetry system is affected by obstacles such as the mountain, building between the distance between two antennas. In addition, weather condtion such as rain, snow, fog, storm are factors that affect the quality of the system. The fields of application of the telemetry system are used in tasks such as meteorology, petroleum industry, space science, unmanned aerial vehicles technology, defense industry, rocket science, medical and health fields, fisheries and wildlife conservation.

2.2.2.3 Screen

It is an electronic device consisting of LCD panel which is used to process signals from telemetry system. Some FPV systems include systems that can be used as pilot glasses instead of monitors.

2.2.3 Lighting System

The Civil Aviation General Directorate must be illuminated in order to carry out UAV night flights according to the instructions for unmanned aerial vehicles. In order to easily detect the directions of the novel tricopter, the right moment arm is colored green, the left moment arm is red, and the aft moment arm at the rear of the tricopter is white.

2.3 Morphing System

The moment arm that connects the motors to the body will be subjected to less drag force when moving in the air with the reason that the shape is at the wing. Novel tricopter, which is exposed to less drag force, ensures fuel economy and performance. The novel tricopter is also designed with a morphic system so that it can fly more stable in bad weather condition like wind. The morphic system is realized by the extension of the moment arms in bad weather conditions by the help of servo motors built into the shaft of the wing profile.

The moment on the tricopter is taken according to the center of gravity. The large momentum of the lifting forces of each motor and the vertical distance of the centers of the lift forces to the center of gravity contributes to the more comfortable flight of the aircraft.

3. Results and Discussion

When selection material of novel tricopter, conceptional design should be prepared. In the concept design stage, the configurations of the aircraft components were selected by evaluating the different configurations in terms of compliance with the design requirements. In this design stage, novel tricopter features should be determined such as the working conditions, how heavy, which systems will be used. After the determine features of novel tricopter, solid modelling should be done. The structure of the novel tricopter should be optimized by numerical analysis of the solid model. Numerical modeling helps to make aerodynamic and system tests. Major changes should not be made in the production stage after the design is made. Because the changes that have been made may changes such as size and weight and performance will change and redesign is required.

Body configuration;

Most important design stage is choise a material of novel tricopter. Early aircraft designer want to make a more powerful and bigger aircraft, but modern UAV systems purpose that more flight time with less power. So that, material of UAV should be light and most effective. It is why composite material technology is popular in aerospace industry. Composite material allows that withstand higher loads and make lighter aircraft. Composite materials is more durable than traditional metarials. Fiber materials which are organic or inorganic in structure have many advantages such as strength and stiffness by combining with resin. Composite materials are also more advantageous than metals due to their easy shape change. Composite body has been preferred for novel tricopter manufacturing because of its many advantages.

Propulsion system;

Novel tricopter has three motor, propeller and electronic speed controller circuit. In addition, novel tricopter has one battery and servo motor. The propellers must have high strength because the propellers produce the forces necessary for the novel tricopter to fly. Carbon fiber composite material propeller was preferred. Thus, both lightweight, durable and flexible structure propeller was used.

As the propellers need to rotate fastly and powerful, a brushless DC motor, which can reach high torque and rpm values, is preferred. High power requires high current so Li-po battery with high current values is used. The propulsion system was determined considering the need of the novel tricopter. In the literature, the thrust requirements of rotary wing unmanned aerial vehicles are at least twice the total weight of the aircraft.

After the prototype extraction process is completed, two main tests are performed: thrust system tests and flight tests. As a result of these tests, the aircraft can be optimized. Thrust system tests are performed to ensure the compatibility between the electric motor, propeller, battery, electronic speed control circuit and receiver of the system and to obtain the best performance. Flight tests include flights that are recorded by means of a form of environmental parameters, especially air density, air temperature, wind strength and humidty content. The data gathered during the flight tests, the best flight time were considered and the success of the flight tests and the data were compiled.

The biggest difference between traditional and novel tricopter is the morphic mechanism. Novel tricopter has morphic moment arm. The motors are connected to these morphic moment arms. So, there will be a difference in torque between the moment arms when they are short and long. As the moment arms are longer, more force is generated. So that, it helps to achieve a more stable flight, especially in windy weather.

4. Conclusion

Unmanned aerial vehicles have become more popular than other aircraft due to many reasons such as cost, ease of use and safety. In unmanned aerial vehicles, rotating wings also have advantages compared to fixed wing unmanned aerial vehicles due to lack of runway needs, low speeds to fly and even hanging in the air. Unmanned aerial vehicles with rotating wings are useful and economical in small areas. Both conventional helicopters and multicopters have demonstrated superiority in tasks that require precision, such as imaging and mapping.

Errors were caused by vibrations in unmanned aerial vehicles with rotating wings used in aerial imagery, mapping and defense industries. In rotating wing unmanned air vehicles, helicopters with single propeller, have disadvantages such as complicated structures, vibrating and audible works; custumers search for new design of rotating wing UAV. Despite the preference for 4-engine and propeller UAV, which provide a more stable flight compared to the helicopter, maneuverability was limited and there were disadvantages with regard to energy consumption. Tricopters, which minimize the adverse effects of classical helicopters and quadrocopters, have proven themselves in recent years, such as fuel consumption and maneuvering. Tricopters, which are mostly used in hobby or academic researches that are not commercially produced, are aerodynamically inadequate and have problems due to unstable flying in bad weather conditions. In this study, the development of negative aspects of tricopter was discussed and propulsion system of novel tricopter was designed. Unlike other tricopter, the novel tricopter has improved stability and performance with aerodynamic body and morphic mechanism.

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References*:*

Maziar, A., Shane, A., Matthew, M., Matthieu, N., and Tong, Z. (2012). Classification of Unmanned Aerial Vehicles. The University of Adelaide

COŞKUN, M. Z. (2012) "Düşük Maliyetli İHA (İnsansız Hava Aracı) ile Mobil Harita Üretiminin Bugünü ve Geleceği", Harita Teknolojileri Elektronik Dergisi, vol: 4, No: 2, p.11-18

Nonami, K., Kendoul, F., Suzuki, S., Wang, W., and Nakazawa, D. (2010). Autonomous Flying Robots: Unmanned Aerial Vehicles and Micro Aerial Vehicles. Springer.

Merç, Y., and Bayılmış, C. (2011). Dört Rotorlu İnsansız Hava Aracı (Quadrotor) Uygulaması. 6th International Advanced Technologies Symposium (IATS'11), Elazığ, Turkey

Özdemir, U. (2015). Dikey İniş Kalkış Yapabilen Sabit Kanatlı İnsansız Hava Aracı Tasarım, Üretimi Ve Uçuş Testleri. İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul

Naze 32 Rev6 manual (2015), http://www.robotshop.com/media/files

Budiyono, A. (2007), Advances in unmanned aerial vehicles Technologies, Chinese science bulletin, Vol.52, No.1, pp.1-12.

MPU-6000 and MPU-6050 register map and Descriptions (03/09/2012), https://store.invensense.com/Datasheets/invensense/

OKTAY T., KONAR M., MOHAMED M. A., AYDIN M. , ŞAL F., ONAY M. (2016), Autonomous Flight Performance Improvement of Load Carrying Unmanned Aerial Vehicles by Active Morphing, *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering*, vol.10, p.123-132.

Staples, G. (2013). Propeller Static & Dynamic Thrust Calculation, http://electricrcaircraftguy.blogspot.com.

Barsk KJ. (2012), Model predictive control of a tricopter, Linköping, Linköpings universitet

Schneider, B. (2011). A Guide to Understanding LiPo Batteries https://rogershobbycenter.com/

Oktay T. , Konar M. , Onay M. , Aydın M. , Mohamed M. A. (2016), Simultaneous small UAV and autopilot system design, *AIRCRAFT ENGINEERING AND AEROSPACE TECHNOLOGY*, cilt.88, ss.818-834

Schofield, L. (2015). Understanding Electronic Speed Controllers (ESC) http://painless360.webs.com

Emma, M. Australia (2000) Propeller & Propulsion Terminology, http://www.propellerpages.com

Oktay, T. and Şahin, H. (2017). Powerplant system design for unmanned tricopter. The Euroasia Proceedings of Science, Technology, Engineering & Mathematics, vol.1, p.1-5

Noami, K., Kendoul, F., Suzuki, S., Wang, W., Nakazawa U., 2010. Autonomous Flying Robots, Unmanned Aerial Vehicles and Micro Aerial Vehicles. Springer, Tokyo, pp. 329.

Şahin, H., Oktay, T. (2017), Powerplant system design for unmanned tricopter, International Conference on Technology, Engineering and Science(IConTES), pp.1-14.

Karabulut, O., (2012) İnsansız hava aracı sistem tasarımı, date: Ocak 2018 site: (https://www.academia.edu/9558436/%C4%B0NSANSIZ_HAVA_ARACI_S%C4%B0STEM_TASARIMI).

Staples, G., (2013) Propeller static & dynamic thrust calculation, date of access: Jan. 2018, web pages: http://electricrcaircraftguy.blogspot.com),