CONSTRUCTING QUINT-ROTOR UNMANNED HELICOPTERS USING A H-AIRFRAME

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Abstract

In the recent years the interest in unmanned helicopters is growing due to the advent of efficient electric motors and batteries. The most abundant helicopters are the multi-rotor aircrafts with four rotors due to their simplicity and lower cost. Nevertheless, researchers, commercial users, organizations, institutions, companies and enthusiasts are planning on implementing unmanned helicopters with more than four rotors. A major element in the design process of these machines is its airframe. A thoroughly designed airframe may significantly increase performance and reliability of the aircraft.

The current paper focuses on airframes of quint-rotor aircraft and specifically reveals the benefits of a new quint-rotor airframe, called H-quint-airframe. The article discloses the benefits of the H-airframe for quint-rotors when compared to the classic quint-rotor helicopter airframes that are used by most parties at present day.

Keywords: Unmanned multi-rotor helicopter, Multi-rotor helicopter airframe, Quad-rotor helicopter, Quint-rotor helicopter

Introduction

Recently, more and more users are conducting research and are starting to use unmanned helicopters for their work, hobby, research or government activities. The most wide-spread unmanned helicopters are the multi-rotors and specifically the quad-rotors, due to their inherent simplicity and lower cost.

Helicopters with less than four rotors are prone to technological overburden from the additional mechanisms used to control their attitude such as collective and cyclic pitch control, tilting rotors, etc. But by increasing the number of rotors above four, the designer may achieve further benefits such as increased payload capability, improved durability and reliability and so on. That's why users are increasingly demanding helicopters with more than four rotors.

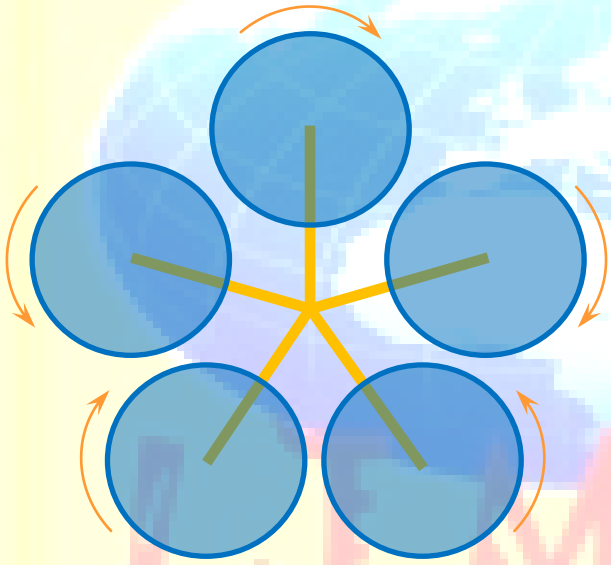

Figure. 1. General view of a "star"-airframe quint-rotor helicopter

The Quint-Rotor Helicopter Based on H-Airframe

The next step from the four-rotor helicopter is the five-rotor helicopter also called quint-rotor helicopter or quint-copter. The most popular airframe for quint-rotors is shown on Fig. 1. This "star"-airframe offers one additional rotor to the classic quad-rotor X-airframe (Fig. 2).

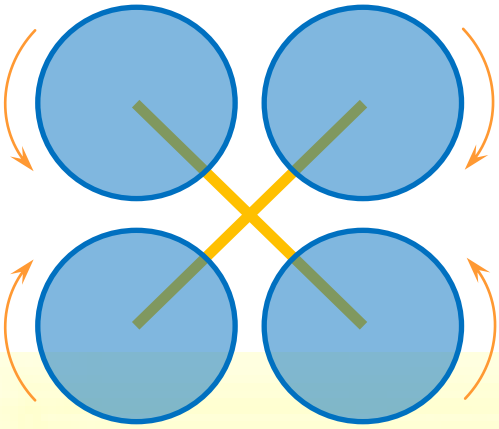

Fig. 2. Classic quad-rotor helicopter in "star"-configuration

The "star"-airframe of the quint-rotor helicopter benefits from the one additional rotor present and has higher lifting capability than its quad-rotor "star"-airframe counterpart. But its airframe structure exhibits certain drawbacks compared to the quad-rotor "star"-configuration. These are:

1. The "star"-quint-rotor aircraft has five beams instead of only two as used in the "star"-quad-rotor machine. This fact leads to fragility of the airframe. Further, the mounting of the five beams at the center of the airframe is harder to achieve and implicated increased weight.
2. The "star"-based quint-rotor is characterized with three right-handed rotors and two left-handed ones (see fig. 1). This imbalance yields three possible solutions in order to keep the integral yaw momentum zero:
    a. If the rotors are with same diameter and pitch then to cancel the yaw momentum of the airframe, the left-handed propellers should be rotating faster or putting out more power, which in the general case will overload these two rotors making them inefficient or unreliable.
    b. If the rotors are with same diameter and rotating with the same speed, in order to cancel the airframe pitch momentum, larger pitch angle of the left-handed propellers is required. Again, the left-handed propellers are working inefficiently or unreliably.
    c. If the rotors are rotating with same speed and have same pitch then, in order to cancel the airframe pitch momentum, larger diameter of the left-handed propellers is required. Such a solution seems better than the first two, but the larger propellers would require heavier motors, mounted on thicker beams making the

airframe non-uniform and hard to manufacture. This approach will also set the center of gravity off-center and make balancing of such a helicopter a challenge.

Further, similarly to the quad-rotor "star"-configuration, the quint-rotor "star"-airframe suffers from gyroscopic effects disturbing the airframe structure, as each beam, holding a given rotor, tends to torsion itself against the star center of the whole structure. The gyroscopic effect disadvantage is also present in the quad-rotor "star"-configuration, but with lesser exacerbation, because there are only two beams and they are passing through the star center, not ending there.

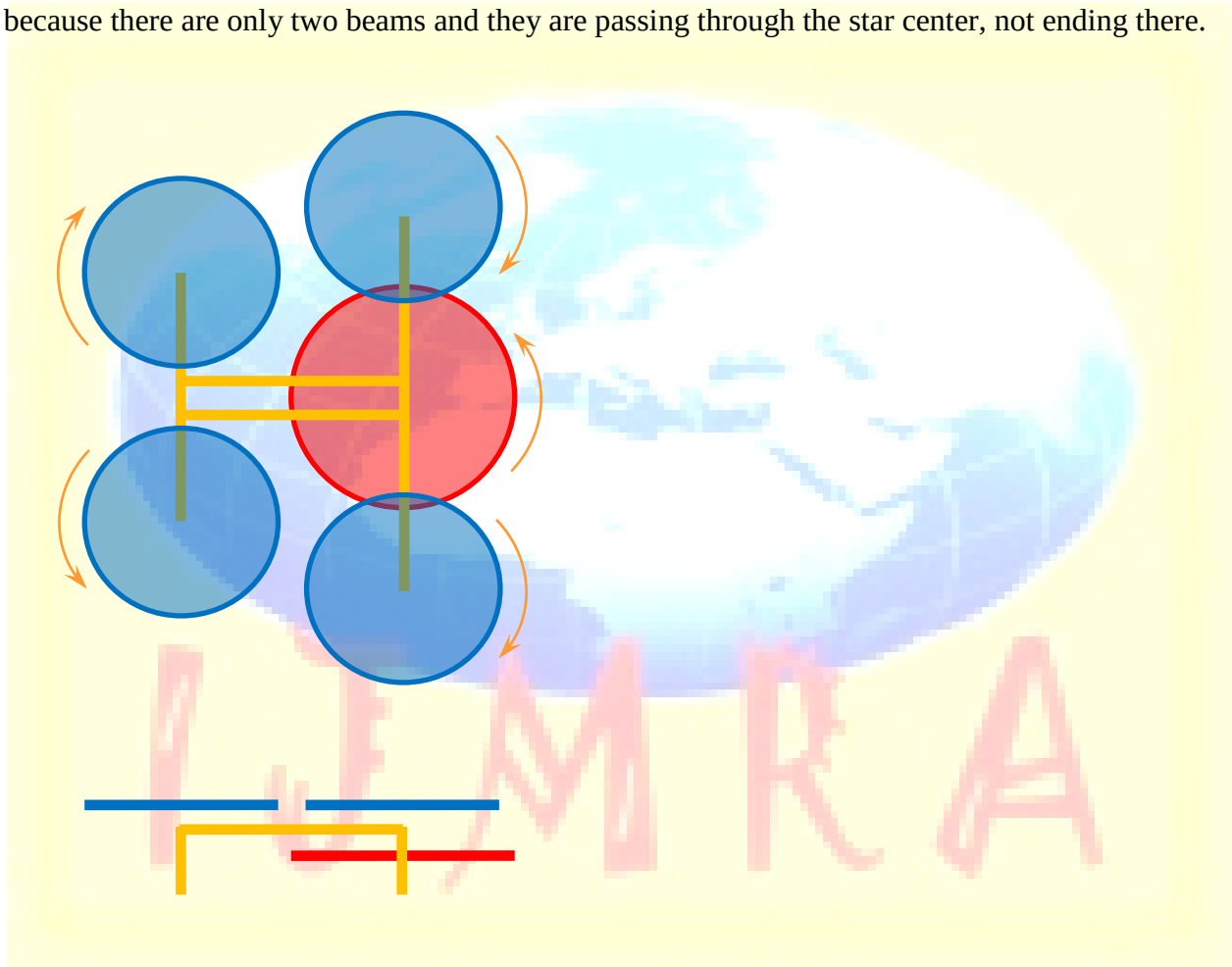

Figure 3. General view of an H-airframe quint-rotor helicopter (model XZ-1A). Above: top view, below: side view

The question arises "Is there a design of a quint-rotor aircraft that will diminish these drawbacks?". The answer is "There is!". The model XZ-1A is a quint-rotor aircraft (see Fig. 3), developed at the Space Research and Technology Institute at the Bulgarian Academy of Sciences that utilizes an innovative airframe, based on the H-airframe for quad-rotors (see Fig. 4).

The helicopter model XZ-1A shown on Fig. 3 dismisses two negative effects of the discussed airframes. The airframe of XZ-1A is based on the quad-rotor H-airframe of XZ-1 shown on Fig. 4 and inherits all its benefits. First of all this airframe has fuselage. The fuselage enables the comfortable mounting of units and modules. Further, setting the center of gravity is an easy task. One more benefit of using the H-airframe is when implementing first person view (FPV) platform. The camera can be mounted at the fuselage end in order not to be obscured by the propellers. The derivation of the XZ-1A airframe from XZ-1 airframe is made by implementing two alternations:

1. A new rotor is added below the airframe surface with a larger diameter propeller compared to the other four propellers. The rotation directions are changed according to Fig. 3.
2. The beam holding the fifth rotor is extended to accommodate three rotors with a small overlap.

As a result, the gyroscopic effect on each of the beams that hold the propellers is zero, just as is the case with the XZ-1 airframe. Further, the yaw momentum of the aircraft is kept zero by using the given configuration of propellers without overloading any of the propellers, in contrast to the quint-rotor aircraft with “star”-airframe from Fig. 1.

There is one further benefit of the configuration of XZ-1A helicopter. The fifth larger propeller, being under the airframe exhibits less aerodynamic drag of its airstream against the airframe thus achieving better efficiency.

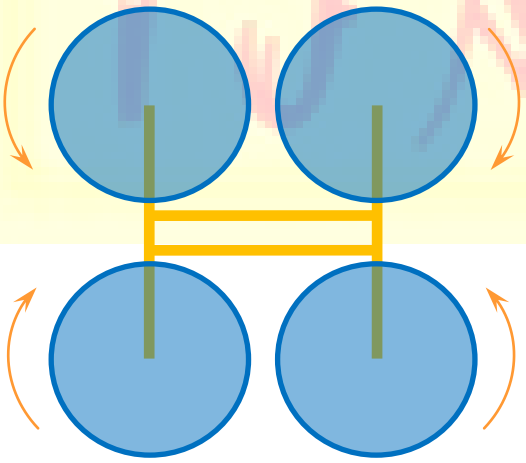

Figure.4. General view of an H-airframe quad-rotor helicopter (model XZ-1)

Conclusion

Quint-rotor unmanned helicopters are not as popular as the quad-rotor ones due to the absence of adequate airframes. The current paper offers an innovative and efficient quint-rotor airframe possessing a number of benefits that make it commercially attractive and still not as complex as six- or eight-rotor helicopters. The H-airframe formulation shows feasible not only to quad-rotor helicopters but for quint-rotor machines and even for aircraft with more than five rotors.

The authors are interested in new innovative developments concerning the H-airframe applied to unmanned multi-rotor aircraft.

REFERENCES:

1. Pounds, P., Mahony, R., Corke, P. (December 2006). "Modelling and Control of a Quad-Rotor Robot". In the Proceedings of the Australasian Conference on Robotics and Automation. Auckland, New Zealand.
2. Hoffman, G., Huang, H., Waslander, S.L., Tomlin, C.J. (20–23 August 2007). "Quadrotor Helicopter Flight Dynamics and Control: Theory and Experiment". In the Conference of the American Institute of Aeronautics and Astronautics. Hilton Head, South Carolina.