

H-Airframe Benefits for Constructing Quad- Rotor Unmanned Helicopters

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Abstract: *The H-airframe also called “fuselage”-airframe is a quad-rotor airframe structure that exhibits a number of benefits over the classical four-rotor helicopter airframes, but it is still underestimated and not widespread among designers. The current paper aims at disclosing these benefits and comparing the H-airframe against most well-known airframes used in the modern quad-rotor unmanned helicopters. Special attention is drawn to the dynamical characteristics of the H-airframe and how unmanned helicopters based on this airframe structure excel the standard quad-rotor airframes in mechanical rigidity, efficiency and maneuverability.*

Keywords: Quad-rotor unmanned helicopter, Unmanned multi-rotor helicopter airframe

1. Introduction

In the last few years unmanned multirotor helicopters became well known and are used by many, for professional purposes [1], entertainment, scientific research, education, etc. As it is well established, there is a minimum number of rotors that guarantees full control over the aircraft without the need for rotor tilting, control surfaces or cyclic and collective pitch control [2]. This number is four. Any greater number is feasible. The simplicity of the quad-rotors compared to hexa-rotors or octo-rotors for example, makes them widespread and with least cost among multi-rotor unmanned helicopters. Even professional users like the British police department are using quad-rotors for surveillance [1]. If the number of rotors is increased, several effects are obtained like lesser risk of catastrophic failure, lesser vibrations, greater stability, lower risk of injuries and larger payload capability. But the lower cost of quad-rotors and their simplicity makes them abundant among unmanned helicopter users [3].

The H-airframe is applicable to quad-rotors as well as to hexa-rotors and helicopters with larger number of rotors. The benefits and drawbacks of the H-airframe are almost the same when changing the number of rotors.

2. H-airframe benefits and drawbacks when implemented for quad-rotors

An H-airframe unmanned quad-rotor helicopter is shown on Fig. 1. It is distinguished from the classic star-configuration for it has a fuselage-like structure. Readily visible is the first major benefit of the H-airframe: there is plenty of room for mounting modules and electronic equipment on the fuselage. Further, one could see that balancing the payload and total weight of the aircraft and choosing center of gravity is an easy task with this setup.

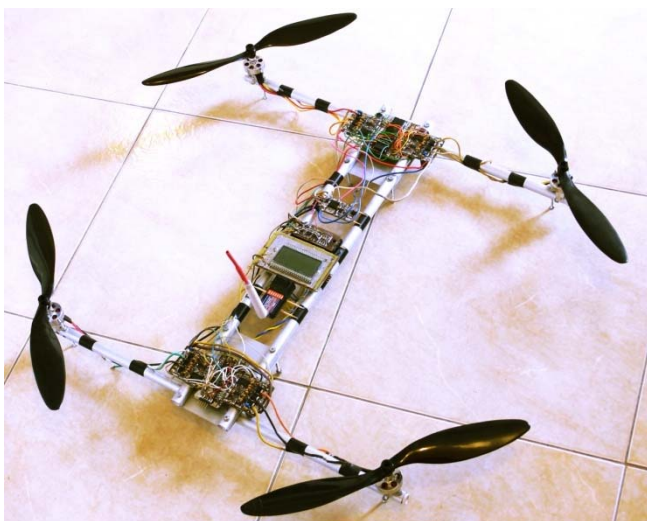


Figure 1: General view of an H-airframe unmanned quad-rotor helicopter (model XZ-1)

Figure 2: Classic quad-rotor helicopter in “star”-configuration

Let’s observe the dynamical characteristics of the H-airframe quad-rotor aircraft compared to the classical star-airframe helicopter. Fig. 2 shows a classic star-shaped

airframe used in most quad-rotor helicopters. The star-airframe is also called cross-airframe. It consists of two beams defining one plane – the horizontal plane of the airframe. The two beams of the cross-airframe helicopter are connected to each other at their centers at right angle. Usually this point of connection between the two beams is also the point of the airframe where most of the payload and electronics are mounted. The battery is also placed there making this point of the airframe overburdened with modules. Motors are placed at the beams ends.

Figure 3: XZ-1 helicopter is based on the H-airframe also called configuration “fuselage”

Fig. 1 and Fig. 3 present the airframe schematic of XZ-1. XZ-1 is an experimental quad-rotor unmanned helicopter being developed at the Space Research and Technology Institute at the Bulgarian Academy of Sciences. XZ-1 is in the H-configuration. The H-airframe has a fuselage and two beams connected at the ends of the fuselage at their centers. The beams meet the fuselage at right angles. The fuselage and the beams lie in one plane. This plane is horizontal. Motors are mounted at beams ends. The benefits of this configuration exceed its drawbacks and for this reason the given design was used in the first model of the XZ series. It was already mentioned the ease of module and unit mounting on the fuselage and the simple center of gravity determination. But the benefits of the H-airframe do not end here. The inevitable torsion and bending of the helicopter airframe may present attitude distortion. Classical airframe based quad-rotor aircraft may even exhibit catastrophic flight due to dynamical distortion.

Dynamical stability of the H-airframe is rather superior to the star-configuration in the following three aspects:

1. In the H-airframe the four rotors are mounted in tandems on two beams and on each beam the rotor pair is counter rotating, thus effectively cancelling the gyroscopic effect of the beam as a whole structure (see Fig. 3). On the X-airframe structure there are similar gyroscopic effects inherent to each beam that are not cancelled, but instead magnified, because each rotor pair is rotating in the same direction (see Fig. 2).
2. The only torsion that the H-airframe exhibits during predictable flight is when executing yaw orientation

change. With this maneuver twisting of the fuselage occurs. This torsion accelerates the yaw motion in the desired direction if the proper rotation directions of the rotors are chosen as depicted on Fig 3 and Fig 4. Thus the H-airframe has higher efficiency of the yaw orientation change process compared to the X-airframe.

3. Because the different units of the avionics and payload are spread along the fuselage, the moment of inertia along the pitch axis is increased compared to the X-airframe based quad-rotor helicopters, thus making the H-airframe helicopter more stable.

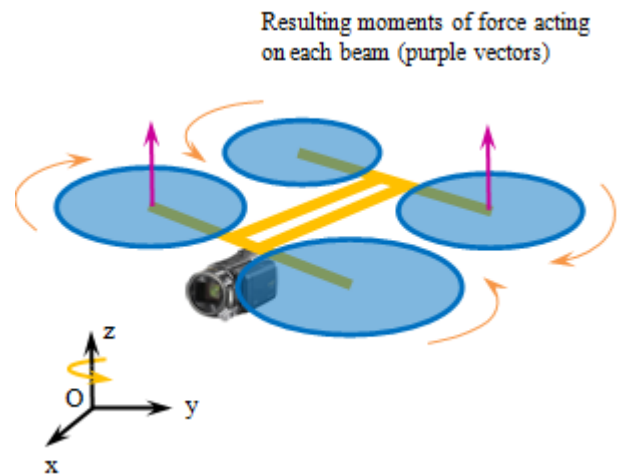


Figure 4: Dynamical characteristics of the H-airframe quad-rotor helicopter during left yaw turn and first person view camera mounting.

Another benefit of using the H-airframe can be seen on Fig 4. In many situations quad-rotors are used for video monitoring purposes and on their airframe a first person view video camera (FPV) is mounted. The best place to attach the camera is to one end of the fuselage. As seen on Fig. 4 camera view will not be “shadowed” by the propellers as is the case with the X-airframe aircraft.

Of course, there are drawbacks to this design. The major drawback is that the H-airframe is heavier than the X-airframe for the same rigidity, but the difference in weight is not more than 10%, which is bearable, when compared to the many benefits the H-airframe offers to the unmanned helicopter designer and user. Another drawback is the somewhat larger overall dimensions of the aircraft. The latter disadvantage is due to the presence of fuselage, which implicates larger distances between the rotors (see Fig 3).

3. Future Scope

Authors are in development of quite a few new models of helicopters in the XZ series, most of which are based on the H-airframe paradigm, but with different number of rotors. All models with H-airframes show similar benefits as does the quad-rotor helicopter XZ-1 when compare to modern standard air-frame multi-rotors.

4. Conclusions

The fast increase in unmanned helicopter usage draws attention to analysis of the existing designs and raises

interest in scientific research for superior new designs. The XZ-series offers the opportunity to demonstrate the benefits of the new designs, some of which are developed at the Space Research and Technology Institute at the Bulgarian Academy of Sciences. XZ-1 helicopter serves as a test bed for experimentation and research.

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