High-Speed Unmanned Octo-Rotor Helicopters

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ABSTRACT

The importance of unmanned aircraft is increasing in the last few years. Although unmanned aerial vehicles were used long ago even before WWII, the advance in electric motor technologies and battery chemistries has made possible for a broad range of users to utilize in their projects and activities the unmanned multi-rotor helicopters.

Multi-rotor helicopters help in a number of situations, from scientific research to man rescue operations. Their most significant drawback is that they hardly withstand wind and travel at low speeds thus having very limited range.

The current paper presents novel development of high-speed unmanned multi-rotor helicopters that solve to great extend these problems by utilizing vertical propulsion propellers in order to achieve high-speed of flight. Two models of the experimental XZ-series are described.

Keywords: High-speed unmanned multi-rotor helicopter, multi-rotor helicopter with pusher propellers, Octo-rotor helicopter

INTRODUCTION

The most unfavourable features of helicopters are their low maximum speed limited by the nature of their propulsion. The main rotor or rotors in multi-rotor helicopters have to create linear force component in order to achieve linear motion, but this force causes the propellers to start working non-efficiently and also the retreating blades gradually enter in a stall area where they create no lift. Fixed wing aircraft are ideal for fast speeds, but the ability of helicopters to hover and vertically take-off and land makes them precious in a number of situations where fixed wing aircraft are unable to fulfil the tasks required. Solution to some of these scenarios comes from the vertical take-off and landing aircraft (VTOL) with fixed wing. Although these aircraft have best efficiency of fast flight, they carry a fixed wing, which during hovering operations only burdens the machine and lowers it hovering efficiency.

Figure 1. Sikorsky X2. Type: experimental. Phase: retired

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The vertical propeller helicopters are a compound type of vehicle that has no fixed wing, but nevertheless can fly fast, much faster than conventional helicopters at high efficiency levels using propulsion vertical propellers either in pusher or tractor configurations.

The current material proposes a novel design of two multi-rotor compound unmanned helicopters with vertical propellers made for high speeds and efficient hovering operations.

Figure 2. Sikorsky S-97. Type: military. Phase: development

HISTORY OF COMPOUND HELICOPTERS

One of the most famous models of compound helicopters is Sikorsky X2 experimental aircraft (see Figure 1).

Figure 3. Eurocopter X3. Type: experimental. Phase: testing

This model although novel has already been retired after 22 hours of flight. It has proven successful and is followed by a serial helicopter designated S-97 Raider high-speed scout and attack helicopter (see Fig. 2). Attained max speed is around 300 MPH in level flight. The model X2 has coaxial rotors and is using a pusher 6 blade propeller to achieve the high speeds that other standard helicopters cannot fly at.

Another design with similar features but with single rotor and two tractor propellers is the Eurocopter X3 shown on Fig. 3. The X3 can fly at 255 knots in level flight and has set so far an unofficial speed record for a helicopter. To counteract the retreating blade stall phenomenon X3 uses small wings that at high speeds generate up to 80% of the required lift.

Figure 4. Mil Mi-X1. Type: passenger. Phase: development

Yet another example of a compound helicopter with pusher propeller and single rotor is the Mil Mi-X1. It is designed to accommodate 25 passengers and has radius of 1,500 km. The helicopter's single main rotor and the absence of wings establish the need for a special system that will overcome the retreating blade stall. Mil has a solution for removing this problem by offloading the main rotor using a proprietary Stall Local Elimination System (SLES).

Figure 5. Kamov Ka-92. Type: passenger. Phase: development.

Kamov have a compound model as well. It is the Ka-92. This helicopter has coaxial rotors and two pusher counter rotating propellers. It is in development at present.

Figure 6. Piasecki X-49. Type: experimental. Phase: testing

Piasecki X-49 SpeedHawk is the last model of compound helicopters that are observed. No other in fact exists. SpeedHawk is based on a production Sikorsky UH-60 Black Hawk. The efficiency using the compound concepts is increased; its range is also increased. The maximum speed is made higher.

OCTO-ROTOR COMPOUND HELICOPTERS DESIGNED USING THE H-AIRFRAME PARADIGM

The XZ-series of helicopters are designed by the cooperation between Zabunov Design Bureau and Space Research and Technology Institute at the Bulgarian Academy of Sciences. A number of multi-rotor models are created, but two of these recent models are of interest to the current publication. Zabunov XZ-2A (see Fig. 8) and Zabunov XZ-2B (see Fig. 9) are compound multi-rotor unmanned helicopters with eight lifting propellers and one pusher propeller for model XZ-2A and two counter rotating pusher propellers for model XZ-2B. Both models are based on Zabunov XZ-2 (see Fig. 7), which is an H-airframe inspired multi-rotor unmanned helicopter.

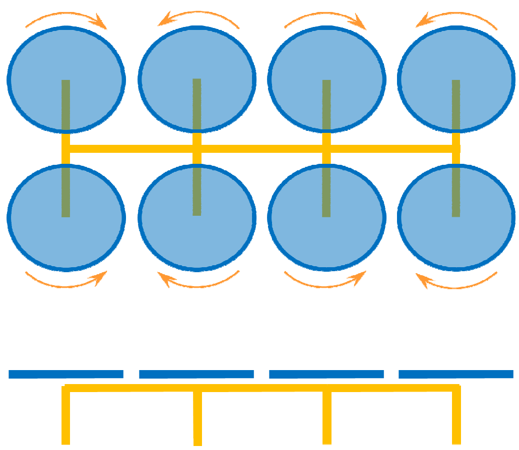

Figure 7. Multi-rotor unmanned helicopter experimental model Zabunov XZ-2

Model XZ-2 is a small unmanned helicopter weighting only 1600 g. It is H-airframe based, which gives it a number of benefits, but it is still conventional multi-rotor helicopter and has limited maximum speed. This fact makes it unsuitable for long-range operations and also prevents it from flying in winds with speed over 40 km/h.

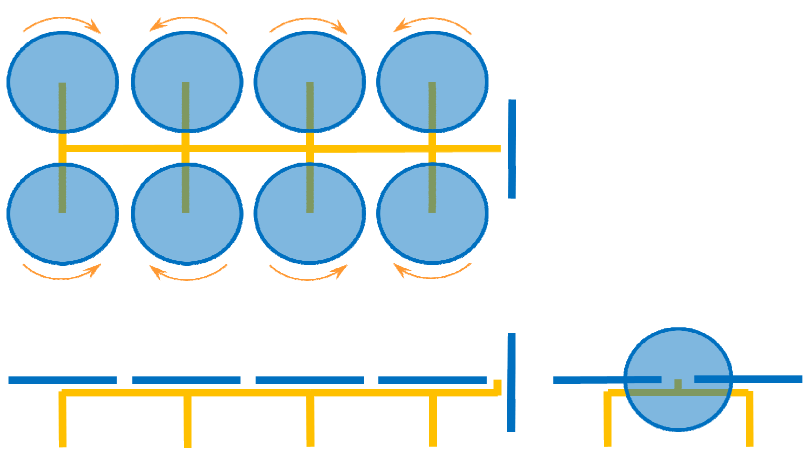

Figure 8. Compound multi-rotor unmanned helicopter experimental model Zabunov XZ-2A

Building on XZ-2 airframe two models were developed using compound techniques. The XZ-2A model is derived from XZ-2 by only attaching a vertical pusher propeller at one and of its fuselage. The increased weight of the machine is only by 5% or 80 g. The benefit is that XZ-2A may fly with speeds of up to 76 km/h and still have acceptable efficiency of flight.

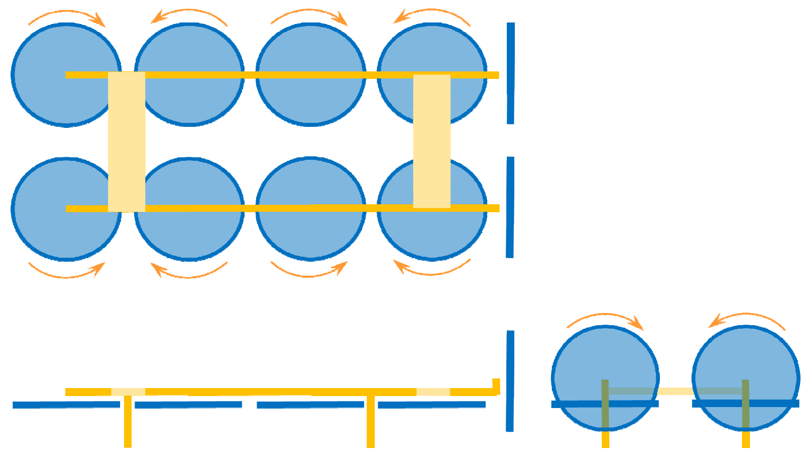

Figure 9. Compound multi-rotor unmanned helicopter experimental model Zabunov XZ-2B

To increase the efficiency and top speed even further, model XZ-2B was devised. Its differences from XZ-2A are as follows:

1. XZ-2B has considerably more aerodynamically sound airframe consisting of double instead of single fuselage when compared to XZ-2A. There are no transverse beams causing drag.
2. The two fuselages are interconnected with two small wings thus attaining higher efficiency of forward flight.
3. All lifting propellers are on the bottom side of the structure thus decreasing propeller airflow drag against the airframe.
4. There are two instead of one pusher propeller. These two propellers have larger area and are counter-rotating thus increasing efficiency of the propulsion system.

The drawback of XZ-2B is that it has heavier airframe and overall weight than XZ-2A, but it is capable of speeds exceeding 100 km/h and its greater flight efficiency compensates for the larger weight.

RETREATING BLADE STALL PROBLEM AND THE XZ-COMPOUND HELICOPTER MODELS

The retreating blade stall problem inherent to high-speed helicopter flight in piloted helicopters is solved by different means. Some of these were mentioned above and include small wings, coaxial rotors and so on. The multi-rotor helicopters of the XZ-series have this problem originally solved by their design. The rotors compensate each other for the stall area they exhibit in their propellers area during high-speed flight. Observe Fig. 10 and Fig 11. XZ-2A and XZ-2B are immune to the retreating blade stall problem. Although almost half of the propeller area of each lifting propeller is stalled during high speed flight there are always two propellers in tandem placed symmetrically and transversely against the fuselage or fuselages and thus balancing their lift force and diminishing the negative effect of the retreating blade stall.

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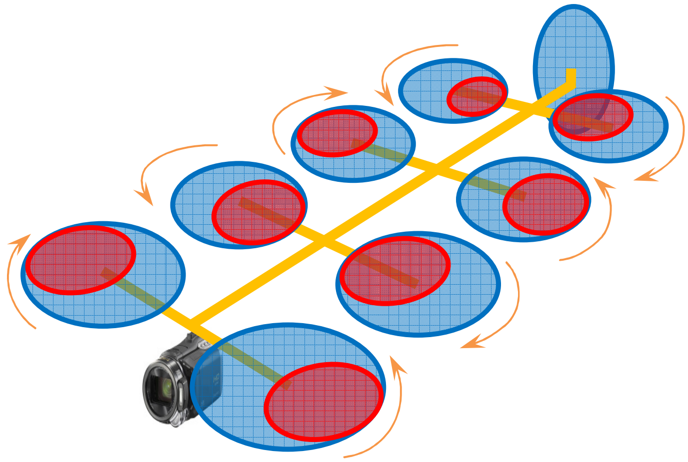

Figure 10. Retreating blade stall in XZ-2A

On Figures 10-11 the stalled areas of each lifting propeller are shown in red. The airframe of XZ-2B is planned in such a manner not to overlap the non-stalled propeller areas with the small wings. This is needed to avoid disturbances between these lifting surfaces.

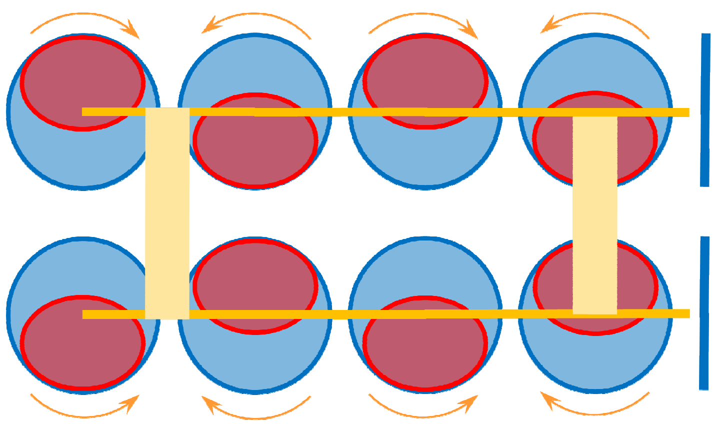

Figure 11. Retreating blade stall in XZ-2B

CONCLUSION

Multi-rotor helicopters are getting ubiquitous. But, just like with larger helicopters, small unmanned machines are not suitable for high speed operations. On the other hand fixed wing aircraft need runway or in the case of vertical take-off and landing vehicles the heavy fixed wing is often an undesired feature of the aircraft.

Either for the piloted large helicopters or for the unmanned small aircraft the solution is the compound type of helicopter. Authors have presented two models with excellent capabilities and novel architecture. Further enhancements are under development and new models are coming soon.

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