# INCREASING OF POWER CHARACTERISTICS OF MINI UAV HELICOPTER BY CHANGING OF ITS GEOMETRICAL PARAMETERS

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**Abstract:** *The article discusses two types of quadrotor rotor designing. Lifting force, produced by one rotor and pair of coaxial rotors is considered. Distributions of air velocity and air pressure are calculated by help of Computational Fluid Dynamics. Changing of lifting force with changing of rotors length is considered also. It is shown that the lifting force created by coaxial rotors is about 50 % higher than the force created by one rotor. The force created by quadrotor is depend on rotor length and with changing of length of upper or lower rotor this force will be changed.*

**Keywords**: UAV, HELICOPTER, QUADROTOR, ROTOR, LIFTING FORCE, CFD

## 1. Introduction

Unmanned aerial vehicles (UAV) are widely used in various civil and military applications. The interest to this kind of vehicles is growth in the academic circles due to small size, unique flight capacities, outstanding maneuverability and low cost of mini UAV.

Quadrotor helicopters are one of the most popular types of UAV platforms. Some research groups designed their own helicopters [1 - 6]. There has been investigated various research areas such as software design and integration [7], modeling identification [8, 9], control techniques implementation [10, 11], aerial image processing [12 - 16] and so on.

This article discusses lifting force of rotors on the base of a quadrotor (Fig. 1), designed by NIU ITMO [17]. It has two pairs of counter-rotating rotors located at the four corners of the aircraft. This construction allows compensating axis torques, created by rotors. The using of four rotors ensures that individual rotors are smaller than the equivalent main rotor on a helicopter for a given airframe size [18]. The smaller rotors store less kinetic energy during flight and can be enclosed within a protective frame, permitting flights indoors and in obstacle-dense environments with reduced risk of damage to the vehicles, their operators, or surroundings.
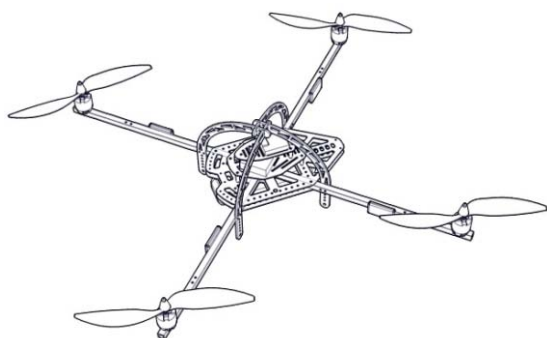


*Fig. 1 Quadrotor helicopter model.*

In this paper are described and compared quadrotors with one rotor on the axis and quadrotors with two coaxial rotors. The lifting force, created by rotors, is calculated by using of Computational Fluid Dynamics (CFD) software SolidWorks Flo Simulations [19]. According to previous experimental results [20], the maximal difference between calculated values of lifting force and values obtained during experiments is ca 3 %.

## 2. Object of research

Quadrotors can be designed with one rotor on the axis (Fig. 2*a*) and with two coaxial rotors (Fig. 2*b*).
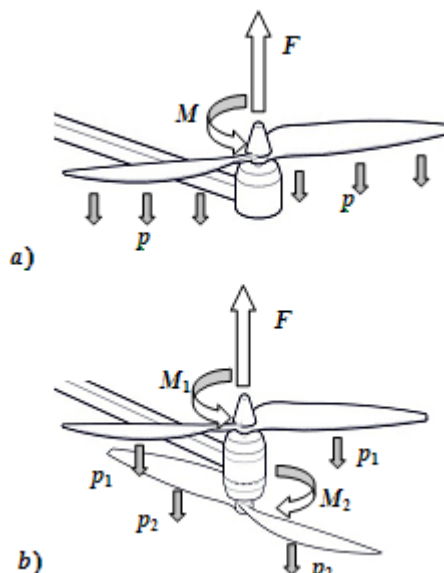


*Fig.2 Rotors of quadrotors.*

Rotors provide lifting of the helicopter and its horizontal moving in air. It is carried out owing to an air current created near the rotor and directed down (Fig. 3). The torque turning the quadrotor can be compensated by rotation of rotor pairs in the different direction.
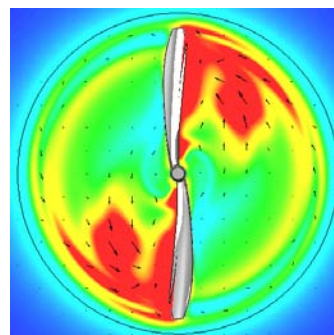


*Fig.3 Air stream near the rotor.*

In quadrotors with two rotors they are located on same axis and rotated in different directions. In this case torques created by rotors compensates each other. The upper rotor creates an air current directed on lower rotor. According to this fact the lifting force created by lower rotor will be decreased.
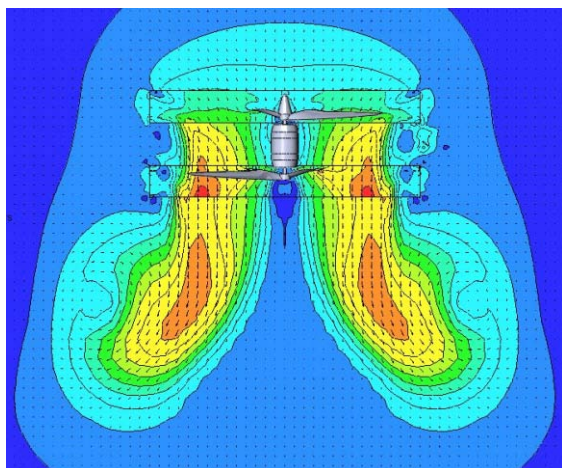


*Fig.4 Air velocity distribution near the coaxial rotors.*

Let us consider changing of lifting force produced by one rotor and by two coaxial rotors with changing of rotation velocity of rotors. Changing of lifting force created by pair coaxial rotors with changing of rotor length will be considered also.

## 3. Test results and discussion

In first series of experiments used one rotor and determined force that is produced on different rotation speeds of this rotor. Rotors 10 x 4.5 from Draganfly Innovations (DF-1045CR) are used. Rotor length is 10 inches and the pitch is 4.5 inches per revolution.

Lower pressure region appears near upper rotor edge (Fig. 5). Same time upper pressure region appears near lower edge, and this pressure difference, according to Kutta–Joukowski theorem [21], creates lifting force. Max pressure difference ca 6500 Pa at rotor rotation speed 7500 rpm. One rotor produces 7.03 N lifting force on 7500 rpm. Force dependence from rotor rotation speed is shown on figure 6.
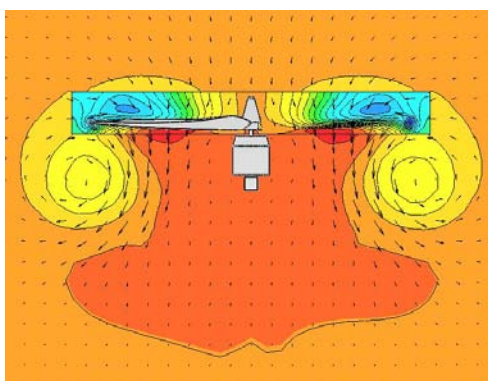


*Fig.5 Pressure distribution near the rotor.*

In second experiment series pair of coaxial rotors is used. Dependency of lifting force created by rotor pair on rotor rotation speed is also shown on figure 6. One can see that the lifting force increases with increasing of rotor length and the largest force is creating by two coaxial rotors. The lifting force, created by two rotors is however only about 50 % more than force created by one rotor. Difference of created forces grows with increasing of angular

velocity. At small velocities forces are practically same in all investigated rotors. Lifting forces created by one rotor with length 10 inches and pair of same rotors increase accordingly 3 and 5 time in comparison to lifting force created by one rotor with length 8 inches at angular velocity 5000 rpm.
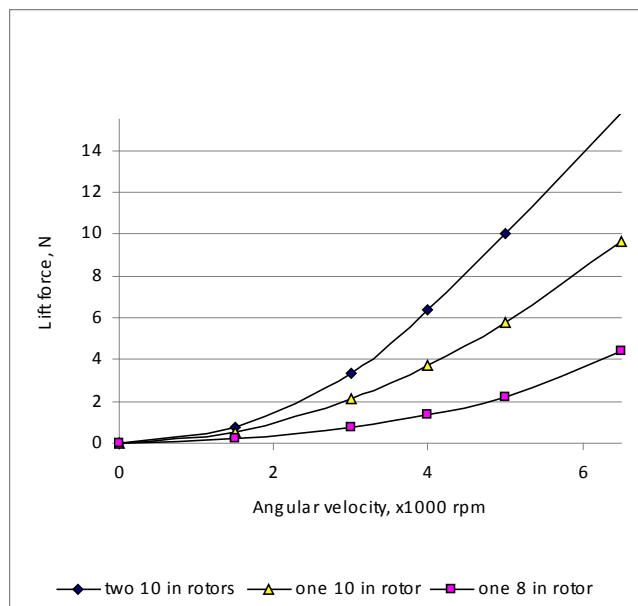


*Fig. 6 Lifting force created by rotors.*

Let us consider now lifting forces created by two coaxial rotors with changing rotors length. Three different combinations of rotors pair will be considered (Fig. 7). First will be analyzed rotors pair with length 10 in (Fig. 7a). Then lower rotor will be exchanged by rotor 8 in (Fig. 7b) and the last combination will be consisting of upper rotor 8 in and lower rotor 10 in (Fig. 7c).
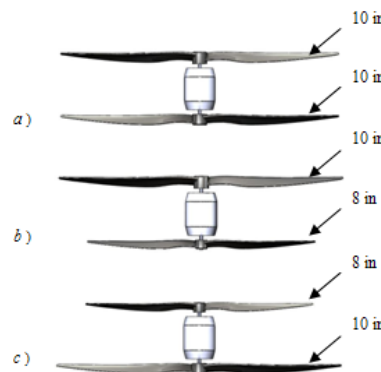


*Fig. 7 Combinations of coaxial rotors.*

Results of analyzing are presented on figure 8. It is shown that the rotors with length 10 inches create the largest force. The upper rotor creates larger force and because of this in combination 10/8 (Fig. 7b) lifting force is larger than in combination 8/10 (Fig. 7c). The increasing of force values in comparison with force produced by one 10 in rotor is about 50 %, 20 %, and 5 % for rotor pairs 10/10, 10/8, and 8/10 accordingly. On base of this it is possible to say that the efficiency of one rotor is more than the efficiency of two coaxial rotors. Energy consumption in helicopters with one rotor will be less than the energy consumption in helicopters with pair of coaxial rotors for lifting of one and the same load.

Lifting force created by rotor pairs is also depend on distance between rotors. The results of these analyzes are shown on figure 9. Here are investigated rotor pairs (Fig. 7) with distance between rotors 46 mm, 56 mm, 66 mm, and 76 mm. Values of lifting force were measured at all three combinations of rotor pairs at angular velocity 5000 rpm.
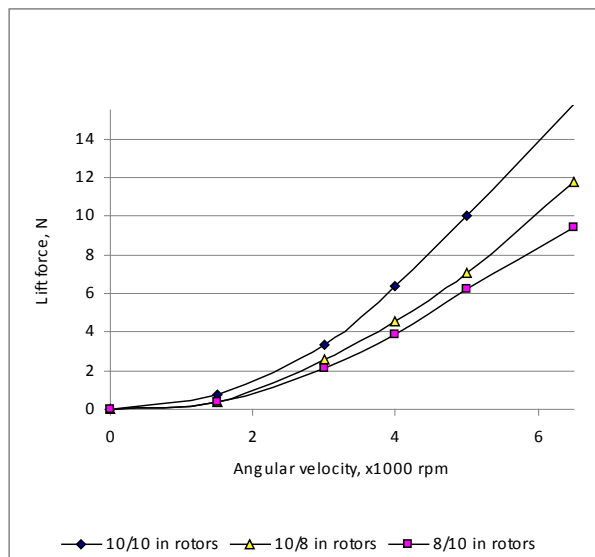
*Fig.8 Lifting force created by rotor pairs.*

The figure 9 shows that lifting force in rotors pair with same rotors decreases with increasing of distance between rotors. This decreasing is about 20 % at increasing of rotors distance 60 %. Contrary to this lifting force changes insignificantly in rotor pairs with different length.
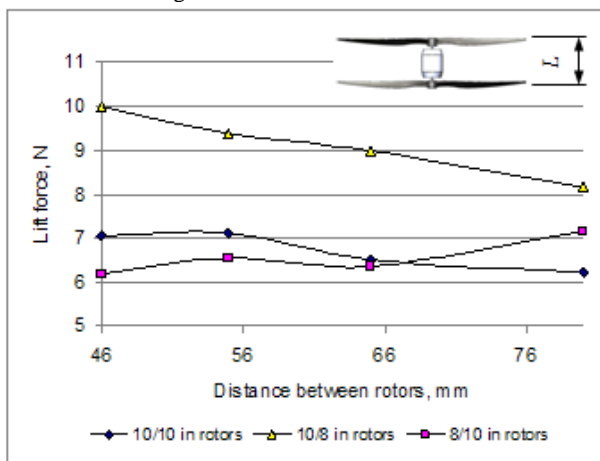


*Fig.9 Dependency of lifting force created by two coaxial rotors on distance between rotors.*

## Conclusions

Lifting forces created by one rotor with length 10 inches and pair of same rotors increase accordingly 3 and 5 time in comparison to lifting force created by one rotor with length 8 inches at angular velocity 5000 rpm.

The lifting force created by rotor pair is depend on rotor length and its position in the pair. In frame of this research it was consider rotor pairs with 10 in and 8 in rotors. 10/10 rotors pair creates the largest force and 8/10 rotors pair creates the smallest force. The increasing of force values in comparison with force produced by one 10 in rotor is about 50 %, 20 %, and 5 % for rotor pairs 10/10, 10/8, and 8/10 accordingly.

Force created by rotors pair with same rotors decreases with increasing of distance between rotors. This decreasing is about 20 % at increasing of rotors distance 60 %. Contrary to this lifting force changes insignificantly in rotor pairs with different length.

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