Hovering ceiling of an electric multicopter

© S.Z. Sverdlov

Vologda State University, Vologda, 160000, Russia

The article considers the hovering ceiling of an unmanned electric multi-rotor helicopter (multicopter) — the height where all available power is equal to the power required to hovering with a given flight weight. In determining the static ceiling of the electric multicopter, the aircraft features distinguishing them from conventional helicopters, are taken into account. It is found that the hovering ceiling of an electric multicopter is determined by the thrust-to-weight ratio and rigidity of the electric motor mechanical characteristics. The analysis of a typical quadrocopter configuration shows that the value of the hovering ceiling can be at least 5000 m. The dependence of the hovering ceiling on the supply voltage is studied; the decrease of the voltage significantly affects the hovering ceiling. The dependence for the minimum value of the thrust reserve ensuring the flight of the multikopter at a given decrease in the supply voltage during the flight is *deduced from the formulae for the hovering ceiling. The formula and tables for calculating the minimum thrust-to-weight ratio, allowing estimation of these values when designing a multikopter, are given.*

Keywords: *unmanned electric multi-rotor helicopter, multicopter, static ceiling, hovering ceiling, thrust reserve, thrust-to-weight ratio, brushless motor*

REFERENCES

[1] Johnson W. *Helicopter Theory*. Princeton University Press Publ., 1980 [In Russ.: Johnson W. Teoriya vertoleta. In 2 books. Moscow, Mir Publ., 1983].

[2] Sverdlov S.Z. *Izvestiya vysshikh uchebnykh zavedeniy. Aviatsionnaya tekhnika — Russian Aeronautics*, 2017, vol. 60, no. 2, pp. 163–168.

[3] *Beskollektornyy motor T-Motor MT3506 650kV* [Brushless motor T-Motor MT3506 650kV]. Available at: http://www.rcteam.ru/t-motor/mt3506/25.html

[4] Ovchinnikov I.E. *Teoriya ventilnykh elektricheskikh dvigateley* [Theory of ac converter-fed motor]. Leningrad, Nauka Publ., 1985, 164 p.

[5] Xia Ch.-l. *Permanent magnet brushless DC motor drives and controls*. John Wiley & Sons Singapore Pte. Ltd. Publ., 2012. ISBN 978-1-118-18833-0

[6] Pritsker D.M., Sakharov G.I. *Aerodinamika* [Aerodynamics]. Moscow, Mashinostroenie Publ., 1968.

[7] Brandt J.B., Selig, M.S. Propeller Performance Data at Low Reynolds Numbers. *49th AIAA Aerospace Sciences Meeting, Orlando, FL, January 2011*. AIAA Paper 2011–1255.

[8] Sverdlov S. *Kvadrolet* [Quadrocopter]. Available at: http://forum.rcdesign.ru/blogs/174358/blog18011.html

[9] Kamov N.I. *Vintovye letatelnye apparaty* [Propeller aircrafts]. Moscow, Oborongiz Publ., 1948.

[10] Magnussen Ø., Ottestad M., Hovland G. *Modeling, Identification and Control,* 2015, vol. 36, no. 2, pp. 67–79.

Sverdlov S.Z., Cand. Sc. (Eng.), Assoc. Professor, Department of Applied Mathematics, Vologda State University. Research interests: information technology, digital photography and image processing, unmanned helicopters. e-mail: c3c@uni-vologda.ac.ru