

## STAND FOR TESTING AND CONTROLLING THE OPERATING CHARACTERISTICS OF PROPELLERS OF MINI UNMANNED AERIAL VEHICLES

In recent years, there has been a rapid advancement in the design and production of unmanned aerial vehicles (UAVs), particularly in the segment of mini- and micro-platforms intended for use across various domains, including research tasks, aerial imaging, cargo delivery, environmental monitoring, as well as military operations [1].

One of the primary objectives in the development of propellers for mini-UAVs is obtaining reliable experimental data that enable the assessment of thrust performance and propeller efficiency under real operating conditions, since the aerodynamic characteristics of propellers significantly influence flight efficiency, control stability, and autonomous endurance.

The development of a compact, modular, and cost-effective test bench for single-propeller evaluation of mini- and micro-UAVs is therefore an essential task. The device must allow rapid experimentation with different propeller types while capturing key parameters – thrust, voltage, and current consumption – with high accuracy and stable repeatability. Having reviewed existing test benches for UAV propeller evaluation [2,3,4], a three-dimensional model of the housing was designed, the bench was assembled, and experimental tests were conducted for 7-, 8-, and 10-inch propellers [5].

The development of the proposed test bench was based on methodologies presented in a number of scientific publications, which also addressed issues of measurement accuracy, structural adaptability, and optimization of assembly. A significant advantage of the proposed bench – while maintaining the fundamental principles such as thrust, current, and voltage measurement – is its implementation in a compact and mobile form factor (*Figure 1*). A real-time visualization module was also integrated.

The test results demonstrated high repeatability (up to  $\pm 5\%$ ) and confirmed that the experimental data align with theoretical dependencies

between thrust, rotational speed, and power consumption. The thrust-RPM characteristics exhibited the typical linear trend with saturation at higher rotational speeds [1], whereas the current-load relationship corresponded to internal resistance models.

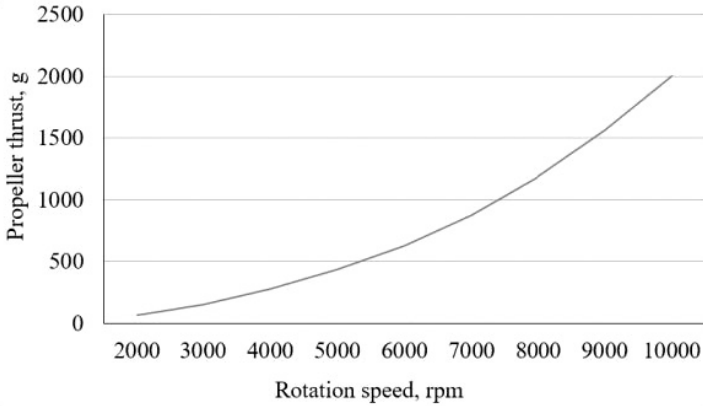


*Figure 1 – Measurement system of the test bench*

The data obtained during the testing process make it possible to perform a comprehensive evaluation of the aerodynamic and energy efficiency of the tested propellers, as well as to analyze the performance characteristics of different size categories under specified operating conditions.

When comparing the characteristics of the tested propellers, several patterns consistent with established blade aerodynamic models of air propellers can be observed. In particular, an increase in propeller diameter leads to higher generated thrust at the same rotational speed, which is explained by the increased effective blade surface area. However, this also results in higher load on the motor.

In this context, the 8-inch propeller demonstrated the optimal thrust-to-power-consumption ratio, especially within the 60–80% range of maximum RPM (*Figure 2*). This provides an advantage when selecting components for lightweight mini-UAVs, where energy efficiency is a critical parameter. Similar conclusions were reported in [1], where the importance of balancing thrust performance and energy consumption during propeller selection was emphasized.



*Figure 2 – Optimal dependence of propeller thrust on revolutions per minute*

Repeated tests showed that the measurement deviation did not exceed 3–5% for thrust and 2% for electrical parameters [6]. The use of preliminary calibration and the elimination of external influencing factors (such as airflow disturbances from nearby objects and unstable power supply) ensured the required measurement accuracy. These results are comparable to those presented in [4], where measurement deviations also remained within a 5% margin.

The research outcomes and comparative analysis of existing solutions allow us to identify several significant advantages of the proposed test bench over analogous systems described in scientific literature and engineering practice.

One of the key advantages of the bench design is its compactness and portability. All components are mounted on a small base, and the housing is made of lightweight plastic. This makes the setup convenient for transportation and rapid deployment in various environments – from laboratory settings to outdoor field conditions – unlike bulky stationary stands such as the one presented in [1].

The test bench is designed for rapid deployment without the need for complex tools. The components used can be easily configured through open-source software, and calibration does not require specialized professional equipment.

Despite its structural simplicity, the setup provides stable and accurate measurements. Experimental trials confirmed the correct operation of the bench – the obtained dependencies correspond to theoretical models, and deviations between repeated measurements do not exceed 5%. The capability to perform repeated experiments with a high degree of reproducibility makes the bench suitable for scientific applications and engineering design tasks.

The use of readily available components and the possibility of local manufacturing (for example, 3D-printing of the housing) make the proposed test bench a cost-effective solution.

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