Results of measurements carried out for the purpose of determining the center of gravity of a convertiplane-type UAV

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Abstract.
Currently, due to the increasing accuracy required to determine the center of mass and gravity, the development of methods and technologies in this direction remains a high priority. In the research work, the characteristics of the available methods and tools for determining the flight load and centering, as well as the analysis of the research work on determining the center of mass of the aircraft, calculating the weight and centering cost were carried out. When designing and preparing aircraft, in order to increase the efficiency and safety of their flights, it is required to correctly determine their loading, centering and center of gravity. The methodology of using the "balance-mass" method, which is widely used in determining the center of gravity of aircraft, was developed in our research conducted for this purpose - in the example of a convertiplane-type UAV. It is known that it is possible to determine the coordinates of the center of gravity of gliders beforehand based on survey books. This data only corresponds to the state of the glider without load and not on the final delivery. The article also describes the essence and capabilities of the developed method for determining the center of gravity of the aircraft with higher accuracy. The results of theoretical and experimental studies on the creation of a system for determining the weight and center of gravity of the UAV in practice are shown. The proposed system construction model is presented.

Keywords:
Center of gravity
weight
loading
unmanned aerial vehicle
tiltrotor
weighing
Accurate determination of the mass and center of gravity (CG) of the aircraft (UA) before flight, as well as correct loading and centering, play an important role in improving the efficiency and safety of flights. Calculating the center of gravity, loading and balance of the aircraft is one of the main procedures in ensuring high flight safety [1, 2].

All aerodynamic forces and effects affecting the glider of an aircraft during flight are going on around its center of gravity. Therefore, its location (centering) has a significant impact on the stability and controllability of the aircraft [3-5].

In our research, it has been reported about determining the center of gravity of the "Skywalker X8 Flying Wing 2120mm", developed on the basis of a fixed "flying wing" and which is the basis of the convertiplane-type UAV, by moving the front part 440 mm backward and 5 mm back and forth in the direction of the central axis [4-8]. These values correspond to the condition that the glider is not equipped with additional details and equipment.

The aim of the work is to determine the coordinates of the real center of gravity of the convertiplane-type UAV in static mode along the x and z axes.

Methodology of measurements carried out for the purpose of determining the center of gravity of the convertiplane-type UAV

Tools
Laboratory table, balance measurer, four scales, length measurer (meters).

Preparation for work
1. 4 digital "B05" brand scales with one percent accuracy are taken;
2. Measuring accuracy of scales is determined by measuring the weight of the standard load;
3. The laboratory table is taken and the horizontality of its surface is ensured. A "level gauge" tool is used for this purpose;
4. The 4 carbon tube legs of the convertiplane are replaced by legs made of aluminum alloy tube with flexible steel springs attached at the ends;
5. The scales are placed on the table with the measuring surfaces at the same level so that when the UAV is placed on the scales, each of its legs is in the middle of their measuring surfaces;
6. The integrity of UAV is checked, as well as the fastening of its elements and assemblies.

Conducting an experiment
1. UAV is placed onto the scales by placing its legs in the middle of the measuring surfaces;
2. The indication of the scales placed under the 1st and 3rd legs is noted \((m_1, m_3)\);
3. The indication of the scales placed under the 2nd and 4th legs is noted \((m_2, m_4)\);
4. The points where the legs of UAV are connected to the arms (support points): The distance \(L\) between the 1st and 3rd and 2nd and 4th legs is measured diagonally with a length measurer: \(L = a + b\);
5. Based on the obtained experimental weight values, the coordinates of the center of gravity of UAV are calculated by the WW formula on both axes (the location is determined)
\[
b = \frac{L \cdot m_1}{m_1 + m_3}.
\]
6. If the centers of gravity on both axes are different, their intermediate point \((\hat{IP})\) is established by the parallelogram rule;

![Figure 1: The diagram of determining the center of gravity of the UAV based on the experimental weight values by the parallelogram rule](image)
7. If the intermediate point falls to the right or left of the central axis, then double measurements are made by shifting the loads and calculations are performed again according to the original formula; Measurements are repeated until the center of gravity falls on the central axis. **Results of measurements:**

According to the methodology, the flatness of the laboratory table was made horizontal with the level gauge and the measurement errors of the digital measuring scales were checked based on the results of measuring the load of 1 kg as the standard load. The measurements were repeated 100 times by changing the position of the scales in a clockwise direction. Due to obtaining the different centers of gravity on both axes of aircraft and the intermediate point fell outside the central axis (to the right or left, back and forth) according to the results of the measurements, double measurements were made by shifting the loads in the appropriate direction to ensure centering during the measurements (table 1). Based on the final results, based on the calculated values of the coordinates of the intersection points of the diagonals, the diagrams of the centers of gravity were created in the "AutoCAD-2020" program with the parallelogram rule. Based on the final results and the calculated values of the coordinates of the intersection points of the diagonals, the diagrams of the centers of gravity were created in the "AutoCAD-2020" program with the parallelogram rule.

The final graph has been created by means of the program based on the established diagrams, the mean square deviation error of the aircraft from the axis of symmetry is equal to \( \sigma = 0.047 \) (Fig. 1).

Based on the weight values measured by means of electronic scales placed under the legs, the coordinates of the center of gravity of the convertiplane-type UAV were calculated along the axes connecting the leg points diagonally. Using the measured and calculated values, the center of gravity of the UAV is graphically depicted in the "AutoCAD-2020" program. Due to the fact that the coordinates of the centers of gravity on both axes are different, an intermediate point was established by the parallelogram rule to find the center of
gravity. Based on the optimization performed using the mean square method, it was found that the mean square deviation error of the intermediate point deviation from the central axis is: \( \sigma = 0.047 \text{cm} \). Thus, the high efficiency of the "scale-mass" method applied to determine the center of gravity was confirmed.

<table>
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<th>Study number</th>
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If additional engineering or design work is carried out on the aircraft with a defined center of gravity, it is advisable to re-measure the distance between the legs and the weights on the legs, recalculate and specify the coordinates of the center of gravity.

References:

