ABOUT THE INFLUENCE OF WIND ON THE ACCURACY OF LOAD DISCHARGE

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Abstract. *This article describes the procedure for calculating the demolition of ammunition depending on the wind speed in the conditions of its discharge from a hovering aircraft. Calculation formulas for calculating the drift of cargo in the presence of a crosswind are given, without taking into account and taking into account the force of air resistance. A linear dependence of the load drift on the factors affecting it, as well as its own characteristics, is derived. The results of the study make it possible to make the necessary adjustments in the practical delivery of goods, which will have a positive impact on the accuracy of the cargo drop.*
Keywords: *aircraft, cargo drop accuracy, formula, wind speed, gravity, air resistance force, average rate of descent, height, initial speed, free fall acceleration.*

In recent decades, the delivery of goods has acquired the widest scope. Large companies and individuals are engaged in the delivery of goods, using the means at their disposal for this. However, if the delivery of goods in cities and their suburbs does not cause big problems, then the same issue becomes extremely difficult under conditions of great remoteness of the delivery point, in conditions with severe climatic conditions, as well as with an undeveloped road network. The use of manned aircraft justifies itself only in the case of the delivery of a large consignment of cargo, but it is not advisable from an economic point of view when delivering small consignments or a single cargo.

The development of unmanned aerial vehicles has made it possible to introduce these tools into the process of delivering goods. These devices, after entering the delivery coordinates into the navigation system, independently deliver the goods, assessing the risks during the flight and making adjustments to the flight trajectory.

At the same time, when dropping the delivered cargo from a certain height, the accuracy of cargo delivery may be unsatisfactory, that is, it may have deviations. One of the main factors influencing the occurrence of deviations is the wind. Taking different directions and values at different heights, wind flows have a significant impact on the accuracy of cargo delivery when it is dropped from a certain height.

The relevance of this article is in considering the issues of determining the calculation formulas for determining the amount of drift of the load depending on the wind speed, without taking into account and taking into account the force of air resistance.

One of the factors that significantly affect the accuracy of the fall of the load is the wind. Typically, the wind vector changes with altitude. However, this change in wind has little effect on the trajectory of the load. Therefore, a simplification is adopted: the wind is constant in all layers of the atmosphere lying below the aircraft, and in direction and speed it is equal to the wind at the height of the load drop. This means that if the wind affects the aircraft and the cargo, then its trajectory differs from the trajectory in calm conditions [1].

The forces that affect the load when it is dropped from the quadcopter are shown in Fig.1. Gravity mg acts on a freely falling load towards the ground, the profile of the load causes the appearance of an air resistance force R, which is directed opposite to the force of gravity. Wind force F wind contributes to the deviation of the load from the aiming point.

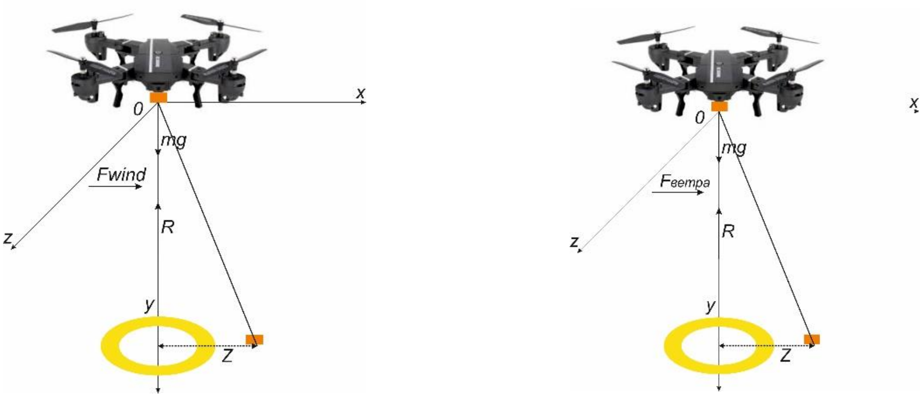


Fig. 1. Forces acting on the load when falling

The projection of the displacement of the dropped body on a horizontal plane under the action of the wind is called the drift of the body (Z) and is calculated by the formula:

$$Z = v_w t_d = h v_w / v_d \quad (1)$$

where Z - is the drift value, m;

t_d - time of lowering the body, sec;

v_w - average wind speed, m/s;

v_d - is the average rate of body descent, m/s;

h - drop height, m.

It follows from formula (1) that the drift value is directly proportional to the wind speed, the time of the body's descent and the height of the drop, and is inversely proportional to the average speed of the body's descent.

According to the laws of free fall physics, which describe the movement of a body under the influence of gravity, a body falling from a height will move at a speed that will increase in proportion to time until the body reaches the earth's surface. The force of gravity acting on a body depends on the height of the body above the surface of the Earth. When bodies fall from a height that is small compared to the radius of the Earth, the force of gravity can be considered constant. In such cases, we can assume that the acceleration of a freely falling body g remains constant (9.8 m/sec), and that a freely falling body moves forward, rectilinearly and uniformly accelerated [2].

The formula for the average speed of a load falling without taking into account the force of air resistance is as follows:

$$v = gt = \sqrt{\frac{2h}{g}} = \sqrt{2gh} \quad (2)$$

Hence, combining formulas (1) and (2), if the force of air resistance is not taken into account, the amount of drift of cargo when dropped from a hovering aircraft from a certain height with an initial speed v0 will be determined by the following formula:

$$Z = hv_w / v_d = hv_w / \sqrt{2gh} = \sqrt{\frac{h}{2g}} v_w \quad (3)$$

Note that the value of the load drift in formula (3) does not depend on its mass. Table 1 shows the results of calculating the drift value, and in fig. Figure 2 shows a graph of changes in the drift of cargo depending on the strength of the wind, provided it is dropped from a stationary aircraft hovering at a height of 100 m.

Table-1

Load drift table when dropped from a height of 100 m

Drop height, m	Gravity acceleration, m/s2	Wind speed, m/s	Drift, m
100	9,8	1	2,3
		2	4,5
		3	6,8
		4	9,0
		5	11,3
		6	13,6
		7	15,8
		8	18,1
		9	20,3
		10	22,6

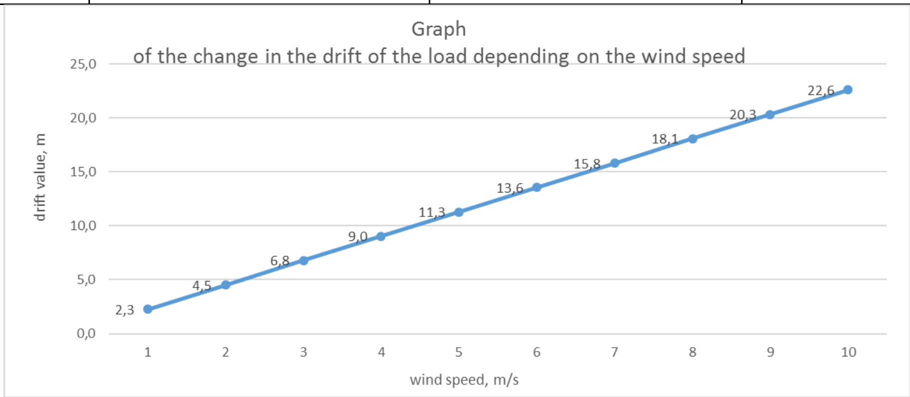


Fig. 2. Graph of the demolition of cargo when dropped from a height of 100 m.

The graph shown in Fig. 2 shows a linear dependence of the load drift depending on the wind speed. It must be remembered that the graph reflects the data obtained without taking into account the force of air resistance.

To obtain year-round data on average values of ammunition drift, we will use the data given in [3], which reflects the average wind speeds in Tashkent by months.

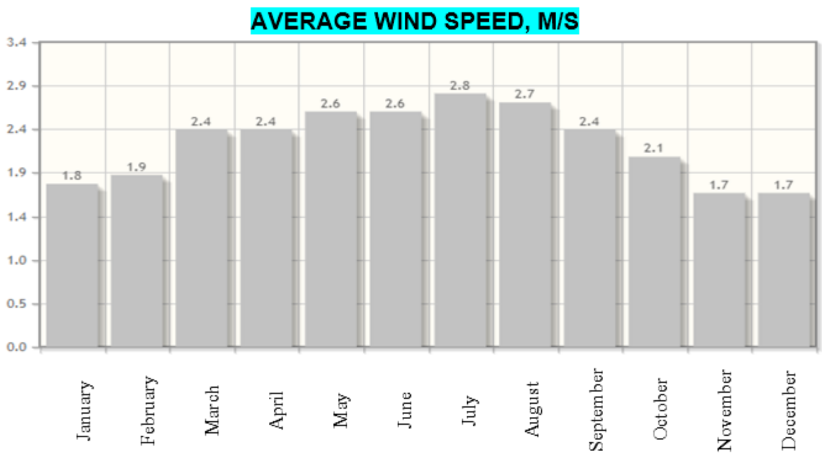


Fig. 3. Diagram of changes in wind speed in Tashkent by months.

Based on the data in Fig. 3, it is easy to calculate that the minimum drift of cargo in Tashkent will be 3.8 m in November and December, the maximum - 22.6 m in July. At the same time, it must be remembered that in different regions of the Republic of Uzbekistan, air gusts at different times of the year and day can reach 20-25 m/s.

However, when a load is dropped from a great height, the force of air resistance will act on its fall, which must be taken into account, since this leads to a decrease in speed and an increase in the time of the fall of the load, and, consequently, increases the amount of drift.

In this case, to calculate the average speed, the formula proposed in 1910 by the American physicist Robert Millican is used:

$$v_{av} = 2v_t /3 \quad (4)$$

where vpr is the limiting speed at which the force of air resistance becomes equal to the force of gravity [4].

In his research, Millikan discovered that when small particles move through gases, there is a certain critical mode when the particle reaches a steady speed and begins to move at a constant speed. In this mode, the average speed of the particle is two-thirds of the terminal speed, and this fact has been confirmed experimentally. Later, the formula $v_{av} = 2v_t /3$ was generalized and applied to describe the movement of a body, taking into account the air resistance force, where the terminal velocity corresponds to the speed at which the air resistance force becomes equal to the force of gravity. Since then, the formula has been widely used in various fields of physics and engineering related to the movement of bodies in a medium with air resistance.

Formula (4) is based on the assumption that when a body falls, taking into account the force of air resistance, the speed changes non-linearly and increases with time until it reaches the limiting speed.

Knowing the formula for finding the limiting velocity of a body falling under the action of gravity and free fall acceleration

$$v_t = \sqrt{\frac{2P}{CS\rho}} = \sqrt{\frac{2mg}{CS\rho}} \quad (5)$$

where: m - body weight;

g - free fall acceleration;

C - coefficient of air resistance;

ρ - air density;

S - is the cross-sectional area of the ammunition.

you can derive the formula for calculating the average speed of the fall of the load, taking into account the force of air resistance:

$$v_{av} = \frac{2}{3}\sqrt{\frac{2mg}{CS\rho}} \quad (6)$$

In the future, combining formulas (1) and (6), we obtain the formula for the drift of the load, taking into account the wind speed and air resistance force, which will look like this:

$$Z = hv_w / v_d = 3hv_w / 2\sqrt{\frac{2mg}{CS\rho}} \quad (7)$$

According to the results of the survey, on the basis of formula (7), as an example, we can give the calculation of the demolition of a square box with a side of 02 m and a weight of 3 kg, depending on the wind speed, taking into account the air resistance force, provided that it is dropped from a hovering aircraft from a height of 100 m (at the same time, the air density is conditionally taken as a constant value equal to the air density near the ground of 1.2041 kg/m3 under conditions of dry air at a temperature of 20 0C and a pressure of 101.325 kPa [6], throughout the fall of the ammunition, the wind speed is assumed to be the same, the wind direction is taken unchanged, the resistance coefficient is conditionally taken equal to 1). The calculation results are presented in Table 2 and in Fig.4.

Table-2

Load drift table when dropped from a height of 100 m, taking into account the force of air resistance

Drop height, m	Load mass, kg	Gravity acceleration, m/s2	Drag coefficient	Cross-sectional area, m2	Air density, kg/m3	Wind speed, m/s	Drift, m
100	3	9,8	1	0,04	1,2041	1	4,3
						2	8,6
						3	12,9
						4	17,2
						5	21,5
						6	25,8
						7	30,1
						8	34,3
						9	38,6
						10	42,9

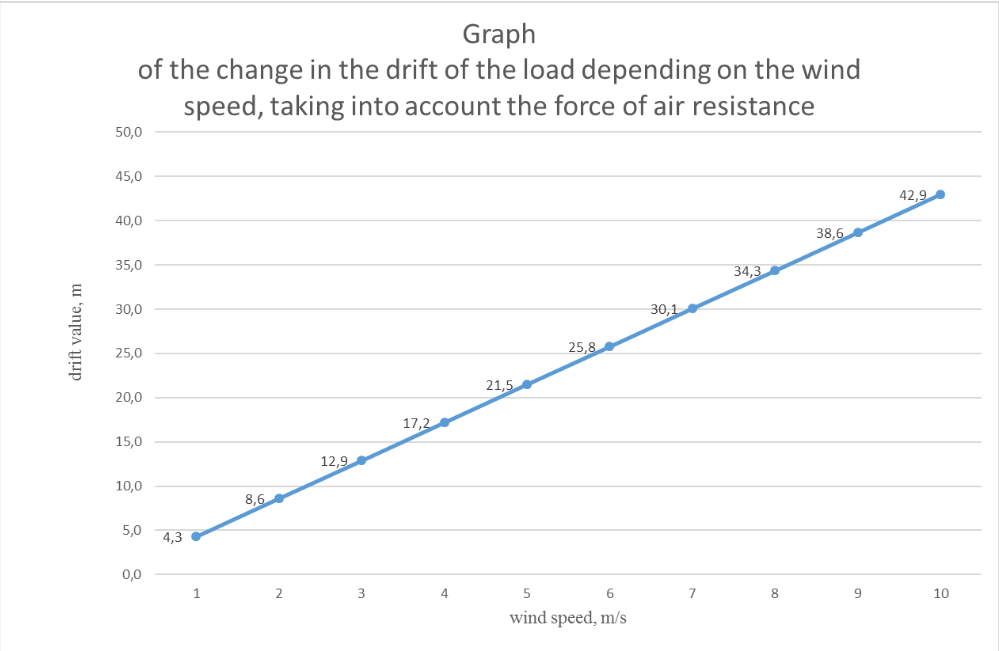
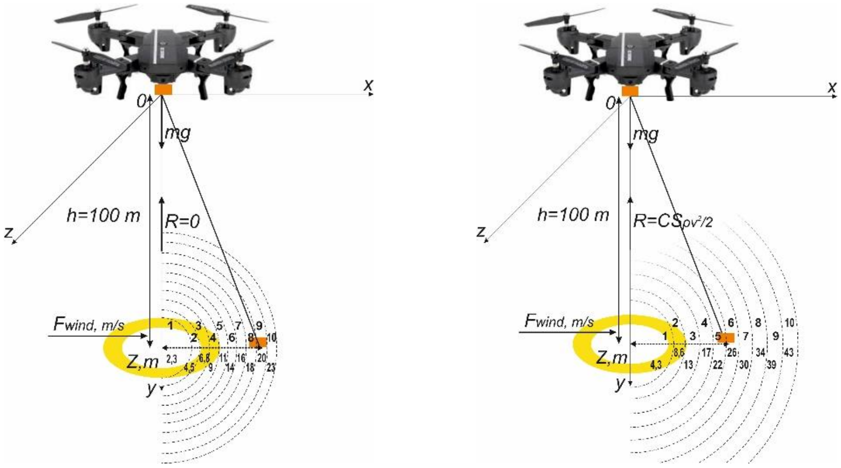


Fig. 4. Graph of the demolition of the load when dropped from a height of 100 m, taking into account the force of air resistance.

Like the graph shown in Fig.2, the graph shown in Fig.4. shows a linear dependence of the load drift depending on the wind speed. The influence of the air resistance force on the increase in the time of the fall of the load leads to an increase in the value of its drift.

Based on the data in Fig. 3, it is easy to calculate that the minimum load drift for Tashkent, taking into account the air resistance force, will be 7.3 m in November and December, the maximum - 12 m in July.

The data obtained in tables 1 and 2 are shown in Fig.5.



a *b*

Fig. 5. Schedule of demolition of cargo when dropped from a height of 100 m:

a) without taking into account the force of air resistance;

b) taking into account the force of air resistance.

Thus, taking into account the information presented in the article, the following conclusions can be drawn:

wind speed has a significant negative effect on the accuracy of the load drop;

load drift is a linear value, directly proportional to the height of the fall, wind speed, drag coefficient and cross-sectional area, as well as air density; inversely proportional to the mass of the cargo;

wind speed and load drift are mandatory values to be taken into account when making corrections to achieve the required accuracy of load release.

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