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SUBSTANTIATION OF PARAMETERS OF UNMANNED AERIAL VEHICLES FOR PESTICIDES AND FERTILIZERS APPLICATION IN PRECISION FARMING SYSTEM

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Abstract: *The technological process of unmanned aerial vehicles (UAV) application in the system of precise farming includes sequential interrelated operations: monitoring and sounding of crops (using light UAVs equipped with multispectral cameras), obtaining, processing and transmitting information for crop management, differentiated application of pesticides and fertilizers according to a specified treatment program (UAV through a large payload).*
KEYWORDS: *PRECISION AGRICULTURE; PLANT PROTECTION; FERTILIZATION; UNMANNED AERIAL VEHICLES.*

Introduction

Recent trends of development of world agricultural production are based on the use of information technology, global positioning and geographic information systems, automated systems in management and technological process control, robotics and integrated precision farming [1-4]. This requires a technology of remote monitoring of agricultural and forest lands with the use of space, manned, unmanned aircraft [5] and variable rate technology (VRT) fertilizer application, plant and seeds protection modes in off-line or on-line regimes for pre-designed maps-jobs on the basis of field monitoring [6].

The use of unmanned aerial vehicles for monitoring and remote sensing of agricultural crops becomes a routine operation and provides data to build digital maps of fields and the formation of map-tasks for the differentiated application of plant protection products and fertilizers [7].

The development of precision agriculture technology requires a high level of technical support based on a programmable, fully-functioning autonomous or remotely controlled unmanned aircraft systems (UAS), which contain complexes of automatic or remote-controlled unmanned aerial vehicles flying in space is segregated in accordance with the standards of ICAO (International Civil Aviation Organization).

The on-board flight control system consists of the autopilot unit, engine control units, the payload control unit, flight and navigation system with integrated navigation system GLONASS/GPS for flight at low altitudes.

The purpose of the study is the choice and justification of main parameters of unmanned aerial vehicles for the targeted application of liquid chemicals in the system of precision farming.

Materials and methods. Used on UAV standards, methodological recommendations on the use of chemicals in the system of precision farming, the concept of development of operational management of mobile technical devices, applied in agriculture using GPS/GLONASS as well as on the analysis of the generalized classification of unmanned aerial vehicles and unmanned aircraft systems [6, 8-11]. Mass structural analysis of the UAV was carried out on the basis of classical methods [12].

The results and discussion. Functional UAVs for agriculture are subdivided into transport, monitoring, sowing, fertilizer application and plant protection means. The type of construction rotary-wing UAV (gyroplane) and multi-rotor (Quad, hexa or oktokopter) types are preferred. UAVs can have automatic or remote control.

The used class of airspace the UAV flight for agricultural purposes must be performed in segregated airspace of established size, designed for the exclusive use of specific users.

From the point of view of take-off and landing the UAV with a small extension for take-off or vertical take-off and vertical landing are preferred.

The most preferred UAVs are those not needing aerodrome for launched and landing, reusable, low-altitude and limited needed height (0-300 m).

The power unit of the UAV may include electric or piston engines with basic refillable fuel tank.

The payload mass is usually 15-30% of the mass of the UAV, and includes the payload (video or photographic equipment, etc.), mass transport of the goods, for example spare parts for agricultural machinery field, a load of fertilizers or pesticides, equipment for their application. Functional load includes a motor (fuel supply) or power supply and servos, aerodynamic controls, complex software and hardware containing the on-board control equipment [13].

The table below shows promising classification of UAV take-off weight and payload.

Table

Classification of UAVs for application of agrochemicals by takeoff weight, payload, range

UAVs	Weight takeoff / useful load, kg	Maximum range of flight, km
Ultra-light near range	(25/7,5)-(150/45)	Less than 30
Light of short range	(50/15)-(250/75)	10-30
Medium short range	(150/45)-(500/150)	80-200
Medium Heavy Short Range	(500/150)-(1500/450)	200-500

In precision agriculture the doses of mineral fertilizers and application rate of pesticides is determined for each elementary area of the field. The number of plots depends on the in-field variability of nutrients, phytosanitary state and the field area. Monitoring of agricultural lands is carried out using a photo or multispectral cameras installed on aircraft or helicopter type drone, i.e. the so-called small take-off weight and low payload multicopter.

The mass balance equations of the aircraft [12] under the all the same conditions shows the connection of take-off weigh t m_0 to the structural elements: the mass of the structure $m_{\text{кон}}$, propulsion engine $m_{\text{су}}$, avionics and control systems $m_{\text{об.су}}$, fuel $m_{\text{т}}$, payload $m_{\text{пн}}$:

$$m_0 = m_{\text{кон}} + m_{\text{су}} + m_{\text{об.су}} + m_{\text{т}} + m_{\text{пн}}. \qquad (1)$$

The mass balance equation (1) in the first approximation is usually presented in a relative form that allows you to compare aircraft utilization per unit mass:

$$1 = \bar{m}_{кон} + \bar{m}_{су} + \bar{m}_{об.су} + \bar{m}_{т} + \bar{m}_{пн}, \quad (2)$$

Where $\bar{m}_i = \frac{m_i}{m_0}$ is the ratio of the mass of the i-th element to the takeoff weight.

The mass of the working fluid (fertilizers and pesticides) from cultivated fields can be variable, so the ratio will be variable, provided that:

$$0 \leq m_{рж} \leq m_{зад}, \quad (3)$$

where $m_{зад}$ is the specified mass of working solutions of pesticides and fertilizers for programmable processing of all sections of the field.

When differentiated treatment of crops UAV in the mode of-line allocated to each elementary area of the treated fields with fixed latitudinal-longitudinal coordinates X, Y has length L_i and a width equal to the working width of the spraying B_p. Then the total area of treatment will be:

$$S_{обр.} = \sum_{i=1}^{k} L_i \, В_р, \quad (4)$$

where k is the number of the processed areas.

The total length of the processed areas is equal to:

$$L_{обр.} = \sum_{i=1}^{k} L_i. \quad (5)$$

Thus, the flight range of the UAV during Shuttle processing method and the total length of all the treated areas of a field may not match; wherein:

$$0 < L_{обр.} \leq L_{п}. \quad (6)$$

The flow of the working fluid for the targeted application on the treated field is set on the basis of calculated doses of pesticides and fertilizers for each defined homogeneous section of fields and the number of extracted elementary parts which are rectangles with a width equal to the working width of the spreading length is equal to the length of a selected path.

Given the fact that the application rate of the working fluid is ensured by its flow through one nozzle $g_{ф}$, number of nozzles $N_{ф}$ on the spraying boom of the equipment of the UAV, the width of the deposit $В_р$ and the working velocity $V_{п}$ and the relative mass of the working fluid can be represented as follows:

$$\bar{m}_{рж} = В_р \sum_{i=1}^{k} L_i \left(\frac{N_{ф} g_{ф}}{В_р V_{п}}\right), \quad (7)$$

where k is the number of sites that require treatment for one flight in accordance with the digital map field.

In generalized form the functional relationship of relative mass of the payload with the key components and technological parameters will be:

$$\bar{m}_{пн} = \Theta\left(\bar{m}, \bar{m}_{н}, \bar{m}_{ар}, \bar{m}_{мп}, S_{п}, k, В_р, L_{обр.}, N_{ф}, q_{ф}, V_{п}\right). \quad (8)$$

Using the expression (8), we obtain the equation of the existence of drones for targeted application fluids pesticides and fertilizers:

$$\begin{gathered} 1 = F\left(\bar{m}_{ф}, \bar{m}_{го}, \bar{m}_{во}\right) + \Omega\left(\bar{m}_{дв}, \bar{m}_{уп.дв.тс}, Н_{п}, V_{п}\right) + \\ +\Phi(\bar{m}_{иэ}, \bar{m}_{эл.об}, \bar{m}_{ап}, \bar{m}_{эб}, \bar{m}_{ано}, \bar{m}_{GPS}) + \quad (9) \\ +\Psi(С_{т}, L_{п}) + +\Theta\left(\bar{m}_{б}, \bar{m}_{н}, \bar{m}_{ар}, \bar{m}_{мп}, S_{п}, k, В_р, L_{обр.}, N_{ф}, q_{ф}, V_{п}\right). \end{gathered}$$

The difference of the equation of existence (9) from the well-known one is that it is, in addition to the mass and flight performance of the UAV, also displays technological parameters of variable rate application of liquid chemicals to agricultural fields.

The UAV carries a multi-spectral monitoring of agricultural fields and test sites. Next, the device transmits the spectral information with associated geographic coordinates of the elementary parts of the field in the information block of the database. At the same time. samples of soil and plants on the test sites are taken for the calibration data when processing of the spectral measurements obtained with the UAV laboratory to determine nutrient content at each site and enter the information in the information unit, connected with unit of analysis, processing and transmission of data on the UAV, through which the differential application of pesticides and fertilizers.

Conclusions

1. It was found that reusable UAVs not needed in aerodrome fro launching and landing, with a small runway for take-off or vertical take-off and vertical landing, low-altitude, helicopter, rotary wing and multi-rotor types, equipped with an autopilot system and a differentiated distribution of the fluids, fertilizers and pesticides for a given program, developed in accordance with the agrochemical cartogram and map of the phytosanitary state of the field for the targeted application of pesticides and fertilizers are preferred.
2. The equations of mass balance of the UAV for agricultural purposes are derived which can more accurately determine the take-off mass given the masses of the components of the payload intended for differential metering and distribution of fluids fertilizers and pesticides.
3. The technological process of using UAVs in precision farming system includes sequentially executed mutually related operations: monitoring and sensing of crops (with light UAVs equipped with multispectral cameras), reception, processing and transmission of information to manage crops, differentiated application of pesticides and fertilizers for a given program working in a field (via a UAV with a large payload).

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