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CONCEPT OF MULTIFUNCTIONAL AGRIDRONE TYPE 4.0-MHRT

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Abstract: Aerial monitoring of agricultural crops involves the creation of reliable measurements for which specialized equipment onboard UAVs are needed. This equipment consists of data acquisition systems from mono, multi or hyperspectral sensors, modularly integrated systems in the agridrone that move, position and orient them above the surface of agricultural crops in the monitored area. The components of the abiotic environment (air, water, soil) are vital for sustainable agriculture. The current trend is to make an intelligent and precision agriculture. All these operations become possible real if and only if we look at the agridrone as a unitary system, a mechatronic system formed by the meeting of several subsystems: mechanical, electronic, IT, communication, hardware and software. This involves the introduction of high-performance technologies, machines and equipment to make the agricultural process more efficient and ensure production control in ecological conditions. Thus, farmers try to get as much agricultural production as possible with the lowest costs. Drones used in agriculture as operational tools (agridrones) are UAS (Unmanned Aerial Systems) air platforms equipped for monitoring the health of crops, for spraying phytosanitary substances or carrying out logistical operations in areas difficult to access or dangerous for the human operator. The paper presents a concept of a multi-functional agridrone type 4.0-MHRT, which is in the category of high-capacity professional drones (heavy lift drones).

Keywords: agridrone, tricopter hexa-rotor, agriculture 4.0

INTRODUCTION

By combining the information provided by the last generation integrated technologies (drones, satellite images, variable application algorithms, multi-parameter sensors and probes, mobile GPS applications, etc.) with the farmer's experience and instinct, effective information is obtained for the farm manager, which will be better informed and will make optimal choices to increase agricultural productivity yields [1].

Aerial monitoring of agricultural crops involves the creation of reliable measurements for which specialized equipment onboard UAVs are needed. This equipment consists of data acquisition systems from mono, multi or hyperspectral sensors, modularly integrated systems in the agridrone that move, position and orient them above the surface of agricultural crops in the monitored area. All these operations become possible real if and only if we look at the agridrone as a unitary system, a mechatronic system formed by the meeting of several subsystems: mechanical, electronic, IT, communication, hardware and software. These subsystems interfaced and commanded by a central unit (controller) can make the drone an autonomous UAS (Unmanned Aerial Systems) system. The current trends are learning these drones by implementing artificial intelligence (AI) in order to obtain dedicated Agent (AS) or MAS systems for certain work operations in agriculture [2-5].

The integration of these technologies in agriculture have taken shape today at a global level and are slowly but surely turning classic agriculture into precision agriculture (agriculture-4.0). The use of aerial drones in agriculture makes it possible to map arable land, to obtain the scanned fingerprint of agricultural crops by recording multispectral maps, as well as to maintain a real record of the health of crops with the possibility of rapid updating as well as of the areas that require attention from farmers [6-11].

Farmers are generally interested in optimizing their return on investment (ROI). ROI is the ratio between the net profit and the cost of the investment or between the earnings and the expenses made to secure certain resources. The return on investment is good, in economic terms, when a ratio results in the advantage of profit, compared to the investment, or in other words, when the way to produce profit from the invested capital is chosen well. As a performance measure, ROI is used either to evaluate the effectiveness of an investment or to compare different investments. Therefore, farmers are interested in finding and using methods and technologies to monitor crop health, spot missing plants, monitor livestock, inspect farms, and more. Thus, the advantage of these devices is the ability to capture information to observe a large number of environmental parameters, continuously: 24 hours a day, 365 days a year, and the values obtained can be monitored in real time. Also, information can be stored and transmitted at any time as long as there is an internet connection in the monitored area [12-14].

The paper presents the design and experimental research carried out on the experimental model of the agridrone (MHRT) for carrying out phytosanitary treatments in field crops.

MATERIAL AND METHOD

The experimental agridrone model for carrying out phytosanitary treatments in field crops, MHRT, is a Y-type hexarotor drone powered by a Tattu Plus 1.0 22000mAh 44.4V 25C 12S1P Lipo battery, equipped with 6 1955 W motors, type KDE5215XF -220, whose rotation speed is controlled by 6 KDE-UAS55HVC electronic speed controllers (ESC), three engines having two CCW type propellers (they rotate in the opposite trigonometric direction) and the other three engines having propellers with two CW type blades (rotate trigonometrically), all the propellers are of the KDE-CF215-DP type with dimensions of 21.5'', it has a 20 liter tank from which an electric pump at 12 Vdc pumps with a pressure of up to at 5.5 bar phytosanitary substances to a circular spray ramp on which 3 nozzle holders equipped with calibrated spray nozzles are mounted. The drone is equipped with Pixhawk 4 autopilot, power management board and GPS module for precise positioning in the field and can be programmed to operate the electric pump to spray agricultural crops only on predefined areas.

Figure 1. MHRT experimental model 3D project

A structural analysis was carried out in static mode, using the solid discretization type. The discretized structure totaled a number of 1429473 nodes, with 789629 standard elements. The minimum element size was 0.982496 mm and the maximum element size was 4.91248 mm. The finite element analysis was done in the Solidworks program. Figure 2 shows the discretized structure.

Loads and boundary conditions were imposed, as follows: the three fixings in which all three translations are canceled correspond to the landing gear soles, and were applied according to the following figure (Figure 2).

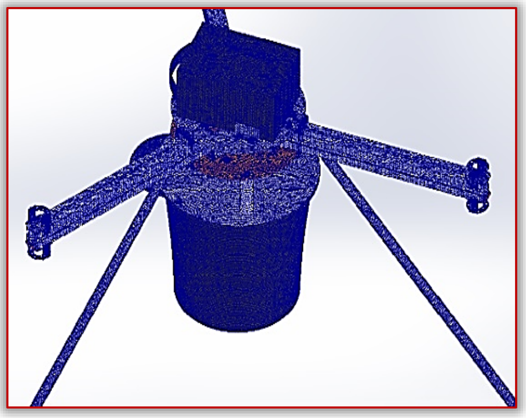

Figure 2. The structural model of the MHRT experimental model: discretization

The loading forces were applied to the drone battery in a vertical direction. The loading force had the value of 150 N. Thus the total reaction force from the fixing points had a value of 323,499 N.

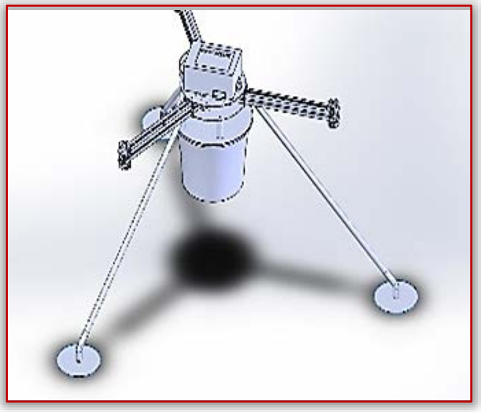

Figure 3. Structural model of the experimental model MHRT: fixings

RESULTS

The minimum and maximum values of the state of equivalent stress (Von Mises) in the structural model of the drone were determined after performing the static analysis according to the fixations and loads presented previously. The maximum value of the equivalent stress is 1,444e+12 N/m^2 and is located at the contact point between the drone arm and the landing gear leg, node 1298283. The minimum value recorded was 7,319e-01 N/m^2 and is located in node 88613 of the discretized structure.

Fig. 4 shows the distribution of the resulting relative displacement field values in the structural model of the experimental model. The representation is made on the deformed shape of the structure.

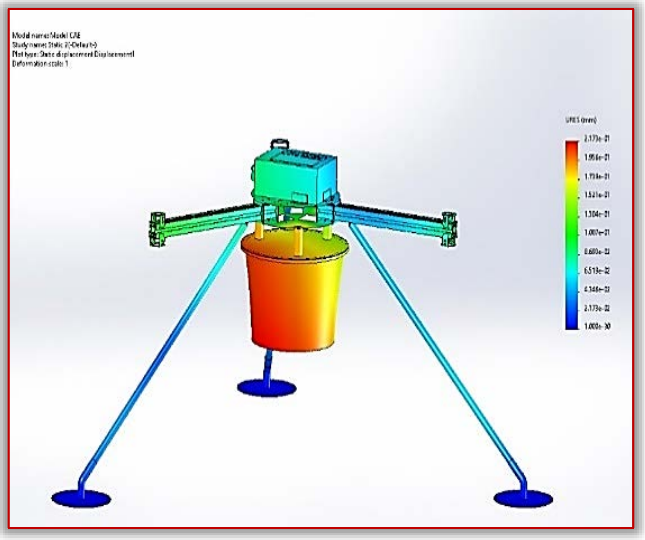

Figure 4. Equivalent displacement

Experiments were carried out in the laboratory and on the experimental fields, in order to determine the maximum take-off mass, the dimensions of the drone, the flight capacity and the sound pressure level. The dimensions of the MHRT experimental model measured are as follows:

- Diameter: 1.58 m
- Height: 0.94 m
- Own weight without battery: 12.5 kg
- Battery weight: 6 kg
- Maximum weight: 38.5 kg

The noise measurement was made on a clean and dry horizontal surface, the microphone being placed at a height of 1.2 m from the ground. The background noise was at least 10 dB(A) lower than the measured one.

Figure 5. Testing the MHRT drone in the lab

Table 1: Drone noise

Acceleration (%)	Acoustic power (db)
25%	73
50%	86
75%	88
100%	95

The maximum take-off mass was determined by measuring the maximum take-off force between the drone and a fixed point on the ground by means of a 1KN load cell placed between the drone and the ground.

Table 2 shows the average values obtained for the MHRT experimental model in terms of the maximum lifting force.

Table 2: Average values obtained for the MHRT experimental model in terms of maximum lift force

Acceleration (%)	Curent ESC(A)	Lifting force 1 engine (N)	Lifting force 6 engines (N)	Engine speed (rpm)
25%	2,5	1330	7900	2520
50%	11	3860	23080	4240
75%	26.4	7520	45000	5750
100%	52.4	11350	67850	7000

The maximum lifting force corresponds to a maximum level of current through the ESC of 52.4 A at a battery charge level of 52.2 V and a maximum electric power of 2735.28 W/motor, having a total power of 16411.68 W. Taking into account the battery capacity of 976.8Wh, this represents an autonomy of 0.06 hours.

In reality, the experimental model will not be operated at full capacity, but will be used with a maximum speed of 75%, which means a total electric power of 8268.48 W and an autonomy of 0.12 hours with the drone charged at full capacity. A series of tests were carried out with the experimental drone model in the field, in order to test the simple functions of take-off, landing and autonomy.

Figure 6. MHRT drone field testing

CONCLUSIONS

Following the design and testing of the MHRT experimental model, the following conclusions were identified:

- the tripod landing gear model provides stability to the drone;
- the length of the drone's arms must be doubled, and the material from which they will be made must be adapted to the attachment of the motors on it;
- the solutions for the autopilot and the radio control had an optimal operation;
- the 12-cell battery is not sufficient to achieve the required autonomy, so it is necessary to replace it with two 14-cell batteries;
- the circular spray ramp pattern provides both uniform spray distribution and undercarriage stiffening;
- for better balancing, the tank should be placed above the central frame and will have the shape of a truncated cone with a cylinder at the base.

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