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UNMANNED HELICOPTER MODEL USED FOR AERIAL AGRICULTURAL CROPS MONITORING

Abstract: *There are situations when the agricultural crops in the field are needed to be monitored because when certain possible pest factors appear to be able to intervene in time without being affected the production on the cultivated surface. It is about field crops cultivated on large surfaces where various tracking or monitoring devices are needed to be used. These devices are unmanned aerial vehicles that usually carry on board a high-resolution camera in order to achieve the proposed crops monitoring objectives. This paper presents the assembly model of an unmanned aerial vehicle that can be used for aerial surveillance of field crops set up on large land areas. A three-dimensional model of the helicopter was built using the Solid Edge ST8 Academic software and analyzed with the ANSYS CFX program in order to emphasize the operating parameters depending on the initially declared conditions. Also the obtained results are presented from the computational fluid dynamics analysis conducted on the virtual helicopter model.*

Key words: *three-dimensional modelling, computational fluid dynamics, helicopter model, unmanned aerial vehicle, agricultural field monitoring, fluid mechanics*

INTRODUCTION

Agriculture is a major component of a country economy and many related industries are linked to the agricultural obtained results. That is why the results obtained in agriculture must be optimal.

In order to achieve good results on the cultivated land, all the factors related to the optimal development of the field plants must be met. For this, various preventive treatments against pests need to be applied in addition to irrigation and field fertilization.

On large cultivated land areas, in order to closely observe the conditions of plant growth and development, aerial monitoring systems are to be used in order to achieve field crops track without the need for human intervention directly on the cultivated field.

The aerial monitoring systems used are unmanned light vehicles that are remote controlled via a command group in the vicinity of the cultivated land.

The proper monitoring activity is possible due to onboard mounted video cameras for video and photos conducted during the flight over the field crops.

The aerial surveillance systems are needed in the agricultural domain because they can help to identify certain pests that threaten the harmonious development of the field crops in order to be able to intervene in time with the indicated prevention countermeasures.

The advantage of using unmanned aerial systems is represented by the fact that these are lightweight devices that operate on non-invasive principles, as they can fly at low heights as they can be positioned very close to the cultivated plants so that can register video films and photos of high resolution from the optimum distance.

2. UNMAMMED AERIAL SYSTEMS USED FOR MONITORING

The unmanned aerial systems are considered as drone systems that can be used primarily to over flight in order to observe and record data at various objectives as road traffic monitoring, monitoring of protected areas, natural parks, monitoring of dams located in river waterways, environmental monitoring, glacier monitoring, monitoring of wind power stations in order to detect possible turbine irregularities, monitoring of high voltage lines, in the forestry field for the monitoring of specific activities as well as in the field of agricultural monitoring for plant crops.

The unmanned systems or drones can also be used to capture photos or videos in hard-to-reach areas in the mountain regions, flooded or snowy areas, helping rescuers who have to intervene at a particular event or objective.

For all these observation and monitoring activities, a non-pilot light mini-aircraft or mini helicopter are to be used which have an electric motor inside powered by batteries placed on board of the device.

For the mini helicopter is adopted the variant of using the classical helicopter model on a small scale, but other variant models are constructed as a multi-copter that has several electric motors each with its own propeller. So a four-engine multi copter is called quad-copter, a six-engine is a hex copter etc.

The operating principle for a helicopter or a multi-copter type monitoring system is represented by the rotation movement of the propeller mounted on the drive shaft being driven by battery powered motors.

A high-speed rotation motion results in the ground take-off and the flight at a certain altitude and distance, depending on the autonomy degree as function of accumulator type and the energy consumption.

To carry out the proposed monitoring activities, the unmanned aerial vehicles have mounted on board cameras capable to transmit in real-time images and videos from the height and position at which they fly to the ground control center.

The operator directs the device via a remote control, having the possibility to permanently change the flight parameters on which the device operates, or to position the camera on a particular field direction.

Over time, the performance of these unmanned aerial vehicles has been continuously developed in terms of flight autonomy, distance from the control center reached by the device, but also the quality of the information provided by the use of high performance cameras to ensure execution of high resolution photos and videos.

Figure 1 schematically shows the main components of an unmanned aerial system necessary for setting in flight mode an aerial device to the proposed flight missions.

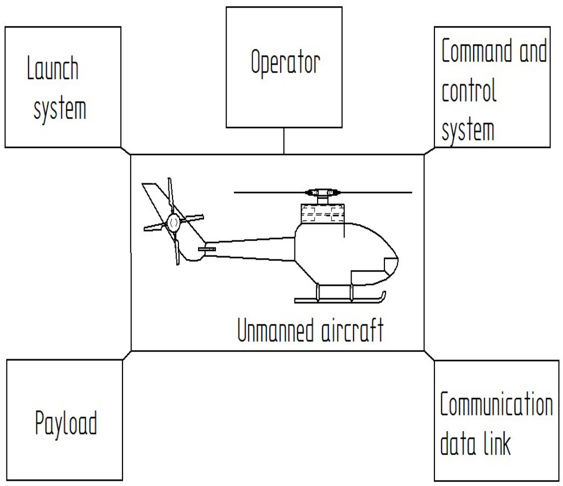


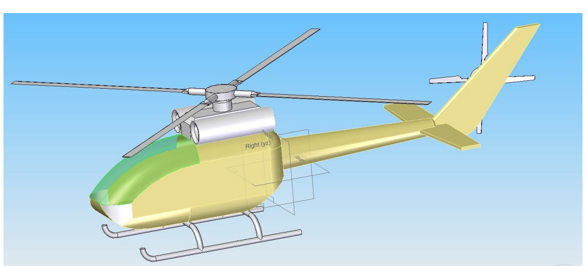
Fig. 1 Schematic representation of unmanned aerial system main components

The satellite connections are used in order to have the permanent connection with the aircraft during the flight, as well as a control system positioned on the ground from which the operator acts on the routing and direction of the flight, as well as sending specific commands to the onboard cam recorders [1], [2].

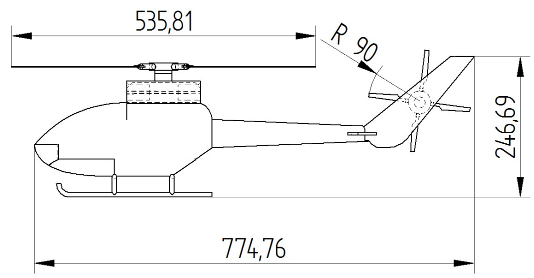
3. HELICOPTER THREE-DIMENSIONAL ASSEMBLY MODEL

A three-dimensional helicopter assembly model was built using Solid Edge ST8 Academic software, shown in figure 2.

The helicopter assembly model is built at a reduced scale and illustrates a special unmanned aerial vehicle model that can be used to carry out comprehensive monitoring of field crops within agricultural farms over large areas.



a) Helicopter assembly model



b) Dimension details for the helicopter [mm]

Fig. 2 Helicopter assembly model

The presented helicopter model is a small scaled model designed on the same operating principle as a full-scale helicopter. Thus in order to achieve the ground take-off is required a rotational movement of the rotor main propeller that acts for helicopter lifting from the ground while the secondary propeller is acting to maintain the helicopter body stability at ground take-off, during the flight and landing.

The propeller blades are thus positioned so as to produce asymmetric air waves through the impeller rotational movement while the forced air ultimately give rise to absorption and pressure forces that determine the formation of an air rising current necessary for the lifting on the vertical direction of the helicopter body [3], [4].

Thus, the helicopter's main propeller takes up the mechanical energy from the engine shaft and delivers it to the environment within the fluid region (air) in which it operates, thus creating the machine's lifting inside the fluid environment.

The thrust force produced by the main propeller is calculated as follows 0:

$$T = \frac{\pi}{4} D^2 \rho v \Delta v \quad (1)$$

$$v = \sqrt{\frac{T}{A} \cdot \frac{1}{2\rho}} \quad (2)$$

where:
T – thrust force;
D - propeller diameter;
ρ - air density;
v - air velocity;
Δv - air velocity when accelerated by the propeller;
A - propeller disk area.

The air absorption power with the propeller is 0:

$$P = Tv = T\sqrt{\frac{T}{A} \cdot \frac{1}{2\rho}} \quad (3)$$

$$v = \frac{P}{T} = \left[\frac{T}{P}\right]^{-1} \quad (4)$$

The ratio between the thrust forces and the disc area described by the helicopter main propeller blades is defined as the total load on the propeller disc that drives the helicopter body in a vertical direction. From the written equation for the induced air velocity, it can be observed that the velocity value is inversely proportional to the load on the disc described by the propeller blades.

The movement in the vertical direction of the helicopter body is described by the ratio of the air velocity in the axial direction and the outer point's velocity located on the propeller circumference 0:

$$\Gamma_V = \frac{v_a}{v_d} \tag{5}$$

The value obtained is part of the displacement diagram for the propeller model being expressed by the following functions:

The thrust force-dependent function:

$$K_T(\Gamma_V) = \frac{T}{\rho n^2 D^4} \tag{6}$$

The function dependent on the torsion force:

$$K_Q(\Gamma_V) = \frac{Q}{\rho n^2 D^5} \tag{7}$$

The function dependent on the tilting angle of the propeller blades:

$$\beta(\Gamma_V) = \frac{T v_a}{2\pi n Q} = \frac{\Gamma_V}{2\pi} \cdot \frac{K_T}{K_Q} \tag{8}$$

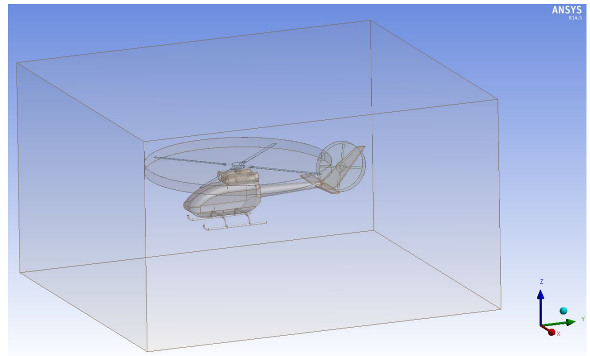
where:
n - propeller rotational velocity;
Q - air flow rate.

The propeller blades have a special profile designed so that one face has a convex surface that forces the air to move on a longer distance than the opposite side, which means a vertical absorption effect. The intensity of this effect is adjusted by varying the rotational speed or by angular positioning of the propeller blades.

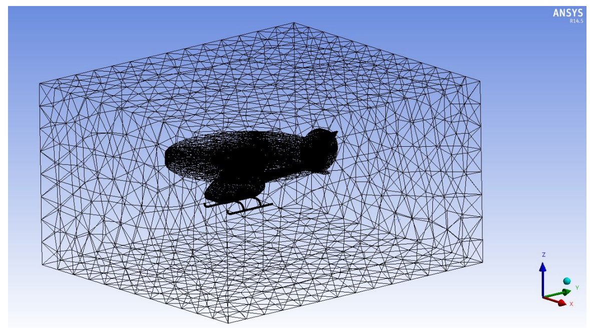
4. CFD ANALISYS FOR THE HELICOPTER ASSEMBLY MODEL

A numerical analysis using ANSYS CFX academic software was performed on the helicopter three-dimensional assembly model in order to emphasize the fluid dynamics within the fluid region when the propeller are moving in a rotational motion. The air it has been declared as the working fluid.

The analysis results shown in the following are being represented by the pressure and velocity values of the working fluid inside the fluid region.



a) the model imported for the analysis



b) the model mesh network

Fig. 3 The imported model and the mesh network

In figure 3 are presented the fluid region containing the helicopter assembly model and the triangle surface mesh network realized with ANSYS mesh modeler having a number of 350013 nodes and 1858879 triangular elements.

The next step was the setup configuration where the main domains were declared.

The first domain is represented by the fluid domain positioned on the external enclosure of the helicopter model. Air at 25 degree Celsius was declared as the fluid and the reference pressure was established at 1 atm.

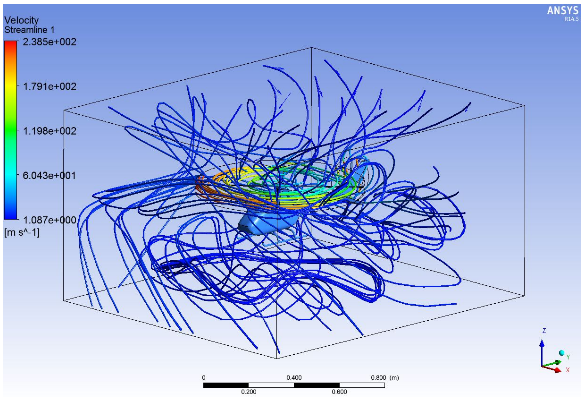
The second domain was the helicopter solid body being considered as immersed solid within the fluid region. The sub domains were declared the helicopter propellers, being considered as rotating bodies with 5000 rev/min after the coordinate axis global z for the main rotor propeller and global x for the small propeller.

In order to complete the analysis setup there was necessary to be declared the mesh deformation option for the regions of specified motions, being adopted a relative displacement to the previous mesh during the calculation.

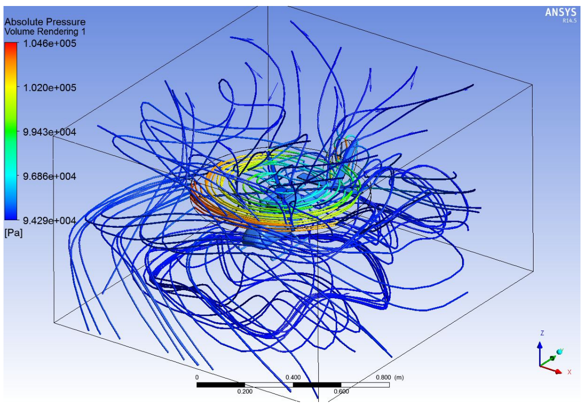
As the analysis type was adopted the transient analysis model having a total declared time of 10 sec with the time steps of 0.1 sec.

As a result of the carried out analysis are presented the results obtained in terms of velocity and pressure of the working fluid (fig. 4).

Thus, as a result of the rotation movement of the main helicopter propeller, an air stream is formed which aspirates the air in the vertical direction from above the main propeller and directs it downwards to the ground.



a) the fluid velocity values



b) the absolute pressure values

Fig. 4 The analysis obtained results

Due to high propeller rotational velocity a lift force is created that has the tendency to move the aircraft from the ground.

This is shown by the results obtained from the analysis regarding air velocity in the propeller area, where the air current path-lines are formed within this region and recorded the proper pressure values. The results are shown in figure 4.

5. CONCLUSIONS

A reduced scale model for an unmanned aerial vehicle of helicopter type was constructed, described and analyzed in this paper.

This type of aerial device can be used in order to conduct aerial monitoring of field crops in the agricultural domain.

The proposed solution is efficient for extensive land areas where human intervention would be difficult or could affect crops development. Thus, with the help of a remote-controlled helicopter, an operator can perform non-invasive field crops observation activities, taking photos or videos with the camera mounted on the unmanned aircraft.

A numerical analysis on the virtual model assembly of helicopter was performed using the ANSYS CFX Academic program, in order to obtain information on the main parameter values within the analyzed fluid region that interfere with the operation of the device when the main and secondary propellers have a rotational motion.

Thus, the results obtained confirm the fact that when the helicopter's main propeller has a high-velocity rotation movement, the upper fluid is absorbed through the propeller action and forced to move downward in a vertical direction, having the result an increased pressure value in the lower region of the fluid region.

Through this propeller-generated current a lift force is provided that allows the helicopter body to move from the ground or take off in a vertical direction. The secondary propeller works on the same principle of circulation of the working fluid, but it is used to achieve body stability at take-off, in the air during the flight and at the landing of the aerial device, eliminating in this way the inertial rotation tendency of the device body that would otherwise follow the rotation of the main propeller.

The unmanned aerial devices used for civil applications have been continuously developed in recent years because their convenient in use solutions provided in various fields of interest especially where the direct human intervention is difficult or cannot be performed.

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