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The Concept and Preliminary Design of a New Drone Destined for Military Rescue/Medical Missions

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Abstract

The most notable machines that currently have the impact of eliminating humans from direct contact with the enemy are various types of remotely controlled or autonomous drones. They wreak havoc and cause fear in the enemy camp, significantly affecting the outcome of current conflicts. The fact of increasing advantage in available attack methods causes the need for adequate defense or rescue measures. Thus, the use of remote-controlled drones for rescue/medical purposes seems a natural or even necessary path for the development of military technology. The described drone is intended to be unmanned, designed to transport only one injured person to be evacuated from an area of intense combat with the usage of an onboard robot. It is intended that the drone will be electrically powered which will reduce the possibility of detection due to acoustic and heat signature.

KEY WORDS: *military rescue drone; UAV; preliminary design*

1. Introduction

Traditional warfare aims to defeat the enemy and take over his territory/resources. Logically this should be done at the least possible cost in both equipment and men. The necessity of enemy defeat makes dead and wounded an inevitable part of any armed conflict. The arms race, however, results in the introduction of newer and newer technologies, for which a considerable amount of money is needed, making war increasingly expensive. New technologies, on the one hand, result in less human involvement in a direct confrontation from the attacker's point of view, but on the other hand they are becoming more and more lethal, and thus more and more undesirable from the point of view of the attacked, whom these means are intended to reach.

The most notable machines that currently have the impact of eliminating humans from direct contact with the enemy are various types of remotely controlled or autonomous drones. Their smaller size compared to aircraft or helicopters makes them more difficult to detect and shoot down. Because of this fact, they wreak havoc and cause fear in the enemy camp, significantly affecting the outcome of current conflicts [1]. Of course, the tasks that drones perform are not limited to attack, but the aspect of eliminating humans from direct contact with the enemy is one of the main factors considered in this work.

2. Justification of the concept

The fact of increasing the advantage in the attack causes the need for adequate defense or rescue measures. Thus, the use of remote-controlled drones for rescue purposes seems a natural or even necessary path for the development of military technology. Such example is presented in [2]. The largest army of NATO, i.e. the United States, announced in 2018 [3] the need for a small rescue flying vehicle for which the summarized requirements are as follows:

1. Ability to transport up to 4 people including one on a stretcher (assuming 2-4 people plus "luggage" leads to total cargo weight up to about 635 kilograms kg) at a speed of 185.2 [km/h] at temperature of 35 [°C] in a diverse environment.
2. Range of about 371 km plus additional time of 30 minutes of operation.
3. Time to unload and prepare for flight (assemble and load) - up to 30 minutes.
4. Ability to be transported by Lockheed Martin Hercules C-130 and Boeing H-47 aircraft. Ability to be transported by Bell-Boeing V22 Osprey aircraft will be an asset, but is not necessary.

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5. Capable of landing in an area of approximately 15.24 × 15.24 meters but no longer than 45.72 meters in varied terrain. The ability to operate on bodies of water is not necessary but will be an asset.

6. Minimize detectability during take-off and landing. Posibility to use non-electric propulsion during flight to increase speed/range.

7. Minimize during take-off and landing. Ability to increase noise - use of non-electric propulsion during flight to increase speed/range.

In the proposed case, discussed in the paper, the drone is intended to carry only one person and should be as undetectable as possible. Nonetheless, the stated requirements can or should be taken into account in the development of a new rescue drone concept. This will allow similar standards and smooth use in allied armies.

3. Main features of the concept

The new concept should take into account the current conditions and manufacturing capabilities in the country where the target drone is to be produced that is, by the assumption, Poland, whose budget and technology development are incomparably smaller than that of the USA. The drone should be manufactured as cheaply as possible, using the simplest solutions that provide the expected features. The developed drone will also be able to successfully serve in civilian rescue missions such as ambulance or fire vehicle.

The main features that have been taken into account from the US guidelines are:

1. STOL (Short Take-Off and Landing) ability.

2. The payload (one person) of about 160 kg.

3. The dimensions of drone (eventually after folding) must correspond to the cargo spaces of above-mentioned aircrafts. They are (length [m] × height [m] × width [m]): 12.0 × 2.7 × 3.0 and 9.14 × 1.98 × 2.53 for Lockheed Martin Hercules C-130 and Boeing H-47 respectively [4,5].

The frame is to be made of CFRP (carbon fibre reinforced plastics) [6] or high-strength aluminum alloys. The described drone is intended to be unmanned, designed to transport only one injured person to be evacuated from an area of intense combat with the usage of an onboard robot. It is intended that the drone will be electrically powered which will reduce the possibility of detection due to acoustic and heat signature.

4. Preliminary design

The wounded is assumed to be taken onboard with the usage of a robot through movable platform and will be transported in a horizontal position (Fig. 1), therefore a natural rotor arrangement seems to be one consisting of two main rotors positioned longitudinally giving the main lifting force and two side rotors giving additional lifting force and together with the longitudinal ones providing an easy control system by changing the rotors speed (Fig 2).

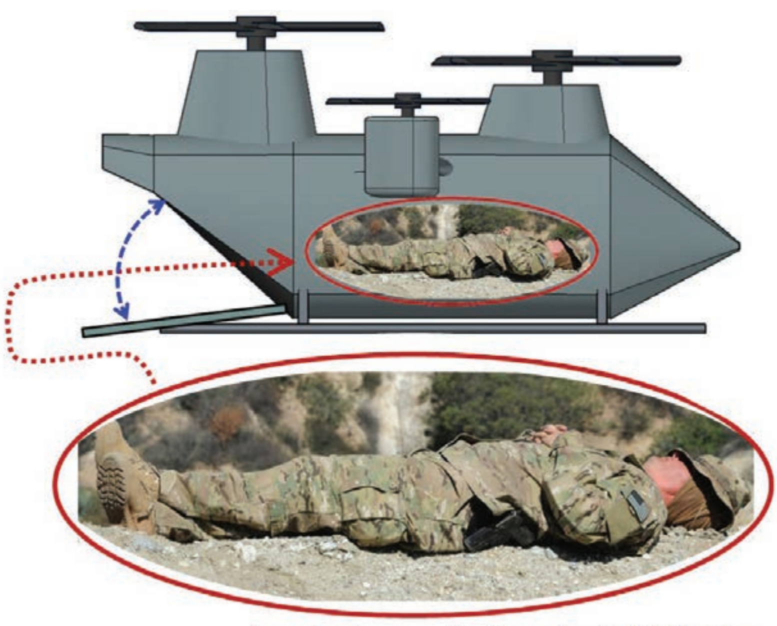

Fig. 1. A wounded position and the way of taking him/her onboard in the concept drone.

Because of the longitudinal arrangement (of the main rotors), data was collected for similar solutions. Three machines were analyzed: two historical helicopters: HERC Jov-3, its military successor McCulloch MC-4C and contemporary unmanned aerial vehicle (UAV) DP-14 Hawk. It was found that for these solutions the weight per power is about of 5 kg/Hp, therefore the power required to lift one kilogram P_{kg} is about 0.2 Hp/kg [7,8,9].

Assumptions of the input data used for preliminary calculations are presented in Tab. 1.

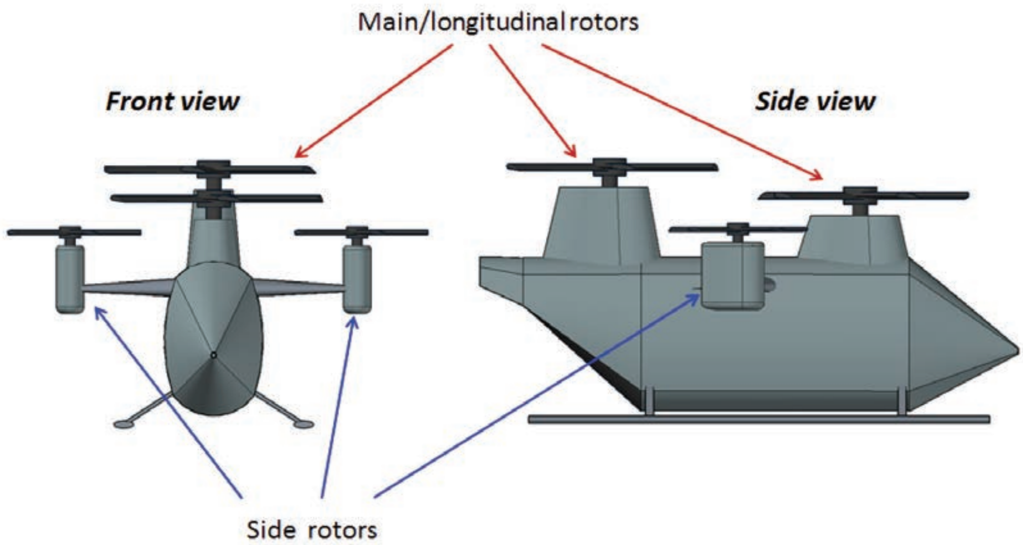

Fig. 2. An Overall concept and rotors arrangement.

The parameters of initially selected electric motors are presented in Tab. 2. These are axial flux permanent magnet synchronous motors [10].

Table 1.

Assumption data for preliminary design.

Element	Symbol	Weight [kg]
Frame	Q_{fr}	100
Passenger (+his “baggage”)	Q_{pas}	160
Robot	Q_r	60
Basic medical equipment	Q_{me}	15
Specialized equipment (cameras, night vision, infrared cameras, radar)	Q_{se}	10
Control system - unit and motors	Q_{cs}	15
Main computer	Q_{com}	3
Motors-battery wiring	Q_{pc}	30

The preliminary drone calculations were performed incrementally. For assumed total weight of the drone Q_T that consist of weights of: frame Q_{fr}, wounded Q_{pas}, motors Q_{pm}, robot Q_r, battery Q_b and all equipment (Tab. 1) and the assumed operational range, the necessary power of motors and battery capacity were calculated and checked with the assumed ones. The presented calculations refers to the case for which assumptions are satisfied and are satisfactory for the concept.

Table 2.

The parameters of initially selected electric motors [9].

Motor	Continuous power [kW]	Peak power [kW]	Weight [kg]	
Longitudinal	90	190	40	
Side	40	160	20	
Total	260	700	Q_{pm}	120

For calculations, there is also a necessity to estimate the weight of a battery. The battery consists of cells and its hardware (case, cooling, battery management system - BMS, wiring). On the basis of analysis of data presented in [11] it was found that the weight of battery hardware is about 74% of the weight of cells. It is too high and must be improved. It was assumed that it would be possible to achieve at least 50% for analyzed vehicle that is to have four rotors (the draft of which can be used for cooling purpose). In such case, for the weight of cells Q_{bc} of 785 kg the weight of battery hardware Q_{bh} is:

$$Q_{bh}=0.5 \cdot Q_{bc} = 392.5 \text{ [km]} \quad (1)$$

where: Q_{bh} – weight of battery hardware; Q_{bc} – weight of cells.

Therefore, the weight of battery $Q_b = Q_{bc} + Q_{bh}$ =1177.5 kg. The assumed total weight of drone Q_T is therefore 1690.5 kg.

If the operational range R is 35 km, the distance to be traveled is:

$$D = 2 \cdot R = 70 \text{ [km]} \quad (2)$$

where: D – distance to be travelled; R – operational range.

If the assumed cruising speed V is 120 km/h, the flight time from point A to B is:

$$T_{AB} = \frac{D}{V} = 35 \text{ [min]} \quad (3)$$

where: T_{AB} – flight time from point A to B; D – distance to be travelled; V – assumed cruising speed.

With the reserve for additional maneuvers of 20 min the total flight time T_T is 55 min (for simplicity of initial calculation it is assumed that for the total flight time the drone travels with the assumed constant cruising speed).

As is was stated before the power required to lift one kilogram for similar constructions P_{kg} is about 0,2 hp/kg, therefore the power needed for conceptual drone is:

$$P_D = Q_T \cdot P_{kg} = 338.1 \text{ [hp]} = 248.6 \text{ [kW]} \quad (4)$$

where: P_D – power needed for conceptual drone; Q_T – assumed total weight of drone; P_{kg} – power required to lift one kilogram for similar constructions.

Therefore the chosen motors would provide necessary power with additional 11,4kW of reserve (the total peak power of motors is 700kW that is almost three times higher than those necessary for cruising speed, see Tab. 2).

The most mature high energy per unit (SE) battery cells for aerospace purposes are the Lithium-Ion (Li-Ion) ones and provides energy capacity E_C of 300Wh/kg [12]. The work W to be done by the motors with power of P_D during the total flight time T_T equals to:

$$W = P_D \cdot T_T = 228.1 \text{ [kW]} \quad (5)$$

where: P_D – power needed for conceptual drone; T_T – total flight time.

Therefore, the required weight of battery Q_{br} is:

$$Q_{br} = \frac{W}{E_C} = 760.3 \text{ [kg]} \quad (6)$$

That gives nearly 25 kg of reserve in relation to assumed battery weight equal to 785 kg.

Preliminary calculations showed that a drone of this type would be able to have a range of 35km (70km round trip) and would have an additional 20 minutes for various air maneuvers related to the task. This seems sufficient to evacuate a wounded person from an area of intense warfare. Of course presented calculations are simplified and based on assumptions that need to be verified. Nevertheless it is seemed that they give insight into the potential possibilities of constructing such a drone. More detailed analysis are to be to performed on the next levels of design. They will concern e.g. aerodynamics or joints [13-15]. At the stage of selecting the propulsion unit and propellers, there is a need to consider their fatigue strength. The issues of fatigue calculations for rotating objects are considered in [16,17].

4.1 Battery capacity variation study

The aforementioned calculations were made with the assumption of the energy density of the batteries that are currently standardly achievable. The battery mass is a crucial factor in the design of electric or hybrid aerial vehicles, therefore development work aimed at producing batteries with higher energy densities is ongoing [8]. For this reason the designed structure should be prone to modifications in the variety of batteries used or, if necessary, to changing the propulsion system to a hybrid one, if the current operational range is unsatisfactory. Taking this fact into account, the trend for achieved operation range in relation to battery capacity was determined and presented in Fig.3. The trend was determined with the assumption of the same constant weight of drone (equal to 1690.5 kg), the same motors and the same reserves both in power of motors and weight of batteries.

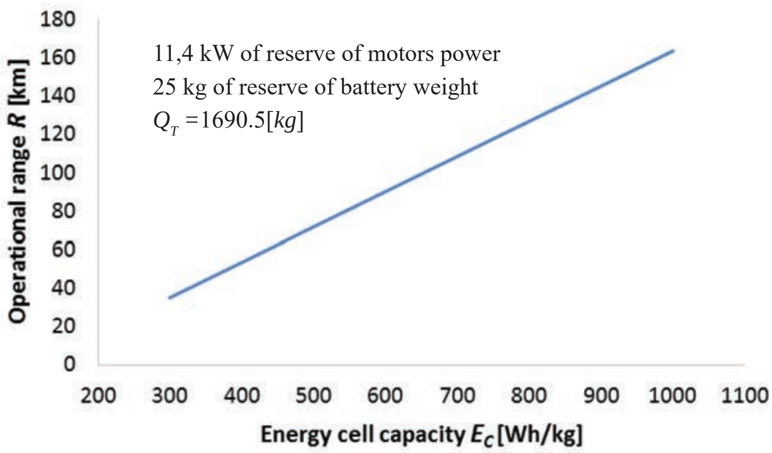

Fig. 3. Operational range trend for different battery capacity

According to aforementioned trend the operational range will be about 72 and 164 km for battery capacity of 500 and 1000 Wh/kg, respectively.

If it were possible to achieve battery capacity of reliable 1000 Wh/kg, then for such a case, assuming an initial operational range of 35 km, the total weight of the drone (with passenger) would be only about 569 kg. The weight of the battery with its equipment for such a case is 153 kg, the power needed for the structure is about 84 kW (114 hp). It would be enough to use motors with powers (values from the catalog [6]) of 40 kW longitudinal and 20 kW transverse. The additional continuous power would be therefore of about 36 kW.

Summary and Conclusions

The unmanned aerial vehicles or drones are becoming more and more important in the contemporary battlefield. Therefore, the use of remote-controlled drones for rescue purposes seems a natural or even necessary path for the development of military technology. The propelling system of a conceptual drone consists of two main rotors positioned longitudinally. The main longitudinal rotors will provide the main lifting force and two side rotors giving additional lifting force and together with the longitudinal ones will provide an easy control system by changing the rotors speed.

The wounded is assumed to be taken onboard with the usage of a robot through a movable platform and will be transported in a horizontal position. The preliminary design showed that a drone of this type would be able to have a range of 35km (70km round trip) and would have an additional 20 minutes for various air maneuvers related to the task which seems sufficient to evacuate a wounded person from an area of intense combat. In addition, it should be taken into account that the calculations were made with the assumption of the energy density of the batteries that are currently standardly achievable. Development work aimed at producing batteries with higher energy densities is ongoing. Reducing the weight of batteries in the future will significantly increase range. The designed structure should therefore feature the possibility of changes in the variety of batteries used or, if necessary, to a hybrid propulsion system.

The drone should be manufactured as cheaply as possible, using the simplest solutions that provide the expected features considering requirements announced by the USA – NATO largest member. This will allow similar standards and smooth use in allied armies. The developed drone will also be able to successfully serve in civilian rescue missions such as ambulance or firefighting ones if the life of casual aircraft vehicle operators is threatened.

Acknowledgements

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