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ANALYSIS OF THE RESCUE SYSTEM IMPLEMENTATION IN THE MEDIUM RANGE UAV

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Abstract:

Modern approach to the aircraft design implies more often rescue system application to the aircrafts with human crew like gliders, ultra-light and trainer aircraft. Likewise different class of the UAVs is more commonly designed with the parachute, or parachute/airbag landing system. Whether the aim is to land UAV in a usual mission or to rescue the aircraft/UAV system and the crew, integration of the parachute system is the solution. This paper represents implementation analysis of the different rescue systems in the medium range UAV with the diverse aspects of limitations like minimum mass increase, limited free space in the UAV to place the system and minimum increase of the aerodynamic load.

Keywords: *rescue system implementation, composite structure modification, aerodynamic load.*

1. INTRODUCTION

Today's designers of aircrafts and unmanned aerial vehicles (UAV) are more than ever considering safety in the early stages of preliminary design. It can refers to minimal take-off weight which can guarantee the adherence to the levels of safety required by the airworthiness design requirement [1]. The easiest way to cover possible malfunction of any system is to integrate a parachute rescue system. It has become usual that we have in every newly design gliders, ultralights or trainer aircrafts and UAVs a recovery system. It can also be implemented later on in it. It is not a secret that there are plenty of research on subject to place a recovery system in a commercial airplanes [2]. Despite the parachute systems that are included within the UAV s for everyday landing at the end of the missions, we can confront, during exploitation, the situations that the aircraft is uncontrollable and you cannot, in many cases, prepare the aircraft for landing or to choose the position of the aircraft for activation of the rescue system. The parachute systems should be reliable, well integrated in the system and in the aircraft or UAV, in order to protect and rescue people's lives and to protect or minimize damage of expensive equipment of cutting-edge technology within it. Subject of this paper is medium range UAV Pegasus (figure 1), a multi-functional intelligence and reconnaissance UAV system with operational radius of 200 km and more.

Figure 1. Medium range UAV *Pegasus*

Table 1. UAVs technical characteristics

UAV Pegasus	
Power	38 KW (52 BHP) two-cylinder, two-stroke boxer
Propeller	wooden two blades, pusher
Wing span	7,068 m
Length	5,580 m
Max. payload weight	54 kg
Max. takeoff weight	265 kg
Max. speed	160 - 180 km/h+
Operational altitude	2000 -3000 m

Technical characteristics of *Pegasus* are given in Table 1. UAV can be used for intelligence, surveillance and reconnaissance missions, striking ground targets, target laser designation, damage effect assessment, etc. With 2

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precision guided weapons, it is able of conducting air-to-ground accurate strike on the ground targets.

2. ANALYSIS OF THE RESCUE SYSTEM IMPLEMENTATION

Medium-range UAV *Pegasus* is fully composites structure with back position of an engine, to make it easy to service the UAV and to place the payload in the front part of the fuselage. Centre section of the wing is the integral part of the fuselage and, in the first phase of the project, it was reserved for integral tanks. In early phase of design, parachute rescue system was planned to be in the fuselage centre, rear of the fuel tanks. With a change of the concept and putting second tank in a fuselage, the space for integral tanks left empty, and the parachute system was left aside. Firstly idea for rescue system integration was replaced with a need for more fuel to increase endurance during two different missions. Expected endurance for the first reconnaissance mission is from 8-10 hours, and for the armed mission from 4-6 hours. With the new request for rescue system, we have analysed two different direction of parachute integration:

2.1 First version- the aim was to find a solution from our own capacity with collaboration between subcontractors from our country and
2.2 Second version-the aim was to find certified solution (ballistic parachute system) from abroad which is in use in many UAV and ultralight aircrafts.

Both versions demanded investigation of the market and parachute companies with certified systems that are already in use. In Table 2, data were presented for reviewed companies and products that were considered and analysed, and the depending on availability shortlist are marked with green.

Table 2. Considered solutions

Name of the system Characteristic	UAVOS 350 Parachute Systems	BRS BRS-6 System 600 Softpack	BRS BRS-6 System 600 VLS	Galaxy GRS GRS 4 270 60m2	Galaxy GRS GRS 4 270 60m2	PR 03-1 Kluz
Maximal UAV mass [kg]	360	272	272	270	270	
Type of the system	ballistic system	ballistic system	ballistic system	ballistic system	ballistic system	
Type of the package	hard	soft	hard	soft	OUT unit	soft
Mass of the system [kg]	5.7	9 (8.2)	11 (10.4)	8.8	9.6	6
Dimension of the system [mm]	210 x 210 x 510	280 x 250 x 150	460 x 293 x 191	195 x 245 x 305 (B1-B12)	Ø185x500 mm	420 x 240 x160
Maximal operational opening dynamic shock at VNE and MTOW				14.5	14.5	
Average UAV horizontal speed [m/s]	up to 6			6.6	6.6	
Average UAV vertical speed [m/s]						
Nominal parachute diameter [m]		8.2	8.2	7.2	7.2	
Maximal airspeed for usage [km/h]		222		230	230	
Parachute surface area [m^2]	56	53.1		60	60	45.5
System volume [l]	22.5	10.50		14.6		16.2
System life-cycle (repacking)	10 usage-(12 months)	24 years		6 years for ballistic system	6 years for ballistic system	

2.1. First approach

Knowing that maximum descending speed should be less than 7 m/s for the safe landing of the aircraft, and for the mass of 265 kg, it was necessary to ensure parachute with diameter at least 60 m^2. There was no enough free space inside the UAV for a parachute, with that area, to be placed. First approach lead us to consider the only free space in the UAV, which is centre section of the wing, with free volume two times of 15 l (figure 2).

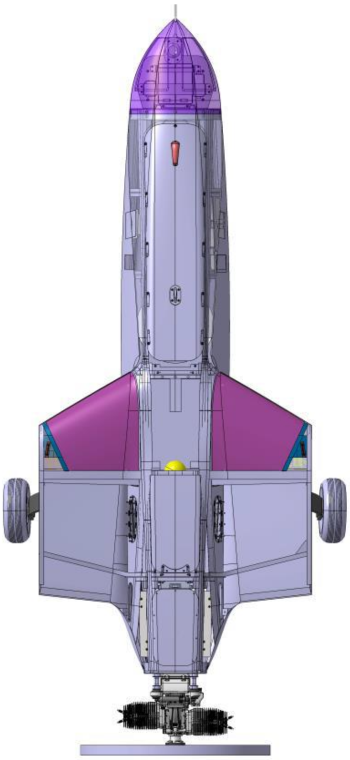


Figure 2. Free space for parachutes (purple)

We decided to start first analysis with two smaller parachutes that are available in short time for us. It was just enough space to place two reserve parachutes PR03-1 with area of 45.5 m^2 in a center sections of the wing. The mentioned parachutes were immediately available to be installed and tested. The system consists of two initial pilot parachutes with springs and two main parachutes which will be connected together. Center section of the wing will be modified making the cover on the upper skin of the wing and the inner place of the center section will be rearranged for easy opening and launching the pilot parachute with its reserved parachute. There will be one method to verify this type of opening in the wind tunnel where we will analyze the opening of the cover and launching the parachutes in the similar flow like in a real time rescue mission (figure 3). The pilot parachutes will be thrown high enough to jump over the tails and empennage of the UAV and to carry out main parachutes with it. In this case there will not be additional numerical and flying tests regarding change of aerodynamics because all parts of the system can be placed inside of the fuselage. Considering mass aspects, increase of the mass will be 10 kg for this type of system. Parachutes will be installed near the center of the mass so the correction of the center of the mass position will be minimal (center of the mass – yellow sphere in figure 2). Carrying parachute system in a UAVs mission would have compensation like decreasing fuel that you take in the different missions.

Figure 3. Cover on the upper skin (green)

2.2. Second approach

Second approach was to investigate foreign market and to find best rescue system for this type of UAV. We considered different types of systems and make contact with different firms. Companies that we found interested were mentioned in a table 2. The leading companies in this field were contacted like *BRS Aerospace*, *Junkers Magnum Rescue System* and *Galaxy rescue system*. For this type of the UAV the only *Galaxy rescue system (GRS)* could meet the requirements for this category of the UAV, and the other two have withdrawn production or don't have products for this type of UAV because *GRS* take primacy on the market for this category. We were considering two types of *GRS* parachute systems, soft pack system and OUT unit. There were many limitations because every system has rocket as a part of parachute launching system and the best solution was to put it at the top of the fuselage but there are front and back tanks, and it was not allowed for rocket to be installed near the fuel. Because we have already pylons under the reinforced wings, and installation was already prepared for the weapons, there will be a little work to put OUT unit under the wing (figure 4).

Figure 4. OUT unit attached to the wing pylon

Second option was to make integral container for soft pack and to mount rocket on it and with aerodynamically shaped cover the system will be well attached to the wing pylon (figure 5). Integral container is weather-resistant pack as well as OUT unit, so the choice will be made based on availability of the mentioned systems, simplicity of use, and the drag force that system make, because the mass of the systems is approximately the same. In the same way as in the case of armed UAV, when the external parachute unit is part of the mission fuel reduction must be calculated to ensure that maximum UAV s mass not exceed 265 kg. Advantage is that center of the mass will not be compromised with the any of the rescue systems integration. System has electronic activation and its unit has to be installed inside the UAV, in the left wing.

Figure 5. Integral container with soft pack and rocked attached to the wing pylon

In a both variants hanging points will be in three points on a fuselage (two in a front of a center of a gravity a one behind). Figure 6 represent position of hanging points marked with purple line and center of gravity marked with yellow sphere.

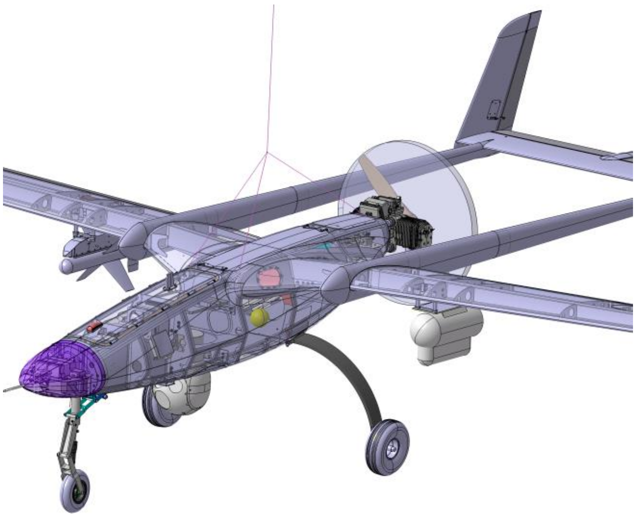


Figure 6. Hanging points and centre of the gravity

Before test with launching the rocket and parachute take place, some numerical calculations should be performed. Because the masses of the systems is less than weapons mass that already has been calculated for static strength of the wing with pylon, the verification of the static strength will be not necessary. Calculation of aerodynamic drag that are occurring with attaching any of these rescue systems described in second approach has been presented in the next chapter.

3. AERODYNAMIC DRAG NUMERICAL CALCULATIONS

To decide which system has minimal influence on mass, performance and any kind of change in the system of the UAV we need to consider both of discussed rescue systems. An aspect of aerodynamic drag that different shapes make are presented in this chapter. Data, which were used for simulations, are presented in Table 3.

Table 3. Data for simulation

Data for simulation	
Altitude	3000 m
Flight speed	42 m/s
Pressure	70109 Pa
Density	0.909 kg/m^3
Kinematic viscosity	1.861 x 10^{-5} m^2/s

Computational fluid dynamic (CFD) has been performed in the commercial ANSYS Fluent software by the finite element methods. Calculated reference surface area is 4.24 m^2 and it has been used K-omega-SST turbulence model. We have analyzed model of integral container with aerodynamically shaped cover and OUT unit of parachute rescue system (figure 7).

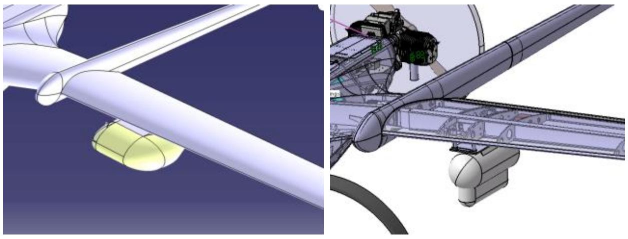
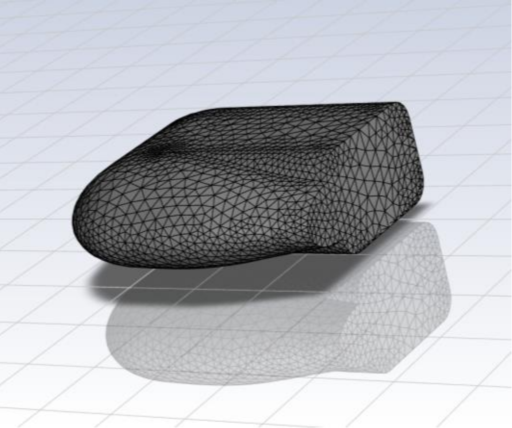


Figure 7. Integral container with soft pack (left) and OUT unit (right)

Computational surface mesh of aerodynamically shaped cover of integral container with rocket and OUT unit is presented in Figure 8.



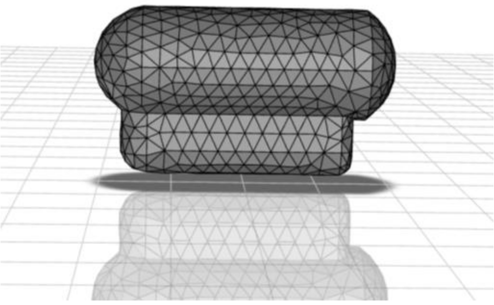


Figure 8. Mesh of integral container (upper) and OUT unit (lower)

Dynamic pressure values on the surface of the OUT unit is lower intensity than the pressure on the surface of integral container (figure 9).

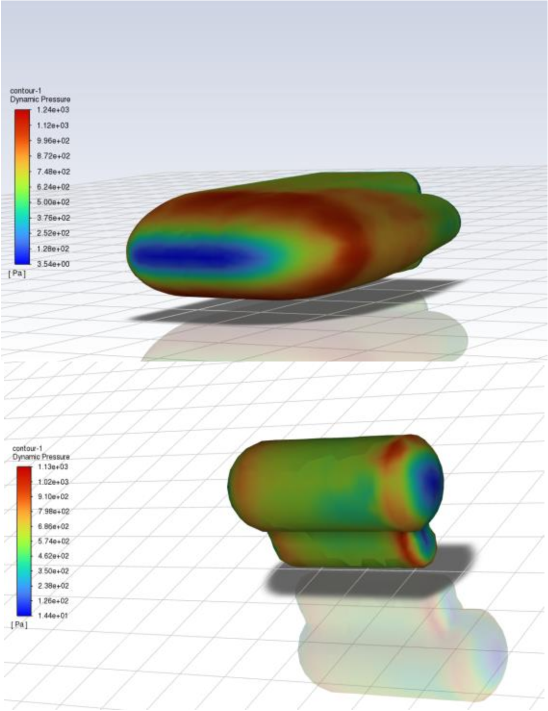


Figure 9. Dynamic pressure distribution of integral container (upper) and OUT unit (lower)

Vectors of velocity around the cover directly influence the total pressure distribution on the surfaces (figure 10).

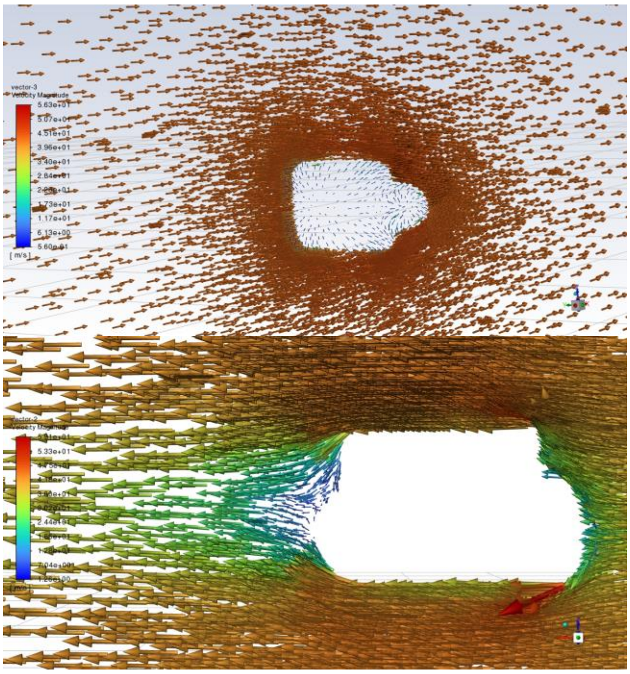


Figure 10. Vector of velocity around integral container (upper) and OUT unit (lower)

Total pressure values on the surface of the integral container is lower intensity than the pressure on the surface of OUT unit (figure 11), which is causing lower drag force.

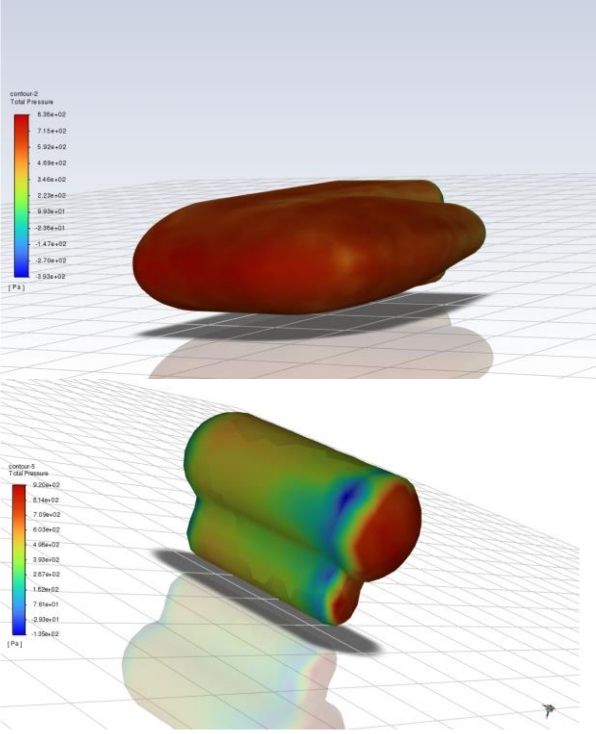


Figure 11. Total pressure distribution of integral container (upper) and OUT unit (lower)

Acquired data by simulation are given in table 4.

Table 4. Calculated data

Calculated data	Integral container	OUT unit
Form drag	12.778 N	16.411 N
Skin friction drag	1.216 N	0.505 N
General drag force	13.994 N	16.917 N
Form drag coefficient	0.00367	0.00484
Skin friction drag coefficient	0.00035	0.00015
General drag force coefficient	0.00402	0.00499

5. CONCLUSION

Parachute systems, today as inevitable part of almost every flying objects, and its integration were analyzed. Both variants of parachute systems that are presented in this paper will be subject of testing in order to decide whether systems are applicable for this purpose and which system is more reliable or available on the market. In a second variant, two different packs are presented and analyzed with the aspect of aerodynamic drag, mass, availability, easiness of application.

Based on data gain with numerical simulation, the integral container has a lower general drag force, but not in an amount that is substantial. So the other factors will decide the final choice for purchasing. Masses of the mentioned systems are similar but the integration and the time that is needed for systems to be functional suggested that OUT unit has advantage over integral container with aerodynamically shaped cover. In the first case we need to produce the container and the cover, to purchase a parachute and the rocket, and to do verification of the system. The faster and easier way is to get OUT unit with cover and packed system that needs minimal tests to perform for approval of its application. Anyhow further research and tests will make more clear which choice is more efficient.

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