VERTICAL TAKE-OFF AND LANDING UNMANNED AIRPLANE

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Keywords: *Vertical take-off and landing (VTOL), unmanned airplane, urban air mobility (UAM)*

Abstract: *It is suggested application of Joined-wing air module in the structure of Pop.UP of Airbus instead of Rotary-wing air module. It will increase efficiency of VTOL UAV used for UAM.*

ВЕРТИКАЛНО ИЗЛИТАЩ И КАЦАЩ БЕЗПИЛОТЕН САМОЛЕТ

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Ключови думи: *вертикално излитащ и кацащ (VTOL), безпилотни самолети (UAV), градска авиационна мобилност (UAM)*

Резюме: *Предлага се в схемата Pop.UP на Airbus вместо rotary-wing air module да се използва joined-wing air module, което ще подобри значително ефективността на VTOL UAV използвани за UAM.*

Introduction

Traffic jams in the European Union cost approximately 100 billion Euros annually. It is only the material evaluation of transport systems' imperfection. More than 125,000 people pass away in transport accidents every year. Even though short distances, citizens waste several hours to move from their homes to working places. This worsens life quality so that alternative transport solutions with application of organizational and technological innovations are being sought.

Population of the world is concentrated in large cities. It is expected that 80% of 9 billion population of the world to live in urban areas in 2050 [1]. Many cities have difficulties with social and ecological problems as a result of overcrowding, poverty, pollution, and big traffic. Providing of effective mobility in urban areas is a key challenge for their future development.

Number of cars has risen with the increase of the number of roads. A radical solution for urban mobility in the future is the opportunity to be used 3D space instead of 1D space which is used at the moment. It means that flying vehicles could be applied.

Let us look at an idealistic model of urban air mobility which is based on application of personal unmanned airplanes (PUA).

Initial requirements of the model are following [2]:

- In order to achieve low operating costs, service companies have to possess and operate these vehicles. They have to provide necessary PUAs on time according to client requests anytime and in different climate condition (excluding storms);
- Door-to-door transport has to be provided within 45 minutes. It has to be comfortable and integrated whereas conditions are close to those at home or in offices;
- Flight safety has to be equal to flight safety of regular aircrafts or to be even higher;
- No pollution is allowed during the flight and the noise level has to comply with urban environment standards;
- Transport costs have to be less than costs with personal cars.

The article discusses opportunities for development of a personal unmanned aircraft that completely corresponds to Urban Air Mobility (UAM).

Urban Air Mobility Aircraft

Requirements for operation in urban areas at low operating costs can be achieved with Vertical Take-off and Landing Unmanned Airplanes (VTOL UA). These planes have a low noise level and zero level of pollution. Many VTOL UA projects have been in a process of development. Some of the projects are on the prototype testing phase. Different schemes are used: airplanes, helicopters, and multi-rotor platforms which correspond to contradictory requirements. An analysis of these platforms shows that Pop.Up platform of Airbus and Italidesign platform are the most suitable and perspective. [3] (Fig.1).

Fig. 1

During the 87th Geneva International Motor Show, Italdesign and Airbus world-premiered Pop.Up, the first modular, fully electric, zero emission concept vehicle system designed to relieve traffic congestion in crowded megacities. Pop.Up envisages a modular system for multi-modal transportation that makes full use of both ground and airspace.

Pop.Up System consists of a three layers concept:

- an Artificial Intelligence platform that, based on its user knowledge, manages the travel complexity offering alternative usage scenarios and assuring a seamless travel experience;
- a vehicle shaped as a passenger capsule designed to be coupled with two different and independent electric propelled modules (the ground module and the air module). Other public means of transportation (e.g. trains or hyperloops) could also integrate the Pop.Up capsule;
- an interface module that dialogues with users in a fully virtual environment.;

The Pop.Up system aims to give time back to commuters through a flexible, shared and adaptable new way of moving within cities introducing a new user-focused transportation system concept.

The Pop.Up vehicle combines the flexibility of a small two seater ground vehicle with the freedom and speed of a vertical take-off and landing (VTOL) air vehicle, thus bridging the automotive and aerospace domains.

POP.UP TECHNICAL SPECIFICATION

AIR MODULE

DIMENSIONS		
Length	mm	4403
Height	mm	847
Width	mm	5000
Rotors	n	4+4
Propeller diameter	mm	1780

POWERTRAIN	
Power train	Electric
Motors	8
Total power	136 kW
Motor power (each motor) (MCP)	17 kW
Range (without payload)	100 km
Charging time	15 minutes
Empty weight ratio (EW/GW)	43.90 %
Total battery(ies) energy / capacity	70.0 kWh
Disc Loading	30.4 kg/m2
Tip Speed	150 m/s
Air Mode	
Number of passengers	2
Vehicle maximum gross weight	600 kg

PERFORMANCE	Top Speed (stand-alone module)	100 km/h

GROUND MODULE

DIMENSIONS		
Length	Mm	3115
Height	Mm	681
Width (front/rear)	Mm	1848/1900
Front overhang	Mm	581
Rear overhang	Mm	534
Kerb weight	Kg	200

PERFORMANCE	Top speed	km/h	100

POWERTRAIN	
Powertrain	Electric
Motorwheels	2 (Rear)
Total Power	60 kW
Range	130 km
Charging time	15 Minutes
Total battery(ies) energy / capacity	15 kWh

CAPSULE

DIMENSIONS		
Length	mm	2647
Height	mm	1415
Width	mm	1540
Number of Passenger		2
Kerb weight	kg	200

The vehicle is divided on three modules that make it suitable and comfortable for door-to-door passenger and freight transport. This gives the opportunity to achieve a high level of thrust effectiveness whereas the energy effectiveness of air transport is not satisfactory.

Usage of a multi-rotor module does not allow achievement of maximum effectiveness of air transport because rotary-wing aircrafts possess low energy effectiveness. It turns out that the rotary-wing air module can be replaced with a fixed-wing air module which will provide higher energy effectiveness. Analysis of numerous schemes of fixed-wing aircrafts shows that the Joined Wing type is the most appropriate [4]. (Fig. 2)

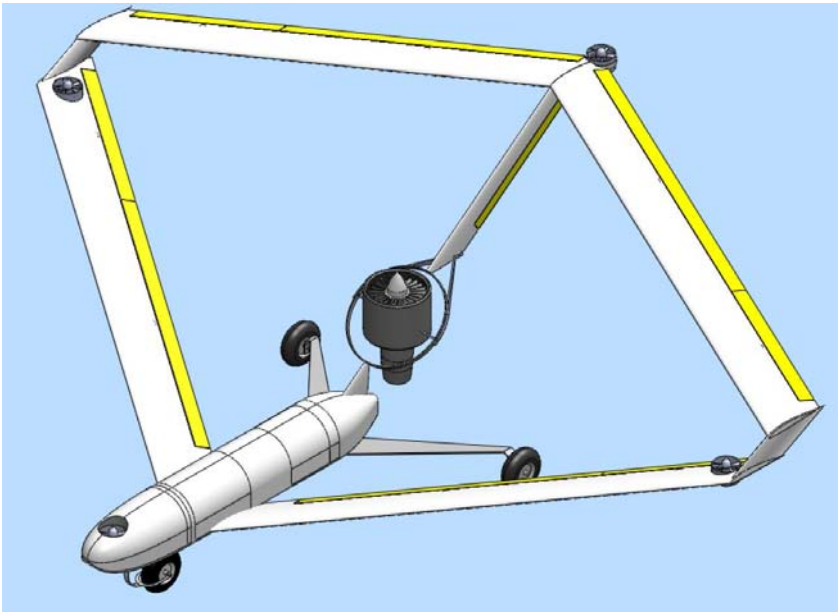

Fig. 2

Many publications [5] prove that Joined Wing aircrafts possess a high level of weight and aerodynamic effectiveness. Instead of the fuselage shown on fig.2, a passenger or cargo capsule can be assembled. Several engines can be used which are placed in a vertical position during take-off, landing and hovering stages. During the flight, engines are placed in a horizontal position. Usage of Electric Ducted Fan (EDF) propulsors is suggested because of space limitation between wings and better thrust efficiency when propeller diameters are equal.

In the joined-wing VTOL UA, shown in Fig. 2, the main EDF (propulsor) is hinged so that its thrust vector always passes through the center of mass of the airplane. Four additional EDFs are placed at the nose, the tail and the two wingtips. The system that maintains the position and the orientation of the UA, the Attitude Head Reference System (AHRS), controls the angular speed of these fans, the thrust from which generate the control moments about the three axes of the body-fixed frame. The main advantage of this layout is that the thrust of the main EDF, which is attached to the swivel hinge of the aircraft, always passes through the center of mass, and thus control during takeoff, landing and hovering can be achieved with minimal control moments.

According to pre-calculations, the joined-wing air module will possess much higher (more than 15 times) aerodynamic and energy effectiveness than the vehicle shown on Fig.1. This fact will increase flight duration, horizontal speed, and flight distance.

Conclusions

In conclusion, usage of the joined-wing air module will allow to design and develop effective UAV for urban air mobility.

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