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Design of solar high altitude long endurance aircraft for multi payload & operations

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Abstract

Research is being carried out at the Turin Polytechnic University with the aim of designing a HAVE/UAV (High Altitude Very-long Endurance/Unmanned Air Vehicle). The vehicle should be able to climb to an altitude of 17–20 km by taking advantage of direct sun radiation and maintaining a level flight; during the night, a fuel cells energy storage system would be used. A computer program has been developed to carry out a parametric study for the platform design. The solar radiation change over one year, altitude, masses and efficiencies of the solar and fuel cells, as well as the aerodynamic performances have all been taken into account. The parametric studies have shown how the efficiency of the fuel and solar cells and mass have the most influence on the platform dimensions. High modulus CFRP has been used in designing the structure in order to minimize the airframe weight. A Blended Wing Body (BWB) configuration of *Solar HALE Aircraft Multi Payload & Operation* (*SHAMPO*) with 8 brushless electric motors has been developed, as a result of the parametric study. The BWB solution, compared with conventional designs, seems to provide the best compromise between performance, availability of surfaces for solar-cells, and volume for multi-payload purposes. Several profiles and wing plans have been analyzed using the CFD software Xfoil and Vsaero. The airfoil coordinates at the root and along the wing span as well as the wing planform were optimised to achieve the best efficiency. A FEM analysis was carried out using the Msc/Patran/Nastran code to predict the static and dynamic behaviour of the UAV structure.

Resumi

La ricerca che si sta portando avanti presso il Politecnico di Torino riguarda il progetto di un velivolo senza pilota HAVE/UAV (velivolo senza pilota da alta quota e lunga autonomia). La Piattaforma dovrebbe salire ad una quota di 17–20 km principalmente sfruttando la radiazione solare dopodichè continuare la missione in volo livellato. Il volo notturno sarebbe garantito da un sistema energetico a celle a combustibile. Nella fase preliminare è stato sviluppato un software per l'analisi parametrica delle principali variabili di progetto quali la variazione dell'irraggiamento solare durante il corso dell'anno, la variazione di masse ed efficienze di celle solari e celle a combustibile così come anche la variazione delle prestazioni aerodinamiche. Lo studio parametrico ha messo in luce come le efficienze di celle solari e celle a combustibile giochino un ruolo fondamentale nel dimensonamento del velivolo. Al fine di minimizzare il peso strutturale del velivolo la struttura è stata progettata utilizzando materiali compositi in fibra di carbonio ad alto modulo elastico. Come risultato dell'analisi parametrica è stata scelta una configurazione senza fusoliera BWB con 8 motori brushless. La soluzione BWB senza fusoliera, confrontata con configurazioni più convenzionali, è stata ritenuta quella di miglior compromesso tra prestazioni, superfici a disposizione per l'installazione di celle solari e volume a disposizione per carichi paganti di differente tipologia. Allo scopo di ottenere una configurazione efficiente dal punto di vista delle prestazioni aerodinamiche, numerosi profili e forme in pianta sono state analizzate utilizzando codici di fluidodinamica computazionale CFD quali ad esempio XFOIL e VSAERO. Allo scopo di caratterizzare il comportamento statico e dinamico della struttura dell'UAV è stata effettuata una analisi agli elementi finiti (FEM) con l'ausilio del codice di calcolo NASTRAN.

Keywords: Aircraft; UAV; Stability; Structure; Flight-dynamic

Parole chiavi: Velivoli senza pilota; Stabilità; Strutture; Dinamica del volo

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Nomenclature

C_D, C_L	Drag and lift coefficients
n	Limit load factor
P_{req}	Required power for the horizontal flight
Re	Reynolds number based on mean aerodynamic chord
η_{blade}	Propeller efficiency
η_{fc}, η_{sc}	Fuel cells and solar cells efficiency
η_{gears}, $\eta_{inverter}$, η_{motor}	Reduction gear, inverter and electric motor efficiency
ρ	Air density
Λ_{ht}, Λ_w	Horizontal tail and wing sweep angle
AR_{ht}, AR_w	Horizontal tail and wing aspect ratio
b_{ht}, b_w	Horizontal tail and wing span
S_{ht}, S_w	Horizontal tail and wing area
c_{mean}	Mean Aerodynamic Chord
V	Platform airspeed
V_{EAS}	Equivalent Airspeed
W_{af}, W_{tot}	Airframe and total platform weight
Z	Altitude
α	angle of attack
EAS	Equivalent airspeed
SHAMPO	Solar HALE Aircraft for Multi Payload & Operation
Heliplat®	Helios Platform
EC	European Commission
POLITO	Politecnico di Torino

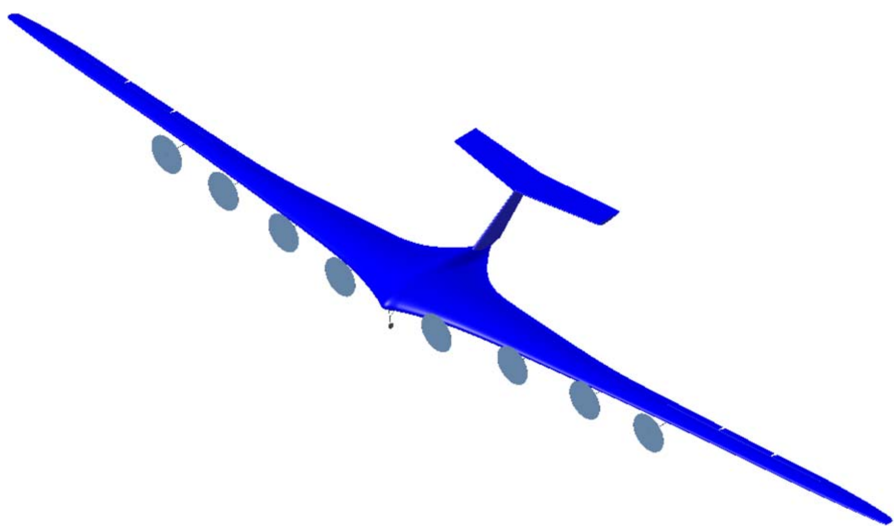

Fig. 1. SHAMPO configuration: external view.

1. Introduction

Extensive research, has been acquired since 1994, by the Politecnico di Torino Dept. of Aerospace Eng. (POLITO/DIASP, Scientific Responsible Prof. G. Romeo) in the Design of Solar Powered UAV as a High Altitude Very Long Endurance Platform positioned in the stratosphere at an altitude of 17–20 km and an endurance of more than six months [10–19].

Flying at high altitudes for extended durations provides a vantage point and capability that is presently not available with conventional air vehicles or satellites. There are a number of potential applications especially for communications or wide area surveillance. These types of aircraft could function as a geostationary satellite with the advantage of lower cost and more flexible operations. They could in fact be self-launched and easily recovered for maintenance, whenever necessary.

Compared to today cost of airborne systems (4500 €/flight hour) as well as MALE UAVs (306 €/flight hour), this kind of platforms show clear advantages in monitoring missions, because continuous observations per year will be performed on the interested area and all required data will usually be available immediately (Fig. 2). Let consider, for example, an airplane that has to cover an area of 300 × 300 km. A Solar Powered Airplane, flying at an altitude of 20 km, can carry out the mission at a cost of about 750 euro/flight hour, while a fleet of five MALE UAVs, flying at an altitude of about 4.5 km and at a flight speed of about 150 km/h, is able to give the same service at a cost of about 3060 euro and revisiting time of 2 hours.

For a renewable energy UAV, regenerative power technologies such as thin film photovoltaic arrays, fuel cells, electrolysers, and power management systems, are the keys to achieving long-endurance. Since the basic power source, the sun, is not available throughout the whole day, effective designs for managing, collecting, storing, and consuming energy are needed to