DESIGN AND DEVELOPMENT OF A LOW ALTITUDE UNMANNED AERIAL VEHICLE

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Abstract

The activities concerning the development of an advanced composite, low altitude Unmanned Aerial Vehicle for civilian applications are presented. The project is co-ordinated by the Dipartimento di Progettazione Aeronautica (DPA) of the University of Naples Federico II and involves also others departments and research centres[1].

The multidisciplinary aspects of the project are pointed out: experimental aerodynamics, utilisation of composite material on airplane structures, technologies related to the navigation, remote and/or autonomous control, data links and storage, sensors utilisation for the mission requirements.

The development of the present UAV has been first considered as a research platform for the activities related to the above mentioned aspects, mainly to enhance skill in composite airframe design and fabrication. Furthermore the growth of interest towards the unmanned vehicles has induced to enable the UAV in civilian applications, such as surveillance and reconnaissance missions.

Introduction

The reason leading towards UAV's interest is the possibility to utilise relatively not expensive airplanes when the human presence on board is not necessary or when the mission involves long operational time or severe risks[1,2,3,4]. On the other hand the development of unmanned technology is strongly due to the evolution in miniaturisation of sensors, guidance systems and composite materials technologies.

The idea to develop an unmanned vehicle arises from the necessity to realise a small airplane using advanced composites for research purposes[6]. The full scale composite vehicle is intended to be tested in the main wind tunnel facility of DPA for both aerodynamic and structural investigations. The overall dimensions of the airplane are therefore limited by the wind tunnel test section, and allow to transport it as far as the starting mission location by a conventional road vehicle (table 1). The autonomy is limited to three hours.

The architecture is traditional: high rectangular wing, two stroke single engine driving a two blade propeller, tricycle landing gear with cantilever legs mounted on fuselage (fig. 1).

The payload to carry out the mission's main purpose varies between 3,5 and 5,5 kilograms, depending on the take off and landing configuration.

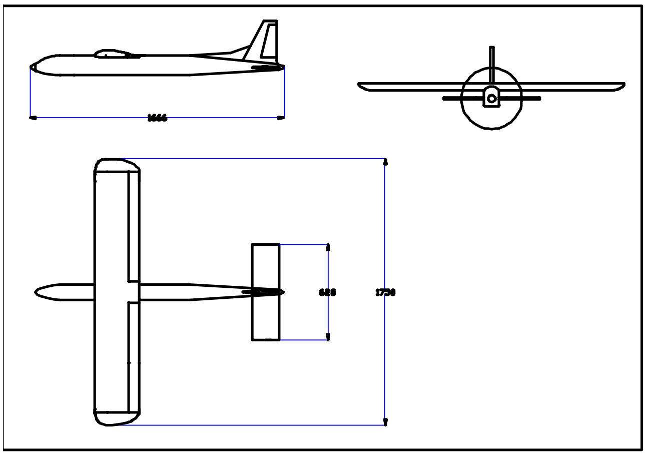

fig. 1 – General views of DPA's UAV

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Lavorazione Materiali Compositi S.p.a.

DIMENSIONS	
OVERALL LENGTH	1.66 m
WING SPAN	1.750 m
ASPECT RATIO	6
WING CHORD	0.29 m
WEIGHTS [kg]	
OEW	6,5
FUEL	3
PAYLOAD	3,5/5,5
MTOW	13/15
POWER PLANT	
WEIGHT	0,83 kg
MAX POWER (bhp)	3,5 a 9000 RPM

table 1 –Characteristics

1. Experimental aerodynamics

The dimension of mean chord (0.29 m) at a flying speed between 20 and 50 m/s has required an accurate investigation for the selection of an efficient wing section at Reynolds number between 3.5×10^5 and 10^6. High lift coefficient at flight Reynolds number are required to contain take off run within 60 meters, although take off from balloon and recovery with a parachute are provided for the future.

As experimental data are not easily available in this range of Reynolds number, five airfoils have been selected from literature [7,8,9] and force measurements on wings (scale 1:2,5) with this airfoils have been conducted in the 0.8m x 0.6m wind tunnel of the laboratory of DPA. A blockage correction procedure based on pressure measurement on the top wall of the test chamber [10] has been applied in order to achieve a good estimation of the maximum lift coefficient (fig. 2). Of the airfoils tested the Göttingen 624 and 797 have the best performances (fig. 3).

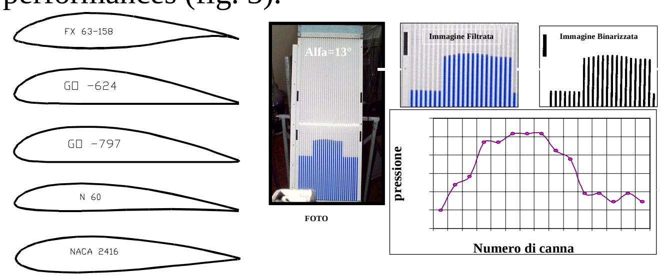


fig. 2 – The five airfoils tested in the 0.8x0.6 m wind tunnel and the high lift correction procedure

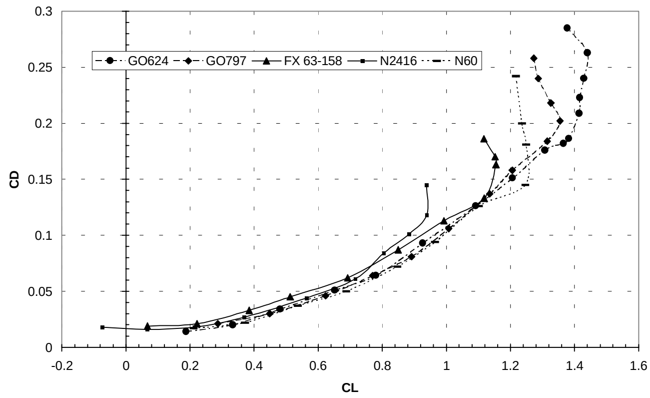


fig. 3 – Comparison of the experimental data of the five airfoils tested

Further experimental investigations have been carried out on two full scale wings with the Göttingen airfoils selected. Full scale wind tunnel tests (fig. 4) have also been performed on flapped wings, wing body and complete aircraft configuration in the main wind tunnel of DPA (2x1.4m test section). In the figures 5,6 and 7 some results are reported.

fig. 4 – Wing and wing-body configuration in the 2x1.4 m test section wind tunnel

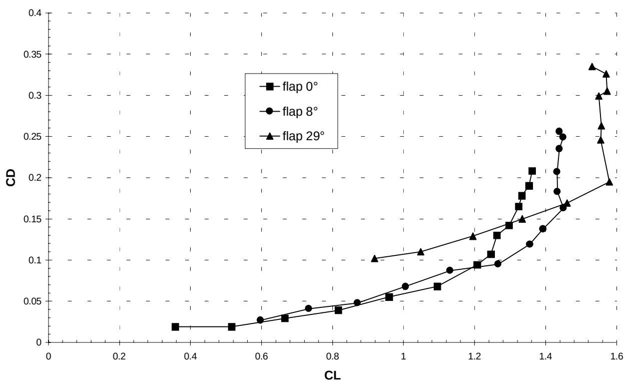


fig. 5 – CD vs CL at various flap deflections (wing)

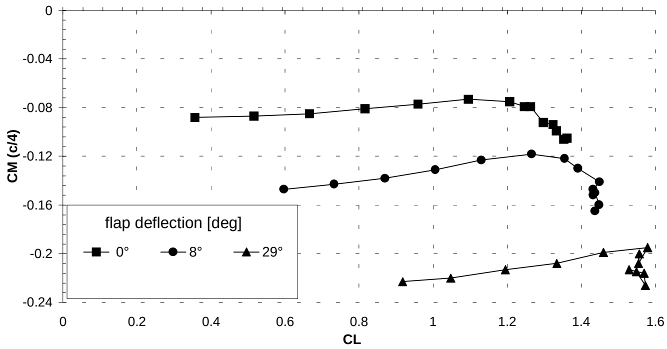


fig. 6 – CM c/4 vs CL at various flap deflections (wing-body)

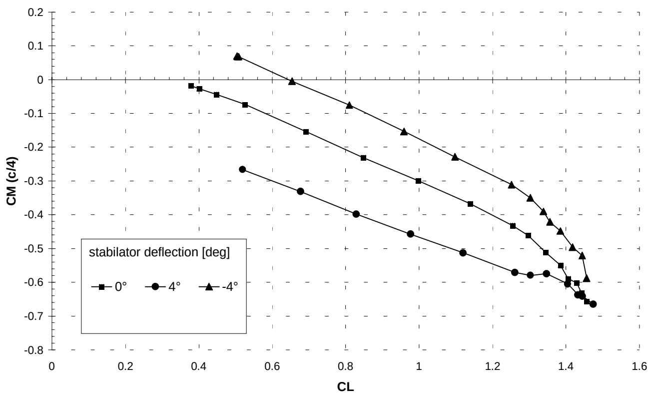


fig. 7 – CM c/4 vs CL at various stabilator deflections (complete aircraft)

2. Structure

As there are not specific requirements applicable to UAV's, loads determination has been performed referring to the simplified section of the Joint Aviation Requirements for Very Light Aircraft. As the aircraft is unmanned, 1,2 has been assumed as factor of safety. Furthermore for the structure verification the limit flight load factor has been assumed equal to 5, to take account of specific manoeuvres.

Limit and ultimate load conditions will be anyway verified in the static tests.

In order to obtain a light-weight high-strength structure and to improve advanced composite technologies in aeronautical applications, graphite epoxy and fiberglass are utilised for the primary structure and non structural components, respectively. A preliminary conceptual analysis of the structural solutions, together with finite elements stress analysis calculations, allowed to meet the light-weight low-production costs requirement (fig. 8,9).

Simplified structural solutions and reduced number of parts have been considered as an important requirement in the structure design, in order to reduce the costs related to the composite manufacturing techniques.

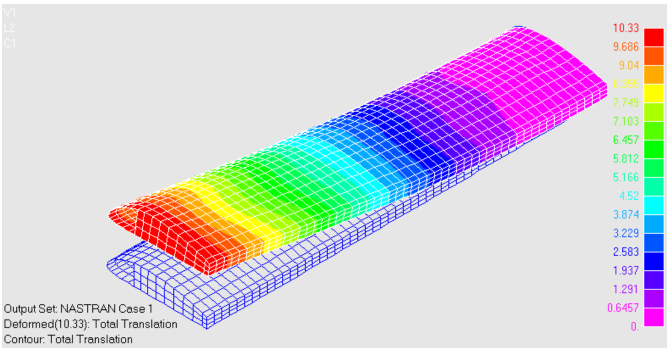


fig. 8 – Finite element model of wing: limit load manoeuvre condition

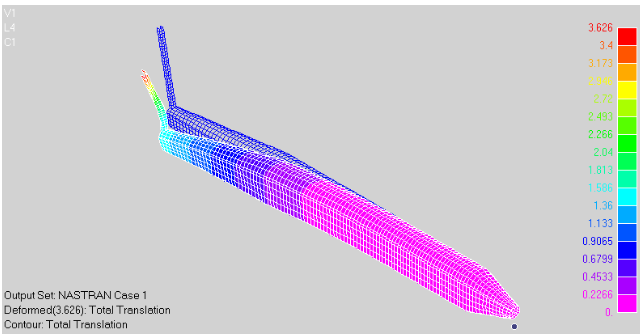


fig. 9 – Finite element model of fuselage: combined empennages limit load condition

2.1. Wing

After a preliminary evaluation a box beam solution has been preferred to a simpler but heavier full monocoque one. A two spars structure with three ribs, covered by a thin skin is adopted. Between the first (root) rib, that ensure the fitting to the fuselage structure, and second rib there is a sufficient space to house a fuel tank in each semi- wing span (fig. 10). Spars and skin are realised with preimpregnated unidirectional carbon epoxy plies, properly oriented to provide structural efficiency and cured with conventional techniques in autoclave. Ribs are realised with carbon epoxy fabric. On each semi wing, a monocoque flaperon ensure rolling control and high lift performances.

2.2. Fuselage and empennages

The fuselage structure consists of two symmetrical semimonocoque assembled together. Five bulkheads spaced along fuselage axis ensure the support for engine mount, the wing to fuselage fitting, and the support for the spar of the vertical empennage and the torsion tube of the horizontal tail (fig. 11).

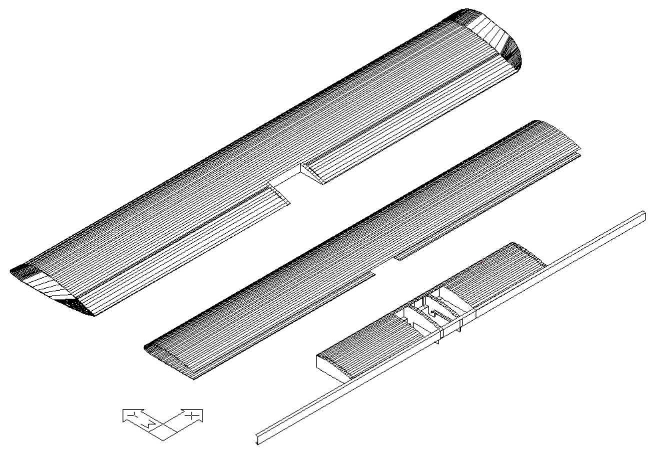


fig. 10 – Wing structural solution

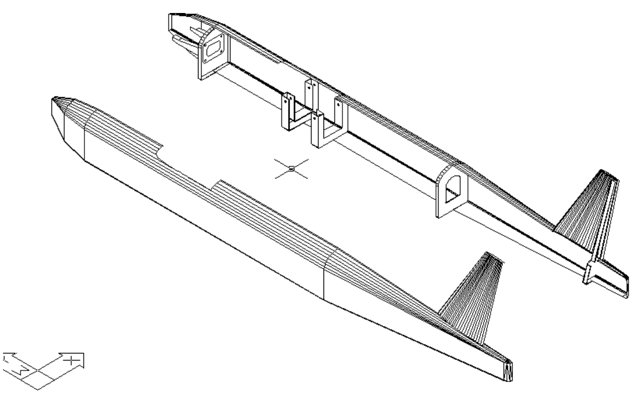


fig. 11– Fuselage structural solution

3. Systems and payload

As first step the aircraft will be equipped with an appropriate instrumentation in order to operate using control signals from a remote surface location. In this phase flight tests will be executed and an in-flight stress measurements activity will be also performed in order to evaluate the behaviour of the main composite structure under the actual load conditions [11].

In the final version the aircraft will be equipped with a flight instrumentation that allows the accomplishment of an autonomous navigation.

The related main on board systems will be:

- Power and distribution system (PD)
- Communication and Data Relay system (CDR)
- Guide, Navigation and Control system (GNC)
- Propulsion system
- On board Computer

A block diagram of the on board systems is reported in fig. 12. The UAV payload will depend on the mission requirement. Some missions will be used as test-beds for experiments on flight mechanics and on the behaviour of composite structures. On the other hand, surveillance and observation missions are scheduled as typical mission so the UAV will be equipped also with EO (Electro-Optical) sensor.

The aircraft systems components actually selected are listed in fig. 13.

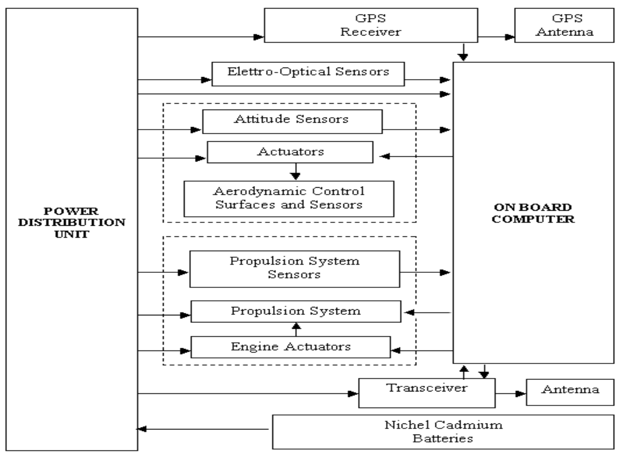


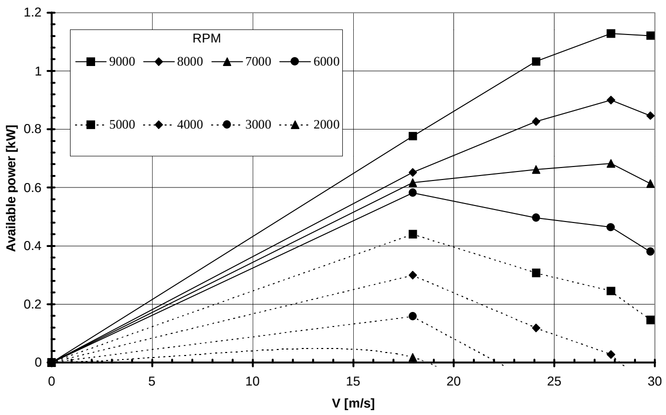
fig. 12– On board systems block scheme

SUBSYSTEM	TYPE	SIZE	POWER	WEIGHT
Communication and Data Relay	Transceiver DIP-UHF Data rate 40 kbps	33 x 23 x 10 (mm)	1 W @ 5 VDC	100g
	Antenna: coil antenna	Φ = 50 mm h = 5 mm		
Guidance, Navigation and Control	GPS Receiver: Garmin GPS 25 LVC Board	2750 x 1830 x 400 (inches)	1 W @ 5 VDC	40 g
	GPS Antenna: patch	Φ = 80 mm h = 10 mm		40 g
	Attitude Sensor: Inertial Platform DMU - DG	100 x 75 x 75 (mm)	10 W @ 30 VDC	600 g
Power	Nichel Cadmium Batteries. Capacity 22 W for 2 hours			
On board Computer	DSP Board, EPROM ADC-DAC,Serial Interface RS 232, Controller UART	200 x 100 x 15 mm	100W @ 15 VDC	300g
Payload	2 Video Cameras	30 x 30 x 15 mm	100W @ 15 VDC	30 g

fig. 13– Characteristics of the on board systems

4. Power plant

A two stroke engine driving a two blades propeller will be installed on the airplane. Experimental tests have been carried out in order to evaluate the engine-propeller coupling in terms of available power (fig. 14).



5. Activities in progress

At the present the carbon epoxy wing has been realised and static tests should be executed. Furthermore static tests will be conducted on the composite prototype also in the major test section wind tunnel, to evaluate the structural behaviour under the effective aerodynamic load conditions. Flight tests will be performed before the end of 2000 for the evaluation of flight performances and measurements of structural stresses in manoeuvre.

During flight test a miniaturised data acquisition system will be housed on board.

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