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DESIGN OF A TWIN ENGINE PROPELLER AIRCRAFT ; AERODYNAMIC INVESTIGATION ON FUSELAGE AND NACELLE EFFECTS

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SOMMARIO

Durante l'anno 2006 la Tecnam ha portato avanti la progettazione di un velivolo bimotore leggero denominato P2006. Il progetto del Prof. L. Pascale è basato sullo sviluppo di un velivolo quadriposto motorizzato con due motori Rotax leggeri da 100 hp. Il nuovo velivolo è caratterizzato da un peso massimo al decollo paragonabile con quello di velivoli monomotori e per questo denominato VELT (Very Light Twin). Nel presente lavoro vengono delineati gli elementi principali del progetto alla base della scelta della configurazione. Nel lavoro vengono poi mostrati i risultati di indagini numeriche e sperimentali svolte presso il Dipartimento di Ingegneria Aerospaziale dell'Università "Federico II". Le prove e le ricerche, oltre che alla determinazione delle caratteristiche aerodinamiche del velivolo, sono state incentrate sulla valutazione degli effetti aerodinamici della fusoliera e delle gondole sull'aerodinamica ed in particolare sulla distribuzione di carico aerodinamico lungo l'apertura, fondamentale ai fini della valutazione dei carichi certificativi.

ABSTRACT

Design of a new twin propeller aircraft named P2006 VELT (Very Light Twin) has been carried out at Tecnam aircraft industries during 2006. The new aircraft design, performed by Prof. L. Pascale, is based on the idea to built a 4-seat aircraft with two light engines (Rotax 912, usually used for ultralight aircraft) and to enter the market with a twin-engine aircraft with the same weight of a single engine aircraft (VEry Light Twin). The present paper shows all main criteria on which the design of the aircraft and the choice of the configuration have been based. At Dipartimento di Ingegneria Aerospaziale (DIAS) of University of Napoli "Federico II" a deep aircraft aerodynamic investigation has been performed both numerically and experimentally (through wind-tunnel tests). All tests and research activities have been focused on the evaluation of aircraft aerodynamics and in particular on the measurement of fuselage and nacelle aerodynamic effects. Deep investigations have concerned the evaluation of fuselage and nacelle effect on lift distribution along wing span, fundamental for the evaluation of certification loads.

1. INTRODUCTION

During the last 15 years *Tecnam Aircraft Industries* has been designing and developing more than 10 light and Ultralight(ULM) 2-seat aircraft characterized by high-wing or low-wing configurations and introducing interesting technological innovation (for light aircraft with the weight of 500-600 Kg) like the retractable gear. The market of light aircraft has been growing in the last decade all over the world and Tecnam has reached a leadership with more than 2000 aircraft sold in 15 years. The Department of Aerospace Engineering (DIAS) of University of Naples have been deeply involved in research activities concerning almost all of these aircraft[1,2]. Extensive activities have been carried out in collaboration with Tecnam on structural analysis, structural tests, aerodynamic analysis and optimisation, noise and vibration tests, wind-tunnel tests and flight tests. Almost all light aircraft produced by Tecnam have been tested in the main wind-tunnel belonging to DIAS. An example of some light aircraft that have been an important commercial success are shown in fig. 1.

Since 2006 *Tecnam* has started his intention to enter the market with a new CS 23 certified 4 seat aircraft.
In the last years, starting from the United States, the General Aviation has been revitalized, due to the necessity to decongest the classical skyway system and to use thousands of small airport in the country. With this aim the AGATE consortium was founded in 1994 to develop affordable new technologies to be applied on next generation light airplanes. In addition the fast economical growth of developing countries (like in Africa, south-America and in south-east of Asia) that do not have developed transportation systems has pushed the use and the diffusion of light aircraft in those areas. In example in some remote area of south Africa the transport through light aircraft can be the only solution, taking into account the absence of asphalt roads and the low acquisition and maintenance costs of these kind of machines.

Fig. 1: P92 Echo and P2002 JR aircraft

General aviation and light aircraft can be also extensively used for touristic transport and to perform services like aerial monitoring (police patrol or fire monitoring) with a reasonable cost respect to the classical use of helicopter. The other aspect (in particular looking at the not-developed countries market) that has been carefully considered by *Tecnam* has been the installation of engines using standard automotive fuel instead of aviation fuel. The reason is based on the lower cost and especially on the easy possibility of finding this fuel everywhere.
The above remarks put clearly in evidence the growing market for light aircraft with 4 seats, with a flight speed around 250-300 Km/h, with capability of flight altitude up to 12000 ft, with relatively simple , light and not-expensive construction (typical of ultralight and VLA certified aircraft) and so with a reasonable cost and with low maintenance costs. It is very important (considering the possibility of use in not developed areas and the take-off and landing capabilities from not-prepared airfields) the characteristic of relatively short take-off and landing run.

2. MARKET ANALYSIS AND P2006 AIRCRAFT DESIGN ASPECTS

Design of a new twin propeller aircraft named P2006 VELT (Very Light Twin) has been carried out at *Tecnam* aircraft industries during 2006. The design of the new aircraft, performed by Prof. L. Pascale, is based on the idea to built a 4-seat aircraft with two light engines (Rotax 912, usually used for ultralight aircraft) and to enter the market with a twin-engine aircraft with the weight of a single engine one. This project starts with the consideration that Rotax 912 S is the only engine available for the aviation market that uses automotive fuel and is FAR 33 certificated. This engine has been recently designed taking all the advantages of the latest technologies developed in the automotive market over the standard G.A. engines. Those mainly are:

- Reduced frontal area and better weight to power ratio
- Lower specific fuel consumption
- Lower propeller rpm i.e. higher efficiency and lower acoustic emissions
- Stable engine head temperatures due to liquid cooling

So far this modern powerplant, given its moderately low power (73 KW or 100 hp), has been used essentially on two seats single-engine light airplanes. It now becomes evident the opportunity to design a four-seats airplane powered by two of these Rotax engines with a neglecting weight difference, higher safety due to the twin engine arrangement and quite lower costs respect the single engine competitors.
In the following table(table 1) we compare the performance of some four seat, 200 hp aircraft available on the market today. It is evident that:

- For the first time ever it is possible to compare a **twin-engine** four seat aircraft with single-engine four-seat aircraft, due to their similar weight and power specifications;

- The P2006 empty weight is the lowest among twin engine aircrafts while the payload is higher. This can be attributed to the high structural and system efficiency and because of the excellent weight-to-power ratio of the Rotax engine. The wing-mounted engines relieve the aerodynamic load on the wing with a consequently lighter structure;
- The remarkable expected propulsive efficiency of P2006 can be ascribed to the low propeller rpm and low engine nacelle drag. These aspects, together with a streamlined fuselage, result in a good aerodynamic efficiency, as also confirmed through wind-tunnel tests (see after);
- From an operating point of view, is worth to consider that the option to use automotive fuel instead of AVGAS allows P2006 operators to dramatically reduce direct costs, making also possible to fly in regional or remote areas where AVGAS is difficult to find or prohibitively expensive;
- Low fuel consumption of Rotax engines and a high aerodynamic efficiency allows P2006 to be flown over long distances and in areas where ground facilities are poor.
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MODEL	Cessna 172R	Cessna 182T	Piper PA28-181	Cirrus	Diamond	EADS Socata	TECNAM
Specifications	**Skyhawk**	**Skylane**	**Archer**	**SRV-G2**	**DA-40**	**TB10 Tobago**	**P2006T**
wingspan (m)	10,97	10,97	10,80	10,84	12,00	10,04	11,20
wing area (mq)	16,20	16,20	16,00	12,50	13,47	11,90	14,76
lenght (m)	8,28	8,84	7,32	7,92	8,02	7,75	8,70
height (m)	2,72	2,84	2,20	2,59	1,98	3,02	2,90
cabin width (m)	1,00	1,07	1,06	1,24	1,14	1,08	1,20
cabin lenght (m)	3,60	3,40	2,49	3,30	n.a.	2,53	2,60
landing gear type	fixed, tricycle	fixed, tricycle	fixed, tricycle	fixed, tricycle	fixed, tricycle	fixed, tricycle	retractable, tricycle
Engine							
manufacturer	Lycoming	Lycoming	Lycoming	Continental	Lycoming	Lycoming	Rotax
model	IO-360-L2A	IO-540-AB1A5	0-360-A4M	IO-360-ES	0-360-M1A	0-360-A1AD	2x 912 S
horsepower	160 hp @ 2400 RPM	230 hp @ 2400 RPM	180 hp @ 2700 RPM	200 hp @ 2600 RPM	180 hp @ 2700 RPM	180 hp @ 2700 RPM	2x98 hp @ 2400 RPM
Propeller							
type	Fixed Pitch, 2 blade	Const. speed, 3 blade	Fixed Pitch, 2 blade	Const. speed, 2 blade	Const. speed, 2 blade	Const. speed, 2 blade	Const. speed, 2 blade
diameter (m)	1,91	2,00	n.a.	1,93	1,80	1,88	1,78
Design weight & Loading							
max. gross weight (kg)	1043	1406	1157	1360	1149	1150	1160
std. empty weight (kg)	588	860	760	929	744	730	750
useful load (kg)	455	550	397	431	405	420	410
seating capacity	4	4	4	4	4	4	4
fuel capacity (lt)	159	348	182	213	148	210	200
Wing loading (kg/mq)	64,4	86,9	72,3	108,8	85,3	96,6	78,6
Power loading (kg/hp)	6,52	6,10	6,43	6,8	6,38	6,39	5,92
Performance							
max. level speed s.l. (kts)	123	149	133	n.a.	n.a.	n.a.	150
cruise speed (kts)	122 (80%,8000 ft)	145 (80%,6000 ft)	128 (75%,7900 ft)	150 (75%)	145 (75%,6500 ft)	127 (75%,6000 ft)	145 (75% 7000 ft)
cruise speed "	116 (10000 ft)		n.a.	n.a.	134 (65%,10000ft)	109 (65%,6000 ft)	140 (65%,9000 ft)
stall speed, flaps up, pwr off (kts)	51	54	n.a	54	52	n.a.	53
stall speed, flaps down, " " "	47	49	52	n.a.	49	n.a.	48
best rate of climb (ft/m')	720	924	n.a.	900	1070	787	1350
service ceiling (ft)	13500	18100	14100	n.a.	15000	13000	16500
fuel cosump. lt/h (65%)	28	41	32	35	32	32	32
cruise range w/reserve (30') nm	580	968	487	634	n.a.	n.a.	750
takeoff, ground roll (m)	288	242	346	409	219	505	235
takeoff, total distance (50 ft) (m)	514	461	490	597	352	n.a.	460
landing ground roll (m)	168	180	280	309	146	460	180
landing distance (50 ft) (m)	395	411	427	622	314	n.a.	420
					* Single eng. R/c (s.l.), ft/m'		350
					Single eng.ceiling, ft		7500

Table 1: 4-seat light aircraft comparison

Fig.2 shows the comparison of frontal area and general characteristics of Rotax 912S engine and Lycoming IO-360 used in Cessna 172 and Piper PA-28 aircrafts. The figure shows that the weight-to-power ratio of Rotax is favourable and so the weight of 2 Rotax 912S is lower than the weight of one Lycoming. It si also possible to see that Rotax 912S engine frontal area is lower and in general allows a wing-mounted streamlined nacelle, reducing drag penalty arising from the twin-engine wing-mounted configuration. Other important consideration is that Rotax 912 max power is obtained at 2390 rpm instead of 2700 rpm relative to Lycoming.
Lower rpm allows higher propeller thrust at low flight speed improving aircraft take-off and climb performances. Fuel consumption is another big advantage of Rotax versus Lycoming.