Aerospace Science and Technology 40 (2015) 1–16

Contents lists available at ScienceDirect

Aerospace Science and Technology

www.elsevier.com/locate/aescte

Design and aerodynamic analysis of a twin-engine commuter aircraft

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ARTICLE INFO

Article history:
Received 9 January 2014
Received in revised form 23 September 2014
Accepted 20 October 2014
Available online 23 October 2014

Keywords:
Commuter aircraft
General aviation market
Conceptual and preliminary design
Wing span loading
Wind tunnel tests

ABSTRACT

The present paper deals with the preliminary design of a new general aviation Commuter 11 seat aircraft. The commuter aircraft market is today characterized by very few new models and the majority of aircraft in operation belonging to this category are older than 35 years. Tecnam Aircraft Industries and the Department of Industrial Engineering (DII) of the University of Naples "Federico II" have been deeply involved in the design of a new commuter aircraft that should be introduced in the market with very good opportunities of success. This paper aims to provide some guidelines on the conceptual design of this new twin-engine commuter aircraft. Aircraft configuration and cabin layout choices are shown and compared to similar solutions adopted by main competitors. The aerodynamic analyses are focused on some particular effects such as the wing–fuselage interference and the nacelle lift contribution and their effect on wing span loading. The aerodynamic analyses have been also essential to validate the preliminary estimation of aircraft stability and control derivatives (both longitudinal and lateral–directional) and to lead to a right sizing of tail surfaces. These analyses have been carried out through the use of a 3-D panel code. Finally some preliminary wind tunnel test results are presented.

0. Introduction

Many in the industry had anticipated 2011 to be the year when the General Aviation manufacturing industry would begin to recover. However, the demand for business airplanes and services, especially in the established markets of Europe and North America, remained soft and customer confidence in making purchase decision in these regions remained weak. This inactivity, nonetheless, was offset in part by demand from the emerging markets of China and Russia. While a full resurgence did not take place in 2011, the year finished with signs of recovery and reason of optimism. GAMA (General Aviation Manufacturer Association) 2011 Statistical Databook & Industry Outlook [9], which is usually a very useful and impressive source of data and statistics for general aviation, reports that the average age of general aviation registered aircraft is 46 year for single-engine piston powered aircraft and 15 years for single-engine turboprop aircraft. The average age for twin-engine 8–12 seats aircraft is 42 years for piston powered models and about 29 years for twin-engine turboprop commuter aircraft. These impressive data dramatically show the need of new aircraft models which will be characterized also by the application of new technologies like composite and light structures, new engines (with lower weight and lower fuel consumption), new and advanced aerodynamics (i.e. optimized airfoil and winglet) and new avionics and flight control systems. Since 1990 Tecnam Aircraft Industries[1] is involved in the design, development and construction of several light and ultra-light aircraft with 2 and 4-seat, characterized by high-wing and low-wing configurations. The company has acquired good and consolidated experience in the design of light aluminum alloy aircraft structures. In the last five years, Tecnam has started also to employ composite materials and some recent model presents an aircraft structure with extensive use of carbon fiber (fuselage and vertical stabilizer). Several research activities have been focused on reducing the empty weight, improving aircraft aerodynamics and flying qualities and reducing aircraft costs. An example of recent innovative design proposed by Tecnam is the P2010 single-engine 4-seat aircraft, see Fig. 1, that combines the carbon fiber fuselage technology employed on previous model (P2008) and efficient aluminum-alloy wing and stabilator derived from recent P2006T twin-engine 4-seat aircraft (that represented a great commercial success for the company). The combined use of carbon fiber and metal structure leads to a global optimization of aircraft aerodynamics, weight, cost and reliability. Carbon fiber ensures smooth surfaces and allows to produce a nice-looking

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[1] Costruzioni Aeronautiche Tecnam website http://www.tecnam.com.

http://dx.doi.org/10.1016/j.ast.2014.10.008
1270-9638/

Nomenclature

AR	wing aspect ratio
AR_h	horizontal tail aspect ratio
AR_v	vertical tail aspect ratio
a_v	vertical tail lift curve slope
b_h	horizontal tail span
BHV	body horizontal and vertical tail
b_r	rudder span
b_v	vertical tail span
BV	body and vertical tail
b_w	scaled model wing span
c	wing mean aerodynamic chord
cC_l	wing span loads
C_D	3D aircraft drag coefficient
c_e	elevator chord
CG	aircraft center of gravity
C_l	2D lift coefficient
C_L	3D aircraft lift coefficient
$C_{L\alpha}$	aircraft lift curve slope
C_M	3D aircraft pitching moment coefficient
$C_{M\alpha}$	aircraft pitching moment derivative with respect to the angle of incidence
C_N	aircraft yawing moment coefficient
$C_{N\beta}$	aircraft yawing moment derivatives with respect to the sideslip angle
$C_{N\beta,v}$	vertical tail yawing moment derivatives with respect to the sideslip angle
$C_{N\delta r}$	aircraft yawing moment derivatives with respect to the rudder deflection
$C_{N\delta r,v}$	vertical tail yawing moment derivatives with respect to the rudder angle
CP	pressure coefficient
C_{roll}	aircraft rolling moment coefficient
$C_{roll\,\beta}$	aircraft rolling moment derivatives with respect to the sideslip angle
$d\varepsilon/d\alpha$	wing downwash angle derivatives with respect to the aircraft angle of attack
i_{to}	horizontal tail tilt angle
l/h	fuselage fineness ratio
l_B	scaled model fuselage length
MAC	wing mean aerodynamic chord
mgc	wing mean geometric chord
N_0	aircraft neutral point as percentage of MAC
OEI	one engine inoperative condition
S	wing surface
S_h	horizontal tail surface
S_v	vertical tail surface
S_w	scaled model wing area
V	isolated vertical tail
$\Lambda_{c/4}$	horizontal tail sweep angle at quarter chord line
V_{EF}	aircraft engine failure speed
V_{EF}	engine failure velocity
V_h	horizontal tail volumetric coefficient
V_{MC}	minimum control speed
V_R	aircraft rotation speed
V_{SL}	aircraft stall speed in landing condition
V_{STO}	aircraft stall speed in take-off condition
V_v	vertical tail volumetric coefficient
W/P	power loading
W/S	wing loading
w_B	scaled model maximum fuselage width
WBV	wing body and vertical tail
W_E	empty weight
W_{TO}	maximum take-off weight
x_{acVT}	longitudinal coordinate of the vertical tail aerodynamic center
x_{cg}	longitudinal coordinate of aircraft center of gravity
z_{cg}	vertical coordinate of aircraft center of gravity
z_h	vertical coordinate of the horizontal tail leading edge
α	aircraft angle of attack
β	aircraft sideslip angle
δ_e	elevator angle
δ_F	flap angle
δ_r	rudder angle
δ_{req}	rudder angle for the yawing equilibrium
$\delta_{r\,max}$	maximum rudder angle
η_h	horizontal tail dynamic pressure ratio
λ_h	horizontal tail taper ratio
λ_v	vertical tail taper ratio
τ_e	elevator effectiveness in the linear range
$\tau_{e\,max}$	elevator effectiveness at maximum deflection
τ_r	rudder effectiveness in the linear range

Fig. 1. P2010 4-seat FAR23 aircraft during flight certification tests (*courtesy of Tecnam*).

aircraft shape. Metal structure is often used for the wing and stabilator to provide further strength and stability. In this paper the design of a new commuter aircraft, named P2012 Traveller, with 11-seats, is presented. The airplane design has been carried out at Tecnam Aeronautical Industries under the guidance of Prof. L. Pascale, designer of all Tecnam aircraft and known all over the world as one of the main expert in the design of general aviation aircraft. The authors are involved in the definition and optimization of aircraft shape and especially on the correct estimation of aircraft stability and control characteristics. Since the middle of 90's the authors have been involved in the design of light aircraft [10]. All software tools and experimental technologies, like wind-tunnel tests to improve the aerodynamic design of light aircraft, developed at the Department of Industrial Engineering of University of Naples have been fully presented in [3]. In [4] the authors have been involved in designing, building and testing of a small RPV model characterized by 3 lifting surfaces. During 2005 the design of an STOL ultra-light aircraft characterized by application of composite material has been carried out by the authors [5]. Previous articles [19,16,15] show research activities performed by the authors in collaboration with Tecnam on the design and test of a new twin-engine four seats light aircraft (P2006T). Since 1996 the