XX Fluid Mechanics Conference KKMP2012,
Gliwice, 17-20 September 2012

MULTI-OBJECTIVE AND MULTIDISCIPLINARY OPTIMIZATION OF WING FOR CESAR AC-1 AIRCRAFT

Wieńczysław Stalewski, Jerzy Żółtak
Instytut Lotnictwa (Institute of Aviation), Warsaw,Poland
E-mail: jerzy.zoltak@ilot.edu.pl

Key words: multi-criteria design, multidisciplinary design, genetic algorithm, aerodynamic of wing

Introduction

The costs of air transport small and medium-sized sequence distances are significantly greater than the costs of alternative modes of transport such as car and train. This is one of the major barriers limiting the potential for improving the competitiveness of this sector. Only to work on reducing the costs generated in the different phases of life cycle of aircrafts may be able to change this situation. The CESAR project (Cost-effective Small Aircraft) supported by the EU in 6 Frame Program was exactly focused on the development of technologies that reduce time to market entry and reducing the costs associated with this process for small aircraft. Basic aircraft configurations (Nae et all, 2006) were selected as demonstrators: AC1- low speed aircraft (turboprop) and AC2 – transonic speed very light business jet. In this study the results of work performed at the Institute of Aviation (Warsaw, Poland) in the development of numerical methods of wing design for a small aircraft will be presented. The proposed methodology is based on parametric modelling of complex aerodynamic objects (Stalewski, 2011), and numerical multi-criteria and multidisciplinary optimization taking account a various types of design constraints (Rokicki et al., 2009). The method has been used to design the turbulent wing for small aircraft. The result, related to AC2 configuration was discussed in the paper (Stalewski, Żółtak, 2011). In this paper research results concerning AC1 configuration are discussed.

Design and Optimisation Methodology

The method for multidisciplinary and multi-objective optimisation, based on a genetic algorithm was adapted to design of small aircraft. The generic parametric model of small aircraft wing geometry was proposed. In this model a relatively small number of parameters describe wide class of wing geometries without and with high lift devices. The optimisation method used the objectives and constraints typical for aerodynamic design. Besides quantitative objectives additional qualitative criteria were applied. The aerodynamic performance was determined using 3D panel method coupled with 2D boundary layer analysis (integral method). Although the optimisation concerned just the wing, the aerodynamic computations were performed taking into account the whole aircraft. The box-beam model of the wing structure was used to estimate a weight of the wing.

Design and Optimisation of AC1 Turbulent Wing for Small Aircraft

The multi-disciplinary, multi-objective optimisation method was developed and adapted to design and optimise the turbulent wing for small aircraft. The design-process requirements and constrains were defined in (Ancik, 2008)

Parameterisation of the wing

It was assumed that wing platform is fixed. The wing surface was described by three cross sections defined by family of airfoils (Wysocki, at all, 2006). Finally the basic geometry was described by 11 design parameters related to relative thickness of root mid and tip section, camber of mean line of root mid and tip section, mid and tip section twist angle and chord and wing area. In the case of optimisation of high lift devices, another 5 parameters were added: angle of flap deflection, horizontal and vertical position of flap nose in limiting cross sections of the flap.

Objectives and constraints

At the first stage of the design process, the clean wing was designed. It was achieved by solving appropriate multidisciplinary, multi-objective optimisation problem. The main goal of optimisation was to design possibly low-drag and low-weight wing, having possibly high values of C_{Lmax}. The three objective functions for clean configuration were defined: first based on value of C_{Lmax}, next joined with lift/drag ratio at cruise condition and last described by lift/wing-weight ratio for flight with constant normal overload in the steady-state conditions. In design process the value of pitching moment was limited. For configuration with active high lift system the value of C_{Lmax} for takeoff and landing conditions were maximised.

Results

The multi-objective genetic algorithm was used to solve defined optimization problem. A population of each generation was constant and set to 48 individuals. The solution process was stopped after achieving the 300-th generation. The solution of the problem was the Pareto set, including 1093 Pareto-optimal wings. Finally from obtained Pareto set, the "optimal" solution was selected. Geometry of this wing (AC1T-IOA-01) fulfils all geometrical constraints and preferences, particularly concerning cost saving oriented classical manufacturability. In the second stage of design process high list system for AC1T-IoA-01 was optimised. The positions and deflections of for takeoff and landing configurations were established by Direct Optimisation method. During the process, the AC1T-IoA-01 wing without and with high lift system was tested for design and off design conditions

Acknowledgments

This research was supported by the FP6-AIP5-CT-2006 Integrated Project CESAR (Cost-effective Small Aircraft), Contract No.: 030888

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