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Aerodynamic shape optimization of aircraft components using an advanced multi-objective evolutionary approach

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Abstract

In this paper, a fast and effective CFD-based automatic loop for optimization of rotorcraft components is presented. The automatic loop is strictly designed around an innovative Multi Objective Evolutionary Algorithm (MOEA) developed at University of Padua, namely the GeDEA-II. This algorithm allows performing multi-objective, multi-point optimization works in a fast and robust way. It combines novel crossover and mutation operators when compared to other state-of-the-art MOEA. Recent papers show its excellent performance when tested on state-of-the-art problems. In order to test the performance of this algorithm, two test cases are presented, each having peculiar characteristics making them even harder to solve. Test cases regard the aerodynamic shape optimization of ERICA components, that is an innovative tilt-rotor concept conceived and designed recently. The first problem regards the single-objective, multi-constrained aerodynamic optimization of the ERICA tilt-rotor cockpit region. The second one is a multi-objective multi-constrained optimization of the ERICA landing gear sponsons. Results demonstrate the effectiveness of this automatic optimization loop in tackling real-world engineering problems.

Keywords: Aerodynamics; Optimization; Multi objective evolutionary algorithm; Aircraft optimization

1. Introduction

Aviation is an essential element of today's global society, bringing people and cultures together and creating economic growth. The air transport industry is paying a lot of attention to growing public concern about the environmental issues of air pollution, noise and climate change. Although today air transport only produces 2% of man-made CO_2 emissions, this is expected to increase to 3% by 2050.

Clean Sky [1] is a European Joint Technology Initiative (JTI) that will develop breakthrough technologies to reduce aviation environmental impact. One of the goals of the Clean Sky JTI is the 50% reduction in CO_2 emission through

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Nomenclature

C_L	Lift coefficient
C_p	Pressure coefficient
C_D	Drag coefficient
C_{Dp}	Pressure drag coefficient
C_{Dv}	Viscous drag coefficient
C_M	Pitching moment coefficient
C_N	Yawing moment coefficient
D	Drag, N
L	Lift, N
M	Mach number
q	Dynamic pressure, Pa
P	Pressure, Pa
P_0	Total Pressure, Pa
T	Temperature, K
T_0	Total Temperature, K
V	Velocity, m s^{-1}
V_∞	Far field velocity, m s^{-1}
$O.A.T.$	Outside Air Temperature, K
$D.O.E.$	Design of Experiments

Greek Symbols

α	Angle of attack, [deg]
ρ	Air density, kg m^{-3}

drastic reduction of aircraft fuel consumption, which means, from the aeronautic industries point of view, to adapt the aircraft and rotorcraft design procedures to new severe standards about aerodynamic drag and engines efficiency. Organized around six major platforms or Integrated Technology demonstrators (ITDs), the Clean Sky project will lead to the development of in-flight or ground demonstrators. Among these ITDs, the Green Rotorcraft platform is specifically devoted to helicopters and tilt-rotor aircraft, whose operations are expected to grow sharply in the future.

Within the Green Rotorcraft ITD, six technological projects have been defined. Specifically, the second project (GRC2) concerns airframe design, which must be made more aerodynamic for more efficient power use in flight. Depending on the rotorcraft configuration and weight class, the aerodynamic cumulated drag benefits are currently estimated in the range 10%–15%, which would translate into a 4%–5% fuel consumption reduction for the same payload and mission. The subject of this paper actually falls within the scope of the GRC2, since the content of the research illustrated here aims at gaining a deeper insight into the computer-based optimization procedure of helicopters and tilt rotor airframe components. In particular, the purpose here is to build up an automatic optimization procedure able to deal with single and multi-objective aerodynamic and multidisciplinary optimization problems in order to create an optimization tool able to drastically improve the aerodynamic characteristics of some fuselage component under investigation. As a consequence, the choice of a multi-objective optimization algorithm, like the home-made algorithm developed recently at University of Padua, i.e. the GeDEA-II [2,3], has been envisaged.

To prove the applicability of that optimization procedure on real engineering problems, two test problems are shown in this paper. The first concerns the aerodynamic optimization of the nose region of the new tilt-rotor concept ERICA (Enhanced Rotorcraft Innovative Concept Achievement) [4]: this is a single objective, multi-constrained optimization work. The second regards the multi-objective aerodynamic shape optimization of the landing-gear sponsons of the same aircraft.

The work is organized as follows. Section 2 introduces some examples regarding the state-of-the-art procedures followed in aeronautics to conduct optimization studies. The proposed progress is then anticipated. The latter is thoroughly explained in Section 3, where the main features of the proposed approach based on GeDEA-II are described.