Shock-Free Aerofoil/Wing Design Optimisation via Morphing Technique: Leading and Trailing Edge Deformation

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Abstract: The paper investigates the drag reduction of aerofoil/wing via morphing technique: Leading and trailing edge deformation (LTED) on Natural Laminar Flow aerofoil (RAE 5243). The concept of morphing technique is to adapt the shape of aerofoil/wing to control transonic flow that results in total drag reduction. Two morphing aerofoil/wing methods considering trailing edge deformation and LTED are optimised using Euler and viscous boundary analyser coupled to Evolutionary Algorithms (EA). The optimisation method is based on Multi-Objective Genetic Algorithm (MOGA) under High Performance Computing (HPC) environment. Two test cases are conducted with numerical experiments; the first test considers a morphing aerofoil/wing design via trailing edge deformation (TED) while the second test uses both leading and trailing edge deformation (LTED) to minimise the total drag. Numerical results are presented and demonstrated that applying morphing technique on existing aerofoil/wing significantly reduces transonic total drag and improves lift on drag (*L/D*) value when compared to the baseline design.

Keywords: Morphing Aerofoil/Wing, Computational Fluid Dynamics, Evolutionary Algorithms, Shock-Free Aerofoil/Wing.

1 Introduction

Improvement of aerodynamic performance is one of the main objectives of civil aircraft manufacturers and civil airliners since it can directly lower direct operating cost (DOC) as well as environmental impact in climate change. Especially for environment, it is importance to remark one of goals of European Aeronautics: A Vision For 2020 [1] that is a 50% cut in carbon oxide (CO_2) emissions per passenger kilometre (which means a 50% cut in fuel consumption in the new aircraft 0f 2020) and an 80% cut in nitrogen oxide (NO_X) emissions. To achieve such objectives, drag reduction is crucial task and can be minimised by using morphing techniques. The concept of morphing technology on aircraft is to adapt its shape which is more suitable to desired flight conditions that leads to improve aerodynamic efficiency (*L/D*) while minimising total drag (Cd_{Total}) [2].

In this paper, one of morphing techniques: Leading and Trailing Edge Deformation (LTED) is studied for drag reduction and it is implemented to a Natural Laminar Flow aerofoil RAE 5243 at the flow condition; $M_\infty = 0.68$, $Cl = 0.82$, Re = 1.9×10^6 and the boundary transition position (x_{tr}) at 45% of the chord. LTED technology is shown in Figure 1 where LTED is parameterised by considering; x_{LE}, θ_{LE}, L_{BSC1}, L_{BSC2}, x_{TE}, θ_{TE}, L_{BSC3}, L_{BSC4}. Two optimisation test cases are conducted using Euler and Boundary solver coupled to advanced Evolutionary Algorithms (EAs) [3, 4]; the first test considers the morphing with trailing edge deformation (TED) and the second test considers the morphing with both leading and trailing edge deformation (LTED).

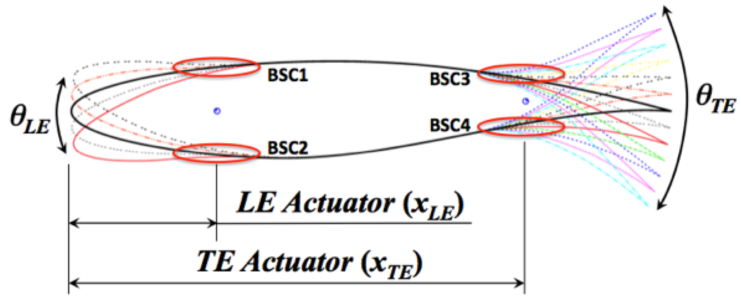

Figure 1: Control parameters for morphing technique at constant leading and trailing edge actuator positions.

Numerical results show that using TED and LTED significantly reduce the total drag (Cd_{Total}) by 25% to 33% when compared to the baseline design as shown in Table 1. The optimal configuration of LTED reduces the wave drag (Cd_{Wave}) by 98% and improves *L/D* by 50% as shown in Figure 2.

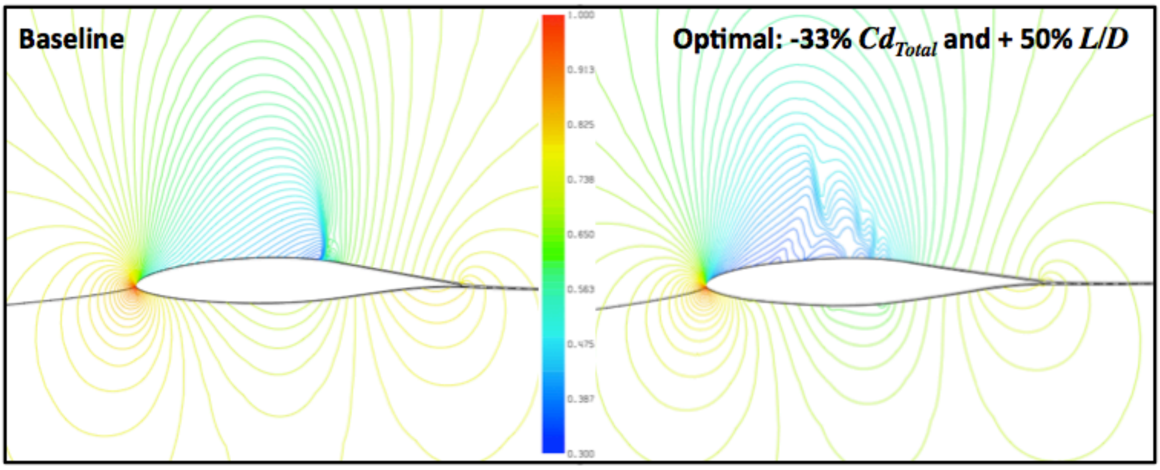

Figure 2: *Cp* contours obtained by the baseline design and the optimal solution of LTED at the flight condition of $M_\infty = 0.75$, $Cl = 0.82$, Re = 1.9×10^6 and x_{tr} = 45%c.

Table 1. Aerodynamic characteristics obtained by the baseline and with TED and LTED at the flight condition of $M_\infty = 0.68$, $Cl = 0.82$, Re = 1.9×10^6 and x_{tr} = 45%c.

Aerofoils	Cd_{Total}	$Cd_{Viscous}$	Cd_{Wave}	*L/D*
Baseline	0.01003	0.00681	0.00322	81.74
TED	0.00754 (-25.0%)	0.00531 (-22.0%)	0.00223 (-30.0%)	108.83 (+33.0%)
LTED	***0.00671 (-33.0%)***	***0.00663 (- 3.0%)***	***0.00008 (-97.5%)***	***122.12 (+50.0%)***

References

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