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Predictive numerical study of cambered morphing A320 high-lift configuration based on Electro-Mechanical Actuators

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Abstract. The principal aim of this paper is to investigate the numerical effects of a deformable flap by means of a quasi-static cambering following an Airbus A320 designed prototype in the Smart Morphing and Sensing European project. This prototype able to camber by means of the Electro-Mechanical Actuators (EMA) to achieve high amplitude deformation up to 10 cm. This mechanism allows to improve the aerodynamic performances of high-lift system during the take-off flight stage. This study reveals the effects of cambering over the pressure field around the flap in different suggested positions. A considerable increase of the static pressure in the pressure side of the flap and a high low-pressure in its suction side is illustrated for the cambered flap compared to the reference test case, which leads to improve lift-to-drag ratio.

Keywords: morphing, camber, airfoil, flap, high-lift, aerodynamic

1 Introduction

During the flight the fluid flow around the wing is affected by many instabilities related to many reasons such as the airplane speed in different flight stages, as for instance the buffet phenomena that occurs during the transonic phase. This instability known as Shock Wave Boundary Layer Interaction (SWBLI), results of a non-linear interaction can may induce a considerable boundary layer detachment. In addition, the flow separation near the flap's trailing-edge is identified according to high angles of incidence or deflections. A rigid wing or flap system is not well adapted to flow change in order to have improved aerodynamic performances and to handle these instabilities to avoid an exceed of fuel consumption or airplane crash. To this end, researchers interested to a partly bio-inspired morphed wings from birds toward active flow control aiming to enhance the lift, reduce the drag, suppress the separation and delay the onset of stall. It is therefore essential to understand the flow response to the dynamic actuation or wing-flap passive deformation known as camber control seeking to an optimized shape to get a desired effective performances. B. K. Woods *et al* [1]

constructed a Fish Bone Active Camber morphing structure concept and investigated its effects with aerodynamic measurements and compared it with flapped airfoils, their study revealed that the FishBAC airfoil generates considerably less drag and an increase of 20%- 25% of lift-to-drag ratio compared to flapped airfoil over a range of angles of attack. Furthermore, G. Jodin *et al* [2] carried out forces measurements and TR-PIV on a wing prototype equipped with a coupled system of Shape Memory Alloys (SMA) and piezoelectric-actuators in the trailing-edge named hybrid morphing. Camber control at low-frequency-high-amplitude is achieved by means of the SMA. This work showed that at a specific range of cambers and trailing edge vibrations an increase of lift in the order of 27 %, where only +4 % are obtained by the small amplitude vibrations. The present study is performed to produce a predictive numerical solution of an Electro-Mechanical Actuator (EMA) structures for the active camber control of a Large-Scale (chord $c = 2.72$ m) Airbus A320 prototype in the take-off position. This concept is suggested by Y. Bmegaptche Tekap *et al* [3] in the context of the Smart Morphing and Sensing SMS European project (www.smartwing.org/SMS/EU). Experimental design of the cambered flap of chord $c = 1$ m as illustrated in Y. Bmegaptche Tekap *et al* [3] employs the articulated concept. An equivalent numerical model is implemented in the Navier Stokes Multi-Block (NSMB) solver and described in this study. Different shapes were tested in order to obtain a better position allowing to obtain improved performances.

2 Computational methodology

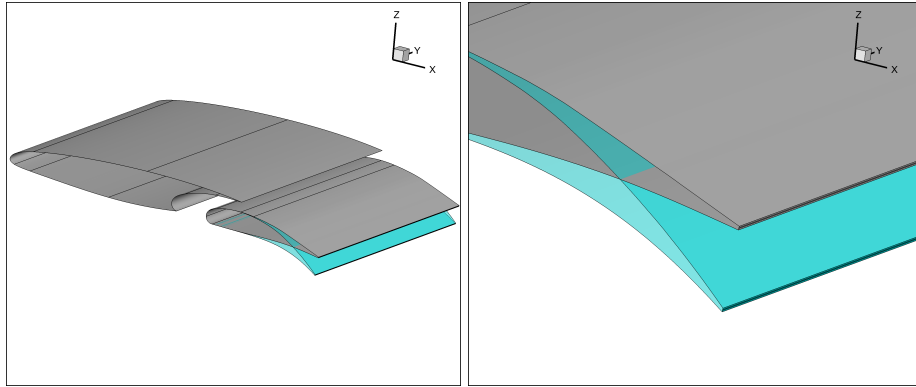


Fig. 1: Quasi-static camber control of the A320 flap similar to the EMA behaviour

The set of the compressible Navier-Stokes (NS) equations was discretized and solved using the NSMB solver J.B. Vos *et al* (1998) [4], Y. Hoarau *et al* (2016) [5]. An implicit dual time stepping was employed using the 2nd order implicit backward scheme. At each time step, iterative approach is used and defined by

an external and internal loop. A 4th order central skewsymmetric scheme is selected for the space discretization. In addition, the artificial compressibility method for the preconditioning is employed to simulate conveniently the incompressible form of NS equations.

A C-type mesh was generated for the Large-Scale airfoil-flap of the Airbus A320 prototype. The boundary domain is supposed as a far-field conditions of 20 chords to capture correctly the pressure field for the two-element configuration. The grid is well refined and validated adopting the right turbulence models in previous studies of A. Marouf *et al* (2019) [6] with literature.

The flow around the A320 airfoil-flap is considered at 0° angle of attack, 10°

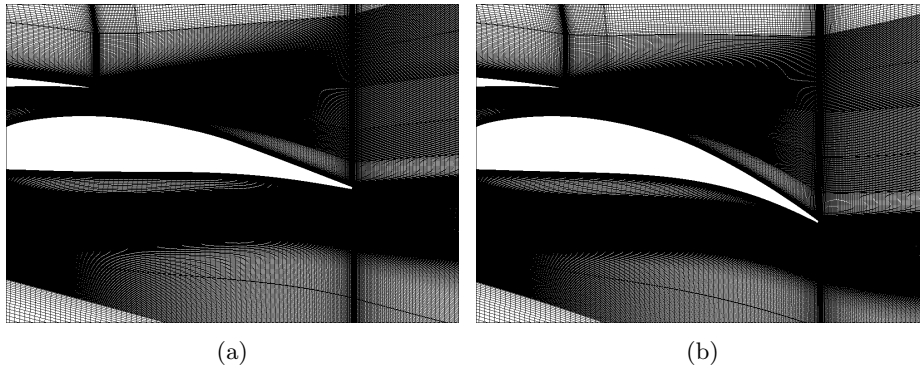


Fig. 2: Details of the used structured grids. (a) : reference case. (b) : cambered case

angle of flap deflection and Reynold number of 2.2×10^6 corresponding to the take-off position. Different positions of camber control were selected (see Fig. 1) with the experimental EMA movement designed in the SMS project. The structured grid is smoothly deformed while maintaining a good quality, orthogonality and skewness of the mesh cells. The reference A320 case and different cambered positions from low to high amplitude of deformation were simulated and compared. The camber distance is of 85% of the total flap's chord and its maximum amplitude is maintained at 10 cm as illustrated in the Fig. 2.

3 Numerical results

In the following section the flow field around the reference and cambered cases is characterized. Pressure and aerodynamic forces are discussed. Converged signals are stored and the mean forces were calculated in order to analyse the camber effects over the performances of the airfoil-flap system.

Different intermediate suggested positions described in the Tab. 1 were selected to analyse the camber of the flap and its effects over the fluid flow.

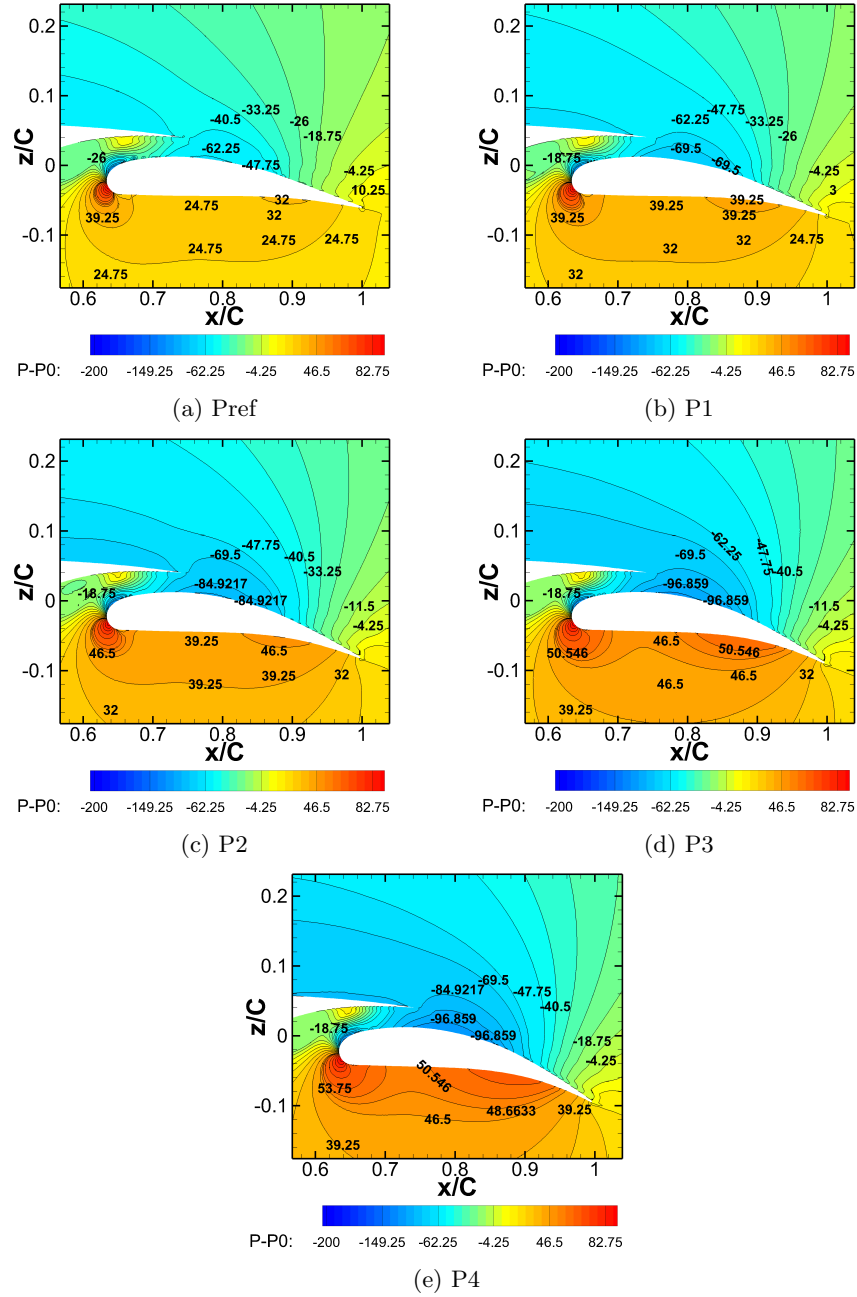


Fig. 3: Distribution of the of pressure field of the flap in different camber positions

Table 1: Different camber positions selected for the computational study

Camber positions	Pref	P1	P2	P3	P4
Trailing-edge distance (cm)	-	3	5.7	7.8	9.2

The Tab. 1 illustrates 4 chosen vertical distances of the flap’s trailing-edge downward following the control law of the EMA actuators.

The Fig. 3 above corresponds to the different selected camber position compares the differential of pressure $p - p_0$, where p_0 is the standard pressure of the air to the reference case in Fig. 3a. A gradual increase the $p - p_0$ from the leading edge to the trailing edge in the pressure side when the flap is cambered downward. In the other hand, in the suction side a pressure decrease varies gradually from -62.25 Pa in the reference position up to -96.859 Pa in the position P4.

4 Conclusion

In this paper numerical simulations were carried out for a high-lift configuration with an implemented predictive camber solution based on a new design of morphing flaps using the EMA structures. The control law of these structures is tested for different quasi-static camber positions in the downward direction in different positions. The pressure around the flap is investigated. As a result, the distribution of the difference of pressure is higher in both sides of the flap compared to the reference case. In addition, calculated mean values of lift and drag forces for different positions revealed an increase of +25% in the *lift-to-drag* ratio.

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