Introduction

Nowadays, the majority of the civil aircrafts are equipped with the conventional design of a high-lift flap in a three-element wing configuration able to create high cambers by rigid surfaces. Control surfaces like flaps and slats, while modifying the aerodynamic profile of the wing, are heavy to move by means of hydromechanical actuation and also create a suboptimal aerodynamic performance and efficiency. According to recent advances made in the field of smart materials, essentially Shape Memory Alloys (SMA) and piezoelectric actuators, adaptive or morphing structures hold the potential to improve the aerodynamic performance during the take-off and landing (subsonic) phases of the flight by providing a fast, light and versatile actuation, able to operate at different time and length scales as shown in the studies of the present multidisciplinary research team since 2009 (cf. studies of the platform www.smartwing.org in Toulouse – France). In this context, a hybridization among the SMA actuator ensuring high deformations (order of 15% of the chord) at low frequencies (order of 1Hz) and of smart piezoeactuators ensuring higher-frequency vibrations (order of 500 Hz) and low deformations (order of 0.001 of the chord) had been derived by the present team and registered as “hybrid electroactive morphing (, Scheller et al, J. Fluids & Structures 2016, among other). This combined morphing is partly bio-inspired from large span hunting birds, but adapted in real world for the wings of the future (cf. CNRS film devoted in our studies, https://lejournal.cnrs.fr/videos/les-ailles-du-futur the wings of the future). The electroactive morphing is able therefore to ensure much lighter, faster and much more efficient embedded systems able to achieve suitable camber control and simultaneously able to manipulate the surrounding turbulent vortices in the shear layers and in the near wake around the trailing-edge region, thus providing a significant increase of lift, decrease of drag especially in take-off and reduce noise. The objective of the present study is to transport these beneficial effects, originally studied by our team in reduced laboratory scale prototypes towards a full-scale morphing high-lift flap of 1m chord, associated to an Airbus A320 wing of 2,40m chord.

This work is carried out within the framework of a strong collaboration with AIRBUS-France “Emerging Technologies and Concepts “ ETCT Department In Toulouse, as well as in the context of the H2020 European research project SMS – “Smart Morphing & Sensing for aeronautical configurations” N°7xxxxxxx, www.smartwing.org/SMS/EU. This project aims at constructing and certifying a full-scale electroactive hybrid morphing high-lift flap and performing the detailed experimental investigation of the wing equipped with this flap in the S1 wind tunnel of IMFT of test-section of 2,5m. This mock-up is made up of two parts: the main fixed wing and the flap. The study will compare the aerodynamic performances on a fixed configuration and on the configuration equipped with the morphing flap during the present three-year European project. The present article is a first step of the study, investigating the dynamics around the fixed take-off configuration. The experiments are carried out by means of conventional averaged pressure measurements, dynamic pressure measurements as well as multi-point pressure acquisition thanks to a novel sensing system based on Bragg grating (Othonos, 1997xx), adapted in the SMS project by the partner Company CEMENTYS in the S1 wind tunnel of IMFT. The results will be compared with High-Fidelity numerical simulation results carried out in parallel in this European project. This paper deals with the design and wind tunnel investigation of the fixed wing at the take-off configuration in different Reynolds numbers and different angles of attack in the framework of AIRBUS operating parameters. The experiments are done with the different mentioned sensors in order to measure the static pressure, the dynamic pressure transducers (of Meggit type) as well as by the novel FBG sensor system of Centemys, to measure the dynamic pressure at multi-points. Therefore, this system will be able to communicate instantaneously with the actuators system through adapted control commands in order to apply in real-time the optimal actuations. Furthermore, the experimental set-up of the present, so called “Large-Scale (LS)” morphing prototype is equipped by fluctuating force sensors to measure the dynamic lift and drag.

1 Results

The CAD model of the wing is made using Inventor [fig1a]. This model is on its central part equipped with 80 static pressure points, a dynamic pressure sensor, an FBG multi-point dynamic pressure system and four multi-axis force sensors for the dynamic balance. The integration of the static pressure made along a significant number of points around the wing’s and flap’s sections in mid-span provides the averaged lift and drag coefficients for each Reynolds number and angle of attack.

In order to verify that the realised design is safe and reliable given a maximum aerodynamic pressure distribution made available from simulations of the present research group and from AIRBUS data, elastic failure theories such as the Max Stress Theory (4) is applied in order to check that the stress in the spanwise direction does not exceed the yield strength of the material used in the wing structure. This material is aluminium for the central ribs, wing skin and beams (‘longerons’),
while wood is used for the laterals ribs. The wing with the flap is placed between end-plates at the span edges. The FE model for the wing is constructed by means of ABAQUS, by considering two aluminium ‘longerons’ with rectangular cross sections as well as aluminium and wood ribs including the skin as shown in figures [1]. After applying the maximum load provided and majored by a safety factor of 5, it was found that the maximum span-wise stress is 47 MPa. By comparing it to the elastic limit, (‘yield strength’) of the constitutive material for the two-element wing, it has been concluded that the designed wing can sustain the loads of the wind tunnel, as well as the real flight ones, in respect of the elastic failure theories.

The experiments have been carried out in the low subsonic wind tunnel S1 of IMFT. The wind tunnel test section of S1 is circular with Ø 2.40 m x 2.00 m of test section. The velocity range vary from 1 to 30 m.s$^{-1}$. The experiments were performed at ambient temperature (25° C) with upstream turbulence intensity about 0.1 %. The experiments have been carried out in different configurations (clean and take-off), according to several angles of attack (0 ° - 8 °) with a step of 2° with different speeds from 6.6m/sec up to 20 m/sec [fig.2]. A comparison with High-Fidelity simulations at the same flight conditions as the experiments will be provided [fig.4].

2 Conclusion

The main objective of this paper was to design and develop an experimental setup for investigation of subsonic trailing-edge of an electroactive morphing two elements airfoil-flap. Future investigation will focus on setup of morphing flaps by associating different kind of electroactive material. The results we obtain will constitute a solid base for comparison with morphing flaps for the next experiments investigation

References
3 Smart Morphing and Sensing project : http://smartwing.org/SMS/EU/.