

EXPERIMENTAL TESTING OF A HIGH-BANDWIDTH MORPHING AILERON FOR A HYBRID ELECTRIC REGIONAL AIRCRAFT

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ABSTRACT

The increasing environmental concerns in the aeronautical sector push researchers to investigate innovative solutions to make future aviation more sustainable. A promising approach to increase aircraft efficiency is the integration of morphing devices, which enable adaptation to different flight conditions, improving the overall performance and reduce fuel consumption [1]. The typical application of morphing devices is in high-lift systems [2,3], but they can be also employed in place of traditional hinged control surfaces, which are characterized by aerodynamic discontinuities due to the presence of gaps. Moreover, such morphing control surfaces, if designed with high actuation bandwidth, can be employed for active control systems, contributing to the alleviation of loads and to further performance improvement [4].

This paper describes the experimental validation of the wind-tunnel prototype of an innovative morphing aileron designed to replace a conventional aileron in a hybrid-electric regional aircraft. The previously completed numerical validation phase demonstrated the capability of the designed device to guarantee the lift variation requirements of the reference conventional devices by employing half the deflections, reducing the associated aerodynamic drag and the corresponding actuation forces [5]. Moreover, the high bandwidth of the device, up to 10 Hz according to the design requirements, has been numerically demonstrated, showing the potential of the aileron system to reduce dynamic actuation loads, with benefits both in terms of power consumption and reduced weight of the actuators.

The objective of the experimental investigation reported in this work is to demonstrate that the prototype behaves in accordance with the design, in terms of device functionality, accuracy of the deformed shapes, actuation forces, dynamic behavior and aerodynamic performances.

To this aim, static and dynamic ground tests, and wind tunnel tests are planned. First, the experimental validation of the morphing aileron fixed on a rig is being conducted to assess the functionality and the mechanical behavior and to verify the capability to reproduce the target morphed shapes and the required high bandwidth, reducing actuation loads. After that, a wind tunnel test campaign of the morphing aileron integrated into a dummy wing box demonstrator will be realized to assess the aerodynamic performance as well the static and dynamic behavior of the device under the application of the external aerodynamic loads.

The experimental validation is in the stage of laboratory tests aimed at numerical-experimental correlation from the structural viewpoint. The morphing aileron prototype, realized in glass-fiber fabric, consists of a variable thickness skin with a flexible internal spar. A sliding bottom skin coupled with the actuation kinematics and the designed stiffness distribution enables the desired shape changing. As an aileron, the designed devices is capable of achieving both downward and upward deflections, as shown in Figure 1.

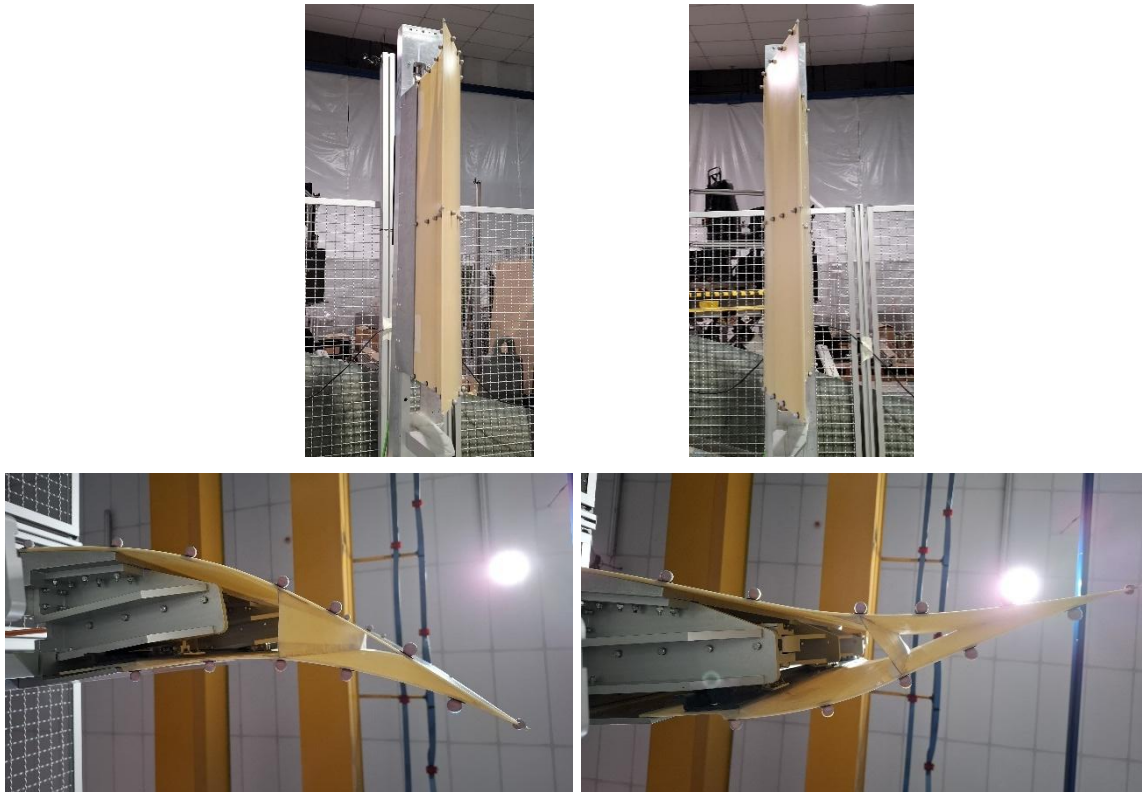


Figure 1: Maximum downward (left) and upward (right) deflections achieved in the experimental tests.

The actuation system consists of electromagnetic actuators connected to rods which transfer the spanwise motion of the motor to the chordwise motion of the bottom skin. A PID control scheme has been adopted and tuned to guarantee the desired actuation bandwidth.

Preliminary tests have been performed to identify the morphing shape change of 2D sections through a motion capture system, for an initial comparison with the finite elements results. Later, a full-field digital image correlation technology will be employed for the identification of the complete 3D shapes. The required actuation forces have been acquired and compared to the finite element model results, showing a satisfactory agreement. The effect of friction forces, not present in the numerical model, has been evaluated with a dedicated Coulomb-viscous friction model. Low frequency tests up to 3 Hz have been already performed, showing the capability of the servo-controller to follow the desired commands. Higher frequencies will be reached when the wing box structure will be available for the complete assembly of the prototype. Therefore, further tests for the dynamic characterization will be reported in the full paper, as well the complete numerical-experimental correlation analysis. Finally, the wind tunnel tests and the associated aero-structural results will be reported in the full paper.

In conclusion, the designed device can replace a conventional hinged aileron providing benefits from the aerodynamic and actuation viewpoints. The numerical validation and the preliminary experimental tests have shown the correspondence between numerical and physical models, confirming the potential of morphing aileron systems.

The planned ground and wind tunnel tests will contribute to this validation and to the enhancement of the technology readiness level of this morphing device, which can have an important role in the near future for a more sustainable aviation.

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