# ACTIVE WING FOR FUTURE REGIONAL AIRCRAFT: MORPHING STRUCTURES AND AEROELASTIC CONTROL

***Francesco Toffol*, Alessandro De Gaspari, Sergio Ricci***

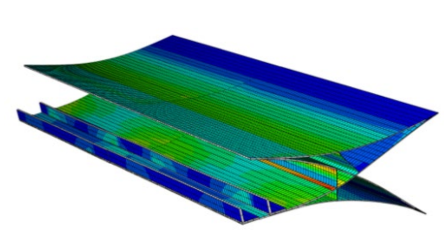
**Politecnico di Milano,*
*Via la masa 34, 20156*
*Milano, Italy*

## ABSTRACT

The Clean Aviation programme sets ambitious objectives for the next generation of regional aircraft, targeting significant reductions in fuel burn, emissions, and environmental impact while maintaining high standards of safety, performance, and operational flexibility. Within this framework, the design of the wing plays a central role, as it strongly influences aerodynamic efficiency, structural weight, aeroelastic behaviour, and overall aircraft performance across the flight envelope. This paper presents an overview of the activities carried out by Politecnico di Milano within the Clean Aviation projects HERWINGT and HERA, focusing on the development, integration, and experimental validation of advanced technologies for an innovative, efficient, and intelligent wing for future regional aircraft.

The common thread of the presented research is the transition from a traditionally passive wing design towards an actively controlled and adaptive lifting surface, capable of responding to varying flight conditions and external disturbances. The activities span structural design, morphing concepts, and active aeroelastic control, with a strong emphasis on experimental validation through wind tunnel testing. Rather than addressing each technology in isolation, this paper highlights how their combined implementation contributes to a new wing design paradigm, where aerodynamics, structures, and control are tightly integrated from the early stages of the design process.

A first major activity concerns the design, manufacturing, and testing of a full-scale wing section equipped with two full-scale morphing ailerons. These control surfaces are conceived not only as conventional high-lift or roll-control devices, but as adaptive aerodynamic components capable of modifying the wing camber and load distribution in a smooth and continuous manner. The morphing ailerons are integrated into a representative wing box structure, designed to meet realistic stiffness, strength, and integration constraints. The experimental campaign, conducted in the Politecnico di Milano wind tunnel, aims at assessing the aerodynamic and aero-structural benefits of morphing technologies, demonstrating their potential to improve efficiency, reduce drag, and enable more flexible load management strategies throughout the mission.



*(a) Morphing aileron FEM model*

*(b) Morphing aileron on its test rig*

*Figure 1: Morphing aileron*

A second key research line addresses the development of active control laws for gust load alleviation. Gust-induced loads represent a major design driver for transport aircraft wings, often leading to structural overdesign and increased weight. Within the HERWINGT project, Politecnico di Milano is developing and comparing different control strategies—ranging from static output feedback (SOF) to optimal control approaches such as Linear Quadratic Regulation (LQR), and adaptive control techniques—to mitigate the impact of atmospheric disturbances. These control laws are designed to exploit the available control surfaces and sensor information to actively counteract gust loads in real

time. The activity culminates in wind tunnel experiments performed on a dedicated aeroelastic half-model, specifically designed to reproduce the relevant dynamic behaviour of a regional aircraft wing. These tests provide a crucial experimental validation of the control concepts and their robustness, while also offering valuable insights into the interaction between aerodynamics, structural dynamics, and control systems.

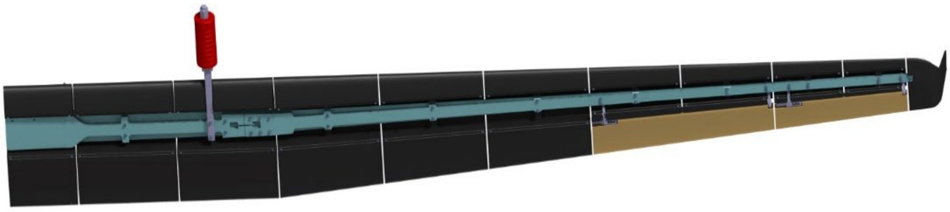


*Figure 2: CAD model of the wind tunnel model for aeroelastic tests*

The third technological pillar presented in this paper concerns active flutter suppression (AFS). Flutter remains one of the most critical aeroelastic instabilities in wing design, often limiting the achievable performance envelope and imposing conservative design constraints. The research activities focus on the synthesis and numerical design of active control laws capable of suppressing or delaying flutter onset, thereby increasing the operational margins of the wing. These controllers are experimentally tested on a clamped-wing wind tunnel model equipped with multiple control surfaces, allowing for the investigation of different actuation and sensing configurations. The experimental campaign aims at demonstrating the feasibility and effectiveness of active flutter control in a realistic aeroelastic environment, as well as at identifying practical challenges related to implementation, robustness, and integration.

All experimental activities are carried out in the wind tunnel facilities of Politecnico di Milano, ensuring a coherent and systematic validation framework across the different technologies. The availability of multiple test articles—ranging from full-scale morphing structures to dynamically scaled aeroelastic models—allows for a progressive assessment of the technologies at increasing levels of complexity and realism. This experimental emphasis is a key element of the presented work, bridging the gap between numerical design and real-world application.

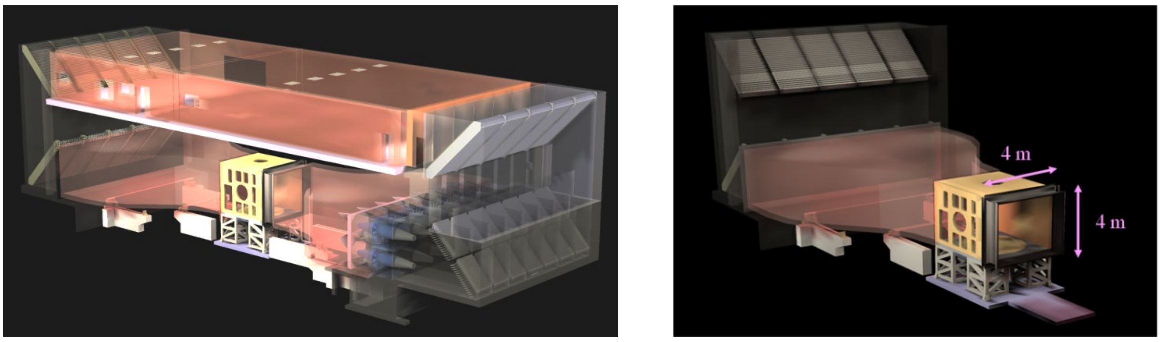



*Figure 3: Polimi's large wind tunnel facility*

Overall, the paper illustrates how morphing structures, gust load alleviation, and active flutter suppression can be jointly considered as enabling technologies for a new generation of wings that are not only lighter and more efficient, but also smarter and more resilient. By actively adapting their aerodynamic shape and dynamic response, such wings can achieve improved performance, reduced structural penalties, and enhanced safety margins. The activities carried out within the HERWINGT and HERA projects demonstrate the feasibility of this integrated approach and provide a solid experimental basis for future developments. While dedicated papers will address each technological aspect in greater detail, this contribution offers a comprehensive perspective on their combined impact on the design of innovative wings for future regional aircraft within the Clean Aviation vision.