Contributions to Aerostructures Morphing with Piezoelectric Actuators

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PhD Thesis Abstract

Since the first models developed in the late 19th century, the applications of piezoelectric materials have been progressively growing in number. The capacity of these materials to couple electric and mechanic fields makes them perfect candidates in the study of geometrical morphing. Their application in aeronautical products has been traditionally seen from two different perspectives: their use as sensors and as actuators. Both functions present potential benefits and improvements with promising applications. While the investigations in the past years focused mainly in the analysis and integration of piezoelectric materials in structures as means of implementing what is known as structural health monitoring systems, the application of this type of materials as actuators in the geometrical control of structures also awakes interest in the scientific community. In its present state of development, the technology for morphing of structures using piezoelectric actuators is not yet advanced enough as to integrate such systems in commercial products. However, the field is in continuous development and the evolution of the materials and the integration solutions bring the technology closer to industrial application.

This thesis aims at studying the feasibility of application of piezoelectric-actuated morphing aeronautical structures in current aircraft concepts. The analysis is performed at theoretical and experimental levels analyzing the static and dynamic performance of currently available actuators and motion amplification technologies.

The research presented in this thesis is directed in two different applications of utilization of the actuators: as static actuators producing deformation of the aerodynamic surface and as dynamic actuators controlling a classic aerodynamic control surface. In each of the applications a different type of piezoelectric actuator architecture has been used: a piezoelectric patch has been selected for static morphing applications and a piezoelectric stack-based actuation system for the dynamic control of the conventional control surface.

The static experiments performed aimed at demonstrating the suitability of piezoelectric actuators as morphing devices. This analysis was performed analyzing the deflections produced in the trailing edge of an aerodynamic profile. The analysis of the obtained experimental results showed promising results as the actuating configurations managed to perform as designed. The static experiments showed substantial deformation of the trailing edge of the wing profile making this configuration mature enough for further experimentation such as wind tunnel testing. The deflections produced were, however, not significant enough for the direct application of the solution into larger scale configurations. Scalability of the technological solutions remains one of the major challenges of the technology in the morphing applications.

The dynamic results showed good performance of the actuators in an anti-flutter demonstrator application during wind tunnel testing. The experiments showed that the system remained stable well beyond the flutter velocity; this allows for further experimentation in structures presenting higher flutter speeds.

With the development of the next generation of advanced piezoelectric ceramics, with piezoelectric coefficients twice as large in comparison to PZT-based ceramics, the application of the deforming structure concept is very promising for application in larger demonstrators in both static and dynamic applications. The next generation of piezoelectric materials presents itself as a first step into a solution to the scalability of the technology for application into full-scale demonstrators.