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Design and development of a hybrid NACA 4412 morphing airfoil

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Abstract *The present paper will describe the design and development of a hybrid NACA 4412 morphing airfoil equipped with both Shape Memory Alloy Actuators providing large deformations over a limited frequency range as well as Macro Fiber Composite Actuators providing small deformations with a large bandwidth. The design choices will be highlighted, the electrical and mechanical actuation performances characterized and finally the static and dynamic effects on the flow will be evaluated and compared to the unactuated airfoil.*

Introduction

Today's wing geometries are usually a trade-off between the optimal shapes at different phases of the flight. Control surfaces, while modifying the aerodynamic characteristics of the airfoil, usually exhibit poor aerodynamic performance and efficiency [12]. Adaptive or morphing structures hold the potential to solve this problem and studies on wing deformation are subject of much interest in the aerospace domain. Recent advances made in the field of smart-materials have renewed this interest [18, 11]. The Electro-active morphing for micro-air-vehicles (EMMAV) research program, which was created as part of the French foundation of «Sciences et Technologies pour l'Aéronautique et l'Espace»'s effort to develop micro- and nano-air-vehicles and is composed of three French laboratories (IMFT, LAPLACE, ISAE), aims at optimizing the performance of micro-air-vehicles in realistic environments via electro-active morphing [15].

As part of this collaborative effort a prototype NACA 0012 wing was developed with embedded Shape memory alloys (SMA) and trailing-edge piezoelectric actuators. This allowed both large deformations (~10% of the chord) at limited frequency (≤ 1 Hz) and small deformations (several μm) at high frequencies (≤ 100 Hz) [4]. The characteristics of the SMA technology, which were activated using the well understood Joule effect [10], make it especially suitable to optimize the shape of the wing and to control the flight [1, 16]. The high-frequent but low amplitude piezoelectric technology on the other hand is useful to produce trailing-edge vortex breakdown [14, 8, 17].

Whereas the hybridization of different smart-materials is a first to the authors' knowledge various previous studies have already addressed the use of SMAs [1, 10, 16] and piezoelectric actuators [2, 3, 9, 13]

separately. Like in the previously mentioned hybrid prototype the materials used in these studies were fairly idealistic. To address the issues emerging when dealing with less compliant materials a second prototype was conceived addressing more industrial concerns.

This paper will describe the design and development of this second prototype, which was designed based on a NACA 4412 airfoil, and highlight the integration issues encountered. This remainder of this abstract will briefly introduce the designed hybrid prototype, illustrate the design choices and used materials and provide an outlook on the full paper.

Prototype

As mentioned in the introduction the proposed hybrid NACA 4412 prototype was conceived in order to address industrial concerns such as the material choice, wing geometry, material distribution, etc. An illustration of the designed wing can be seen in Figure 1. As can be seen in the illustration the deformable area was limited to ~50% of the chord. Further constraints included the use of aluminium or carbon fiber instead of more compliant materials as well as the absence of a compliant skin.

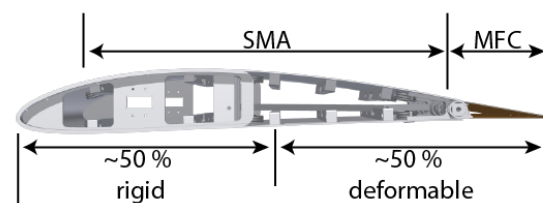


Fig. 1: NACA 4412 hybrid prototype

In order to conduct flow visualizations the chord size of the prototype was limited to 45 cm. Due to the

limited available space the high frequency vortex breakdown is to be done using Macro Fiber Composite (MFC) actuators. These piezoelectric fiber actuators provide a high frequency of actuation as well as a suitable displacement range.

Conclusions and Outlook

The work to be presented is developed twofold: first the actuation performance of the hybrid prototype from both a mechanical and electrical point of view is highlighted, including the maximum achievable deflection as well as the energy consumption. This data is then compared to the achievable gains both macroscopically in terms of lift increase and/or drag decrease as well as mesoscopically in terms of vortex breakdown.

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