Design and Manufacturing of a Morphing Trailing Edge Using a 3D-Printed Piezoelectric Polymer

Amin Moosavian [‡], Mohammad H. Malakooti [‡], Jiajun Lin [§], Henry A. Sodano [‡*] and Daniel J. Inman [‡]

[‡] Department of Aerospace Engineering
[§] Department of Macromolecular Science and Engineering

University of Michigan, Ann Arbor, MI 48109, USA
Email: amoosavi@umich.edu - Web page: http://www.aimslabumich.com

[*] Presenting Author

ABSTRACT

Morphing aircraft technologies have recently moved to the forefront of modern aerospace innovation due to the simultaneous advancements in smart materials and investigations into avian flight. Inspired by birds, bats, and insects, a benefit of morphing aircraft is their ability to adapt to a variety of flight conditions by changing the underlying geometry, unlike their traditional counterparts, which remain designed and optimized for a single flight condition. In nature, particularly in birds, this is predominantly achieved through changes in the wing geometry achieved using the underlying wing structure and the feathers, decreasing drag and allowing for high speed maneuvering. One particular shape change which is of great interest to the morphing field is the change in the camber of the airfoils, making up the cross sections of the wing. One such change in camber is known as reflexed camber. Reflexed airfoils have been shown to have substantial benefits at stall due to their ability to generate comparable lift with substantially less drag compared to conventionally cambered airfoils. It is believed that high angles of attack passively induce reflex in the trailing edge feathers of bird wings. In a previous work, a hybrid concept that utilizes shape memory alloys (SMAs) and macro fiber composites (MFCs), which are piezoelectrically actuated, was proposed and demonstrated to achieve the reflexed shape [1]. This concept was used as the basis for investigating the effect of combining the changes in the airfoil shape and wing sweep [2], as well as studying the impact of variations in speed on the effectiveness of the changes in the airfoil shape and the sweep [3].

In all of the above instances, the shape changes were achieved through a combination of SMAs and MFCs. In the current work, we propose an approach to obtain the reflexed shape via 3D printing a piezoelectric polymer laid out in a particular geometric configuration. More specifically, we attempt to utilize the direct writing approach to print polyvinylidene flruoride (PVDF) into a section of the wing trailing edge. The section would take on a reflexed shape when subjected to an electric field, and some nominal shape when the electrical input is taken away. For the purpose of this exercise, a NACA 0012 airfoil is used for the nominal shape. With the two shapes, that is, unactuated and actuated, known a priori, and the mechanical properties of the printed material established, the placement of the material can be set up as a topology optimization problem, and solved using the finite element method. The paper will discuss the design process, and the manufacturing efforts in detail. A sample of the printed prototype will be presented and compared to the finite element simulations.

REFERENCES

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