Morphing Airfoil with Adaptive Stiffness

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8) External researcher(s): no entry

9) Funding source(s):
   - Own resources of the professorship

10) Partner organizations: no entry

11) Short Summary: Manifold work has been done on airfoil concepts actively adapting their shape based on elastic compliance instead of rigid-body motion. In this project adaptation strategies using stiffness control by means of smart materials are investigated which promise advances
in efficiency and performance.

12) **Keywords:** Aeronautics, Aerospace Engineering, Engineering Sciences, Materials Technology, Structural Mechanics

13) **Project description:**
Most structural systems operate under conditions that vary with time. As an example, the incident airflow velocity of a commercial airplane’s wing changes considerably between take-off, cruise flight and landing. For each of the flow velocities, a different airfoil geometry provides optimum flight qualities, whether in terms of efficiency, performance or other criteria. Being classical lightweight structures, conventional airfoils are designed for high stiffness and their ability to adapt to varying operating conditions is limited to the effect of single control surfaces and high-lift surfaces as ailerons, flaps and slats. These discrete structural elements, that are realized based on rigid-body mechanisms, are not only, in terms of shape adaptivity, far from the respective aerodynamic optimum, they have, due to their high weight and the differential construction method, also a detrimental influence on the structural efficiency, they are wear-afflicted, are prone to errors and have to be lubricated.

Stimulated by the set of problems described and also by the flight of birds, that is characterized by wing geometries with much more pronounced variability, many attempts have been made to develop airfoils with a higher adaptation capability and the expression “morphing airfoils” has been established for suchlike systems. Most of these approaches can be classified into the following two groups: on the one hand designs that permit better shape adaptivity, but that are still based on the working principle of conventional mechanisms, on the other hand so-called compliant systems, which accomplish geometrical changes by elastic deformations. While the first display the mentioned drawbacks of rigid-body mechanisms, the second are affected by the conflict of aims between the high stiffness that is required for carrying operational loads and the high compliance needed for an effective and efficient adaptation, which again leads to compromise-ridden solutions.

A promising way to avoid this conflict of requirements and to realize adaptive airfoils that approach each of the respective optimal configurations under a set of time-varying operating conditions is constituted by the integration of structural elements with controllable stiffness, which is at the bottom of the idea of the present research project. Suchlike lightweight structures with integrated variable-stiffness capability allow overcoming the paradigm in conventional design of seeking trade-off solutions of the multi-objective optimization problem characterized by the conflicting requirements of loadability, shape adaptivity and lightness. Adaptive-stiffness structures can in principle be designed to be all lightweight, shape-adaptable and load-carrying and have thus a great potential of application in morphing airfoils.

14) **Popular description:** no entry

15) **Graphics:**
Morphing airfoil based on adaptive stiffness

Wolfram Raither, IMES-ST

Experimental wing structure with thermal activation

Wolfram Raither, IMES-ST

Experimental wing structure with electrostatic activation
16) Publications:
   - Raither, Wolfram; Bergamini, Andrea; Ermanni, Paolo. 2011-01-01. Profile Beams with Adaptive Bending-Twist Coupling by Adjustable Shear Center Location. 22nd International Conference on Adaptive Structures Technologies (ICAST2011).
   - Raither, Wolfram; Heymanns, Matthias; Bergamini, Andrea; Ermanni, Paolo. 2012-01-01. Morphing wing structure based on variable coupling stiffness. Nanjing University of Aeronautics & Astronautics.
   - Raither, Wolfram; Heymanns, Matthias; Bergamini, Andrea; Ermanni, Paolo. 2013-01-01. Morphing wing structure with controllable twist based on adaptive bending-twist coupling. Smart materials and structures, Institute of Physics, (6/ 22), Bristol, 065017.
17) **Links to important web pages:** no entry