Fish-like propulsion of an airship based on electro-active polymers

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Introduction

Dielectric electro-active polymers (EAP) are highly flexible actuators and allow for deformation of large areas when voltage is applied (Fig. 1).

The goal of this PhD thesis is to include shell-like actuators based on dielectric EAP in an airship hull. The airship will be propelled in a fish-like manner by sinusoidal bending of the body and a tail fin (Fig. 2).

Specifications:
- Length 6 m
- Velocity 1 m/s

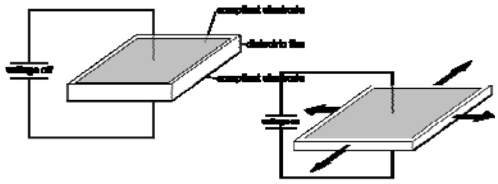


Figure 1: *Working principle of a dielectric EAP.*

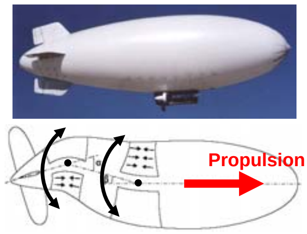


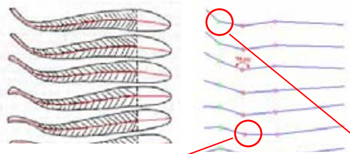
Figure 2: *Nature inspired propulsion of an airship.*

Approach

The continuous motion pattern of a fish is split up in the following subsystems:
- Body bending segments (Figure 3)
- Hinge for tail fin actuation (Figure 4)

The movement of a rainbow trout was analyzed and specifications for the airship determined [1]. An actuator design needs to be found, which fulfills the requirements below.

- Deflection angle up to 25º at tail fin
- Deflection angle up to 15º at body segment
- Strain up to 15 %
- Frequency 0.2 Hz



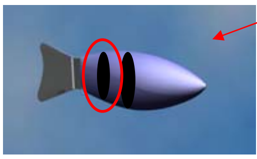


Figure 3: *Bending body segment.*

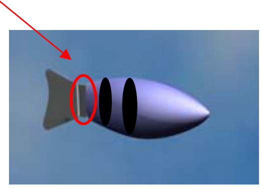


Figure 4: *Hinge for tail fin actuation.*

Measurements and Results

Bending body segment

Several concepts for an active bending body segment were qualitatively compared. In order to characterize the actuator configuration independent of the airship envelope, the actuator design in Figure 5 was developed and deflection angles measured (Figure 6).

Deflection angles up to 12.8º were reached with one-layered actuators at a frequency of 0.2 Hz. Several layers and electrical connections might help to improve the results

Active tail fin

An active hinge of the final size (1mx0.3mx0.15m) was realized and characterized (Figure 7-9).

Deflection angles of 25º were measured at a frequency of 0.2 Hz at an activation voltage of 3.5 kV. A peak current of about 3 mA is necessary for the activation. Several electrical connections lead to better results.

Figure 5: *Actuator configuration for bending body segment.*

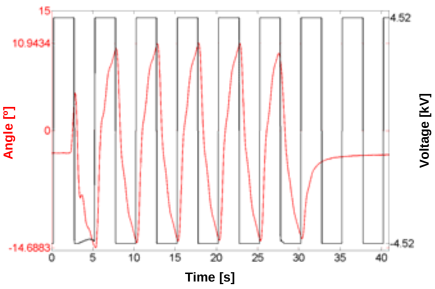


Figure 6: *Resulting deflection angle for bending body segment at 4 kV.*

Figure 7: *Active hinge for tail fin actuation*

Conclusions and Outlook

The desired deflection angles and response time were achieved with the tail fin actuation hinge. From voltage and current measurements a needed input power of 4 W could be determined for 4-layer-actators. A light-weight construction of the hinge will be the next step.

With the bending body segment, the desired angles were not quite reached at 0.2 Hz. Multi-layer actuators might help to achieve the missing degrees and have to be characterized more closely.

A model airship of this size filled with helium can carry about 6 kg. Buoyancy is therefore the critical factor in this project. Therefore a rigid airship with an exoskeleton is difficult to realize in a model airship. More integrated solutions with actuators directly on the airship envelope will be studied.

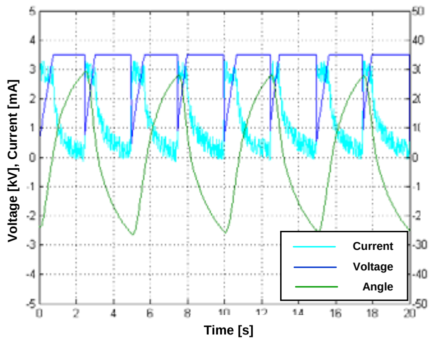


Figure 8: *Active hinge deflection at 0.2 Hz and 3.5 kV.*

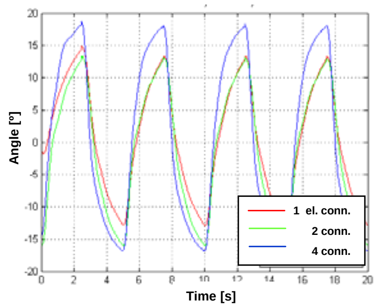


Figure 9: *Comparing active hinge deflection with one and several electrical connections.*

References:
[1] Bormann A, Gephardt C, AEROIX, EAP Blimp als Empa Demonstrator - Machbarkeitsstudie (2007) 67.

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