**Abstract**

Back-relaxation of carbon-based ionic electroactive polymer actuators.

Ionic electromechanically active polymers (IEAP) is one of two main classes of electroactive materials, where actuation is primarily caused by the displacement of ions inside the laminate. Perhaps the first and most distinguished IEAP is ionic polymer-metal composite (IPMC). In recent years the range of IEAP materials has been significantly extended by means of materials used for electrodes (e.g. nanoporous carbon, carbon nanotubes, etc.), separator membrane, as well as the electrolyte (e.g. ionic liquid). At first glance, all IEAPs seem similar in construction and bending behavior – but their actuation mechanisms can be significantly different.

Already since the very first reports about IPMC, the authors have described the „back-relaxation“ effect – an IPMC actuator excited with a DC input will slowly relax back towards its initial state. This effect appears clearly in slow driving signals and interferes the exact control of the actuators. Although one prevalent theory explains the effect with flow of the water molecules across the ion-exchange membrane, the dispute over the physical mechanism of back- relaxation of IPMC still continues.

We demonstrate that regardless of the absence of the fluent liquid, the IEAP actuators with electrodes made of carbon exhibit similar back-relaxation. It appears that the long-term behavior of carbon-based actuators and water-based IPMC is similar by means of their nonuniform transient spatial actuation, and nonuniform transient moment of force. Although the physical mechanisms of the actuation and back-relaxation of the different materials may be different, the resulting model describes all of them and supposedly facilitates the long-term control of the actuators.

**1. Introduction**

Ionic electromechanically active polymers (IEAP) is one of two main classes of electroactive materials, where actuation is primarily caused by the displacement of ions inside the laminate. Perhaps the first and most distinguished IEAP is ionic polymer-metal composite (IPMC). In recent years the range of IEAP materials has been significantly extended by means of materials used for electrodes (e.g. nanoporous carbon, carbon nanotubes, etc.), separator membrane, as well as the electrolyte (e.g. ionic liquid). At first glance, all IEAPs seem similar in construction and bending behavior – but their actuation mechanisms can be significantly different.

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The objective of the current paper is comparison of back-relaxation of three different types of IEAP actuators.

**Vektor esitus…**

**Momendid**

For characterization of the force or curvature output of the actuator, one needs to have an overview of bending moment distribution of the beam. Obviously, the bending moments and also the curvatures are largely affected by the configuration of an actuator. In this paper, we place the actuator in cantilever configuration and derive the bending moments directly from curvature according to the Euler-Bernoulli law:

|  |  |  |
| --- | --- | --- |
|  | $$\frac{dφ}{ds}=\frac{M(s)}{EI},$$ |  |

where $E$ is the modulus of elasticity and $I$ is the second moment of area. For rectangular cross-section, the second moment of area is expressed as

|  |  |  |
| --- | --- | --- |
|  | $$I={bh^{3}}/{12},$$ |  |

where $b$ and $h$ are width and height of the cross-section of the sample respectively.

It must be noted that in the scope of current paper the inertia and mass of the actuator are ignored and we treat each time step as an independent static problem. The weight of the actuator is neglected by holding the actuator edgewise

The described methodic does not pose any restrictions to the shape of the actuator, it works as well when the second moment of inertia is not constant along the sample e.g. the sample is tapered, or its cross-section differs from rectangular. In our case the summarized bending moment of the time-dependent behavior of the sample presented in Fig. 1. reflects exactly its bending depicted in Fig. 6., yet in a different vertical scale.

**Nurkade leidmise metoodika?**

**Distributed mudel, missugune on momentide jaotus?(ei pane miskit vastu, lihas liigub vabalt)**

**Kõverus on selline**

|  |  |  |
| --- | --- | --- |
|  |  |  |
| **MS** | **CPC** | **Kullaga IPMC** |

**Ainult tagasivajumise component.**

According to previous

|  |  |  |
| --- | --- | --- |
|  | **D:\doktorantuur\ASME-SMASIS 2012\pics\CPC_relax_components.tif** |  |
| **MS** | **CPC** | **Kuld IPMC** |

**Nüüd otsime funktsiooni, mis kirjeldaks seda. Näeme, et see peab olema integraal, mille all on asi mis liigutust põhjustab (laeng), sest kuidagi peab arvesse võtma liigutuse ajalugu.**

**Discussion**

**…**