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Position control of an Ionic Polymer Metal Composite actuated rotary joint using Iterative Feedback Tuning

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ABSTRACT

Ionic Polymer Metal Composites (IPMCs) are a novel material that has been the subject of considerable interest over recent decades because of their unique electrochemical and mechanical properties which allow them to be used as smart transducers. However, there has been insufficient research to determine if the electro-active polymer can reliably actuate common engineering mechanisms due to its nonlinear and time-variant nature. This paper explores a model-free approach for controlling the position of an IPMC actuated rotary linkage for micro-manipulation. The mechanism was developed based on the mechanical characteristics of the IPMC actuators. A Proportional, Integral (PI) controller was initially developed and tested to control the tip displacement of the mechanism. Test results show that this classical controller is capable of actuating the rotary mechanism to microscopic deflections but would not completely stabilise at the steady state position. An adaptive, nonlinear tuning method called Iterative Feedback Tuning (IFT) was developed to tune the performance of the PI controller. Empirical results show that the new control scheme improved the steady state response. However, the enhancement of the transient response could not be definitively validated as solely the work of the IFT algorithm due to the time-variant and variable response behaviour of IPMCs.

1. Introduction

Ionic Polymer Metal Composites (IPMCs) are a type of electroactive polymer that can convert electrical energy to mechanical energy and vice versa. This unique property allows the novel material to be used as either a smart actuator or sensor. An IPMC is composed of a flexible ionomeric membrane sandwiched between two thin electrode layers made from gold, silver or platinum [1]. The smart material behaves as an actuator when a voltage is applied across the thickness of the membrane. The voltage induces an electric field across the electrodes causing hydrated mobile cations to migrate towards the cathode boundary layer of the membrane while the anions are fixed [1–3]. Within milliseconds, the accumulation of water molecules to the cathode side of the IPMC cantilever strip causes the material to mechanically deform due to the swelling and contraction along the opposite side of the polymer membrane. These chemical reactions are illustrated in Fig. 1.

IPMC actuators possess many advantageous characteristics such as being able to produce large tip deflections, require low excitation voltages to actuate, are light weight, bio-compatible, capable of bi-directional motion and produce minimal noise when actuated. However, IPMC actuators also possess a number of key drawbacks such as low output force potential, back relaxation, hysteresis, membrane dehydration and hydrolysis [2–4]. Despite these challenges, IPMCs have been successfully utilised for biomedical, aquatic and linear actuation, as well as in vibration damping devices, micro-fluidic pumps, grippers and manipulators [5,3]. Current research is focussed in the following areas: (i) improving the internal microstructure and composition of the ionic polymer; (ii) Understanding the chemical relationship the composite has with solvents; (iii) improving manufacturing techniques; (iv) developing models to quantify the electro-mechanical behaviour of these ionic polymers; and (v) examining the potential of IPMCs to be used as actuators and sensors in engineering applications. Currently there has been minimal investigation into the practical application of IPMC transducers to actuate typical engineering mechanisms. Most research to date has been focused on the free bending behaviour of the material or in flexible jointed mechanisms which have limited application. IPMC actuators could be a suitable alternative of conventional actuators and currently available smart materials in micro-scale and low force applications. The primary objective of this research is to develop a model-free adaptive tuning technique to control the position of a rotary linkage actuated with an IPMC. The rotary mechanism was selected because it has many potential applications in common engineering fields.

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