Dynamic Behavior of SMA Actuated Catheter

Arun S. Veeramani, Gregory D. Buckner, Stephen B. Owen, John H. Crews, Richard C. Cook, and Gil Bolotin
North Carolina State University, Raleigh, NC, USA

Introduction: While catheters have proven effective in numerous cardiovascular procedures, their functionality and versatility can be greatly improved by incorporating active steering capabilities to the catheter tip. Shape memory alloy (SMA) actuation is ideally suited to this application, as these materials offer superior power density, energy density and biocompatibility. In this research, we investigate the transient behavior of an SMA-actuated active catheter to optimize its design and enable precise computer-controlled navigation. Methods: The active catheter prototype consists of a central beam actuated by a single SMA tendon, both enclosed by an outer Teflon sleeve. Joule heating is used to generate tip deflections, which are measured in real time using a dual-camera imaging system. SMA actuation is described using the Seelecke-Muller-Achenbach single-crystal model whose parameters are experimentally derived from stress-strain characteristics of the SMA tendon measured at different temperatures. These characteristics are used to optimize the design parameters of the catheter to maximize the bending response. The effects of outer sleeve thickness on the transient behavior of the catheter are also studied. Results: The catheter's bending mechanics are described using a circular arc model, which is experimentally validated. Catheter actuation is found to be slower with increased sleeve thickness, as explained by heat transfer analysis. Dynamic simulation of the system model shows excellent correlation to experimental data for low frequency actuation.

