



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

Name of the Student : Sagar Mohan

Roll Number : 166103018

Programme of Study : Ph.D.

Thesis Title: Exploring Self-Sensing in Shape Memory Alloy Wire Actuators under Practical Loading Conditions

Name of Thesis Supervisor(s) : Dr Atanu Banerjee

Thesis Submitted to the Department/ Center : Department of Mechanical Engineering

Date of completion of Thesis Viva-Voce Exam : 07/08/2023

Key words for description of Thesis Work : Shape Memory Alloys; Self Sensing; Extended Kalman Filter; Particle Filter; Forced Cooling; LSTM

SHORT ABSTRACT

Shape Memory Alloy (SMA) wire actuators offer large force and displacement capabilities following a non-linear, hysteretic behaviour. This necessitates sophisticated feedback controllers, making the system bulkier. It can be avoided by utilizing the self-sensing capability of SMA, wherein the change in the electrical resistance of the SMA wire can be used to estimate the system output. In literature, various empirical relations are derived based on the experimental results or system model, and are used for the same. These approaches are system specific and needs to be repeated for the change in system parameters or loading conditions. To obviate this, few state estimation-based models have been developed to predict the system output from the change in electrical property of the SMA actuator. To develop the system model, the SMA constitutive model of Boyd and Lagoudas (1996) is modified, to simulate the minor loop response of SMA. Based on the modified SMA constitutive model, an Extended Kalman Filter and a Particle Filter model are developed for the SMA wire actuated linear and nonlinear systems. The linear system comprises of a linear spring biased SMA wire actuator and the nonlinear one consists of SMA wire actuated single degree of freedom manipulator. Correspondingly two experimental setups are fabricated to obtain electrical resistance variation in the SMA wire actuators of these systems for a set of given time varying voltage signals. The voltage signals are taken as inputs and electrical resistance data are taken as measured data and the corresponding response of these systems are estimated using the developed EKF and PF models and the same are compared with the experimental outcome. Under natural convection, the estimation accuracy is found to be reasonably good. Next, forced cooling of varying durations and magnitude is introduced into the system to mimic practical scenario, for which the estimation accuracy is found to deteriorate significantly. The filters are then modified to estimate the convective heat transfer coefficient as well in addition to the systems' response. In this approach, estimation accuracy improved significantly particularly with

the PF model. Similar performance is observed in case of SMA actuated single DOF manipulator, in case the stress and temperature of the SMA wire varies non-monotonically. Finally, an LSTM-based Deep Neural Network models are also developed for these systems and are found to be capable of yielding appreciable accuracy while harnessing self-sensing feature of the SMA wire actuators.

