Materials Discovery 2 (2015) 1–15

Contents lists available at ScienceDirect

Materials Discovery

journal homepage: www.elsevier.com/locate/md

A methodology for using Kalman filter to determine material parameters from uncertain measurements

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ARTICLE INFO

Article history:
Received 4 September 2015
Received in revised form 17 March 2016
Accepted 26 March 2016
Available online 6 May 2016

Keywords:
Least-squares
Kalman filter
Material parameters
Diffusion in bone
Viscoplastic parameters
Uncertain measurements

ABSTRACT

A Kalman filter can be used to determine material parameters using uncertain experimental data. However, starting with inappropriate initial values for material parameters might cause false local attractors or even divergence. Also, inappropriate choices of covariance errors of the state and the measurements might affect the stability of the prediction. The present method suggests a simple way to predict the parameters and the errors required to start the Kalman filter based on known parameters and generated data with different noises used as "measurement data". Diffusion coefficients for bovine bone and viscoplastic steel parameters are chosen as case studies in this work.

1. Introduction

The Kalman filter is an inverse method to determine variables or parameters using input data with noise and get output data with reduced noise. It was first presented by Kalman [1]. The Kalman filter has the advantage of taking the random noise for state and measurements into consideration, while also being an optimal estimator for linear models because it minimizes the mean square error between the states. In addition, it converges quickly. A more complete introduction to the Kalman filter is given by Brown [2]. The Kalman filter can be found under different updated forms that used in many different fields such as tracking objects [3–5], control systems [6,7], and weather forecast [8–10].

A Kalman filter can be used to determine material parameters from uncertain and inaccurate measurements. Aoki et al. [11] used a Kalman filter to identify Gurson's model constant. They found that the accuracy of parameter prediction is affected by both specimen geometry and measurement type, and the shape of the tested specimen affects the convergence of the parameters. Also, they noticed that the rate of convergence can be improved by combining measurements of two different specimens in shape. The identification of Gurson–Tvergaard material model parameters via a Kalman filtering technique is studied by Corigliano et al. [12]. They stated that the estimated values of the parameters are in good agreement with those obtained in previous work, but the initial suggested values for the seeking parameters affects the estimated parameters.

Nakamura and Gu [13] implemented a Kalman filter to determine elastic–plastic anisotropic parameters for thin materials using instrumented indentation. They observed that the initial chosen values for the parameters converged to a specific small area, but not to one value. Also, based on the convergence intensity, the parameters are determined. The same findings are obtained by using a Kalman filter to determine the nonlinear properties of thermal sprayed ceramic coatings [14]. Bolzon et al. [15] used Kalman filter to identify parameters of a cohesive crack model. They reported that a nearly linear correlation between convergent parameters is found, and the reason for the multiple local minimum might be related to using the linear Kalman filter for non-linear models.

Vaddadi et al. [16] used a Kalman filter to determine critical moisture diffusion parameters for a fiber reinforced composite. They estimated the parameters from the intensity of the convergence, which was found to be consistent with known values. Another study made by Vaddadi et al. [17] to determine hygrothermal properties in fiber reinforced composites using a Kalman filter. The parameters are extracted by reading the intensity of the convergence plot.

A Kalman filter is an efficient way to filter noisy experimental data for determination of material parameters. However, the initial

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http://dx.doi.org/10.1016/j.md.2016.03.002
2352-9245/