MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Interactive Session on Materials and Structures (9)

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A NEW ADAPTIVE ESTIMATION METHOD OF SPACECRAFT THERMAL MATHEMATICAL MODEL WITH AN ENSEMBLE KALMAN FILTER

Abstract

In spacecraft thermal designs, thermal mathematical models, which predict temperature changes on orbit, plays an important role for efficient thermal designs. One of the difficulties in building the thermal mathematical models is to identify some uncertain thermal characteristic parameters, such as thermal contact resistances between components, before launch. These parameters are usually identified by using thermal vacuum test data on the ground and the thermal mathematical model is updated until the model meets the thermal design requirements. The accuracy of the model is limited by how precise the vacuum test can simulate the orbital spacecraft environment. In future space missions, such as an advanced space telescope, the thermal design requirements tend to become more and more severe and the accuracy of the thermal model estimated based on the thermal vacuum test could be insufficient. To meet such requirements, more precise thermal mathematical models are needed to develop effective thermal designs and control systems. The aim of this paper is to present a new adaptive estimation method of spacecraft thermal mathematical models that can constantly identify uncertain thermal characteristic parameters by using observation data on orbit. In our method, we utilize an ensemble Kalman filtering technique to update the thermal mathematical model continuously at each observation time step. The thermal mathematical model is highly nonlinear due to radiation terms and is difficult to be estimated with the conventional adaptive Kalman filtering techniques. The ensemble Kalman filter can effectively handle the nonlinearities contained in the model. At first, we derive the state space equations of the thermal mathematical model. Both the temperatures and the uncertain thermal characteristic parameters of the spacecraft are considered as the state variables of the thermal model. Next, the estimation procedure with the ensemble Kalmain filter is presented. In this procedure, the thermal characteristic parameters are automatically estimated as the outputs of the filtered state variables, whereas, in the usual thermal model correlation, they are manually identified by experienced engineers using try-and-error approach which could be time consuming. Finally, some numerical examples of a simple small satellite is provided to verify the effectiveness of the presented method.