Universal Framework of Bayesian Creep Model Selection for Steel

Yoh-ichi Mototake[1], Hitoshi Izuno[2], Kenji Nagata[3,4], Masahiko Demura[2] and Masato Okada[1,2,*]

[1]Graduate School of Frontier Sciences, University of Tokyo, Kashiwa 277-8561, Japan.

[2]Research and Services Division of Materials Data and Integrated System, National Institute for Materials Science, 1-2-1 Sengen, Tsukuba 305-0047, Japan.

[3]Artificial Intelligence Research Center, National Institute of Advanced Industrial Science and Technology, 2-4-7, Koto, Tokyo 135-0064, Japan.

[4]JST PRESTO, Kawaguchi, Saitama 332-0012, Japan.

[*]Corresponding Author: Masato Okada. Email: okada@edu.k.u-tokyo.ac.jp.

Abstract: The creep deformation process is constructed by complex interactions of multiple factors, and the measurement of creep deformation requires enormous economic costs and a long experimental time, so there is a small amount of measurement data. In such a situation, multiple models are often proposed to explain the same experimental data. The coexistence of multiple models based on different physical assumptions makes it difficult to understand the creep deformation process.

The purpose of this study is to construct a framework to compare and evaluate coexistence models based on measurement data using the Bayesian model selection framework. Basically, in the creep deformation model, basis functions, usually the exponential function eat or power function tb, corresponding to the primary creep stage and the tertiary creep stage are set, and the time series of the whole creep deformation process is regressed as the linear sum of these bases. The parameters a and b of the basis functions are parameters that must also be optimized to regress the time series data. Izuno et al. proposed the Bayesian model selection method for the creep deformation process, and it was confirmed that the model with the linear term corresponding to the secondary creep stage, called the modified theta method, is a good model compared to the model without adding the linear term. To obtain the criterion of Bayesian model selection analytically, which can reduce the computational cost greatly, Izuno et al. treated only the regression coefficients as the probabilistic parameter of the creep model. In this method, parameters a and b of the basis functions are optimized by a grid search. Because the grid search requires significant computational costs if multiple basis functions are set for each creep stage, as in the model proposed by Kimura et al., it is difficult to apply the algorithm to models with multiple bases. In addition, if parameters a and b of the basis functions correlate with the regression coefficients, the method of Izuno et al. would offer a biased evaluation of the models.

To improve such an existing method, we proposed a Bayesian model selection method that treats the parameters of the basis functions as probabilistic parameters. The large computational cost to treat the parameters of the basis functions as probabilistic parameters was reduced using the exchange Monte Carlo method, which is an efficient sampling method. By applying our proposed method to the evaluation of the creep deformation model, information was obtained to understand the creep deformation process deeply. For example, it was confirmed that there exists a model in which there is a correlation between the parameter of basis function and the regression coefficients.

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