System Identification for Structural Health Monitoring
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Preface

When structural designers and engineers assess the safety and functionality of building structures, they first construct models for structural analysis. One, two or three-dimensional modeling of structural members and elements is usually introduced based on their experiences and knowledge. Appropriate modeling of members or element connections and elaborate setting of boundary conditions are very significant for reliable structural analysis.

System identification (SI) techniques are important in reducing gaps between the constructed structural systems and their structural design models, and in health monitoring for damage detection. Modal-parameter SI and physical-parameter SI are two major branches in SI. Non-parametric SI and parametric SI are other classifications.

In spite of the importance of damping in the seismic-resistant design of buildings, it does not appear that its identification techniques have been developed sufficiently. Furthermore, it is believed in general that the acceleration records in all the floors above a specific story are necessary to evaluate the story shear force, which is required in the stiffness–damping evaluation. This instrumentation may be unrealistic in multi-storied buildings. To overcome this difficulty, Udwadia et al. (1978) proposed a unique system identification theory for a shear building model. They clarified that unique identification of story stiffness and viscous damping coefficients is possible when acceleration records at the floors just above and below a specific story are available. While the applicability of their theory to actual earthquake records with noises is not clear, their approach is pioneering in the physical-parameter SI and constructs its theoretical basis. However, their theory includes unrealistic manipulation to take the limit of frequency into infinity in order to identify the viscous damping coefficients.

In the first stage of this book, a new physical-parameter SI method is explained in which a linear hysteretic damping ratio can be identified together with the viscous damping coefficients, in addition to the identification of stiffness. It should be noted that both the hysteretic damping and the viscous
damping can be identified simultaneously in a unified manner. Only a simple and efficient fast Fourier transform (FFT) technique is needed in the proposed identification method. The validity and accuracy of the present method are investigated through numerical simulation models and actual earthquake records in a base-isolated building. It is further shown that a new advanced identification technique for mechanical properties of a Maxwell-type model can be developed by combining the present method with a perturbation technique.

The above-mentioned method has a drawback of noise-sensitive properties. In the subsequent research, the effects of extraneous noises have been eliminated partially when a record at either one of floors just above or below a specified story contains a noise. In a realistic situation, however, both records usually contain noises. Furthermore, in the records of microtremors, the level of noise seems to be relatively large compared to the true signal. In these cases the effect of noise on the accuracy of system identification is significant. To overcome this difficulty, a novel noise-effect compensation method is proposed in which unfavorable effects by extraneous noise can be eliminated. By using this method, the formulas are derived to evaluate the level and correlation of noise in addition to the identification of story stiffness and damping. The validity and accuracy of the proposed method are investigated through numerical simulation models and small-scaled tests.

In usual environments around buildings, miscellaneous noise affects buildings. Traffic vibration may vibrate buildings and that vibration source comes from the building base. In addition, buildings contain various electrical or mechanical facilities or equipment too. For these vibration sources, inner vibration modeling is appropriate. In the later part of this book, the stiffness–damping simultaneous identification method for inner vibration sources is explained. The validity and accuracy of the proposed method are investigated through numerical simulation models and small-scale tests.

In the final part of this book, autoregressive with exogenous terms (ARX) models are introduced to remove the bias due to noise and enhance the reliability of the newly developed physical-parameter SI method. The derivation of the relation of the ARX parameters with physical parameters makes the physical-parameter SI method more reliable.

**Special character of this book:**

i. The physical-parameter SI method explained in this book requires only two accelerometers for the measurement of records. Furthermore, only a simple manipulation of Fourier transformation is required.
ii. The stiffness and damping can be identified simultaneously.
iii. The modal-parameter SI can supplement or support the result by the
physical-parameter SI method.
iv. In place of usual low-pass or high-pass filter techniques, a novel noise-bias compensation method is explained. Because the noise itself is not known in many cases, the identification and elimination of noise is a tough problem.
v. A new technique of system identification is explained in the case where an inner vibration source exists.
vi. The accuracy of the explained SI methods is examined by the actual recorded data.
vii. MATLAB codes are available from the WIT Press website. Please follow the link on the book order page.

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Kyoto, 2012