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Accurate damage inspection and reliable health monitoring of dynamical systems rely on accurate dynamical data computation. In theory, if all three variables (i.e., displacement, velocity, and acceleration) of each point on a dynamical system are available from measurement, system identification/damage detection methods can be easily and accurately performed. In the experiment, however, there is often only one variable is measured because collocating three different sensors at a point is too difficult even if the sensors are small enough not to affect the system’s dynamic characteristics. Numerical investigations reveal that velocity is the best choice because the corresponding acceleration and displacement can be estimated by numerical differentiation and integration and because today’s laser vibrometers can provide very accurate measurements of velocities. Therefore, with the velocity signal as the single measurand, efficient and accurate numerical computation methods are needed to compute the corresponding displacement and acceleration signals.

Ideally, an intelligent structure will be able to realize real-time monitoring that the occurrence of damage can be identified at a very early stage. Then, by localizing the existed damage, a detailed analysis of the damaged structure section can be carried out such as determine the severity of the damage or the remaining service life of the structure. Two direct time-domain methods and two indirect time-domain methods for system identification are reviewed in this thesis. The feasibility of using these system identification methods for level 1 damage detection has been discussed in this thesis. While some of the methods can realize a real-time monitoring and quick feedback, some can only realize periodic inspections or cannot reflect a small change in modal parameters.

Two origin methods as stiffness-characteristic matrix method (stiffness-CMM) and mass characteristic matrix method (mass-CMM) for damage localization are proposed in this thesis, and it is the concentration of the thesis. Different from traditional damage detection methods, proposed methods do not require the corresponding intact beam structure for comparison. While measured signals only processed in the spatial domain, a weighting matrix developed from the finite element model of the beam structure is used for computing the damage index on each measured location. The largest (filtered) damage index indicates the actual damage location. Two different weighting matrixes are used in proposed methods and the mass-CMM is more robust to measuring noise. Application of the two methods is demonstrated through numerical examples. In addition, experimental vibration data of damaged beam structure measured using a PSV-200 scanning laser vibrometer are also used to verify the accuracy of these methods.