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Non-overlapped random decrement technique for parameter identification in operational modal analysis

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ABSTRACT

The random decrement technique (RDT) is used to estimate free vibration response from output data generated by Gaussian white noise. The principle is to decay the excitation via averaging of segments in output data. With RDT, the triggering condition for determining the initial points of segments causes overlap during averaging; the consequence is a residual excitation, peaking at the first natural frequency. This paper presents a modified RDT with non-overlapped segments to eliminate this peak. Numerical comparison between non-overlapped RDT (NRDT) and RDT shows the accuracy improvement of damping. However, time history data is sometimes not long enough in NRDT, which results in an inevitable overlap. In order to keep the accuracy of NRDT, the first natural period is viewed as the critical length between adjacent initial points to distinguish the inevitable overlap from that in RDT.

1. Introduction

Random Decrement Technique (RDT) is an approach to extract free vibration from responses excited by zero-mean Gaussian white noise. The white noise excitation constraint is needed because the technique operates by canceling (through averaging) the contribution of the forced response and the nature of the loading allows one to claim zero expectations for certain averaging. The key to the accuracy which is attainable with the RDT is related to what extent the forced response is removed. In the paper we examine an approach designated as NRDT which is designed to improve the effectiveness with which the forced response contribution is removed from the output signals. The paper presents the rationality for the proposed modification and compares results with those obtained using the traditional implementation of RDT.

RDT was firstly put forward in 1971 by Cole [1] to estimate damping of airplane wings. RDT obtains free vibration response from forced response signals by averaging segments of output data.

The white noise excitation follows the way in which random response is divided into short segments. Both response and excitation segments are averaged in general. After numerous times of averaging, overlap leads to a special spectrum characteristic of averaged excitation, which is named residual excitation. It is proposed in Ref. [2] without explanation that the spectrum characteristic is related to fundamental frequency of the system. The averaged response, i.e. random decrement (RD) signal, is a superposition of residual response generated by residual excitation and free decay response actually. The residual excitation is the source of error in RDT.

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Filtering of harmonic components from response in OMA may perturb modal identification, especially under the condition of the harmonic frequency is close to system frequency [3,4]. Asayesh [5] studied the influence of periodic excitations in RDT and tried to extract harmonic excitations from white noise. He pointed out that harmonic part may lead bias in modal identification. If the residual excitation is decoupled with system frequency and keeping Gaussian distribution, the residual response can be suppressed and the accuracy of modal identification will be improved. Thus, NRDT is proposed to achieve this goal by improving triggering condition.

Triggering condition is a rule to select a time series for overlap-averaging in time history response in one of the system dofs. The original triggering condition which was raised by Cole [1] was named level cross triggering condition. After then other triggering conditions, such as positive point triggering condition, up cross triggering condition and vector triggering condition, were presented to enhance the accuracy [6,7]. NRDT does not set a new rule to obtain triggering time series. It suggests an extra condition to filter triggering time series before averaging. The condition is to escape some triggering points to make sure that the length between adjacent triggering points is longer than that of RD signal. By this treatment, NRDT avoids overlap. However, NRDT has an extreme requirement of data length. A restricted overlap, which is limited by a critical value of the first modal period, is proposed to keep accuracy of NRDT as well as consume less data. Specifically, if the length between adjacent triggering points is longer than the critical value, the modal identification shows a similar accuracy with that by NRDT.

The residual excitations in RDT and NRDT are compared to show the effect of non-overlap in simulation. Then the comparison of RD signal and non-overlapped random decrement (NRD) signal is presented in both time and frequency domain. To compare errors between RDT and NRDT, the discrete to continuous (d2C) time transfer of state space models [8] is employed for modal identification. After that, the critical value is verified to enhance the efficiency of data usage.

To summarize, this paper aims to improve the accuracy of RDT. In traditional RDT, the segments are averaged under overlap, which leads to errors in identification. NRDT avoids overlap by keeping the distance between adjacent triggering points longer than the length of RD signal. If overlap is inevitable, a critical value can be employed to restrict the overlap.

This paper is organized as follows. RDT is represented in state space and modal identification method is outlined in discrete time in Section 2, while uniform length average of random signal, triggering gaps, NRDT and critical value of restricted overlap are coped with in Section 3. Then a simulation by Matlab is illustrated to compare the error of RDT and NRDT in Section 4.

2. State space representation of RDT and modal identification

For a linear time invariant system with $n$dofs, the state space description is

$$\begin{cases} \dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u} \\ \mathbf{y} = \mathbf{C}\mathbf{x} + \mathbf{D}\mathbf{u} \end{cases} \quad (1)$$

where $\mathbf{y} \in R^{m\times 1}$ is the measured output, $\mathbf{u} \in R^{r\times 1}$ are the wide band excitations inputs, $\mathbf{x} \in R^{2n\times 1}$ is the state, $\mathbf{A} \in R^{2n\times 2n}$ is the transition matrix, $\mathbf{B} \in R^{2n\times r}$ is the input to state matrix, $\mathbf{C} \in R^{m\times 2n}$ is the state to output matrix and $\mathbf{D} \in R^{m\times r}$is the direct

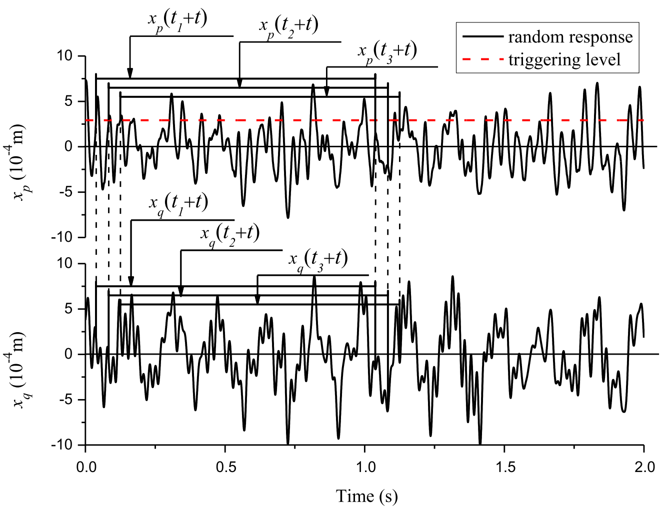

Fig. 1. Acquisition of short time segments.