I - B76 **IDENTIFICATION OF AEROELASTIC PARAMETERS BY MITD METHOD**

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1. Introduction: In the recent research of Wind Engineering, intensive efforts have been made to the extraction of the aerodynamic parameters or flutter derivatives. In the past research, various method of the system identification have been developed. The EK-WGI method (Yamada et.al, 1992) has carried out using an indirect method in its identification in which, first,.from single-degree-of-freedom test, the observation response are filtered to obtain all the unknown parameter, the second, the modal information which are consisted of the complex frequencies and the complex mode shape from the filtered responses are calculated, and the third, this modal information are reassembled to the equation of motion to obtain the flutter derivatives in reduce frequency domain. The other research (Scanlan and Tomko 1971) has also used an indirect method that was, first, from single-degree -of- freedom test a limited number of aeroelastic parameters (direct flutter derivatives) were found and used to calculate certain other aeroelastic parameters (cross-flutter derivatives) from two-degree-of-freedom coupled motion test. These both method are very time consuming.

A reliable but simple system-identification method has been developed recently by Sarkar (1994) called the Modified Ibrahim Time Domain (MITD) method. This method could be implemented easily to extract all the aeroelastic parameters from the simultaneously motion time histories of section model test. In this paper, this method is employed in identifying of the flutter derivatives of Akashi Kakyo bridge section model. Experimental set up has been conducted for three-degree-of-freedom mounting of the section model under smooth wind flow in wind tunnel.

2. Flutter Derivatives Formulation: Linear dynamic system due to an aerodynamics force (self excited force) can be defined as

$$M\ddot{X}(t)+C\dot{X}(t)+KX(t)=F_{se}(t) \tag{1}$$

The aerodynamics force, $F_{se}=[L_{se}, M_{se}, D_{se}]^{\mathrm{T}}$ (for three-degree-of-freedom system), can be written in the real formulation proposed by Scanlan as

$$L_{se}=\tfrac{1}{2}\rho U^2 B\left[KH_1^*(K)\frac{\dot{h}}{U}+KH_2^*(K)B\frac{\dot{\alpha}}{U}+K^2H_3^*(K)\alpha+K^2H_4^*(K)\frac{h}{B}+KH_5^*\frac{\dot{p}}{U}+K^2H_6^*\frac{p}{B}\right]$$

$$M_{se}=\tfrac{1}{2}\rho U^2 B^2\left[KA_1^*(K)\frac{\dot{h}}{U}+KA_2^*(K)B\frac{\dot{\alpha}}{U}+K^2A_3^*(K)\alpha+K^2A_4^*(K)\frac{h}{B}+KA_5^*\frac{\dot{p}}{U}+K^2A_6^*\frac{p}{B}\right]$$

$$D_{se}=\tfrac{1}{2}\rho U^2 B^2\left[KP_1^*(K)\frac{\dot{p}}{U}+KP_2^*(K)B\frac{\dot{\alpha}}{U}+K^2P_3^*(K)\alpha+K^2P_4^*(K)\frac{p}{B}+KP_5^*\frac{\dot{h}}{U}+K^2P_6^*\frac{h}{B}\right]$$

where, h, α and p = displacement (lift, moment and sway); ρ = air density; B = width of the bridge deck; $K=\omega B/U$ = reduced frequency; U=wind speed; ω = natural frequency of oscillation; and $\dot{h}$, $\dot{\alpha}$ and $\dot{p}$ = velocities; and A_i^*, H_i^*, and P_i^* , $i=1,\ldots\ldots,6$, are nondimensional functions of reduced velocity ($1/K$) known as flutter derivatives. Since the system of three-dof under aerodynamic force will give three frequencies differently, the reduce frequency, K in Eq.1 can be specified based on the assumption that they are the function of the frequency dominant in each time history oscillation. For example, $K_h=B\omega_h/U$ is as the reduce frequency in h, $\dot{h}$ component, $K_\alpha=B\omega_\alpha/U$ is as the reduce frequency in α, $\dot{\alpha}$ component and $K_p=B\omega_p/U$ is as the reduce frequency in p, $\dot{p}$ component. This assumption will be perfectly correct in case there are no coupling are taking placed among all the oscillation. However in case of strongly coupled, this assumption should be revised.

3. MITD method: This method, in principle, use the free vibration response analysis of linear dynamic system (Eq. 1) to identify the parameters in matrices $\overline{C}$ and $\overline{K}$ (these matrices are formed by transferring the right hand side of Eq.1 to the left hand side), in which consist of the information of flutter derivatives.

Key words: Simple system identification, flutter derivatives, simultaneously motion of time history, free vibrations response analysis
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A brief description of this method can be explained as follows.

(1). Matrices Φ and $\hat{\Phi}$ are formulated as follow :

$$\Phi = \begin{bmatrix} Y(0) & Y(\Delta t) & ....Y[(N-N_1-N_2-1)\Delta t] \\ Y[(N_2)\Delta t] & Y[(N_2+1)\Delta t] & ....Y[(N-N_1-1)\Delta t] \end{bmatrix}$$

$$\hat{\Phi} = \begin{bmatrix} Y[(N_1)\Delta t & Y[(N_1+1)\Delta t] & ....Y[(N-N_2-1)\Delta t] \\ Y[(N_1+N_2)\Delta t] & Y[(N_1+N_2+1)\Delta t] & ....Y[(N-1)\Delta t] \end{bmatrix}$$

where Φ and $\hat{\Phi}$ have order 2n x N - N_1 - N_2 and n = number of degrees of freedom of the system; N = Number of sample data points of $Y(t)$; N_1 and N_2= shifts in the time intervals of the histories $Y(t)$ (integers N_1 and $N_2 << N$); and Δt = time interval between sampling of $Y(t)$. The complex eigenvalues of $[\hat{\Phi}\Phi^T][\Phi\Phi^T]^{-1}$ yield parameters, that is, modal frequencies and modal damping of the system; (2). Using these estimated parameters, N data points of $\overline{X}(t)$ are generated where $\overline{X}(t)$ is pseudo representation of the response $X(t)$. $\overline{\Phi}$ and $\hat{\overline{\Phi}}$ are formed just like Φ and $\hat{\Phi}$ except that $\overline{X}(t)$ is used instead of $Y(t)$. The complex eigenvalues of $[\hat{\overline{\Phi}}\overline{\Phi}^T][\overline{\Phi}\overline{\Phi}^T]^{-1}$ yield a revised set of parameters of modal frequencies and modal damping of the system; (3). Step 2 is repeated with the revised parameters until the values of these parameters converge, then matrices $\overline{C}$ and $\overline{K}$, that consist of the information of flutter derivatives, can be estimated using the converged values of these parameters.

4. Result: The flutter derivatives of Akashi Kakyo bridge section model (truss type) have been successfully identified by the MITD method. Some of the them are presented in Figure 1.

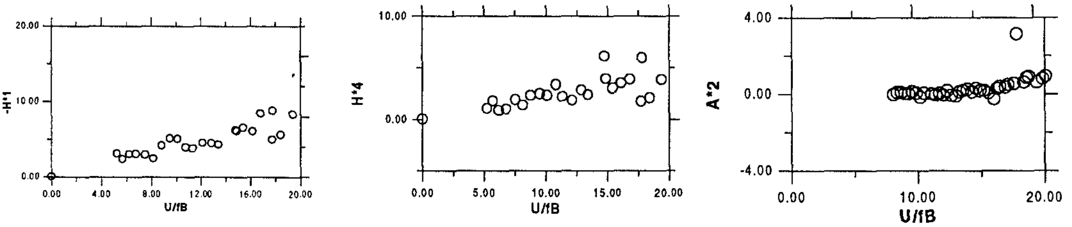

Figure 1. Flutter derivatives of H^*1, H^*4, and A^*2

These figure show the correspondence between flutter derivatives and the reduce wind speed. In the above figure, coefficient H^*1 and H^*4 are related to the frequency ω_2 that is the frequency dominant which is closely to the frequency vertical bending oscillation in case of uncopled system, A^*2 is related to frequency ω_3 that is the frequency dominant which is closely to the frequency of torsional oscillation in case of uncoupled system.

5. Conclusion: The extraction of the flutter derivatives have been carried out using the MITD method through the simultaneously data observation time history displacement. This method principally is processed based on the free vibration formulation of the equation of motion. The flutter derivatives are extracted based on the assumption that the reduce frequency is the function of the frequency dominant in each time history oscillation. However, in case the strongly coupling among the response are taking placed, this assumption should be revised.

6. References

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