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Discussion

Discussion on "Time domain buffeting response calculations of slender structures" by K. Aas-Jakobsen, E. Strommen

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Abstract

The authors (J. Wind Eng. Ind. Aerodynam. 89 (2001) 341) presented a time domain framework for predicting the buffeting response of slender structures utilizing aerodynamic forces based on the quasi-steady theory. The example studied clearly demonstrated the significant influence of structural nonlinearities on the buffeting response, and reaffirmed the overall versatility of the time domain analysis approach. In the light of the time domain presentation in this paper, we would like to offer some comments which we believe would expand the scope of the time domain approach as applied to bridge buffeting response. Our discussion focuses on three key aspects: the simulation of the random wind field, the quasi-steady aerodynamic force model and the element discretization as presented in this paper.

1. Simulation of random wind field

In any time domain approach one of the important components is the time history of the input, which in this case is a multiple-point correlated wind velocity field. As noted by the authors, the most important practical issue concerns the computation speed and storage requirements when velocity input at a large number of discretized nodal locations is required. The authors dismissed time series approaches like ARMA by citing difficulty in choosing suitable model order in obtaining good match with the target flow features. Li and Kareem [1,2] provide an approach to overcome

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the noted lack of straightforwardness associated with ARMA-based simulations. These references particularly address the issues peculiar to wind-related problems, namely, matching of wind spectra, model order and difficulties associated with simulation at small time increments.

Regardless of the straightforwardness of the spectral approach adopted in this presentation, concerns remain, however, regarding the limitations imposed on the large number of simulated locations and the length of time series dictated by the computer memory. Once again, we would like to suggest a reference to Li and Kareem [3] in which an approach was presented that provides a time series of unlimited length while utilizing the FFT approach. The authors have pointed out an interesting observation following Eq. (5). This concerns deletion of rows and columns from the target spectral matrix of the points at which the fluctuations are either fully coherent or have a zero mean square spectral density at a particular frequency. This results in a smaller matrix and enhances computational efficiency. We note that the approach, based on stochastic decomposition, by Li and Kareem [4] takes advantage of such a situation by transforming the original space to the one in which the component processes are either fully coherent or non-coherent. This has led to a number of applications both in simulation and dynamic response analysis. This can be achieved either by Shur (modal) or Cholesky decomposition. In this approach, one can even drop some of the components of fluctuations at any desired range of frequencies with minimum influence on response, thus reducing simulation time without loss of accuracy akin to the modal analysis in structural dynamics. The attractiveness of this approach has been recently reaffirmed by Di Paola and Gullo [5] for the simulation of wind fields. Additional applications to simulation and state-space modeling can be found in [6].

2. Quasi-steady aerodynamic force model

In the specific example of this study, the emphasis was placed on the alongwind displacement of the cantilevered beam and the corresponding torsional moment on the pillar. Unlike long-span bridges, the motion-induced aerodynamic forces are less important. However, the quasi-steady-theory-based buffeting force model certainly overestimates the buffeting forces and attendant response. The quasi-steady aerodynamic force model used in this study has been shown to be appropriate at only very high reduced velocities, however, due to its simplicity, it has been often utilized in time domain simulations. It fails in capturing unsteady fluid memory effects, which are better characterized by frequency-dependent aerodynamic descriptions. In the frequency domain, these characteristics are described in terms of flutter derivatives for self-excited forces and admittance functions for buffeting forces. Typically, a frequency domain approach can conveniently account for the frequency dependency in the response analysis. The authors briefly hinted at the two usual shortcomings in their loading approach based on quasi-steady theory. However, we find it important that the state-of-the-art developments in the time domain modeling of frequency-dependent unsteady aerodynamic forces be introduced to future users of this approach. The authors mentioned only the inclusion of the frequency-dependent terms in the force coefficients (Eq. (13)), and suggested a filter based on a trial-and-error-type matching between the simulated and measured load spectra.

Recently, the discussers have proposed a time domain approach that incorporates the frequency-dependent characteristics of aerodynamic forces [7]. By expressing the flutter derivatives and admittance functions in terms of rational function approximations, the unsteady aerodynamic forces can be calculated in the time domain. This time domain approach has been further extended to account for the nonlinear dependence of aerodynamic forces on the effective angle of incidence [8]. Diana et al. [9] have also proposed a nonlinear aerodynamic force model which is based on the so-called "quasi-static corrected theory". This nonlinear force model incorporates frequency-dependent characteristics by decomposing the total response into components with different frequencies.

3. Finite element discretization

The authors discussed the effects of element discretization of the structure on the buffeting response, and concluded that structural element size criteria are necessary to capture the significant spatiotemporal features of the wind field. The allowable element length was reported to be dependent on the integral scale of the coherence function of wind fluctuations, which is a function of wind velocity, decay factor of coherence function, and frequency (Eq. (17)). In fact, this requirement on the element length is unnecessary, provided that the spanwise coherence of aerodynamic forces within each element is appropriately modeled in the calculation of the total element forces. This is generally accomplished in frequency domain analysis by introducing a joint acceptance function characterized by the coherence function and results in a reduction of the total element forces compared to those in which full coherence within each element has been assumed. In the time domain, this reduction effect can also be modeled for an accurate response analysis [7]. In fact, the consideration of the joint acceptance function is equivalent to introducing a filter that yields the aerodynamic forces on each element with the aerodynamic forces on unit length as an input. This filter is characterized in terms of the joint acceptance function in the frequency domain. By incorporating this reduction effect, the element discretization would be independent of the spatio-temporal features of aerodynamic forces or wind fluctuations. Therefore, the time domain buffeting analysis would not render special requirements on the finite element size, which otherwise limits the versatility of the finite element structural discretization used for static and dynamic response analyses of structures.

The authors directly calculated the aerodynamic forces on structural elements from the simulated wind fluctuations at element nodes. By assuming that the aerodynamic forces have the same spanwise coherence as the approach flow, this study somehow models the spanwise coherence among aerodynamic forces acting on different elements. However, the coherence of forces within each element is neglected, which led to the time domain results being larger than those based on the frequency domain solution (Fig. 7). In Appendix C, it is evident that the spanwise coherence within each element and among different elements are appropriately modeled in the frequency domain.

In closing, we believe that the preceding remarks would help to promote the application of recent developments in simulation and aerodynamic modeling thus building upon an already very practical analysis framework offered by the authors.

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