I－B43

Some Considerations about the Gust Response of Structures

Ritsumeikan University member Peter Schrader*)

1. Introduction

Models of power spectra of strong wind in the atmospheric surface layer are specified in the literature for certain ideal conditions (flat and uniform terrain, stable weather, etc.). However, the ideal conditions are often violated. Hence, in the low frequency range the real power spectra often differ from these models /1/. But in general, in the high frequency range, both are proportional to $f^{-5/3}$ provided the measurements are carried out properly. When the gust response of lightly damped towers, high-rise buildings etc. is to be predicted, one often uses the spectral method /2//3//4//5/. Wind spectra are then needed as basic input.

According to /1/, in a wind blowing from the sea to the shore , the power spectrum was measured over land and found to exhibit the following characteristics: For U/f << fetch over new terrain, the spectrum was in equilibrium with the new terrain, but for U/f > fetch over new terrain, the spectrum was in equilibrium with the sea surface. This is an example of a sudden smooth-to-rough roughness change. In such cases, for calculating the gust response of structures accurately, is it necessary to now the wind spectra in full detail? Or may more easily available partial information be sufficient?

According to /6/, when power spectra and cross-spectra of strong wind are estimated by fitting an AR model to wind records with high sampling frequency, the high frequency spectra can be estimated properly, but the low frequency spectra may easily be estimated incorrectly. This is due to the tendency of classical criteria to yield too low AR orders for such wind records. However, usually the fitting is realized by first estimating covariance and autocovariance functions $C(\tau)$ from the wind records and then solving the Yule-Walker equations for a chosen AR order. If algorithms like those in /7/ or /8/ are employed for this purpose, then wind covariances and variances of the AR model are equal to the measured ones, even if the low frequency spectra are incorrect. Can such an AR model be used to calculate the gust response of structures accurately? Or is it necessary to know the low and medium frequency wind spectra in full detail?

2.Basic assumptions about the spectral method and the gust response /5/

It is assumed that the structure is line-like, linear elastic and lightly damped (3% or less modal viscous damping), showing a significant resonant response due to wind turbulence (buffeting). The external forces are not affected by the structural motion. The effect of vortex shedding is not considered either. The natural frequencies of the structure are lying in or close to the -5/3 range of wind power spectra. The wind pressures on the structure can be modelled as a gaussian stationary process; their power spectra and cross-spectra have the same basic shape as the corresponding wind spectra.

The latter assumption can usually be expected to be satisfied. To obtain pressure spectra from velocity spectra, frequently either quasi-stationary theory is used /3//4/ or an aerodynamic admittance /4//9/. In the first case, wind pressure fluctuations are obtained from wind speed fluctuations by a time-invariant linear transformation. In the latter case, wind pressure power spectra are calculated from wind speed power spectra by multiplying by an aerodynamic admittance function, which is roughly constant for low frequencies and falls off rapidly for high frequencies /9/.

*) Ritsumeikan University, Noji-Higashi 1-1-1, Kusatsu-shi, 525-0058 Shiga-ken, TEL: 0775-66-1111, FAX: 0775-61-2629 .

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It is assumed that the spectral coherence is basically an exponentially decreasing function of frequency, like, e.g., Davenport's model (see e.g. /9/).

3. What information about wind spectra is really relevant to design?

The structural responses relevant to design are the maxima of deflections, reactions, moments, etc. during a fixed period (e.g. 10 min. or 1hr). Hence, the spectra of the structural responses are considered here as intermediate results from the spectral method, of interest only in so far as they are used to estimate (expected values of) maxima of structural responses. Consequently it is enough to obtain response variances and peak factors. As wind power spectra show a very high peak near f=0 (double linear plot in fig.1), it can be shown /5/ that the following limited information about wind spectra is sufficient: a) wind variances and spatial cross-correlations at $\tau=0$, i.e. integrals over wind power and cross-spectra, and b) wind power and cross-spectra within the -5/3 range of wind speed power spectra.

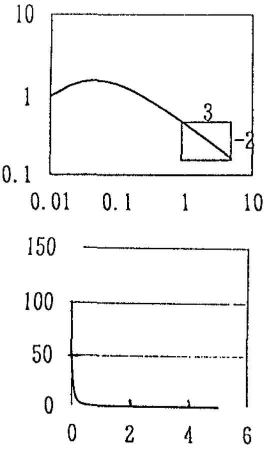

Fig.1 typical wind power spectrum (above: fG(f), loglog scale; below: G(f))

4. Conclusions

For design purposes, relatively limited information about wind spectra (section 3, items a and b) is often sufficient. Hence, the incorrect AR model mentioned in section 1 can nevertheless be used to compute correct results.

In case of the roughness change mentioned in section 1, measurements of spatial cross- spectra of wind speed fluctuations are rare. However, supposing that the wind cross-spectra behave analogously to the power spectra (but I am not certain that this is so), the response of a structure on the shore might be estimated in the following way: the resonant response contribution can be calculated with the spectra over the shore, the quasistatic contribution can be estimated with the variances and spatial correlations over the sea. The same principles might be applicable certain situations of complicated topography.

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