The distribution of turbulence driven wind speed extremes; a closed form asymptotic formulation

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The distribution of turbulence driven wind speed extremes - an asymptotic closed form formulation

Abstract:
The statistical distribution of extreme wind speed excursions above a mean level, for a specified (large) recurrence period, is of crucial importance in relation to design of wind sensitive structures. This is particularly true for wind turbine structures.
Assuming the stochastic (wind speed) process to be a Gaussian process, Cartwright and Longuet-Higgens [1] derived an asymptotic expression for the distribution of the largest excursion from the mean level during an arbitrary recurrence period. From its inception, this celebrated expression has been widely used in wind engineering (as well as in off-shore engineering) - often through definition of the peak factor, which equates the mean of the Cartwright/Longuet-Higgens asymptotic distribution. However, investigations of full-scale wind speed time series, recorded in the atmospheric boundary layer, has revealed that the Gaussian assumption is inadequate for wind speed events associated with large excursions from the mean [2], [3], [4]. Such extreme turbulence excursions seem to occur significantly more frequent than predicted according to the Gaussian assumption, which may under-predict the probability of large turbulence excursions by more than one decade. This obviously has unfortunate consequences for the applicability of the Cartwright/Lounguet-Higgens asymptotic extreme distribution in the description of extreme turbulence excursions, especially for long recurrence periods. Another related problem with the Cartwright/Longuet-Higgens expression, associated with description of extreme wind speed events in the atmospheric boundary layer, is, that many investigations of full-scale wind speed gusts (e.g. [5], [6]) have shown, that the observed occurrences of these are excellently described by the Gumbel EV1 distribution, which, on the other hand, differs from the asymptotic Cartwright/Longuet-Higgens distribution.
We present an asymptotic expression for the distribution of the largest excursion from the mean level, during a large but otherwise arbitrary recurrence period, based on a Generalised Hyperbolic type of "mother" distribution that reflects the Exponential-like distribution behaviour of large wind speed excursions. The derived asymptotic distribution is shown to equal a Gumbel EV1 type distribution, and the associated two distribution parameters are expressed as simple functions of basic parameters characterizing stochastic wind speed processes in the atmospheric boundary layer.

References
[1] D.E. Cartwright and M. S. Longuet-Higgins (1956). The statistical distribution of the maxima of a random function.
[2] M. Nielsen, G.C. Larsen, J. Mann, S. Ott, K.S. Hansen and B.J. Pedersen (2003). Wind Simulation for Extreme and Fatigue Loads. Risø-R-1437(EN).
[3] F. Boettcher, C. Renner, H.-P. Waldl, and J. Peinke (2003). On the statistics of Wind Gusts. *Boundary Layer Meteorology*, **108**, 163-173.
[4] H.A. Panofsky and J.A. Dutton (1984). *Atmospheric Turbulence - Models and Methods for Engineering Applications*. John Wiley & Sons.
[5] G.C. Larsen, K.S. Hansen and B.J. Pedersen (2002). Constrained simulation of critical wind speed gusts by means of wavelets. 2002 Global Windpower Conference and Exhibition, France.
[6] G.C. Larsen and K.S. Hansen (2001). Statistics of Off Shore Wind Speed Gusts. EWEC'01, Copenhagen, Denmark, 2-6 July.