18th International Conference
ENGINEERING MECHANICS 2012
Svratka, Czech Republic, May 14 – 17, 2012

pp. 256–257
Paper #96

LIFETIME PREDICTION OF WIND LOADED MAST AND TOWERS WITH RESPECT TO LATERAL AND LONGITUDINAL WIND SPECTRUM

S. Pospíšil[*], J. Lahodný[**], V. Janata, S. Urushadze, R. Král, S. Hračov

Abstract: *The paper describes an analysis for the purpose of theoretical lifetime prediction of telecommunication towers, guyed masts and antenna's extensions. It brings simple and practical calculation method and the theoretical results are compared with long-term measurements on several existing structures. Wind load has been described taking into account the probability distribution function of the mean velocity and corresponding wind pressures. The dynamic response of structure is caused by the turbulence described with a spectral model both for longitudinal and lateral direction. Structural response takes into account the contribution of more vibration modes. Based upon this knowledge, the number of cycles during certain period was determined. The fatigue analysis has been carried out and the residual time life prediction of antennas was determined for an industrial partner.*

Keywords: ***Life-time prediction, masts, towers, fatigue, wind, spectrum.***

1. Introduction

Slender structures like chimneys and antennas are repeatedly exposed to dynamic loading by the wind. The consequent vibration may cause the cumulating damage, which sometimes leads to the collapse of structure. To prevent the breakdown by timely replacement or reconstruction, or to predict the expenses for further tower operation, one should determine the remaining lifetime. In this article along wind vibration caused not only by the longitudinal but also by lateral turbulence obtained from the long-term measurement is analyzed see e.g. Repetto & Solari (2002). Depending on structural characteristics, lateral vibrations in some cases are more important. The method for the determination of remaining life of guyed masts, towers and antenna extension is presented. The age and regular inspection revealed that these components could be in danger. Based on the long-term monitoring stress cycles the remaining life of the elements was determined. For practical as well as analytical reasons, it was compared with theoretical calculation and prediction using just the knowledge of dynamic characteristics of the structure and the wind.

2. Damage assessment of existing structures

In the period 2005-2011, the authors collected several measurements on several broadcast towers. The suitability of the procedure is documented on the analysis of towers and guyed masts. Three examples are presented in the full paper; Two towers Veselský kopec, Vraní Vrch and one guyed mast Domamil with two sets of ropes.

The ultrasonic anemometers in several elevations have measured the wind speed up to 60 m/s and the direction of the flow. Dynamic measurements of the tower response consisted in determining of resonant frequency of the tower based on the evaluation of the ambient vibration of the structure. Strain measurements were carried out using strain gauges mounted on the tubular antenna or directly on the guy-rope tensioning rods. These strain gauges were connected to a bus and the numbers of cycles and the stress range was calculated using the rainflow method. The measured number of cycles is extrapolated to the projected lifespan, usually 45 or 50 years.

[*] Doc. Ing. Stanislav Pospíšil, Ph.D.: Institute of Theoretical and Applied mechanics, CAS, Prosecká 76; 190 00, Prague; CZ, e-mail: pospisil@itam.cas.cz

[**] Ing. Jiří Lahodný, Ph.D..: Excon, a.s., Sokolovská 187; 190 00, Prague; CZ, e-mail:lahodny@excon.cz

3. Theoretical determination of number of cycles

The number of cycles with the amplitude of fluctuating component of the stresses is formed according to the practical formula, expressing the cumulative probability of mutually independent phenomena:

$$n_i = P_1 \cdot P_2 \cdot P_3 \cdot d_t \cdot \sum_{k=1}^{N} P_{4,f_k} \cdot f_k \tag{1}$$

where f_k is the k-th resonant frequency and d_t is the desired (projected) lifetime of the structure. Coefficients P_i, $i = 1,\ldots,4$ stand for the probability density function related to a) occurrence of the mean wind speed, b) fluctuating stress component at certain mean wind speed, c) occurrence frequency of the mean wind speed blowing in one direction and, finally, d) the fact that the structure vibrates in certain shape with certain frequency.

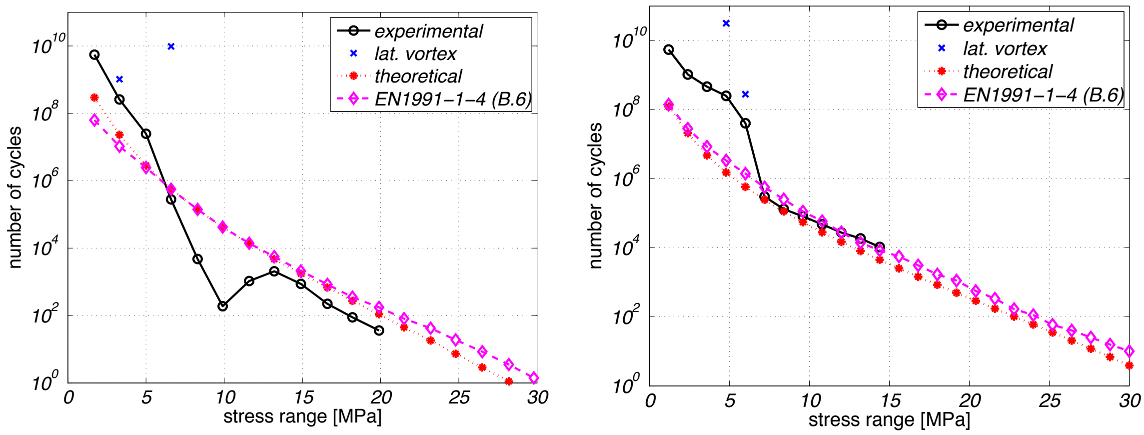

Fig. 1: Stress spectra ascertained from the strain-gauges measurement (circles) and number of cycles determined theoretically (red asterisks, magenta diamonds). Left: Veselský kopec, Right: Vraní vrch.

In case we know the measured values, we may set the number of cycles in every stress range. Finally we may assess if it complies with the so-called Palmgren-Miner criterion and/or determine the residual life of the structure. The suitability of the proposed method is demonstrated in Fig. 1, where the comparison between measured and calculated number of cycles is presented for the observed time interval on selected towers.

4. Conclusions

The paper presented the analysis focused on the prediction of theoretical lifetime of antenna cantilever and mast guys and the comparison with long/short time measurements on the real structures. Examples of slender towers and masts subjected to the turbulent wind were presented. The wind load has been described by relatively simple formulas and the number of cycles during certain period was determined. The load description agreed very well with the measurements on the structure. Though there are differences in some of the stress ranges especially higher one which cannot be measured in the relatively short interval, there exists general agreement between theoretical predictions and onsite measurements, when correct assumption of the wind and the structure are employed. The work offers practical method for the clients to better estimate the service life of towers and their parts.

Acknowledgement

The support for this work was provided by the projects of the Ministry of Industry and Trade No. MPO TIP FR-TI3/654, RVO: 68378297, the Czech Grant Agency by project No. GAČR 103/09/0094, the research project AV 0Z 2071913 and by the company České radiokomunikace a.s.

References

Repetto, M. P., Solari, G. (2002) Dynamic crosswind fatigue of slender vertical structures. *Wind and Structures*, Vol. 5, No. 6, pp. 527-542.