EXPERIMENTAL STUDY OF THE CAVITATION NOISE SPECTRAL LINE BREADTH

K. Vokurka

Department of Physics, Faculty of Electrical Engineering,
Czech Technical University, Prague)*

Results of the experimental study of the cavitation noise spectral line breadth are presented. It was found, that the power spectrum varies as $1/|\Delta f|^\alpha$ in the vicinity of spectral lines. A possible qualitative explanation of the phenomenon is given on the basis of the theory of group pulse processes. However, this theory fails to explain the observed facts quantitatively.

1. INTRODUCTION

Under a closer investigation of the published cavitation noise spectrograms [1, 2] it may be observed that the discrete components in the spectrum do not rise from the flat continuous part abruptly but gradually, that is they have a tapered form. As this phenomenon may be expected to be due to the behaviour of cavitation bubbles we have decided to study it in more detail.

2. METHOD OF MEASUREMENT

The experimental set-up used for cavitation noise spectra measurements is schematically shown in fig. 1. The driving ultrasonic field in the liquid was excited by an ultrasonic generator. This generator consisted of a composite piezoelectric transducer with a double quarter-wave cylindrical step velocity transformer and of a 300 W

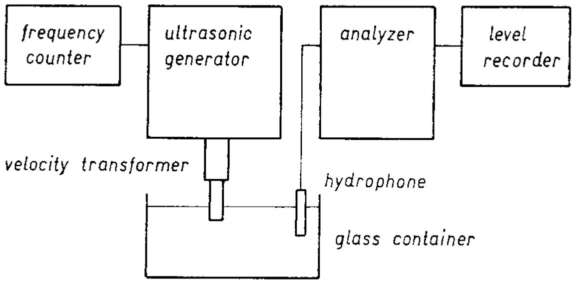

Fig. 1. Experimental arrangement used for cavitation noise power spectra measurements.

---

*) *Suchbátarova 2, 166 27 Praha 6, Czechoslovakia.* Present address: *LIAZ n. p., V. Kopeckého 400, 466 05 Jablonec n. Nisou, Czechoslovakia.*

power amplifier with feedback which enabled the generator to oscillate at transducer resonance frequency and kept the transducer amplitude at the pre-set constant level. The generator frequency $f_0 = 20$ kHz was continuously checked by a frequency counter.

Cavitation was generated in the 300 × 200 × 150 mm glass container filled with tap water. The radiating surface of the velocity transformer, under which cavitation occurred, was dipped 15 mm in the liquid. A hydrophone was situated 100 mm from the centre of the cavitation region and was connected directly to the input of a Brüel & Kjaer Heterodyne Analyzer Type 2010. During the first part of the measurement a Brüel & Kjaer Level Recorder Type 2305 was interconnected with the analyzer.

The active element of the hydrophone was a hollow cylinder made from PKM-30 piezoelectric material (Tesla Hradec Králové). The outer diameter of the cylinder was $D = 20$ mm, the inner diameter $d = 17$ mm and the height $h = 8$ mm. The resonance frequency of the cylinder was approximately 56 kHz. The cylinder was mounted on the dur-aluminimum skeleton and was rubber-coated (Lukopren N 1524). The hydrophone resonance was appropriately damped so that the hydrophone had a flat frequency response up to the resonance frequency. The static capacitance of the hydrophone was $C_0 = 2{\cdot}7 \times 10^{-9}$ F and the voltage sensitivity was $M = 58$ μV/Pa which is −210 dB re. 1V/μPa. The hydrophone was calibrated by the substitution method in the air.

3. RESULTS AND THEIR INTERPRETATION

The experimental work consisted of two parts. First the whole spectrum in the range from 5 kHz to 100 kHz was analysed and recorded by the analyzer and the level recorder interconnected. The purpose of this measurement was to check the general form of the spectrum. The measured spectrogram (fig. 2) was in good agreement with the results published in the literature [1, 2]. The broadening of the lower parts of spectral lines may also be observed.

Next the detailed examination of the discrete component vicinity was performed. In this measurement the level recorder was disconnected and the analyzer was tuned manually. The analyzer bandwidth was set to $B = 10$ Hz and the averaging time to $T = 10$ s which gave the relative statistical error $\varepsilon = 100/(BT)^{1/2} = 10\%$.

The form of the measured power spectra in the vicinity of the discrete components $f_0 = 20$ kHz, $2f_0 = 40$ kHz and $3f_0 = 60$ kHz is shown in fig. 3. Here $\Delta f = f - kf_0$, $k = 1, 2, 3$ and L is the spectrum level in dB corresponding to the frequency f. In fig. 3 the spectral line breadth may be seen clearly. This breadth is several hundreds of Hz in the lower part and as the level increases the lines slowly taper off. The form of the spectrum in the vicinity of the frequencies kf_0 may be approximated by the formula $1/|\Delta f|^{\alpha}$, $\Delta f \neq 0$, where α ranges from 0·5 to 1. During the measurement the frequency of the ultrasonic generator fluctuated only by several Hz.

This rather large spectral line breadth may qualitatively be explained using the theory of the random pulse processes. While oscillating, the cavitation bubbles radiate pressure waves into the liquid. When the bubble reaches its minimum volume, maximum pressure is radiated. Because of the non-linear character of the bubble oscillations the radiated waves have the form of pressure pulses. In the driving ultrasonic field the bubbles usually oscillate so that they grow during the strain half-period and are compressed during the stress half-period. Thus the single bubbles radiate the pressure pulses mostly in periodically repeated time intervals and in the point of the hydrophone groups of more or less overlapping pressure pulses occur. If the groups followed one another strictly periodically, the considered cavitation noise could be approximated by the periodic group pulse process, the power spectrum of which contains discrete components having the form of the delta functions $\delta(\omega - k\omega_0)$ [3]. However, it may be expected that for diverse reasons in a real environment the groups will not follow one another strictly periodically but rather quasiperiodically. Then the cavitation noise may be approximated by the quasiperiodic group pulse process, the power spectrum of which contains spectral lines with finite height and non-zero breadth [4, 5].

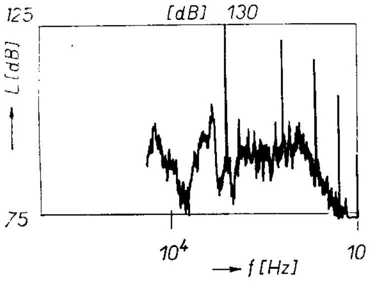

Fig. 2. Cavitation noise spectrogram. Analyzer bandwidth: $B = 10$ Hz. Level recorder: writing speed 8 mm s^{-1}, paper speed 0·03 mm s^{-1}.

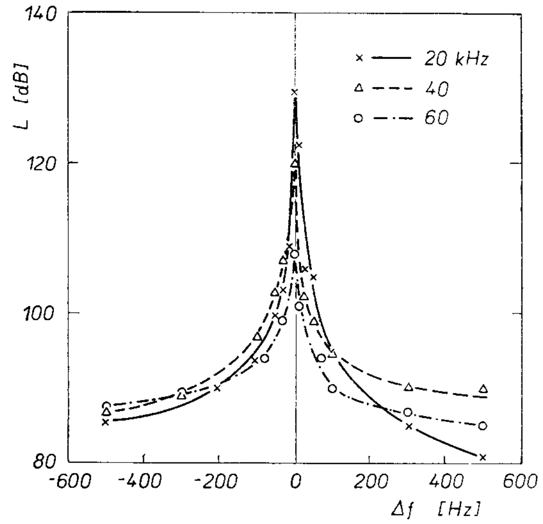

Fig. 3. Measured cavitation noise power spectra in the vicinity of the discrete components kf_0: $B = 10$ Hz, $T = 10$ s, $f_0 = 20$ kHz, $k = 1, 2, 3$.

In the considered cavitation noise model we have not taken into account any interaction between the pressure pulses and the bubbles. However, as we discuss elsewhere [6], such an interaction seems to be quite important and may be the cause of the differences between the measured and the calculated spectral lines peak levels. Thus, unfortunately, the model cannot be used for quantitative analysis.

There is also a difference in the value of α. In the theoretical model it was found that $\alpha = 2$ [5]. However, as we have mentioned earlier the experimental data yield the value of α in the range from 0·5 to 1. This surprisingly low value of α seems to correspond to similar values of α for $1/f$ noise and it is not possible to judge at present whether this value of α is also due to the pulse-bubble interaction or to some other cause.

The hydrophone used in this work was designed and constructed by Ing. P. Janeček with a kind help of Dr. A. Boleslav.

Received 15. 5. 1981.

References

[1] Esche R.: Akustische Beihefte (1952) 208.
[2] Bohn L.: Acustica *7* (1957) 201.
[3] Vokurka K.: VI. konf. čs. fyziků, referát 09-06, Ostrava, 1979.
[4] Vokurka K.: Kybernetika *16* (1980) 462.
[5] Vokurka K.: Kybernetika *17* (1981) 298.
[6] Vokurka K.: The XXth Int. Conf. ULTRASOUND, ČSVTS, Praha, 1981, p. 53.