POWER SPECTRUM OF THE CAVITATION NOISE AT ULTRASONIC CAVITATION

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The picture of the cavitation region at ultrasonic cavitation is rather complex. The oscillating cavitation bubbles chaotically move from one place to another. They grow during the strain half-periode of the driving ultrasonic field and they are compressed during the stress half-periode. While oscillating the bubbles radiate the pressure waves into the liquid. Because the bubbles collapse and radiate the pressure pulses mostly during the stress half-periode, the groups of the more or less overlapping pressure pulses occur at the place of an observer periodically.

To be able to create a mathematical model of the cavitation noise we have to make a number of assumptions, the most important of which are: the bubbles are mutually independent, they perform only one oscillation during their lifetimes and any interaction among radiated pressure pulses and bubbles may be neglected. It may be shown [1], that under these assumptions the cavitation noise may be represented by the Poisson periodic pulse process. The expression for the power spectrum of this process was derived in the paper [2] in the form

$$W(\omega) = W_C(\omega) + W_D(\omega) = \tag{1}$$

$$= \frac{2\bar{N}}{T_0}\overline{|s(\omega,\hat{a})|^2} + \frac{2\bar{N}^2}{T_0^2}\overline{|s(\omega,\hat{a})|}^2 |\chi_y(\omega)|^2 \, 2\pi \sum_{k=0}^{\infty} \delta(\omega - k\omega_0)$$

This expression has two terms. The first one, $W_C(\omega)$, represents the continuous part of the spectrum, the second one, $W_D(\omega)$, represents the discrete part of the spectrum.

The power spectrum of the cavitation noise at ultrasonic cavitation has been measured, for example, by Esche [3], Bohn [4] and lately by Haussmann [5]. The measured spectra also have two parts - the continuous part and the discrete part which is composed of the basic component f_e and the number of ultraharmonic and subharmonic components. In this work only the ultraharmonic components will be considered. The peak level of these components falls quite slowly with the growing frequency and it is usually possible to discriminate the components kf_e for $k \geq 30$ in the spectrum. The peaks of the lowest ultraharmonic components exceed the continuous part of the spectrum at about 35 - 40 dB.

The mentioned experimental data may be compared with the expression (1). To match the extent of ultraharmonic components present in the measured spectra, the mean square root of the random variable φ would have to be rather small - approximately $\sigma_\varphi \doteq T_e/30$. However, such a value of σ_φ is in contradiction both to an intuitive feeling and to experimental results (e.g. Radek [6]), from which it may be estimated that $\sigma_\varphi \doteq T_e/k \approx 10$,

Now the height the ultraharmonic components exceed over the continuous part of the spectrum will be examined. Let us denote L_C the level of the continuous part and L_D the level of the discrete components peaks. If we consider the first components only, then $|X_\varphi(\omega)|^2 \doteq 1$ approximately. Putting $\overline{|s(\omega,a)|^2} \doteq |\overline{s(\omega,a)}|^2$ and taking into account that $W_D(\omega) \gg W_C(\omega)$, the following approximate formula may be obtained from (1) after some rearrangements

$$\bar{N} \doteq \frac{1}{\omega_0} \, 10^{\frac{L_D - L_C}{10}} \quad . \qquad (2)$$

Substituting $L_D - L_C = 40$ dB and $f_e = 20$ kHz we get $\bar{N} < 1$!

The results obtained both experimentally and theoretically are schematically shown in the figure. The energy in spectrum seems to be shifted from the lower ultraharmonic components to the higher ones. We believe this is due to the nonlinear interaction of the pressure waves with the bubbles because the assumption about nonexistence of this interaction is evidently the most unmaintainable. According to our hypothesis the small bubbles serve as frequency converters that absorb the wave energy from the lower spectral components and radiate it at the frequencies of their natural oscillations that coincide with the frequencies of the higher spectral components.

References:

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