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CAVITATION IN PULSED AND CONTINUOUS ULTRASOUND FIELDS

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A comparative study of cavitation generated by the high intensity focused ultrasound fields (HIFU) in chopped and continuous ultrasound fields have been undertaken. It has been shown that pulse modulation of the ultrasound field is an effective tool for controlling the dynamics of cavitation zone development, for transient cavitation thresholds increasing and for increasing the efficiency of acoustic energy transformation into shock waves inside and outside bubbles.

Key words: cavitation, pulsed ultrasound, sonoluminescence, cavitation zone development.

A comparative study of cavitation generated by the high intensity focused ultrasound fields (HIFU) in chopped (pulsed) and continuous ultrasound fields have been undertaken. The detailed description of the experimental set-up is given elsewhere [1,2]. The stainless steel cylinder of 10 cm in diameter and 16 cm in height was used as an experimental chamber. The focusing piezoceramic transducer of 65 mm in diameter with a resonance frequency of 720 kHz was mounted at the cell bottom. The hydrophone was placed in the chamber in such a way that its spherical sensitive piezoceramic unit (the diameter of 2 mm and the side thickness of 0.25 mm) was at a distance of 25 mm above the center of the transducer's focal point. Its output (after amplification) is indicated below as H. The central region of the chamber was viewed through a light guide by a photomultiplier. Intensity of the sonoluminescence (SL) and of the hydrophone output were registered by the HP 54601 multichannel memory oscilloscope in the peak mode display regime. In investigations of the influence of pulse period T on SL intensity the value of T was decreased starting from T = 2000 ms. The pulse duration τ was changed by increasing τ from 0.1 ms. The reason for changing T and τ in this manner was to decrease, as much as possible, the influence of the previous experiment on the results of the subsequent experiment.

The use of chopped ultrasound permits strongly decrease the rate of cavitation zone development and increase the time delay between the generator switching on and the cavitation appearance. By decreasing ultrasound pulse duration and increasing pulse period we were able to increase this time period up to 10 minutes.

It has been shown that cavitation zone passes through different stages of evolution with either increasing pulse duration t, decreasing pulse period T or increasing driving voltage U. Sonoluminescence (SL) is absent at the first stage, ultrasound absorbance at this stage is not increased in respect to conditions below cavitation threshold. The second stage corresponds to the onset of sonoluminescence and the smooth increase of its intensity. In the third stage, the SL intensity L increases in a sudden manner, what manifests itself through a considerable increase of slopes of the L dependencies on the above parameters (t, T, U) and is accompanied by the synchronous strong increase of the ultrasound absorption in the cavitation zone. Upon further increasing t, decreasing T or increasing U, the SL intensity reaches a maximum value and then decreases while ultrasound absorption decreases smoothly. From the above results two thresholds of cavitation zone development can be distinguished: the first one is related to the SL appearance and the second - to the sudden increase of the SL intensity, possibly due to an avalanche-like multiplication of cavitation bubbles.

Both the first and the second thresholds are increased as US pulse duration is decreased or pulse period is increased, i.e. as inverse pulse duty ratio N of the pulses is increased. Cavitation noise spectra are changed significantly with the stages of the cavitation zone development. This is indicative that the different regimes of sonification could be identified by spectral analysis of the acoustic emission from the cavitation zone. It should be noted that it is difficult to distinguish stages of cavitation zone development in a continuous ultrasound field.

Decrease of the cavitation activity after achieving L_{max} (i.e. at high bubble volume concentration) can be induced by the reasons discussed by Dezhkunov et.al., [3] and Leighton [4]. These are bubbles interactions, clustering and screening action of the cavitation field. Thus, with increasing in the density of bubbles, the SL intensity experiences the influence of two competing factors: increase of the number of cavitation events (collapses) per unit time, on one hand, and the decrease of the efficiency of concentrating the energy by bubbles upon collapse, on the other hand.

SL intensity maximum L on L(t) and L(T) dependencies is shifted to lower t and higher T respectively with increasing the ultrasound intensity. In conditions corresponding to maximal cavitation activity SL intensity achieves maximal value at the beginning of the ultrasound pulse and then stays more or less stable. In oversaturation conditions after achieving maximal value it decreases rather quickly with time. For low bubble volume concentrations SL intensity is increased with time during pulse of ultrasound.

Conclusions: pulse modulation of the ultrasound field is an effective tool for controlling the dynamics of cavitation zone development, transient cavitation thresholds and efficiency of acoustic energy transformation into shock waves inside and outside bubbles.

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