P-43: Stages of the HIFU Cavitation Zone Development and their Identification

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The experimental chamber was a stainless steel cylinder with a diameter of 75 mm and a height of 120 mm. A focusing 40 mm diameter piezoceramic transducer with a resonance frequency of 0.88 MHz was mounted at the cell bottom. The hydrophone was placed in the chamber in such a way that its spherical sensitive piezoceramic unit (diameter of 2 mm and wall thickness of 0.2 mm) is at a distance of 30 mm above the centre of the focal spot of the transducer. Its output (after amplification) is indicated below as H. The central region of the chamber was viewed through a 25 mm diameter lightguide by a photomultiplier. Intensity of sonoluminescence (SL) and hydrophone output were registered by HP 54601 multichannel memory oscilloscope in regime of peak mode display.

It has been shown that cavitation zone generated by the high intensity focused ultrasound (HIFU) passes through different stages of evolution with either increasing pulse duration, decreasing pulse period or increasing driving voltage of pulsed ultrasound. In the first stage sonoluminescence (SL) is absent. Here sound absorption is weak in the cavitation zone and the hydrophone output is nearly constant if the transducer voltage is constant. The second stage corresponds to the onset of sonoluminescence and the smooth increase of its intensity. In the third stage, the sonoluminescence intensity increases in a sudden manner and this increase is accompanied by the synchronous increase of the ultrasound absorption in the cavitation zone. Two cavitation thresholds separate these stages: first 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.

Existence of the threshold values for pulse duration τ at constant pulse period T voltage U can be explained as following. Nuclei of cavitation start to grow due to rectified diffusion and coalescence at the moment of ultrasound switching on.   Grows time is equal to the pulse duration τ. During time period T-τ between two ultrasound pulses the sizes of bubbles are diminishing. If during this period (T-τ) the size of the bubble is decreased up to its initial value i.e. integral grows for given T,τ and U is absent. In this case τ is below its threshold value τ_{th1}.

If τ value is big enough, for the time t>>T, the average grows of the bubbles will be observed and they may achieve the resonance size at which bubbles start to collapse and produce characteristic effects such as sonoluminescence and shock waves. With increasing active bubbles concentration cavitation activity is increasing also. But at the same very time the phenomena are enhanced which influence negatively on the efficiency of energy concentration by collapsing bubbles. They are first of all bubbles interactions by Bierkness forces and shock waves. An important factor may be also bubbles clustering.

Thus, with increasing in the density of bubbles, the SL intensity experiences the influence of two competing factors connected with the increased bubbles concentration: increase of the number of cavitation events (collapses) per unit time, on one hand, and the decrease the efficiency of concentrating the energy by bubbles upon collapse, on the other hand. At $\tau < \tau_{max}$ the prevailing factor is the growth of the number of collapses per unit time and probably the increase of the intensity of collapses. At $\tau > \tau_{max}$ the prevailing factor is decreasing the efficacy of energy transformation and concentration by collapsing bubbles. This leads to decreasing the cavitation activity in this range of τ. This conclusion is confirmed by the results of registration of the dynamics of the SL emission during an ultrasound pulse. Direct observation of the cavitation zone have shown that big stable bubbles are produced intensively at these conditions. This may be one of the reasons of increased absorption and shielding of ultrasound by cavitation zone and decreased cavitation activity $\tau > \tau_{max}$. The same explanation can be given for the threshold values for pulse period T taking into account that silence time between US pulses is increased with T if pulse duration is constant.