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TRANSFORMATION OF RAREFACTION WAVE INTO COMPRESSION WAVE WITH AMPLIFICATION AT LIQUID CAVITATION

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Abstract. The results of experimental investigation of transformation of shock-acoustic waves with amplification at cavitation in a liquid are presented**.** The generation of extending cavitation using an electromagnetic generator of spherically focusing shock wave is described. Stimulated radiation of the compression waves by a focal zone was observed. It was shown that the source of a secondary shock-acoustic waves is expanding cavitation bubbles in a trace of focusing wave. Amplified generation of a compression acoustic pulse was observed.

INTRODUCTION

Cavitation is a phenomenon results in non-linear processes like an energy cumulating in cavities. Hence, many effects in a liquid can be observed only while cavitation. The luminescence of a liquid in a pulsing rarefaction wave is now known [1]. Investigation of cavitation in a liquid have shown, that an extended cavitation bubbles emits a secondary radial shock waves. A basic question is a role of secondary shock waves for luminescence in a liquid at an early stage of cavitation.

In the present work the results of observation of wave pattern at cavitation in spherically focusing acoustic pulse far from boundaries of a liquid are presented.

EXPERIMENT

On the Fig. 1 the scheme of experimental installation to research the transformation of shock-acoustic wave (SAW) at cavitation in a liquid are presented. In the experiments the SAW electromagnetic generator with a radiating surface (6) as sphere segment with the aperture of D=220 mm, the radius of a curvature of R=170 mm [2] was used. The radiator was installed on the bottom of the glass cuvette (2) measured 300õ300x480 mm. The focusing was made due to the set form of an acoustic pulse front, which coincide the form of a radiating membrane. The focal point F was placed above a centre of the membrane on a distance of 170 mm.

The cavitation and wave processes development in a liquid was observed by shadow method. Photo-recording was lead by high-speed photo-camera ÑÔÐ-1ì with frame display mode (16 ❍s per frame). Both the picture of cavitation bubbles and acoustic wave pattern in cuvette one can receive with this technique.

The pressure field was measured by absolutely calibrated needle pressure gauges. The time resolution of 0.05 ❍s, space resolution of 0.7 mm.

RESULTS

On the Fig. 2 the separated frames of the shadow high-speed photo-recording of a hydrodynamic and cavitation processes near to a focal point of the generator are shown. The crossing point of the horizontal and vertical lines on the frames coincides a focal point of the generator. In the experiments the focal point location was determined by a maximum value of a pressure for weak shock-acoustic wave (~1MPa) without a cavitation.

On the figure 2 the focusing of shock-acoustic wave, developing of cavitation zone and stimulated acoustic scattering waves near to the focus one can see. This process as a whole will be called the shock-acoustic breakdown, because the general patterns of cavitation process in this case are similar to the laser breakdown of a liquid [3, 4].

The shock wave (1) and edge rarefaction wave (3) from electromagnetic generator initiates a shock acoustic breakdown. The emitted secondary cavitation waves (SCW) (4) represent a complex wave field, consisting of a discreet spherical waves radiated by a driven source. The source is a point K which is the crossing of a toroidal surface of edge rarefaction wave on the z-axis. The point K moves along the z-axis with speed *u* (*u* = *c*/cos *ö*, where *ö* is an angle between ERW normal and the y-axis at the point K, c is the sound speed 1.5 mm/❍s). In our case, the formation of SCW will be realised for the angles *ö* from 45° to 55°, which corresponds to the speed *u* within the range from 2.1 to 1.8 mm/❍s. Cavitation area (5) is appeared to be extended along the z-axis.

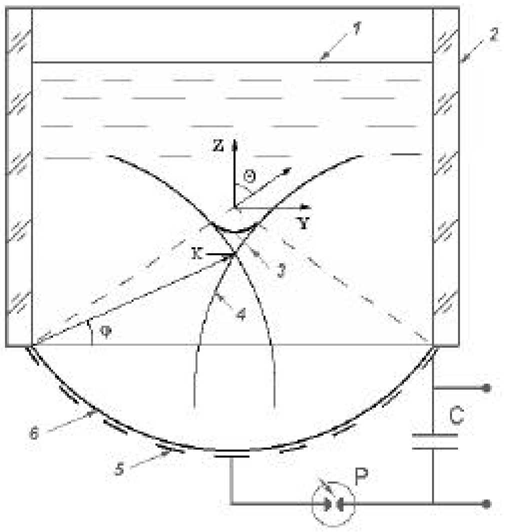

Figure 1. *Scheme of experiment. 1 – surface of a liquid, 2 – cuvette, 3 – focusing shock-acoustic wave, 4 – edge rarefaction wave, 5 – one-layer inductance, 6 – membrane.*

On the Fig. 3 a signal from the pressure probe placed at a point Z=0, Y=25 mm, located in the same horizontal plane as a focal point on a distance of 25 mm from it is shown. It is visible, that after a rarefaction wave (2) a cavitation compression wave (3) follows.

Figure 1 also includes in self the scheme of a wave pattern restored on the photo-recording and to the results of the pressure measurement near to the focus of the spherical generator.

CONCLUSION

The analysis of photo-recording film and pressure measurements shows, that the sources of the secondary acoustic waves are an extended bubbles in the trace of focusing wave. Extending cavitation in a liquid forms a complex interference wave picture. The superposition of waves from many bubbles results in secondary acoustic waves in liquid. This effect will be called the transformation of rarefaction wave in compression wave at liquid cavitation.

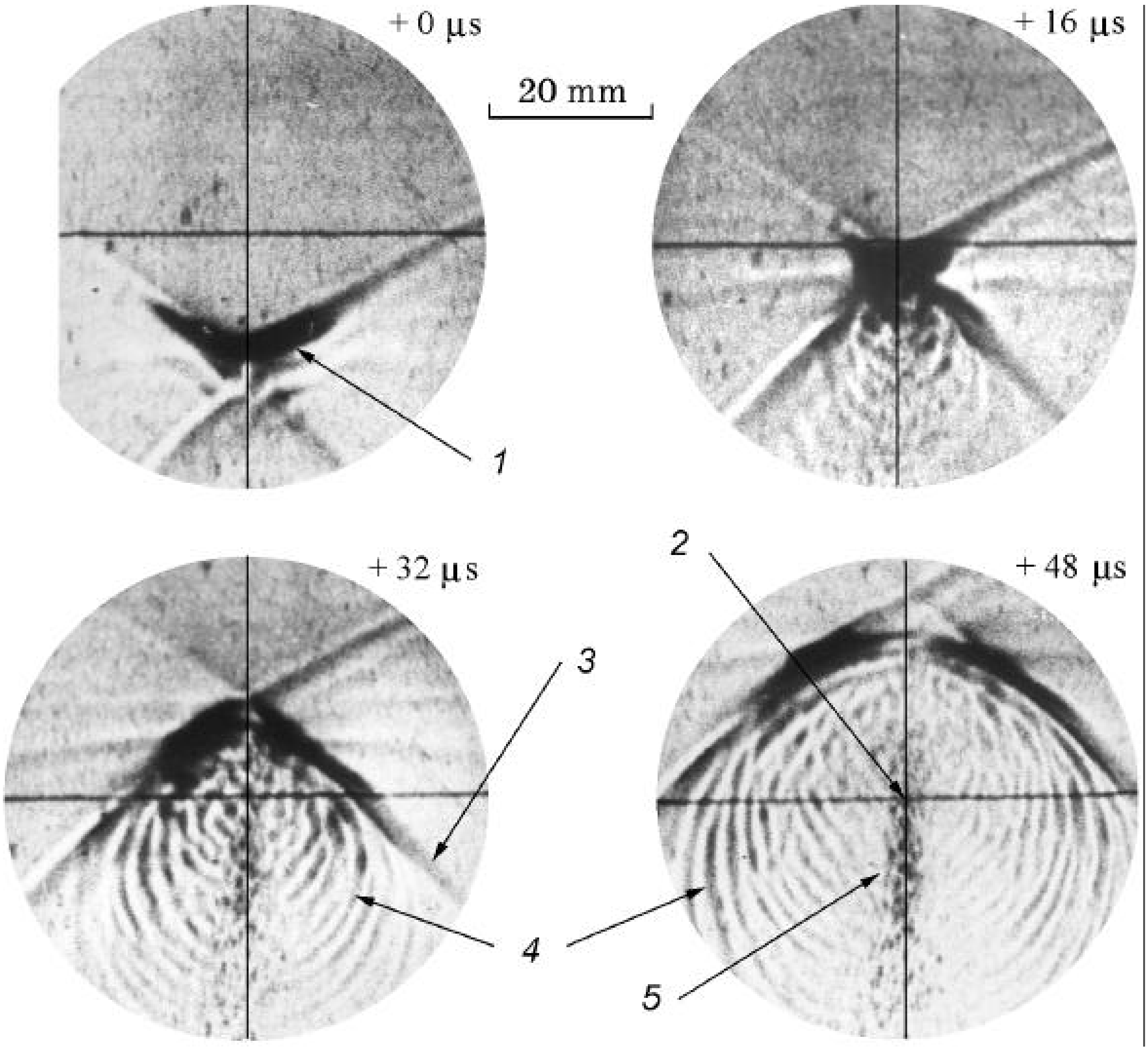

Figure 2. Shadow photo-recording near to the focus. 1 – spherically focusing shock-acoustic wave, 2 – focal point, 3 – edge rarefaction wave, 4 – secondary acoustic waves, 5 – cavitation bubbles.

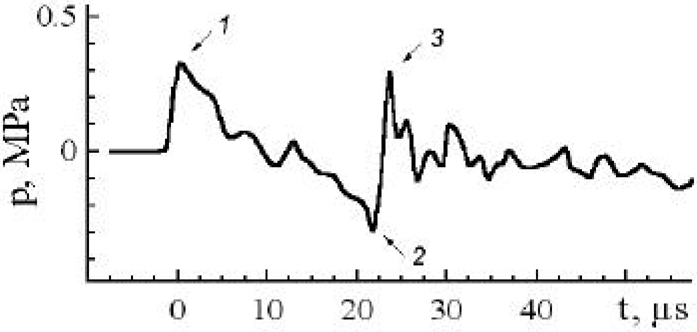

Figure 3. Pressure in a point Z=0, Y=25 mm, 1 – compression wave, 2 – edge rarefaction wave, 3 – secondary cavitation wave.

As the cavitation zone is distributed with the speed above the sound speed, radiated within angle range ✈=35⊕-45⊕ the secondary waves interfere each with other with addition of amplitude. For other angles the waves are separated in space and hence, the amplification does not occur. The considered mechanism results in amplified generation of a short package of compression acoustic pulse for a given angle range.

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