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Getting Longitudinal-Torsional Elliptically Polarized Oscillations in Liquids through Complex Acoustic Field

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Abstract

This paper proposes a method of obtaining the similarity of longitudinal-torsional elliptically polarized oscillations in liquids by means of complex acoustic field from two operating mutually perpendicular coherent sources, having the same amplitude of acoustic pressure and oscillation frequency, but with a certain phase shift between the oscillations. The specified recommendations are meant for the use of this type of oscillations and their excitation for the intensification of various technological processes with the use of ultrasound in liquids.

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Keywords: Complex acoustic field; elliptically polarized oscillations; circularly polarized oscillations; longitudinal-torsional oscillations; the resulting acoustic pressure; ultrasound in liquids; ultrasound cleaning.

1. Introduction

The intensification of a large number of technological processes which using ultrasound in liquid environments (such as ultrasonic cleaning or production of different suspensions) is an actual problem in modern engineering. However, there are a number of factors which impeding further improvement of the fundamental parameters of these processes. Thus, at ultrasonic cleaning it is possible to note two main difficulties which preventing the increase of the efficiency of this process [1]:

- The change of the physical properties of the liquid to enhance its chemical activity leads to a decrease in erosional activity of a single cavitation bubble.

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- The change in liquid properties and parameters of the acoustic field in direction that reducing the cavitation strength of liquid, and, consequently, contributing to increasing erosion, leads to a decrease in erosional activity of a single bubble.

The presence of these acting in the opposite direction of the dependencies does not allow any significant increase in the efficiency of cavitation erosion.

One of the ways, which allow for further intensification of these processes, is the use of effects which using a complex acoustic field [2].

Nomenclature

P_1	acoustic pressure for wave without lag, Pa
P_2	acoustic pressure for wave with lag of 90 degree, Pa
P_0	resulting acoustic pressure, Pa
P_m	acoustic pressure amplitude, Pa
ω	frequency of ultrasonic field (frequency of oscillations), Hz
t	time, s
π	Pi
φ	angle between oscillations, deg
A	constant (for water one may assume that $A = 3.3011 \cdot 10^5$, Pa)
B	constant (for water one may assume that $B = 3.3 \cdot 10^5$ Pa)
n	constant (for water one may assume that $n = 7$)
γ	isotropy index that defines the state of the gas in the cavity ($\gamma = 4/3$ in the case of adiabatic pulsations)
σ	surface tension, Pa
ρ_0	fluid density, g/cm^3
P_{st}	hydrostatic pressure, Pa
u	cavitation bubble pulsations speed, m/s

2. About the form of complex oscillations vector

At interaction of oscillations from two coherent sources with same frequencies and amplitudes of acoustic pressure, but with phase delay or outrunning between oscillations, the resulting vector can be found as the geometric sum of the vectors of the oscillations from individual sources (without taking into account the nonlinear interaction). For plane harmonic waves, we assume that the acoustic pressure varies in accordance with the following expression:

$$P_1 = P_m \sin \omega t \quad (1)$$

For the same wave but with a phase difference (delay) in relation to (1) of 90 degrees:

$$P_2 = P_m \sin \left(\omega t + \frac{\pi}{2} \right) \quad (2)$$

For the two collinear waves, i.e. waves traveling in the same direction, where the acoustic pressure varies in accordance with (1) and (2), the expression for the resulting acoustic pressure from their joint action is given:

$$P_0 = P_1 + P_2 = P_m \left(\sin \left(\omega t + \frac{\pi}{2} \right) + \sin \omega t \right) \quad (3)$$

Using the formula for the sum of sines, we have:

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