Pulse Mode of the Electronic Generator of the Ultrasonic Technological Apparatus

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***Abstract* – The article is devoted to the research of the characteristics of the present ultrasonic equipment, namely the possibility of producing short ultrasound impulse, which could be useful when cavitation in the processed medium is not desirable.**

***Index Terms* – Ultrasound, impulse, rise time, fall time.**

I. INTRODUCTION

AT PRESENT ultrasonic technologies are widely used in chemical, food and other branches of industry. Most of the processes with the application of ultrasonic vibrations are realized in liquid technological media and dispersed systems with liquid phase. At that the main intensifying factor of ultrasonic influence is a cavitation [1], which provides changes of structures and properties of processed media.

At the same time in many cases there is a necessity to accelerate the processes, which do not allow cavitational damage. Such processes are breaking of emulsions, coagulation of solid particles in liquids, impregnation of the materials by dyes and protective layers, etc. In several studies it was proved [2], that, for instance, breaking of “water-oil” stable emulsion, purification of wine material and honey fluidifying are possible only without realization of cavitation process.

Evident advantage of pre-cavitation processing is the ultrasonic treatment of large technological volumes, as cavitation zone charged with steam and gas bubbles is not formed near the radiator and the radiation is not absorbed [1]. Moreover the operation of ultrasonic equipment in such radiation mode excludes cavitation damage of radiating surface.

Essential disadvantage of ultrasonic processing in pre-cavitation mode is insufficient energy influence, which determines impossibility to accelerate realized processes.

In this connection there is a need to increase energy efficiency of ultrasonic treatment without cavitation in liquid media.

The solution of the problem of cavitation appearance can be the application of pulse mode of the generation of vibrations in liquid media.

Such method is widely used in hydrolocation, where special pulse generators form ultrasonic pulses with the help of broadband radiators providing maximum action radius of the active sonars. At that there is no cavitation and loss of acoustic power for absorption and dissipation of vibrations in the cloud of cavitation bubbles, distortion of the radiator performance features and erosion of its surface [4]. The equipment used on the base of the pulse generators with the application of high-voltage capacitors required long period of energy storage before the discharge and low resonant piezoelectric transducer allows generating short pulses, but it is not suitable for solution of the problems of acceleration of the technological processes.

Used in practice for the acceleration of the technological processes ultrasonic technological equipment designed on the base of the continuous-wave oscillators and high-Q piezoelectric vibrating systems is not intended and is not applied for the operation in pulse mode.

In this connection there is a need to study functional capabilities of the operation of existing equipment in pulse mode and design powerful ultrasonic technological apparatuses, which are able to provide pre-cavitation mode of the intensification of the technological processes.

II. EQUIPMENT

For carrying out studies we use the ultrasonic generator of the technological apparatus “Bulava” [5] with the ultrasonic vibrating system intended for the treatment of liquid media.

The choice of the apparatus “Bulava” for the investigations is determined by its suitability for the realization of the technological processes in production quantities.

The distinctive feature of the apparatus “Bulava” is the application multi-packet piezoelectric transducer, which sums the radiation of seven pairs of piezoelectric elements in one multi half-wave radiator, its radiating surface is 300 cm² [6].

As the electrodes of the piezoelectric elements are connected in parallel, the supply of electric voltage and deenergization are realized for each of the piezoelectric element simultaneously, vibration onset and their damping occur at each of the piezoelectric elements independently, the similar results are expected to be at the use of one-packet transducers. It allows applying obtained results for the ultrasonic devices of the series Volna, Volna M, Aljona, Potok [7,8,9,10].

The studies were carried out at the generation of pulse vibrations in aqueous medium. The repetition interval (T) of ultrasonic pulses of ultrasonic frequency equals 3.26 ms, this period is in an order of magnitude higher than the time of generation of ultrasonic vibrations, and it is sufficient for the damping of vibration processes in the ultrasonic vibrating system.

The time of pulse group generation is T1 (see Fig.1).

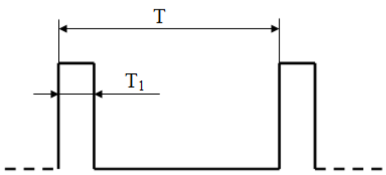


Fig. 1. Time diagram of switching on (switching off) of the ultrasonic vibrating system power stages (T1 is the operation time of the power stages of the ultrasonic generator; T is the pulse-repetition interval)

III. EXPERIMENTAL PART

The series of ultrasonic vibrations of the radiator were formed during the time T1 by the supply of the driving pulses to the transistor keys of power output cascade of the ultrasonic generator, the pulse repetition frequency was set equal to the resonance frequency of the ultrasonic vibrating system (22000 Hz). At that power bridge was consciously supplied by direct-current voltage.

The ultrasonic vibrating system was connected with the power transistored bridge by the matching transformer throttle circuit (see Fig.2). The control under vibrating process of the ultrasonic vibrating system was carried out by the check of current flowing in the feed circuit of the ultrasonic vibrating system (the signal on the element R1, see Fig.2).

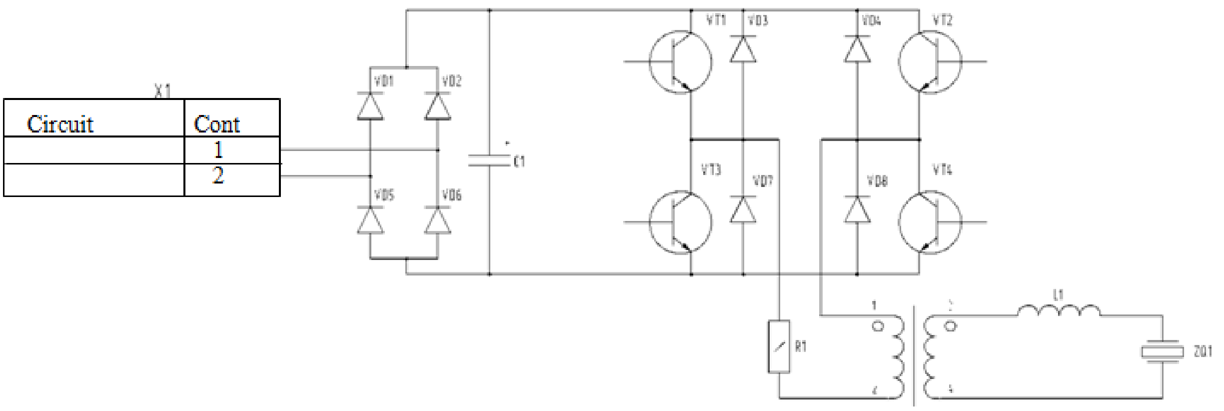


Fig. 2. The circuit of the output part of the ultrasonic generator at the operation of ultrasonic vibrating system in the mode of forced vibrations

After time T1 transistor switches of the bridge circuit were locked and the ultrasonic vibrating system started operating in the free oscillation regime. The equivalent circuit of the output part of the ultrasonic generator at the operation of the ultrasonic vibrating system in the free oscillation regime is shown in Fig.3.

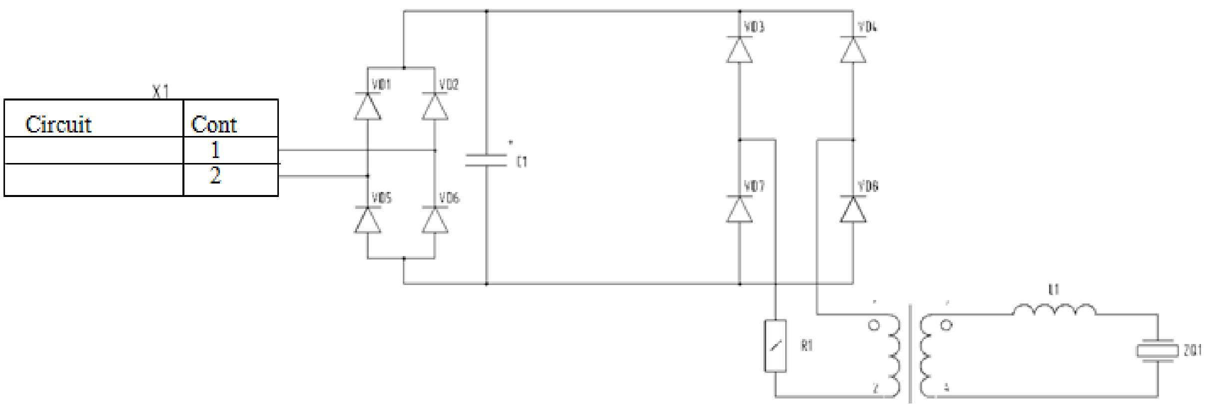


Fig. 3. The circuit of the output part of the ultrasonic generator at the operation of the ultrasonic vibrating system in the free oscillation regime

In the free oscillation regime the electrical input of the ultrasonic vibrating system remained connected with the rectifying part of the ultrasonic vibrating system linked through the diodes of transistor switches to the rectifying part of the ultrasonic generator, that accelerated damping process of free oscillations of the ultrasonic vibrating system (current damping).

The aim of carried out studies was to determine time parameters of generated pulse of the ultrasonic vibrations in aqueous medium.

IV. THE RESULTS OF MEASUREMENTS

Fig.4 shows the oscillogram of the signal, which is in proportion to current flowing in the piezoceramic elements of the ultrasonic vibrating system. The operation time T1 of the ultrasonic vibrating system in the mode of forced vibrations was set 590 mcs that was 25.9 half-period of forced vibrations of the ultrasonic vibrating system.

After generation switching off the time of vibration damping was 86 mcs that corresponded to 3.8 half-periods of the current oscillations of the ultrasonic vibrating system (the frequency of current oscillation of the ultrasonic vibrating system registered on the resistor R1 matched with the frequency of forced mechanical vibrations of the ultrasonic vibrating system). Fig.4 presents the ultrasonic pulse-repetition interval and signal envelope shape on the current sensor.

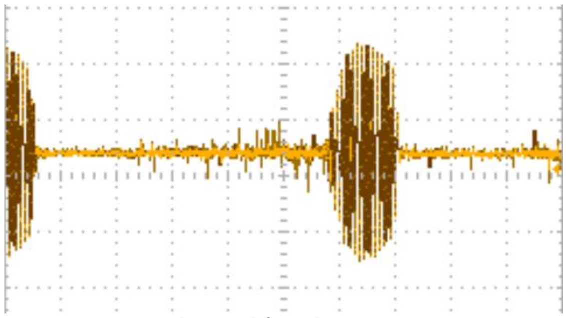


Fig. 4. The signal from the current sensor

For the signal presented in Fig.4:

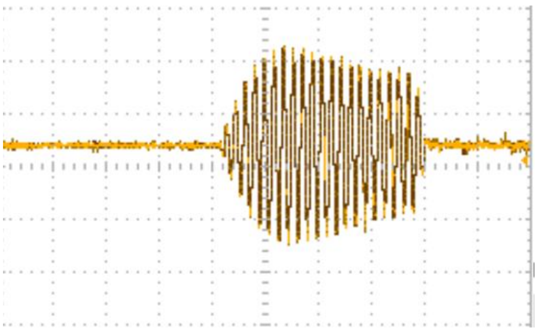
– pulse duration (the operation time in the mode of forced vibrations and free oscillation regime) was 681 mcs (30 half-period of forced vibrations of the ultrasonic vibrating system);

– operation time of the ultrasonic vibrating system in the mode of forced vibrations was 590 mcs (26 half-periods of forced vibrations of the ultrasonic vibrating system);

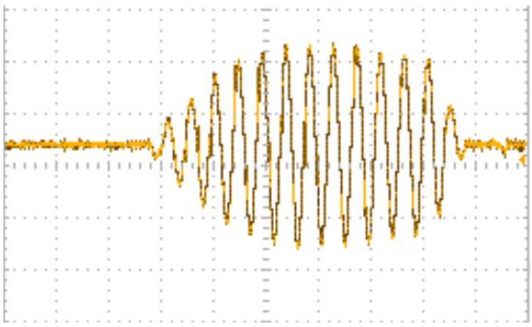
– pulse rise time was 295 mcs (13 half-periods of forced vibrations of the ultrasonic vibrating system);

– time of fall was 87 mcs (3.8 half-period of forced vibrations of the ultrasonic vibrating system);

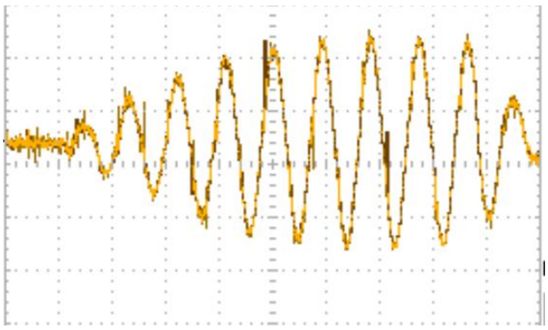
Fig.5 shows the oscillograms of current consumed by the ultrasonic vibrating system during the generation of vibration series, at that pulse ratio initiating test signal was increased in each experiment.



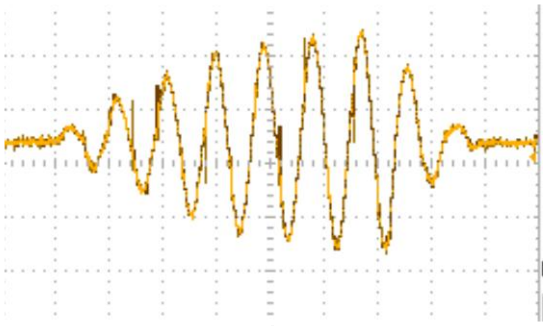
a)



b)



c)



d)

Fig. 5. The signal from the current sensor for the times of operation in the mode of forced vibrations 870 mcs (a), 500 mcs (b), 350 mcs (c), 300 mcs (d)

Tab. I shows the time characteristics, which correspond to the oscillograms presented above.

The following conventions were used in the Tab. I:

T_{For1} – Operation time in the mode of forced vibrations, mcs;

T_{For2} – Operation time in the mode of forced vibrations, vibration periods;

T_{D1} – Pulse duration, mcs;

T_{D2} – Pulse duration, vibration period;

T_{R1} – Rise time, mcs;

T_{R2} – Rise time, vibration periods;

T_{F1} – Time of fall, mcs;

T_{F2} – Time of fall, vibration periods.

TABLE I

TIME CHARACTERISTICS OF PULSE EXCITATION MODE OF THE ULTRASONIC VIBRATING SYSTEM

Fig. Number	T_{For1}	T_{For2}	T_{D1}	T_{D2}	T_{R1}	T_{R2}	T_{F1}	T_{F2}
5, a	870	38.3	950	43.0	295	13.0	80	3.50
5, b	500	22.0	590	25.9	295	13.0	90	3.96
5, c	350	15.4	436	19.2	295	13.0	87	3.82
5, d	300	13.2	375	16.3	295	13.0	75	3.30

Fig.6 demonstrates the oscillogram of the signal, which is in the proportion to current flowing in the piezoceramic elements of the ultrasonic vibrating system. Time T1, was set 159 mcs that was 7 half-periods of forced vibrations of the ultrasonic vibrating system. After switching-off the generation time of vibration damping was 68 mcs that corresponded to 3 half-periods of the oscillations of the ultrasonic vibrating system. Such small period of excitation time of the ultrasonic vibrating system does not allow achieving operation mode, i.e. the amplitude of oscillations is not maximum b constant.

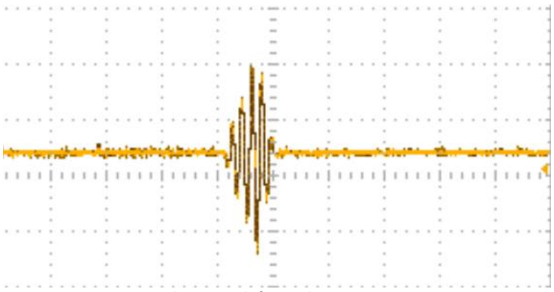


Fig. 6. The signal from the current sensor

For the signal presented in Fig.6:

– pulse duration (the operation time in the mode of forced vibrations and free oscillation regime) was 227 mcs (10 half-period of forced vibrations of the ultrasonic vibrating system);

– operation time of the ultrasonic vibrating system in the mode of forced vibrations was 159 mcs (7 half-period of forced vibrations of the ultrasonic vibrating system);

– pulse rise time was 159 mcs (7 half-period of forced vibrations of the ultrasonic vibrating system);

– time of fall was 68 mcs (3 half-period of forced vibrations of the ultrasonic vibrating system).

V. Conclusion

As a result of carried out researches it was found out the possibility of generation of short pulses of ultrasonic influence on aqueous medium.

Time of generation of electrical pulse with maximum amplitude characterizing vibrations of the ultrasonic radiator corresponds to 13 half-periods of vibrations on the resonant frequency of the vibrating system.

Damping time of electrical oscillations of the piezoelectric transducer does not exceed 4 half-periods.

The decrease of the duration of pulse generation of less than 13 half-periods leads to the fall of vibration amplitude (decrease of the amplitude of generated vibrations).

Thus, generated by the ultrasonic technological device with the piezoelectric vibrating system the pulse of ultrasonic influence on technological media cannot be less than 8 half-periods of vibrations on operating frequency of the vibrating system, i.e. no less than 180 mcs.

In carried out experiments the time between ultrasonic pulse packets was chosen equal to 3.26 ms. Taking into account the fact, that minimum duration of the pulse (from rise to the maximum and then to total attenuation) is 0.386 ms, the interval between the pulses can be reduced up to 0.386 ms.

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