ON THE STABILITY OF THE INTERFACE BETWEEN DENCE PLASMA AND LIQUID UNDER ELECTRICAL PULSE DISCHARGE IN LIQIUD MEDIUM

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It is shown that the most important influence on the plasma of electrical pulse discharges in liquid have the processes in a zone of its contact with condensed medium. The investigations of growth of corrugations are conducted which arise on an interface between both the plasma channels of electrical pulse discharges and limiting it liquid. It is shown that the growth of perturbations caused by Rayleigh-Taylor instability are nonlinearly saturated. It is established the interconnection between both the pointed perturbations and the parameters of a dense plasma of discharge channel.
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1. INTRODUCTION

The most important influence on the plasma of electrical pulse discharges in liquid (EPD) have the processes in a zone of its contact with condensed medium. In existing theoretical models of EPD a stream of energy on a wall of the channel and backflow of the evaporated substance were considered homogeneous [1-3]. But at the initial stage of EPD small-scale irregularities of heat flow distribution were detected on a surface of channels [4,5]. Development of such perturbations was accompanied by space modulation of irradiation intensity, strain of a surface of channels, drop of conductance of plasma. One from reasons it is established further by comparison of a strain of a surface of plasma channels of EPD with outcomes of simulation on the basis of a solution of the task to development of Rayleigh-Taylor instability (RT-instability). RT-instability in similar conditions was investigated with usage of the numerical methods for a problem of laser thermonuclear synthesis [6-8]. In this paper it is studied the influence of the pointed perturbations on properties of the dense plasma of the EPD channel in liquid.

2. GROWTH OF PERTURBATIONS ON THE PLASMA-LIQUID INTERFACE

Experimental investigations of processes under electrical discharges in water were conducted on the experimental setup where the discharge was created in the chamber filled with water (see [5-8]). To initiate the discharge an explosive wire was used that had allowed us to localize the position of appeared plasma channel. The evolution of plasma channel was recorded through the window by the optical system and the high-speed photochamber.

Observation of development of perturbations of a surface of plasma column is carried out by photography of the bit channel by a fast-track photographic camera. For visualization of a channel surface is applied highlightings by an oblong exterior radiant (flashlight valve). The discharges with various rate to input of an energy were researched. In the Table the characteristics of certain types of discharges are presented: R1 is fast, R2 is average, R3 and R4 are sluggish.

The characteristics of the discharges

Type of EPD	R1	R2	R3	R4
Parameters				
C, μF	15	15	15	15
L, μH	0.47	0.47	0.47	1.55
U_0, *kV*	30	20	10	30
l, mm	40	40	40	100
I_{max}, *kA*	160	105	50	95
$\sigma,(\Omega\cdot cm)^{-1}$	750	600	460	300
T_{max}, *kK*	38	33	30	20

Here C is a electrical capacity in circuit, L is a full inductance, U_0 is the applied voltage, l is the length of a discharge gap, I_{max} is the measured maximal current, σ is the estimated mean specific electrical conductivity, T_{max} is the estimated maximal temperature in the channel.

The experimental studies have revealed the occurrence of the various kinds of the instabilities of the contact interface, the part from which can be related to the type of the instability of deflagration waves, others to Rayleigh-Taylor ones of an ablative interface.

The perturbations look like ripple on a channel surface, which amplitude reaches 0.2-0.5 mm (5-10 % to radius). Is retrieved, that their development depends on conditions of initiation and rate to input of an energy in EPD. Spectrum of space harmonics of perturbations is bounded above by values of a wave vector k=100-150cm^{-1}. Filing of the extension of the channel is realized by photography by the camera in the condition of slot-hole development. The computer handling of these data allows to allocate boundary of the channel and to receive time dependence of radius, velocity of the extension and acceleration of a wall of the channel. It is possible to select two different phases of development EPD that are phase of acceleration, when acceleration g to a surface is directed to the direction towards liquid (g > 0), that encloses the channel, and phase of deceleration, for that of acceleration is directed towards plasma (g < 0). The duration of an acceleration phase 2.2 - 6 μs is less than a first halfperiod of an electrical current (10 μs) in discharge (Figs.1,2).

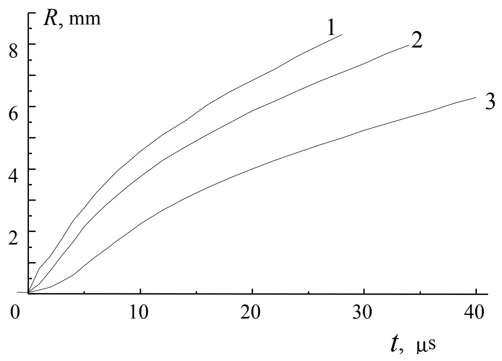

Fig. 1. The expansion of the channel radius R: curve 1 corresponds to the discharge type R1, 2 - R2, 3 - R3

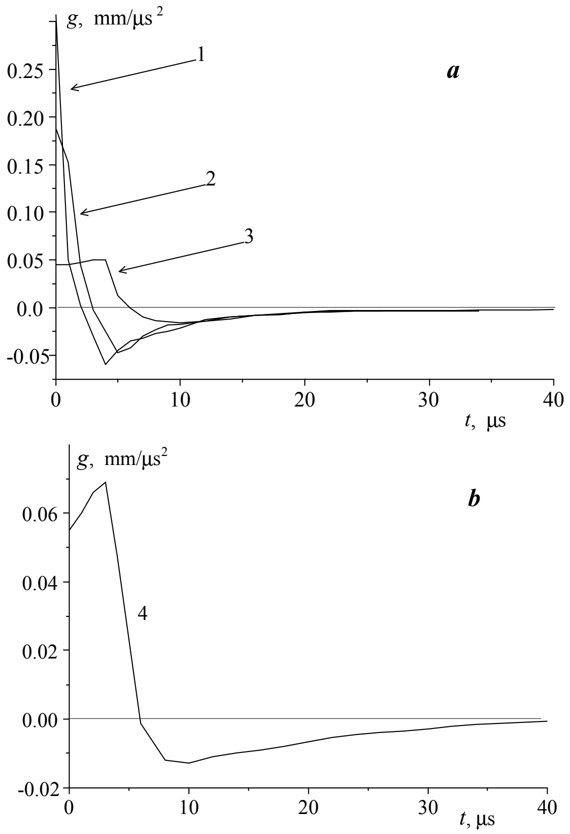

Fig.2. The acceleration of the discharge channel interface. The values recalculated from the experimental data: a) curve 1 corresponds to the discharge R1, 2 - R2,3 - R3; b)-4-R4

Fig.3 shows the evolution of perturbation on the interface. We can see that after the fast growth the saturation of the interface instability are observed. The similar effect is also found by numerical simulations for the case of inertial confinement [7].

Thus, the perturbations on the discharge interface are the essential features of EPD, and it is obvious its have an influence on the properties of the discharge. To establish this correlation we are carried out the directed studying of the influence of the perturbation on the discharge plasma properties.

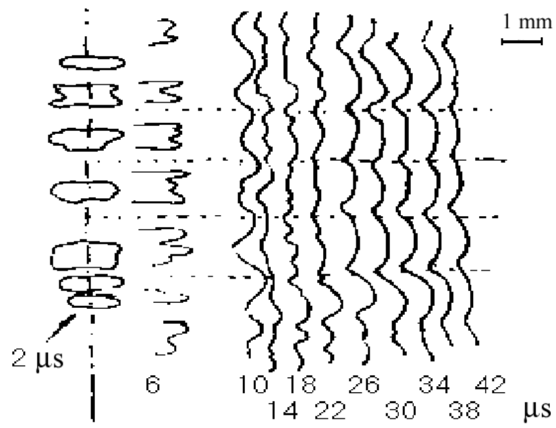

Fig. 3. The evolution of the discharge channel interface for the discharge R2

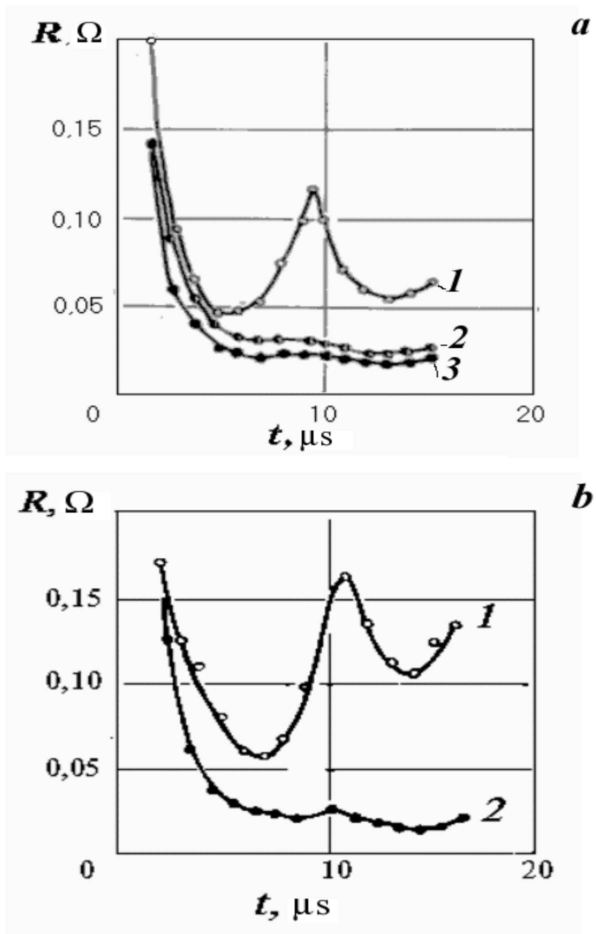

Fig.4. The resistance of the discharge channel: a) EPDs (U_0=20 kV, l=30 mm) initiated by the plain and inhomogeneous exploding wires: curves 1 - IEW d_1=0.16 mm, d_2=0.008 mm, Δl=1.9 mm; 2 – PEW d=0.08mm; 3 - PEW d=0.16 mm;
b) EPDs (U_0=32.6 kV, l=50 mm) initiated by the plain and curved exploding wires: curves 1 - CEW d=0.16 mm; 2 – PEW d=0.16 mm

3. PROPERTIES OF DENSE DISCHARGE PLASMA

To study the resistance of discharge channel it is used the EPDs initiated by the plain, inhomogeneous and curved exploding wires. The plain wires (PEW) and curved ones (CEW) are characterized by only the diameter *d*, and inhomogeneous wires (IEW) are did by the two diameters of corrugations d_1,d_2 and its lead Δl.

From the experiments (Fig.4) it follows that the discharges with the directed corrugations have the sharply different properties of plasma from the plain discharge case. There is for both the inhomogeneous and curved types of perturbations. Also, it should be mentioned that the increasing of the discharge gap play a second-order role for plasma properties. These results take the possibility to the directed creation of EPD with the certain properties.

4. CONCLUSION

The properties of dense plasma of electrical pulse discharges in liquid are essentially depended on the presence of the corrugations of discharge channel.

The most important perturbations of discharge channel are caused by the Rayleigh-Taylor instability at initial stage of discharge. The perturbations of plasma-liquid interface are non-linearly saturated that, in turn, leads to the stabilization of the temperature in discharge channel.

The perturbations of discharge channel interface caused the inhomogeneity of a dense discharge plasma. That fact is necessary took into account under theoretical study the electrical pulse discharges in liquid.

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ОБ УСТОЙЧИВОСТИ ПОВЕРХНОСТИ РАЗДЕЛА МЕЖДУ ПЛОТНОЙ ПЛАЗМОЙ И ЖИДКОСТЬЮ ПРИ ЭЛЕКТРИЧЕСКОМ ИМПУЛЬСНОМ РАЗРЯДЕ В ЖИДКОЙ СРЕДЕ

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Рассмотрено пространственно-временное развитие неустойчивости Рэлея-Тэйлора поверхности раздела между плотной неидеальной плазмой и жидкостью при импульсном электрическом разряде в жидкой среде. Показано, что, за исключением начальной стадии разряда, развитие возмущений указанной поверхности насыщается, вследствие чего поверхность стабилизируется. Указанные возмущения имеют существенное влияние на свойства плазмы разрядных каналов, что может быть использовано для создания импульсных разрядов в жидкости с заданными свойствами.

ПРО СТІЙКІСТЬ ПОВЕРХНІ РОЗПОДІЛУ МІЖ ГУСТОЮ ПЛАЗМОЮ ТА РІДИНОЮ ПРИ ЕЛЕКТРИЧНОМУ ІМПУЛЬСНОМУ РОЗРЯДІ В РІДКОМУ СЕРЕДОВИЩІ

П.Д. Старчик, П.В. Порицький

Розглянуто просторово-часовий розвиток нестійкості Релея-Тейлора поверхні розподілу між густою неідеальною плазмою та рідиною при імпульсному електричному розряді у рідкому середовищі. Показано, що, за виключенням початкової стадії розряду, розвиток збурень вказаної поверхні насичується, внаслідок чого поверхня стабілізується. Вказані збурення мають суттєвий вплив на властивості плазми розрядних каналів, що може бути використано для одержання імпульсних розрядів в рідині з наперед визначеними властивостями.