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**STRUCTURAL PROPERTIES OF THE ELECTROPULSE PHENOMENA OF HEAT AND MASS EXCHANGE IN NON-UNIFORM LIQUID**

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*Paper shows the opportunity of describing nonlinear properties of heat and mass exchange processes in a non-uniform liquid at pulse influence based on research behavior of open system, which is capable to self-organize structures. The formulas to calculate polytrope parameter received, and, there are considered change of structural and dynamic properties of a non-uniform liquid at change of gas concentration.*

**Keywords:** heat and mass exchange, non-uniform liquid, self-organize structures, polytrope parameter.

Usage of an electric discharge in water as a source of high pressure and temperature allows creating essentially new perspective technologies of processing various materials, for instance, an electro-hydraulic processing of metals by pressure. Creation of energy converters, which are electro-hydraulic installations, is linked with construction of consecutive model of various physical phenomena. Since the transformation of an electro-digits energy process into energy of powerful impulses is accompanied by compression of gas and liquid medium process, then, consequently, it is needed to define technical opportunities, processing materials speed, etc. For an electro pulse phenomena in non-uniform liquids it is typical the formation of high density of energy ( $10^8 \div 10^9$ ) J/m<sup>3</sup>, accompanied by sharp increasing of pressure and temperature, in the channel of discharge for short period of time ( $10^{-4} \div 10^{-5}$ ) sec. Radiation of an impulse compression which is used for generation various sort of deformations, destructions, morphogenesis and fluctuations of elastic systems contributes to a fast expansion of the channel with ( $10^2 \div 10^3$ ) m/s under action of a high pressure and temperature [1-4].

Pulse methods of materials processing based on usage an electro-hydraulic effect, enable to intensify many technological processes, to process various materials, causing in them structural changes [2]. It is necessary to spend basic researches to create an opportunity of management parameters process with purpose of an effective transformation of energy. Changes of structural properties of liquid medium in-process are considered in the issue of electro-pulse influence.

Determination of structure as a condition is the basic concept of synergetic which results from multiple and ambiguous behavior of multi component mediums. Practice shows, that properties of non-uniform liquids which are exposed to electro-hydraulic processing, do not submit to standard averaging for the closed systems of thermodynamic type, but change in consequence of openness, inflow of energy from the outside, nonlinearity of internal processes, occurrence of special modes with presence more than one steady condition. In such systems it is not carried out neither the second beginning of thermodynamics nor Prigozhin's theorem of a speed minimum of manufacture entropy, that in turn, can lead to formation of new structures and systems, sometimes more complex, than initial structures. This phenomenon is treated as the universal mechanism of evolution: from elementary and primitive - to complex structure and more perfect. In some cases new structures formation has regular and wave character and then it refers to and calls as autowave processes (by analogy with self-oscillations). It is necessary to have some norm of a randomness degree that can be defined and maintained by calculating quantitative estimations of relative randomness degree.

Available in a stream of a technical liquid fine firm particles or gas bubbles, accumulate in separate places and form various structures. The formed structures are unstable and vary or break constantly, but in slow streams can keep the form long enough. At volumetric concentration of gas phase  $\varphi \leq 5\%$  it is possible to observe a bubble mode of current gas and liquid stream with formation small-scale fractal structures. With increase in a degree of gas concentration separate bubbles accumulate and form so-called «shells» that are also possessing fractal properties. The sizes of «shells» can be compared with characteristic scales of the gas and liquid stream, they form large-scale clusters. Structural clusters at a various degree of volumetric gas concentration in a liquid stream which slowly moves on the vertical channel are shown in figure 1.

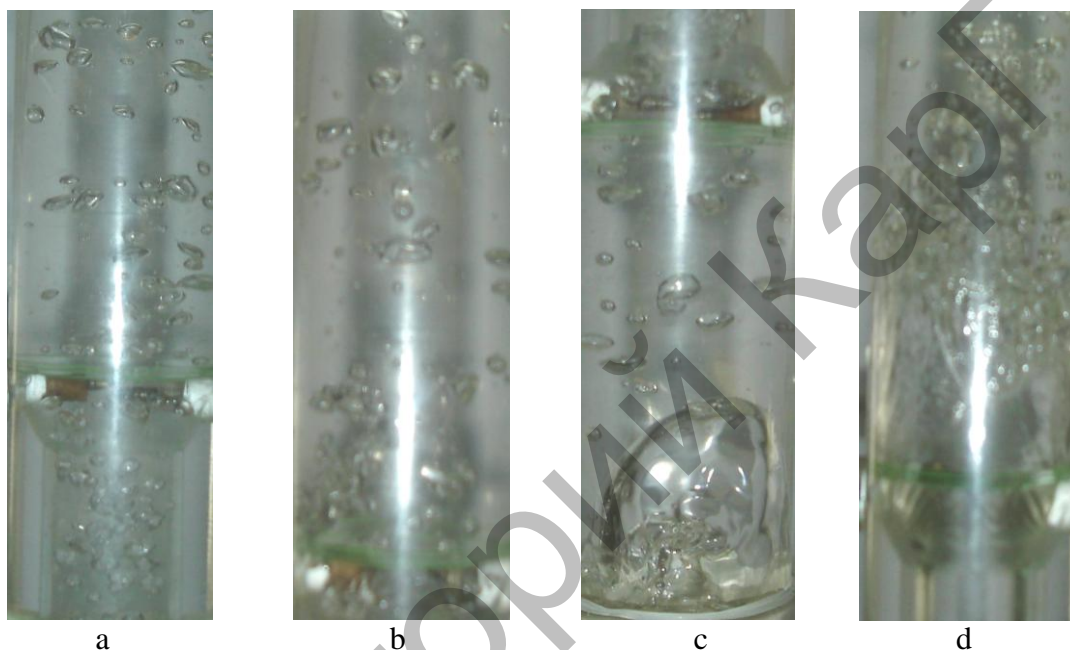


Fig.1. Structures at movement of a stream on vertical channel with conic diffuser [4]; speed of current  $u = 1\text{m/s}$ ,  $\varphi_g =$  : a) 0,5%, b) 1%; c) 1,5%, d) 2%.

Character of the pulse phenomena accompanying electro-hydraulic effect in a non-uniform liquid depends on properties of the environment itself, because here are shown structural properties of turbulent hashing with change of thermo-physical parameters in very short time interval. In a stream of a liquid clustering process is accompanied by balanced with it process of disintegration and cascade crushing of structures. The sizes and extent of inter phase border play a main role for heat and mass exchange processes but as they constantly vary it is practically impossible to measure or calculate them.

High-voltage pulse influence leads to spontaneous infringement of symmetry. According to [5] quantitative measure of structure with the broken symmetry is fractal dimension. It allows to establishing the some synergetic laws of the heat and mass exchange phenomena accompanying electro-hydraulic effect in a non-uniform liquid.

The structure of a non-uniform liquid possesses fractal properties because inclusions of one phase in the form of bubbles of gas or air in the liquid medium have a wide dispersion in the sizes, the inter phase border accepts freakish irregular forms. All small-scale and large-scale structures differ themselves physical properties, where it is possible to formulate basic property as follows - with growth of concentration of impurities (solid particles, bubbles) maximal size of small-scale structures grows, and at large-scale structures - decreases.

For curve of inter phase border  $x(t)$  fractal dimension is metric characteristic. More general, both metric, and the topological characteristic is information entropy of distribution points along a

curve  $x(t)$ . At self-organizing entropy decreases in comparison with its value in an equilibrium condition, therefore normalized entropy can serve as criterion of a degree of self-organizing. It is possible to enter characteristic spatial scale  $\delta = \frac{r_0}{r_m}$ ,  $0 \leq \delta \leq 1$  where  $r_0, r_m$  - the minimal and maximal scales of structural cells which are described and entered in [3].

To define communication  $\delta$  with fractal characteristics, here is used concept of fractal measure  $M$  which in work [6] is considered as measured additive physical size, and it is generally defined as

$$M \sim \delta^d N(\delta) = \delta^d \delta^{-D} = \delta^{-n}, \quad \gamma = D - d, \quad (1)$$

where  $N(d)$  - number of cells of fractal structure,  $d$  - topological dimension of a cell,  $D$  - fractal dimension of cells set,  $\gamma$  - a parameter scaling.

As fractal measure of gas and liquid stream here is accepted volume of liquid  $V_f = V_f(D)$  as some fractal the object which has been cut up by gas bubbles. Presence of gas inclusions assumes an opportunity of the description of all volume of heterogeneous liquid  $V$  as fractal measure of structures set. Using the formula (1) and entering dimensionless variables

$$V = V_f \delta^{-\gamma}, \quad V_f = V - V_g, \quad \varphi_g = V_g / V,$$

it is possible to write down:

$$\left(\frac{r_0}{r_m}\right)^\gamma = (1 - \varphi_g), \quad 1 = (1 - \varphi_g) \left(\frac{r_m}{r_0}\right)^\gamma, \quad r_m = r_0 (1 - \varphi_g)^{-\frac{1}{\gamma}}, \quad (2)$$

where  $V_g$  - volume of a gas phase,  $\varphi_g$  - volumetric concentration of a gas phase.

If fractal structures are large-scale (a greater degree of gas concentration), then it is necessary to consider a change of their spatial scales and to look through volume of superseded liquid as fractal measure  $V_f$ :

$$V_f = V_g \left(\frac{r_m}{r_0}\right)^\gamma, \quad r_m = r_0 \left(\frac{V}{V_g}\right)^{\frac{1}{\gamma}} (1 - \varphi_g)^{\frac{1}{\gamma}}. \quad (3)$$

If large-scale fractal structure is formed from firm particles, then, in the formula (3)  $V_g, \varphi_g$  are replaced through  $V_s, \varphi_s$ , then values  $r_0, r_m$  are concerned to structures from firm particles. Out of formulas (2), (3) follows, that with growth of concentration of disperse phases  $\varphi_g$  ( $\varphi_s$ ) the spatial scale of small-scale structures grows, and large-scale - decreases. Such law explains that at addition of impurities and when in medium appearance chaotic movement, threadlike, flat structures are increasing on thickness, and, spherical structures - are flattened, accepting average forms with fractal dimension  $2 \leq D \leq 3$ , [5]. With growth of dispersion of liquid medium fine particles are self-organized and sticking together, making clusters, and large structures are disintegrated.

In formulas (1) - (3) parameter scaling  $\gamma$  defines intensity of dynamic phenomena in system in which self-organizing is shown under some conditions. In formula [6] is shown, that information criterion of a degree of the self-organizing, completely describing hierarchical levels of complex system can be information entropy  $S(J)$  which is defined by average value of information  $J$ :

$$S(J) = \int_J^\infty J \cdot f(J) dJ = (J + 1) e^{-J}. \quad (4)$$

For a range of change  $0 \leq J \leq \infty$  values  $0 \leq P(J) \leq 1$  and  $0 \leq S \leq 1$  are received. Accepting as characteristic functions information entropy  $S(J)$  and function of probability  $P(J)$ , their motionless points are found:

$$P(J_1) = J_1, \quad e^{-J_1} = J_1, \quad J_1 = 0,567 \quad (5)$$

$$S(J_2) = J_2, (J_2 + 1)e^{-J_2} = J_2, J_2 = 0,806. \quad (6)$$

It is shown that these motionless points are unique steady as they are limits of infinite displays which can be reached at any initial values of the information  $J$ . The number  $J_1$  corresponds to the informational (local) description, number  $J_2$  - entropy (average) description of complex system. The given values allow to define limiting values of a scaling parameter  $\gamma$ .

In [6] to define fractal measures by using formulas, at  $D_* = d + \gamma_*$ , received dimension of self-similarity of a fractal of the complex form. In this case it is possible value  $\gamma_* = S_*(J) = 0.806$  - criterion of self-similarity, i.e. motionless point information entropy. To other limiting case - to the most simple form fractal in the form of  $(n + \gamma)$ - measured sphere with individual radius corresponds  $\gamma_* = f_*(J) = 0.567$  - the criterion of self-similarity, that is also corresponding a motionless point for function of density of probability of information distribution. Numbers  $f_*, S_*$  - are universal and are used for the description of the various phenomena in works [3, 6]. For instance, at the description of pulse heat and mass exchange phenomena in a non-uniform liquid it is necessary to consider condition of a working medium as a polytropic.

To define a parameter of polytrope it is possible to use classical formula:  $\kappa = i + \frac{2}{i}$ , but here  $i$  - is number of macroscopic degrees of freedom,  $0 < i < \infty$ . In the developed turbulence mode the number of macroscopic degrees of freedom can be defined as the relation:

$$i \approx (r_m/r_0)^3 \approx (\text{Re}/\text{Re}_k)^{9/4}, \quad (7)$$

where numbers  $Re$  and  $Re_k$  - are Reynolds's criterion and its critical value.

Considering the equations (1) - (3), for polytrope parameter  $\kappa$  can be received following:

$$\kappa = [2 + (1 - \varphi)^{-3/\gamma}] \cdot (1 - \varphi)^{3/\gamma} \text{ and } \kappa = [2 + \left(\frac{V}{V_g}\right)^{3/\gamma} (1 - \varphi)^{-3/\gamma}] \cdot \left(\frac{V}{V_g}\right)^{-3/\gamma} (1 - \varphi)^{3/\gamma}, \quad (8)$$

accordingly for «bubbles» and «shell» modes of current.

In the received formula for polytrope parameter many factors are considered, such as structural properties of a working medium, freedom degree of formed macroscopic dynamic structures, their dynamic characteristics. Limiting values of polytrope at specified values of scaling parameter are included into an interval from 1 up to 3. Thus, the synergetic approach allows to study mechanisms of self-organizing, stability and disintegration of various nature structures that are formed in open systems which are far from balance condition, and, to operate with dissipative structures, that are formed as a result of an exchange of energy with an environment.

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