SECTION 11. MATH

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11.1 Modeling the characteristic features of the processes of structure formation in some building composites

To this day, there is a large volume collected of the results of experimental studies on structure changes in various dispersions serving as base for production of most construction materials. The analysis of collected information revealed that there is an entire category of stick-slip phenomena, the case history of which is represented by *N*-and *S*-type inflections on rheological, kinetic and other curves. We should emphasis that the view of such non-trivial charts is alike with geometry of standard curves of standard conditions. And this alikeness predetermines the possibility of applying topological models of «fold» and «ruffle» types for studying various abnormal effects. We must also note that besides *N*- and *S*-types there is a range of other characteristics («flags») pointing to applicability of the methods of catastrophe theory to studying certain processes initiating the apparition of interruptions in system development. Recognition of above-mentioned particularities allows determining the fact and type of catastrophe, the standardised structure of which facilitates finding strict patterns and thus defines directions of optimisation of various situations of research and practical nature. This work shows that pieces of evidence and consistent patters are reliably interpreted within the framework of the proposed concept.

As is known, mortars and concretes based on mineral or organic binders and a great variety of building materials are typical dispersion composites. The technology of obtaining such materials on the basis of disperse systems is characterized by a number of general and typical processes associated with interaction and mutual distribution of dispersion phases [355-357]. Such processes as mixing, transportation, compaction, de-compaction, deformation of basic disperse systems are inevitably accompanied by the formation and disintegration of dispersion structures. These distinctive features of the cross-linking of highly concentrated and highly dispersed systems, under the conditions of dynamic influences, radically influence the

technology of high-quality dispersion composite materials. In this regard, the solution of the complex problem of obtaining the majority of construction composites with a given structure and predictable performance criteria while reducing the resource intensity for their production is inextricably linked with theoretical and experimental studies in the field of physics-chemistry of initial disperse systems.

For most structured disperse systems in a variety of heterogeneous chemical-technological processes of the production of composite materials carried out during forced convective diffusion of dispersion phases, the non-equilibrium dynamic state is predominant. Therefore, the determining elements of regulation of these processes should be based on modern concepts and principles of physical and chemical dynamics – the new physics-chemistry scientific direction of disperse systems developed in recent years by N.B. Uriev and his school [355-357].

The physics-chemical dynamics of disperse systems mainly considers the dynamic processes taking place in the aggregate of particles of disperse phases connected by the action of dispersion forces into the spatial structural grid; the mechanism of the decay of such structures under dynamic conditions with the formation of aggregates out of them; their development, mutual interaction and interaction with the dispersion medium (up to the disintegration into separate particles with the release of the dispersion medium immobilized in them). Along with the processes of destruction of the structure of aggregates within the framework of physical-chemical dynamics, reverse processes of the formation of structures under conditions of dynamic influences on the system are also considered.

The basis of the physicochemical dynamics of structured dispersions consists essentially of the understanding of the laws and methods for implementation of the optimal dynamic state of systems. It is in this case that the lowest viscosity level and the corresponding maximum fluidity of the maximally and isotropic ally destroyed structure (equiprobably in terms of the volume of the system) may be achieved, which is a necessary condition for obtaining materials with specified properties.

To describe the processes of development of disperse structures under dynamic conditions, the methods based on rheological measurements are traditionally used with

the plotting and analyzing of complete process curves. Understanding the nature of the anomalous rheological behavior of dispersions provides the opportunity of creating a controlled isotropic dynamic state; it serves as the background on which the main technological process is carried out [357]. In this regard, the question of an informative analysis of non-trivial results of the study of the dynamics of contact interactions between particles of disperse phases, processes of structure formation and disruption of dispersions under dynamic conditions is practically significant for optimizing the technology of composites.

It is known that construction composite materials (mortars and concretes based on mineral or organic cements, slips for making ceramics, coating compositions and many other such dispersions) may be approached as self-organizing systems, the evolution of which in time and space is accompanied by apparition of dissipative structures. Since most above-named systems are characterised by stick-slip phenomena conditioned by interruption of continuity in developing processes of various types, it is proposed to enrich the synergetic approach to studying structure formation particularities with methods of catastrophe theory, which is studying sudden qualitative system reformations resulting from smooth change of external conditions or internal properties.

As indicated in [357], the production of dense, strong and durable composite materials is largely determined by the conditions for the formation of the structure upon mixing. The overriding importance of mixing in comparison with other technological processes is regulated by the fact that the basics of the future structure are laid already in the course of the mutual distribution of the constituent components during shear deformation due to rotation of the machine's mixing organs. Description of the behavior of most disperse systems during mixing, as well as in a variety of chemical-technological processes carried out during forced convective diffusion of disperse phases, consists in constructing a complete rheological process curve. Since shear deformation occurs during mixing, the behavior of the disperse system in the gap between the coaxial cylinders of the rotational viscometer may to some extent simulate this operation.

Such curves, obtained with the help of rotational viscometers, show the dependence of the effective shear viscosity η on the deformation rate gradient $\acute{\varepsilon}$ or the shear stress P with the obligatory realization of the isotropy of the destruction of the system located in the measuring cell. Under such conditions, a shear with a given intensity extends over the entire gap («pure homogeneous shear» under Rebinder) [358], which determines the isotropic character of the structure breakdown.

In accordance with the known classification proposed by Bartenev and Ermilova [359], the existence of the flow curves of two types is typical of structured disperse systems. A single-valued dependence of viscosity and the shear rate gradient on stress is typical of fairly well-studied flow curves of type I. For less studied type II curves, one observes regions of viscosity variation or the rate of deformation development corresponding to an ambiguous change in stress, that is, a drop of P in a certain range of $\acute{\varepsilon}$ values. Such an anomalous effect is manifested in the *S*-shaped flow curves. Rebinder *et al.* [358] obtained the *S*-shaped flow curves for some clay suspensions that were investigated by Bartenev and Ermilova [360] and explained in terms of the proposed molecular-kinetic theory of a non-Newtonian flow (Fig. 1).

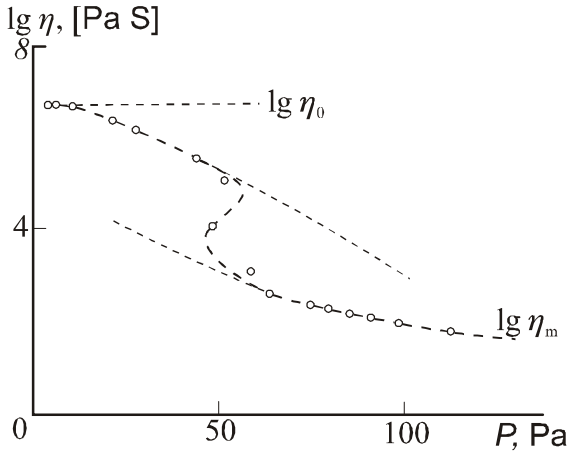


Figure 1. Dependence of logarithm of viscosity η from shear stress P for 10% suspension of Na-bentonite; η_0 is the highest viscosity of a virtyally undestroyed structure, and η_m **i**s the least viscosity of the completely destroyed structure

It should be noted that compliance with the «pure homogeneous shear» in the general case is violated when a certain critical concentration of elements of microinhomogeneities in the volume of the system is reached and exceeded. The deformation of the systems therewith is accompanied by an irreversible local aperture

of continuity. As a result, the shift does not extend over the entire gap, but is realized in a relatively thin layer while maintaining an undisturbed or far less disturbed structure in zones immediately adjacent to the discontinuity surfaces. This effect means a violation of the continuum in changing the linear velocity over the cross section of the gap when the strain rate is exceeded.

The anomaly of the shear flow process characterized by the type II curves as a consequence of a local structure discontinuity (i.e., when the shear flow is not distributed over the system bulk)was presumably for the first time interpreted in [361]. The theory of this phenomenon was elaborated in [362] on the basis of notions about the presence of local structural microinhomogeneities, whose coalescence under the shear conditions determines the nucleation of a macroingomogeneity; it was also based on the comparison of relaxation times of processes taking place near the discontinuity nucleus during its development. The proposed approach rather accurately describes the main singularity of the η (P) curve for concentrated suspensions, namely, the appearance of a «plateau» region associated with the formation of discontinuity at low P values. The discontinuity is experimentally detected from the abrupt drop of shear stress on reaching the critical, for a given system, deformation rate $\acute{\varepsilon}_c$ as it increases within a very narrow range. The subsequent increase in P with $\acute{\varepsilon}$ reflects the behavior of a system merely in the discontinuity region rather than throughout its bulk. Thus, the shear deformation of disperse systems in the gap of coaxial cylinders leads to a significant rearrangement of the microstructure with the formation and development of one or several local shear zones, depending on the concentration of the dispersion phase in the dispersion medium. One of the possible factors for the appearance of local slip zones, equivalent to aperture of continuity, is a jump in concentration near the boundary of the macroinhomogeneity formed during deformation.

The hypothesis about such a mechanism of destruction in the shear flow was confirmed in by microphotographs of the structure of aqueous dispersions of calcium bentonite. The kind of discontinuity thereby strongly depends on the solid-phase content in the dispersion medium and correlates with the graphically general view of

the dependence of the structure strength on the particle concentration. The following variants are possible: true discontinuity under the conditions of liquid-phase deficiency ($\varphi >> \varphi_{2c}$); the formation of one ($\varphi \geq \varphi_{2c}$) or several ($\varphi << \varphi_{2c}$) slip zones at an excess content of the liquid phase with the formation of solid-like layers (φ_{2c} is the second concentration corresponding to the onset of a sharp strengthening of the structure).

The appearance of discontinuity and its subsequent development during deformation exclude [361] the shear distribution over the system bulk, which makes it impossible to reach the minimal level of viscosity and the total failure of the structure. Such a phenomenon leads to a misrepresentation of measurement results and, accordingly, to the impossibility of plotting the total flow curve. This is evidenced [357] by the reproducibility of flow curves in the case of downward and upward motion (the presence of hysteresis loops). This effect is most pronounced at $\varphi > \varphi_{2c}$.

Thus, under dynamic non-equilibrium conditions, qualitative changes are observed in the behavior of disperse systems with an increasing intensity of external action: the original structure is destroyed, and a new, laminar structure is formed. This phenomenon is reflected in an unusual run of flow curves.

To further develop the notions on the laws and mechanism of formation, stability, and destruction of structured dispersions, it is expedient to add [363-365] to the explanation of their possible anomalous behavior as a specificity of coagulation under dynamic conditions the analysis of the processes in terms of synergetics and the theory of catastrophes taken together. As is known, synergetics deals [366-368] with the investigation of the processes of self-organization of structures of various nature formed in systems that are far from equilibrium, and the theory of catastrophes describes [369] those threshold situations in which dissipative self-organized structures arise, are maintained, and lose stability. Within the framework of this approach, disperse systems under dynamic conditions are interpreted as self-organized systems whose evolution in space and time is accompanied by the formation of dissipative structures. It should be noted that whole variety of real stepwise changes of states of such systems (their qualitative restructuring) caused by smoothly varying

external actions is described by a small finite number of canonical models – catastrophes.

Because the catastrophe theory provides a method to simulate some violations of the continuous development of various processes, it was suggested [363-365] to interpret possible forms of the manifestation of qualitative structural changes in the shear flow as catastrophes. The *S*-shaped inflections of flow curves (Fig. 1) illustrate the radical changes in the character of the flow of structured disperse systems. Hence, it is assumed that their anomalous run is identical to that of the standard curve of stationary states [370]. This fact permits the existence of three stationary regimes with the same values of some (master) parameter, thereby making hysteresis phenomena possible [367]. The inflection points of the curve correspond to bifurcation parameters, at which the number of stationary states changes in a jumpwise fashion («catastrophically») with a simultaneous change in the type of stability. Moreover, the unstable states in the middle part of the curve are virtually never realized in real systems.

Thus, the features typical of the flow curves II are inherent to the curve of stationary states. It should be noted that this analogy is presumably both apparent and meaningful. In accordance with [360], two stable and one unstable flow regimes are observed (Fig. 1) in some zone of drastic drop of viscosity at the same shear stress. Consequently, it can be assumed that the theoretical *S*-shaped dependence adequately reproduces the real pattern of the loss of the original flow stability and transition to a new stable regime. Such an assumption allows to predict the character of flow curves in the situations where it is difficult to obtain experimental data.

In the case of rheological curves on which the region of recovery of stresses is due to the discontinuity [359], this model takes into account the phenomenon of stepwise transition of a deformable system from the state with a practically undestroyed structure to a qualitatively new state with a specific (layered) kind of destruction. The «threshold» stresses at which changes in the shape of rheological curves are noted are considered as bifurcation stresses. The anomalous portion between the bend points corresponds to unrealizable states of the volume isotropic damage of the structure,

since a full rheological curve in the region where the effective viscosity changes from η_{max} to η_{min} can only be obtained [362] when «pure homogeneous shear» is realized. The lower part of graphical dependence corresponds to distorted measurement data describing actually only the processes of friction between the layers confined by the slipping surfaces and a possible partial failure of the structure in the zones adjacent to the facture. In accordance with the experimental data, such an approach allows to interpret the jump on a flow curve as a consequence of the development of macroinhomogeneity, namely, discontinuity, from the microinhomogeneities of dispersion structure under external action.

As was shown in [361], for some systems, one can obtain the set of flow curves that are characterized by even more pronounced *S*-shaped pattern with increasing concentration of the solid phase. In particular, this tendency is clearly observed in the flow of an aqueous calcium bentonite dispersion. It is proposed [363-365] to employ the «ruffle» catastrophe for studying the peculiarities of shear flow, since the considered curve of stationary states represents the cross sections of this model at fixed φ values (Fig. 2). The catastrophe of such a type describes the investigated process using one state variable (η or $\acute{\varepsilon}$), two master parameters P and φ and represented by a qualitative model (surface) in the 3D space of these generalized coordinates. The most interesting property of a given surface is the presence of two fold lines beginning at the so-called ruffle point B and forming a bifurcation curve (semi-cubic parabola with the tip at point B_1) on the plane of master parameters P, φ. These points correspond to the first critical concentration φ_0. On reaching the latter, 3D network starts to form, and the anomalies are observed in the flow of disperse system.

The stable stationary regimes geometrically correspond to the points on the surface of manifold of the catastrophe «ruffle», that lie on the upper and lower sheets outside the fold curve, whereas the unstable regimes, to the points on the middle sheet inside the fold curve (the region of inaccessibility which may presumably be treated as a zone of unrealizable states of isotropic failure even with increasing intensity of external effects).

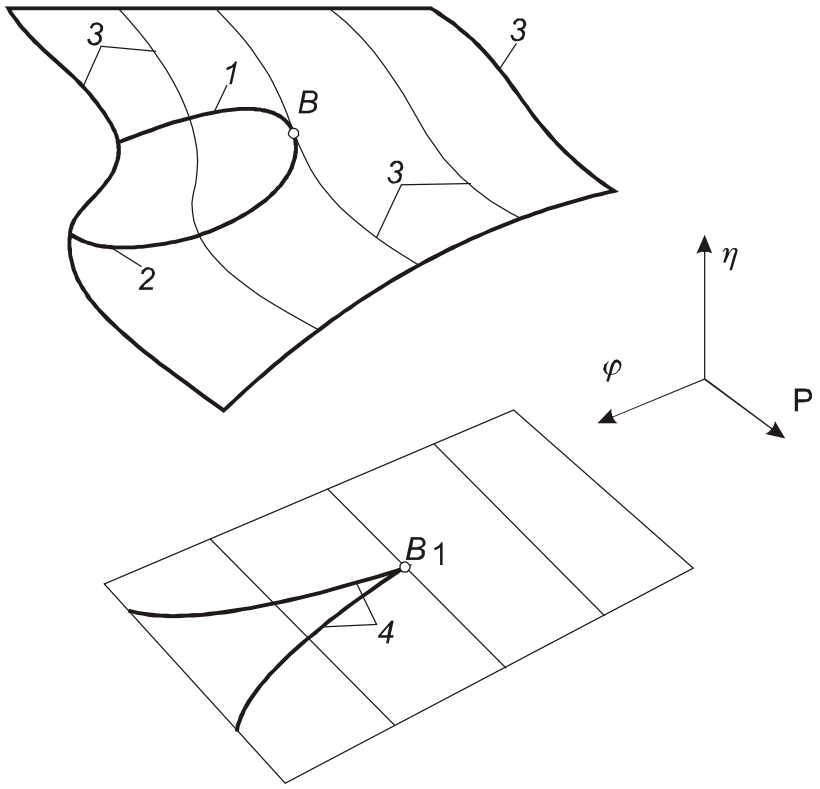
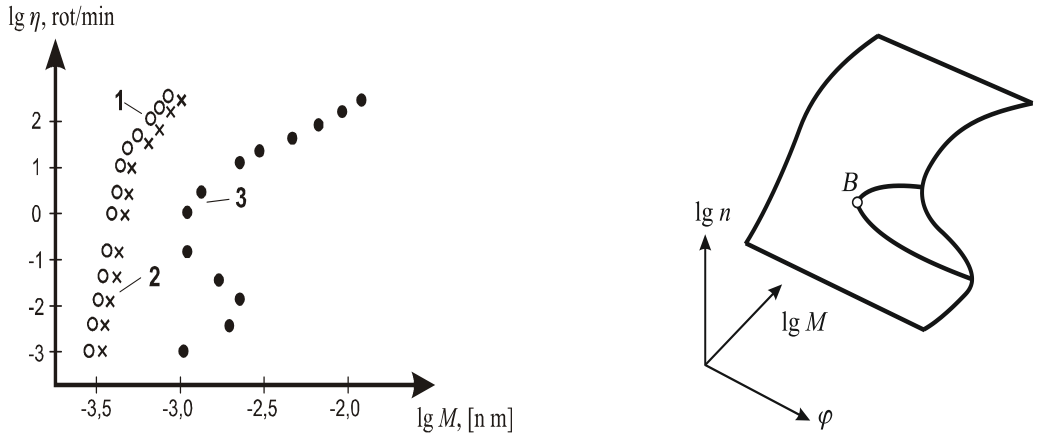


Figure 2. The schematic representation of the dependence of viscosity η of the aqueous calcium bentonite dispersion on shear stress *P* and the content of dispersed phase *φ* (the «ruffle» model, the principle of maximal delay); 1 and 2 are fold lines; 3 is the cross sections model; *B* is the ruffle point; 4 is the bifurcation curve; B_1 is the bifurcation point

Qualitative diversity of the system is determined by various combinations of master parameters. In the considered case, the parameter *φ* is called splitting parameter, since, on exceeding its critical value, the model surface is splitted up into two sheets, i.e., its variation controls the probability of ambiguity of *η*(*P*) function and the emergence of jumps. If the condition ($\varphi > \varphi_0$) is fulfilled, then, on varying the second (normal) master parameter *P*, the right-hand edge of the ruffle is reached. This leads to a jump from one stable stationary flow regime with a virtually undestroyed structure on the upper sheet to another stable stationary regime having local slipping zones on the lower sheet. The fold lines (the right- and left-hand ruffle edges) correspond precisely to those combinations of master parameters that initiate the jumpwise state variations. Such a representation, combining the whole set of possible variants of the aforementioned flow curves in one scheme, is in good agreement [362] with the known experimental results and provides fairly complete information on the

qualitative changes in the rheological behavior of disperse systems upon a continuous shear deformation due to discontinuities.

In particular, similar patterns of an extreme nature were also found [371] when studying how rheology of aqueous dispersions of calcium bentonite of a coarse-dispersion phase is influenced by quartz sand with different grain sizes. The influence of the volumetric concentration φ (10, 30 and 50%) of a coarse-dispersion filler 0,22 mm upon the size on the configuration of the graphical dependences of the torque M on the inner cylinder of the rotary viscometer «Reotron» depending on the number of revolutions n of the outer cylinder was considered (Fig. 3, a). Comparison of the results obtained confirmed the assumption of a significant change in the rheological behavior of the compositions with an increase in φ, which manifested itself in the qualitatively different nature of the experimental curves. The geometry of the curve *3* with a clear *S*-shape can be explained by the formation of slip zones in the system being deformed with an increase in the content of the coarse-dispersion phase up to 50%. Similarly, anomalous effects (but in the region of higher φ) were recorded for dispersions containing a coarse-dispersion filler with a particle size of 0,05 mm.



(a) (b)

Figure 3. Impact of density φ of coarsely dispersed filler over rheological behavior of inorganic: *1* – 10%, *2* – 30%, *3* – 50% (a); transformations of rheological relationship lg n (lg M) with increase of content of coarsely component (the «ruffle» model) (b)

According to the above, it is assumed that the pronounced specificity inherent in the totality of the considered graphical dependencies allows us to interpret each of them as a cross-section of the «ruffle» catastrophe at a certain value of φ (Fig. 3, b).The

possibility of such a model generalization testifies to the general nature of the phenomenon under consideration.

It should be noted that in modeling real situations with sudden catastrophic changes of regimes, it is necessary to take into account [367] the presence of two main directions connecting the geometry of catastrophes to the system being investigated (maximal delay and Maxwell principles). The choice of one of the principles is determined by the nature of the phenomenon itself. For instance, in the above-considered case, the first principle is realized according to which the system makes a jump to another state only if it has no other choice. Moreover, it is expedient to use it, in particular, in describing and analyzing phenomena associated with the loss of physicochemical stability and hysteresis effects [355]. Hysteresis is [369] one of the basis qualitative features of the ruffle-type catastrophe in the case of using the principle of maximal delay.

As is known from [357], the appearance of a discontinuity means that the continuum in the change of velocity *v* in the cross section oh the viscosimeter running clearance Δr at $\acute{\varepsilon} > \acute{\varepsilon}_c$ is broken. The analysis of the velocity *v* distribution scheme at a continuous shear deformation has shown that the observed effect [367] can be described fairly well by a model of the «ruffle» type whose geometry obeys the Maxwell principle. In this case, there arises a situation analogous to the formation of the so-called shock ware (break) characterized by sharp changes in the profile. With increasing velocity of shear in passing through some critical value of $\acute{\varepsilon}_c$ the shock ware suddenly kick the system into a new state. It should be noted that the profile of velocities v is interpreted in [369] as «ruffle» type catastrophe cross sections for various $\acute{\varepsilon}$. Here the deformation rate acts as a splitting parameter predetermining the possibility of a considerable change in the clearance linear velocity profile.

Extending the list of possible kinds of schematic representations of *v* profiles Extending the list of possible kinds of schematic representations of *v* profiles corresponding to different variants of structural changes in systems in a shear flow by using the nonlinear ware theory seems informative as well. Since a rigorous

mathematical analysis is rather difficult, it makes sense to qualitatively determine the most important features of the break formation on the basis of an analogy with the investigations of collective phenomena in plasma, which also use [372] the model notion of the shock wave. The character of the structure of the latter depends on the viscosity of the system being investigated. If the viscosity is small enough, then the general qualitative profile shape corresponding to the velocity jump is a shock ware with a decaying oscillating structure located ahead of its front (soliton packet). The lover the viscosity, the larger the number of oscillations (breaks). With increasing viscosity an ordinary shock ware without oscillations with a monotonous structure takes place. Thus, ordinary aperiodic shock wares and soliton packets are interpreted as various limiting situations for one and the same nonlinear process. As applied to disperse systems, these model notions agree with experimental results: to monotonous and oscillating profiles there correspond single and multiple discontinuities [355].

Within the framework of the catastrophe theory allowing to model some discontinuities in developing processes of various types, for establishing the most significant features of the occurrence of high density zones, an analogy can be drawn with the formation of a cluster of particles («birth of pancakes») according to Zeldovich. Zeldovich's theory [373] describes similar structural reorganizations using a number of geometric forms – elemental catastrophes, including the «ruffle» type (taking into account the presence of two scenarios for the development of compaction formation processes, namely, the principles of maximum delay and Maxwell).In the first case, the model of occurrence of three-stream (S-shaped) configurations is considered. In this scenario, the intersection of particle trajectories leads to local features being equivalent to caustics resulting from the intersection of rays in geometric optics and which are the places with the largest cluster of particles. In this case, the continuity of the flow velocity change is violated. The velocity profile becomes three-digit: three streams of particles pass through one point of space with different velocities; an «overlap» occurs, i.e. a fold is formed. The density of substance in a «pancake" being limited by caustics is the sum of the densities of these flows. Such an approach is appropriate in interpreting the effect of compression of structured

dispersions; collapse leads to lamination and breaches in the system. The second approach illustrates, through ideas about the shock wave, the origination of compacted regions during shear deformation. This model takes into account collisions of particles; therefore, a jump-like transition of the system to a new state at a certain critical value of the deformation velocity is accompanied by the transfer of particles and their sticking to the structure of the base layer. The proposed interpretation describes the process of «layering» of particles of solid phases, contributing to the formation of a compacted structure.

Thus, the qualitative peculiarities of the behavior («the catastrophe features») of the investigated disperse systems the possibility of simulating the general pattern of processes, thus facilitating the prediction and study of separate anomalous phenomena that are observed during the flow of structured dispersions.

As mentioned above, structured dispersions away from the thermodynamic equilibrium in the field of external actions are typical synergetic dissipative systems. In the course of their evolution, under dynamic conditions, a considerable reorganization of the microstructure at a certain critical value of the velocity of shear (parameter corresponding to the bifurcation point) occurs. The initial structure is split into layers (i.e., local volumes bounded by the slip surfaces). Inside these volumes contacts between dispersed-phase particles are not broken and the degree of nonuniformity, which corresponded to the moment of the appearance of the initial (static) structure in the systems, is preserved. A breakage of cross-links, with respect to the flow direction, between the structural elements of the initial cellular-type space mesh and a displacement of the liquid phase from the spacing between particles when the cell boundaries break down are observed. There is a clear tendency for a transformation of the cellular structure to a layer structure, which becomes most pronounced when the solid phase concentration decreases with in limits sufficient for self-organization. The cells extend in the shear direction and dissipative layer structures are formed. The development of these structures was preceded [355] by a compaction in local volumes of particle microaggregates wit a gradual formation of shear planes in the zones of the largest aggregations of packing defects.

Thus, at a deformation in disperse system irreversible processes of restructuring caused by the cooperative interaction of defects can proceed [367]. A deformable dispersion with defects (initial local imperfections) displays a behavior which can be represented as an asymmetric bifurcation diagram. In terms of the theory of catastrophes to such an evolution pattern there corresponds the above-mentioned assembly-type catastrophe («ruffle» model**).**

It also seems informative to describe the mechanism of layering of disperse systems as a process of formation of contrast dissipative structures [374]. Since for the existence of such a structure the presence of a set of «activator-inhibitor»-type parameters in the literal sense is not necessary, it is expedient to consider, as a deforming variable, the initial nonuniformity [375].

Consequently, the moment of the appearance of a layering is a precursor of the transition tj the accumulation of reversible damages under the action of external force fields. The superposition on a deformable system of a vibration with optimum parameters radically changes [361] the character of its destruction in the shear flow. A destruction of compacted layers with an avalanche formation of microaggregates of particles with simultaneous formation of a structure in the form of cells with loosened coagulation contacts is observed, and the slip zones thereby disappear. From the point of synergetics such an effect can be explained [376] by the increase in the degree of nonequilibrium of the system under an additionalaction of the vibration, as a result of which the structure is shredded, as a rule. This interpretation is in qualitative agreement with experimental results: a combination of a continuous shear wich an oscillation orthogonaly directed to it causes [362] the structure to break down into aggregates whose size decreases and whose number increases with increasing vibration intensity $I = a^2w^3$ (a is the oscillation amplitude and w is the circular frequency). It is assumed that the «ruffle» model, located as indicated in Fig. 4, clearly illustrates the peculiarities of structural changes in disperse systems with increasing I that are manifested in the reconstruction of flow curves.

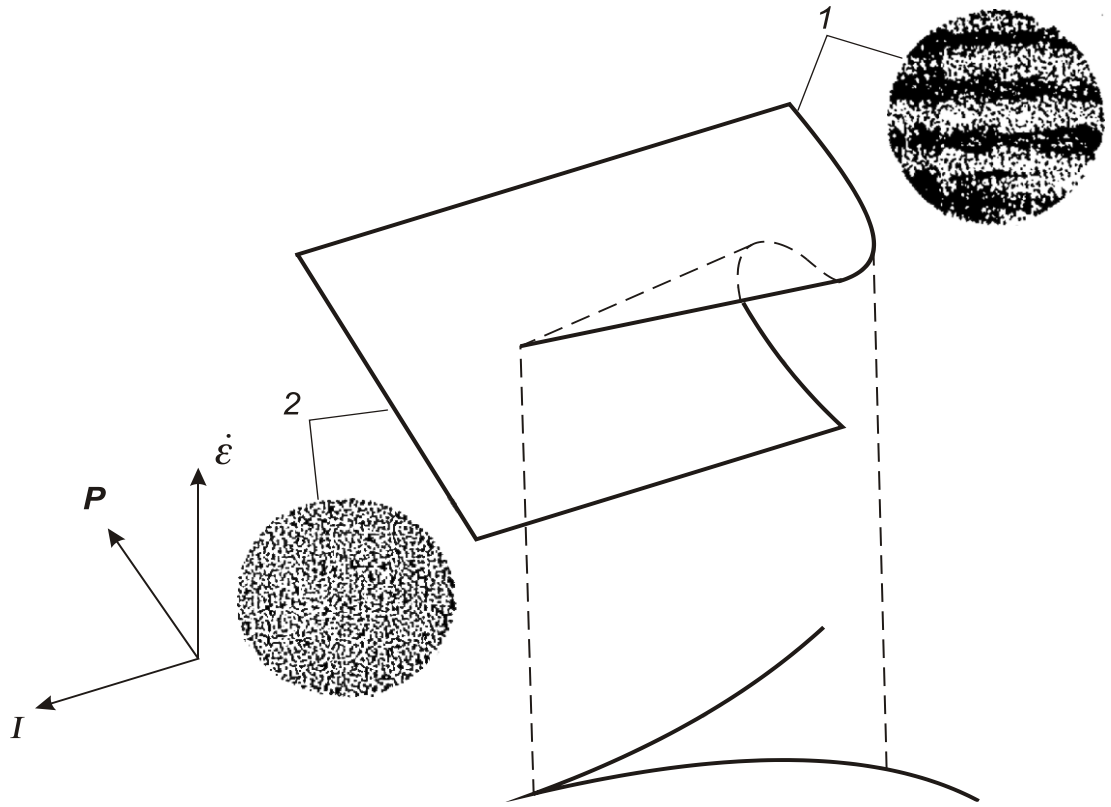


Figure 4. The transformation of flow curves $\dot{\varepsilon}(P)$ with increasing vibration intensity I upon the orthogonal oscillation (the «ruffle» model); the rheological dependences and corresponding dispersion structures:(1) without vibration and (2) during the vibration with optimal parameters

It should be noted that, along with the above *S*-shape, the pattern of development of the anomaly in the flow process of dispersed systems can also take the form of *N*-shaped kinks in the experimental graphs. The class of *N*-shaped dependencies is a simpler (in the sense of a standardized interpretation) case; in this situation, obviously, the «fold» catastrophe is applicable. In this regard, the results of studying the rheological properties of concrete mixtures using a technical vibro-viscometer published in [377] are indicative. This work presents the dependences of the vibro-viscosity of the concrete mixture η upon the frequency n and the vibration amplitude A for different values of the water-cement ratio *W/C* (Fig. 5, a). Experimental rheological curves (*W/C*= 0.41), which differ in the degree of change in wave-like behavior with increasing *A*, can be informatively considered as cross-sections of «fold» catastrophe (Fig. 5, b). In this case, vibro-viscosity acts as a state variable, while frequency and amplitude act as control parameters. It should be emphasized that at the smallest value of the amplitude of the superimposed oscillations, the $\eta(n)$ dependence is characterized by the presence of a minimum and a maximum, apparently due to self-organization

processes [367]. With increasing *A*, these points gradually converge and the graphs take on a less extreme form. Based on the configuration of the model surface, it should be assumed that there is a certain value $A = A_{cr}$, at which the singular points merge into one fold point *D*,which separates functions of two qualitatively different types.

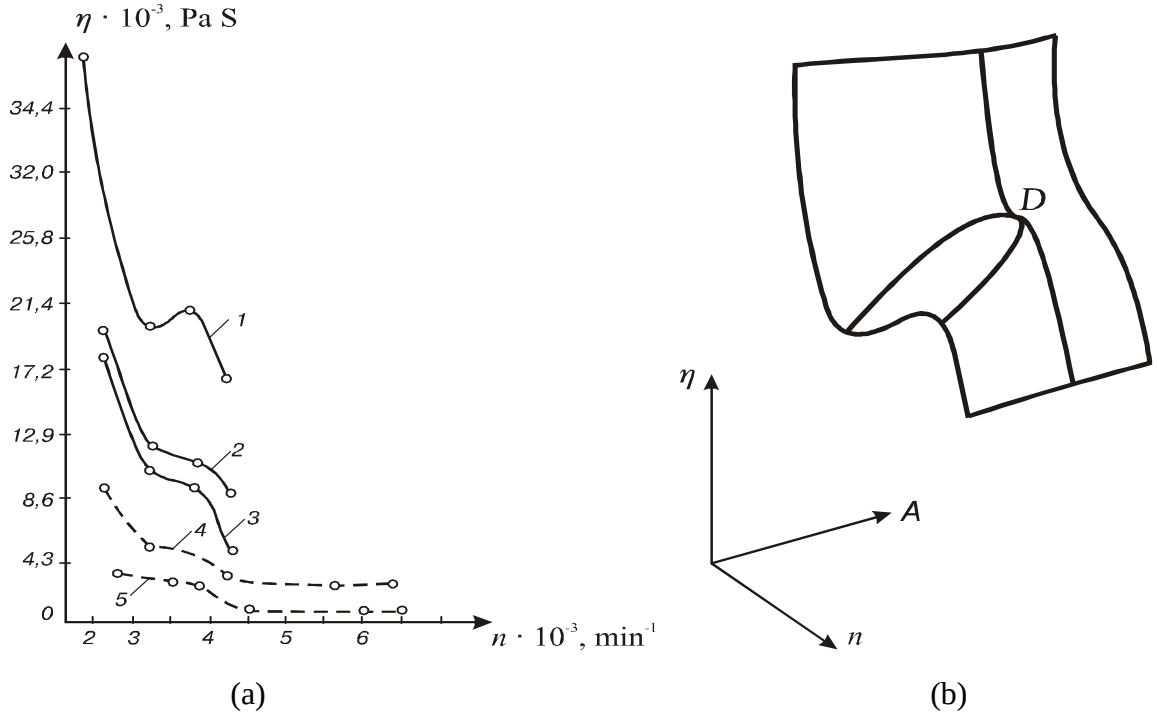


Figure 5. Dependence of vibroviscosity$\eta$of concrete mix from the frequency *n* and amplitude *A* of vibration: *1*– 0.24, *2* – 0.32, *3*– 0.37 mm (water-cement ratio WCR = 0.41); *4*– 0.17, *5*– 0.37 mm (water-cement ratio WCR = 0.54) (a);transformations of rheological relationship with increase of vibration amplitude (model «fold») (b)

A similar description is probably appropriate when analyzing two graphical dependencies when *W/C* = 0,41 and *W/C* = 0,54. The governing parameter in this case is the water-cement ratio *W/C*. There is a tendency towards a decrease in the slope of the dependence with an increase in the water-cement ratio. To explain the observed effect of a decrease in the vibro-viscosity of a concrete mixture with a change in the frequency and amplitude of oscillations, it seems quite reasonable to use the assumption of an increase in the degree of non-equilibrium of the system and the corresponding crushing of the structure. The qualitative correspondence of the model surface to the known experimental curves is very meaningful, since it leads to the conclusion that the nature of the dependences presented has a well-defined regularity.

It also seems to be expedient to describe and analyze from the above standpoint the kinetic curves of the structure formation of solidifying disperse systems. In the initial stages of the process of spontaneous evolution of these systems, there occur qualitative jumps registered on the plots of such kinetic characteristics as fast elastic deformation modulus, resonance frequency, and limiting shear stress. The effective theoretical description of such transitions is hindered, since the structure formation of disperse composite materials is continuous processes of dissolution, solvation, coagulation, etc. that are superimposed on one another. From the point of view of synergetics, solidifying disperse composites are interpreted as complex nonequilibrium physicochemical systems whose development is accompanied by a self-organization of dissipative structures. Therefore, to reveal the general laws of the behavior of such systems, it is expedient to use [363-365] the approach based on the possibility of modeling the transition of smooth quantitative changes to qualitative ones, i.e., the theory of catastrophes.

The literature data [378, 379] point to the existence of a certain group of structure-formation kinetics curves whose extreme *N*-type form reproduces the geometry of the simplest «fold»-type catastrophe. Agreement between experimental and model curves manifests itself not only in the above-mentioned superficial resemblance of the character of the curves. but in their logical generalization as well.

The explanation of the shape of the curves describing the time change in the fast elastic deformation modulus E and resonance frequency v of magnesium-oxide-containing water suspensions of moulding powders is associated in [379] with the specificity of the behavior of MgO. Dispersions including this component are characterized by a low critical concentration of the structure formation at which a coagulation structure arises and bonding powers of MgO manifest themselves similarly to cement-mineral mixtures. After a few hours, a sharp strengthening of the system due to the interaction of MgO particles with water and formation, as a result of this, of links between them in the form of OH–Mg–O–$(MgO)_n$–Mg–OH chains is observed. Such chains form with time a spatial skeleton and go into condensation-crystallization structures, which is illustrated by an increase in the deformation modulus. The definite

decrease in the values of the kinetic indices after 3,5 h is explained by the possible softening of the suspension in the initial stage of formation of point contacts. To prevent the formation of condensation-crystallization structures and preserve the stability of the rheological properties of dispersions, it is necessary to constrain the growth of structural chains and their interaction. The required effect is achieved by introducing into the suspension 0,5–1,0% (of the solid-phase mass) citric acid $C_3H_5O(COOH)_3$ interacting chemically with a hydrated surface of magnesium oxide particles and molecules that are present in the solution. Since the dissociation constant of citric acid is small, the reaction proceeds slowly. The reaction products formed block the particle surface, which restricts the formation of strengthening structures and determines the constancy of the system's properties.

It should be noted that the experimental results given in the references [378] indicate the existence of a number of similar kinetic curves, with their *N*-shaped course beingidentical to the loop on the Van der Waals isotherms. Ambiguous dependences of the deformation modulus *E*, the resonant frequencies and the ultimate shear stress P_m on timeτhave been obtained, in particular, for aqueous dispersions of tricalcium silicate, cement-water dispersions with and without polymer additives, slips of ceramic radio-electronic materials, vulcanizers based on butyl rubber, filled with soot, cement or chalk. According to the authors, pronounced decays of kinetic activity indicators on graphic dependencies are the result of destructive processes in the systems under consideration. It is also noted that although the essence of the phenomena in progress is theoretically not clear enough due to the complexity of the objects under study, the structure formation processes can be influenced for a definite purpose through introduction of surface-active substances (SAS). As a result of applying the appropriate additives, the properties of the dispersions are stabilized, while the kinetic curves take on a monotonically increasing form. Within the framework of the theory of catastrophes, the characteristic features of these dispersed systems are similar, most likely, the geometry of the catastrophe being «fold» [369].

In the light of the above, it is assumed that the «fold» catastrophe joins in one scheme two possible in this case qualitatively different «marginal» options of structure

formation curves. The three-dimensional model picture reproduces the peculiarities of changes in the indicators E, v or P_m as functions of time (in terms of the theory being applied τ is the generalized coordinate) at various SAS concentrations (control parameter C,%). The family of curves corresponding to different values of C in the order of its ascending have a configuration adequate to Van der Waals configuration. In the absence or minor content of the additive, dependencies have a maximum and minimum. As C increases, these points approach, and at a certain $C = C_{cr}$ value, similar to the Van der Waals critical temperature, merge into one. This concentration of the additive and the corresponding kinetic curve are interpreted as critical. The critical curve of structure formation rises monotonously throughout, except for one point, which is the inflection point of the graph which separates function of two qualitatively different types. A parabola formed by points of maxima, minima and inflection limits the region of thermodynamically unstable states of the system. It seems likely that the moment at which the «fold» points arise on the model surface correlates with destructive changes in the kinetic characteristics due to the self-organization processes in hardening systems. Thus, the results of kinetic studies can be presented as an example of applying of the theory of catastrophes. At the same time, the model being considered, while summarizing some true effects, clearly illustrates the qualitative structural changes in hardening dispersions.

The promise of further development of the kinetic research methodology through combining the above-described topological approach and the methodology of experimental statistical modeling based on «time sections» is also worth noting. In such a situation, it seems quite informative for each fixed point in time τ to build experimental-statistical models being third degree polynomials. These models contain third order effects, which determine undulation of single-factor curves, and the corresponding interactions, which vary the degree of undulation in multifactorial space. According to the topological concept, these single-factor dependencies are be considered as the projections of the catastrophe «fold», but, unlike what was stated earlier, in another coordinate system (for example, «concentration SAS – P_m or its relative change», etc.). The grouping of single-factor curves into a model surface

allows, at each moment in time, to evaluate not only quantitative, but also qualitative changes in the system.

Thus, a comprehensive generalization of the experimental data from studies of the structure formation of dispersions will make it possible to reinterpret some features of the development of these systems. The proposed approach will expand the understanding of the patterns of their formation, which is important for solving many problems in various fields of materials science.

It is noteworthy that, in addition to *S*-and *N*-similitude, there are also other signs indicating the possibility of using methods of the theory of catastrophes in the study of certain processes which initiate the occurrence of gaps in the development of the system. In particular, this approach is applicable when describing the transition of three-phase disperse systems «solid-liquid-gaseous» with a highly viscous dispersion medium from the state of vibro-compaction to pseudo-liquefaction under conditions of shear deformation under the action of vibration. As indicated in [355], the patterns of interaction of highly dispersed and coarsely dispersed solid phases between themselves and with a liquid medium in the process of structure formation under dynamic conditions in producing various materials (filled polymer composites, concrete, technical ceramics, etc.) are similar, although the differences in chemical composition and rejection mechanism for the initial components can be significant. According to [362], the graphical dependence of the effective viscosity of a highly filled disperse system on vibration acceleration has the form of an edge formed by two branches at a point with g_{cr} value with causing the maximum value η_{eff}. In this case, the critical acceleration of vibration corresponds to boundary of dispersion transition from the state of vibro-compaction to the state of pseudo-liquefaction. It appears possible to describe the transition being studied using a «ruffle» model surface, since the above experimental dependence is identical in shape to a semi-cubic parabola, which is the projection of this catastrophe on the plane of control parameters $g$and η_{eff} according to the principle of maximum delay. This bifurcation curve, consisting of two «fold» lines connecting at the «ruffle» point, divides the control space into areas corresponding to different modes of system operation. Qualitative changes in the behavior of the

dispersion occur only in the case when the «trajectory», preset by the variation of the control parameters, leaves the region inside this curve; the transition vibro-compaction – pseudo-liquefaction seems to take place under similar conditions.

From the same perspective, the behavioral patterns of highly dispersed powders in vibration can be considered. Highly dispersed powders are characterized by [361] spontaneous occurrence of spatial structures formed by particles with direct atomic contacts, which causes considerable difficulties in carrying out a number of technological processes (dosing, drying, initial stages of mixing, transportation, etc.). The elimination of aggregation is one of the main conditions for optimizing the technology of dispersed systems and materials with a given structure and properties. As emphasized above, this effect is achieved by creating a controlled dynamic state; it serves as the background against which the main technological process is carried out.

The number of characteristic dynamic states of the system being investigated is small, but each of them is inherent in a number of technological processes being of the same type in the sense of the same level of rheological properties, and is a necessary condition for principal possibility of their realization [355]. A universal form of dynamic influences which allows to create and maintain such a state is vibration. The imposition of vibration brings the system of particles into one of two possible dynamic states: vibro-liquefaction, in which the powder particles move in relation to each other without disconnection with a decrease in volume as a result of compaction of the structure; vibro-boiling, separation by the mutual movement of particles in relation to each other with complete separation, their intensive mixing and an increase in the volume of the layer. The first dynamic state is preferable in such processes as dosing, transportation, compaction, and the second dynamic state determines realization conditions of the processes of mixing, drying, burning. The main characteristic of these dynamic states is the boundary between them, caused by a combination of circular frequency values and oscillations amplitude, at which the transition of powders from the state of vibro-liquefaction to the state of vibro-boiling occurs. Geometrically, such a phenomenon can be depicted as a qualitative model «ruffle» in the three-dimensional space of generalized coordinates (states of the system, circular frequency and

amplitude). The analysis of the projections of this model on the control plane allows us to establish a relationship between the parameters and highlight areas of qualitatively different types of dynamic system behavior. The determination of vibration modes corresponding to the transition of highly dispersed powders from vibro-liquefaction to vibro-boiling provides the opportunity to influence in the most effective way the forming structures beingunder processes of obtaining dispersed composites.

Thus, the specific examples show the possibility of applying a topological approach for analyzing situations which have a threshold nature, namely, the transition from vibro-compaction to pseudo-liquefaction and the transition from vibro-liquefaction to vibro-boiling (effects typical of real technological processes).

In addition, recognition of above-mentioned particularities allows determining the fact and type of catastrophe, the standardised structure of which facilitates finding strict patterns and thus defines directions of optimisation of various situations of research and practical nature.

It should be emphasized that the previously considered N- and S-shaped kinks are inherent not only in rheological and kinetic curves, but also in a number of graphical dependences experimentally obtained in studying various properties of building materials. In this regard, it seems quite probable that a topological approach may be used to interpret some nontrivial experimental data.

The applicability of the topological approach in the study of the anomalous behavior of the isotherms of water desorption of cement stone, cement-sand mortar, asbestos cement, calcium hydrosilicates C-S-H and C-S-H (I) in a certain region of relative vapor pressure is shown p/p_S [380, 381]. Figure 6 shows the initial sectors of the isotherms (18°) of water sorption-desorption on calcium hydrosilicates at C/S = 0.1-1.0 (black dots – desorption) according to the data [380]. The appearance of a step on the desorption branch of isotherms at $p/p_S = 0.35$, which is absent in silica gel,

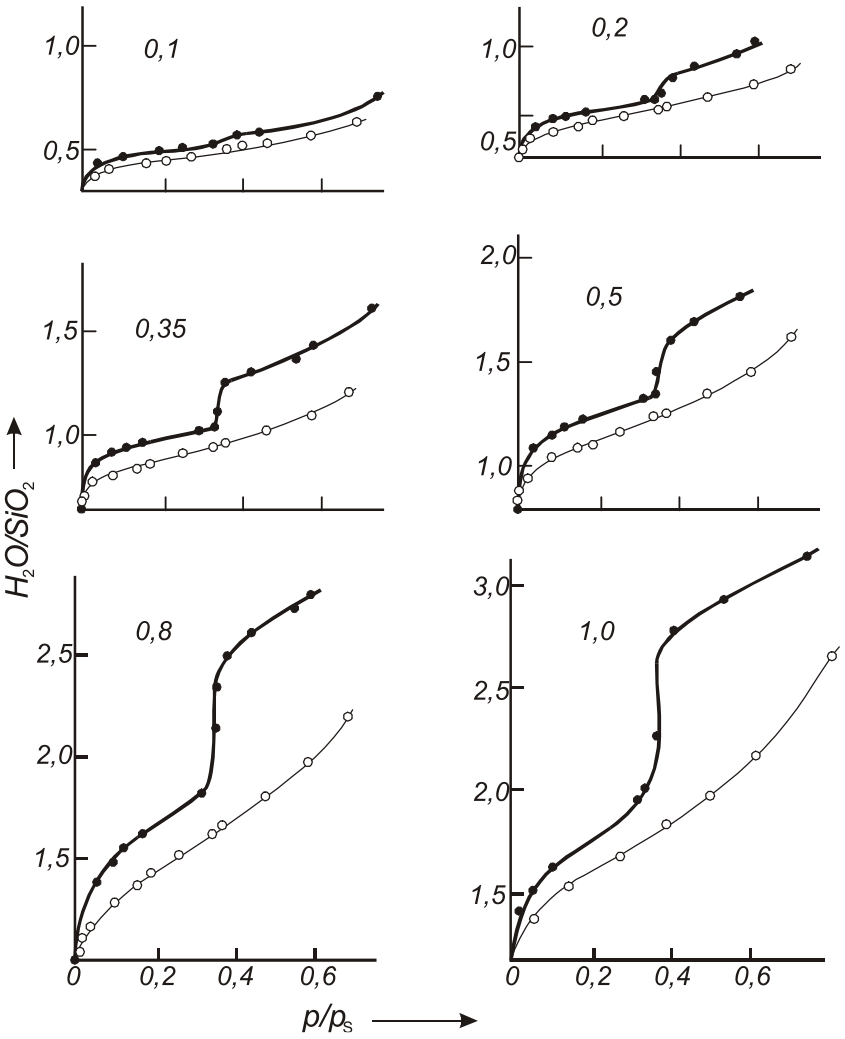


Figure 6. The initial sectors of the sorption isotherms - water desorption on calcium hydrosilicates at C/S = 0.1 - 1.0

was first recorded for a sample with C/S = 0.1. The decrease in the isotherm increases with increase in basicity and reaches a maximum for the sample with C/S = 1. In [380, 381], two possible main reasons for the inception and development of the detected effect were put forward: the dissociation of a specific crystalline hydrate or the release of water sorbed by a mobile layered (according to the authors) hydrosilicate structure. It is assumed that these methods of interpreting the isotherm recession are not mutually exclusive, however, their difference lies in the degree of localization of water molecules in the structure. Along with the above, there are [381] a number of other ideas regarding water which is removed during recession, and the mechanism of its influence on the structure. Nevertheless, with all the variety of interpretations, from the standpoint of physical chemistry, the observed phenomenon is of a very general nature,

which is expressed in a specific qualitative scheme (Fig.7). Moreover, the topology of the complex of the available graphic dependencies coincides with

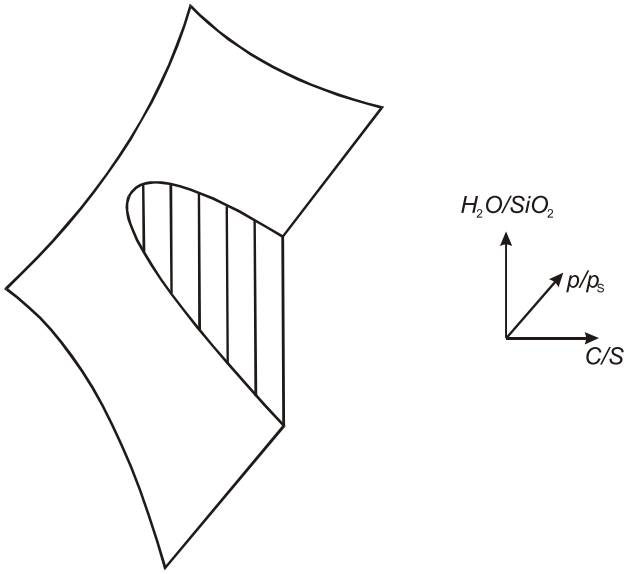


Figure 7. Transformation of desorption isotherms with increasing C/S (the «ruffle» model, Maxwell's principle)

the shape of the model surface of the «ruffle» catastrophe being correspondent to the Maxwell's principle. As the basicity increases, when passing through its some critical value, a step appears on the desorption branch, the height of the vertical section of which (i.e., the recession) increases with increasing C/S. In accordance with the topological approach, the isotherms in Fig. 6 are treated as cross sections of the «ruffle» catastrophe for calcium hydrosilicates of different values of basicity. Such a model representation combines individual nontrivial experimental effects into a certain fundamental regularity.

The dependences of temperature deformations of dry and wet concrete also have a qualitatively different character [382]. Dry concrete shortens during cooling according to curve *1* in Fig. 8, a its thermal deformation is characterized by a coefficient of linear thermal expansion. Curve *2* of temperature deformations of wet concrete has an anomalous configuration, since the pressure of water freezing at -7,5˚C in large capillary pores causes an jump-like elongation of the sample. The second maximum on curve *2* is caused by freezing of water in smaller pores during severe frost (-47˚C). Elongation indicates that the phase transition of water into ice causes internal

expanding stresses in the pores' walls. Comparison of graphs from [382] with the outlines of the models «fold» revealed their satisfactory convergence (Fig. 8, b). Apparently, the fold point *D* corresponds to the degree of water saturation of the sample at which the features of the development of deformation begin to appear when freezing a moist porous material.

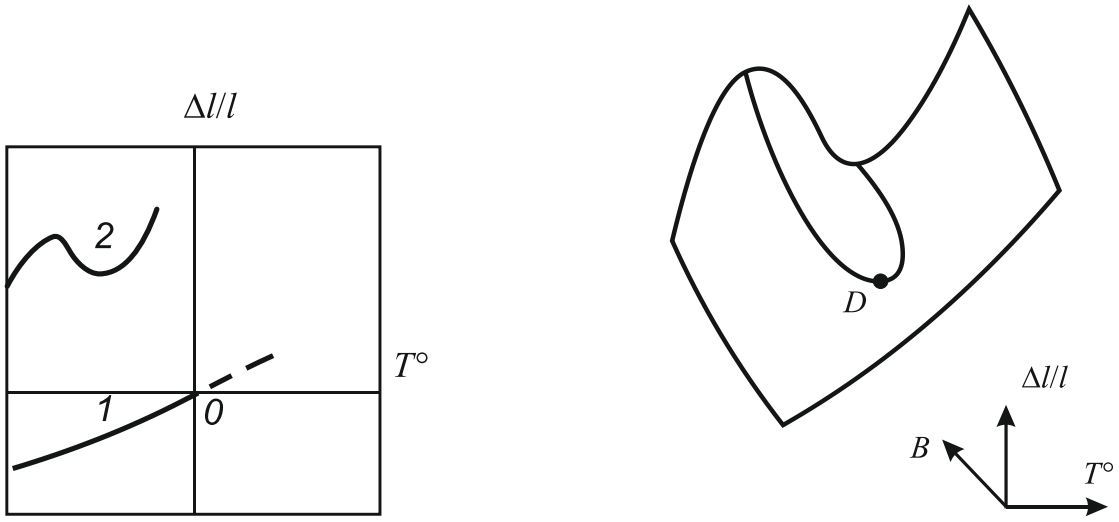


Figure 8. Curves of thermal deformation of fine-grained concrete: *1* – dry sample, *2* – sample saturated with water during freezing (a); transformation of temperature deformation curves of fine-grained concrete with increasing water saturation *B* (the «fold» model) (b)

The results of the study of the influence of the percentage of reinforcement on the temperature deformation of reinforced concrete are also illustrative from the standpoint of the approach involved [383]. Curves *2* and *1* (Fig. 9, a) clearly demonstrate revealed in [384] mismatch between the deformations of water-saturated concrete and reinforcement during freezing: concrete expands, while reinforcement contracts. As can be seen from the figure, the expansion of concrete with decreasing temperature causes significant deformation of reinforcement in reinforced concrete. In this case, the deformation of reinforced concrete samples increases with a decrease in the degree of reinforcement. Thus, the temperature deformations of concrete expansion in reinforced concrete elements due to the presence of reinforcement are approximately 1,5 –2 times less than the free deformations of wet concrete being frozen. Since the complex of the considered dependences is characterized by an increasingly pronounced

N-shapedness as the reinforcement coefficient decreases, it is assumed that the model «fold» (Fig. 9, b) is best suited to generalize the observed effects. In this case, the fold point *D* corresponds to the moment of occurrence of significant expanding stresses in the sample. Such a model representation combines individual experimental effects into a certain general regularity. The results obtained can be used for practical implementation.

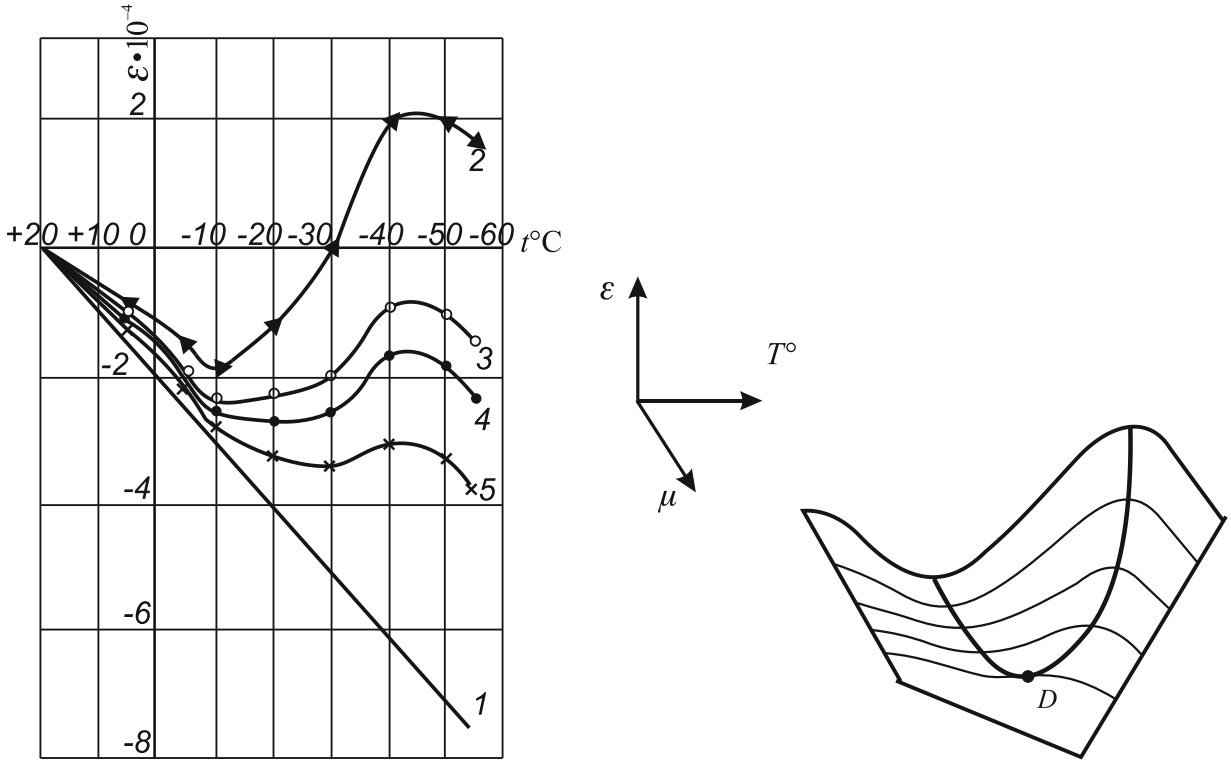


Figure 9. Deformation of reinforcement of reinforced concrete samples depending on the temperature of freezing at various reinforcement coefficients: *1*– steel grade St. 3; *2*– concrete, μ = 0; *3*– the same, μ = 1,13%; *4*– the same, μ = 2,01%; *5* – the same, μ = 5,24% (a); Transformation of deformation curves of reinforced concrete samples as a function of temperature with increasing reinforcement coefficient (the «fold» model) (b)

It should be noted that catastrophe theory may also be applied in the study of various anomalous effects characteristic not only of technological processes for the formation of various composites, but also for operational practice. In particular, it was proposed to use a topological approach to describe some aspects of the mechanochemical effect of the sign of deformation in stress corrosion phenomena.

As you know, stress corrosion is a process which occurs under conditions when a material experiences external loads and deformation. It should be noted [385] that from the standpoint of mechanochemistry with making allowance for presence of the

initial stress in the surface layer of any hard body in the form of surface tension, any naturally occurring corrosion is stress corrosion. As a result of the application of external forces to a body and its subsequent deformation, an additional surface stress is formed, which significantly affects the speed of the physicochemical dissolution process and, therefore, the rate of destruction of the material (in particular, metal structures). In this regard, finding of the laws of this phenomenon is not only of scientific, but also of practical interest.

It was experimentally established [386] that the applied mechanical stress accelerates corrosion. In order for the effect to be clearly expressed, sufficiently large stresses are needed. This result is most easily achieved through bending samples, in particular metal plates. In the thesis [387], it was for the first time experimentally discovered that the corrosion rate for the concave side of the plate is higher than for the convex side. Since the opposite sides of the curved plate differed in the sign of deformation, this phenomenon was called the mechanochemical effect of the sign of deformation in the phenomena of corrosion. It should be noted that for the first time the mechanochemical effect of the sign of deformation was recorded [388] in experiments on the dissolution of curved plates of single-crystal calcium chloride. In [387], it was also established that over time, the deformation sign effect reverses.

As follows from [385], the mechanochemical effect of the sign of deformation is inherent not only in stress corrosion processes, but also to any solid-body surface reactions. Thus, the effects discovered in [387] can be interpreted as universal and obeying a limited number of laws of nonlinear development of complex systems.

In connection with the above, the purpose of this research is to establish the regular patterns of the development of the processes of metals corrosion under stress. The research program provides for solving problems associated with the description and analysis of the phenomena, in which an increase in the influence leads to a qualitatively different behavior of the system.

Some aspects of the mechanochemical effect of the sign of deformation in the phenomena of stress corrosion are proposed [364] to be interpreted from the standpoint of synergetics [366–368] and catastrophe theory [369]. In particular, it is assumed that

a steel plate placed in an aggressive environment and subjected to additional force is recommended to be interpreted as a synergistic system, since within the framework of this approach, much attention is paid [366–367] to the understanding of the fundamental significance of symmetry and violation of symmetry. In this aspect, the violation of symmetry (i.e., the manifestation of internal differentiation between different parts of the system or between the system and its environment) embodies one of the first preconditions of complex behavior and is accompanied by the emergence of new properties.

In turn, various symmetry violations (including spatial symmetry) are taken into account [367, 369] in the structure of standard models – catastrophes: canonical equations contain a term playing the role of a «symmetry violator» or the imperfection parameter, which is geometrically represented by the asymmetric bifurcation diagram. According to catastrophe theory, a «ruffle» type catastrophe corresponds to such an evolutionary picture. In accordance with this theory, whatever character the system imperfections may have, while it in the absence of imperfections is described in canonical form by means of a function:

$$V_c(x) = \frac{1}{4}x^4 + \frac{1}{2}c_2x^2, \quad (1)$$

then, if imperfections are available, by the function:

$$V_c(x) = \frac{1}{4}x^4 + \frac{1}{2}c_2x^2 + c_1x. \quad (2)$$

A «trident»-type graph which is of frequent occurrence in bifurcation theory corresponds to the «perfect» system (1). The geometry of this diagram regulates the absence of catastrophic jumps, while in system (2) they necessarily occur when moving from one stable branch to another with increasing control parameter c_2. In this case, parameter c_1 is interpreted as initial imperfection. It should be noted that not only various defects (structural, geometric, etc.) are permissible to be considered as imperfections, but also the effects of external fields.

In light of the foregoing, it seems possible to use the above approaches in describing and analyzing both the previously indicated effect of deformation sign (Fig.10) and the case of its reversal over time (Fig.11).

For a more complete picture of the representation of the process under study at short time periods (Fig.10), two variables (control variables in terms of catastrophe theory) are additionally introduced: the load *P* on the sample and deformation ε of the sample (in [387] these parameters are constant). Accordingly, the mass loss of the sample (%) is interpreted in accepted terminology as a state parameter.

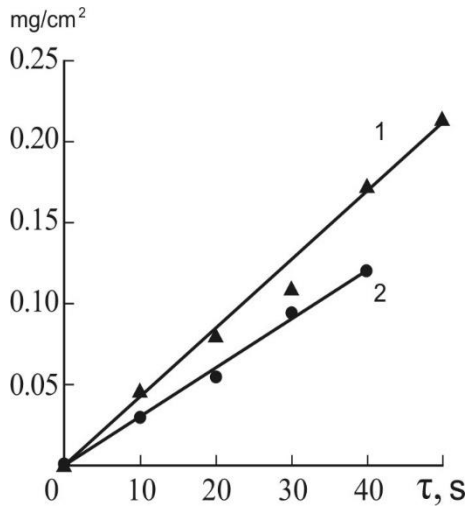


Figure 10

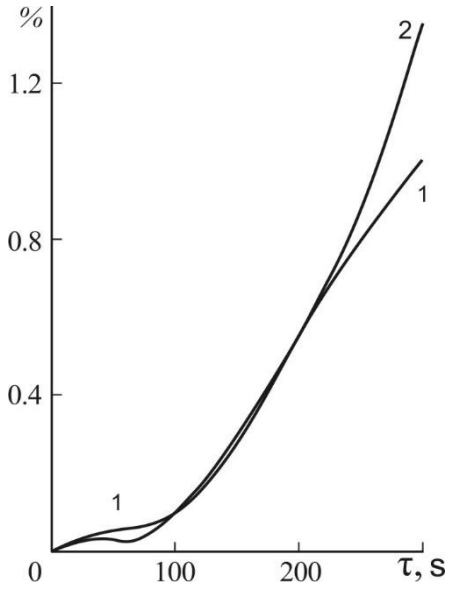


Figure 11

Figure 10. Dependence of sample mass decrease per a surface unit (in mg/cm^2) on the time τ for the concave (1) and convex (2) sides of a curved steel plate in a 35% hydrochloric acid solution. The slope of the lines represents the corrosion rate

Figure 11. Inversion of the deformation sign. Curves of dependence of the sample mass loss (%) on the time τ for the concave (1) and convex (2) sides of a curved steel plate in a 35% hydrochloric acid solution

Catastrophe theory rigorously proves that the only type of model surface in such systems with one state parameter and two control parameters is «ruffle» (Fig. 12). Qualitatively different system behavior is determined by various combinations of control parameters. In the case under consideration, the parameter *P* is called splitting parameter, since when its critical value is exceeded, the model surface splits into two sheets, i.e. its variation regulates the very probability of ambiguity of the dependence (%) on the sign ε and the occurrence of jumps. The normal parameter ε is directed along the normal (perpendicular) to the splitting factor.

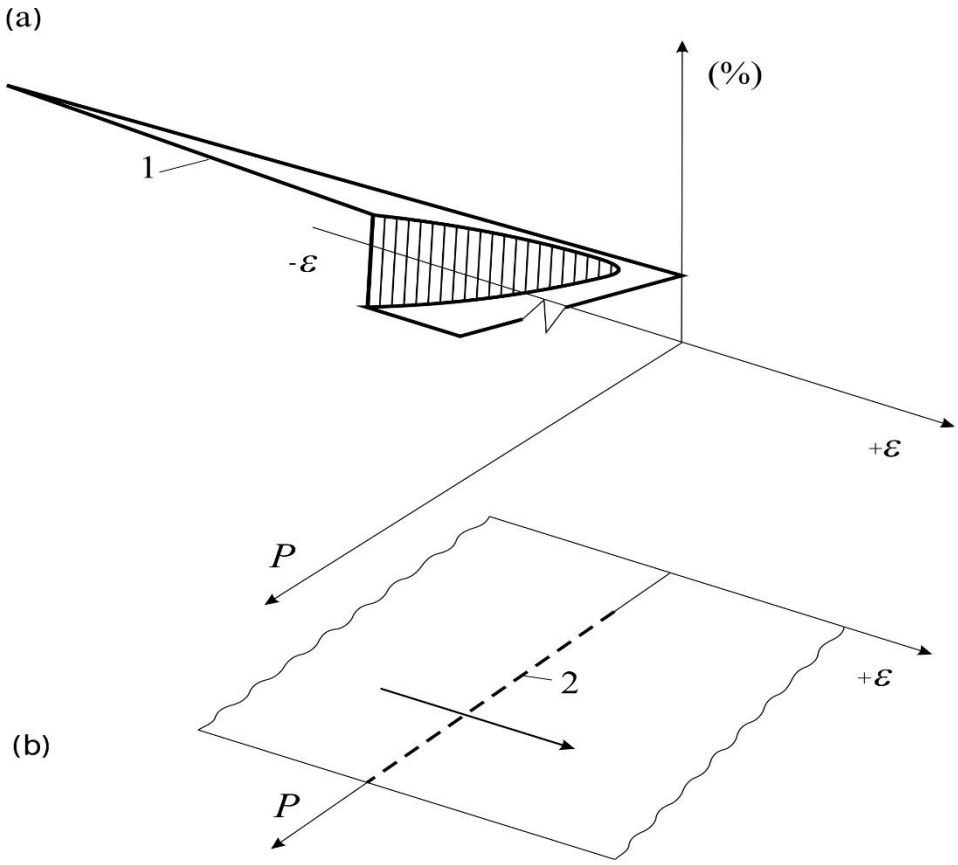


Figure 12. Topological model of the mechanochemical effect of deformation sign in the phenomena of corrosion under stress (catastrophe «ruffle», Maxwell's principle): (a) – three-dimensional surface in coordinates (%), ε and P (1 – cross section of the model); (b)–projection of the model onto the plane of the control parameters ε and P (2 – Maxwell's set)

An analysis of the scheme of distribution of deformations of a curved steel plate and curves of the dependence of the weight loss of the sample for its concave and convex sides in a 35% solution of hydrochloric acid at short time periods revealed [387], that the effect under consideration may be satisfactorily described by a model which geometry obeys the Maxwell's principle. In this case, a situation [367, 369] occurs, similar to the formation of a shock wave (gap) or phase transition of the first order in the areas of coexistence of different phases. In the absence of an external load ($P = 0$), the mass loss (%) is the same for the opposite sides of the sample. After passing through some value P_{cr} a manifestation of the deformation sign effect begins, which increases as the load increases. The structure of the model is designed with consideration to the fact that the dissolution rate is higher for the concave side than for the convex side. The upper sheet of the assembly corresponds to the mechanochemical

dissolution effect for the compressed side of the curved plate, and the lower sheet – for the stretched side.

The position of the topological model in Figure 12 (a) at an angle to the axis (%) illustrates the well-known fact of acceleration of corrosion under stress, regardless of the sign of deformation [387]. Thus, all the points of the model surface are above the value of the parameter of state in the absence of external influence. For better visualization of the image of the quality situation being observed, the bottom sheet of the assembly is conditionally torn off.

The projection of the flat sector of manifold of the catastrophe «ruffle» onto the plane of control parameters is the so-called Maxwell's set (dashed line in Figure 12). According to this bifurcation scheme, movement from one sheet to another occurs whenever the control parameter ε crosses the set (structure of the shock wave), i.e. changes its sign to the opposite.

Thus, deformation of the sample ε in this case should be interpreted as the initial imperfectionwith making allowance for presence in the initial (undistorted) state of surface tension which is added to the applied stress when the plate is stretched and subtracted from it when the plate is compressed. In other words, this symmetry-breaking single control parameter of geometric imperfection is adequate to the balance of all stresses in a bent sample. Consequently, the effect of the sign of deformation in the phenomena of corrosion under stress may be interpreted (in the terminology of the involved theory) as sensitivity to imperfection.

To simulate the reversal of the deformation sign effect (Fig.11) it also seems appropriate to use a catastrophe of the «ruffle» type, but under condition of observing the principle of maximum delay (Fig.13). According to this scenario, the system jumps into another state only when it has no other choice.

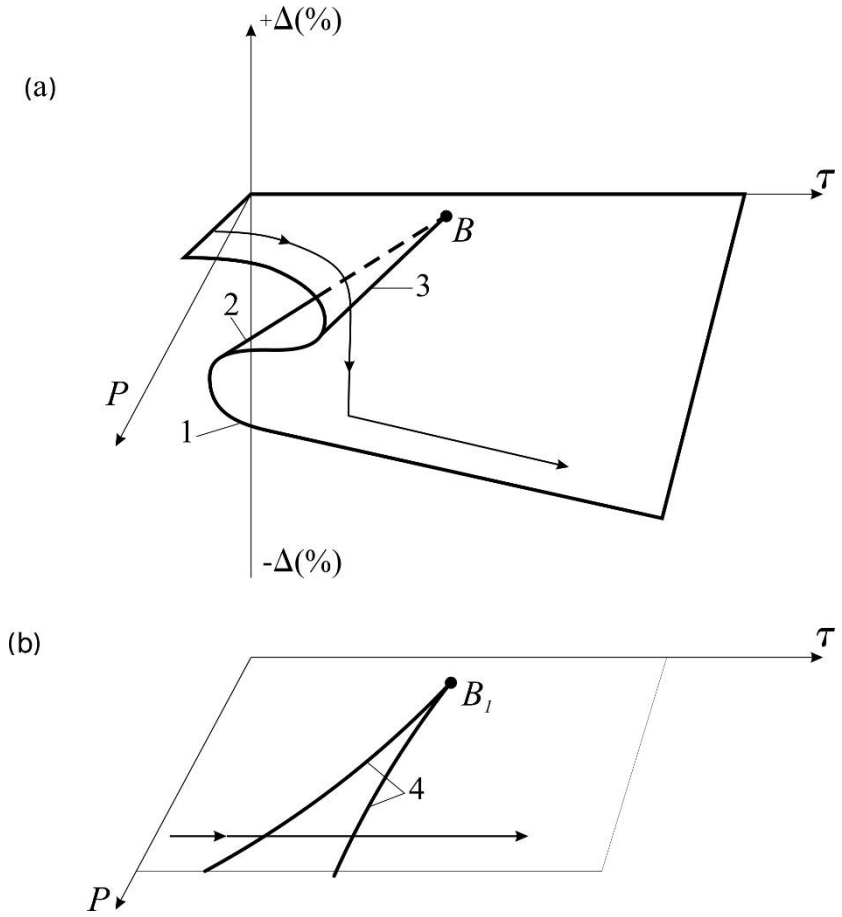


Figure 13. Topological model of reversing the effect of the deformation sign (catastrophe «ruffle», the principle of maximum delay): (a) – three-dimensional surface in the coordinates Δ(%), τ and P (1 – cross section of the model; 2 and 3 – fold lines; B – assembly point); (b) – projection of the model onto the plane of the control parameters τ and P (4 – bifurcation curve, i.e. bifurcation set; B_1 – bifurcation point)

The investigated phenomenon is proposed to be described using two control parameters: P (as in the first case) and the time τ. As the state parameter, the difference in mass loss Δ (%) of the concave and convex sides of the curved sample was chosen:

$$\text{if } (\%)_{\text{concave}} > (\%)_{\text{convex}}, \text{ then } (\%)_{\text{concave}} - (\%)_{\text{convex}} = +\Delta(\%);$$
$$\text{if } (\%)_{\text{concave}} < (\%)_{\text{convex}}, \text{ then } (\%)_{\text{concave}} - (\%)_{\text{convex}} = -\Delta(\%).$$

Thus, the top sheet of the surface corresponds to the realization of the effect of the sign of deformation, and the bottom sheet corresponds to the fact of its reversal. Since in the absence of external influence the symmetry of the sides of the plate is not broken, i.e. Δ(%) = 0, thus the corresponding section of the assembly coincides with the axis τ.

The most interesting property of this surface is the presence of two fold lines starting at the so-called assembly point B which form a bifurcation curve with a tip at

point B_1 on the plane of the control parameters τ and P (Fig.13). These points correspond to the P_{cr} value (in presence of the time coordinate), which, if reached, after some time [387] causes occurrence of cracks, which initiate the phenomenon of reversal of the deformation sign effect. It should be noted that when constructing the topological model, the acceleration of the onset of crack formation according to increase in load (i.e., a decrease in withstanding) is to be taken into account.

In the general case, the bifurcation curve divides the control space into areas which are adequate to the various modes of the system functioning. Qualitative changes in its behavior occur only when the «trajectory», formed by a combination of control parameters, leaves the region inside this curve. It is in such a situation the state parameter Δ (%) jumps.

Qualitative features of behavior (signs of catastrophe) of the under study make it possible to simulate the general picture of the ongoing mechanochemical processes. If the sample mass loss (%) is presented as a function of two properly selected control parameters, then gap changes in the state of the system under study are described quite clearly with the help of a catastrophe of the «ruffle» type. In particular, the interpretation of the effect of the sign of deformation as sensitivity to imperfection does not contradict the provisions of mechanochemistry. In addition, expanding the scope of the experiment (due to the directed variation of the qualitative and quantitative composition of the aggressive environment, the type and value of external influences, etc.) will make it possible to use synergetic ideas for further research of these nontrivial effects, which have been first discovered in laboratory systems [387].

Thus, the experimentally discovered regularities considered above, despite diversity of types of control parameters, may be described from a single point of view and in a single topological scheme.

According to Poston and Stewart [369], the catastrophe theory approach should be seen as predicting what would be useful to look for, rather than what should certainly be seen. At present, only experiment may serve for determining which aspects of the considered phenomena may be effectively described using this approach, and which may not.

In the future, the use of this approach would be expedient to be extended to a wider range of problems in building materials science related to the variety of phenomena which have not yet been studied enough.