Irreversibility and physics of evolution

V.M. Somsikov

Institute of Ionosphere, Almaty, Kazakhstan
(E-mail: vmsoms@rambler.ru)

Abstract. The short description of creation of the mechanics of the structured particles is given. The essence of this mechanics is that in it instead of the basic model of the material point, used in Newton's mechanics, the model of the structured particle is used. The taking into account structure in basic model of the bodies' led to a possibility of the description of dissipative processes. The principle of duality of the symmetries (PDS) is a basic concept of this mechanics. According to the PDS, the body dynamics is determined not only by the symmetry of space, as in the case of a material point, but by the symmetries of the body also. The concept of evolutionary nonlinearity responsible for the violation of symmetry of system dynamics is introduced. It was shown, why and how the infinite divisibility of matter follow from the laws of mechanics. The D-entropy, defined as the ratio of the change of internal energy of the system to its full value is proposed. The possibility of rationale of the laws of thermodynamics, statistical physics, in the frame of the mechanics of the structured particles is shown.
Keywords: Classical mechanics, irreversibility, entropy, chaos, evolution.

> "If you find that your theory contradicts the observations, - well, and experimenters might be wrong. But if it turns out that your theory contradicts the second law of thermodynamics, then you have not the slightest hope: your theory is doomed to an ignominious end"
>
> A.S. Eddington

1 Introduction

The Newton's mechanics that was created about three centuries ago and the formalisms of Lagrange and Hamilton, which was developed basing on it, is a foundations of modern physics. The successes of the mechanics in the 18th century were so impressive that the Boltzmann set out to build a mechanistic model of matter in accordance with Darwin's theory of evolution basing on the molecular-kinetic theory of the structure of substance [1-3]. He was convinced that all natural phenomena, including the development of living matter, could be described under the laws of mechanics. However, Boltzmann at the very beginning of his way has been faced with contradiction between a mechanistic picture of model of the world and reality. Indeed, in according with the formalisms of the classical mechanics, the processes in nature are reversible. However, the natural processes, including the evolution of the surrounding world, irreversible. Boltzmann and all of his followers could not overcome this contradiction. Up to now the modern physics, which is based on the formalism of classical mechanics, well enough describe the dynamics of the system near

Received: 26 October 2017 / Accepted: 12 December 2017

ISSN 2241-0503

equilibrium states, but does not describe the process of their emergence and evolution. Prigogine showed that it is impossible to construct evolution physics, without having solved an irreversibility problem. In addition, it is impossible to substantiate of the empirical thermodynamics, statistical physics, kinetics, quantum mechanics, etc. without solution of the irreversibility problem. It is also impossible to explain the nature of the violation of symmetry and the nature of evolution, including the explanation of the changing climate on the Earth [4, 5]. Therefore, the problem of irreversibility up to now is a key problem of physics [6].

Impossibility of a solution of the irreversibility problem within the frames of the laws of classical mechanics required to use the hypothesis about existence of the fluctuations in the Hamiltonian systems for its decision. These fluctuations cause irreversible dynamics in the exponentially unstable Hamiltonian systems [2]. However, this hypothesis is alien to laws of the fundamental physics. Its use means that either classical mechanics is not complete, or the evolution of nature is probabilistic in nature. An analysis of numerous attempts to solve the problem of irreversibility leads to the conclusion about the limitations of formalism of classical mechanics, but not the restrictions of the laws of mechanics, based on which they are built [7]. We will show that if to build the mechanics for the structural bodies, we obtain possibility to describe the processes of the evolution. Here, we will discuss the key ideas that formed the basis of the mechanics of the structural particles (**SP**), the stages of its construction, as well as the main results obtained during its construction. The paper will consists from the three parts: the study of the hard discs systems, the study of the systems of potentially interaction of the material points (**MP**), and the analyzing of the mechanism of irreversibility of the non-equilibrium systems (**NS**).

2. Dynamics of discs systems

The dynamics of hard discs and spheres was studied for a long time for understand the irreversibility nature. The main results of their research are the exponential instability, mixing property, etc. [8-10]. Based on these results, which was obtained around the end of the 90s of the last century, we began to study the dynamics of colliding hard-disks systems [11-12]. The purpose of our research was to study the mechanism of the equilibration in the disk systems.

Based on the collision matrix for discs the motion equation for the discs systems has been obtained [11, 12]:

$$\dot{V}_k = \Phi_{kj}\delta(\psi_{kj}(t))\Delta_{kj} \tag{1}$$

where $\psi_{kj} = [|l_{kj}(t)| - D]/|\Delta_{kj}|$; $\delta(\psi_{kj})-$ is a delta function; $l_{kj}(t) = z_{kj}^0 + \int_0^t \Delta_{kj} dt$ – is a distance between centers of the colliding discs; $\Phi_{kj} = i(l_{kj}\Delta_{kj})/(|l_{kj}|\,|\Delta_{kj}|)$; $z_{kj}^0 = z_k^0 - z_j^0 -$ is the initial values of the coordinates of disks; $D-$ is a disks diameter. Strikes are considered central, friction is neglected. The masses and diameters of the disks are assumed equal to unity. Moments of collision and the colliding partners defined by the condition, $\psi_{kj} = 0$.

The important result obtained of the discs investigation are that the work of external forces, acting on the discs system, is going both on the motion of the disks system, and on the change of its internal energy. The internal energy of the discs system is determined by the motion of the disks relative to the center of mass (CM) of their system. It was obtained from the numerical calculations that if the amount of the disks in the system is large enough, the internal energy will only increase [9-11]. This allow introducing the concept of entropy for the dynamics of the systems, defining it as the ratio of the increment of internal energy of the system to its full value.

The following key results of the disks investigation were obtained: the main factor the transformation of disks motion energy into the internal energy of the system is the processes of collisions of the disks; the laws of mechanics do not prohibit irreversibility for transformation motion energy of the disks system into the its internal energy [7].

Further study of the irreversibility problem, based on the hard-disks system, was faced with fundamental limitations. For example, they are connected with non-potentiality of the disks colliding. Therefore, at the following stage of researches of a problem of irreversibility it was decided to consider dynamics of systems of potentially interacting MP. These models are in excellent accordance with Newtonian mechanics, as well as with the molecular - kinetic theory.

3. Dynamics of systems of potentially interacting MP

3.1. The principle of duality of symmetry

By studying of the discs systems, we concluded that irreversibility is impossible for structureless bodies. Indeed, if the homogeneity of time is associated with the invariance of the motion energy, then its transformation into other types of energy is equivalent to breaking of the time symmetry. It is just as the brick's motion energy is converted into heat, when the brick slides on the inclined surface. In this case although the motion energy and internal energy are no invariants, the full energy which equal their sum is invariant. Therefore, we can assume that the irreversibility connected with the increasing of the internal energy of the system due to the motion energy, when the sum of these energies is invariant. Thus, for the solving of the irreversibility problem, it is necessary have the equation describes the transformation of the energy of the body's motion into the internal energy. We will show how this can be done using the possibility of obtaining the motion equation of the MP system in an inhomogeneous field of forces directly from the energy when it is submitted as the invariant sum of the system's motion energy and its internal energy.

The trajectory of the motion of the MP system in space and its energy are determined by the symmetries of space-time. The internal energy of the system is determined by the distribution of MP relative to the CM, that is, by internal symmetries. The nature of the system's motion depends on the work of external forces, which go to both on the motion of the system and on the change in internal energy. Thus, the system's motion is determined not only by the symmetries of space as in the case of unstructured body, but also by its internal symmetries. This conclusion is a key to the construction of the mechanics of the systems therefore; it was called as the principle of the duality of the symmetry

(PDS) [7]. **In according with the PDS, the dynamics of bodies is determined both as their internal symmetries and as the symmetries of space**. The PDS is connected with Galileo's principle of relativity [13,14]. Indeed, in a homogeneous space the system retains a state of rest or uniform rectilinear motion, regardless of the nature of the internal forces and the motions of its elements relative to the CM. That is, the internal dynamics of the elements of the system is determined by internal symmetries.

Each group of symmetries associated with invariants [15]. A key invariant for dynamical systems is energy. In accordance with the PDS, the energy of the system should be represented as the sum of the internal energy and the motion energy. As will be shown, the need for such a representation of energy follows from the independence of the dynamic groups: the group of variables that determine the motion of the elements of the system relative to the CM, and the group of variables that determine the motion of the system as a whole. Therefore, in order to obtain the system's motion equation, energy has to be written down in the two groups of variables: in the variables that determine the energy of the motion of the each MP of the system relative to its CM, and in the variables that determine the motion energy of the system. We called the first group as micro variables, and the second group are macro variables.

Let us show that the micro - and macro variables are independent groups of variables, in which the full energy of the system decays on the motion energy and internal energy. Let us take the system, which consists from the N potentially interacting MP. Each MP have a unit mass. The potential forces acting on each MP are equal to the sum of forces acting from other MP and from external forces. The additivity of the forces for each MP follows from their potentiality. The forces between MP are determined by the distance between them. The kinetic energy of the system is equal to the sum of the kinetic energies MP. I.e., $T_N = \sum_{i=1}^{N} mv_i^2/2$, where v_i -is velocity of i-th MP in laboratory systems of the coordinate. The potential energy of the system in the field of external forces is U_N^{env}. It is equal to the sum of the potential energies for each MP. The potential component of the internal energy is a sum of the energies of pair interactions between each MP. It is equal to: $U_N^{ins}(r_{ij}) = \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} U_{ij}(r_{ij})$, where i, j - is a number of each MP, $i, j = 1,2,3...N$, N -is amount of MP; $r_{ij} = r_i - r_j$ is a distance between i and j elements. The energy in laboratory system of coordinate has an appearance:

$$E_N = T_N + U_N^{ins} + U_N^{env} = const \tag{2}$$

Let us write the expression (2) in the micro - and macro variables and call the appropriate system of coordinates as a "**dual coordinate system**". We will show that in a dual coordinate system, the energy is the sum of the motion energy of the system and the sum of the energies of the relative motion of MP. After that, we will show that the amount of energy of the relative motion of MP coincides with the sum of the motion energies of MP with respect to the CM.

The quadratic function of the kinetic energy can be written as quadratic function, in which the arguments are the speeds of MP relative to the CM and the speed of CM of system. It is follows from the equation: $N\sum_{i=1}^{N} v_i^2 = (\sum_{i=1}^{N} v_i)^2 + \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} v_{ij}^2$. Let us execute replacement in this equation: $V_N = (\sum_{i=1}^{N} v_i)/N$ - is a velocity of CM; $v_i - v_j = v_{ij} = \dot{r}_{ij}$. We will have $T_N = [M_N V_N^2 + m/N\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} v_{ij}^2]/2$ (a). Let us execute replacement in (a) $v_i = V_N + \tilde{v}_i$, where $\tilde{v}_i$ - is a particles' motion velocity relative to the CM. Because $\sum_{i=1}^{N} \tilde{v}_i = 0$, we will have: $T_N = M_N V_N^2/2 + \sum_{i=1}^{N} m\tilde{v}_i^2/2$. Therefore, the sum of the relative motions energies of MP are equal to the sum of kinetic energies of motion of MP relative to CM. Thus, the kinetic energy of the system, in the micro - and macro variables broke up on the sum of independent quadratic functions of speeds.

The potential component of the system motion energy in the external field of forces is determined by the sum of potential energies of all MP in the external field of forces. This energy corresponds to the potential energy of the MP, with mass is equal to the mass of the system, located in the CM, and determined by the macro variables. The potential component of the internal energy is the interaction energy of the MP determining by the micro variables.

Thus, micro - and macro variables belong to the two different symmetry groups. The independence of micro - and macro variables is a mathematical confirmation of the PDS and indicates on the presence of two invariants corresponding to symmetry groups defining the motion of bodies [15].

The state of the SP in the laboratory system of the coordinate is determined by the ambiguous function of variables, because in it the coordinates and velocities of each MP are dependent from the independent internal and external forces. This confirms the need for a transition to micro - and macro variables. The necessity of such a representation is clear on the example of the solution of the task of motion of oscillator through a potential barrier [16, 17]. Only taking into account the exchange between motion energy and internal energy it possible to explain its sub barrier passage, when the barrier energy is above the motion energy, but less than the total energy of the oscillator. This effect cannot be find without of the energy representation as a sum of motion energy and internal energy. It is also hardly possible to find solution of the *N*-body problem without such representation of the energy.

The expression for the energy in the dual coordinate system has the form [7]:

$$E_N = E_N^{tr} + E_N^{\text{int}}, \tag{3}$$

where $E_N^{\text{int}} = T_N^{ins} + U_N^{ins}$ - is internal energy (without part of the external potential energy which appearing in inhomogeneous field of forces), $T_N^{ins} = \sum_{i=1}^{N} m\tilde{v}_i^2/2$ - is a kinetic part of the internal energy of the system, T_N^{tr} - is a kinetic part of the motion energy of the system, $E_N^{tr} = T_N^{tr} + U_N^{tr}$ - is a motion energy. Thus, in accordance with the PDS we have the next law of the energy conservation of the system: **the energy of the system so change along of the CM path, that the sum of the motion energy and internal energy is invariant.**

3.2. The system's motion equations

Differentiating the system's energy (3) with respect to time, we obtain [18]:

$$V_N M_N \dot{V}_N + \dot{E}_N^{ins} = -V_N F^{env} - \Phi^{env}, \qquad (4)$$

Where $M_N = mN$, $F_i^{env} = \partial U^{env} / \partial \tilde{r}_i$, $F^{env} = \sum_{i=1}^{N} F_i^{env}(R_N, \tilde{r}_i)$, $\Phi^{env} = \sum_{i=1}^{N} \tilde{v}_i F_i^{env}(R_N, \tilde{r}_i)$, $\dot{E}_N^{ins} = T_N^{ins}(\tilde{v}_i) + U_N^{ins}(\tilde{r}_i) = \sum_{i=1}^{N} \tilde{v}_i (m\dot{\tilde{v}}_i + F(\tilde{r}_i)_i)$.

The eq. (4) determines the change of the system's energy and in an external field of force. Multiplying eq. (4) on V, dividing it by V^2, leaving the inertial force on the left hand-side, we obtain the system's motion equation:

$$M_N \dot{V}_N = -F^{env} - \alpha_N V_N, \qquad (5)$$

where $\alpha_N = (\Phi^{env} + \dot{E}_N^{ins}) / V_N^2$ -is a coefficient that determines the change of the internal energy. The first term in the right-hand side of eq. (5) is the force applied to the CM of the system. It determines the system's motion as a whole. The second term depends on the micro- and macro variables and determines the change of the internal energy. This term is nonzero only in the presence of the gradient of the external forces [18]. In this case, the system motion energy is no invariant. This means breaking of the time symmetry.

There is exist another way for obtaining of the system's motion equation by summing up the energy changes for each MP. This way allowed us to divide the all forces on forces that change internal energy and the forces that move the system as a whole. This equation has the form [7, 18, 19]:

$$M_N \dot{V}_N = -\sum_{i=1}^{N} F_i^0 - \frac{V_N}{N V_N^2} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} v_{ij} (m\dot{v}_{ij} + F_{ij}^0 + NF_{ij}) \qquad (6)$$

Here F_i^0 -is external force, acted on i-th MP; F_{ij} - is interaction force i and j MP; $F_{ij}^0 = F_i^0 - F_j^0$. In the eq. (6), the first and second terms equivalent to the first and second terms of the eq. (5) consequently.

The second term in eq. (6), determining the change in internal energy, arises only in the presence of a difference in the velocities of the MP and the gradients of the forces acting on them.

In generally the eqs. (5, 6) are non-symmetrical on times.

Let us emphasize that the eqs. (5,6) automatically follow from the condition of conservation of the system energy, which in accordance with the PDS is represented as a sum of internal energy and its motion energy through the micro and macro variables.

4. Evolution of non-equilibrium systems

4.1 Formalism of nonequilibrium systems

In the approach of the local thermodynamic equilibrium, the NS can be presented as a set of equilibrium subsystems [21-23]. Therefore, the SP should be taken as a basic model for analyses of NS, which takes into account the role of structure. The internal energy of SP is «clean». The word of "clean" means that for any partition SP on the subsystems, these subsystems do not have the energy of the relative motion. Otherwise, the SP is NS and must be submitted by a set of equilibrium subsystems. In this case, the system motion equation become more complicated due to the terms determining transformation of the energy of relative motion of equilibrium subsystems into their internal energy.

The states of NS are determined by a set of moving SP. Therefore, it can be determined in the phase space of 6(*R*-1) measurements, where *R*- is a number of SP. Accordingly, three coordinates and the three components of their moments define the position of each SP. This space we will call as the S-space, to distinguish it from the usual phase space of Hamiltonian systems.

The SP internal energy increase due to the energy of their relative motion. Therefore S -space is compressible [7, 16], and for to each points of S-spaces correspond different values of the internal energy of the SP. This ambiguity can be eliminated, if to supplement the S-space by the space of micro variables (D-space), which determine the motion of the MP relative to the CM of each SP. Such dual space, we will call by the SD - space. The volume of the SD - space is invariant. The most simple the SD -space is for the case when all SP may be considered in equilibrium during all the time. In this case, the SD-space will be reduced to an S-space with additional *R*-dimensional space. This follows from the fact that to the SP there is only one parameter, which determines the internal state of the system. This parameter is the internal energy [21, 22].

The study of NS is performed based on various empirical modifications of the kinetic equations [21, 22]. Kinetic equations were built based on formalisms of classical mechanics. In turn, these formalisms were constructed based on the Newton's motion equation for MPs using the hypothesis of holonomicity of constraints be fulfilled [13, 14]. This led to the loss of the possibility of a rigorous description of irreversible processes within the framework of canonical formalisms [18]. However, this disadvantage can be eliminate having the extended of the Lagrange, Hamilton, Poisson brackets and Liouville equations. Their obtaining is carried out in a similar way, as in the classical case, but instead of the Newton's motion equation, the motion equation for SP (5, 6) used.

The extended of the Liouville equation has the form [7, 12]:

$$\frac{df_p}{dt} = \frac{\partial f_p}{\partial t} + \sum_{k=1}^{T} \{ v_k (\partial f_p / \partial r_k) + \dot{p}_k (\partial f_p / \partial p_k) \} = - f_p \sum_{k=1}^{T} \partial F_k^p / \partial p_k \qquad (7)$$

Here f_P – is a distribution function for MP in p -th SP, v_k, r_k, p_k - velocities, coordinates and momentum for κ- th MP, *T*- is a quantity of MP in SP, F_k^p - is external forces, acted on κ-th MP.

The condition of holonomic connection is equivalent to the potentiality of the collective forces that determine the motion of the system. This is evident from the fact that the Lagrange equation can be obtained at either by a variation method or by integrating of the d'Alembert equation with respect to time, if the external forces are potential. Integrating the d'Alembert equation with fixed initial and final points of the trajectory of the system, we obtain [13, 14]:

$$\int_{t_1}^{t_2} \delta w dt = \delta \int_{t_1}^{t_2} L dt = \delta A = 0, \qquad (8)$$

where $A = \int_{t_1}^{t_2} L dt$ - is action. The eq. (8) is the principle of the least of action. According to this principle, the system's motion occurs in such a way that a definite integral with fixed initial and final positions of the system has a stationary value with respect to any possible changes of its trajectory.

However, for SP we will have [19]:

$$\int_{t_1}^{t_2} \delta w dt = \delta \int_{t_1}^{t_2} L dt = \delta A^d \neq 0, \qquad (9)$$

Here A^d is the bilinear term, which appeared due to the nonlinear transformation of the system motion energy into internal energy. The eq. (9) was called as the ***extended principle of the least of action.***

4.2. Thermodynamics and mechanics of SP

One of the topical problems of fundamental physics is the justification of thermodynamics in the frames of the laws of the classical mechanics [24, 25].

In the basics of thermodynamics lie the empirical principles: the principle of temperature, the principle of energy, the principle of entropy and the Nernst's postulate. If the parameters of the system in mechanics are the coordinates and velocities of the MP, then in thermodynamics this is the volume, pressure, temperature, entropy. The relationship between the thermodynamic parameters and the parameters of mechanics is established by integrating the MP dynamic parameters. The thermodynamic principle of energy is written as follows [21]:

$$dU = \delta Q - \delta A \qquad (10).$$

where U - is the adiabatic potential, Q - is a thermal energy, A - is a work of external forces to change the volume of the system.

Mechanics SP in accordance with the PDS is based on the dual representation of the system energy as a sum of internal and motion energies. According to eq (3), the total differential of the work of external forces with respect to the displacement SP can be written as follows:

$$dU^{sp} = \delta A^{\text{int}} + \delta A^{tr}, \qquad (11).$$

where δA^{int} - is a change of the internal energy; δA^{tr} - is a change of the motion energy of SP due to the work of the external forces. By analogy with thermodynamics, the eq. (11) can be called as the ***mechanical principle of energy***. The mechanical principle of energy allows taking into account the violation of the time symmetry that arises when the SP moves in an inhomogeneous field of forces.

The common for the thermodynamic and mechanical principle of energy is that they both follow from the PDS. Both in mechanics of SP and in thermodynamics, structured bodies are studied. Both the mechanics of SP and thermodynamics rely on the ideas of the molecular-kinetic theory [21]. However, there are differences as well. While the mechanical principle of energy is determined by the complete work of external forces over a system, the thermodynamic principle of energy includes only work on changing of the internal energy. This work is equal to the sum of work on changing the volume of the body and changing the thermal energy. Hence for the adiabatic potential U there is an equality: $U = A^{\text{int}}$, which is quite natural, since the adiabatic potential corresponds to the law of conservation of the internal energy of the system. In the mechanics of SP, unlike thermodynamics, the work of external forces is considered completely, including the work which go on the moving the system. However, the work on changing the internal energy in the mechanics of SP is not divided into work on changing its volume and heat, as in thermodynamics. In addition, in the mechanics of SP, the gradient of the external field of forces is taken into account. In thermodynamics, the motion energy of the entire system are excluded from consideration [21]. Thus, the mechanical principle of energy more general then thermodynamic principle.

The work on changing of the body volume corresponds to the work for move of the equilibrium subsystems, by a set of which the body can be given. In addition, the thermal energy of the body is equivalent to the sum of the internal energies of these subsystems. Consequently, the thermodynamic and mechanical principles of energy in their physical essence coincide. Therefore, we can argue that the mechanics of the SP allows substantiating thermodynamics.

In the mechanics of SP, as in thermodynamics, the entropy can be introduced if defining it as $\delta E^{\text{int}} / E^{\text{int}}$. It was call as ***D-entropy*** - S^d [20, 24]. D-entropy allows to determine the work of external forces which go on the changing the internal energy of the system. For a closed NS whose volume does not change, the D-entropy is determined by the amount of energy of the relative motions SP that have passed into their internal energy. This leads to the equilibration of NS. For SP, the D-entropy is equivalent to the Clausius entropy, i.e., the second law of thermodynamics is valid for it: $dS^d / dt \geq 0$.

For an NS the change in the D-entropy is determined by the sum of the entropy increments of each SP. This can be written as follows [20, 26-28]:

$$\Delta S^d = \sum_{L=1}^{R} \left\{ N_L \sum_{k=1}^{N_L} [\int \sum_s F_{ks}^L v_k dt] / E_L \right\} \tag{12}$$

Here E_p is internal energy of p-SP; s - is external MP for p-SP which interaction with the k-th MP from p-SP; F_{ks}^p - is a force changing the velocity of k-s MP relative of CM p-SP. This force act from the s - MP from another SP; v_k -is a velocity k-s MP relative CM of SP.

The D-entropy is applicable for a system with a small number of MP. For a small system, the change of the D-entropy can be negative [16].

The D-entropy allows justifying of the Boltzmann's entropy [22]. The Boltzmann entropy, S^B, for the system has the form [22]:

$$S^B = -\int f_p \ln f_p dpdq \, , \qquad (13).$$

Where f_p - is a distribution function.

To justify the eq. (13) in the frame of the classical mechanics laws, it must be shown that $dS^B / dt \neq 0$ [10].

Differentiating the S^B with respect to time, we obtain:

$$\frac{dS^B}{dt} = \int (1 - \ln f_p) \frac{df_p}{dt} dpdq \cdot \tag{14}$$

But according to the canonical Liouville equation, we have: $df^p / dt = 0$ [22]. Therefore, $dS^B / dt = 0$. This contradicts to the second law of thermodynamics. Within the framework of the probabilistic mechanism of irreversibility, the contradiction is removed by "coarse graining" of the phase space, which realized with the help of coarsened distribution function [22]: $F = (\int f_p d\Gamma) / \delta\Gamma$, where $\delta\Gamma$ - is a region of coarsening of phase space. For the coarsened F, the expression (14) is not equal to zero. The disadvantage of this definition of entropy is obvious. Its connected with uncertainty of $\delta\Gamma$. In the mechanics of SP, this shortcoming does not exist. Indeed, according to the extended Liouville equation (12), we have:

$$\frac{dS^B}{dt} = -\int (1 - \ln f_p) f_p (\sum_{k=1}^{T} \frac{\partial F_k^p}{\partial p_k}) dpdq \neq 0 \tag{15}$$

Thus, the Boltzmann entropy can be obtained from the deterministic laws of mechanics basing on mechanics of SP. The character of the system entropy change is determined by integrating the dynamic parameters of the SP, which are the elements of the NS.

4.3. Evolutionary nonlinearity and irreversibility

The aspiration of NS to equilibrium state is connected with that that the energies of the relative motion SP's irreversibly converted into internal energy when the full energy of NS is invariant. However, the mechanism of equilibration is clear only when SP can be considered in equilibrium during all the time. Therefore, there is a question, how to prove the aspiration NS to equilibrium state in the case of strong interactions SP, when their equilibrium can be disturbed? We will show that in this case the irreversibility of NS proving by that that the positive flow of internal energy for each SP greater than its negative flow [26].

Let us consider the motion of SP in an inhomogeneous field of forces. According to eqs. (5, 6) the SP motion energy can be converted into internal energy. Suppose that the value of this transformation is equal to ΔE^{tr}. The value ΔE^{tr} is determined by bilinear terms of the expansion of the field of external forces, which depend from macro - and micro variablesles [28, 29]. The value of the ΔE^{tr} has the second order of smallness. It can be written as: $\Delta E^{tr} \sim \varepsilon^2$ where $\varepsilon << 1$, is a small parameter, for example, the ratio of the small characteristic scale of the SP to the big characteristic scale of inhomogeneity of the external field of forces.

If the field of external forces is small, the equilibrium violation can be ignored. This means that all energy of SP motion will be transformed into their internal energy. However, for sufficiently strong external forces and their gradients, the equilibrium of the SP can be broken. In this case, the SP can be represented as a set of equilibrium subsystems having nonzero relative velocity. Then the increase of the internal energy for SP - ΔE^{tr}, is equal to the sum of the increments of energy of equilibrium for relative motions of the subsystems, and ΔE^{h} - is increase of internal energy of these equilibrium subsystems. Consequently, the inequality: $\Delta E^{tr}_{ins} < \Delta E^{tr}$ have a place.

According to the eqs. (5, 6), only the energy of the relative motions of the subsystems can go back into the motion energy of the SP. Let it is equal to ΔE^{tr}_{ret}. The value ΔE^{tr}_{ret} is also determined by a nonlinear function of the macro - and micro variables that characterize the motion energy and internal energy of the subsystems. Here, the micro variables determine the motion MP relative to CM of the subsystems, and macro variables determine the motion of the CM of the subsystems. Because positive and negative flows of the energy in the system are determined by bilinear terms, then ΔE^{tr}_{ret} also will be determined by the terms not more than the second order of smallness ΔE^{tr}. But the ΔE^{tr} is already term of a second order of smallness. Therefore, ΔE^{tr}_{ret} not more than fourth order of smallness. Hence we have: $\Delta E^{tr}_{ret} \le \varepsilon^{4}$. Then, for sufficiently large systems the inequality $\Delta E^{tr}_{ret} << \Delta E^{tr}$ will be have a place. Thus, the value of reverse energy flow ΔE^{tr}_{ret} less than the value of ΔE^{tr}. It is leads to an increase in D - entropy, and hence to equilibration NS. This is a key role of "evolutionary nonlinearity" in the dynamic of the systems.

Let us explain why for small systems the D - entropy can be negative and only for a big enough systems, the D - entropy is positive. Thus, only big enough systems are irreversible.

According to analytical and numerical calculations of the system motion equations, moving in an inhomogeneous field of external forces, the internal energy for small systems can be converted into the motion energy for some initial conditions. This effect has a place for the oscillator. However, with the increase of number of MP in a system, the part of the internal energy, which can return into the motion energy of the system, decreases. The change of the internal energy only positive when the $N > 100$. When $N >> 10^{3}$, the D-entropy of the systems goes to the asymptotic [16, 17].

The numerical calculations of the D-entropy showed that the value fluctuations of the motion and internal energy, due to different initial conditions, obey the law $1/\sqrt{N}$ [21, 22]. Therefore, the inequality $\Delta E^{tr} > \Delta E^{tr}_{ret}$ have a place only in average. For sufficiently small N, the value of the reverse flow δE^{tr}_{ret} for some beginning point, may be greater than the value ΔE^{tr} (where δ used to indicate the fluctuations of the corresponding parameter). That is, for sufficiently small N in some cases the inequality $\delta E^{tr}_{ret} > \Delta E^{tr}$ have a place, despite the fact that in average the value of ΔE^{tr} on two orders of magnitude higher than the ΔE_{ret}^{tr} . With increasing of number of particles, the fluctuations are reduced and the inequality $\delta E_{ret}^{tr} < \Delta E^{tr}$ always has a place.

Thus, we showed that the tendency of the system to an equilibrium state, which corresponds to the maximum probability, is following from the laws of mechanics. We also shown **that the statistical laws for systems follow from the laws of classical mechanics!** Note that for stationarity of NS is necessary that the equality $\Delta E_{ret}^{tr} = \Delta E^{tr}$ has a place at all hierarchical levels of the matter. However, the laws of classical mechanics no longer describe the realization of this equality, because in nature, it can be realized through the heat radiation of the body defined by Planck's formula [19].

Conclusions

The reversibility of the Hamilton formalism have a place due to the hypothesis of holonomicity of the constraines, which is used for the construction of this formalism basing on the Newton’s laws [14]. This hypothesis limits the applicability of the formalism only for description of reversible processes in equilibrium systems or for the systems near to equilibrium. The attempts to find a solution of the irreversibility problem basing on formalisms of classical mechanics, led to using of the hypothesis about probabilistic fluctuations, which alien for the classical mechanics. To exclude this alogism, arose the idea to seek irreversibility mechanism basing on the laws of classical mechanics but without using the formalisms of classical mechanics. Based on the PDS, this idea was realized by constructing the mechanics of systems, when instead of the body model in the form of MP, the system is used.

In connection with the PDS to obtain of the motion equation from the energy expression of the system, the energy should be submitted as the sum of the motion energy and the internal energy. It can be done in spaces of the independent groups of micro - and macro variables. This allowed obtaining the motion equation describing the transformation of the motion energy into the internal energy and explaining of the irreversibility problem in the frame of the classical mechanics laws [26-29].

The transformation of the systems motion energy into the internal energy is described by nonlinear bilinear terms of expansion of the external field of forces. These terms depend on the micro- and macro variables. The class of nonlinearities determined by these bi-symmetrical terms was named as *evolutionary nonlinearity*. Because this nonlinearity determine the transformation of the systems motion energy into internal energy it responsible for the violation of time symmetry.

The irreversibility of the system motion equations is due to the fact, that the motion energy flow into the internal energy is proportional to the second degree of smallness, but the reverse flow is proportional to the fourth degree of smallness.

Ability to describing of the dissipative processes in the framework of the classical mechanics allowed us to introduce the concept of D - entropy. The D -

entropy was defined as the ratio of the change of the system's internal energy to its magnitude. Thermodynamics and probabilistic types of entropy are following from the D - entropy for systems with a sufficiently large number of MP.

The ideas used to solve of the irreversibility problem have a significant commonality for different branch of the physics. For example, the extended Schrödinger equation constructed based on the PDS allows one to describe the violation of the time symmetry in the dynamics of quantum systems and to submit new explanation of the EPR paradox [31] based on idea that all microparticles have an internal structure, with which the uncertainty of energy is connected [19].

The mechanics of the systems are applicable to calculate the energy fluxes in the universe, since galaxies, stars, planets move in the external inhomogeneous fields. The motion equation of SP can be useful for estimation of the mass and energy of the Universe. It is difficult to understand the nature of nuclear processes in high-energy physics without taking into account the internal structure of microparticles. Problems of climate change are faced with the lack of the necessary fundamental equations describing the processes of evolution of the NS, for the production of which the mechanics of systems are needed.

The mechanics of systems testifies to the possibility of constructing models of matter based on its elements. Since bodies have new properties, such a construction is equivalent to explaining the transition of 'quantity to quality", which characterizes the processes of the evolution of matter. Such a transition is built within the framework of fundamental principles: the Galilean relativity principle, the PDS, and the energy conservation law. Therefore, the existence of the transition from the "quantity to quality" within the framework of the fundamental laws of physics testifies in favor of the possibility of constructing a physical "theory of everything" based on basic principles, as suggested in [30].

The solving the irreversibility problem shows that the development of physics can go not only along the path of revealing the essence of new physical phenomena, but also as a result of removing restrictions from existing theories. After all, the mechanism of irreversibility was found because at the stage of constructing of the body's motion equations within the framework of the classical mechanics laws, the structure of matter was taken into account whose existence at the first stage of the construction of mechanics had to be neglected [27-29].

The key idea underlying the deterministic mechanism of irreversibility is that that in nature all bodies have a structure. So, the energy must be represented in the form of the body motion energy and its internal energy. In accordance with it, the law of the energy conservation of the system is that the energy of the system so change along of the CM path, that invariant is the sum of the motion energy and internal energy. The irreversibility is appeared due to transformation of the motion energy into internal energy when their sum of it is preserved. Therefore, irreversibility cannot exist for unstructured body. From the system's mechanics is follows that the matter in the Universe is infinitely divisible; because the matter cannot be created without dissipation, but dissipation cannot be exist without body's structure.

The SP mechanics open the way to creation of the physics of evolution, as it describes dissipative processes in the open non-equilibrium systems.

References

1. I. Prigogine. From Being to Becoming, Nauka, Moscow, 1980.
2. G. M. Zaslavsky. Stochasticity of dynamical systems, Nauka, Moscow, 1984.
3. J. L. Lebowitz. Boltzmann's entropy and time's arrow, Phys. Today, 46, 9{32, 1993.
4. A. Yu. Loskutov, A.S. Mikhailov. Introduction to Synergetics, Sci., Moscow, 1990.
5. D. A. Stainforth, T. Aina1, C.Christensen et.al. Uncertainty in predictions of the climate response to rising levels of greenhouse gases, Nature, 433, 2005.
6. V. L. Ginzburg. Special session ed. Collegium of the journal, dedicated to the 90th anniversary of the Ginzburg V.L. UFN, 177, 4, 345, 2007.
7. V. M. Somsikov. To the basics of the physics of evolution, Almaty, 2016.
8. N. S Kryilov. Papers on substantiation of statistical physics: L. Publishing House of USSR AS, 1950.
9. Y. G. Sinai, G. Ya. Dynamical system with elastic reflection ergodynamic properties of scattering billiards. Uspekhi Mat. Nauk, 25, 141{192, 1970.
10. Y. G. Sinai. Modern problems of ergodic theory, FIZMATLIT, Moscow, 1995.
11. V.M. Somsikov. Non-recurrence problem in evolution of a hard-disk system, IJBC, 11, 11, 2863{2866, 2011.
12. V. M. Somsikov. The equilibration of a hard–disks system, IJBC, 14, 11, 4027{4033, 2004.
13. H. Goldstein. Classical Mechanics, Science, Moscow, 1975.
14. C. Lanczos. The variational principles of mechanics, Peace, Moscow, 1962.
15. G.Y. Lyubarskii. Group theory and its application in physics,Fiz.mat, Moscow, 1958.
16. V. M. Somsikov, A.B Andreev. On criteria of transition to thermodynamic description of system dynamics, Russian Physics Journal, 58, 11, 2016.
17. V. M. Somsikov, A. Mokhnatkin. Non-Linear Forces and Irreversibility Problem in Classical Mechanics, Journal of Modern Physics, 5, 1, 17{22, 2014.
18. V. M. Somsikov. Transition from the mechanics of material points to the mechanics of structured particles, Modern Physics Letter B, 4, 1{11, 2016.
19. V. M. Somsikov. Extension of the Schrodinger equation, EPJ Web of Conferences Baldin, ISHEPP XXIII, Dubna, 1{7, 2017.
20. V. M. Somsikov. Thermodynamics and classical mechanics, Journal of physics: Conference series, 23, 7{16, 2005.
21. Yu. B Rumer, M. Sh. Rivkin. Thermodynamics, Statistical physics and Kinematics, Nauka, Moscow, 1977.
22. L. D. Landau, E.M. Lifshitz. Statistical physics, Nauka, Moscow, 1976.
23. Yu. L. Klimontovich. Statistical theory of open systems, Janus, Moscow, 1995.
24. V. M. Somsikov. The Dynamical Entropy. International Journal of Sciences, 4, 30{36, 2015.
25. D. Castelvecchi. Battle between quantum and thermodynamic laws heats up, Nature, 543, 597{598, 2017.
26. V.M. Somsikov. Non-Linearity of Dynamics of the Non-Equilibrium Systems, World Journal of Mechanics, 2, 7, 11{23, 2017.
27. V. M. Somsikov. The Irreversibly Mechanics of the Structured Particles Systems, 2nd Chaotic Modeling and Simulation International Conference, Chania, Crete, Greece, 1{6, 2009.

28. V. M. Somsikov. About Principles creating of the structured particles mechanics, Proceeding 4thChaotic Modeling and Simulation International Conference, Agios Nikolaos, Grete ,Greece, 565{571, 2011.
29. V. M. Somsikov. How irreversibility was lost in classical mechanics and how it's can be returned, Proceedings 8-th Chaotic Modeling and Simulation International Conference, Henri Poincare Institute, Paris, France, 803{817, 2015.
30. G. W't. Hooft. Free Will in the Theory of Everything arXiv:1709.02874v1 [quant-ph] 8 Sep 2017.
31. J. S. Bell. On the Einstein-Podolsky-Rosen paradox, Physics, 1, 195{200, 1964.