HOW TO CONSTRUCT OF MECHANICS OF THE STRUCTURED PARTICLES

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(Dated: May 1, 2014)

The mechanics of structured particles (SP) consisting from potentially interacting material points are discussed. For this purpose the derivation of the SP equation motion in the field of external forces is submitted. The differences between the properties of the dynamics of material point and properties of the dynamics of SP are analyzed. The explanation of how mechanics of the SP leads to the account of dissipative forces is submitted. The derivation of Lagrange, Hamilton and Liouville equations for SP is shown. The question of why the motions of the SP are determined by the two types of symmetry: internal symmetry of the system and symmetry of space and how it leads to two types of energy and forces accordingly are discussed. It is shown how the concept of entropy arises in classical mechanics. The question how the mechanics of the SP leads to thermodynamics, statistical physics and kinetics is explained.

PACS numbers: 05.45; 02.30.H, J

I. INTRODUCTION

Structure of the world is hierarchical in nature. Upper stage is the Universe. It is composed from galaxies. Galaxy, in its turn, is composed of structural elements. At the lower hierarchical level are molecules and atoms. But they are also systems consisting of "elementary" particles. It is hard to tell how deep it goes down the hierarchical ladder. The limit of divisibility of matter has not yet been found. Thus the world is a hierarchy of systems. Therefore, we can say with confidence that the systems lie at the basis of the world, rather than elements. From this it follows that for correctly building a picture of the world we need to know the laws of creation, interaction and evolution for the systems but not for indivisible elements as it have a place in modern physics.

Since all the bodies have a structure, they have different properties than the elements. First of all, they have internal energy which appeared due to the relative motions of their elements. Therefore as a result of motion of bodies in the external field of forces some part of the energy will go into the internal energy. Consequently, the properties of their dynamics can be studied using the SP motion equation since it describes the process of equilibration.

Thus the mechanics of SP based on the known dynamic properties of the MP must be constructed to investigation of the non-equilibrium systems. The SP mechanics can be constructed on the basis of Newton’s laws for MP in the frames of the following restrictions [5-8]:

1). Every MP belongs to its SP during all process.

2). SP is in equilibrium during all time.

The first restriction eliminates inessential complications related to the necessity to including of MP transition between SP.

The second restriction is equivalent to the requirement of weak interaction.

The aim of this paper is to show how to construct mechanics of SP, based on Newton’s laws for MP and what are the qualitative differences between the dynamics of SP from the dynamics of MP. For this purpose mainly will explained the following questions: how the motion equation for SP can be obtained from the symmetry properties of the space and time; how based on the SP motion equation possible to derive the laws of thermodynamics, statistical physics and kinetics; how the concept of entropy can be introduced in the classical mechanics;
what is a nature of the deterministic irreversibility.

II. THE SYMMETRY PROPERTIES OF SP MECHANICS

Let us explain how the SP motion equation can be obtained based on the symmetry properties space and systems.

If we have a SP where interactions between MP are absent, the motion equation of SP is the sum of the independent MP motion equations. In this case the motion of SP is determined by the sum of solutions of the MP motion equations. But the presence of MP interactions precludes the summation of equations of motion. Thus the presence of interactions between the MP systems is equivalent to the imposition of additional restrictions or external links [3]. On the example of the two-body problem it can be shown that the interaction between MP leads to the interdependence of the coordinates and velocities of MP in the laboratory coordinate system (LCS) [7]. Hence it is clear that the symmetry of the motion equation for the system will be different than the symmetry of Newton’s equation for each MP.

It is well known that for solving the tasks N-body systems necessary to find such transformation of the coordinate of system which leads to separation of the variables. It is equivalent to find transformation of the vector space $L_q$ of the dimension $q$ which determined the motion of the system, into another vector space of the same dimension but in which the vector space splits into independent orthogonal subspaces. In the language of group analysis [9] it is equivalent to the separation of the group representations $T(G_a)$ of the symmetry of the equations of motion of the $G_a$ group (here $a = 1, 2, 3...n$ -number of elements in the $G_a$ group of symmetry) in the vector space $L_q$ into irreducible representations $T_i \subset T_q$, where $i = 1, 2, 3...k$ and $k$ is a number of irreducible representations of the group of symmetry, where $T_q = T_1 \oplus T_2... \oplus T_k$. Each irreducible representation $T_i$ acted in subspace $L_i$, for which we can write $L_q = L_1 + L_2... + L_k$. Thus the vector $r_q = \sum_{i=1}^{k} r_i$ in $L_q$ space decomposed into irreducible components $r_i$. If $q = k$, i.e. $L_q$ decomposes into the basis vectors, the system’s motion equation is integrable. It turns out that for the MP system there exists a transformation of the vector space where it splits into two orthogonal subspaces. Thus we have: $L_q = L_{ins} + L_{out}$, where $L_{ins}$ is a subspace which determined by the internal degree of freedom, $L_{out}$ is a subspace which determined by the symmetry of space. Such replacement of coordinate system corresponds transition to the coordinate system in which the motion of the system decomposes into the motion of center of mass (CM) and the motion of MP with respect to the CM system.

The symmetry of the system is determined by its structure and the nature of the interactions between MP. The $MP$ interactions is determined by the distance between them. Therefore the distance between $MP$ should be choose as the independent variables. In our case these variables will determine the internal dynamics of the system. As the variables that determine the motion of the system in space, we should take the coordinates of the CM of the system. As it easy to see on the example of two-body problem, this a set of variables forms a complete basis of the independent variables that determined the systems dynamics in space [7]. In the next section will shows why and how in these variables the systems energy divided into energy of motion of the system as a whole and the internal energy of the system.

In the new coordinate system we have the motion of the CM in space and motion of the MP relative to the system’s CM. The motion of the CM system is determined by macro variables (coordinates and velocity of the CM system). The motion of MP with respect to the CM expressed in terms of micro variables. Thus the vector space in which the SP motion is defined splits into two orthogonal subspaces.

The motion of an element that has no internal structure in the external field of forces is determined only by the symmetry of the space. But the motion of the system is determined by two types of symmetry: the symmetry of space and symmetry of the system. In this case according to the Noether’s theorem, the dynamics of the system is determined by two types of energy. This is the internal energy and the energy of the system. These energies are independent. They correspond for two types of forces that determine the dynamics of the system. One type of forces determines the system motion; the other is responsible for the SP internal energy.

The forces that change the internal energy do not change the SP velocity because their sum is zero. These forces can only be found through the value of their work. Therefore the SP motion equation can be determined from the energy of the system. This approach allows us to get all the collective forces that determine the dynamics of SP, without imposing on them the requirements of potentiality, as is done in obtaining of the principle of least action [2, 3]. Thus we will construct the mechanics of SP based on the energy.

III. THE ENERGY OF SP

Let us define an expression for the energy of a system of potentially interacting MP with unit mass, i.e. $m = 1$. In a homogeneous space the energy of such a system is not changed although the energy of each MP may vary due to their interactions. Therefore in a homogeneous space the momentum of SP is conserved. Its preservation means the constancy of the CM velocity. The CM velocity is equal to: $V_N = \dot{R}_N = (1/N) \sum_{i=1}^{N} \dot{r}_i$, where $\dot{r}_i$ - velocity for $i$-MP. From here the kinetic energy of the system motion is equal to $T_N^e = M_N V_N^2/2$, where $M_N = Nm$. This energy coincides with the energy of the body with
mass $M_N$ which moving with the velocity of $CM$.

Let us show that the internal kinetic energy $T^{ins}_N$ is equal to the sum of the kinetic energies of $MP$ with respect to the $CM$.

From equality $N \sum_{i=1}^{N} v_i^2 = V_N^2 + \frac{N}{m/N} \sum_{i=1}^{N} \sum_{j=i+1}^{N} v_{ij}^2$ is following that $T_N = M_N V_N^2 / 2 + m/N \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} v_{ij}^2 / 2$ (a),

where $v_{ij} = v_i - v_j$. The first term in (a) is $T^{tr}_N$.

Since the total kinetic energy of the system is equal to the sum of the kinetic energy of the $CM$ and the kinetic component of the internal energy. Then we have:

$$T^{ins}_N = m/N \sum_{i=1}^{N} \sum_{j=i+1}^{N} v_{ij}^2 / 2.$$

Let us transform the energy by a change of variables: $v_i = V_N + \tilde{v}_i$, where $\tilde{v}_i$ is a $MP$ velocity relative to the $CM$. We obtain: $T_N = M_N V_N^2 / 2 + \sum_{i=1}^{N} m\tilde{v}_i^2 / 2$ because $\sum_{i=1}^{N} \tilde{v}_i = 0$.

$$1/N \sum_{i=1}^{N} \sum_{j=i+1}^{N} m\tilde{v}_{ij}^2 / 2.$$

Hence the kinetic energy of the relative motion of the $MP$ is equal to the sum of the kinetic energy of motion relative to the $CM$ and the total kinetic energy of the system is $T_N = T^{tr}_N + T^{ins}_N$.

Because $r_{ij} = \tilde{r}_{ij} = \tilde{r}_i - \tilde{r}_j$, where $-\tilde{r}_i, \tilde{r}_j$ is a coordinate of $MP$ relative to the $CM$ then the potential energy of $i$ and $j$ $MP$ interaction is $U_i(r_{ij}) = U_i(\tilde{r}_{ij})$.

From here the potential internal energy is equal to $U_N = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} U_i(r_{ij}),$ and total internal energy of $SP$ is $E^{ins}_N = T^{ins}_N + U_N$. In homogeneous space the energies $T^{ins}_N$ and $U_N$ are invariants of the motion.

Because $\sum_{i=1}^{N} \tilde{v}_i = 0$ then we have: $\sum_{i=1}^{N} \dot{\tilde{v}}_i = 0$. It means that the sum of the internal forces is equal to zero. But this sum is the sum of the forces of $MP$ interaction. So the internal forces can’t change the momentum of the $CM$. Therefore micro and macro variables are independent. If the system does not affect the properties of space then its total energy is the sum of the kinetic energies of the $MP$, the potential energy of mutual interaction and the potential energy determined by the inhomogeneity of the space. I.e. $E_N = T_N + U_N + U^{env} = const$. Separating the internal energy, we can write:

$$E_N = T^{tr}_N + T^{ins}_N + U_N,$$

where $E^{ins}_N = T^{ins}_N + U_N$, is internal energy, $T^{ins}_N = \sum_{i=1}^{N} m\tilde{v}_i^2 / 2$ is a kinetic part of internal energy, $U_N$ is a potential part of internal energy, determined by the interactions of $MP$.

Thus the internal energy and the energy of motion along the trajectory of the $CM$ system changes so that their sum is always constant. It is the law of conservation of energy of the systems.

**IV. THE MOTION EQUATION OF SP**

Differentiating the energy of $SP$ with respect to time, we obtain [7, 8]:

$$V_N M_N \dot{V}_N + \dot{E}^{ins}_N = -V_N F^{env} - \Phi^{env}$$

Here $F^{env} = \sum_{i=1}^{N} F^{env}_i(R_N, \tilde{r}_i); \dot{E}^{ins}_N = T^{ins}_N(\tilde{v}_i) + \dot{U}^{ins}_N(R_N, \tilde{r}_i) = \sum_{i=1}^{N} \dot{v}_i(m\dot{\tilde{v}}_i + F(\tilde{r}_i)); \Phi^{env} = \sum_{i=1}^{N} \tilde{v}_i F^{env}_i(R_N, \tilde{r}_i); \ \tilde{r}_i = R_N + \tilde{r}_i; \ M_N = m/N;$

$v_i = V_N + \tilde{v}_i; F^{env}_i(R_N, \tilde{r}_i)$-is external force which acts on the $i$-th $MP$; $\tilde{r}_i, \tilde{v}_i$ are the coordinates and velocity of $i$-th $MP$ in the $CM$ system; $R_N, V_N$ are the coordinates and velocity of the $CM$.

Eq. (2) represents the balance of system energy in the field of external forces. The first term in the left hand side gives the change in kinetic energy of the system. The second term determines the change of its internal energy. Thus in the micro and macro variables the work of external forces splits into two terms.

Now let us take the external forces which scale of heterogeneous is commensurable with the systems scales. In this case we can write $F^{env} = F^{env}(R + \tilde{r}_i)$ where $R$ is the distance from the source of force to the $CM$ of the system. Let us assume that $R >> \tilde{r}_i$. In this case the force $F^{env}$ can be expanded with respect to a small parameter. Leaving in the expansion terms of zero and first order we can write: $F^{env}_i = F^{env}_i(R) + (\nabla F^{env}_i)R \tilde{r}_i$. Taking into account that $\sum_{i=1}^{N} \tilde{v}_i = 0$ and $\sum_{i=1}^{N} F^{env}_i |R = NF^{env}_i |R = F^{env}_0,$ we get from (2):

$$V_N (M_N \dot{V}_N) + \sum_{i=1}^{N} \tilde{v}_i (m\dot{\tilde{v}}_i + F(\tilde{r}_i)) \approx -V_N F^{env}_0 - \sum_{i=1}^{N} (\nabla F^{env}_i)R \tilde{v}_i \tilde{r}_i \ (3)$$

In the right-hand side of equation (2) the force $F^{env}$ in the first term depends on $R$. It is a potential force. The second term depending on coordinates of $MP$ and their velocities relative to the $CM$ of the system determines changes in the internal energy of the system. It is proportional to the divergence of the external force. Therefore, in spite of the condition $R >> \tilde{r}_i$ the values of $\tilde{v}_i$ may be not small, and the second term cannot be omitted. Forces corresponding to this term are not potential forces since we can not express them in terms of a gradient of a scalar function. So the change of the
internal energy will not equal to zero when the characteristic scale of inhomogeneities of the external field is commensurable with the scale of the system.

Multiplying eq. (2) by \(V_N\) and dividing by \(V_N^2\) we find the equation of a system motion [5-8]:

\[ M_N \dot{V}_N = -F^{env} - \alpha_N V_N \quad (4) \]

where \(\alpha_N = \frac{\dot{E}_N^{ins} + \Phi^{env}}{V_N^2}\) is a coefficient determined by the change of internal energy.

Unlike the Newton’s motion equations, in the right hand side of eq. (4) the additional term which determines the change in internal energy is appeared. This term depends on the time. Therefore the symmetry of the time of the motion equation for the systems is another then the symmetry of the time for the Newton motion equation for \(MP\).

The equations of Aristotle and Newton are special cases of equation (4). Indeed, according to Aristotle, the motion equation has the form: \(\alpha_N \dot{V} = F\). As can be seen from (4) this condition occurs when the friction force is equal to the external force and acceleration of the system is zero. At the beginning of the movement by the friction force for system can be neglected. Then we obtain Newton equation: \(m\ddot{v} = -F\).

The state of this system composed from a set of \(SP\) can be defined in the phase space which consists of \(6R - 1\) coordinates and momentums of \(SP\), where \(R\) is a number of \(SP\). Location of each \(SP\) is given by three coordinates and their momentums. Let us call this space as \(S\)-space for \(SP\) in order to distinguish it from the usual phase space for \(MP\). The \(S\)-space unlike usual phase space is compressible though total energy of all \(MP\) is a constant. It is caused by transformation of the motion energy of \(SP\) into their internal energy. The velocity of the \(CM\) and the internal energy change when the system moves from one point of \(S\)-space to another. Therefore, the system does not return to initial state if you rotate the velocity of all \(SP\). This ambiguity does not exist in the usual phase space which defines the position of all \(MP\). \(S\)-space coincides with the usual phase space when the internal energy of the \(SP\) does not change.

Hamiltonian formalism is constructed based on the Newton’s motion equation [8]. But the Newton’s motion equation is followed from eq. (4) when the change of internal energy is absent. Therefore, the Hamiltonian systems can be regarded as a special case of dissipative systems.

Because the dynamics of systems from \(SP\) characterized by the trajectory of the \(CM\) in the \(S\)-space, the class of dissipative systems is convenient to call as \(S\)-systems. Most likely, \(S\)-systems as well as the Hamiltonian’s systems are the subsystems of a larger class which is still to determine. This follows from the fact that the \(SP\) model are simplification of real bodies, although more appropriate for reality than the \(MP\) model.

The fact that we’re able to determine the \(SP\) motion equation from expression for its energy or Hamiltonian; follows from the validity of homogeneity of time condition, both for \(MP\) and for the \(SP\) as a whole. The internal energy is expressed through the micro variables which form vector space independent with respect to macro variables space in which the \(SP\) motion determined.

The internal energy can’t be transformed into the system’s motion energy. It is follows from the momentum conservation law of the system. The change of the internal energy is going due to the non-potential collective forces. These forces are changing the \(MP\) velocities with respect to the \(CM\) but they can’t increase the \(SP\) velocity. At the same time a potential component of the total external force that determines the rate of change of the \(CM\) does not change the internal energy. An important fact is that the forces that change the internal energy are determined by the nonlinear terms. These terms depend on the gradient of the external forces [6].

V. THE SP MECHANICS AND THERMODYNAMICS

The task of the thermodynamics is the description of the dynamical processes in the systems consisting from the large number of elements [10]. The thermodynamic method of describing the system is inherently phenomenological. This method does not explain the physical laws of processes in the systems but reveals the characteristic relation between the parameters that determine the systems’ state: the temperature, pressure, density, entropy, etc. The fact that thermodynamics does not allow to understand the physics of the processes is its biggest weakness. To eliminate this drawback should find a connection the laws of classical mechanics with thermodynamics laws. That is the laws of thermodynamics should be follow from the laws of classical mechanics. Let us explain how this problem can be solved with the help of the mechanics of \(SP\) [8, 10].

The work of external forces in thermodynamics breaks up into two parts. One part is related to the reversible work. Another part of energy goes into heating system. According to it, the basic equation of thermodynamics looks like [10]:

\[ dE = dQ - PdY \quad (5) \]

Here \(E\) is the energy of a system; \(Q\) is the thermal energy; \(P\) is the pressure; \(Y\) is the volume. As we deal with equilibrium systems, then \(dQ = TdS\), where \(T\) - temperature, \(S\) - entropy.

According to the eq. (5), coming into the system energy can be divided on two parts. There are energy of relative motion of the \(SP\) and its internal energy. It was showed [5] that in thermodynamics to the change the \(SP\) energy of relative motion corresponds to \(PdV\), and the change in \(SPs\) internal energy corresponds to \(TdS\). Thus, we will come to the basic thermodynamic equation if one carries out standard transition to thermodynamic parameters in the equation (4) [6,7].
Let us take the system consisting from \( R \) numbers of \( SP \). Each \( SP \) consists from \( N_L \) number of \( MP \) and \( N_L \gg 1 \), where \( L = 1, 2, 3, \ldots R \); \( N = \sum_{L=1}^{R} N_L \). Then the share of energy, which goes on internal energy increasing, is determined by the expression [5-7]:

\[
\Delta S = \sum_{L=1}^{R} \{N_L \sum_{k=1}^{N_L} \int \left( \frac{\sum_{s} F_{ks} v_k}{E} \right) dt \}
\]

(6)

Here \( E \) is the kinetic energy of \( L-SP \); \( N_L \) is the number of elements in \( L-SP \); \( L = 1, 2, 3, \ldots R \); \( R \) is the number of \( SP \); \( s \) is the number of external elements which interact with \( k \) element belonging to the \( L-SP \); \( F_{ks} \) is the force acting on the \( k \)-element; \( v_k \) is the velocity of the \( k \)-element.

The eq. (6) can be viewed as an entropy definition in the classical mechanics. This definition of the entropy corresponds to Clausius one [10, 12]. The only difference is that classical entropy follows from analytical expression for the change of an internal energy obtained by us on the basis of Newton’s laws. Thus the internal energy is the energy of the chaos.

From the Eq. (6), it is possible to obtain the value of the entropy production and obtain the conditions which necessary to sustain the non-equilibrium system in the stationary state [10].

Mechanics of \( SP \) leads to statistical physics and kinetics. Indeed, the velocities of \( SP \) are determined by average values of velocities of \( MP \). The sum of the \( MP \) velocities relative to the \( CM \) of \( SP \) is equal to zero. It means that the parameters which defining the dynamics of \( SP \) can be express through the first and second moments of \( MP \) function of distribution [12].

**VI. DETERMINISTIC IRREVERSIBILITY**

The mixing is inherent property of the Hamiltonians systems. This property and the ”coarse-grain” of the phase space hypothesis are used in the basis of the currently known explanations of irreversibility which we will call probabilistic irreversibility [11].

The ”coarse-grain” hypothesis is equivalent to postulating the existence of fluctuations of the external restrictions on the system. But this hypothesis contradicts to the determinism of classical mechanics because it is inconsistent with the laws of classical mechanics. This disadvantage is eliminated in submitted here the deterministic mechanism of the irreversibility [8]. Below we briefly explain the nature of the deterministic irreversibility and compare it with the explanation of probabilistic irreversibility.

Key questions which related to the problem of deterministic irreversibility are the next questions: why irreversibility for the \( SP \) followed from reversibility of the Newton’s motion equation for one \( MP \); how this irreversibility from the Newton’s laws for \( MP \) is followed; what are the limitations of classical mechanics which do not allow to come to the deterministic irreversibility for one \( MP \).

The motion equation for \( SP \) has been obtained subject to the fulfillment the Newton’s laws for \( MP \). Indeed, the energy of \( SP \) is the sum of the energies of \( MP \). The energy of each \( MP \) is equal to the energy of motion and potential energy in the external field and the field of forces acted from another of \( MP \). The motion equations each \( MP \) are Newton’s motion equation and connected with the Newton’s second law for \( MP \). But in a result of construction of the motion equation for \( SP \) basing on the Newton’s laws for \( MP \) it was found that the Newton’s second law is not fulfilled for \( SP \). It is because the work of external forces going not only to the motion of \( SP \) but also change its internal energy. It is the main difference between the dynamics of the \( SP \) and \( MP \).

This result do not contradict to the classical mechanics. Indeed, recall that the principle of the least of action follows from the Newton’s equation if one requires the forces acting on the system to be conservative. Rigorous proof of this hypothesis has not been found. So this condition was assumed a priori [3]. But it was shown that for the non-equilibrium systems this condition is violated. The violation has a place because the internal energy are changes when the motion of the system in an nonhomogeneous space [7]. Therefore the non-equilibrium systems isn’t the Hamiltonian systems and the Poincare’s theorem about reversibility does not apply to them [11].

Thus the deterministic mechanism of the irreversibility was obtained by the strictly mathematical calculations based on the Newton’s laws for \( MP \). This was achieved by describing the system dynamics in the micro and macro variables. Behind the simplicity of the calculations is hidden deep physical reason the break-symmetry of the time for the \( SP \) dynamics in the inhomogeneous space.

Initially, we note that in \( LSC \) the coordinates and velocities of each \( MP \) into \( SP \) are coupled and interdependent. This was shown on the example of system of two \( MP \). It is means that we have no right to do any conclusion about the type of symmetry of the \( SP \) motion equations before transforming the dependent variables in \( LSC \) into the independent variables in the another coordinate of the system.

The differential relations between the coordinates and velocities of \( MP \) are not differentiable in \( LSC \). That is, the presence of \( MP \) interactions due to, for example, Coulombian forces, is equivalent to the nonholonomic constraints. Therefore they do not lead to a decrease in the dimension of the configuration space which determines by the position of the \( SP \) [8]. The nonholonomic constraints are equivalent to the violation of potentiality of the collective forces acting on the system [8]. It is easy to show on the example of the task of two interacting systems [6]. Therefore non-equilibrium systems consisting from the potential interaction of \( MP \) are not Hamiltonian’s systems.
As soon as we go to the micro and macro variables, the space variables for $SP$ are splitted into two orthogonal subspaces. In one of them the dynamics of $MP$'s relative to $CM$ is defined while in the second subspaces the motion of the system as a whole is defined. From here we obtain the energy conservation law for the $SP$. According to this law only total energy which equal to the sum of the energy of motion and internal energy is preserved while each of its components can not be stored in the non-homogeneous space. I.e. the $SP$ can have different values for the internal energy and the motion energy in the given point in the S-space.

The change of the internal energy is determined by the nonlinear terms of the external forces which cause an irreversible transformation of kinetic energy of the $SP$ into internal energy. The irreversibility connected with the inability to change the momentum of $MP$ due to relative moves of the $MP$. It is the essence of deterministic irreversible.

The non-equilibrium system can be submitted as a set of $SP$. Thus in the non-equilibrium systems which are a set of $SP$, the energy of relative motion of $SP$ is transformed into internal energy of the $SP$. When the non-equilibrium system comes close enough to equilibrium, the relative motions of the $SP$ disappears and then the work on changing of the internal energy of the $SP$ disappears too. As a result the system becomes a Hamiltonian and reversible.

Thus the nature of breaking-symmetry of the time for $SP$ associated with the presence of internal degrees of freedom and due to non-linear transformation of the motion energy into internal energy. Such transformation is possible in the presence of inhomogeneities in the external field of forces. The nonlinear terms in the $SP$ motion equations leads to breakdown of the invariance of the two types of energy. But the total energy $SP$ remains invariant.

In non-equilibrium systems which represented by a set of $SP$, the irreversibility appeared due to the fact that the energy of motion of $SP$ is transformed into internal energy of $SP$. We call this irreversibility as a deterministic irreversibility since it strictly follows from the Newton’s laws for $MP$.

In contrast to the probabilistic mechanism of irreversibility the deterministic irreversibility does not require a hypothesis about the "coarse-grain" of the phase space [11]. But in the rest these two explanations are not mutually exclusive.

Thus the irreversibility of the systems dynamics connected with the presence of the body internal energy and the possibility of its change in inhomogeneous external field of force. The internal energy caused by such a class of motion of the elements which does not change the energy of motion of the system. This class of the motion is determined by the second term in the right-hand side of the eq. (4).

The existence of the internal energy is possible to take into account only through the introduction of micro variables, determining the position and velocity elements with respect to the $CM$ of $SP$. This means that the dynamics of systems can be determined through the two type of variables. There are micro variables and macro variables. The body motion is determined by the total energy flow between the body and its environment. Therefore it is impossible to describe the dynamics of the body and creation a new structure if do not take into account the change of two type of its energy.

VII. CONCLUSION

The model of the body in the form of a set of $SP$ is more general and closer to reality than the model of a structureless body. Indeed, the energy of the external field does not go only to change of the body velocity. This energy also go to the change of the body internal energy. Therefore the dynamics of the body is determined by the changes in the two types of energy: the internal energy and the motion energy of the body while maintaining their sum.

The $SP$ acceleration is not uniquely associated with the flow of external energy as it takes place in the case for $MP$ because part of this energy going to the increasing of internal energy. The body acceleration is proportional to the external force only in special cases when the internal energy of the body does not change.

The $SP$ motion equation was obtained based on Newton’s laws for $MP$ by using the law of energy conservation. By differentiating the $SP$ energy with respect to the time, the expression for the energy change is defined. From this equation the $SP$ motion equation is obtained. The $SP$ motion equation in contrast to Newton’s equation for the $MP$ includes terms that determine the change of the $SP$ internal energy.

Derivation of $SP$ motion equations is performed in the system of coordinates micro and macro variables taking into account that the motion of the $SP$ in the space defined by its $CM$ and the motion of $MP$ defined relative to the $CM$. In these variables the $SP$ energy is naturally splitted into internal energy and the energy of motion of the $SP$. The internal energy is expressed through the micro variability. It is determined by motion of the $MP$ in relative to the $CM$. The energy of motion of the system expressed in terms of macro parameters. It is energy of $SP$ motion in space. This system of coordinate connected with the symmetry of the systems’ dynamics which splits on the symmetry of the system and the symmetry of the space.

In contrast to the Newton’s equations for $MP$, the $SP$ motion equation is irreversible. The breaking-symmetry of the time for $SP$ takes place because the motion energy of $SP$ transformed into the internal energy and the internal energy can’t go back to the $SP$ motion energy. Therefor we can say that the internal energy is the energy of the chaos.

Thus the mechanism of deterministic irreversible can
be find only when to take into account two hierarchical levels: the micro and macro variables and the presence of the nonlinear terms in the external forces which depending from the micro and macro variables.

Scope of $SP$ motion equation is much broader than $MP$ motion equation because it takes into account the energy dissipation which is connected with the internal motions of the elements of bodies. For example the motion equation of $SP$ in contrast to the motion equations of $MP$ allows to describe the processes of emergence and evolution of structures. It is because the non-equilibrium system when the condition of local thermodynamic equilibrium have a place, can be represented as a set of equilibrium subsystems [10, 12] whose dynamics is described by the $SP$ motion equation.

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