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Original Research Article

Impulse as a true measure of inertia

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Abstract: Based on the system-energodynamic method of analyzing natural and technological processes, the necessity of abandoning the paradigm of homogeneity and isotropy of space filled with matter is substantiated, and a retrospective analysis of the state of mechanics is given. The principles of the determinism of the state and the opposite direction of processes in inhomogeneous (internally non-equilibrium) systems are formulated and proved. The inevitability of the emergence of an oscillatory form of energy in them and the need to consider the latter in the law of its conservation are revealed. In this way, the necessity and possibility of generalizing all three "beginnings" of Newton's mechanics and considering irreversibility in its equations with the introduction of the "force" efficiency of mechanical processes are shown. The non-equivalence of the momentum to Descartes' momentum is revealed, and the invariance of the mass in acceleration is proved. It is shown that the true measure of the inertial properties of a substance is the impulse, not the mass, and a generalization of the concept of inertia to non-mechanical forms of motion is proposed. The principle of interconvertibility of the oscillatory, translational, and rotational components of the impulse of internal motion in isolated systems is proved, and thus the possibility of creating a new class of propellers in outer space on this basis is substantiated.

Keywords: amount of motion and impulse; energy and power; irreversibility and inertia; mass and acceleration; stresses and forces; principles, and postulates of mechanics

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1. Introduction

Our knowledge of inertia and the forces generated by it has practically not changed since the time of Newton, who formulated his 1st postulate (the law of inertia) in the form of a statement that "everybody continues to be held in its state of rest or uniform and rectilinear motion until and since it is forced by the applied forces to change this state"[1]. This formulation raises several questions at once: what is "uniform inertia motion", if the concept of its speed has not yet been defined? What is force (including the force of inertia) in its most general sense, and what is its source? Why in mechanics, inertial reference systems (ISRs) that do not actually exist turned out to be preferable, if rotational motion predominates in nature and technology?

Does not give an exhaustive answer to these questions and Newton's 2nd postulate (the law of force), according to which "an increase in the amount of motion is proportional to the driving force and occurs in the direction of the straight line along which this force acts"[1]. On the contrary, there is an added ambiguity associated with the uncertainty of the concept of "momentum" without a preliminary definition of the concept of mass, speed, and duration of the process, during which there was an increase in this momentum. There are many such questions. Therefore, there are still discussions about what a measure of inertia is, whether this property is innate or bought, whether inertia forces depend on speed, whether there are fields of inertia forces, what time is, etc.

These issues have bought fundamental importance in connection with the advent of the special theory of assumes the role of a measure of the inertia of the body. This situation in the general theory of relativity (GR) was further aggravated in connection with Einstein's postulate about the identity of "inertial" and "gravitational"[2]. All this led to the final distortion of the Newtonian definition of mass as a measure of the amount of matter and led to serious confusion in the minds of "not only students but also academicians"[3].

Therefore, it is of particular importance to consider controversial issues not in their historical sequence but from the standpoint of a more general theory, in which mechanics appears on an equal footing with other fundamental disciplines and the study is carried out "from the general to the particular" and "from the whole to the part", characteristic of the deductive method and the systematic approach. Such is the unified theory of the power of real processes of transfer and transformation of any form of energy, called for brevity energy dynamics[4] and now recognized as a "new direction in science"[5].

2. Energy, amount of motion and impulse of mechanical systems

The main feature of energy dynamics is the rejection of the concept of the homogeneity of space continuously filled with matter, since only in internally non-equilibrium media can any processes occur. To prove this, it suffices to express any extensive parameter of the system Θ_i (its energy U, mass M, number of moles of k-substances N_k, entropy S, electric charge Z, impulse P, its momentum L, etc.) by an integral of its local density $\rho_i = d\Theta_i/dV$ and average density $\overline{\rho}_i = \Theta_i/V$ by an expression like $\Theta_i = \int\rho_i dV = \int\overline{\rho}_i\, dV$. It follows from this:

$$\int[(d(\rho_i - \overline{\rho}_i)/dt]dV \equiv 0 \quad (1)$$

It is easy to see that identity (1) vanishes only if the sign of the speed of any i-th process $d(\rho_i - \overline{\rho}_i)/dt$ is opposite at least in several elements of its volume dV. This position, called in energy dynamics the "principle of counter-directivity of processes", reflects the dialectical law of unity and struggle of opposites[6] and can serve as a mathematical expression.

This principle excludes the possibility of macroprocesses in homogeneous systems, where $d(\rho_i - \overline{\rho}_i)/dt$ is everywhere equal to zero, as well as the one-sided direction of all processes occurring in them (when $d(\rho_i - \overline{\rho}_i)/dt > 0$ everywhere). This excludes the possibility of considering any systems as homogeneous and it becomes necessary to distinguish between parts (regions, phases, components) in them with a different value of the sign of the deviation of any parameters from their average value.

In turn, the recognition of spatial heterogeneity entails the inevitability of the occurrence of oscillatory motion in such media. Indeed, since their density $\rho \equiv dM/dV$ becomes dependent on the radius vector of the field point r and time t, its total change in time includes the local $(\partial\rho/\partial t)_r$ and convective $(\partial\rho/\partial\boldsymbol{r})(d\boldsymbol{r}/dt) = (\boldsymbol{\upsilon}\cdot\nabla)\rho$ components:

$$d\rho/dt = (\partial\rho/\partial t)_{\boldsymbol{r}} + \boldsymbol{\upsilon}\cdot(\partial\rho/\partial\boldsymbol{r}) \quad (2)$$

This expression has the form of the so-called "kinematic" wave equation in its "single wave" approximation (of the first order), in which $d\rho/dt$ plays the role of the wave damping function[7]. According to (2), in an initially immobile inhomogeneous medium (including ether), undamped ($d\rho/dt = 0$) standing waves of matter compaction$(\partial\rho/\partial t)_{\boldsymbol{r}}$ can arise, due to the "draining" of the medium from the vicinity of the point r at a speed υ due to the presence of its density gradient $\nabla\rho \equiv \partial\rho/\partial\boldsymbol{r}$. This phenomenon is reminiscent of the formation of a tsunami in "shallow water" or solitons (solitary "elevation" waves). In isotropic media, such seals have a spherical shape due to the equality of velocities υ in all directions. The latter is the rate of propagation of perturbations in each medium and is decided by its properties, which makes this rate one of the parameters of the state of the system. In Descartes' concept of the universe[8], this is of fundamental importance, since only then the total amount of motion $P = M\upsilon$ did not depend on its direction and could remain constant. This circumstance makes it possible to obtain the most general expression of "live force"[9], renamed in the 19th century at the suggestion of Jung into "energy", and somewhat later—into internal energy U. Energy is measured by the work W, determined by the product of the force F and the displacement $ds = \upsilon dt$ of the object of its application caused by it. In this case, it is spent on excitation of oscillations with a speed $\upsilon = \text{const}$, which, by the Newtonian definition of the concept of force $F = dP/dt$, gives the expression of "live force" by Leibniz[9]:

$$U = W = \int F ds = \int \upsilon dP = M\upsilon^2 \quad (3)$$

In transparent and semitransparent media with a refractive index n, the propagation velocity of excitations υ is less than the speed of light c and is equal to $\upsilon = c/n$. Therefore, the representation of the energy of the system in terms of the speed of light c requires, strictly speaking, the introduction of a certain proportionality coefficient æ:

$$U = æMc^2 \quad (4)$$

It was to this form (with coefficients æ ranging from 0.5 to 1) that Schramm (1871), Umov (1873), Thomson (1881), Heaviside (1890), Poincaré (1898) and Hazenorl (1904) came before Einstein[10]. However, the expression $E = Mc^2$, obtained by Einstein in 1905[2] by expanding the relativistic expression for the mass M_{rel} into a series in terms of velocity υ, became widely known. At the same time, he interpreted this relation as "the principle of equivalence of mass M and total energy E", extending it to all forms of matter, i.e., assuming for all media $æ = n^{-2} = 1$. Since then, this ratio has been considered the "quintessence" of all physics, although, strictly speaking, it expresses only the proportionality to mass that is usual for all extensive quantities and cannot be interpreted either as the interconvertibility of mass and energy (since one of them must increase with the decrease of the other), or as their interchangeability (since the mass M is only one of the arguments of the total energy E and differs from it in meaning and dimension).

If, following Descartes and Leibniz, we accept the concept of the emergence of a "living force" from a fixed ether, then from (3) we can also obtain the law of conservation of mass in an isolated system. Since for undamped oscillations $(\partial\rho/\partial t)_{\boldsymbol{r}} = -\boldsymbol{\upsilon}\cdot(\partial\rho/\partial\boldsymbol{r})$, and the speed υ when the mass flow crosses the imaginary boundary of any of its areas is unchanged, then, introducing it under the sign ∇, we find:

$$(\partial\rho/\partial t)_{\boldsymbol{r}} = -\nabla\cdot\boldsymbol{j} \quad (5)$$

where $\boldsymbol{j} = \rho\boldsymbol{\upsilon}$ is the mass flux density.

Integrating this expression over the volume V occupied by the system and transforming $\int\nabla\cdot\boldsymbol{j}dV$ based on the Gauss-Ostrogradsky theorem into the integral $\int\boldsymbol{j}\cdot d\boldsymbol{\check{S}}$ over the vector elements $d\boldsymbol{\check{S}}$ of the closed surface of the system $\check{S}$, we obtain:

$$dM/dt = \int(\partial\rho/\partial t)_{\boldsymbol{r}}dV = -\int\boldsymbol{j}\cdot d\boldsymbol{\check{S}} \quad (6)$$

According to this expression, the source of the mass of the system M is exclusively its flow through the boundaries of the system, so that in its absence ($\boldsymbol{j} = 0$), it stays unchanged. This also applies to the energy associated with the mass by relation (4). Thus, both the concepts of amount of motion $P = M\upsilon$ and impulse $\mathbf{J} = \int\boldsymbol{j}dV = M\boldsymbol{\upsilon}$ are legitimized, since they are parameters that serve as quantitative measures of two fundamentally different forms of motion: disordered and ordered. This emphasizes the fallacy of finding the amount of motion P and the impulse $\boldsymbol{J}$, which is often emphasized by placing the latter in brackets as an abbreviated name for the former.

Let us now pay attention to the fact that when oscillations are excited in any medium, some part M_o of its mass M can remain motionless, a part can come into locally ordered (translational and rotational) relative motion similar to diffusion and vortex) with velocities $\boldsymbol{w} = ds/dt$ and $\boldsymbol{u} = \omega \times \check{\boldsymbol{r}}$ or acquire the character of standing density oscillations described above. For all these forms of motion, the modulus of the propagation velocity of excitations remains the same ($\upsilon = |\boldsymbol{\upsilon}|$)—only the masses M_w, M_ω and M_λ corresponding to them ($M = M_o + M_w + M_\omega + M_\lambda$), their amount of motion $P = M_o\upsilon^2$ and impulse $\boldsymbol{J}_w = M_w\boldsymbol{w}$ and и$\boldsymbol{J}_\omega = M_\omega(\boldsymbol{\omega} \times \check{\boldsymbol{r}})$, where $\check{\boldsymbol{r}}$ is the instantaneous radius of rotation, change. If we denote by U_o, U_w, U_ω and U_λ the corresponding components of the internal energy U (potential U_o due to the interaction of the particles of the system, the kinetic energy of the translational U_w rotational motion U_ω, and the energy of disordered oscillatory motion U_λ), then the energy balance of an isolated system will take the form:

$$U_{из} = (U_o + U_w + U_\omega + U_\lambda)_{из} = \text{const} \quad (7)$$

In mechanics, this law of conservation of energy is usually interpreted as the constancy of the sum of the external (kinetic $E_k = M_k\boldsymbol{\upsilon}_k^2/2$, external potential $E_o = \int\boldsymbol{F}\cdot d\boldsymbol{r}$ and internal energy U of an isolated system:

$$E_{is} = (E^\upsilon + E^r + U)_{is} = \text{const} \quad (8)$$

From (8) follows the most general definition of the force $\boldsymbol{F} = \partial E^r/\partial\boldsymbol{r}$ as the gradient of the corresponding form of energy. However, it should be noted that such a record of the conservation law is incorrect, if only because in an isolated system the concept of external energy is meaningless. Therefore, law (8) reflects the same law of conservation of internal (intrinsic) energy (7). However, unlike (8), the energy of the ordered (translational and rotational) motion U_w and U_ω in total is less than the “live force” $U = M\boldsymbol{\upsilon}^2$. This means that “order” in a real system arises from “chaos” according to Prigogine[11], and not vice versa. Such is the true direction of the processes in the Universe, if one does not postulate, following Clausius, as a “self-evident” one-sided direction of its processes towards equilibrium, which leads to its inevitable “thermal death”[12].

Moreover, from (7) it follows that the potential energy U_o of the interaction of particles of systems as part of the internal energy of the system cannot be a negative value, as is usually accepted based on an arbitrary calibration of Newton’s law of gravitation. Consequently, all arguments about the origin of the Universe “out of nothing”[13] and its accelerated expansion due to the negative energy of “dark matter”[14] are untenable. Both circumstances radically change some of our ideas about the nature of the processes occurring in nature.

It is also important that, according to (7), in inhomogeneous media, not only the “total” internal energy U, internal energy U, but also each “partial” energy U_i of any of its i-th form and its density $\rho_{ui} = dU_i/dV$ is generally a function of not one, but three independent parameters: energy carrier density ρ_i, its displacement $\boldsymbol{s}_i$, and rotation angle $\boldsymbol{\varphi}_i$. By this, the total differential $d\rho_u$ of the density ρ_u of its energy $U = \Sigma_i U_i(\rho_i, \boldsymbol{s}_i, \boldsymbol{\varphi}_i)$ can be represented as an identity:

$$d\rho_u \equiv \Sigma_i\psi_i\cdot d\rho_i + \Sigma_i\boldsymbol{x}_i\cdot d\boldsymbol{s}_i + \Sigma_i\boldsymbol{\mu}_i\cdot d\boldsymbol{\varphi}_i \quad (9)$$

where $\psi_i \equiv (\partial\rho_u/\partial\rho_i)$—generalized potentials of the i-th form of energy U_i (absolute pressure p, chemical μ, electrical φ, gravitational ψ_g, etc. potentials); $\boldsymbol{x}_i \equiv (\partial\rho_u/\partial\boldsymbol{s}_i) = \nabla\psi_i$—force field strength $\boldsymbol{F}_i = \int\boldsymbol{x}_i dV$; $\boldsymbol{\mu}_i \equiv (\partial\rho_{ui}/\partial\boldsymbol{\varphi}_i) = \boldsymbol{x}_i \times \check{\boldsymbol{r}}_i$—density of their moment $\boldsymbol{M}_i = \int\boldsymbol{\mu}_i dV$.

The three sums of its right side describe the processes occurring in the general case in any of the material components of the system and in any element of its volume. Members of the 1st sum describe the processes of emergence or disappearance in the system of i-th forms of energy due to its evolution or involution; the members of the 2nd sum are the processes of transfer (redistribution) of energy carriers Θ_i within the system, and the members of the 3rd sum are the reorientation of the displacement vectors $\boldsymbol{s}_i$ in space and, in particular, its rotation of the volume element with the angular velocity $\boldsymbol{\omega}_i = d\boldsymbol{\varphi}_i/dt$. Due to this, it covers all categories of internal processes occurring in various parts (regions, phases, and components) of a nonequilibrium system.

Formally, this identity is the result of the joint definition of the "conjugate" parameters ψ_i and ρ_i, $\boldsymbol{x}_i$ and $\boldsymbol{s}_i$, $\boldsymbol{\mu}_i$ and φ_i, regardless of their value. Therefore, it stays valid for non-static (irreversible) processes as well. According to (9), the intensity of the force field arises wherever there is a gradient of the potential of the same name, and forces of any nature $\boldsymbol{F}_i$ have a single meaning of the gradient of the corresponding form of energy, a single dimension, and a single method of definition. This gives energy dynamics huge advantages over TIP, which allows arbitrariness in their sense and dimensions, and the inevitable transition of its basic equations into inequalities[15].

From (9) follows the previously unknown expression for the power of internal processes in isolated systems ($d\rho_u = 0$):

$$\Sigma_i\psi_i\cdot\sigma_i + \Sigma_i\boldsymbol{x}_i\cdot\boldsymbol{w}_i + \Sigma_i\boldsymbol{\mu}_i\cdot\boldsymbol{\omega}_i = 0 \qquad (10)$$

where $\sigma_i = d\rho_i/dt$ is the rate of excitation of oscillations in the volume elements of the medium under study. Thus, (10) for the first time allows us to consider the processes of evolution, transfer, and transformation of various forms of energy in isolated systems such as the universe as a whole, including all fundamentally possible forms of motion in it—oscillatory, translational, and rotational. For celestial mechanics, which ran exclusively with the concept of external energy, this was inaccessible.

3. Inadmissibility of treating mass as a measure of inertia

The principles of Newton's mechanics[1] were postulated at a time when the law of conservation of energy had not yet been set up. There was also no principle for setting up the necessary and enough parameters to describe the state of one or another object of study (system). An urgent need for this arose only in the study of polyvariant systems (with many degrees of freedom) and especially continual media with distributed parameters, the number of which can be infinite. We managed to find such a principle in our doctoral dissertation[16] and the monographs "Thermokinetics"[17] based on it by proving a specific "theorem on the number of degrees of freedom" of an arbitrary system. According to this theorem, "*the number of arguments of the internal energy U of the system as the most general function of its state is equal to the number of independent (i.e., special, phenomenologically distinct and irreducible to others) processes occurring in it*." This theorem is proved "by contradiction". Indeed, if during any independent process several parameters necessarily change, then obviously these parameters are not independent, which contradicts the original premise. Let us now assume the opposite, that any of the parameters changes with necessity during several independent processes. Then, obviously, these processes will not be independent, which also contradicts the original premise. It stays to be concluded that for each independent process there exists and with the help of the entire arsenal of experimental tools a single independent state coordinate can be found so that the number of parameters that decide the state of a particular system is equal to the number of independent processes occurring in it. We called this position the "*principle of certainty (determination of the state*" and put it at the basis of the mathematical apparatus of energodynamics[18]. It allows us to avoid both "underdetermination" and "redefinition" of the system, i.e., tries to describe its state with a missing or excess number of coordinates, which is the main source of methodological errors in most modern theories. It is far from obvious, for example, the "redefinition" of a continual medium caused by its division into elementary volumes dV with the same properties, which leads to the conclusion that it has an infinite number of degrees of freedom (despite the finite number of independent processes occurring in it). Another example is the assignment of 3 degrees of freedom of rotational motion to a material point in the mechanics of the Einstein-Cartan point[19] and, moreover, three added degrees of freedom of rotation in 4-dimensional space-time in the theory of physical vacuum by Shipov[20], even though the rotational point is zero.

Equally unobvious is the "underdetermination" of the system, caused, for example, using the hypothesis of local equilibrium in TIP[11]. According to it, the elements of the continuum can be described by the same set of thermodynamic parameters as in equilibrium (even though "thermodynamic forces" are used for this as functions of potential gradients). The same thing happens in quantum mechanics, when the mass M as the only quantity that changes in mass transfer (i.e., its coordinate) is taken as a measure of the inertial properties of the system, i.e., as a quantity that depends on the speed of the system (for the coordinate of the acceleration process).

Thus, the basis of the energodynamic research method, as well as for thermodynamics, is the search for parameters that decide the quantitative measure of the material carrier of a certain form of energy. For brevity, we called such parameters energy carrier. Energy carriers are extensive quantities, since each of them separately decides some form of energy of the system U_i—the quantity is also extensive. Such are the mass of the system M, the number of moles of k-th substances N_k, the entropy S, the charge Z, the impulse $\boldsymbol{P}$, its moment $\boldsymbol{L}$, etc. The change in each of these parameters characterizes the corresponding independent process (mass transfer, diffusion, heat transfer, electrization, acceleration, rotation, etc.). If for the process of mass transfer, characterized by the invariability of its composition, such an energy carrier is the mass of the system M, then for the diffusion process, characterized by a change in the composition of the system without changing its mass M—the number of moles of its k-th components N_k. In the absence of mass transfer and diffusion, these parameters should not change. This also applies to the system acceleration process. Therefore, the interpretation of mass as a measure of inertia is in flagrant contradiction with the principle of state determinism mentioned above. It is also possible to verify the invariance of the mass with respect to the acceleration process, i.e., its independence from the speed, based on the simplest mental experiment with an isolated system in which an explosion of matter is started. In this case, the flying fragments buy, in principle, an unlimited speed, but the system stays motionless, and its internal energy stays unchanged. If the mass of these fragments at the same time increased with speed, the total mass of the isolated system under consideration would also increase, which is incompatible neither with the law of conservation of its mass, nor with the law of conservation of energy. This contradiction deprives of any grounds the conclusion that the mass M changes with velocity[21].

4. Momentum as a true measure of inertia

At the time of Descartes, Leibniz, and Newton, when vector algebra did not exist, the concept of momentum and the division of motion forms into ordered and unordered were absent. Therefore, when formulating the law of force, Newton used the concept of "momentum" $P = Mv$, understanding M as "the amount of matter", and v is the speed of a material point: $F = dP/dt$. According to this expression, the momentum of the inertial forces Fdt is proportional to the increment dP of the momentum P, which directly gives the latter the meaning of the measure of these forces, i.e., the "inertia" of the object of their application.

With the advent of vector algebra in the 19th century, the momentum was renamed into momentum $\boldsymbol{P} = M\boldsymbol{v}$, and the force law began to be written as:

$$\boldsymbol{F} = M\boldsymbol{a} \tag{11}$$

introducing an acceleration unknown in Newton's time $\boldsymbol{a} = d\boldsymbol{v}/dt$. In this case, the acceleration $\boldsymbol{a}$ under the action of the force $\boldsymbol{F}$ turned out to be inversely proportional to the mass M, which gave it the meaning of the measure of "inertia". Such an understanding of mass has become predominant, despite the obvious distortion of the original meaning of mass and the obvious limitations of the law of force (11), which is not applicable to systems of variable mass such as rockets, not to mention relativistic systems, where $M = M(\boldsymbol{v})$, and other absurdities. So, from expression (11) it followed that the same force $\boldsymbol{F}$ is both the cause of a change in impulse $\boldsymbol{P}$ (i.e., “active” (applied from the outside), and a consequence of the acceleration process, i.e., “inertial”. The latter is a function of the process, since it disappears with the cessation of acceleration; the first, like the gravitational force $\boldsymbol{F}_g$ in Newton’s law of gravity, is a function of the state since it is decided solely by the parameters of the state (masses and the relative position of bodies). Active forces arise from a variety of causes and can be either mechanical or non-mechanical. The force of inertia, on the contrary, refers to the reaction forces that oppose the applied force, and only those of these forces that depend on the speed of the process.

This duality gave rise to many discussions that periodically appear on the pages of scientific and pseudo-scientific publications and have not left their pages to this day. One can often hear that “the problem of the origin of inertial forces has been and remains the most obscure issue in the theory of particles and fields”[22]. The questions that most often arise are whether the forces of inertia are real, whether they are external or internal, and what their source is. Thus, the problem of inertial forces has already gone beyond the framework not only of Newtonian mechanics, but also of classical mechanics in general.

It is generally accepted that the Newtonian understanding of the forces of inertia and the very phenomenon of inertia cannot be transferred to other forms of motion (other processes). However, the matter looks completely different if mechanics is considered not as the basis of all natural science disciplines but as one of the “equal” sections of energy dynamics[4]. Then the need to generalize all three laws of mechanics becomes obvious. Newton’s first postulate (the law of inertia) requires generalization in connection with the recognition of the legitimacy of the concept of “rotation by inertia” and the predominance of this form of motion in the universe. Characteristically, this does not require changing the wording of this law itself[20]. At the same time, the existence of a predominant frame of reference in it at once deprives the grounds for the search for non-existing ISOs.

Newton’s second postulate (the law of force) requires generalization in connection with the existence of many forces of non-mechanical nature and processes not related to the acceleration of bodies. In energodynamics, this is achieved by defining the force as a derivative of the energy of the system U with respect to the displacement $d\boldsymbol{s}_i$ of any of the energy carriers of the system $\boldsymbol{F}_i \equiv (\partial U_i/\partial \boldsymbol{r}_i) = \nabla U_i$, as a result of which any forces acquire a single meaning of the gradient of the corresponding energy form U_i, a single dimension and a method of finding[23].

Newton’s third postulate (action and reaction) requires generalization in connection with the existence of polyvariant systems in which there are many forces. In this case, the absence of the resultant internal forces of the closed system ($\Sigma_i \boldsymbol{F}_i = 0$) means that any “active” force $\boldsymbol{F}_i$ is counteracted by all other forces ($\boldsymbol{F}_i = \boldsymbol{\Sigma}_j \boldsymbol{F}_j$). This leads to a “branching” of the process trajectory in the space of variables $\boldsymbol{F}_j$, because of which even processes occurring in conservative systems become irreversible. This kind of irreversibility is since when the sign of any of the opposing forces $\boldsymbol{F}_j$ is reversed, a “fan” of other opposing forces arises, because of which the reverse process almost never follows the same path as the direct one, and the first state is unattainable. In this case, not only the set of opposing forces plays a role, but also how quickly certain forces “react” to a given disturbance. This circumstance considers irreversibility in mechanical systems even in the absence of dissipation in them, which raises the question of introducing a specific term “mechanical efficiency” for mechanics:

$$\boldsymbol{F}^a = \eta_{ij}^{-1} d\boldsymbol{P}/dt = -\eta_{ij}^{-1} \boldsymbol{F}^u \quad (12)$$

In the thermodynamics of irreversible processes (TIP)[15], this circumstance is considered by introducing its kinetic equations of added terms:

$$\boldsymbol{F}_i = \Sigma_j R_{ij} \boldsymbol{J}_j \tag{13}$$

where R_{ij} are the coefficients of resistance of the j-th flow $\boldsymbol{J}_j$ to the applied force $\boldsymbol{F}_i$, reciprocal of the coefficients of thermal conductivity, electrical conductivity, diffusion, etc.

According to such "phenomenological" coefficients, each i-th applied force $\boldsymbol{F}_i$ generates several so-called "energy carrier flows" $\boldsymbol{J}_j \equiv \Theta_j \boldsymbol{v}_j$ ($i, j = 1, 2, n$), in the system at once, having the meaning of its "generalized impulse". This is the answer to the question about the universality of the concept of momentum.

It was after the creation of the special theory of relativity (SRT) that the need to introduce a proportionality factor into the dependence of the momentum J on the applied force $\boldsymbol{F}$ should have become obvious. After all, it was in it that the existence of a limiting velocity of propagation of perturbations equal to the speed of light in vacuum c was asserted. In this case, when the speed $v = c$ is reached, no, even an infinitely large force $\boldsymbol{F}$ can cause further acceleration of the body. This means that dependence (11) is non-linear, which requires the introduction of a variable "proportionality coefficient". After all, if an accelerated body moves away from the source of active force at the same speed as the propagation speed of the perturbation created by it, then the effect on it will be equal to zero, no matter what force its source creates. This is exactly what is seen in elementary particle accelerators and in many experiments on changing the trajectory of accelerated particles, where the inertia manifests itself in a certain "delay" of the reaction forces. Thus, the concept of efficiency is most directly related to the operation of charged particle accelerators, showing the existence of a regime with maximum efficiency in them, and a regime like a "short circuit" of the secondary winding of a transformer, when all the power supplied to them is wasted on heat losses, and the efficiency is equal to zero. This fully applies to Kaufman's experiments on electron acceleration[24], explaining the clear increase in the ratio of the electron mass to its charge seen in them by non-relativistic effects, a decrease in the efficiency of the acceleration process as the speed increases. Hence, it follows that experiments at the large collider prove this dependence of the efficiency on the setup mode rather than the dependence of the mass on the velocity[21].

Thus, we have received an unambiguous answer to the questions posed at the beginning of the article. The forces of inertia are real to the extent that the reaction forces are real, or rather, that part of them that depends on the speed of the process. Like reaction forces, they are internal in relation to the system in which they arise. The source of inertial forces is the processes occurring in the system, with the termination of which the inertial forces, unlike active forces, disappear. Consequently, specific "forces of inertia", which, like other forces, are functions of the state, do not exist. Therefore, any statements about the presence in nature of specific "fields" of these forces[20], characterizing the properties of the "physical vacuum", i.e., which are a function of his state, have no real basis.

5. The principle of interconvertibility of impulse components of mechanical systems

In the classical mechanics of conservative systems, based on the works of Newton and Euler, the laws of conservation of momentum Ji and its momentum L are usually considered independent, generated by various reasons—the homogeneity and isotropy of space[25]. Meanwhile, from the standpoint of Newtonian mechanics, both of these laws are a single and direct consequence of the definition of force ($\boldsymbol{F} = d\boldsymbol{P}/dt$) and the closedness of the system ($\boldsymbol{F} = 0$), since the impulse $\boldsymbol{P} = Mv$ can always be decomposed into translational $\boldsymbol{J}_w = M_w \boldsymbol{w}$ and rotational $\boldsymbol{J}_w = M_\omega(\boldsymbol{\omega} \times \check{\boldsymbol{r}})$ in accordance with the decomposition of the velocity $\boldsymbol{v} = \boldsymbol{w} + \boldsymbol{\omega} \times \check{\boldsymbol{r}}$. This shows the possibility of their mutual transformation when the components of the speed of ordered movement in a closed system change:

$$M_w \boldsymbol{w} + M_\omega(\boldsymbol{\omega} \times \check{\boldsymbol{r}}) = \text{const} \quad (14)$$

However, Newtonian mechanics from the very beginning excluded from consideration the internal processes of rotation in the bodies under study and limited itself to the description of a material point. Therefore, relation (15) could not arise within the framework of this theory. On the contrary, from the standpoint of energy dynamics, this ratio, by the law of conservation of energy, should be supplemented by a scalar amount of motion $M_o\upsilon$, which we called "thermal impulse" for brevity, thereby allowing the transition of ordered motion into disordered one[26]:

$$M_o\upsilon + M_w \boldsymbol{w} + M_\omega(\boldsymbol{\omega} \times \check{\boldsymbol{r}}) = \text{const} \quad (15)$$

This expression does not contradict either the law of conservation of momentum, or the law of conservation of energy in a closed nonequilibrium system and was called by us the "principle of the interconvertibility of momenta".

Unfortunately, this and several other postulates of Newton's mechanics were not prompt generalized to non-mechanical forms of motion. This explains the negative attitude of the "scientific community" to the known experimental facts confirming the possibility of such an interconversion of impulses.

Meanwhile, back in the 1930s of the twentieth century, the Russian engineer Tolchin invented a trolley on which two loads oscillated[27]. This allowed her to move in jerks on a horizontal surface without any wheel drive. He proved many designs of such devices, proving the absence of environmental influences. However, the "scientific community" did not recognize their legitimacy.

In the meantime, a working model of a forklift, based on the same principles, was presented to NASA in 1956 by Norman Dean, an autodidact from Washington[28]. The demonstration of his load lifter made a sensation and gained wide popularity; however, neither NASA experts nor the patent offices of the United States, England and Germany began to deal with it, referring to the fact that the device for converting rotational motion into translational is contrary to Newton's laws.

For the same reason, tests in space of the 4-D gyroscope of the Russian scientist Shipov[29], manufactured at the Research Institute of Space Systems of Roscosmos and launched in 2008, did not take place. into space on the "Yubileiny" satellite. When tested in the laboratory, he developed a thrust of 1–3 years with dimensions of 200 × 82 × 120 mm, weight 1.7 kg and power consumption of 6–8 watts[30]. The reason for the refusal to test was the fear of the leadership of the Russian Academy of Sciences that "an experiment in space with the inclusion of a new engine will damage the prestige of Russia and the reputation of domestic science, since the principle of operation of the engine contradicts the fundamental laws of mechanics and tries to implement an anti-scientific idea".

In 2003, British engineer Roger Shawyer designed a propulsion device called "EmDrive". In the closed conical resonator of this device, a vortex electromagnetic field created by a conventional magnetron was kept[31]. In 2006, his engine produced 16 Millinewtons of thrust during a demonstration. Research in this direction received state support, but critics still deny the theoretical part of the work and insist that, according to the law of conservation of momentum, the EmDrive engine cannot work.

However, in 2009–2010, a Chinese research group from Northwestern Polytechnical University, Xi'an, China led by Prof. Yang Juan built an analogue of "EmDrive" and confirmed that the engine thrust reached 720 Millinewtons[32]. In 2016, this engine was tested in space on one of the satellites and proved that its thrust was enough to correct its orbit.

In August 2013, a message appeared on the official website of NASA about testing a model of the "corrective" space engine "Cannae Drive" by the American inventor Guido Fett[33]. For eight days, a group of researchers from the Johnson Space Center in Houston (USA) tested this engine in various modes and became convinced of the viability of the idea of creating thrust due to directed microwave radiation. Tests have shown that the unique design of the microwave engine allows you to create a thrust of 30–50 Millinewtons[32]. Convinced of the occurrence of thrust in conditions where "nothing leaves the boundaries of the system", NASA specialists found themselves in a very difficult position and were forced to limit themselves to very vague considerations, such as the fact that the device "demonstrates interaction with the quantum vacuum of a virtual plasma". The doubtfulness of such "explanations" lies in the fact that the "physical vacuum" consists of "virtual" and not real particles. It would be more reasonable to recognize the existence of an all-penetrating ether, in relation to which the system is not closed[34].

In 2009, 2014, and 2018, the engine of the Russian scientist and inventor Leonov was tested in the private Russian company "Kvanton". Leonov, which he called "quantum"[35]. The principle of its operation and design details were not disclosed; however, the apparatus, with a mass of 54 kg and an electrical power consumption of 1 kW, created during tests a vertical thrust impulse of more than 100 N/kW), which was more than 100 times higher than the performance of the best liquid rocket engines and ensured vertical take-off along guides with an acceleration of 10 ÷ 12 g.

Despite these experimental facts, most physicists still exclude the possibility of creating such "self-propelled" devices since they violate the "laws" of Newtonian mechanics. Meanwhile, thanks to the improvement of technical means of observation, astronomers and astrophysicists are constantly discovering the birth and disappearance of large and small celestial bodies, as well as their translational and rotational motion at very high speeds. This means that in some regions of the Universe, which is closed, and immobile, internal sources of momentum and its momentum arise and disappear, violating the law of their conservation.

Of particular interest in this regard is the use of the moment of quantity (momentum) of rotational and rotational-oscillatory motion, which can be given a single form $\boldsymbol{L}_\omega = M_\omega(\boldsymbol{\omega} \times \check{\boldsymbol{r}})$. According to the energodynamic identity (9), where potential gradients $\boldsymbol{x}_i = \nabla\psi_i$, appear, the strength of the field of the same name, as well as forces $\boldsymbol{F}_i = \int \boldsymbol{x}_i dV$, also arise. This is also characteristic of media in which there is a gradient of the angular velocity of rotation $\nabla\boldsymbol{\omega}$. We called the corresponding force $\boldsymbol{F}_\omega$ "gyroscopic thrust"[36]. It is clearly manifested in experiments with a gyroscope moving in a circle suspended from one of the ends of the gyroscope axis[37]. This force is easy to calculate from the angle of deviation of the suspension from the vertical. This force also exists in the rotational-oscillatory motion of massive bodies along a segment of a circle, as is the case in Tolchin's inercoids[28]. A similar situation is seen in the "overturned" pendulums with an oscillating suspension by Academicians Kapitza[38] and Chelomey[39], when the fulcrum of which oscillated compared to a vertically stretched string, their rise was seen. Thus, we conclude about the existence of another type of interaction in non-uniformly rotating media, which cannot be reduced to its four known types (strong, weak, electromagnetic, and gravitational).

The latter directly follows from the basic identity of the energy dynamics of isolated systems (10), which, along with the constancy of their energy, considers the possibility of interconversion of its various forms, as well as the presence of internal sources in them, and, so, in their energy carriers. This means that the momentum conservation law can be violated in nonequilibrium systems[40,41].

This does not contradict either classical mechanics or Noether's theorems[42], since the latter go ahead from postulates about the homogeneity and isotropy of non-empty space and time, and not from real facts.

At the same time, energy dynamics reveals the incompatibility of the laws of conservation of energy carriers with evolution since the emergence of new properties in a closed system in the absence of energy exchange with the environment is impossible without internal processes of interconversion of various forms of energy and their energy carriers. This incompatibility has repeatedly become the subject of discussions at scientific forums of various levels but has not received an explanation. Meanwhile, the reason is simple and lies in the fact that the impulses of various forms of energy in the general case are not conserved, as are the energy carriers Θ_i themselves. This is most clearly manifested in entropy, which can arise from dissipation in isolated systems as well as in the masses of *k*-th substances that appear or disappear during chemical reactions.

Thus, a more general approach from the positions of energodynamics reveals the possibility of violating the law of conservation of momentum in mechanical motion due to its transformation into other forms of energy. Accounting for this circumstance opens new prospects for creating means of transport that violate the postulates of classical mechanics[43].

6. Conclusion

(1) The existing paradigm of homogeneity and isotropy of space does not consider the uneven distribution of matter in it (internal non-equilibrium of material systems) and therefore is not able to explain the reason for the occurrence of any macroprocesses in them.

(2) The "principle of non-equilibrium processes counter-direction" justified in the article reveals the inevitability of the occurrence of disordered oscillatory motion in inhomogeneous systems, the measure of which is Leibniz's "living force" Mv^2. This energy is twice the external kinetic energy of ordered motion with the same speed $M\mathbf{v}^2/2$, which forces us to rethink the concept of total energy and reformulate the law of its conservation.

(3) For isolated systems, "living force" is its internal energy U, and thermal energy and the energy of ordered translational and rotational motion are its components. This deprives the meaning of the concept of external energy in such systems and the failure of the orientation of classical mechanics to conditional "conservative" systems and imaginary "inertial" frames of reference.

(4) The system-energodynamic method of analyzing natural and technological processes proposed in the article dictates the need for and makes it possible to generalize all three principles of Newtonian mechanics:

- 1st beginning (principle of inertia)—on systems rotating "by inertia";
- 2nd beginning (the law of force)—on the forces of a non-mechanical nature;
- 3rd beginning (the law of action and opposition)—in case of the presence of reaction forces of different nature.

(5) A generalized definition of a force of any nature as a gradient of the corresponding form of energy shows that the impulse $M\mathbf{v}$ is not identical with the amount of motion $M\mathbf{v}$ and makes it possible to distinguish reaction forces from active forces by introducing the concept of "mechanical efficiency" as their ratio. This allows you to correct the dynamic laws of mechanics, considering the irreversibility of the processes studied by it.

(6) The definition of the force of inertia as a kind of reaction force depending on the speed of the process allows us to distinguish forces as functions of the state and as functions of the process, and to substantiate their reality of both, thereby generalizing the concept of "inertia" to processes of any nature.

(7) The mistaken interpretation of mass as a measure of inertia is a consequence of the simplification of Newton's law of force on the assumption of its constancy. The true measure of inertia is the impulse $M\boldsymbol{v}$, which includes translational, rotational, and oscillatory components.

(8) The relativistic dependence of the mass on the velocity is the result of a mistaken substitution of the impulse $M\boldsymbol{v}$ as the coordinate of the acceleration process by the mass M, which is the coordinate of the mass transfer process. This violates the principle of "determinism of the state" proved in the article, which asserts their independence.

(9) The law of conservation of the impulse $M\boldsymbol{v}$ in an isolated system does not exclude the possibility of the mutual transformation of its rotational and translational components, which opens the possibility of creating on this basis movers capable of moving in space due to internal forces.

(10) The consequences of the system-energodynamic method of analysis presented in the article confirm its heuristic value. The possibility of converting the energy of oscillatory motion into ordered forms of energy is consistent with the concept of the emergence of "order" from "chaos" and opens new prospects for the synthesis of mechanics with thermodynamics and other fundamental disciplines.

Conflict of interest

The author declares no conflict of interest.

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