Introduction to Mechanodynamics

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For 322 years, Newton's dynamics have operated despite clear violation of the laws of cause and effect originating from his first law. A transition of dynamics into the framework of the cause and effect relationships has proved to be possible only when the new scientific notions have been introduced and its laws have been systematized.

1. Introduction

A concept of "Dynamics" was introduced long ago and acquired various prefixes, which limit the areas of study involved, but nevertheless give a more concentrated and concise focus of the respective phenomena and processes being described. Terms such as "Electrodynamics", "Hydrodynamics" and "Aerodynamics" have been used for a long time. The field of study of microelectrodynamics has recently appeared. As a result, it has become necessary to distinguish dynamics, which describes the mechanics of rigid bodies only, from other uses of the term 'dynamics.' Taking this into account, we introduce ~~a~~ the term "Mechanodynamics", which deals with the dynamics of mechanical motions of rigid bodies, which has formerly been described by the term "Dynamics."

"Mechanodynamics" is a part of theoretical mechanics, in which a relationship of the motion of ~~the~~ material points and bodies and the forces exerting influence on them is established and studied.

A material point and a perfectly rigid body are the main objects mechanodynamics deals with. Such physical objects, in which variations in the motion of its separate points can be neglected, are considered as one material point. Taking this into consideration, the motion of such an object can be considered ~~as~~ to be the ~~a~~ motion of a single rigid body.

A perfectly rigid body is a complex of its individual material points, the distances between which are not changed through time. Thus it can be seen that a material point is a particular case of a rigid body.

A complex of physical bodies, which cannot move independently from each other due to the relationships between them, is called a mechanical system.

The laws of mechanodynamics are based on the fundamental axioms of natural science: space and time are absolute; space, matter and time are inseparable. The authenticity of the axioms originates from the obviousness of their statements. An authenticity of the laws of mechanodynamics, which are based on the axioms, is not obvious and must be proved experimentally; that's why of the laws of mechanodynamics cannot be considered axioms, they are postulates.

Initially, the laws of dynamics were systematized by Isaac Newton in his book *Mathematical Principles of Natural Philosophy* (1687). He formulated the first law of dynamics in the following way: "*Every body continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change this state by forces impressed upon it*". In this statement, we see at once a violation of the principle of the cause and effect relationships. Any motion is ~~a~~ caused by the action of a force, but that is missing in Newton's first law. There is no mathematical formula for this law. Instead, Newton's first law describes only the motion itself – the body moving with a constant velocity – without dealing with the cause of the motion: $\overline{V} = \text{const}$ (Fig. 1, position A).

The discrepancies being described are ~~a~~ caused by a violation of the principle of sequence of an analysis of the phenomenon or the process being described. This principle requires a description of the process or the phenomenon from its very beginning, not just from the middle. An accelerated motion is the beginning of any motion, and a uniform motion is its result. Thus, in order to return to the principle of cause and effect relationships when dealing with Newtonian dynamics, it is necessary to consider his second law, which deals with the acceleration of a body, first. As a result, we get a new dynamics. In order to differentiate it from the old dynamics, let us call it "Mechanodynamics". It will describe only mechanical motions of the bodies. The centuries-old experience using Newton's second law has proved its absolute authenticity; that's why we have every reason to put it in first place and to call it the main law of mechanodynamics.

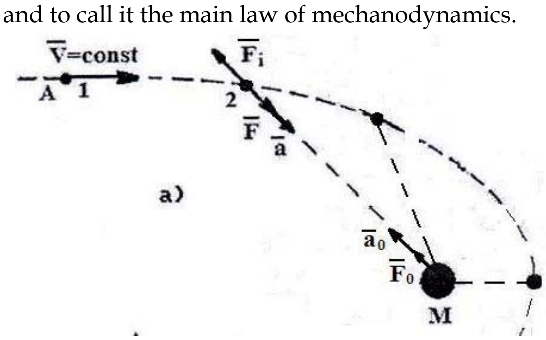

Fig 1a. Apparent forces acting on asteroid A approaching planet M

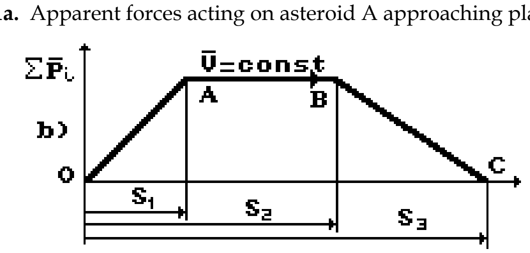

Fig. 1b. Change of resistance forces $\sum_{i=1}^{n} \overline{P}_i$ acting on a body having the accelerated motion (OA), a body having the uniform motion (AB) and a body having the decelerated motion (BC)

2. The Main Law of Mechanodynamics

Force $\overline{F}$ acting on a material body, which moves with acceleration $\overline{a}$, is always equal to mass m of the body multiplied by acceleration and coincides with an acceleration direction (Fig. 1, a, position 2).

$$\overline{F} = m \cdot \overline{a} \tag{1}$$

In order to discriminate force $\overline{F}$, which causes acceleration, from other forces, let us call it Newtonian force. It always coincides with the direction of acceleration $\overline{a}$, which it produces. All other forces are the motion resistance forces.

In 1743, Jean d'Alembert supplemented Newton's second law, noting that the inertial force $\overline{F}_i$, which is directly opposed to the acceleration direction $\overline{a}$ is equal to

$$\overline{F}_i = -m \cdot \overline{a} \tag{2}$$

It then appears from this that two forces, which are equal in value and opposite in direction, act on the body, which nevertheless accelerates. At any given instant of time the Newtonian force is $\overline{F}$ and d'Alembertean inertia force is $\overline{F}_i$. Newtonian force $\overline{F}$ acting on asteroid A, which approaches planet M, and the inertia force $\overline{F}_i$ which acts in the opposite direction to the Newtonian force are shown in Fig. 1, a, position 2. As there is no mechanical resistance in space, these equal and opposing forces should bring the body to a quiescent or steady motion state. Instead, it accelerates, proving a discrepancy exists which demands elimination

The First Law of Mechanodynamics

For more than 300 years, it was supposed that Newtonian force $m\overline{a}$ moves a body, and a sum of resistance forces $\sum_{i=1}^{n} \overline{P}_i$ hinders this motion without involvement of the inertial force $\overline{F}_i$, which is also directed in opposition to the motion (Fig. 2, b). In order to make certain there is an error in the standard approach to this dilemma, let us consider the accelerated motion of a car in detail (Fig. 2, b).

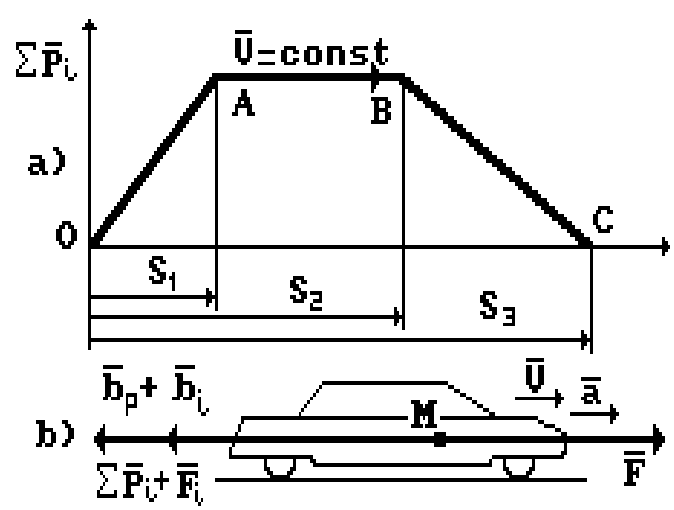

Fig. 2. Forces acting on the car in acceleration (OA)

We have all driven cars, and we know when the car accelerates, it presses us into the seat. If our car is hit from behind by another car, the resulting acceleration can overpower the ability of our muscles and neck vertebrae to resist it, snapping the head back. A head-rest helps to save us from severe whip-lash injuries. In the opposing scenario, if our car hits an obstacle, vehicle acceleration is suddenly stopped, but the inertial force thrusts our body forward. In order to prevent this force from throwing us through the windshield, we use seat belts.

The reality of the process just described involving inertia has been proved by millions of deaths of those who have perished in automobile accidents. However the physicists and theoreticians go on ignoring it, thinking that the inertia force $\overline{F}_i$ is not among the forces $\sum_{i=1}^{n} \overline{P}_i$ acting on the body during its accelerated or decelerated motion. Let us correct their mistake.

When a car accelerates (Fig. 2. b), the following forces act on it: Newtonian force $\overline{F}$ being generated by its engine, the inertia force $\overline{F}_i$ directed in opposition to the acceleration $\overline{a}$ of the car and arresting its motion, and the aggregate forces of all external resistances $\sum_{i=1}^{n} \overline{P}_i$, which are also directed in opposition to the motion of the car. As a result, we have a clear equation of the forces exerted on an accelerating car (Fig. 2, b).

$$\overline{F} = \overline{F}_i + \sum_{i=1}^{n} \overline{P}_i \tag{3}$$

This is the first law of mechanodynamics. It reads: the accelerated motion of a body takes place under the influence of Newton's active force $\overline{F}$ and the motion resistance forces in the form of the inertia force $\overline{F}_i$ and the mechanical resistance forces $\sum_{i=1}^{n} \overline{P}_i$.

If we agree with d'Alembert, who thought that the inertia force value $\overline{F}_i$ is equal to the body mass m multiplied by the same acceleration $\overline{a}$, which takes place under the influence of Newtonian force $\overline{F} = m \cdot \overline{a}$, the resistance force $\sum_{i=1}^{n} \overline{P}_i$ being a part of the equation (3), equals zero. There is only one way out of this contradiction: it is necessary to introduce the concept of a force, which generates acceleration $\overline{a}$, and a force, which generates deceleration $\overline{b}$. Thus, Newtonian force $\overline{F}$ will always generate acceleration $\overline{a}$, and all other forces will generate deceleration. We have every reason to think that Newtonian force $\overline{F}$ coincides with the acceleration $\overline{a}$ direction, and the forces, which hinder the motion and, consequently, generate deceleration, coincide with the direction of decelerations $\overline{b}$ being formed by them (Fig. 2, b). If we designate the deceleration, which belongs to the inertial force, as $\overline{b}_i$ and the deceleration, generated by the forces of mechanical resistances $\sum_{i=1}^{n} \overline{P}_i$, as $\overline{b}_p$, we can rewrite the equation (3) in the following way

$$m \cdot \bar{a} = m \cdot \bar{b}_i + \sum_{i=1}^{n} \bar{P}_i \tag{4}$$

It is easy to see that in case of a complete absence of the forces of mechanical resistances $\sum_{i=1}^{n} \bar{P}_i = 0$ (for example, in space), the inertial force $\bar{F}_i = m \cdot \bar{b}_i$ equals Newtonian force $\bar{F} = m \cdot \bar{a}$. However it should be noticed the body is moving. This is possible only when the Newtonian force exceeds the inertial force. That's why a mathematical model, which describes the motion of a body in space, should be presented in the form of an inequality

$$\bar{F} \geq \bar{F}_i \Rightarrow m\bar{a} \geq m\bar{b}_i \tag{5}$$

or

$$\bar{a} \geq \bar{b}_i \tag{6}$$

This is the condition of a body in motion through space when resistance is absent. It appears from this that an actual inertial deceleration $\bar{b}_i$ of a body can be determined under conditions when external resistances are absent. It must be assumed that the specialists in space engineering are in possession of the methods of such determinations and have experimental information concerning them.

Thus, a value of final acceleration $\bar{a}$ of the accelerating body, equals ~~a~~ the sum of the decelerations being generated by the forces resisting motion.

$$\bar{a} = \bar{b}_i + \bar{b}_p \tag{7}$$

In old dynamics, an inertial component of deceleration $\bar{b}_i$ was a part of a deceleration $\bar{b}_p$ being generated by the forces of mechanical resistances to motion; it hindered an analysis of the forces acting on all types of motions: accelerated motion, uniform motion and decelerated motion. It was considered that the inertial force $\bar{F}_i$, which also hindered the accelerated motion of the body, was not a part of the sum of all forces of mechanical resistances $\sum_{i=1}^{n} \bar{P}_i$. This is the main fundamental error of Newtonian dynamics, which has remained unnoticed for 322 years. In the beginning, the inertial force was by implication a part of the aggregate forces of mechanical resistance $\sum_{i=1}^{n} \bar{P}_i$, but no one gave it consideration. As a result, all experimental coefficients of mechanical resistances to body motion prove to be erroneous.

It appears from ~~the~~ equation (4) that the inertial force $\bar{F}_i$, which acts on the car when it accelerates, equals

$$\bar{F}_i = m\bar{b}_i = m\bar{a} - \sum_{i=1}^{n} \bar{P}_i \tag{8}$$

and a scalar value of inertial deceleration $\bar{b}_i$ is determined according to the formula

$$b_i = a - \frac{\sum_{i=1}^{n} \bar{P}_i}{m} \tag{9}$$

A value of complete Newtonian acceleration is determined from the kinematical equation of the accelerated motion of the body

$$V = V_0 + at \tag{10}$$

If the initial velocity of the car $V_0 = 0$, complete acceleration a equals velocity of the car V at the moment of its transition from the accelerated motion to the uniform motion divided by time of the accelerated motion.

$$a = V / t \tag{11}$$

In principle, when the problems are being solved, it is possible to assume that a value of velocity V equals a value of constant velocity ($V = const$) of the body during its uniform motion, which takes place after the accelerated motion. A sum of the resistance forces $\sum_{i=1}^{n} \bar{P}_i$ is **an experimental value**, which should be determined only in case of uniform motion in order to exclude the inertial force from it.

Thus, all the data, which are necessary for a determination of inertial deceleration $\bar{b}_i$ and a calculation of the inertial force $\bar{F}i$ according to equation (8), are available. It appears from this equation that a fraction of inertial deceleration $\bar{b}_i$ depends on the resistance of the medium $\sum_{i=1}^{n} \bar{P}_i$ (9).

If it is necessary to determine the resistance forces of the moving body, it should be done only during its uniform motion. If a sum of these resistance forces $\sum_{i=1}^{n} \bar{P}_i$ is determined during its accelerated motion, the inertial force $\bar{F}_i$, in accordance with the equation (3), is automatically included in the sum of the motion resistance forces $\sum_{i=1}^{n} \bar{P}_i$, and as a result, the determination of resistance forces will be completely erroneous.

3. The Second Law of Mechanodynamics

After acceleration is complete and the car begins uniform motion (Fig. 3, b), the inertial force $\bar{F}_i$ changes its direction ~~for~~ to the opposite one automatically, from opposition to acceleration to continued movement, and the equation of the sum of the forces (3), which act on the car, becomes as follows:

$$\bar{F}_K + \bar{F}_i = \sum_{i=1}^{n} \bar{P}_i \tag{12}$$

This is the second law of mechanodynamics - the law of uniform motion of the body (the former first law of Newtonian dynamics). It reads: if there are no resistances, uniform motion of the body (Fig. 1, a, position 1) takes place under the influence of the inertial force $\bar{F}_i$. If there are resistances, uniform motion of the body takes place under the influence of the inertial force $\bar{F}_i$ as well as a constant active force $\bar{F}_K$ which overcomes the motion resistance forces $\sum_{i=1}^{n} \bar{P}_i$ (Fig. 3, b).

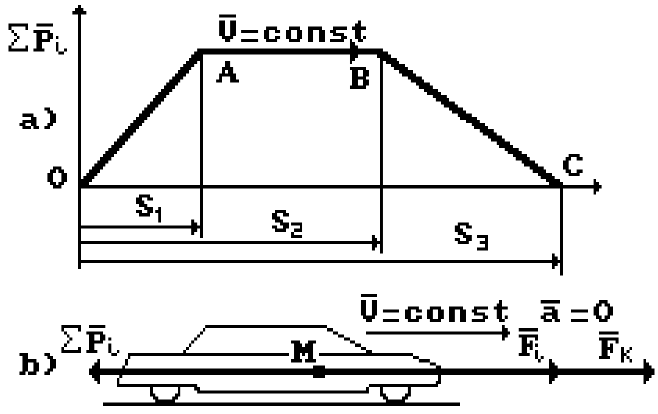

Fig. 3. Forces acting on the car in uniform motion

Thus, the essence of the second law of mechanodynamics is that uniform motion of the car (body) is provided by the inertial force $\overline{F}_i$, and the constant force $\overline{F}_K$ being generated by the car engine which overcome all external resistances $\sum_{i=1}^{n}\overline{P}_i$. The force $\overline{F}_K$ is constant, because the car has uniform motion, and its acceleration equals zero: $\overline{a}=0$.

In space, where there are no mechanical resistances to motion, the constant force to overcome them is not required. That's why when the body changes its accelerated motion to uniform motion, the inertial force changes its direction to the opposite one and thereby provides ~~its~~ uniform motion with constant velocity $V=const$ (Fig. 1, position 1).

Let us now return to the centuries-old error involved in Newtonian mechanics. For this purpose, let us rewrite ~~the~~ equation (12) in the following way:

$$\overline{F}_K=\sum_{i=1}^{n}\overline{P}_i-\overline{F}_i \qquad (13)$$

This is a mathematical formula for the second law of mechanodynamics (the former first law of dynamics). There was no mathematical model for the description of uniform motion of a body for more than 300 years. Now it exists (12), (13).

Now we can set aircraft pilots' minds at rest. Uniform flight of their plane is described by the second law of mechanodynamics (12). According to this law, the sum of the forces, which act on a plane having uniform motion, does not equal zero (13). The force which provides uniform motion of a plane is the inertial force, which was in opposition to its motion when it accelerated at take-off. When the plane begins uniform motion, the inertial force changes its direction and coincides with a force being created by the engines of the plane. As a result, the inertial force begins to provide uniform flight for the plane, and the force of the engines overcomes the resistance forces to flight. Thus, the uniform flight of the plane is governed by the second law of mechanodynamics (12), according to which a sum of the forces acting on it does not equal zero.

4. The Third Law of Mechanodynamics

It is necessary to have a clear understanding about the change of the direction of the inertial force when a transition from uniform motion to decelerated motion takes place. When a car changes from uniform motion to decelerated motion, the primary inertial force $\overline{F}_i$ (Fig. 4, b) does not change direction; the deceleration $\overline{b}_p$, which has occurred and is generated by the resistance forces, is directed opposite to the primary inertial force, $\overline{F}_i$

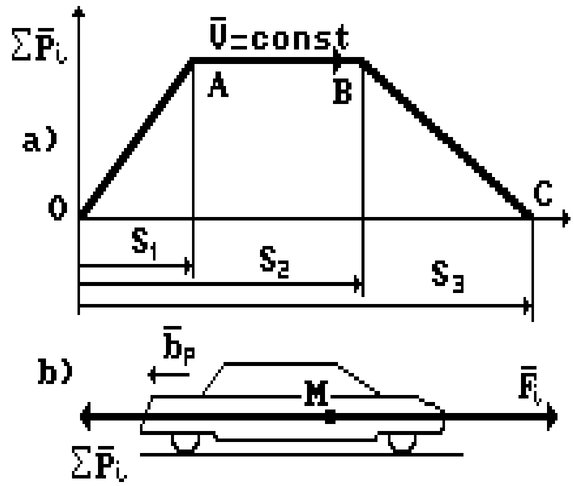

Fig. 4. Forces acting on the car in deceleration

Thus, if the car changes its uniform motion for decelerated motion, the former inertial force $\overline{F}_i$ and the motion resistance forces $\sum_{i=1}^{n}\overline{P}_i$ do not change their directions. The inertial force does not generate acceleration, and irregularity of the resistance forces results in a gradual reduction of the inertial force $\overline{F}_i$, and the body stops.

$$\sum_{i=1}^{n}\overline{P}_i>\overline{F}_i \qquad (14)$$

This is the mathematical formula for the third law of mechanodynamics. It reads: decelerated motion of a rigid body is governed by exceeding the motion resistance forces over the inertial force.

If the car's accelerator is released, or disconnected, active force disappears $\overline{F}_K$ (Fig. 3, b), and two oppositely directed forces remain: the inertia force $\overline{F}_i$ and the sum of forces of mechanical resistance to motion $\sum_{i=1}^{n}\overline{P}_i$ (Fig. 4, b). As the inertial force has no continuing source, which previously kept it in a constant state, it proves to be less than the motion resistance forces ($\overline{F}_i<\sum_{i=1}^{n}\overline{P}_i$), and the car, begins decelerating (Fig. 4, b), and then stops (Fig. 4, a, point C). Taking this into account, we now have reason to call the inertial force a passive force which cannot generate acceleration, as it, itself, was a consequence of that acceleration.

Let us pay attention to the fact that a distance S_1 of the car motion with acceleration is less than a distance of motion with deceleration S_3-S_2 (Fig. 4, a). This is required by the fact that the value of the resistance forces $\sum_{i=1}^{n}\overline{P}_i$ in the case of acceleration from a stop, as indicated by S_1, exceeds the resistance forces, in case of decelerated motion. This is because decelerated motion means the engine and/or the accelerator are not being used (This is the main reason for fuel conservation when automatic speed control periodically releases the accelerator.)

5. The Fourth Law of Mechanodynamics

The fourth law of mechanodynamics (There is always an equal and opposite reaction to every action): the forces with which two bodies act on each other (Fig. 1, a, pos. 2) are always equal according to the modulus and are directed in a straight line, which connects the centers of masses of these bodies, to the opposite directions.

In the second position of Fig. 1, a, it is clear that force $\overline{F}$ of the action of planet M equals $\overline{F} = m \cdot \overline{a}$, and the force $\overline{F}_0$ of action of asteroid A on the planet equals $\overline{F}_0 = M \cdot \overline{a}_0$ (a, a_0 - accelerations of the asteroid and the planet, respectively). As $\overline{F} = -\overline{F}_0$, it means that $m \cdot \overline{a} = -M \cdot \overline{a}_0$ or

$$\frac{a}{a_0} = \frac{M}{m}. \qquad (15)$$

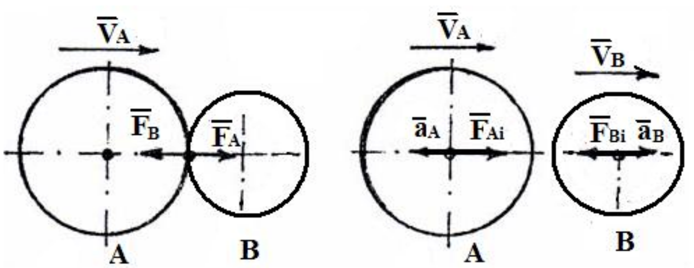

Fig. 5. Contact interaction of two bodies

This means that the accelerations, which two bodies give each other, are inversely proportional to their masses. The accelerations are directed along one and the same line but in opposite directions. It should be noted that the fourth law of mechanodynamics reflects an interaction of the bodies both at a distance (Fig. 1, a, position 2) and in the case of ~~a~~ direct contact (Fig. 5). It is shown in Fig. 5 that when the bodies A and B contact each other, the forces of their interaction $\overline{F}_A$ and $\overline{F}_B$ are equal in ~~their~~ value and are opposite in direction. Both forces $\overline{F}_A$ and $\overline{F}_B$ are the forces of external impact, and they emerge simultaneously. The inertial forces $\overline{F}_{Ai}$ and $\overline{F}_{Bi}$ are equal in value but opposite in direction.

6. The Fifth Law of Mechanodynamics

The fifth law of mechanodynamics (independence of action of the forces): If several forces resisting motion $\sum_{i=1}^{n} \overline{P}_i = \overline{P}_1, \overline{P}_2, \overline{P}_3, ..., \overline{P}_n$ act simultaneously on a body or a point, the Newtonian acceleration $\overline{a}$ of the material point or ~~a~~ body is equal to the geometrical sum of decelerations caused by each force which resists the motion: $\sum_{i=1}^{n} \overline{P}_i = \overline{P}_1, \overline{P}_2, \overline{P}_3, ..., \overline{P}_n$. Taking into account that in equation (7) $\overline{b}_p$ the geometrical sum of decelerations caused by all resisting forces is $\sum_{i=1}^{n} \overline{P}_i = \overline{P}_1, \overline{P}_2, \overline{P}_3, ..., \overline{P}_n$, except the inertial force $\overline{F}_i$, i.e. $\overline{b}_p = \overline{b}_1 + \overline{b}_2 + \overline{b}_3 + ... + \overline{b}_n$. Equation (7) can now be written:

$$\overline{a} = \overline{b}_i + \overline{b}_1 + \overline{b}_2 + \overline{b}_3 + ... + \overline{b}_n \qquad (16)$$

This is a mathematical formula for the fifth law of mechanodynamics. It reads: when a rigid body accelerates, the Newtonian acceleration formed by the Newtonian force is equal to the sum of decelerations caused by all forces resisting motion.

Let us recall Galileo's experiment, in which he placed ~~the~~ bodies having different masses and densities in a tube. He pumped the air out of it, and it turned out that if the tube was placed vertically, all bodies fall down at the same rate. In accord with the main law of mechanodynamics, the force acting on the body equals the product of mass by acceleration. It seems that bodies having different masses should move at different rates, but this is not observed. Why?

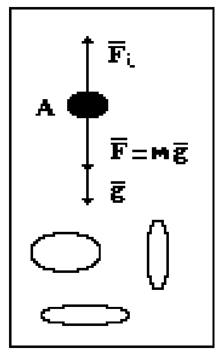

Fig. 6. Action of the forces on the bodies, moving in the evacuated tube

If only one force, gravity, $\overline{F} = m\overline{g}$ acted on the bodies in the evacuated tube (Fig. 6), each body would move at a different rate; but as all of them move at the same rate and with exactly the same acceleration, two forces are acting on each of them: the force of gravity $\overline{F} = m\overline{g}$ and the inertial force $\overline{F}_i = -m\overline{g}_i$. This equal rate of acceleration points out that the force of gravity exceeds the inertial force $\overline{F} > \overline{F}_i$. Thus, we have:

$$g = g_i \Rightarrow g > g_i \qquad (17)$$

as

$$\overline{F} = m \cdot \overline{g} \Rightarrow m = F / g \qquad (18)$$

shows, the mass of a material body (equal to its weight) is given by , F divided by free fall acceleration in ~~a~~ any given place on the surface of the earth.

A "Newton" (N) is accepted as the unit that measures force in the SI system. A force of one Newton produces an acceleration of 1 m/s^2.

In a technical unit system, 1 kg is accepted as a force measurement unit, and 1 kg·m/s^2 is accepted as a mass measurement unit. As $F = mg$, it means that 1 kg=1·9.81 N or 1 N=0.102 kg.

New knowledge in the field of mechanodynamics makes it possible to determine exactly the forces resisting the motion of any physical body. Equations 3-11 provide a method for determining these forces. To determine the forces resisting the motion of a car, it is necessary to choose a uniform horizontal section of road, to drive a specified distance along it at a specified constant velocity and to measure fuel consumption. The energy from the fuel consumption will be equal to the work of a force $\overline{F}_K$, which counteracts all forces resisting motion, $\sum_{i=1}^{n}\overline{P}_i$, at the registered part of the road. It appears from this that the force $\overline{F}_K$ is equal to a sum of forces $\sum_{i=1}^{n}\overline{P}_i$.

If a similar experiment is carried out when a car is accelerating, the inertial force $\overline{F}_i$, according to equation (3), which hinders acceleration, will be automatically included in the sum of resistance forces $\sum_{i=1}^{n}\overline{P}_i$, and as a result, the resistance force determination will be completely erroneous.

Newtonian or motive force will be determined in accordance with Newton's second law

$$F = m \cdot \frac{dV}{dt} = m \cdot a \tag{19}$$

In this case it is more convenient to determine Newtonian acceleration a according to equation (11) and an inertial component b_i according to equation (9). The inertial force will be determined according to equation (8).

7. Mechanodynamics of AcceleratedCurvilinear Motion, Uniform Motion, and Decelerated Motion of a Point

7.1. Mechanodynamics of Accelerated Curvilinear Motion of a Point

Curvilinear motion of a point is usually described by a natural system of coordinates, which has a normal axis on, a tangential axis $o\tau$ and a binormal ob (Fig. 7). A plane $on\tau$ is called an osculating plane. The axis ob is perpendicular to the osculating plane. Velocity $\overline{V}$ of the point is along the direction of motion.

As the motion is a curvilinear one, a normal component $\overline{a}_n$ of complete acceleration $\overline{a}$ is always directed to a concavity of the curve (Fig. 7). The direction of the tangential component $\overline{a}_t$ of complete acceleration $\overline{a}$ depends on the nature of the curvilinear motion. If it is accelerated, the directions of the tangential acceleration $\overline{a}_t$ and a velocity vector $\overline{V}$ coincide (Fig. 7).

As the motion is an accelerated curvilinear one, the following forces act on the material point: the Newtonian (active force) $\overline{F}$, the sum of resistance forces $\sum_{i=1}^{n}\overline{P}_i$ directed oppositely to the motion, the tangential component $\overline{F}_{it}$ and the normal component $\overline{F}_{in}$ of complete inertial forces $\overline{F}_i$. A vector of Newtonian force $\overline{F}$ is directed along a vector of complete acceleration $\overline{a}$ to the concavity of the curve. It is separated into two components: the normal component $\overline{F}_n$ and the tangential one $\overline{F}_t$.

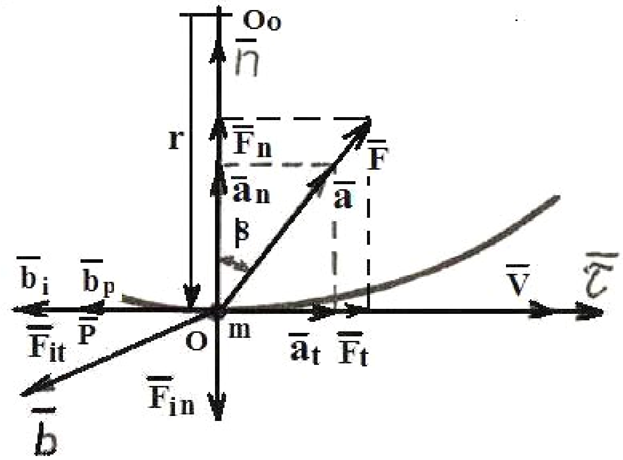

Fig. 7. Diagram of accelerations and forces acting on the material point, which moves curvilinearly and with acceleration

As the tangential inertial force $\overline{F}_{it}$ is directed oppositely to the acceleration $\overline{a}_t$, the normal component $\overline{F}_{in}$ of the inertial force is always directed from the trajectory curvature centre along a curvature radius, and the tangential component $\overline{F}_{it}$ of the inertia force is directed oppositely to the tangential component $\overline{a}_t$ of the complete Newtonian acceleration $\overline{a}$ and coincides with the direction of the tangential deceleration $\overline{b}_i$.

Thus, an equation of the forces which act on the material point along a tangent to the curvilinear trajectory, will be written in the following way

$$\overline{F}_t = \overline{F}_{it} + \sum_{i=1}^{n}\overline{P}_i \tag{20}$$

or

$$m \cdot \overline{a}_t = m \cdot \overline{b}_i + \sum_{i=1}^{n}\overline{P}_i \tag{21}$$

As it is clear, equations (20) and (21) are similar to the equations of the forces (3) and (4) acting on a body, which accelerates in a straight-line motion. In order to solve this equation, it is necessary to know acceleration $\overline{a}_t$ and deceleration $\overline{b}_i$. In order to determine them, it is primarily necessary to know the equation of the motion of the point. In the case being considered, it is preset in a true form

$$S = S(t) \tag{22}$$

When we know the point motion equation (22), we find its velocity

$$V = \frac{dS}{dt} \tag{23}$$

and the tangential acceleration

$$\overline{a}_t = \frac{dV}{dt} \tag{24}$$

A normal acceleration modulus $\overline{a}_n$ is determined according to the formula

$$a_n = \frac{V^2}{r} \tag{25}$$

where r is a trajectory curvature radius.

A deceleration modulus $\bar{b}_i$ can be determined only in the case when a sum of the resistance forces $\sum_{i=1}^{n}\bar{P}_i$, which act on the point, is known. The value $\sum_{i=1}^{n}\bar{P}_i$ is determined experimentally. If we know it, we can find the deceleration $\bar{b}_i$, which is given by the tangential component $\bar{F}_{it}$ of the inertial system (Fig. 7).

$$b_i = a_t - \frac{\sum_{i=1}^{n}\bar{P}_i}{m} \tag{26}$$

It appears from this equation that the deceleration $\bar{b}p$, which comes from the resistance forces $\sum_{i=1}^{n}\bar{P}_i$, is equal to

$$b_p = \frac{\sum_{i=1}^{n}\bar{P}_i}{m} \tag{27}$$

or

$$b_p = a_t - b_i \tag{28}$$

Thus, the new laws of mechanodynamics make it possible to describe a process of accelerated curvilinear motion of a material point correctly. Let us now describe a uniform curvilinear motion of a point.

7.2. Mechanodynamics of Uniform Curvilinear Motion of a Point

In the case of uniform curvilinear motion of the point, the tangential acceleration $\bar{a}_t$ equals zero, but the tangential force of inertia, $\bar{F}_{it}$, which acted on the point when it moved with acceleration prior to transition to a uniform motion, does not disappear. It changes to the opposite direction (Fig. 8). As a result, the sum of the tangential forces, which act on the material point, will be written in the following way

$$\bar{F}_{tk} + \bar{F}_{it} = \sum_{i=1}^{n}\bar{P}_i \tag{29}$$

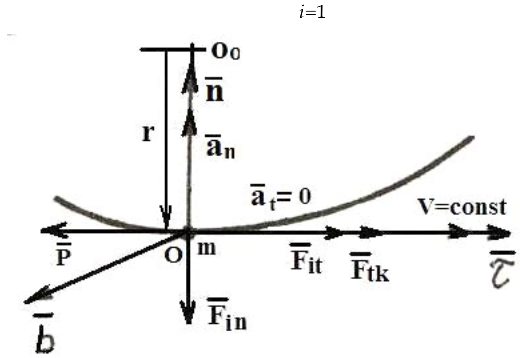

Fig. 8. Forces acting on the material point in uniform curvilinear motion

Let us remember that the sum of the point motion resistance forces $\sum_{i=1}^{n}\bar{P}_i$ is an experimental value. As velocity of the curvilinear motion of the point is a constant value, $V = const$, in this case, the tangential component of its complete acceleration $\bar{a}$ equals zero, $\bar{a}_t = 0$, and there remains only the normal acceleration $\bar{a}_n$, which corresponds to the normal component of the inertial force $\bar{F}_{in}$ which is now in the opposite direction to the normal acceleration (Fig. 8).

A physical meaning of equation (29) is as follows. The active tangential force $\bar{F}_{tk}$ overcomes all motion resistances $\sum_{i=1}^{n}\bar{P}_i$, and the inertial force $\bar{F}_{it}$ moves the point uniformly. Thus, we have all the information necessary for a determination of the forces acting on the material point, which moves curvilinearly and uniformly.

7.3. Mechanodynamics of Decelerated Curvilinear Motion of a Point

When a material point changes its uniform motion for a decelerated curvilinear motion, the tangential component $\bar{F}_{tk}$ of the active force disappears. There remains a tangential component $\bar{F}_{it}$ of the inertial force and the sum of the motion resistance forces $\sum_{i=1}^{n}\bar{P}_i$, which generate a deceleration $\bar{b}_p$ (Fig. 9). As the sum of the forces resisting motion $\sum_{i=1}^{n}\bar{P}_i$ exceeds the inertial tangential force $\bar{F}_{it}$ (which does not generate acceleration), the deceleration $\bar{b}_p$ (which corresponds to force $\sum_{i=1}^{n}\bar{P}_i$ and coincides with its direction), forms together with the acceleration normal component $\bar{a}_n$ the complete acceleration $\bar{a}$ which is directed away from the left side of the normal axis on (Fig. 9).

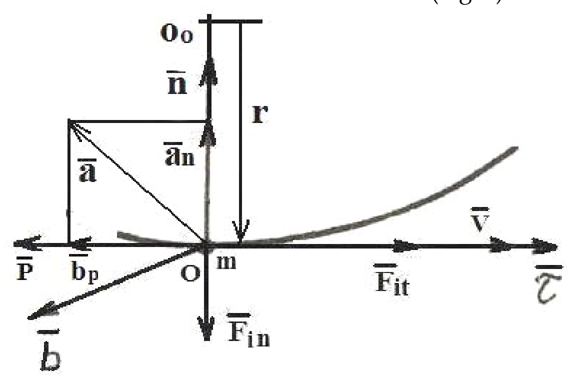

Fig. 9. Diagram of accelerations and forces acting on the point in case of its decelerated curvilinear motion

When the point decelerates, the sum of the forces resisting motion $\sum_{i=1}^{n}\bar{P}_i$ exceeds the inertial force $\bar{F}_{it}$, and the motion of the point is decelerated gradually.

New knowledge in the field of mechanodynamics makes it possible to determine precisely the forces resisting the motion of any physical body. Equation (29) allows these forces to be determined. If they are to be determined, it is necessary to do ~~it~~ so only when the point is moving uniformly. If the sum of the forces resisting the point's motion $\sum_{i=1}^{n}\bar{P}_i$ is determined while the point is being accelerated, the inertial force $\overline{F}_{it}$, (in accordance with equation (29), which hinders the acceleration of the point), will become ~~a~~ part of the total forces resisting motion, $\sum_{i=1}^{n} \overline{P}_i$ automatically. This will result in a completely erroneous determination of the resistance forces.

In case of curvilinear motion, Newtonian, or active, force is determined according to Newton's main law

$$F = m \cdot \frac{dV}{dt} = m \cdot a \tag{30}$$

Complete Newtonian acceleration a is connected with its normal component $\overline{a}_n$ and the tangential one $\overline{a}_t$ by simple dependence:

$$a = \sqrt{a_n^2 + a_t^2} \tag{31}$$

That's why if $\overline{a}_n$ and $\overline{a}_t$ are known, it gives an opportunity to determine complete acceleration a. Let us note that if the radius of curvature of the point motion trajectory is constant, all the facts, which are described in this lecture, belong to a motion of the point in a circle as well.

8. Conclusion

These two introductory lectures in mechanodynamics have enough information for a review of all other parts of Newton's old dynamics. The specialists in theoretical mechanics will understand the essence of the first two lectures and will write all other ones without our participation. But if they fail to understand the essence of the error of Newton's first law, erroneous dynamics will exist for a long time.

New laws of mechanodynamics have already allowed us to describe in detail the shock force of the second power unit, of the Sajano-Shushenskoj, HYDROELECTRIC POWER STATION. The sum of the forces resisting the power unit movement exceeded $F_0 = 2580 + 21764 = 24344 tonn$. Physical and chemical processes in the water delivery zone on the turbine blade generate a shock force equal to

$$F_y = \frac{F}{t_y} = \frac{5.10 \cdot 10^8}{0.05} = 1.030000 \cdot 10^{10} N/S = 1.030.000 tonn/s.$$

Results of the calculation of the pulse force by means of the laws of mechanodynamics coincide very closely with calculations of this force by means of the laws of physchemistry with regard to processes which have been generated by this force.

References

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