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The movement investigation of an axisymmetric rotation body under the action of electromagnetic fields

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ABSTRACT

Purpose: To ensure an adequate level of accuracy, it is rational to study the ponderomotor forces of the ring, which drive a hollow disk of variable thickness, hung on the ring.

Design/methodology/approach: The solution of the motion problem of a hollow disk of variable thickness suspended on a force ring of rectangular cross section is based on the method of solving the equations of the theory of thermoelasticity. The stress-strain state, as well as the motion of the specified body of rotation, the disk, in studies in a cylindrical coordinate system, under the action of ponderomotor forces.

Findings: The motion equation of a hollow disk hung on a force ring-torus is made, exact solutions of the motion equations of a ring in the torus form of rectangular cross section are found. New component expressions of ponderomotor forces, which appear from the action of the ring's own electromagnetic field and cause the motion of a hollow disk, have been found on the basis of Maxwell's equations. It is proved that at high speeds and low natural accelerations the stress - strain state of the disk material does not cause the destruction of the structure.

Research limitations/implications: Calculations of ponderomorphic forces are valid for the ring, which drives a hollow disk of variable thickness, hung on the ring.

Practical implications: It is proved that at high velocities and small natural accelerations the stress-strain state of the disk medium does not cause structural damage. It is determined that the rotation in the direction of movement at an angle of 90 degrees changes only the direction of the acceleration vector without increasing its value.

Originality/value: The dependences between own time and coordinate time are formulated. It is proved that a small change in the natural time for the studied disk can significantly change the coordinate time, and the pulsed electromagnetic field provides the ability to cover infinitely large distances over finite periods of time.

Keywords: Hollow disk, Stress-strain state, Ponderomotor forces, Force ring-torus, Electrically conductive medium, Coordinate time, Natural time, Natural acceleration, Natural velocity, Gravitational field

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ANALYSIS AND MODELLING

1. Introduction

It is known that the axisymmetric problems of the elasticity theory belong to the class of spatial problems, the solution of which has great mathematical difficulties due to the fact that finiteness of dimensions causes additional mathematical difficulties associated with the need to meet boundary conditions on lateral surfaces and ends. Today there is no exact solution to the axisymmetric problem of the theory of elasticity, which would strictly and completely satisfy all boundary conditions on the lateral surfaces and ends of the studied bodies of rotation [1,2]. Exact analytical models of the torus motion of rectangular cross-section of the hollow disk type mounted on the force ring-torus have not been compiled today, and existing models [1,3,4] do not take into account the presence of all force factors, including ponderomotor forces which arise as a result of the action of the ring's own electromagnetic field and bring the hollow disk into a movable state.

Existing models do not provide for the establishment of the destruction possibility of the metal structure at the emerging speeds and accelerations [5-7], as well as with increasing travel time. For the practical implementation of existing or development of new tools for analysis of reliability and strength [8-15] of any structures with preliminary evaluation and diagnosis requires the creation of stress-deformed state calculation [16-24] models of their structural elements [25-31] as a function that takes into account maximum all components of the state of the studied systems. It is necessary to study the motion of an elastic medium – an axisymmetric body of rotation, a ring in the torus form of rectangular cross section, within the framework of Newton's mechanics and relativistic mechanics by forming exact solutions of equations. To ensure an adequate level of accuracy, it is rational to study the ponderomotor forces of the ring, which drive a hollow disk of variable thickness, hung on the ring. concentration distribution (in volume fraction) of nitrogen and natural gas components depending on the distance from the injection point of nitrogen and the duration of the purge process, to determine of parameters of a non-stationary process, and to establish the optimal parameters of the purging process under conditions of the given flow chart.

2. Methodology of research

The solution of the motion problem of a hollow disk of variable thickness suspended on a force ring of rectangular cross section is based on the method of solving the equations of the theory of thermoelasticity proposed in [3]. The investigated hollow disk is under the action of the Earth's gravitational field; its motion is caused by the ponderomotor forces of its own electromagnetic field of the force ring. The stress-strain state, as well as the motion of the specified body of rotation, the disk, in studies in a cylindrical coordinate system, under the action of ponderomotor forces are considered in [1,3], but not all their components have been established which by solving the Maxwell's electrodynamics equation are investigated and defined in this article. In the system of cylindrical coordinates (r, φ, z) connected to a ring, its conductive medium should be considered based on Maxwell's equations. In the state studies of the electrically conductive medium of the ring, we have the assumption that the ring is in an electromagnetic field, which is formed by an electric current in the medium of the ring-torus.

The equation of the vector of ponderomotor forces relative to the unit volume of the conductive medium of the body [4]:

$$\overline{F} = \rho_{sd.} \cdot \overline{E} + \left[\overline{j} \cdot \overline{B} \right], \tag{1}$$

where $\overline{j}$ is the electric current density vector; ρ_{cd} – charge density; $\overline{B}$ – vector of magnetic induction; $\overline{E}$ – electric field voltage vector.

Suppose that the following components of vectors (in cylindrical coordinates) are formed in an electrically conductive medium by an electric field (r, j, z)).

$\overline{j}\left\{ j_r;0;0 \right\}$; $\overline{B}\left\{ 0;B_\varphi;0 \right\}$.

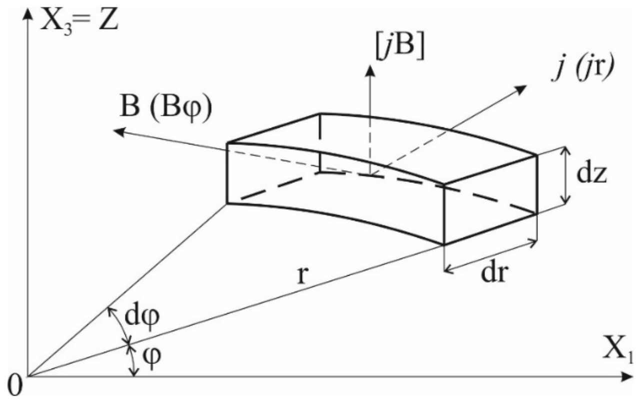

Fig. 1. Schematic of the component composition of ponderomotor forces

The scalar product of these vectors is zero, therefore, these vectors are mutually perpendicular, and their vector product has one component and is directed normally to the plane of the ring, therefore, for the components of ponderomotor forces (Fig. 1).

$$\overline{F}_r = \rho_{cd} \cdot E_r\,;\; F_\varphi = 0\,;\; F_z = j_r \cdot B_\varphi\,. \tag{2}$$

With the accepted components, the vectors of bulk current density and magnetic induction of the electrodynamics equations in cylindrical coordinates (r, j, z) for a body of rotation with axial symmetry and acting axially ponderomotor forces will take the form:

$$\frac{1}{r}\left(r \cdot E_r\right)_{,1} = \frac{\rho_{cd}}{\varepsilon\varepsilon_0};\, B_{\varphi,t} = 0;\, \left(r \cdot B_\varphi\right)_{,1} = 0;$$
$$\tau_1 \cdot j_{r,t} + j_r = \gamma \cdot E_r^* \tag{3}$$

where $\tau_1 = \frac{\varepsilon\varepsilon_0}{\mu}$ = – relaxation time of the conductive medium; ε_0 - electrical constant, taking into account that the medium has a finite electrical conductivity m; E_r^* – radial component of the voltage of a foreign electric field; e – relative dielectric constant.

Solving of (3):

$$E_r^* = 2D \cdot \rho_0 \cdot g_0 \cdot r;\, E_r(r,t) = -D \cdot \rho_0 \cdot g_0 \cdot r \cdot e^{-t/\tau_1};\, B_\varphi(r) = \frac{C}{r};$$
$$\rho_{св.}(t) = -2D \cdot \varepsilon \cdot \varepsilon_0 \cdot \rho_0 \cdot g_0 \cdot e^{-t/\tau_1};\, j_r(r,t) = \gamma \cdot D \cdot \rho_0 \cdot g_0 \cdot r \cdot \left(2 - e^{-t/\tau_1}\right) \tag{4}$$

where ρ_0 is the mass density of the conductive medium; g_0 – Acceleration of gravity.

Arbitrary constants D and C are related to the electrical conductivity dependence gDC = 1.

The components of ponderomotor forces are found by formulas (2):

$$F_r(r,t) = P_0(t)r;\, P_0(t) = P_1 \cdot e^{-2t/\tau_1};\, P_1 = 2 \cdot \varepsilon \cdot \varepsilon_0 \left(D \cdot \rho_0 \cdot g_0\right)^2 = const;$$
$$F_z(t) = \rho_0 \cdot g_0 \left(2 - e^{-t/\tau_1}\right). \tag{5}$$

An arbitrary structure can be hung on the torus ring, the mass of which is added to the mass of the ring (Fig. 2). Analyzing (4), the magnetic field $B_\varphi(r)$ is constant in time and appears in the annular coil of the power system. At the same time, the conductive medium of the ring is affected by a frequency-varying, but constant in the direction of the electric field $j_r(r,t)$ current perpendicular to the magnetic field.

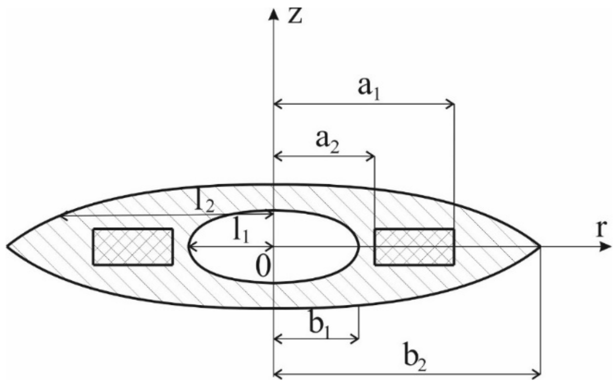

Fig. 2. Geometry of the hollow disk

The equation of motion of the ring is written as 3:

$$F_i + F_T - \left(\rho \cdot u_{i,t}\right)_{,t} = 0 \tag{6}$$

where $F_i\left(F_r; F_\varphi; F_z\right)$ are the components of the ponderomotor force per unit volume of the ring sector; u_i – moving the points of the ring body; F_T – gravity per unit volume of body of rotation:

$$F_T = -\frac{\rho_0 \cdot g_0 \cdot R^2}{z^2(t)} \tag{7}$$

The motion equation of a ring as a rigid body, in spherical coordinates (Fig. 3), (η, ψ, θ) is obtained from (6) taking into account (7) and (5):

$$\left(\rho \cdot u_{\theta,t}\right)_{,t} = F_\theta;\, \left(\rho \cdot u_{\psi,t}\right)_{,t} = F_\varphi;$$
$$\left(\rho \cdot u_{\eta,t}\right)_{,t} = \rho_0 \cdot g\,_0\left[\left(1 - \frac{R^2}{\eta^2(t)}\right) + \left(1 - e^{-t/\tau_1}\right)\right] \tag{8}$$

At the speed of the body, much less than the speed of light, $(v << c)$, $\rho = \rho_0$.

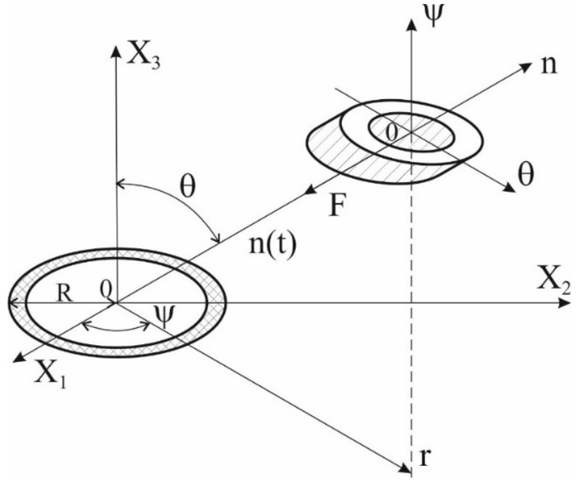

Fig. 3. The motion diagram of the ring as a rigid body

From (8), the expression of acceleration for the motion of a ring along the axis h, h(t) – the distance from the center of the Earth to the center of the coordinate system is associated with the ring:

$$\alpha_\eta = g_0 \left\{ \left[1 - \frac{R^2}{\eta^2(t)} + \left[1 - e^{-t/\tau_1} \right] \right] \right\} \tag{9}$$

From (8), after integration and fulfillment of initial conditions for the vertical component of velocity:

$$V_\eta = \sqrt{2g_0 \left[\left(\eta + \frac{R^2}{\eta} \right) - 2R + \eta \left(1 - e^{-t/\tau_1} \right) \right]} \tag{10}$$

Acceleration and speed will satisfy the following initial conditions:

$\eta(t) = R,$ at $t = 0; V_\eta = 0,$ at $t = 0; \alpha_\eta = 0,$ $t = 0$

That is, near the Earth's surface $\eta = R$, the ring is in a state of weightlessness. The structure attached to it, with biological objects inside the structure, g0 is accelerated by free fall; the specified structure is in equilibrium.

The acceleration of free fall $g(t) = g_0 R^2 / \eta^2(t)$ at relatively low altitudes varies slightly - indeed, since the average radius of the Earth = 6371 km, even at an altitude of several hundred kilometers above its surface $R \le \eta \le R + 300$ km acceleration varies slightly (≈ 4.5%). Thus, in the specified environment of the Earth it is possible to accept acceleration (9) and speed (10) at the movement normal to a surface of the Earth, km/s:

$$\alpha_\eta = g_0 \left(1 - e^{-t/\tau_1} \right); V_\eta = \sqrt{2g_0 \cdot \eta \left(1 - e^{-t/\tau_1} \right)}.$$

Taking $\frac{1}{\tau_1} \approx 4$ at $t =$ 3 s, it turns out $1 - e^{-t/\tau_1} \approx 1$: $\alpha_\eta \approx g_0 = 9{,}81 \text{ m}/s^2; \; V_\eta \approx \sqrt{2g_0 \cdot R} = 11{,}2\, km/s.$

Considering that the disk moves evenly, it moves away from the Earth with medium acceleration $b \approx 400g_0$. In fact, the actual acceleration of the disk $\alpha \le g_0$ does not exceed the acceleration of free fall g0 near the Earth's surface. Thus, the moving disk reaches the second cosmic speed in 3 seconds and can leave the Earth's boundaries. Observing from the Earth obviously, the disk will move away with huge acceleration $b \approx 400g_0$. It is well known that when a body moves with acceleration 20g$_0$, visually through the eyes of an observer on the Earth, such acceleration of the observation object is perceived as almost instantaneous disappearance. Thus, the well-known thesis about large overloads that can occur in a disk that moves at speed $V >> 11{,}2 \text{ km}/s$ is not reasonably convincing, as its actual acceleration will not exceed g$_0$. Therefore, the metal structure of the disk and the biological objects inside will not be significantly overloaded.

3. Results and discussion

The previously obtained acceleration formula $\alpha_\eta = g_0 \cdot \left(1 - e^{-t/\tau_1}\right)$ characterizes the actual acceleration of a moving disk, which, of course, does not coincide with the acceleration of the disk observed in the frame of reference associated with the Earth. According to Einstein's work [4], every reference body (coordinate system is connected to the body) has its own special time. The time indicator makes sense when the count to which it refers is indicated. Next, it is assumed that *t*- the coordinate time, which is measured for the body on the Earth's surface. The reference frame of a disk moving relative to the Earth registers its own time τ. In this case, the formula for the acceleration of the disk will be as follows:

$$\alpha_{\eta\tau} = g_0 \left(1 - e^{-\tau/\tau_1} \right) \tag{11}$$

This is natural, because the ponderomotor force that drives the disk arises from the action of the body's own electromagnetic field of rotation. So it is written:

$$F_z(t)=\rho_0 g_0\left(2-e^{-\tau/\tau_1}\right).$$

The speed of the disk when considering its speed relative to the Earth is written as (12):

$$V_\eta = V_{\eta\tau} = V_{\eta t} = \sqrt{2g_0\eta}\cdot\sqrt{1-e^{-\tau/\tau_1}} \quad (12)$$

Find the formula for the acceleration of the disk observed from the surface of the globe. To do this, it is necessary to formulate the relationships between proper time τ and coordinate time *t* in the framework of Newton's theory of long-range and Einstein's theory of short-range [12,13]. The special theory of relativity considers a relativistic slowdown of time – an event in one inertial frame of reference is simultaneous in another reference frame, which moves relative to the first, they can be separated in time. When the body moves in this system with speed, *V* its motion is described by counting time *t* (coordinate time), the differentials of coordinate and natural time τ are related by the dependence [12]:

$$d\tau = dt\sqrt{1-\frac{V^2}{C^2}}.$$

where, $d\tau >> dt\left(V<C\right)$ that is, the interval between signals for the observer moving relative to the signal source increases.

We study the property of space-time near the gravitational mass *M*, which is considered as a material point. Nearby *M* there "realized" static centrally symmetric space-time [5]. This means that all values of the Schwarzschild's solution[5] are functions only at a distance from the center of mass of the sphere and do not depend on time *t*. At a considerable distance from the mass *M*, the obtained solution leads to the same result that follows from Newton's theory at $\eta \geq R$ (*R*- the radius of the globe by mass *M*). From the Schwarzschild's solution the dependence between own time and coordinate time is received t [13]:

$$d\tau = dt\sqrt{1-\frac{r_g}{\eta}}, \quad (13)$$

where $r_g = 2\gamma M / C^2$ is the gravitational radius of the body (for the globe = 0.89 cm).

Clocks that are in the gravitational field work differently than clocks that show their own time at a great distance from the gravitational masses, which comes from the dependence:

From the formulas $d\tau = dt\sqrt{1-\frac{V^2}{C^2}}$ and $d\tau = dt\sqrt{1-\frac{\tau_n}{\eta}}$ it is clear that $V << C\left(r_g << \eta\right)$ $dt = d\tau$, and own time coincides with the coordinate.

From (11), for the velocity, the vector of which is directed vertically to the Earth's surface, we obtain and is written as (14):

$$\frac{V^2}{2} = g_0\eta\left(1-e^{-\tau/\tau_1}\right).\left[\eta=\eta(t)\right] \quad (14)$$

From (13):

$$\frac{mV^2}{2} = mg_0\eta\left(1-e^{-\tau/\tau_1}\right).$$

Near the Earth:

$$mg_0 = \frac{\gamma Mm}{\eta^2}\left(\eta \approx R\right).$$

Using this expression:

$$mg_0 = \frac{\gamma Mm}{\eta\left(1-e^{-\tau/\tau_1}\right)},$$

where:

$$V^2 = \frac{2\gamma M}{\eta}\cdot\frac{C^2}{C^2\left(1-e^{-\tau/\tau_1}\right)}, \text{ or } \frac{V^2}{C^2}\cdot\frac{r_g}{\eta\left(1-e^{-\tau/\tau_1}\right)}; \left(r_g = \frac{2\gamma M}{C^2}\right).$$

On the other hand, the known speed formula[1]:

$$\frac{V^2}{C^2} = \frac{r_g}{\eta\left(1-\frac{r_g}{\eta}\right)}.$$

If we assume $\frac{r_g}{\eta} = e^{-\tau/\tau_1}$ that the formulas are the same and in our case of Newton's mechanics there is a similar formula for slowing down time:

$$dt = \frac{d\tau}{\sqrt{1-\frac{r_g}{\eta}}} = \frac{d\tau}{\sqrt{1-e^{-\tau/\tau_1}}} \quad (15)$$

when the initial moment of own time we accept not equal to zero $\tau = \tau_0$, and, at the beginning of movement of a disk $t = \tau_0$, coordinate time is equal to own.

$$\alpha_{\eta\tau} = 0, \text{if } \tau_0 = t\left(t = t_0\right); \quad V_\eta = 0, \text{if } \tau_0 = t\left(t = t_0\right); \quad \eta = R, \text{if } \tau_0 = t\left(t = t_0\right). \tag{16}$$

Expressions (16) are the initial conditions for the disk near the Earth's surface. In this case, all formulas can be rewritten by replacing τ with τ – τ_0. For example, for the vertical component of the ponderomotor force:

$$F_z = F_\eta\left(t\right) = \rho_0 g_0 \left[2 - e^{-(\tau-\tau_0)/\tau_1}\right].$$

$$\left(F_z = F_\eta\right)$$

For the time delay formula (15):

$$dt = \frac{d\tau}{\sqrt{1 - e^{-(\tau-\tau_0)/\tau_1}}} \tag{17}$$

When $\tau - \tau_0 \to \infty, dt = d\tau$ we have the coincidence of our own time with the coordinate. Formulas for disk speed and acceleration in their own frame of reference:

$$\alpha_{\eta t} = g_0\left(1 - e^{-(\tau-\tau_0)/\tau_1}\right); V_{\eta t} = V_{\eta\tau} = \sqrt{2g_0\eta} \cdot \sqrt{1 - e^{-(\tau-\tau_0)/\tau_1}}.$$

When $\tau = \tau_0$, then $\alpha_{\eta t} = 0$ and V = 0, at the same time $\alpha_{\eta t} \le g_0; 0 \le V \le 11{,}2$ km/s, $R = 6371$ km - the radius of the Earth. The formula for velocity has a meaning near the Earth's surface $\eta \approx R$ since $\tau - \tau_0 \to +\infty$ and $dt = d\tau$. Practically this equation of intervals of own and coordinate time comes at $\frac{1}{\tau_1} = \frac{\sigma}{\varepsilon\varepsilon_0} = \frac{4}{c}; \tau - \tau_0 \approx 3\,s$ and near the Earth ($\eta = R$), we receive: $\alpha_{\eta\tau} = g_0;\ V_{\eta t} = V_{\eta\tau} = \sqrt{2g_0 R}.$

We believe that at the initial moment of time $t = \tau = \tau_0$ the disk does not move and is near the Earth's surface. From the physical essence of the problem we obtain and is written as (18):

$$0 < 1 - e^{-(\tau-\tau_1)/\tau_1} < 1; \text{ that is } 0 \le e^{-(\tau-\tau_1)/\tau_1} < 1. \tag{18}$$

From here: $\frac{\tau - \tau_0}{\tau_1} \ge 0$ (19)

To find the relationship between proper time τ and coordinate time t, it is necessary to integrate (17). By substituting the variable and using the initial conditions ($t = \tau = \tau_1$) it is obtained

$$t = \tau_0 + \tau_1 \ln\left[\frac{1 + \sqrt{1 - e^{-(\tau-\tau_0)/\tau_1}}}{1 - \sqrt{1 - e^{-(\tau-\tau_0)/\tau_1}}}\right] \tag{20}$$

Dependence (20) characterizes the coordinate time as a function of its own time. By analogy, the inverse expression is obtained:

$$\tau = \tau_0 + \tau_1 \ln\left\{1 - \left[\frac{1 - e^{-(t-\tau_0)/\tau_1}}{1 + e^{-(t-\tau_0)/\tau_1}}\right]^2\right\}. \tag{21}$$

The actual acceleration of the disk is calculated by (11). Now we find the acceleration of the disk, which the observer sees from Earth ($\alpha_{\eta t}$), for which we use the equation of disk speed and expression (21) we obtain and is written as (22):

$$V_{\eta\tau} = V_{\eta t} = \sqrt{2g_0\eta}\sqrt{1 - e^{-(\tau-\tau_0)/\tau_1}} = \sqrt{2g_0\eta}\,\frac{1 - e^{-(t-\tau_0)/\tau_1}}{1 + e^{-(t-\tau_0)/\tau_1}}. \tag{22}$$

Due to the equality of absolute values of velocity relative to the observer on Earth and the observer from the side of the disk ($V_{\eta t} = V_{\eta\tau} = V_\eta$), there was found the acceleration of the disk observed from the Earth:

$$\alpha_{\eta\tau} = \frac{dV_\eta}{dt} = \sqrt{2g_0\eta}\,\frac{2e^{-(t-\tau_0)/\tau_1}}{\tau_1\left(1 + e^{-(t-\tau_0)/\tau_1}\right)^2}.\left(\eta = R\right) \tag{23}$$

At the initial moment ($t = \tau = \tau_0$)is written as (24):

$$\alpha_{\eta\tau} = \frac{\sqrt{2g_0\eta}}{2\tau_1}.\left(\eta = R; t = \tau_0\right) \tag{24}$$

Hence, at $\frac{1}{\tau_1} = \frac{4}{c}$, we get: $\alpha_{\eta\tau} = 2\sqrt{2g_0\eta}.\left(t = \tau_0\right).$

At $t = \tau_0 + 3s$ and $\frac{1}{\tau_1} = \frac{4}{c}$: $\alpha_{\eta t} \approx 0$.

Therefore, the acceleration of the disk observed from the Earth varies from its mechanical value at the initial moment of time $t = \tau_0$ to zero at $t - \tau_0 \to +\infty$ this occurs at $t - \tau_0 = 3\,s$ when $1/\tau_1 = 4/c$ for the coordinate time. Thus, the acceleration of the disk observed from the Earth varies from the maximum value to zero. The actual acceleration of the disk varies from zero to g_0 and does not exceed the acceleration of free fall. The average acceleration of the disk observed from the Earth, using the known theorem on the average, for 3 seconds ($\tau_0 \le t \le \tau_0 + 3$) from the initial time $t = \tau_0$:

$$b=\frac{1}{\Delta t}\int_{\tau_0}^{\tau_0+\Delta t}\alpha_{\eta t}dt,$$

where $\Delta t=(\tau_0+3)-\tau_0=3$ s.

From here:

$$b=\frac{1}{3}\int_{\tau_0}^{\tau_0+3}\sqrt{2g_0\eta}\,\frac{2e^{-(t-\tau_0)/\tau_1}}{\tau_1\left(1+e^{-(t-\tau_0)/\tau_1}\right)^2};dt=\frac{\sqrt{2g_0\eta}}{3}\approx 400g_0.$$

Thus, the above-found equation of the average acceleration is obtained, which proves that the formula for the acceleration of the disk (23) observed from the Earth and the dependence of the coordinate time on its own time (15) are valid.

It is investigated (20) that expresses the coordinate time t through its own time τ in the disk, from the conditions $\frac{\tau-\tau_0}{\tau_1}\ge 0$. Hence, two cases were obtained, taking into account, $\frac{1}{\tau_1}=\frac{\sigma}{\varepsilon\varepsilon_0}$, $\varepsilon\varepsilon_0 > 0$, σ – conductivity of the torus-ring depending on the positive or negative value of the conductivity. It is known that there are semiconductors in which the volt-ampere conductivity characteristic has a branch of negative and positive resistance. For conductors that obey Ohm's law, their volt-ampere characteristic is straightforward.

The case of positive conductivity of the medium when changing its own time τ that is in the disk:

$\frac{1}{\tau_1}=\frac{\sigma}{\varepsilon\varepsilon_0}>0$, and since $\sigma>0$, then from the condition $\frac{\tau-\tau_0}{\tau_1}\ge 0$, received $\tau-\tau_0>0$; $\tau>\tau_0$.

Let $\tau-\tau_0\to 3\,s$; $\frac{1}{\tau_1}\to 4$, then $1-e^{-(\tau-\tau_0)/\tau_1}\approx 1$.

From here:

$$\lim\ln\frac{1+\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}}}{1-\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}}}=+\infty.$$

so $t\to+\infty$ at $\tau-\tau_0\to 3\,s$; $\frac{1}{\tau_1}\to\frac{4}{s}$.

For negative conductivity of the medium: $\frac{1}{\tau_1}=\frac{\sigma}{\varepsilon\varepsilon_0}<0$, and $\sigma<0, \tau-\tau_0<0,\ \ \tau<\tau_0, \varepsilon\varepsilon_0>0$ and (19) written so:

$$t=\tau_0-|\tau_1|\ln\frac{1+\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}}}{1-\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}}}\ \text{at}$$

$$\tau-\tau_0\to-3\left(\tau\to\tau_0+3\right),\frac{1}{\tau_1}\to-4, t\to-\infty.$$

Thus, in the interval of the relaxation parameter change of the conductive medium: $-\frac{1}{4}\le\tau_1\le\frac{1}{4}$

For coordinate time it is $-\infty\le t\le+\infty$. For the interval of own time it is $\tau_0-3\le\tau\le\tau_0+3$. Where, at insignificant change of own time in a disk, coordinate time can change considerably in positive and negative time directions.

For tangential disk movement in the direction ψ and θ it is enough just to turn on the sector of the power ring, which produces a radial component of the ponderomotor force. Consider the element of the sector that produces the radial force (Fig. 4).

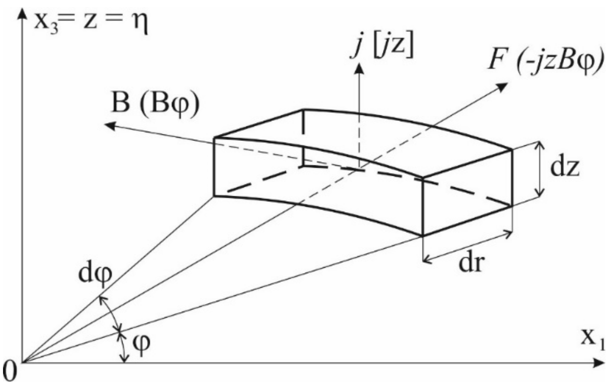

Fig. 4. Diagram of a sector element that produces a radial force

In this case, for a unit volume of the power ring sector, the direction of the current density $\bar{j}$ and $\bar{B}$ magnetic induction vectors: $\bar{j}\{0;0;j_z\};\bar{B}\{0;B_\varphi;0\}$.

All components of vectors are considered in the system of cylindrical coordinates of a disk $(r;\varphi;z)$. In this case, the components of ponderomotor forces: $F_r=-j_zB_\varphi;F_\varphi=0;F_z=\rho_{cв.}E_z$.

Maxwell's electrodynamics equations take the form:

$$E_{z,3}=\frac{\rho_{cв.}}{\varepsilon\varepsilon_0};B_{\varphi,t}=0;B_{\varphi,2}=0.$$

Their solution was obtained in the form of:

$$j_z = \mu D \rho_0 g_0 r\left(1-e^{-t/\tau_1}\right); \rho_{cв.} = 0; E_z^* = -D\rho_0 g_0 r\left[1-e^{-(t-t_0)/\tau_1}\right].$$

In this case, the radial components of the ponderomotor force per unit volume of the ring sector:

$$F_r = \rho_0 g_0\left(1-e^{-t/\tau_1}\right); F_\varphi = 0; F_z = 0,$$

where $\sigma DC = 1$ and equation (8) will look like:

$$\left(\rho u_{\theta,t}\right)_{,t} = \rho_0 g_0\left(1-e^{-t/\tau_1}\right); \left(\rho u_{\varphi,t}\right)_{,t} = \rho_0 g_0\left(1-e^{-t/\tau_1}\right);$$
$$\left(\rho u_{\eta,t}\right)_{,t} = \rho_0 g_0\left\{\left[\frac{1-R^2}{\eta^2(t)}\right]+\left(1-e^{-t/\tau_1}\right)\right\}. \quad (25)$$

Assuming, as before, $\rho \approx \rho_0$ and integrating (25), we obtained the component of acceleration and velocity of the disk in the horizontal direction:

$$\alpha_\theta = u_{\theta,tt} = g_0\left(1-e^{-t/\tau_1}\right); V_\theta = u_{\theta,t} = g_0\left[t-\tau_1\left(1-e^{-t/\tau_1}\right)\right],$$

Similar expressions for velocity and acceleration in direction ψ for spherical coordinates associated with the Earth.

Consider the motion in the plane (r, η), acceleration:

$$\alpha_{\eta\theta} = \sqrt{\alpha_\eta^2+\alpha_\theta^2} = \sqrt{g_0^2\left\{\left[1-\frac{R^2}{\eta^2(t)}\right]+\left(1-e^{-t/\tau_1}\right)\right\}^2 + g_0^2\left(1-e^{-t/\tau_1}\right)^2}.$$

Velocity:

$$V_{\eta\theta} = \sqrt{V_\eta^2+V_\theta^2} = \sqrt{2g_0\left[\left(\eta+\frac{R}{\eta}\right)-2R+\eta\left(1-e^{-t/\tau_1}\right)\right]+g_0^2\left[t-\tau_1\left(1-e^{-t/\tau_1}\right)\right]^2}.$$

Near the Earth, believing, $\eta \approx R$, we find:

$$\alpha_{\eta\theta} = g_0\sqrt{2}\left(1-e^{-t/\tau_1}\right); V_{\eta\theta} = \sqrt{2g_0R\left(1-e^{-t/\tau_1}\right)+g_0^2\left[t-\tau_1\left(1-e^{-t/\tau_1}\right)\right]^2}.$$

Hence, the acceleration $\alpha_{\eta\theta} \le g_0\sqrt{2}$ does not exceed $1.41g_0$ and significant overloads in the body do not occur, and the speed can be much higher than the first space speed. Since the movement occurs when the engine is turned on ($1-e^{-t/\tau_1} \approx 1$), then:

$$\alpha_{\eta\theta} = g_0\sqrt{2}; V_{\eta\theta} = \sqrt{2g_0R + g_0^2(t-\tau_1)}.$$

The accelerations experienced by biological objects inside the disk are shown in Figure 5. Taking into account the action of gravity, biological objects will experience acceleration $\alpha \le 2.2\ g_0$. When turning on the engine sector in the direction perpendicular to the plane (η, θ), acceleration is $\alpha \le g_0\sqrt{6} \le 2{,}4g_0$. This is the maximum acceleration in three mutually perpendicular directions, taking into account the free fall, for biological objects and the structure hung on the power ring. The speed of movement will be huge. The force ring will have less acceleration because it is affected by the acceleration of gravitational force, which it levels. When leaving the Earth's gravitational field, the maximum acceleration does not exceed: $\alpha \le g_0\sqrt{3} \le 1{,}71g_0$.

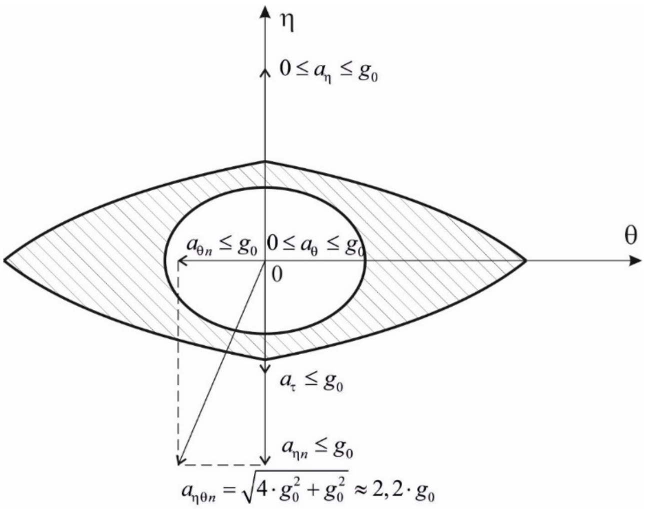

Fig. 5. Accelerations acting on biological objects in the hollow disk

All accelerations are short-lived and do not cause overload.

Now consider the problem of moving the disk in the horizontal direction. Provided that the disk is above the Earth in weightlessness, its motion along the tangent to the surface in the direction, Θ or Θ_1 (Fig. 6) is considered.

$V_{0,t} = X$, that is the tangent Θ direction $X(t)$ - the tangent law of motion to the Earth of the disk, which is observed by the observer from the middle of the hollow disk. Acceleration in Newton's mechanics ($\rho = \rho_0$):

$$\alpha_{x\tau} = x_{,tt} = g_0\left[1-e^{-(\tau-\tau_0)/\tau_1}\right]$$

where τ_0 is the reference time for horizontal motion.

The speed of the disk relative to the Earth:

$V_x = X, \tau$

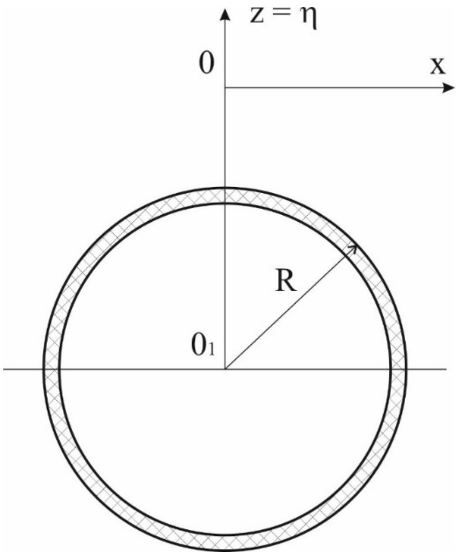

Fig. 6. Diagram of the disk in the horizontal direction

Acceleration of gravity:

$$\alpha_{x\tau} = V_{x,\tau} = V_{x,x} X_{,\tau} = V_x X_{x,x} = \frac{1}{2}\left(V^2 x\right)_{,x}.$$

From there:

$V_{x,x}^2 = 2g_0\left[1-e^{-(\tau-\tau_0)/\tau_1}\right]$, integrating obtained

$$V_{x,x}^2 = 2g_0 x\left[1-e^{-(\tau-\tau_0)/\tau_1}\right]+\xi,$$

where ξ – arbitrary integration function.

From extreme conditions $V_x = 0$, when $\tau = \tau_0$ and $C = 0$ the velocity equation is obtained:

$$V_x = \sqrt{2g_0 x}\cdot\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}} \tag{26}$$

Hence, when $\tau-\tau_0 \to \infty$, the speed increases indefinitely with increasing distance *X*. Now we get the speed as a function of our own time τ :

$$\alpha_{x\tau} = V_{x,\tau} = g_0\left[1-e^{-(\tau-\tau_0)/\tau_1}\right] \tag{27}$$

from (27):

$$V_x = g_0\int\left[1-e^{-(\tau-\tau_0)/\tau_1}\right]d\tau+\zeta_1,$$

where ζ_1 – arbitrary integration function.

After integration: $V_x = g_0\left[\tau+\tau_1 e^{-(\tau-\tau_0)/\tau_1}\right]+\zeta_1$

so $V_x = 0$, at $\tau = \tau_0$, then $g_0(\tau+\tau_1)+\zeta_1 = 0$.

From here, for speed we get and is written as (28):

$$V_x = g_0\left\{\tau-\tau_0-\tau_1\left[1-e^{-(\tau-\tau_0)/\tau_1}\right]\right\}. \tag{28}$$

at $\tau\to\infty, V_x\to\infty.$

Find the law of motion $X(\tau)$ and the distance covered by the disk for the interval of its own time. Since, $V_x = X_{,\tau}$ then:

$$dx = \sqrt{2g_0 x}\left[1-e^{-(\tau-\tau_0)/\tau_1}\right]d\tau \text{ or } \int\frac{dx}{\sqrt{x}} = \sqrt{2g_0 x}\int\left[1-e^{-(\tau-\tau_0)/\tau_1}\right]d\tau+\zeta_2$$

where ζ_2 – arbitrary integration function.

Replacing a variable by formulas:

$$u = \sqrt{1-e^{-(\tau-\tau_0)/\tau_1}};u^2 = 1-e^{-(\tau-\tau_0)/\tau_1};2udu = \frac{1}{\tau}\left[e^{-(\tau-\tau_0)/\tau_1}\right]d\tau;1-u^2 = e^{-(\tau-\tau_0)/\tau_1},$$

received $d\tau = \dfrac{2\tau_1 udu}{1-u^2}$ whereupon:

$$\int\frac{dx}{\sqrt{x}} = \sqrt{2g_0}\int\frac{2\tau_1 u^2 du}{1-u^2}+\zeta_2.$$

After integration found:

$$2\sqrt{x} = \sqrt{2g_0}\tau_1\left\{\ln\left[\frac{1+\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}}}{1-\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}}}\right]-2\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}}\right\}+\zeta_2.$$

From the boundary conditions $X = 0, \text{if } \tau = \tau_0 \text{ i } \zeta_2 = 0,$ the law of motion in the horizontal direction is obtained (29):

$$X(\tau) = \frac{2g_0\tau_0^2}{4}\left\{\ln\left[\frac{1+\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}}}{1-\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}}}\right]-2\sqrt{1-e^{-(\tau-\tau_0)/\tau_1}}\right\}^2 \tag{29}$$

at $\tau-\tau_0\to+\infty, X\to+\infty.$

However, this result can be obtained in a short period of time

$\tau_0 \le \tau \le \tau_0+3\,\text{s},$ at $\frac{1}{\tau_1}\to\frac{4}{c}$. Really $X(\tau)\to+\infty,$ at $\tau-\tau_0\to 3\,\text{s};\frac{1}{\tau_1}\to\frac{4}{c}.$

Thus, for a finite period of your time you can cover long distances.

4. Conclusions

The motion of a hollow disk suspended on a force ring-torus is investigated, exact solutions of the motion equations of a ring in the torus form of rectangular cross section are found. Based on Maxwell's equations, analytical dependences have been found for calculating the components of ponderomotor forces that arise from the action of the ring's own electromagnetic field and cause the motion of a hollow disk. It is proved that the obtained equations of average acceleration, disk acceleration and the dependence of the coordinate time on the natural time are valid. It is proved that at high velocities and small natural accelerations the stress-strain state of the disk medium does not cause structural damage. It is determined that the rotation in the direction of movement at an angle of 90 degrees changes only the direction of the acceleration vector without increasing its value.

The dependences between natural time and coordinate time are formulated, it is proved that a small change of natural time for the studied disk can significantly change the coordinate time, and the pulsed electromagnetic field provides the ability to cover infinitely large distances over finite time periods and cover large time intervals for insignificant natural time.

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