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GTR and Perpetuum Mobile Rehabilitation

> "My small work will bring them (perpetual motion seekers) advantage: they will not have to flee from the kings and rulers without fulfilling their promises"
>
> *Leonardo Da Vinci*

Contents

Annotation

First of all, the author solemnly declares that he recognizes the energy conservation law (understanding, however, that it will not help). Next we shall show that this law does not contradict the possibility of building a perpetual motion machine that uses the force of gravity. This, of course, reduces the kinetic energy of the Earth, but the author ignores this problem (in the same way as it is ignored by the designers of hydropower plants).

1. Introduction

It is known that the work of gravity for a body displacement along a closed pass is equal to zero.

In [1] one may read: After having reformed many efforts of building a perpetual motion machine, Leonardo**,** after trying to comprehend, why such motion machines of different systems do not work, **claims the inevitability** of the existence of inherent effects disrupting the work of such machines. His followers, based on his authority, use the principle of the impossibility of perpetual motion as an already **firmly established law of nature.** The Academy of Paris, basing on the views of these followers, had not presented a rigorous proof of the impossibility of the existence of a perpetual motion machine. Academy of Paris "meant well", when saying: "such work (of the creators of perpetual motion) is too wasteful, it has destroyed a lot of families. Often happens that a talented mechanic, who could take his rightful place, had squandered in that way his reputation, time and talent."

But the mechanics can not get calm down, because principle of the impossibility of perpetual motion is **not** firmly established as the law of nature. Repeated attempts to build a perpetual motion machine have been taken for centuries [2] and are continued now. But they only allow, as Leonardo wrote, to assert the inevitability of the existence of some interfering factors. There is no proof of the existence of such reasons, and the law of energy conservation has nothing to do with it.

2. Did not Flee…

There is a known history of Orferius's successful test of perpetual motion machine [3]. This work has been financed by Count Karl, who also led the "selection committee" including famous scientists. Count Karl was also considered one of the leading scientists of his time. Hard to imagine that Orferius undertook to deceive such a man. It seems to me less likely than a successful test. Orferius did not have to flee from the Count due to not having fulfilled his promises.

3. Unbalanced Wheels

Among the projects of perpetual motion the so-called unbalanced wheels are rather common. As described in [3] "the first design of unbalanced wheels was described by Marquis Worchester. From the description, it follows that it was a wheel with two rims - one within the other. To the rims weights are attached by means of strings so that when they are moved downward they are displaced towards the outer rim, and at movement upwards - towards the internal. "The author was unable to find a description of the wheel, but in [4] descriptions of several such devices are provided.

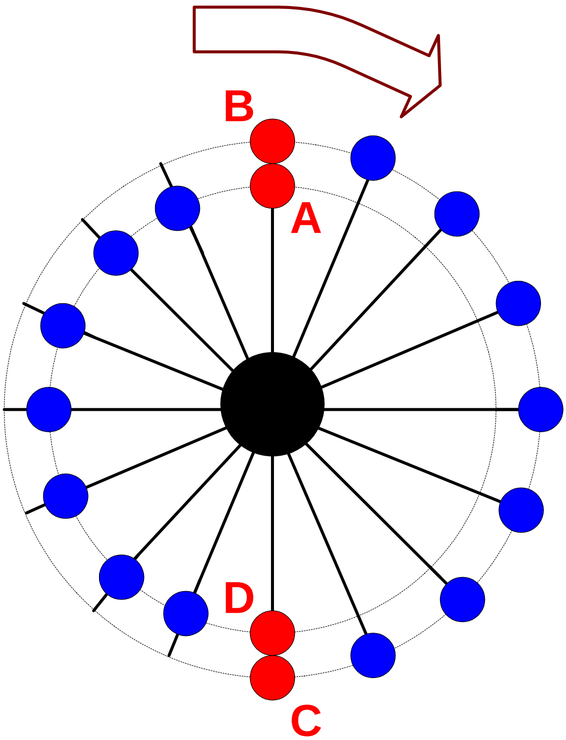

Fig. 1.

We shall consider the most impressive of them. In [5] the gravitational motor of Aldo Costa is described. Its design can be summarized as follows - see Fig. 1. The loads attached to the spokes revolve around a common axis. At the points A and C the loads move along the spoke in the points B and D respectively. Thus, if you move down (right) the loads rotate along the radius R_1 and moving up (right) loads rotate along the radius $R_2 < R_1$ - this is similar to what was proposed by the Marquis of Worcester - see above.

The wheel is mounted vertically, has a diameter of 18 m and contains 236 complex mechanisms for switching the position of loads - see Fig. 2. Machine parts are described in detail in the patent [9]). Several videos of the device are given in [10].

Note that here, as well as in the work of Marquis Worcester, there is a "wheel with two rims - one within the other. ... The weights are attached to the rim so, that during the downward movement they are displaced towards the outer rim and at movement upwards - towards the internal rim. "

Another device of this type Dmitriev suggested [11]. Detailed description of the device and a few videos of his work presented in [12].

Fig. 2.

4. The Main Idea

Gravity is a conservative force, i.e. the work of the force of gravity does not depend on the motion path and depends only on the initial and final position of the point of this force application. In this statement speed of this point is not considered. As a rule, the work of gravity force does not depend on that speed. For example, the work of gravity force can be spent to overcome the friction and the point speed change. At the same time, the spent potential energy is equal to the work of friction force (directed **opposite** to gravity force) and is increasing the kinetic energy of the body, regardless of the trajectory and speed.

We shall call the work of gravity force which does not depend on the speed and trajectory, - the **conservative** work of gravity force. Apparently, in mechanics we cannot find an example when the speed of movement affects the work of gravity force, i.e. when gravity force work is not conservative.

Formally, however such example can be found. Let us assume that the "quasi-friction" force, directed **along** the gravitational force and is dependent on the speed and, moreover, the force of this "quasi-friction" is created by the motion under the influence of gravity (as well as conventional friction force). Then the increase of the body kinetic energy is the sum of conservative work and the work of "quasi-friction" force. However, the latter is also accomplished by gravity force (by just adopted assumption). Consequently, in this case, the work of gravity force is more conservative, i.e. work of gravity force is not conservative.

Apparently, in the mechanical system such a case cannot be found. However, such case is possible in an electromechanical system. Consider the motion of charged bodies - heavy electric charges (HEC) in the gravitational field. Such charges are under the influence of gravity force, of electric attraction \ repulsion force and of the Lorentz force. Lorentz force, are known not to do work, but to use the work of external forces - in this case - the gravity force (electric forces may be neglected). Because the Lorentz force depends on the speed, in this case the work of gravity force depends on the speed (of HEC) at a given path.

Thus, **in the electromechanical system the gravity forces are not conservative**. (Note that there is another case of fundamental difference between the laws in mechanics and electromechanics: mechanics observes Newton's third law, and in electromechanics it is not observed due to that same Lorentz force).

From the basic equations of general relativity it follows that in a weak gravitational field at low speeds, i.e. in the world, you can use the Maxwell-like equations to describe gravitational interactions. This means that there are gravitational waves, and the mass moving in the gravity and magnetic field with a velocity is affected by gravitomagnetic Lorentz force (analog of the Lorentz force). [7] describes the Maxwell-like gravitational equations and experiments for their detection in terrestrial conditions.

Thus, Lorentz forces may appear in a mechanical system (as well as in electromechanical system), i.e. **in the mechanical system the gravity forces are not conservative, if the motion under gravity causes appearance of gravimagnetic Lorentz forces.**

It means that **gravity forces can perform work.**

In [8] on the basis of this statement the functioning of Tolchin's "inertioid" is explained. Below the same basis is applied for explanation of the functioning of Aldo Costa's wheel: on the author's assumption the reason for continuous movement is in the fact that the moving loads interact by gravimagnetic Lorentz forces.

5. The Definition of Gravimagnetic Lorentz Force

In [7] it is shown that gravimagnetic Lorentz force, acting from mass m_1 on mass m_2, is determined by an expression of the form (here and further the CGS system is used)

$$\overline{F_{12}} = \frac{k_g m_1 m_2}{r^3}\left[\overline{v_2} \times \left[\overline{v_1} \times \overline{r}\right]\right], \tag{1}$$

where

- coefficient $k_g = \frac{\xi G}{c^2}$, (2)
- $G \approx 7 \cdot 10^{-8}$ - gravitational constant,
- $c \approx 3 \cdot 10^{10}$ - the speed of light in vacuum,
- ξ - gravimagnetic permeability of the medium,
- $\overline{r}$ - a vector directed from point m_1 to point m_2,
- $\overline{v_1}$, $\overline{v_2}$ - speeds of masses m_1 and m_2 accordingly

It is important to note that the effects in the above experiments are so significant that to explain them within the Maxwell-like gravitational equations it is necessary to enter gravimagnetic coefficient of permeability of the medium ξ (the same as the coefficient of permeability of the medium μ in electromagnetism). However, the value of coefficient ξ in these experiments may be estimated only very roughly.

6. The Mathematical Model of Aldo Costa's Wheel

Consider Fig. 3, which shows the two weights on the wheel Aldo Costa. In our case the velocities in the formula (1) - are the linear speed of loads rotation. We shall select in the formula (1), the expression

$$\overline{f_{12}} = \left(\overline{a} \times \left(\overline{b} \times \overline{r}\right)\right), \tag{3}$$

where

$$\overline{a} = \overline{v_2}, \quad \overline{b} = \overline{v_1}\,.$$

In the right Cartesian coordinate system, this expression takes the form

$$\overline{f_{12}} = \begin{bmatrix} a_y(b_x r_y - b_y r_x) - a_z(b_z r_x - b_x r_z) \\ a_z(b_y r_z - b_z r_y) - a_x(b_x r_y - b_y r_x) \\ a_x(b_z r_x - b_x r_z) - a_y(b_y r_z - b_z r_y) \end{bmatrix}. \qquad (4)$$

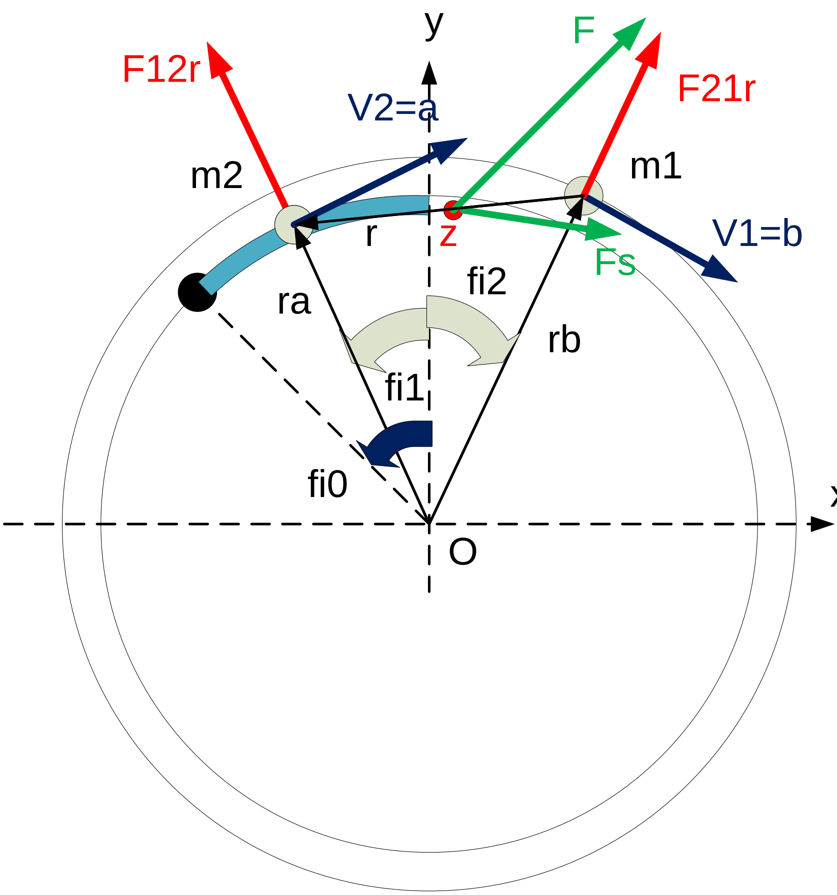

Fig. 3.

The loads rotate at the same speed and in opposite directions. So

$$|a| = \omega R_2, \quad |b| = \omega R_1, \qquad (5)$$

where $R_2,\ R_1$ are the radii of the semicircles, - angular velocity. We shall further denote radius vectors of loads m_1 and m_2 as r_b and r_a, respectively. Then

$$r = r_a - r_b. \qquad (6)$$

As the loads rotate in one plane, so

$$r_z = 0,\ a_z = 0,\ b_z = 0. \qquad (7)$$

With this in mind, we obtain:

$$\overline{f_{12}} = \begin{bmatrix} a_y\left(b_x r_y - b_y r_x\right) \\ -a_x\left(b_x r_y - b_y r_x\right) \\ 0 \end{bmatrix}$$

or

$$\overline{f_{12}} = D\left[a_y,\ -a_x\right],\ D = \left(b_x r_y - b_y r_x\right). \qquad (8)$$

Similarly,

$$\overline{f_{21}} = D_2\left[b_y,\ -b_x\right],\ D_2 = -\left(a_x r_y - a_y r_x\right) \qquad (8.1)$$

Now we shall find

$$\Delta f = \overline{f_{12}} - \overline{f_{21}} = \begin{bmatrix} Da_y - D_2 b_y \\ -Da_x + D_2 b_x \end{bmatrix} \qquad (9)$$

From Fig. 3 it follows

$$\angle AOm_2 = \varphi_1,\ \ \angle AOm_1 = \varphi_2$$

$$a_x = \omega R_1 \cos\varphi_1, b_x = \omega R_2 \cos\varphi_2,$$

$$a_y = \omega R_1 \sin\varphi_1, b_y = -\omega R_2 \sin\varphi_2,$$

$$r_a = R_1\left[-\sin\varphi_1,\ \cos\varphi_1\right],$$

$$r_b = R_2\left[\sin\varphi_2,\ \cos\varphi_2\right], \qquad (10)$$

$$r = r_a - r_b. \qquad (11)$$

Let us denote

$$\Delta f_L = \Delta f \Big/ |r|^3. \qquad (16)$$

From (1, 3) it follows that

$$\Delta F = k_g m_1 m_2 \Delta f_L, \qquad (17)$$

One can assume that the force acts on a pair of **rigidly** connected (through rim and spoked of wheels) masses and is applied to the center of the segment r - see the point in Fig. 3. The radius vector of this point

$$\overline{r_z} = \left(\overline{r_a} + \overline{r_b}\right)/2. \tag{20}$$

Let us find the projection ΔF_s of the force ΔF on the tangent to the circle of radius r_z. It is equal to the scalar product of this force on the unit K_w of vector perpendicular to the radius $\overline{r_z}$, i.e.

$$\Delta F_s = \overline{\Delta F} \otimes K_w. \tag{21}$$

If

$$r_z = \left[r_{zx},\ r_{zy}\right], \tag{22}$$

then

$$K_w = \left[-r_{zy},\ r_{zx}\right] / \left|r_z\right|. \tag{23}$$

In such way we may find the force (21). It creates a torque

$$M_s = \Delta F_s \left|r_z\right|. \tag{24}$$

Taking into account (21-23), we get

$$M_s = \overline{\Delta F} \otimes \left[-r_{zy}, r_{zx}\right]. \tag{25}$$

Mass m_2 moves along the arc φ_o of radius R_1 - see Fig. 3. In this it interacts with the mass m_1, which also moves along the arc φ_o of radius R_2. The distance between them remains constant: $|r| = const$. The length of vector oz also remains constant: $|r_z| = const$. The torque (25) also remains constant: $M_s = const$ - see further. In the highest point m_2 switches to a circle of radius R_2 ("top jump"), i.e. assumes the role of the mass m_1. At this point the mass moving on a circle of radius R_1 after the former mass, assumes the role of the mass m_2, etc.

Counting moment (25), we can show can be shown that on the bottom of the wheel a similar torque of opposite sign is created. Thus in a real device the “bottom jump” must be excluded.

It can be shown that on the bottom wheel (where occurs the "lower jump") create the same momentum and with the same sign

Fig. 4 shows the results of the overall calculation. Thus:

- The first window shows projections of vector (21): ΔF_{sy} - above, ΔF_{sx} - below.

- The second window shows hodograph of vector (21) in the form $\Delta F_s = \Delta F_{sx} + j \cdot \Delta F_{sy}$.
- The third window shows projections of vector (22): r_{zx} - above, r_{zy} - below.
- The fourth window shows hodograph of vector (22) in the form $r_z = r_{zx} + j \cdot r_{zy}$.

Similarly, we can consider the forces involved in the movement of loads vertically - see Appendix 2.

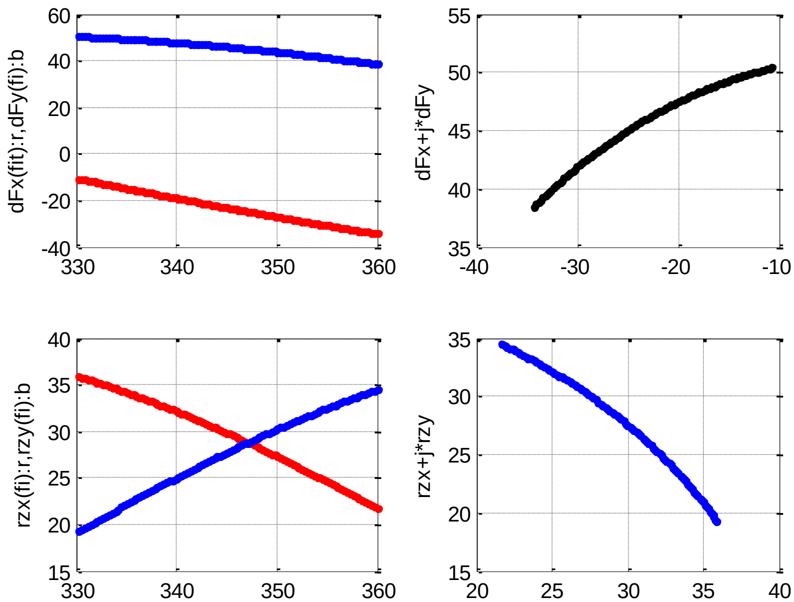

Fig. 4.

7. Quantitative Estimates

In the example $|r| \approx 48$, $|r_z| \approx 41$ for $R_1 = 45,\ R_1 = 50$ (in CGS system), and the forces and forces torques are calculated in the conditions

$$K_{gm} = k_g m_1 m_2 = 1. \tag{31}$$

The torques are equal to: above - $M_s \approx 2000$ and below - $M_s \approx -2000$. The torque acts in the time period $T_1 \approx 0.05$. Consequently, in the highest point the structure is affected by the torque

$$\left(F\Delta t\right)_o = K_{gm} M_s T_1 / R_1 \approx 2K_{gm}, \quad (32)$$

where the coefficient K_{gm} needs determination. In Appendix 1.4 it is shown that each load in such structure for continuous rotation needs to get a force impulse

$$\left(F\Delta t\right)_1 \approx 2500. \quad (33)$$

Consequently, to obtain continuous rotation by the Lorentz forces a following condition should be observed:

$$\left(F\Delta t\right)_o = 2\left(F\Delta t\right)_1 \quad (34)$$

or

$$K_{gm} = 2500. \quad (35)$$

Let us estimate for this case the value of coefficient ξ. Let the masses be $m_1 = m_1 = 500г$. Then from conditions (31, 35) we shall find

$$2500 = k_g 500^2 \quad (36)$$

or

$$k_g = 0.01.$$

Further from (2) we find

$$\xi = k_g c^2 / G = 0.01\left(3 \cdot 10^{10}\right)^2 \Big/ 7 \cdot 10^{-8} = 10^{26}. \quad (37)$$

This value coincides with that obtained in the analysis of Tolchin's inertioid [8]. With this value of ξ (in order of magnitude) the presented explanation is legitimate.

In this example, the angle $\varphi_o = \pi/6$. Consequently, in one revolution of the masses 12 pairs interact and we can assume that the torque $M_s \approx 2000$ is acting permanently. Thus, **a structure is possible in which the motion is due to the energy of the gravitational field.**

8. Some Comparisons

However, similar to the described problem of gravitational mass movement, we can consider exactly the same problem of the heavy electric charges motion, where there is no question about the legality of Maxwell-like gravitational equations and the value of the coefficient of gravimagnetic permeability of medium

Let us compare the Lorentz force in the interaction of mass and charge. Above we have described the Lorentz force acting from the first body to the second, in the form

$$F_{Lg} = k_g \frac{m^2}{r^3} \bullet \left[\overline{v_2} \times \left[\overline{v_1} \times \overline{r}\right]\right],$$

where $k_g = \frac{\xi G}{c^2}$. Similarly the Lorentz force acting from the first charge to the second has the form:

$$F_{Le} = k_e \frac{q^2}{r^3} \bullet \left[\overline{v_2} \times \left[\overline{v_1} \times \overline{r}\right]\right],$$

where $k_e = \frac{\mu}{c^2}$. So, the Lorentz force F_{Le}, acting on the charges, relates to Lorentz force F_{Lg}, acting on the masses (for the same speeds and distances), as

$$\frac{F_{Le}}{F_{Lg}} = \frac{k_e q^2}{k_g m^2} = \frac{\mu}{k_g c^2} \left(\frac{q}{m}\right)^2 .$$

Assuming that $\mu = 1$ and $k_g = 0.01$ (as was shown above), we find:

$$\frac{F_{Le}}{F_{Lg}} = 10^{-19} \left(\frac{q}{m}\right)^2 .$$

Let us compare this with ratio of attraction forces:

$$\frac{F_{Pe}}{F_{Pg}} = \frac{(1/\varepsilon) q^2}{G m^2} .$$

For $\varepsilon = 1$ and $G \approx 7 \cdot 10^{-8}$ we find that:

$$\frac{F_{Pe}}{F_{Pg}} \approx 10^7 \left(\frac{q}{m}\right)^2$$

If $F_{Le} = F_{Pe}$, then $F_{Lg} 10^{19} = F_{Pg} 10^{-7}$ or $F_{Lg} = F_{Pg} 10^{26}$. Thus, if for $k_g = 0.01$ the conditions (distance and speed) are such that for two charges the Lorentz force is equal to the attractive force, then for two masses the Lorentz force is 10^{26} times stronger than the attractive force. This means that the structure using the energy of gravitation field and based on gravitomagnetic Lorentz forces is significantly more effective than the same design based on magnetic Lorentz forces – and so, the latter is not worth to try implementing.

9. Technology

Those 18 m, which Aldo Costa demonstrates, may be explained, apparently, by the size of switches - they are complex, and therefore large. Furthermore, they are complex and therefore require constant adjustment, which complicates operation.

The author can offer much less complex and compact structure. Investment is needed and any other assistance in advancing the project.

Appendix 1. Circumferential Body Movement by Force of Gravity

Here we consider some idealized design, equivalent wheel Aldo Costa. For this construction, we can strict construct a mathematical model.

1. Ball Movement within a Tubular Circle

Let us consider a globular body of weight P, moving along a rigid tube coiled in a circle – see Fig. 1. The circle is located on vertical plane.

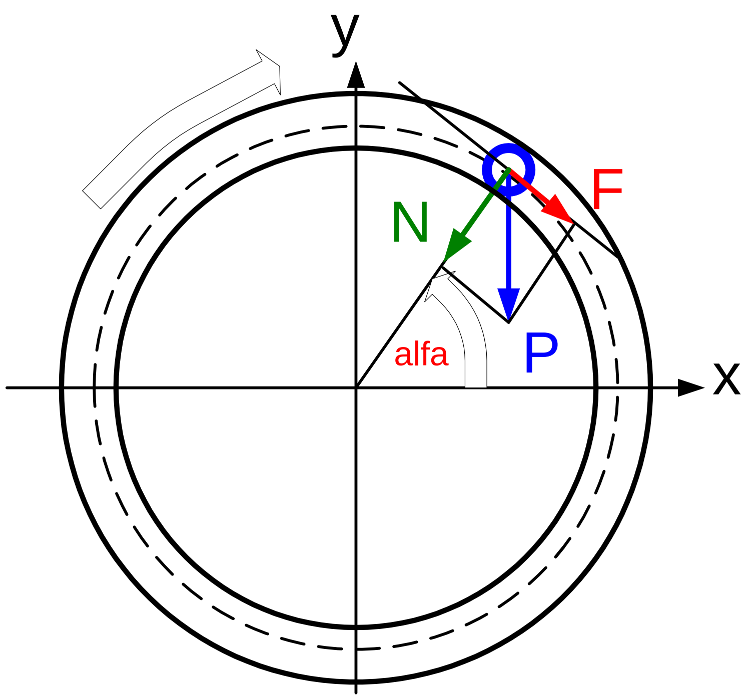

Fig. 1.

Find the force F, acting on the body along a tangent

$$F = P\cos\alpha = xP/R.$$

The force torque is

$$M_F = FR = xP.$$

Let us take a moment to be positive if it is directed clockwise. Find the pressure force N, acting on the circle along the radius:

$$N = P\sin\alpha = -yP/R.$$

The body's friction force along the circle is

$$T = kN = -kyP/R.$$

where k - friction coefficient. The torque of this force is:

$$M_T = TR = -kyP.$$

The Table 1 shows formulas for these forces and torques in the 4 quadrants.

Table 1.

	1	2	3	4
	$F = xP/R$	$F = xP/R$	$F = xP/R$	$F = xP/R$
	$M_F = xP$	$M_F = xP$	$M_F = xP$	$M_F = xP$
	$T = -kyP/R$	$T = kyP/R$	$T = kyP/R$	$T = -kyP/R$
	$M_T = -kyP$	$M_T = kyP$	$M_T = kyP$	$M_T = -kyP$

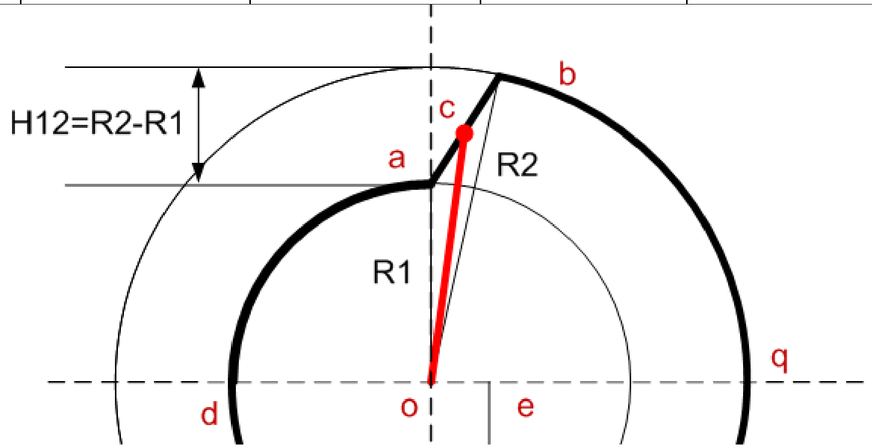

Fig. 2.

2. Movement of a Ball within a Deformed Tubular Circleference

Now let us assume that the ball is moving within a tube shown on Fig. 2. The Figure shows only the axis line of the tube and several positions of the ball. Shows only the upper half of the tube. This tube consists of three parts: arc 'ad' of radius R_1, arc 'bq' with radius R_2 and segment AB ("the step"), located at an angle φ to the horizontal.

Table 2 shows formulas for the forces named above and their torques in the 4 quadrants for such deformed tube.

Table 2.

	1	2	3	4
	$\varphi=\overline{\left(\frac{\pi}{2},0\right)}$	$\varphi=\overline{\left(0,\ -\frac{\pi}{2},\right)}$	$\varphi=\overline{\left(-\frac{\pi}{2},-\pi\right)}$	$\varphi=\overline{\left(-\pi,\frac{\pi}{2},\right)}$
	$F=xP/R_2$	$F=xP/R_2$	$F=xP/R_1$	$F=xP/R_1$
	$M_F=xP$	$M_F=xP$	$M_F=xP$	$M_F=xP$
	$T=-kyP/R_2$	$T=-kyP/R_2$	$T=-kyP/R_1$	$T=-kyP/R_1$
	$M_T=-kyP$	$M_T=kyP$	$M_T=kyP$	$M_T=-kyP$
	$A_1=(1-k)PR_2$	$A_2=(1-k)PR_2$	$A_3=(-1-k)PR_1$	$A_4=(-1-k)PR_1$
	$dv_1=g\cdot\left(\cos\varphi-k\sin\varphi\right)\frac{d\varphi}{v_1}$	$dv_2=g\cdot\left(\cos\varphi+k\sin\varphi\right)\frac{d\varphi}{v_2}$	$dv_3=g\cdot\left(\cos\varphi+k\sin\varphi\right)\frac{d\varphi}{v_3}$	$dv_4=g\cdot\left(-\cos\varphi-k\sin\varphi\right)\frac{d\varphi}{v4}$
	$\frac{v_{1k}^2-v_{1o}^2}{2}=gR_2(1-k)$	$\frac{v_{2k}^2-v_{2o}^2}{2}=gR_2(1-k)$	$\frac{v_{3k}^2-v_{3o}^2}{2}=gR_1(-1-k)$	$\frac{v_{4k}^2-v_{4o}^2}{2}=gR_1(-1-k)$

The summary work of gravity force done by the torques acting on the ball moving along quadrant 1, is equal to

$$A_1=\int_{\pi/2}^{0}(M_F+M_T)d\varphi=P\int_{\pi/2}^{0}(x-ky)d\varphi=P\int_{\pi/2}^{0}\left(x-k\sqrt{R_2^2-x^2}\right)d\varphi$$

$$A_1 = PR_2 \int_{\pi/2}^{0} \begin{pmatrix} \cos\varphi - \\ k\sin\varphi \end{pmatrix} d\varphi = PR_2 \Big|_{\pi/2}^{0} \begin{pmatrix} -\sin\varphi - \\ k\cos\varphi \end{pmatrix}$$

$$A_1 = PR_2(1-k)$$

The work done in quadrants 2, 3, 4 is calculated similarly – see Table 2. All work performed on the semicircle is:

$$A_o = A_1 + A_2 + A_3 + A_4$$
$$A_o = 2P((R_2 - R_1) - 2k(R_1 + R_2))$$

The work performed on the step is:

$$A_s = (-1-k)P(R_2 - R_1)/\sin\varphi .$$

Summary work performed by gravity force is:

$$A = A_o + 2A_s$$

Note the following. The sliding friction coefficient is $k = \overline{0.1;\ 0.5} \approx 0.25$. The rolling friction coefficient of a roll of radius r is $k = f/r$, where $f \approx 0.5mm$ when rolling steel on steel [6] If $r = 20mm$, then $k \approx 0.025$.

3. The Dynamics of Ball Movement within a Deformed Tubular Circleference

Let us find the ball's speed change on an element of length ds of the circle in the first quadrant due to the forces $F_1,\ T_1$. We have:

$$dv_1 = adt = \frac{F_1 + T_1}{m} dt = \frac{F_1 + T_1}{m} \frac{ds}{v} = \frac{F_1 + T_1}{m} \cdot \frac{R_1}{v_1} d\alpha .$$

Considering Table 2, we get

$$dv_1 = \frac{xP/R_2 - kyP/R_2}{m} \cdot \frac{R_2}{v_1} d\alpha = g\frac{x-ky}{v_1} \cdot d\alpha ,$$

$$dv_1 = g\frac{x-ky}{v_1} \cdot d\alpha ,$$

$$dv_1 = g\left(x - k\sqrt{R_2^2 - x^2}\right)\frac{d\varphi}{v_1},$$

$$dv_1 = g(\cos\varphi - k\sin\varphi)\frac{d\varphi}{v_1} \text{ and } \varphi = \overline{\left(\frac{\pi}{2},\ 0\right)}.$$

Similarly we may calculate the velocity increment on quadrants 2, 3, 4 - see Table. 2. In two steps, we have

$$dv_S = -\frac{kP\cos(\varphi)}{m} \cdot dt ,$$

$$dv_S = -kg\cos(\varphi)\frac{dh}{v_S} \text{ and } h = \left(\overline{0, \; R_2 - R_1}\right),$$

where φ -is step angle to the horizontal.

We shall integrate the expression for the first quadrant:

$$\int_{v_{1o}}^{v_{1k}} v_1 dv_1 = \int_{\pi/2}^{0} gR_2(\cos\varphi - k\sin\varphi)d\varphi ,$$

$$\left.\frac{v_1^2}{2}\right|_{v_{1o}}^{v_{1k}} = gR_2\Big|_{\pi/2}^{0}(-\sin\varphi - k\cos\varphi),$$

$$\frac{v_{1k}^2 - v_{1o}^2}{2} = gR_2(1-k).$$

Similarly we may calculate kinetic energy increment on quadrants 2, 3, 4 – see Table. 2. On the steps we have:

$$\int_{v_{so}}^{v_{sk}} v_s dv_s = \frac{-kg}{\sin\varphi}\int_{0}^{R_2-R_1} dh , \quad \left.\frac{v_s^2}{2}\right|_{v_{so}}^{v_{sk}} = \frac{-kg}{\sin\varphi}\Big|_{0}^{R_2-R_1} h ,$$

$$\frac{v_{sk}^2 - v_{so}^2}{2} = \frac{-kg}{\sin\varphi}(R_2 - R_1).$$

In these formulas, the assumption is made that the step does not change the length of the semicircle.

Since the ultimate speed in a certain segment coincides with the initial velocity in the next section, from the preceding formulas we may find the change in velocity across the tube in one revolution Δv. The loss of kinetic energy then is equal to

$$\Delta W = \frac{v_b^2 - (v_b - \Delta v_b)^2}{2}.$$

4. The momentum of force for Movement of Ball within a Deformed Tubular Circleference

In wheel Aldo Costa all weights (in our scheme - balls) rotate with angular speed ω around the point 'o'. Above the change in kinetic energy ΔW has been found. In our case, to preserve the kinetic energy of the ball, an external energy source must add value ΔW for each revolution of the ball. We assume that this energy is brought by application of force torque $F \cdot \Delta t$ on a certain time interval. This torque increases the angular speed. When the torque is applied to the ball in the point 'b', then

$$F \cdot \Delta t = m \cdot \Delta v_b, \tag{1}$$

where

$$\Delta v_b = R_2 \cdot \Delta \omega_b. \tag{2}$$

This value can be calculated for a given $\boldsymbol{W}$ by the following formula:

$$\Delta W = \left((v_b + \Delta v_b)^2 - v_b^2 \right) / 2 \tag{3}$$

or

$$2 \frac{\Delta W}{R_2^2} = (\omega_b + \Delta \omega_b)^2 - \omega_b^2 \tag{4}$$

or

$$\Delta \omega_b = \sqrt{\omega_b^2 + 2\Delta W / R_2^2} - \omega_b. \tag{5}$$

From (20, 21, 24) we find:

$$F \cdot \Delta t = mR_2 \left(\sqrt{\omega_b^2 + 2\Delta W / R_2^2} - \omega_b \right). \tag{6}$$

If the torque exceeds the specified value, the angular velocity will increase and if the torque is less than the specified value, the angular velocity will decrease and in a certain moment the ball stops. Fig. 3 shows the relationship - $F \cdot \Delta t = f(\omega_b)$. When calculating assumed that in the CGS system

$$P = 5 \cdot 10^5, R_1 = 44, R_2 = 50, \omega = 10, k = 0.025$$

In this the momentum of force must be equal

$$F \cdot \Delta t \approx 2500 \text{ (dyne * s)}$$

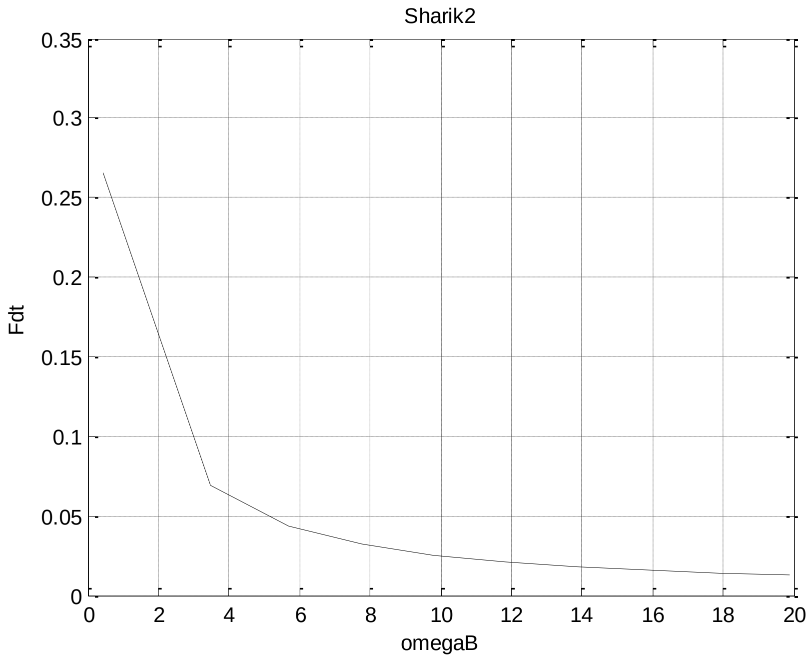

Fig. 3.

Appendix 2. Movement of Load on Vertical Step

Let us consider the case when load m_2 rotates with angular speed ω, and load m_1 moves vertically with the speed v_1 .Then

$$|a| = \omega R_2, \quad b = [0, v_1, 0], \tag{1}$$

As the loads are moving in one plane, then

$$r_z = 0, \ a_z = 0, \ b_z = 0 . \tag{2}$$

Considering this, from (4) – see section 6), we get:

$$\overline{f_{12}} = \begin{bmatrix} a_y(-v_1 r_x) \\ -a_x(-v_1 r_x) \\ 0 \end{bmatrix} \tag{3}$$

or

$$\overline{f_{12}} = D[-a_y, \ a_x], \ D = v_1 r_x . \tag{4}$$

So, from m_1 to m_2 the force (4) is acting. Similarly, let us consider the case, when load m_1 rotates with angular speed ω, and load m_2 moves vertically with the speed v_2. Then

$$|b| = \omega R_1, \quad a = [0, v_2, 0], \tag{5}$$

and from ((4) – see sector 6), we get

$$\overline{f_{21}} = -\begin{bmatrix} v_1(b_x r_y - b_y r_x) \\ 0 \\ 0 \end{bmatrix}. \tag{6}$$

So, the force (6) is directed horizontally from m_2 to m_1 and has no influence of the vertical movement.

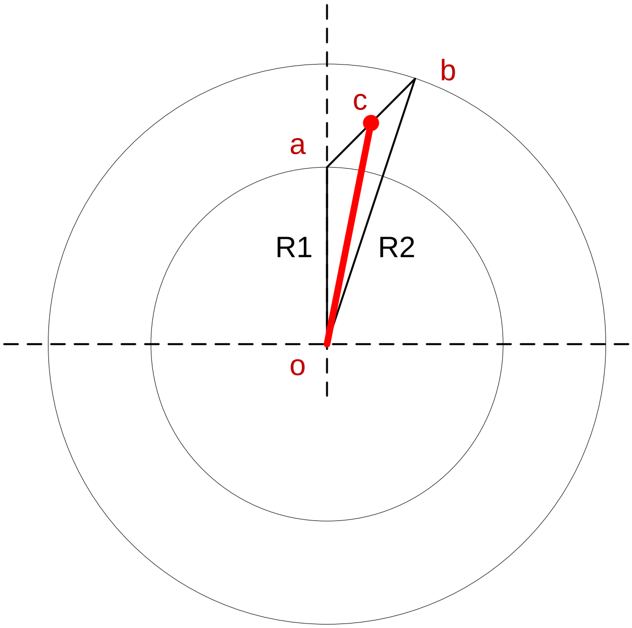

Fig. 4.

Above the assumption was made, that the speed of motion on the step is constant. In fact, this speed varies even with constant angular speed. Let us consider this question in detail - see Figure 4. Find the speed of the body on the segment "as". Denote:

$$\gamma = 'ga' = \angle aob, \ \gamma_2 = 'ga2' = \angle aoc, \ u_1 = 'u1' = \angle bao,$$

$$u_2 = 'u2' = \angle abo, \ u_{22} = 'u22' = \angle aco.$$

Solving the triangle "oab", we find:

$$d = \sqrt{R_1^2 + R_2^2 - 2R_1 R_2 \cos(\gamma)}$$
$$\sin(u_2) = \sin(\gamma),$$
$$u_1 = \pi - \gamma - u_2 .$$

Radius "oc" rotates with angular speed ω. Thus

$$\gamma_2 = \omega t .$$

Solving the triangle "oac", we find

$$u_{22} = \pi - \gamma_2 - u_1 ,$$
$$d_2 = R_1 \sin(\gamma_2)/\sin(u_{22}),$$
$$R_{22} = R_1 \sin(u_1)/\sin(u_{22}).$$

The body's speed on segment "ab"

$$v = \frac{d(d_2)}{dt}.$$

Speed of approach of the body to this segment along a circle of radius R_1 is equal to $v_a = \omega R_1$, and the rate of removal from it along a circle of radius R_2 is equal to $v_a = \omega R_1$. At the points "a" and "b" the speeds change their values as a result of elastic collision, i.e. without energy loss.

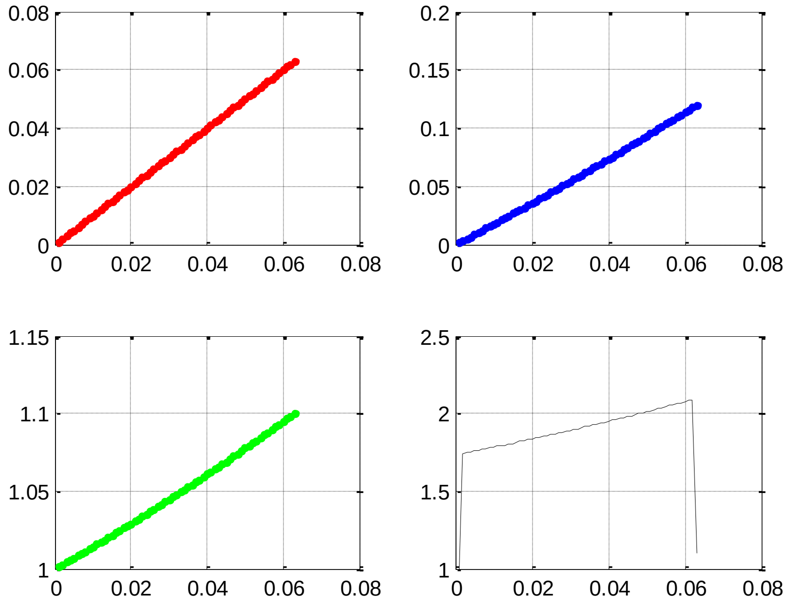

Fig. 5.

Fig. 5 shows functions of time γ_2, d_2, R_{22}, v (in windows 1-4, respectively).

Speed of the body along a segment "ab" is substantially higher than circular speed. Therefore, above we examined the interaction of the body rising vertically with the speed v, and the body moving in a circle with the speed $v_a = \omega R_1$ or $v_b = \omega R_1$.

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