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THE EFFECT OF SURFACE ROUGHNESS AND ELECTROSTATIC BONDS OF RESIDUAL GASES ON THE SETTLING OF THE GYROSCOPE ROTOR

Abstract. Consider the rotor of an electrostatic gyroscope (ESG) for contactless operation. The rotors of the ESG are made in the shape of a ball and placed in an electric field. The gyroscope operates contactless between the rotor and the mutual oscillation force of the electrodes. Air is sucked out of the chamber in which the rotor is located. Due to the lack of air resistance and the lack of friction force, the rotor can rotate for a long time. But the rotor, located inside the vacuum, also slows down. The reason for this is the roughness and residual deposits of the rotor surface. This is the notorious effect of the rotor of these residual gases on braking. When calculating the effect of residual gases on the rotor, it is considered as separate gases, and not as a homogeneous medium. For this reason, the viscosity of the gas can be set without consideration. The effect of the action of individual particles on the rotor is determined by the roughness of its surface. That is, the momentum by which the particles somehow hit the "peaks" or "troughs" creates a torque that acts on the rotor.

Keywords. Electrostatic gyroscope, contactless gyroscope, gyroscope, gyroscope rotors, residual gases, vacuum.

Introduction.

It is impossible to create an absolute vacuum. It is obvious that residual gases remain in the vacuum. But because of the low pressure and low density, we consider this medium as separate particles, not as a whole. That is, the effect of residual gas on the rotor is considered as the effect of individual particles on a solid.

It is also known that the rotor surface will not be uneven. By enlarging the surface of the rotor, we see a shape similar to Image 1 [1]

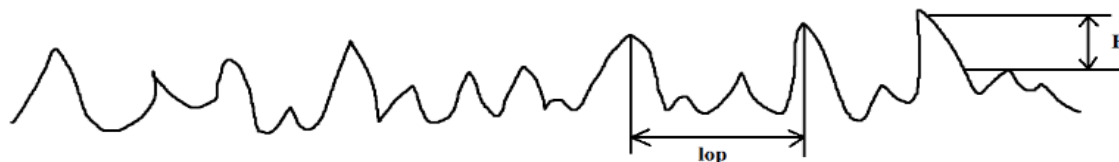


Figure 1

When the rotor rotates, the rotation speed slows down due to the friction of the rotor surface against the residue gases and the resistance of the "tops" of roughness.

Materials and methods.

Where the rotation speed of the gyroscope rotor and the density of the material from which the gyroscope rotor is made refer to factors characterized by the design features and

technical properties of the gyroscope. And the viscosity of the gas varies depending on the temperature. Fortunately, the dependence of the viscosity of the gas on the temperature has already been determined. And is characterized by the expression below [1]:

$$\eta_1 = \eta_0 \left(\frac{T_0 + C}{T + C} \right) \left(\frac{T}{T_0} \right)^{\frac{3}{2}}. \quad (1)$$

The resulting equation shows only that the viscosity of this gas (air) under normal conditions depends on temperature, and not the viscosity of the residual gas surrounding the ball of the gyroscope rotor. And the fact that the gas (air) changes depending on the pressure is a sign. Therefore, by converting the obtained density by pressure, we obtain the viscosity of the residual gas (air) surrounding the ball of the gyroscope rotor [2]:

$$\eta = \frac{\eta_1 \times P_r}{P_{\text{атм}}}. \quad (2)$$

Combining the two expressions obtained, we obtain an expression describing the dependence of the viscosity of the residual gases surrounding the rotor ball on the temperature under pressure of the residual gases. This expression is shown below.

$$\eta = \frac{\eta_0 \left(\frac{T_0 + C}{T + C} \right) \left(\frac{T}{T_0} \right)^{\frac{3}{2}} P_r}{P_{\text{атм}}}. \quad (3)$$

It was discussed above that the rotation speed changes with time.

$$\omega = \omega_0 - \omega_T. \quad (4)$$

And the value of the braking speed depends on the torque and the initial speed. The moment itself is defined as a function depending on the initial velocity and time.

$$\omega_T = f(M_T; \omega_0). \quad (5)$$

Therefore, the above-mentioned integral turns into a complex differential equation consisting of functions of one variable. I do not think that it is possible to solve this problem with the help of an analytical tool. Therefore, in order to solve the problem, you need to divide it a lot and count each detail separately. To do this, we determine the dependence of the braking torque on the gas lever surrounding the Rotor and the speed of rotation of the rotor [1] [2]:

$$M_T = \eta R^3 \omega \pi^2. \quad (6)$$

The instantaneous speed change is defined as the product of the instantaneous time value with the instantaneous angular deceleration value.

$$\Delta \omega_T = \Delta \varepsilon \times \Delta t. \quad (7)$$

And at any given time, the value of angular braking is defined as the ratio of the braking moment to the moment of inertia of the rotor ball.

$$\Delta \varepsilon = \frac{M_T}{J_{\text{ш}}}. \quad (8)$$

And the expression of the dependence of the moment of inertia of the ball on the radius of its mass is known earlier.

$$I_{ш} = \frac{2mR^2}{5}. \quad (9)$$

If we enter an expression defining the dependence of viscosity on pressure with temperature on the expression of viscosity with the speed of rotation of the braking torque on temperature, we get an expression describing the dependence of the braking torque on temperature.

$$M_T = \frac{\eta_0 \left(\frac{T_0 + C}{T + C} \right) \left(\frac{T}{T_0} \right)^{\frac{3}{2}} P_r R^3 \omega \pi^2}{P_{атм}}. \quad (10)$$

The pressure of the residual gas around the Rotor is not constant. Since gas of constant size accumulates in a closed field, the processes in it can be considered isochoric. That is, an increase in temperature leads to an increase in gas pressure. This dependence is shown in the expression below.

$$P_r = P_1 \times \frac{T}{T_0}. \quad (11)$$

It turns out that the gas pressure varies not only depending on the temperature, but also on the volume of the gas. A decrease in volume leads to an increase in pressure, and an increase in volume leads to a decrease in pressure.

$$P_1 = P_0 \times \frac{V_0}{V}. \quad (12)$$

It is a mistake to think that the deposit between the Rotor and the shell of a gyroscope with a permanent design is constant and never changes. The change in idle speed is associated with a change in the radius of action of the Rotor depending on temperature, i.e. with an increase in temperature. The volume of the deposit between the shells with the rotor is determined by the inner volume of the shell as the difference in the volume of the rotor ball [3]:

$$V_0 = \frac{4}{3} \pi R_1^3 - \frac{4}{3} \pi R_0^3 = \frac{4\pi(R_1^3 - R_0^3)}{3}. \quad (13)$$

And when the temperature changes, the radius of the rotor changes and the volume of the free deposit changes.

$$V = \frac{4\pi(R_1^3 - R^3)}{3}. \quad (14)$$

The rotor is made of metal, the temperature of which is much higher than that of ceramics with a magnification factor. Therefore, I think that when calculating the volume, ceramics can be without taking into account the temperature increase of the shell.

The ratio of the initial volume to the volume formed as a result of the increase in the rotor ball is determined by the expression below.

$$\frac{V_0}{V} = \frac{4\pi(R_1^3 - R_0^3)}{3} \times \frac{3}{4\pi(R_1^3 - R^3)} = \frac{R_1^3 - R_0^3}{R_1^3 - R^3}. \quad (15)$$

By entering this expression into an expression describing the dependence of pressure on volume, we obtain the dependence of the pressure around the rotor on the change in radius.

$$P_1 = \frac{P_0(R_1^3 - R_0^3)}{R_1^3 - R^3}. \quad (16)$$

And the change in radius directly depends on the change in the temperature of the initial radius and the coefficient of temperature increase of the material.

$$R = R_0\beta(T - T_0). \quad (17)$$

The above expressions give an expression describing the dependence of volume on temperature, which affects the amount of pressure in the rotor.

$$P_1 = \frac{P_0(R_1^3 - R_0^3)}{R_1^3 - (R_0\beta(T - T_0))^3}. \quad (18)$$

And if we introduce temperature components into this expression, then we determine the dependence of the pressure of residual gases around the rotor on temperature.

$$P_r = \frac{TP_0(R_1^3 - R_0^3)}{T_0 [R_1^3 - (R_0\beta(T - T_0))^3]}. \quad (19)$$

This, in turn, gives the dependence of the instantaneous value of the braking moment on all factors. This dependency expression is shown below.

$$M_T = \frac{\eta_0 \left(\frac{T_0 + C}{T + C}\right) \left(\frac{T}{T_0}\right)^{\frac{3}{2}} R^3 \omega \pi^2 TP_0 (R_1^3 - R_0^3)}{P_{атм} T_0 [R_1^3 - (R_0\beta(T - T_0))^3]}. \quad (20)$$

Results and Discussion.

The torque of the rotor slows down the speed. The work of bees is focused on the same independence. In order to overcome the score, we take the height of all the "vertices" and the average distance between them (2 – figure) [3] [4].

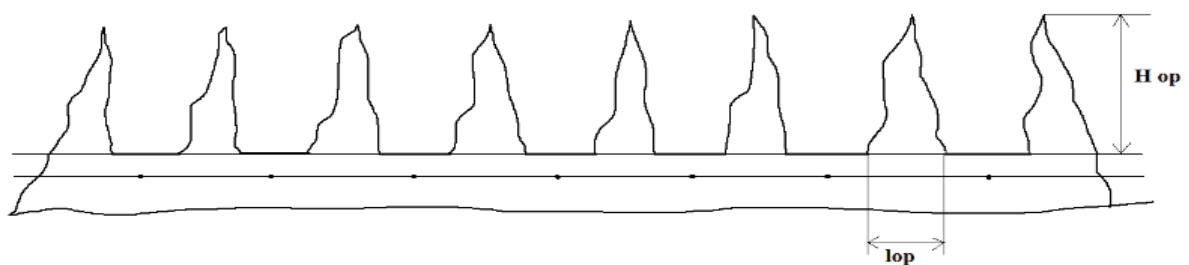


Figure 2

The rotating rotor "sweeps" the parts in its path, creating the roughness of the Concrete. In addition, the other marker is not forgotten by the u-speed until it is empty (3 – figure).

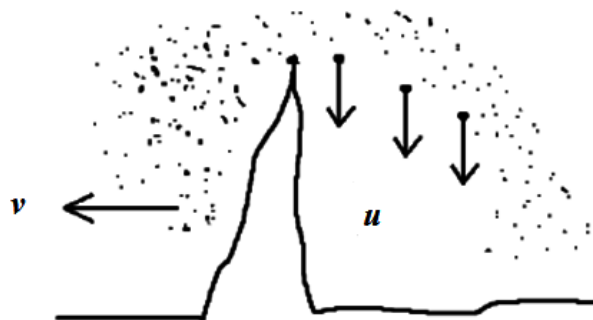


Figure 3

This rate depends on the gas content and pressure of the residue. When a gas moving at this speed hits a surface, dynamic pressure acts on the surface. This pressure is equal to the pressure that created this velocity.

$$U = \sqrt{\frac{2p}{\rho}}. \quad (21)$$

The residual particles reach the "bottom" of the rotor roughness at a distance l from the "top". In the same interval, he goes through a certain path. The length of the path is equal to the height of the vertex.

$$l = vt. \quad (22)$$

Here v – is the surface velocity. And t – gas particles must travel a distance of H – time.

$$t = \frac{H}{u}. \quad (23)$$

That is

$$t = \frac{H}{\sqrt{\frac{2p}{\rho}}}. \quad (24)$$

But it is also possible that the particles between the "tops" of the two cannot reach the "bottom" of the surface. The reason lies in the small distance between the vertices. Or the particle may "hit" the next one before it reaches the bottom of the depression. Therefore:

$$l \leq l_{op} \text{ then } h = H_{op}, \quad (25)$$

$$l > l_{op} \text{ then } h = u t_1 \quad (26)$$

But

$$l = vt, \quad (27)$$

$$t_1 = \frac{l_{op}}{v}, \quad (28)$$

or (4 – figure)

$$l = \frac{Hopv}{\sqrt{\frac{\rho p}{\rho}}}. \quad (29)$$

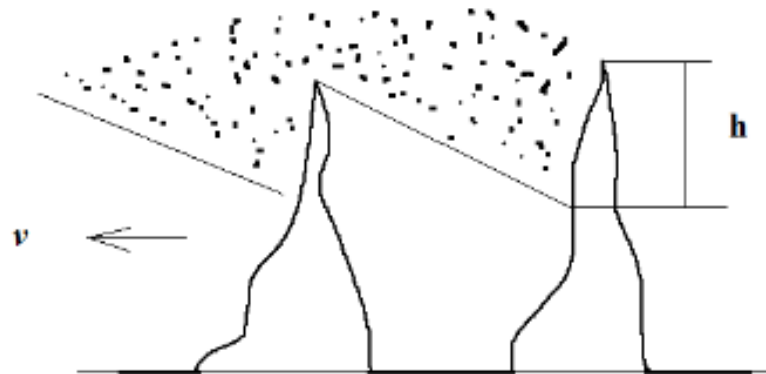


Figure 4

That is

$$h = ut_1 = \frac{u \text{lop}}{v} \quad (30)$$

or

$$h = \frac{\text{lop} \sqrt{\frac{\rho p}{\rho}}}{v}. \quad (31)$$

If $h > H$ then it is called $h = Hop$.

Now we need to find the resistance of the elementary surface that moves in the residuals. It is proportional to the area and velocity of the surfaces of interaction of the resisting bulges with the gas, to the dynamic pressure through velocity. (5 – figure)

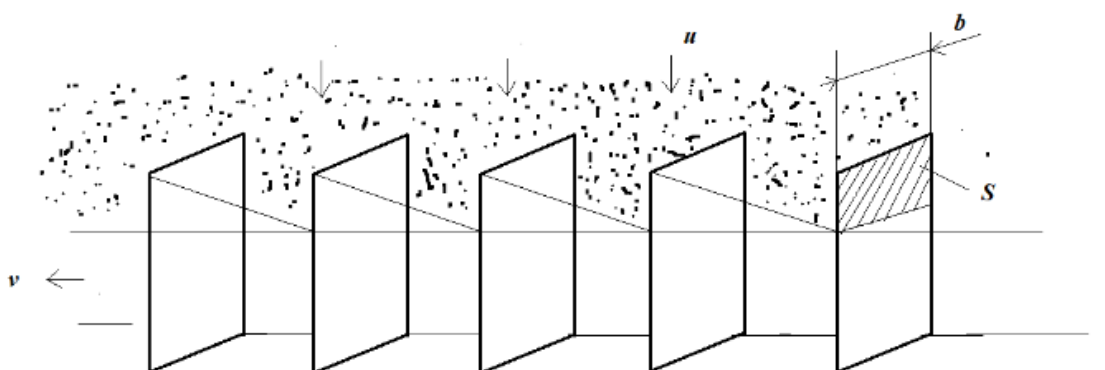


Figure 5

At the moment of movement of the elementary surface, each time there was a selection of the S – zone of the "vertex". The resulting element F has a strong resistance effect.

$$F = \frac{\rho v^2}{2} S n. \quad (32)$$

Here n – is the number of " vertices " along the length of the element.

$$n = \frac{l_{\Sigma}}{l_{op}} \quad (33)$$

but

$$S = hb. \quad (34)$$

That is

$$F = \frac{\rho v^2 hb l_{\Sigma}}{2l_{op}}. \quad (35)$$

To calculate the rotor braking, we divide the rotor surface into elements. And the speed is proportional to the radius of the element. For this reason, the force in each element is also different, for which we divide the surface of the rotor into elements in order to calculate the deceleration of the rotor (6 – figure).

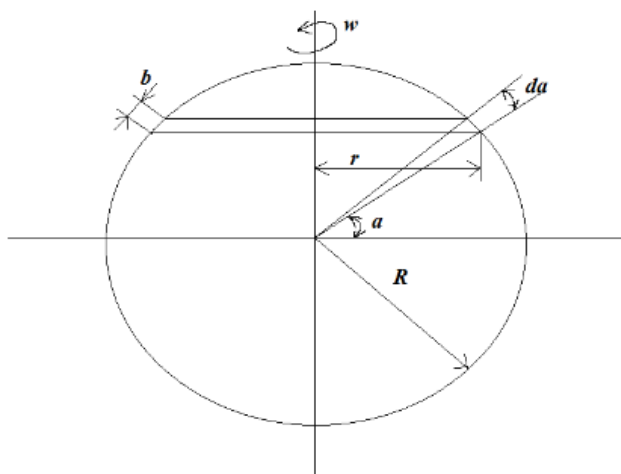


Figure 6

The surface of the rotor is divided into many "rings". If we write each "ring", then the "ring" will become a shelf equal to b .

That is

$$l_{\Sigma} = 2\pi r. \quad (36)$$

Here r – is the radius of the element.

$$r = R \sin a. \quad (37)$$

That is

$$l_{\Sigma} = 2\pi r R \sin a \quad (38)$$

but

$$b = R da. \quad (39)$$

The surface velocity element is proportional to the rotation speed of the rotor. It also depends on the radius of the ring.

$$v = \omega r = \omega R \sin \alpha. \quad (40)$$

And the drag force acting on the element creates a torque that slows down the rotor. This strong computational expression was defined above.

$$M = Fr = FR \sin \alpha \quad (41)$$

or

$$F = \frac{\rho(w^2 R^2 \sin^2 \alpha)h(2\pi R \sin \alpha)R}{2l\omega p} d\alpha = \frac{\rho w^2 R^4 h \pi \sin^3 \alpha}{l\omega p} d\alpha. \quad (42)$$

The braking torque is defined as the sum of the moments of each element. We use the integral to determine the sum of elementary quantities, the number of which tends to infinity, and the magnitude to 0.

$$M_T = 2 \int_0^{\frac{\pi}{2}} \frac{\rho w^2 R^5 h \pi \sin^4 \alpha}{l\omega p} d\alpha \quad (43)$$

or

$$M_T = \frac{2\rho w^2 R^5 h \pi}{l\omega p} \int_0^{\frac{\pi}{2}} \sin^4 \alpha d\alpha. \quad (44)$$

$$\int_0^{\frac{\pi}{2}} \sin^4 \alpha d\alpha = \frac{3\pi}{16}. \quad (45)$$

That is

$$M_T = \frac{6\rho w^2 R^5 h \pi^2}{16l\omega p} \quad (46)$$

or

$$M_T = \frac{3\rho w^2 R^5 h \pi^2}{8l\omega p}. \quad (47)$$

Conclusion.

It was found that when the rotor residue interacts with gases, braking is proportional to the 5th degree of its radius (ball rotor). Given that the inertia of Al-Sharda is proportional to the square of the radius of the moment, we determine whether the cube of the radius of deceleration is proportional to one velocity.

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БЕТТІҢ КЕДІР – БҰДЫРЛЫҒЫ МЕН ҚАЛДЫҚ ГАЗДАРДЫҢ ЭЛЕКТРОСТАТИКАЛЫҚ КОНТАКТСЫЗ ГИРОСКОП РОТОРЫНЫҢ ТЕЖЕЛУІНЕ ӘСЕРІ

Аңдатпа. Контактсыз жұмыс істейтін электростатикалық гироскоп (ЭСГ) роторын қарастырамыз. ЭСГ роторы шар формасында жасалғын және электр өрісінде орналастырылған. Ротор мен электродтардың өзара тербелу күшінің арасында гироскоп контактсыз жұмыс істейді. Ротор орналасқан камерадан ауа сорылып алынған. Ауа кедергісі болмағандықтан және үйкеліс күшінің жоқтығынан ротор көп уақыт айналып тұра алады. Бірақ уақыт өте келе вакуум ішінде тұрған ротор да тежеледі. Оған себеп ротор бетінің кедір бұдырлығы мен қалдық газдар. Бұл мақалада сол қалдық газдардың ротор тежелуіне әсері қарастырылады. Қалдық газдардың роторға әсерін есептегенде, оны біртекті орта емес, жекелеген бөлшектер ретінде қарастырылады. Сол себепті газдың тұтқырлығын есепке алмай ақ қоюға болады. Жекелеген бөлшектер әсерінің роторға әсері оның бетінің кедір-бұдырлығы арқылы анықталады. Яғни бөлшектердің «шыңдарға» немесе «ойпаттарға» әлдебір жалдамдықпен соғылу импульсі роторға әсер ететін моментті тудырады.

Түйінді сөздер. Электростатикалық гироскоп, Контактсыз гироскоп, гироскоп, гироскоп роторы, қалдық газдар, вакуум.

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ВЛИЯНИЕ ШЕРОХОВАТОСТИ ПОВЕРХНОСТИ И ЭЛЕКТРОСТАТИЧЕСКИХ СВЯЗЕЙ ОСТАТОЧНЫХ ГАЗОВ НА ОСЕДАНИЕ РОТОРА ГИРОСКОПА

Аннотация. Рассмотрим ротор электростатического гироскопа (ЭСГ) для бесконтактной работы. Роторы ЭСГ выполнены в форме шара и размещены в электрическом поле. Между ротором и силой взаимного колебания электродов гироскоп работает бесконтактно. Из камеры, в которой расположен ротор, всасывается воздух. Из-за отсутствия сопротивления воздуха и отсутствия силы трения ротор может долго вращаться. Но ротор, находящийся внутри вакуума, также тормозит. Причиной тому является шероховатость и остаточные отложения поверхности ротора. Это пресловутое влияние ротора этих остаточных газов на торможение. При расчете влияния остаточных газов на ротор его рассматривают как отдельные больше, а не как однородную среду. По этой причине вязкость газа можно ставить без учета. Влияние воздействия отдельных частиц на ротор определяется шероховатостью его поверхности. То есть импульс, с помощью которого частицы каким-то образом ударяются о «вершины» или «впадины», создает крутящий момент, который действует на ротор.

Ключевые слова. Электростатический гироскоп, бесконтактный гироскоп, гироскоп, гироскоп роторы, остаточные газы, вакуум.
