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GEOMETRICAL SOLUTIONS TO OPTIMIZE THE ROTOR SHAPE IN CASE OF THE ELECTROSTATIC MOTOR

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***Abstract*—** In the construction of the electrostatic motor, which was developed, the rolling spherical bodies caused the rotation at the level of the rotor. For this reason the mechanical collector design solution is very important. The number of the rotor arms and the angular value between them can influence the period of rotation of this rotor. This work attempts to set the cause and to establish as much as accurately as possible an optimum angular value.

***Keywords*—** electrostatic, electrical field, electrostatic effects, motor, propulsion

I. Introduction

WHEN studying the function of electrostatic motor proposed and developed, the rolling bodies caused the rotation of the rotor in direct physical contacts. In the present case one tried to determine an optimal geometry in the rotor construction, because this rotor has a mechanical collector where the rolling body pushes the rotor arm.

For its scope one proposes three types of rotors, one of them endowed with tree arms altering in plane at one hundred and twenties degrees (symmetrical), a second one with four arms altering in plane at nineteen degrees, and finally the third rotor with six arms altering in plane at sixteen degrees. In each of them there are mounted different numbers of rolling bodies in various orders, one to three in the case of the first type rotor and of course, one to four in the case of the second one.

In each case it has been put forward that the rolling of the metal ball/balls is/are caused by the concurrence of many forces and interactions, among which there are the following: the effect of the Coulomb's force between the sphere and the metallic ring of the spatial condenser fitting, the effect of the centrifugal force of the rolling body, the instantaneous distribution of duties on the surface of the rolling body reported to the upper condenser fitting, and last but not least the rolling of this body on the surface of the superior insulator, [1]. The rolling motion of the body involves the precession of the instantaneous axis of the body rotation involving a continuous variation of the length of the rolling circle and its orientation towards the top of the condenser fitting. Electrostatic forces cause the motion of approach and moving away from the metal ring; the effect of the electric charges distributed on the surface of the rolling body forces combined with rolling friction cause the metal ball rolling.

The combinations of the two afore-mentioned motions generate sinusoidal motion of the center of mass relative to the upper insulator plane, see Fig. 1. Experiments revealed physical contact between the metal ring and the rolling body where the electric potential is the same and causing the removal of the metal ring relative to the rolling body motion to remove the ring. Rolling body loses electrical charge by removing it to ring; for this reason, the body will be attracted to the metal ring again. This oscillation takes place by the superposition with the rotation motion of the rotor generated by the sinusoidal trajectory of every rolling body. Theoretical studies shaped this motion by means of a parametric equation that approximates the center of mass motion.

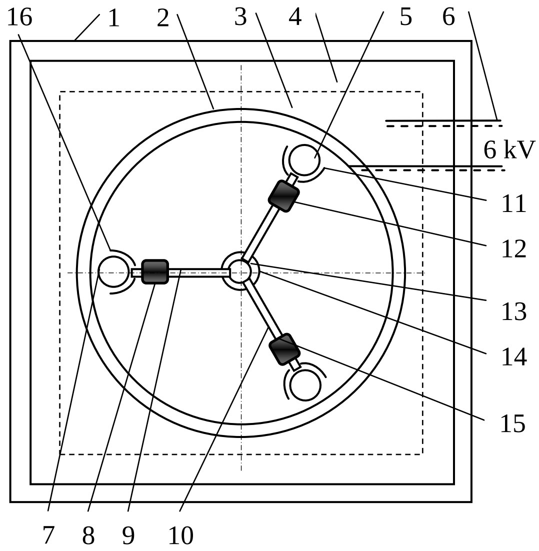

Fig. 1. The electrostatic motor standing elements without power supply connected.

This study involves phenomena caused by a number of independent rolling bodies motion so that it is interesting to find out what happens in experimental situation when hawse has more than three or four rolling bodies (metal balls), [2], [3]. Assuming that it takes four metal balls inside the spatial condenser and one inputs the supply at 6~7 kV, as shown in previous studies, the group of four balls start to execute a rolling motion inside of the superior fitting and suddenly the first rolling body is rolling faster at the inner of the ring in the same direction to the remaining group of three balls which continue the rolling motion but a little slower. This motion takes place until the faster ball catches the last three balls which is the momentum when the phenomena described continues as shown above.

The entire experiment as it was described briefly above takes place in the similar spatial condenser as it is presented in Fig. 1, excluding the rotor of course.

The conclusion at the level of this experiment was that the number of arms at the rotor level is very important because if two successive arms are so close, (angular) it might appear a disturbance effect at the electrostatic level between the rolling bodies and cause a reduction of the propulsion.

Briefly about Fig. 1: this figure represents the rolling area of the spherical body 5, 7, and the superior surface 4 of the spatial condenser which is a glass plate.

Rotor arms 9, 10 are dynamically balanced by using the masses 8, 12 and 15. The metallic collector 16 ensures the motion transfer from the rolling body to the rotor 13 with the three horizontals arms, like type 9 and 10. Spatial condenser is formed by the square stand 1 and the lower electrical insulator, fitting 3, upper dielectric 4 made of glass, metallic ring 2, it represents the second fitting of the spatial condenser, see also Fig. 2.

Inside the metallic ring there are placed the rolling balls which are stand on the the upper insulator of the space condenser.

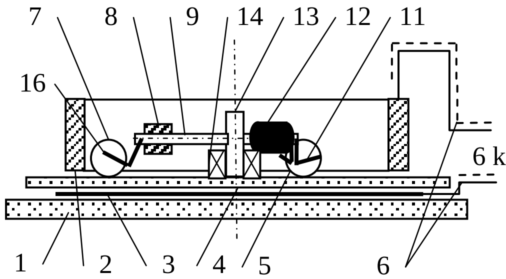

Fig. 2. Electrostatic motor cross section with electrical connections

Within the metallic ring 7 it is placed the rotor leaning on the roller bearing 14; in the meantime the rolling bodies are places in the motion collectors placed at the ends of the rotor arms.

Based on this theoretical support three different rotors with three, four and six arms respectively were mounted successively in the following order: one rolling body, two rolling bodies, and so on. The three arms types have approximately the same weight, and are obtained by adjusting the tuning masses 8, see Fig. 1, as a condition to compare the rotation periods which will be determined for all these possible situations, (different numbers of balls).

II. Mathematical Model

Reconsidering the experimental model of the spatial condenser where there is a single spherical body, a mathematical relation can be written for the Coulomb effect and the centrifugal force.

$$T_b = \sqrt[3]{(2\pi)^2 \frac{7mR^2}{10\, i\, U}} \quad (1)$$

Where: T_b – represent the rotation period for a single spherical steel body, m – mass of the rolling body, R – interior radius of the metal ring, part of the spatial condenser, i – polarization current, U – high voltage to supply the condenser.

The start of the rotor rotation motion is ensured by the spherical rolling body/bodies, which, through the electric field produced by the spatial condenser, ensures the rotor's rotation. It is essential to determine the equation of motion of the rolling body placed in an electrostatic field for a subsequent writing of the equation of this body motions which propel the rolling bodies.

The rolling of the spherical body is caused by the concurrence of many forces and interactions, among which there are the following: the effect of the Coulomb force between the sphere and the metallic ring of the spatial condenser's fitting, the effect of the centrifugal force of the rolling body, the instantaneous distribution of duties on the surface of the rolling body reported to the condenser's fittings, and last but not least, the rolling of this body on the surface of the superior dielectric, [4], [5]. Experimentally, the rolling motion of the body involves the precession of the instantaneous axis of the body's rotation – implying a continuous variation of the sphere's rolling circle, a variation of both this circle's plane on the rolling area, and of the length of this circle.

These experimental observations explain the winding, (sinuous) trajectory of the rolling body on the inner perimeter of the superior fitting's ring of the spatial condenser.

During the above mentioned phenomenon, the rolling body performs a complex rolling where the instantaneous rotation axis makes a precession to the theoretical perpendicular which passes through the mass center, a perpendicular to the superior dielectric 4.

The experimentally determined model involves the existence of a rolling circle of the spherical body that changes the perimeter and gradient of the rolling plane of the circle defined inside it. The precession, the proper rotation and the motion of the instantaneous axis become evident for the model defined and experimentally determined.

As one noticed the rotational motion of the rolling body recorded at the center of the ring by a position vector that follows the mass center will take place in a variation of the instantaneous module of the vector; this variation takes place within approximate limits experimentally determined. The fixed reference system placed in the geometric center of the metallic ring Fig. 1, records the motion of the components vector (r_{x2}, r_{y2}). If the inner radius of the fitting is noted R_e, and the radius of the rolling body is noted r_{cr}, it results that the maximum and the minimum radiuses where the mass center is moved on the inner perimeter of the metallic ring, as follows:

$$r_{max} = R_e - r_{cr} \quad ; \quad r_{min} = R_e - r_{cr} - \delta \qquad (2)$$

Where: δ represents the oscillation of the mass center to the theoretical circular trajectory, respectively the double value of the motion's amplitude in the direction of the vector radius,

$$r_m = \frac{1}{2}\left(r_{max} + r_{min}\right) \quad ; \quad \delta = \left(r_{max} - r_{min}\right) \qquad (3)$$

The variation of the position vector's module is expressed according to the parametric relation of the position vector expressed in the system above;

$$\begin{aligned} r_{x_2} &= r_m + \frac{\delta}{2}\sin(n\alpha)\cos\alpha \\ r_{y_2} &= r_m + \frac{\delta}{2}\sin(n\alpha)\cos\alpha \end{aligned} \qquad (4)$$

The parametric equation to approximate the motion of the mass center corresponds to the suggested form, where "n" represents the number of loops made on the trajectory of the mass center. Given the present resources, one considers that the rotation period of the rotor is a constant value, a fact which in the case of previous resources is acceptable.

The mathematical model for this observation is corresponding with the angular areola speed with constants value too. The form of relation could offer some information about the trajectory of the spherical body; in the general case where the angular speed is not considered constant, for simplifying the calculations, the hypothesis of the areola speed can be accepted as being constant, like in mathematical model, [6].

$$\vec{\Omega} = \frac{1}{2}\begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ r_{x_2} & r_{y_2} & 0 \\ \dot{r}_{x_2} & \dot{r}_{y_2} & 0 \end{vmatrix} = ct. \qquad (5)$$

The experimental determinations pointed out that the instantaneous rotation axis performs a precession motion, the geometrical locus being identified in a cone having its top in the mass center of the spherical rolling body 5. In this way one could explain the continuous variation of the inclination of the rolling center plane reported to the dielectric plane.

These afore-mentioned consequences generate, at their turn, a "sinusoidal" winding motion of the mass center trajectory to the inner perimeter of the superior fitting's ring of the spatial condenser.

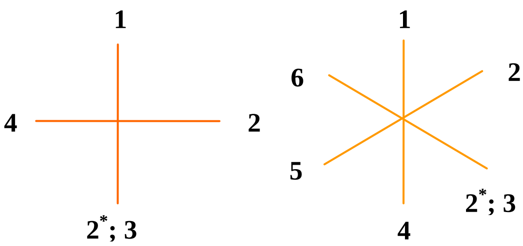

Fig. 3. Order to load the rottors type with rolling bodies in successivelt for four armrs and six arms.

Considering that the energy of one single rotation body at the same hay voltage value equals the energy of the rotor in different constructions one can use the relation that provides the period of rotation.

$$T^{(i)}_{M\,n\,t} = T_b\sqrt{n + \frac{5m_1^{(i)}}{7m}} \qquad (6)$$

The left member of relation 2 determines the period for the type "i" of rotor where there are "n" balls for traction. The mass of the rotors – $m_1^{(i)}$, for the three types of them is equalized by masses 8 in Fig. 1, and m- represents the mass of the ball (rolling body). Equation (2), is tested for metal balls and metal collector of motion. For such conditions, the obtained results are very close to the experimental ones.

Comparing these theoretical results with the experimental ones for the metal motion collector, it results a very good approach.

III. Results

After performing some research on the influence of the rolling bodies' numbers to the rotation period, it is necessary to study the influence of the angle of two successively rotor arms.

One does the same to make three different rotors which have one hundred and twenties degrees, the second one with nineteen degrees and the last one with sixteen degrees.

In every one of them in order the rolling bodies are emplaced successively one by one and one measures the rotation period for each of them. The three types of rotors have nearly the same weight condition that allows comparing the experimental values between the solutions. Now one will name the first rotor that has the arms at the angle of one hundred and twenties degrees the second will be with nineteen degrees and the third with sixteen degrees between their arms.

To increase the trust in the experimental values some controls/checks are performed between the rotation period of these rotors such as the following ones: one compares the rotation period between the rotor number two for two balls in position, see Fig. 4, position 1 and 2* with the rotor number three with two balls in positions 1 and 4: the second control/check is made between the rotor number one with two balls and the rotor number three with two balls in positions 1 and 2*.

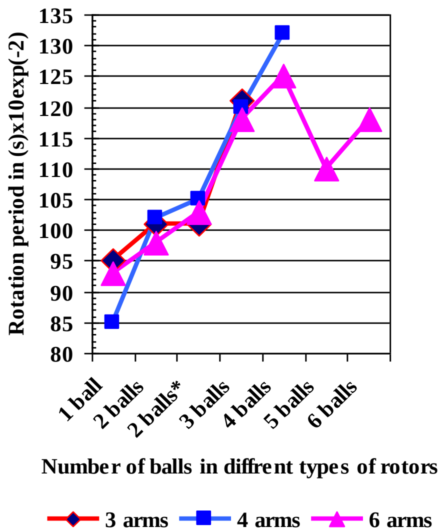

Fig. 4. Experimental values about rotations periods for the three rotors loading with different numbers of rolling bodies.

Of course one can compare situation for the first rotor with three balls with the rotor number 3 with three balls in the positions 1, 2,* and 5, see also Fig. 3.

In our current experiment it is difficult to determine the optimum angular position for the rotor arms because the increasing number of rolling bodies causes a longer period of rotation for the rotor.

Theoretical the increase of the number of bodies implies an increased friction among the rolling bodies and mechanical motion collectors; on the other hand the friction between the rolling bodies and the upper insulator, made of glass, provides the propulsion.

In Fig. 4, there are shown the experimental values for the present resource for every one of the rotors' type. Every experimental value is obtained by arithmetic mean of another three determinations in the same configuration and rotor type.

IV. Conclusions

As one can notice in the Fig. 4, the most experimental values are centered up to four rolling bodies, and the three types of rotors had nearly the same values for the rotation period. Of course for the same weight of each rotor, the positions of the balls are similar to those.

The rotation period for the three rotors increases with the numbers of rolling bodies which is logical because of the increasing frictions among these bodies 5 and their related motion collectors, and the glass insulator.

Most interesting results are for the rotor number three with five and six rolling bodies where the rotations periods are decreasing which mean the speed is increasing exactly that was searched for. This fact shows whether that the third type of rotor provisioned with six arms is better than the previous ones. Evidently a question is raised maybe there is an optimum value for angular distance between two of successively arms from the rotor.

The geometrical construction of the rotor at this motor is consistent with the axe of the precession con: they must be perpendicular to offer a smooth rolling of the spherical rotation body. In this case, of course, the frictions between the ball and rotor are smaller for the entire electrostatic motor. The material of the rotor is very important for the distribution of the electrical charge, [7]. One determined experimentally that the insulator material increases the effects of propulsion generated by the metal ball (rolling body).

Finally one should add a conclusion shown from the last experimental determination: the metal motion collector generates a perturbation at the surface of the rolling body at the electrical charge level; this perturbation causes the diminutions of the propulsion effect generated by the rolling body. The composite solution for the collector decreases the period of the rotation at the rotor level. One should mention at least that the geometrical shapes of the motion collector in these cases are identical.

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