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EXPERIMENTAL OBSERVATIONS ON THE MOTION OF ELEMENTS PROPPELING THE ELECTROSTATIC ENGINE

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Abstract—Rolling elements driving the electrostatic engine rotor perform a complex mechanical motion under the forces exerted on them. This motion has repercussions on the motion collector geometry that can diminish the action of the rolling elements. Setting the rotation axis, its precession, the directions of the elements and the axe precision will determine the shape of the motion manifold.

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

I. INTRODUCTION

THE basis of the electrostatic motor operating principle is a propulsion phenomenon that is currently not fully elucidated. It was highlighted an electrical interaction that occurs between a circular metal wall 2, see Fig. 1, charged to a positive high level potential i.e. several kilovolts, and a metallic spherical body 3, placed inside and in contact with this ring; obviously the latter is loaded at the same potential as that of the metal ring.

The ring is placed on a glass plate and it is keeping a distance from the plate 1 by means of three supporting legs. Below this plate there is the negative load plate 4 of the spatial capacitor condenser thus formed as against the metal ring. In this context it is clear that from electrical point of view between the positive load plate, the metal ring and the spherical body the Coulomb force interaction occurs which initially tends to push the ball located near the wall, [1].

In terms of physics this would be the phenomenon one would reach at least theoretically. In reality there is an interaction between the electric field generated by the spatial capacitor format and the spherical body surface charged at the same potential, at least at the beginning. The phenomenon appears to be complex given that the distribution of charges on the spherical body is influenced by both the upper ring and the same capacitor plate, focusing on the difference in geometric shape of these fittings; the fact is that the spherical element will perform a rolling circular motion on the metal ring inner perimeter. Fig. 1 shows the annular surface area 6 in contact with the ball throughout the rolling, given that the ball will run a continuous oscillation motion as against the annular wall.

When getting in contact with the wall the electrical polarization of the ball will be similar to the wall, the ball will move away from the wall. Afterwards, due to electric polarization losses through the dielectric glass and air the, the electric loading falls, and the ball will start to be attracted by the annular wall.

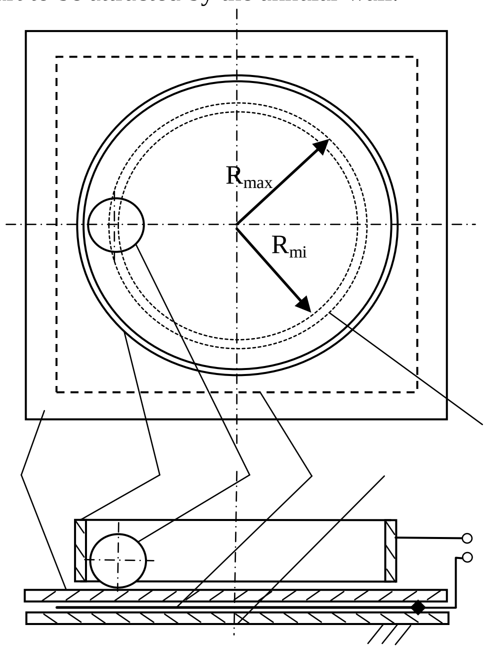

Fig. 1. Components of experimental stand.

The process described above is virtually the way the spherical body would move in the inner perimeter of the upper ring, as shown, contact between the spherical body and dielectric from above 1, and see Fig. 1; the contact between the spherical body and the above dielectric 1 being made on the annular area showed in the same figure. Thus, the spherical body performs a continuous oscillation in this area under the effect of both the Coulomb interaction force and centrifugal force, [2].

When Coulomb force is higher the rolling element moves inside the ring to R_{min}, see Fig. 1. In this process and due to electric polarization losses, the spherical body decreases resulting in both an electrostatic attraction between the metal ring and a decrease of the spherical body load and thus causing an electrostatic attraction between the metal ring and spherical body while the centrifugal force is driven outward, towards the metal ring. Now the spherical body is directed accordingly even slightly hitting the metal ring loaded to its full electric polarization. Obviously the element will now be loaded to the same level of electric polarization which is why the repulsion reaction force occurs again between the metal ring and the spherical body which makes the above mentioned phenomena to resume, [3].

Throughout this route the spherical body rolls over upper dielectric glass. This rolling is basically generated by the interaction between the electrostatic field generated by the spatial capacitor condenser and the distribution of electrical charges on the surface of the rolling element. Unfortunately this phenomenon is currently not precisely elucidated in terms of responsibility for generating the spherical body rolling moment.

II. Experimental Considerations

The motion of approaching to and moving away from metal ring is caused by Coulomb interaction force overlapped with the centrifugal force underwent by the rolling body. It was experimentally proved that this oscillation as against the metal ring occurs by R_{max} to R_{min} radii as shown in Fig. 1; it is noted that both forces show strength variation which causes the rolling of the body in plain, see the bottom of Fig. 1.

The potential of the ring 2 and the ball 3, shown in Fig. 1, are the same in the case when they are both in direct contact, reason for which the electrostatic repulsion reaction pushes the rolling element to the center of the metal ring. Meanwhile, the ball rolls obviously on the upper surface of the dielectric 1, see Fig. 1, while gradually loosing its polarization potential by loosing electric charges through dielectric and air, [4].

During this time the rolling circle guiding the roll motion is becoming shorter and shorter in terms of length by changing the axis of rotation of the rolling body, which reduces the motion speed on the body trajectory. At this moment a return of the ball rotation axis occurs due to electrostatic interaction between the metal ring and rolling body. Since the electric charges on the ball surface are now decreasing ball is attracted to the metal ring.

Moreover by changing the position of the axis of rotation of the ball, the circumference of circle according to which the ball is rolling increases which leads at its turn to an increase in the rolling speed over the inner circumference of the metal ring, and the increase of the centrifugal force. Now both forces are guided toward the metal ring, the ball rolling towards and colliding with the metal ring. Following this contact the electric polarization potential of the ball is restored, the electrostatic repulsion reaction occurs and the latter is now directed towards the inner part of the metal ring, the centrifugal force being probably slightly diminished by the contact with metal ring wall, [5].

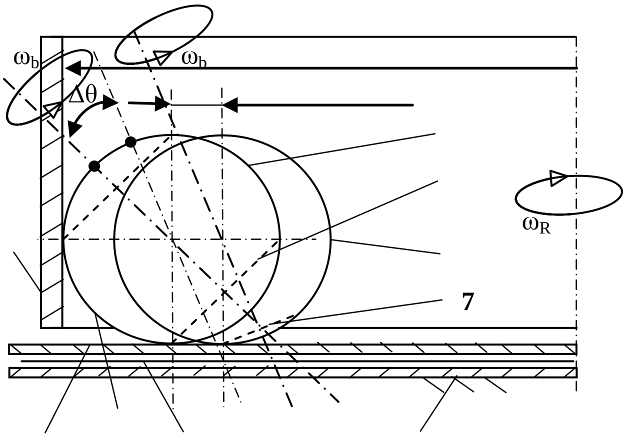

Fig. 2. Nutation of the ball own rotation axis.

According to Fig. 2, one may notice the two limit positions of the ball, the 3a outside position see Fig. 2 also showing the ball position on the trajectory by the inner circumference of the metal ring, representing the maximum radius, R_{max}. The corresponding inner position of the same ball 3b in the Fig. 2, when pushed by electrostatic repulsion reaction gets on the trajectory of the minimum radius, R_{min}, as shown in Fig. 1. Meanwhile the ball is rolling by the inner perimeter of the metal ring ω_R at angular speed, moving away from it at R_{min} and colliding with it at R_{max}, respectively.

The difference between the two radii is equal to the circle arc AB shown in Fig. 2, respectively, and with the segment corresponding to the supporting points of the balls in the extreme points in terms of the distance from the metal ring.

It is assumed that the oscillation of the ball's own rotation axis in the plain of Fig. 2 is performed by a pure rolling without slipping over the upper dielectric 1 shown in Fig. 2. The equality suggested in Fig. 2 regarding the congruency of measures between the arc AB, and the difference between the R_{max} and R_{min} radii results as a first consequence of the rolling without slippage of the ball between these two positions.

Thus one could speak about a combined rolling, one carried in the plain perpendicular on the upper insulator 1 in Fig. 2, which is identical to the figure plain and a second rolling driving the propelling of the ball by the inner circumference of the metal ring, motion carried out through the rolling circle, the circle 5 for the position 3a and the circle 6 for the position 3b as shown in Fig. 2, which was seen above as varying depending on the ball own axis of rotation oscillation. The rolling circle having the maximum diameter for the corresponding position 3a, see Fig. 2, and 3b for the position generating the small rolling circle 7, see Fig. 2.

The observation is valuable and implies the possibility of approximate calculation of both the positions of balls' own axes of rotation and rolling circles of course. This is an important factor in establishing a correlation between the speeds of a rolling body by the inner perimeter and determining roughly the rolling body's own rotation. At the same time this observation provides the opportunity for comparison between the values determined from geometrical reasons and the experimental ones. Obviously the inevitable questions that arise is how the balls' rotation by the metal ring circumference is influenced depending on the diameters of these two elements and whether there is an optimum speed of rotation by the inner perimeter of the metal ring.

The fact that the ball is drawn to and then rejected by the metal ring wall is to some extent explained above, but it is far more difficult to explain which is the factor driving the rolling along the inner perimeter of the metal wall, and which is the phenomenon responsible for the occurrence of ω_b in Fig. 2.

Rolling phenomenon was experimentally proved to be precisely generated by a rolling moment generated in the ball. Therefore, if on the surface of the insulator 1 see Fig. 2 a silicone droplet was poured, for example, and was scattered throughout the metal ring area 6, the above phenomena do not occur anymore.

Therefore the frictional forces between the ball and the upper glass insulator have a clear role in rolling, acting as conditioning factors.

The interaction between the charges accumulated on the ball and the potential of the metal ring should obviously exist; the existence of the plate 4 in Fig. 2 makes the load distribution on the surface of the ball complicated and influence the distribution of charges. Moreover, every ball points during its own rotation and motion by the inner perimeter of the metal ring are generating in terms of charges distribution other charges distribution, [6].

The continuous movement of charges on the surface of the ball generates, perhaps varying strength currents that can interact with the electric field of the spatial capacitor condenser formed by the following: the ring, the upper plate 2, the glass insulator upper glass 1, the lower plate 4 and the lower glass insulator.

The Ball motion itself distorts local distribution of this field. In conclusion the moment generating rolling should appear on the rolling body which is when the frictional forces have a decisive role in this case above.

III. Mathematical Model

Formulating the law of motion for the points on the surface of the rolling body is an important step forward in the study of the interactions between ball surface charges and the electric field generated by the electrical condenser.

Especially when taking into account that a steady point of the ball has the rotation motion around balls' own axis, which coincides with the rotation of the inner perimeter of the metal ring, it is clear that the motion of points on the surface of the ball will generate a continuous reorganization of electric charges on the ball's surface according to laws of electrostatic force.

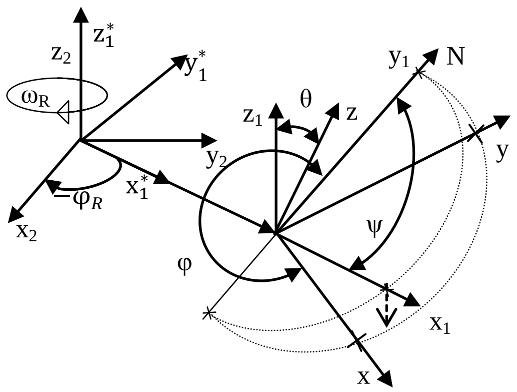

Fig. 3. Adequate systems for the motion of a steady point on the ball surface.

This continuous reorganization of charges on the ball complex moving surface described above generates virtually shifts of charges that can be considered as currents.

Their interaction with the electric field of the electrical condenser might be responsible for the effective propulsion of the ball. Of course the above is an assumption to explain the propulsion phenomenon.

As shown in Fig. 3, there are presented the reference systems proposed to formulate in order the law of motion of a point on the sphere; the system $Ox_2y_2z_2$ which is in the center of the metal ring 2 in Fig. 2, which is a system positioned at an equal distance to the radius of the ball as against the upper glass insulator 1 as shown in Fig. 1 and Fig. 2. That makes that the plain x_2Oy_2 includes the balls' center of gravity during the ball movement. This system is considered fixed, firmly attached to the stand.

The system $Ox_1^*y_1^*z_1^*$ has a rotating axis $Oz_1^* \equiv Oz_2$ and the rotating angular speed φ_R equals ω_R which is the balls' rotation speed inside the metal ring.

The axis Ox_1^* is geared towards and passes permanently through the ball's center of gravity, which is valid in case the latter would rotate by the ring at constant rotational speed which is considered theoretically permissible.

The system $O_1x_1y_1z_1$ originated in the ball's center of gravity and moves with the ball inside the metal ring but its axes remain permanent in parallel with the system $Ox_1^*y_1^*z_1^*$; therefore these two systems rotate in parallel. Compared to the latter system presented above and taking into account the movements made by the rolling body, it is considered useful to approach the issue via the Euler angles, considering that the ball makes its own rotation around its own axis denoted obviously by φ.

Nutation described in the previous paragraphs and caused by centrifuges by electrostatic forces occurs as shown in Fig. 3 in the plain of the axes z_1zx_1, which is a perpendicular to the plain nodes denoted N, [7].

The peculiarity in this case is the fact that at least accepting the hypothesis that there is no movement of precession of the own rotation axis, as shown in Fig. 3, it results a constant precession angle.

These four systems offer the possibility of writing the law of motion as vector for a steady point motion on the surface of the rolling body.

Given the simple geometric constructive elements, the ball's own rotation speed can be determined quite accurately, in other words φ is known. As nutation takes place in the plain of the axes z_1zx_1 it becomes virtually an oscillation of its own rotation axis, the axis tilting from the position of contact of the ball with the wall of the metal ring 2, as shown in Fig. 2, from 45° up to even a 90° angle.

This phenomenon also depends on the constructive geometric factors, and on the voltage used in the experiment.

In conclusion the rotation matrices that ensure smooth conversion from one system to another are slightly simplified in terms of shape.

Homogeneous transformation between the coordinates of the systems $Ox_2y_2z_2$ and $Ox_1^*y_1^*z_1^*$ is given by the formula 1 below.

$$\begin{Bmatrix} x_2 \\ y_2 \\ z_2 \end{Bmatrix} = \begin{Bmatrix} \cos\varphi_R & \sin\varphi_R & 0 \\ -\sin\varphi_R & \cos\varphi_R & 0 \\ 0 & 0 & 1 \end{Bmatrix} \cdot \begin{Bmatrix} x_1^* \\ y_1^* \\ z_1^* \end{Bmatrix} \tag{1}$$

Simplified the above formula becomes:

$$\{x_2 \ y_2 \ z_2\}^T = \{\varphi_R\} \cdot \{x_1 \ y_1 \ z_1\}^T \tag{2}$$

Given these clarifications one could formulate the law of motion of rolling body's gravity center as the vector equation corresponding to the following formula (3).

$$\{\bar{i}_2 \ \bar{j}_2 \ \bar{k}_2\} \cdot \begin{Bmatrix} x_2 \\ y_2 \\ z_2 \end{Bmatrix} = \{\bar{i}_2 \ \bar{j}_2 \ \bar{k}_2\} \cdot \{\varphi_R\} \cdot \begin{Bmatrix} x_1^* \\ y_1^* \\ z_1^* \end{Bmatrix} \tag{3}$$

In the formula 3 above, the coordinates of the balls' gravity center are as follows: $(x_1^* y_1^* z_1^*)$, marked as against the system $Ox_1^*y_1^*z_1^*$.

On the other hand, the steady point on the surface of the sphere will observe a law of motion as against the system $O_1x_1y_1z_1$ given by the formula (4) as follows:

$$\{\bar{i}_1 \ \bar{j}_1 \ \bar{k}_1\} \cdot \begin{Bmatrix} x_1 \\ y_1 \\ z_1 \end{Bmatrix} = \{\bar{i}_1 \ \bar{j}_1 \ \bar{k}_1\} \cdot \{A_\theta\} \cdot \{A_\varphi\} \cdot \{A_\varphi\} \cdot \begin{Bmatrix} x \\ y \\ z \end{Bmatrix} \tag{4}$$

In the formula (3) the right side matrices denoted by "$\{A_{\theta,\varphi,\varphi}\}$" are the Euler angles rotation matrices and for our particular case it is the precession rotation matrix, where φ angle is a 90° constant.

The transformation between the systems $O_1x_1y_1z_1$ and $Ox_2y_2z_2$, given the fact that the systems $O_1x_1y_1z_1$ and $Ox_1^*y_1^*z_1^*$ are equivalent, having parallel axes is as follows:

$$\{\bar{i}_2 \ \bar{j}_2 \ \bar{k}_2\}^T = \{\varphi_R\} \cdot \{\bar{i}_1 \ \bar{j}_1 \ \bar{k}_1\}^T \tag{5}$$

This being clarified and according to the formulas 4 and 3, the laws of motion is formulated as a vector, for a fixed point on the ball surface.

IV. CONCLUSION

Tilting axis of rotation by shifting its direction requires the changing of the constructive geometry of the rotor and motion collector in order to reduce friction and ensure the continuous propulsion.

The presence of currents on the ball surface through the reorganization of charges during rotation of the ball may generate the factor that propels the ball or unbalanced electrostatic pressure on the ball surface might be liable for this process, or ultimately these varying currents could generate (through Lorentz effect) the propulsion moment of the rotating body's own rotational axis.

Balls' rotating and propulsion are performed at ball's level, if annular area between R_{max} and R_{min} radii in Fig. 2 is slightly greased the rolling does not occur. The friction coefficient between the glass insulator and the ball is responsible for rolling; in conclusion the rotation moment occurs at the level of rolling body.

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