Building and Studying an Electrostatic Motor

Mahsa Geramimanesh
Ariaian Young Innovative Minds Institute, AYIMI, Tehran, Iran.

E-mail: info@ayimi.org

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Abstract

For building a simple electrostatic motor which its propulsion is based on corona discharge, we used a rotor with 4 electrodes with sharp blades on them. By attaching them to the Van de Graaff and a power supply, the rotor could rotate in its place. To optimize the setup, the effect of different parameters such as the angle of the electrodes, diameter of the rotor, number of the electrodes or the distance between the electrodes have been investigated and the rotor reaches the maximum speed at a fixed input voltage.

Keywords: Electrostatic motor, Corona discharge, Electrodes, Rotor.

Resumen

Para construir un motor electrostático simple cuya propulsión se basa en la descarga de corona, usamos un rotor con 4 electrodos con cuchillas afiladas. Al conectarlos al Van de Graaff y a una fuente de alimentación, el rotor podría girar en su lugar. Para optimizar la configuración, se ha investigado el efecto de diferentes parámetros como el ángulo de los electrodos, el diámetro del rotor, el número de electrodos o la distancia entre los electrodos y el rotor alcanza la velocidad máxima a un voltaje de entrada fijo.

Palabras clave: Motor electrostático, Descarga corona, Electrodos, Rotor.

I. INTRODUCTION

Despite the multitude of patents on electrostatic engines, researchers recognize that data on the rotation of an engine rotor and its interaction with a “stator” are not yet sufficient for rapid development in this area [1].

We have two types of motors, first the electromagnetic ones, which the rotation of the rotor is based on motor’s magnetic field and electric current which nowadays they use this types of motors in industry much more than the other type which is the electrostatic motors. Rotation of the electrostatic motors, is just based on electric current.

The first electric motor invented was a corona-based electrostatic motor (ESM) and it was about 100 years before the conventional magnetic motor was conceived. The ESM is characterized by simplicity of construction without winding and lightweight. The influence of corona electrodes' configurations on output torque was experimentally investigated in ESM with multi-blade electrodes. The motor fabricated consisted of a 100 mm diameter hollow cylindrical rotor made of acrylic resin as a dielectric and several knife-blade corona electrodes with 100 mm length [2]. We built an electrostatic motor which with a fixed input voltage, it will reach the maximum angular velocity which is based on corona discharge and causes the air molecule to be ionized. The same charges of the electrode, will accumulate on the rotor and with the attraction of the opposite charge on the next electrode and the repulsion of the similar charge, the rotor will rotate.

II. EXPERIMENTAL SETUP

Our experimental setup consists a Van de Graaff, power supply, four electrodes with sharp blades on them, and a rotor which itself is a plastic cylinder that has an aluminum shield inside it (Fig.1).

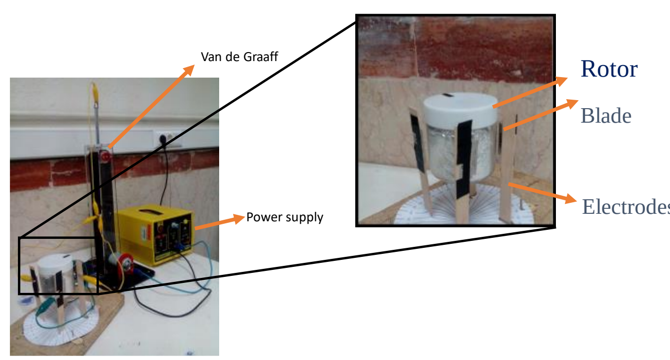

FIGURE 1. Corona Motor Experimental Setup.

The electric field doesn’t penetrate in the metal area so in the fixed voltage, larger angular velocity will be observed because it’s like we are decreasing the distance between two electrodes. When the electrodes are attached to the opposite charges of the Van de Graaff and Van de Graaff to the power supply, the rotor will start to rotate. Two electrodes in front of each other will gain similar charges which means every electrode next to each other have opposite charges with each other. These blades with opposite charges on them and the electric field around the charges, due to the corona discharge, will cause the air molecules to ionized and the both charges in one molecule will be separated [3].

The similar charge with the charge of the blade will accumulate on the edge of the rotor, and the repulsion of the electrode will cause the charges to repulse and this cause the rotor to rotate and also the next electrode which has an opposite charge, will attract the charges on the electrode and after it reaches to the next electrode the charges will be absorbed by the electrode itself and the cycle will happen again and again and it will cause the rotation of the motor. Each single charge which is placed on the edge of the rotor which is dielectric and the conductive shield behind it, have two different forces applying to it which is the repulsion of the same charge and the attraction of the opposite charge.

III. METHODS AND THEORY

The magnitude of the force, depends on the relaxation time of the system and how much it takes for the charge on the rotor's surface to dissipate. So, the static net charge will be dissipating on the rotor based on this equation which it shows for example if the moisture of the environment increases, it will cause the relaxation time to decrease which means that the charges will be dissipated sooner, and the phenomenon can't be observed (Eqs. 1 and 2).

$$Q = Q_0 \times e^{-\frac{t}{\tau}} , \tag{1}$$

$$\tau = \varepsilon\rho \, . \tag{2}$$

According to Newton's rotational second law (Eq. 3) the angular velocity is a function of time which depends on "T" as the electric force applying to the rotor, "b" as the friction coefficient and the "I" as the momentum of inertia of the system (Eq. 4).

$$I\frac{d\omega}{dt} = T - b\omega \, , \tag{3}$$

$$\omega = \frac{T}{b}(1 - e^{\frac{-b}{I}t}) \, . \tag{4}$$

If the time of the experiment goes to infinity, the maximum angular velocity is found which is not depended on the momentum of the inertia of the system. This graph shows that as we decrease or increase the momentum of inertia, the angular velocity will change as a function of the time and the slope of the graph at the end shows that it reaches the maximum angular velocity which has a constant magnitude (Fig. 2).

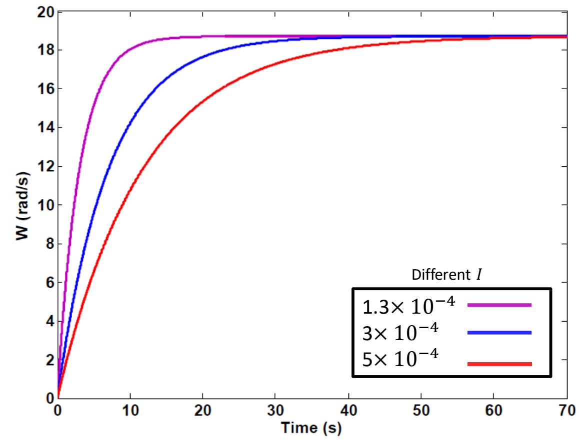

FIGURE 2. Angular Velocity versus time in experiment.

When time reaches to the infinite, $e^{\frac{-b}{i}-\infty} \approx 0$, the maximum angular velocity will be as equation (5).

$$\omega_{max} = \frac{T}{b} \, . \tag{5}$$

For finding the coefficient of the friction we let the motor reach its maximum angular velocity and then the power supply is turned off which means that the only force applied to the rotor will be friction. By equations (6 - 8) the slope of the angular velocity versus time is found (Fig. 3).

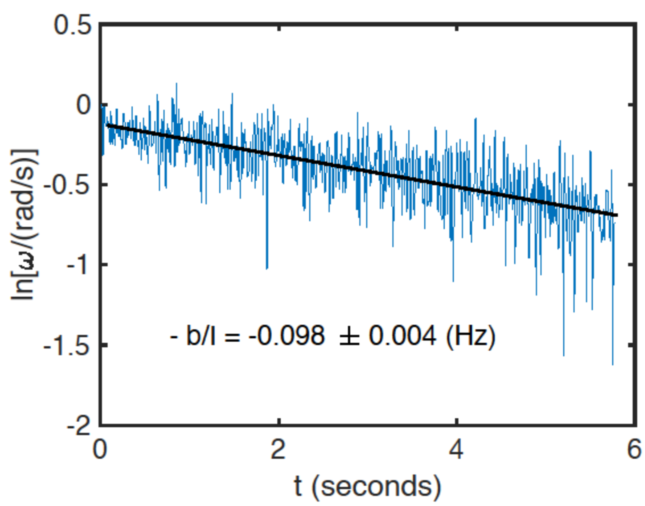

FIGURE 3. Logarithmic trend of Angular Velocity versus time.

$$I\frac{d\omega}{dt} = -b\omega \, , \tag{6}$$

$$\ln\frac{\omega}{\omega_0} = -\frac{b}{I}(t - 0) \, , \tag{7}$$

$$\ln\left(1 - \frac{b}{T}\omega\right) = -\frac{b}{I}t \, , \tag{8}$$

$$-\frac{b}{I} = 0.3,$$

$$\alpha = 0.287.$$

By calculating the momentum of inertia in this system with both a disk and a cylinder, the coefficient of friction and then the maximum electric force due to the maximum angular velocity could be obtained theoretically and experimentally (Eqs. 9-12) (Fig. 4).

$$Idisk: \frac{1}{2} m_d r^2 \,, \tag{9}$$

$$Icylinder: m_c r^2 \,, \tag{10}$$

$$I_{total} = I_d + I_c = 5.12 \times 10^{-5} kgm^2 \,, \tag{11}$$

$$\omega_{max} = \frac{T}{b} \,. \tag{12}$$

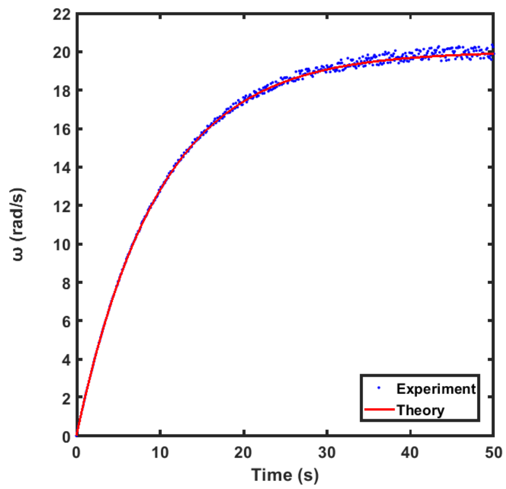

FIGURE 4. Comparing angular velocity versus time both theoretically and experimentally.

The efficiency of the whole system consists of the efficiency of the rotor and the Van de Graaff (Eq.13).

$$\text{Efficiency}=\frac{torqe \times \omega_{max}}{VI} \times 100 = \frac{b\omega^2}{VI} \,, \tag{13}$$
$$= \frac{4 \times 10^{-5} \times 20^2}{12 \times 0.5} \times 100 = 0.26\%.$$

To increase the whole efficiency and the maximum angular velocity with the same input voltage, the effect of different parameters and how each of them can change the angular velocity are investigated.

IV. EXPERIMENTS

The first parameter was the angle of electrodes which in our experiment the best angle is 40 degrees which can give us the most angular velocity. It is a critical point because less or more than this angle, the angular velocity will decrease (Fig.5).

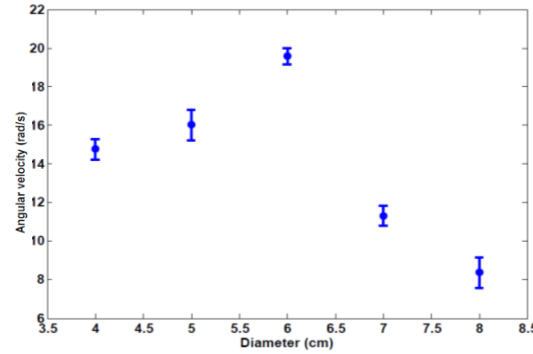

FIGURE 5. Angular Velocity versus angle of electrodes.

The diameter of the rotor as the second parameter has a limitation and by decreasing or increasing the diameter much more than the certain point the angular velocity will decrease (Fig. 6).

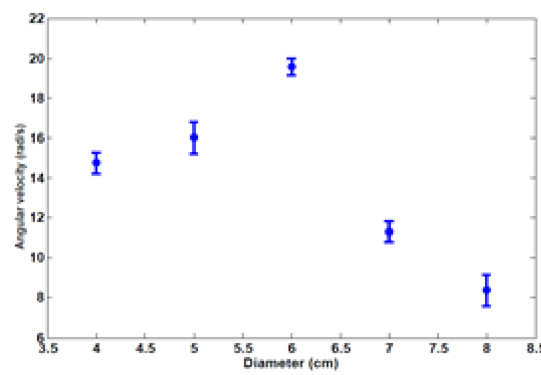

FIGURE 6. Angular Velocity versus diameter of rotor.

The next parameter is the number of electrodes which by increasing, the force that applies to rotor will increase too but we have a limitation for the number of electrodes.

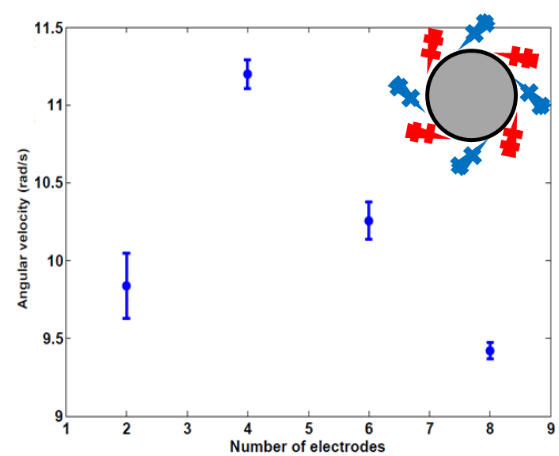

FIGURE 7. Angular Velocity versus the number of electrodes.

As we increase the number of them, the charges place on each of them will be absorbed by the next electrode which means the total net force applying to the rotor is decreasing due to the dissipation of the charges between the blades themselves. So increasing the number of electrodes, will cause the ionized atoms to be collected by the neighbor electrodes (Fig. 7).

Also, for finding the best distance of the electrodes, as one of the other parameters, with rotor the distance is varied and we observed that by increasing the distance, the force applies to the system is decreasing but we also have a minimum distance which this phenomenon could be observed. As we decrease the distance too much, the corona discharge cannot be seen anymore and what we observe is sparks of a discharge instead of corona discharge, it means in a quick time a conductive path will be made between blades and the rotor which will be dissipate the charges (Fig. 8).

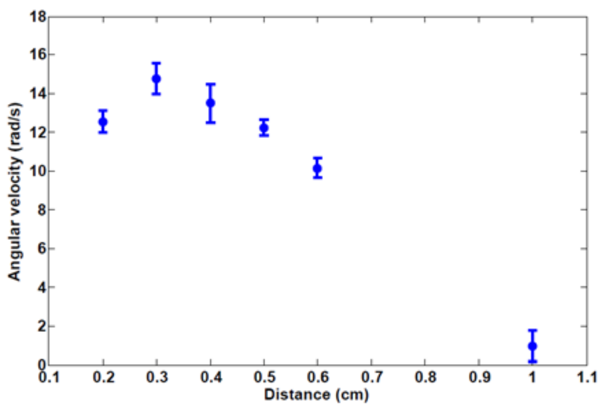

FIGURE 8. Angular Velocity versus the distance of electrodes.

V. CONCLUSIONS

Based on corona discharge, we used a rotor with 4 electrodes with sharp blades on them. For optimizing the setup, the effect of different parameters such as the angle of the electrodes, diameter of the rotor, number of the electrodes or the distance between the electrodes have been examined and the rotor reaches the maximum speed at a fixed input voltage. The critical angle of electrodes in this research is 40 degrees which less or more than this angle, the angular velocity will decrease.

By increasing the number of the electrodes, the total net force applying to the rotor is decreasing and the motor speed increases with the increase of the applied voltage. Also by increasing the distance, the force applies to the system is decreasing but we also have a minimum distance which less than this, the corona discharge cannot be seen anymore and what we observe is sparks of a discharge instead of corona discharge. By optimizing the setup due to the investigations in this experimental research, the angular velocity has been increased and the efficiency of our new setup was 2.46 times greater.

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