BUILDING AN ELECTROSTATIC MOTOR

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ABSTRACT

In this project, the motor was built to create torque using the corona discharge phenomena. The DC excitation was replaced with electrostatic generators. Effect of some parameters (e.g. geometrical configurations and input voltage of the electrodes) were investigated. The fabrication was somehow done that with a fixed input voltage, the maximum rotation speed of 2150 rpm was attained.

1 Introduction

Electrostatic motors are usually used in special environments. Their non-magnetic fabrication and structure simplicity make them have great potential for limited, magnetic or other environments that electromagnetic motors' operation could be disturbed [1].

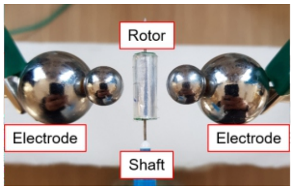
On the other hand, corona motors work with low repulsive forces and the smaller their dimensions are, the higher is their force per volume and thus, the higher would be the output per unit weight [2]. Also, their insensitivity to material properties and their ability to produce torque with DC excitation makes them a possible interest in miniature applications [3].

In previous works by M. Hattori, et al, J. D. N. Van wyk and G. J. Kühn, M. K. Bologa, et al and Mazen Abdel-Salam, et al, the voltage on the electrodes was supplied by high voltage sources [2,4,5,6]. In this case, an exchange for a high voltage source and investigation of some effective parameters on the rotation is desired.

2 Materials and Methods

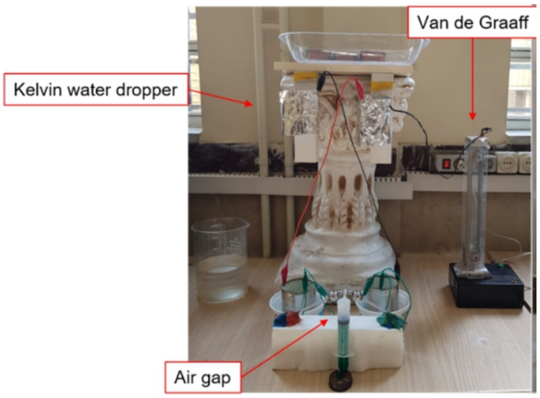
For experiment, a hollow cylindrical rotor made of polyethylene with aluminum coating beneath was used. The inner lining is used for sake of obtaining stable output. It has a constant potential. As a result, it plays the role of an opposed electrode against the corona electrodes. Thus, corona occurs in stable position.

The rotor was placed between two metallic electrodes and the electrodes were connected to the containers of Kelvin water dropper. The Kelvin water dropper is neutral after each spark; so, a Van de Graaff was continuously supplying it with charge. A syringe was used as the shaft so that the height of the rotor could change. Also, the electrodes were placed on EPS because of the high resistivity and the fact that the air gap spacing could change (Fig.1).



(a)

(b)



(c)

Fig. 1: a) (a) Placing the rotor between the electrodes ; b) the rotor; c) Experimental setup

For collecting data, a noticeable sign on the rotor was marked on the rotor. The rotor and a stopwatch were both placed in one frame and the rotation was recorded using a camera with the shutter speed of 240 fps. For sake of the precision, the recordings' speed was reduced one more time, then, the analyzing process took place.

3 Theory

There are two perspectives to explain the rotor's rotation, one of them is based on the ionization of the molecules and the other one is conferring to the charge dissipation. The explanation would be as following.

The voltage on the electrodes increases until the air in the air gap ionizes, then a charge which is the same polarity as the electrode, will be deposited on the rotor. If the rotor is slightly disturbed, a couple of charges will act on it, which according to Coulomb's law, causes the rotation, carrying the charge with it [4]. By reaching the opposite electrode, the charges would be neutralized by the ionized air gap of the other electrode with the opposite polarity. If this process carries on continuously, the rotor will rotate.

Relaxing time is another explanation to complete the rotor's rotation clarification. This term refers to the time that takes the charges to dissipate in the surrounding air. The time interval for charge dissipation could be calculated using the following formulas (Eq.1 and 2)

$$\Delta t = Q_0 e^{\frac{-t}{\tau}} \tag{1}$$

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

where Q_0 is the initial charge placed on the surface, ε is the electrical resistivity and ρ the dielectric constant of the surface material.

To have a prediction over the motion of the rotor, the torque equation could be used to obtain a foresee over the rotation speed per time (Eq. 3), where *C* is a constant and depends only on the mechanical configurations and environmental effects.

$$\tau = c\omega \tag{3}$$

By simplifying equations (4-8) we will find the angular velocity of the rotor (Eq.9) , where *I* is the length of the rotor.

$$\tau = \int_0^{\omega} \frac{d\omega}{F_e - c\omega} = \int_0^{t} \frac{dt}{I} \tag{4}$$

$$\int_0^{\omega} \frac{-1}{c} ln(F_e - c\omega) = \frac{t}{I} \tag{5}$$

$$\frac{-1}{c}(ln(F_e - c\omega) - ln(F_e)) = \frac{t}{I} \tag{6}$$

$$e^{ln\left(\frac{F_e - c\omega}{Fe}\right)} = e^{\frac{-ct}{I}} \tag{7}$$

$$\frac{F_e - c\omega}{F_e} = e \tag{8}$$

$$\omega = \frac{F_e}{c}(1 - e^{\frac{-ct}{I}}) \tag{9}$$

Using MATLAB, the rotation of the rotor per time based on equation (9) can be observed.

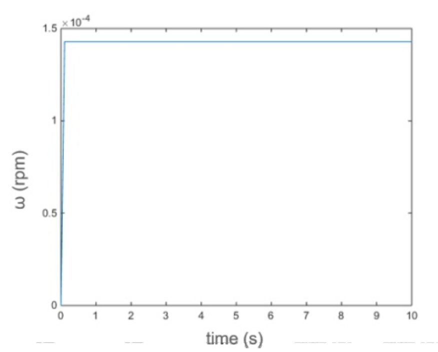


Fig. 2: Rotation of the rotor vs time

4 Experiment

The effects of input voltage of the electrodes, air gap spacing, lining of the inner surface of the rotor and the material of rotor's surface are investigated (table 1). The material of rotor is affected by the relaxation time of rotor's surface which could be calculated using the equation (1), where ε_0 ($= 8.85 \times 10^{-14}\, F/cm$) is the electrical resistivity of vacuum air.

Table 1: Rotor's properties and relaxation time

Surface Material	Electrical Resistivity ε ($\times \varepsilon_0$)	Dielectric Constant ρ ($Ohm.m$)	τ ($F.Ohm$)	Δt (s)
HDPE (High Density Polyethylene)	2.30	16~18 $\times 10^{13}$	3.2568~3.6639 $\times 10^{3}$	149.38
PVC (Polyvinyl chloride)	40	10~16 $\times 10^{13}$	3.54~5.664 $\times 10^{4}$	149.38

The time interval of charge dissipation is bigger than duration of one rotation. Thus, the charge dissipation theory could be neglected. As a result, the only effect of the surface material is caused by its changes on the inertia.

5 Results and Discussion

According to the experiments, based on the theory, the data are analyzed. The lesser the air gap spacing causes, the stronger the electric field thus, the rotational speed would increase (Fig. 3). The input voltage has a direct influence on the rotation. The rotor's inner lining plays the role of an opposed electrode against the electrodes. So, the electric field strength increases which makes the rotation speed increase too (Fig.4). The maximum speed of 2150 rpm was attained in the air gap of 0.6 cm using the rotor with the height of 12mm.

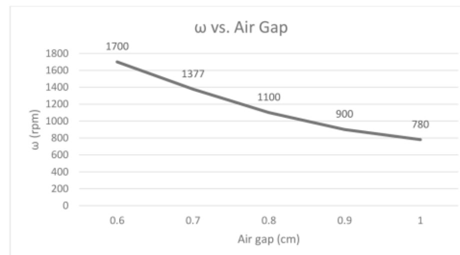


Fig.3: The effect of air gap spacing between the electrodes on the rotational speed

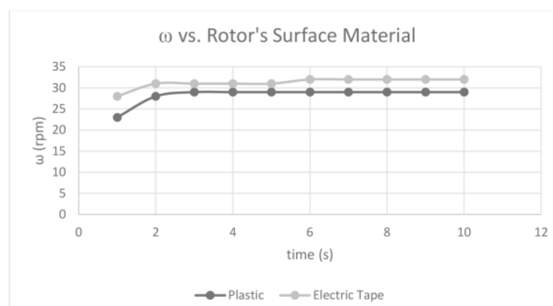


Fig. 4: The effect of rotor's surface material on the rotational speed

References

[1] Yamamoto, A., (2010), "Applications of Electrostatic Actuators within Special Environments". In Next -Generation Actuators Leading Breakthroughs (pp. 363 -373). Springer, London.

[2] Hattori, M., Asano, K. and Higashiyama, Y., (1992), "The fundamental characteristics of a cylindrical corona motor with multi-blade electrodes". Journal of electrostatics, 27(3), pp.223-235.

[3] Krein, P.T., (1995), "Analysis of corona motors and micromotors by means of effective gap conductivity". IEEE transactions on industry applications, 31(4), pp.752-760.

[4] Van Wyk, J.D.N. and Kühn, G.J., (1961), "A Novel Electrostatic Machine : the Corona Motor". Nature, 192(4803), p.649.

[5] Bologa, M.K., Grosu, F.P., Shkilev, V.D., Kozhevnikov, I.V. and Polikarpov, A.A., (2015), "A corona-discharge dipole engine". Surface Engineering and Applied Electrochemistry, 51(4), pp.401-405.

[6] Abdel-Salam, M., Ahmed, A., Ziedan, H. and Diab, F., ANALYSIS OF CORONA DISCHARGE IN ELECTROSTATIC MOTOR GAPS.