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Some theoretical and experimental aspects of a new electrodynamic separator

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1. INTRODUCTION

Commercial equipments based on the DC corona discharge are widely used in separation and cleaning of agricultural seeds.
All the electrostatic methods have the following characteristics:

(i) high DC voltages,
(ii) very low corona currents,
(iii) different electric conductivity of components,
(iv) small size and mass of the particles.

Because of this properties the output mass current of electrostatic separator is low.
In what follows, we shall show that may be achieved electrodynamic separator without this disadvantage.
The base of AC separator is a physical effect, which states that in a field of AC corona discharge an attractive or repulsive force acts on a particle of some materials. The electric force is resulted by the transient dielectric behavior of material particle. It is well known that in the case of impulse like signal the corona voltage can be extremely increased over corona onset voltage without electrical breakdown. For that very reason the corona current, the electric force and the mass flow trough the separator may be increased.

2. PHYSICAL BACKGROUND OF ELECTRODYNAMIC SEPARATION

In the following section we shall give a simplified physical theory of the electrodynamic separation. We begin with a discussion of the corona charging of a seed (see Figure 1.). The corona discharge electrode is supplied by an asymmetric AC voltage U, which is shown in Figure 2. It is important to note that the voltage in second half period is lower than the corona onset voltage U_0.

It is well known that the permittivity of an organic material is a function of the time. We assume that this function is described by the Debay equation

$$\varepsilon(t) = \varepsilon_\infty + (\varepsilon_0 - \varepsilon_\infty)\left(1 - e^{-\frac{t}{T}}\right), \qquad (1)$$

where ε_0 is the static, ε_∞ is the high frequency permittivity and T is the so called relaxation time.

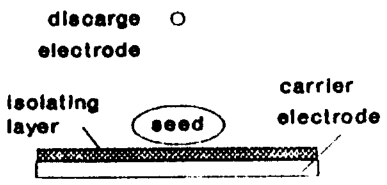

Figure 1.

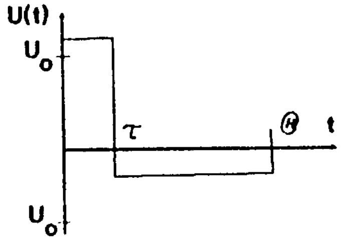

Figure 2.

Since the seed dimension in our experimental apparatus is small compared to the characteristic length of the electric field non-uniformities near the carrier electrode. We can assume that the electric field is uniform trough the seed. With this assumption it is easy to see that the charging process of a seed may be described by the equivalent circuit, with is shown in Figure 3.

The components of the equivalent circuit are

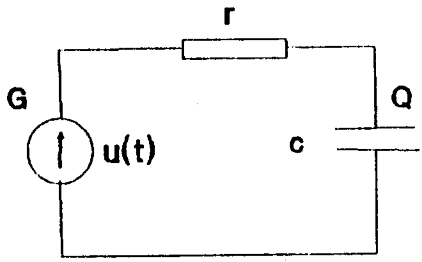

Figure 3.

$$r = \frac{k}{2 \gamma R^2 \pi}, \qquad (2)$$

$$c = \frac{\varepsilon_0 2 \pi R^2}{k}, \qquad (3)$$

where R is the average dimension of the seed, γ is the specific conductivity of charged air, ε_0 is the permittivity of free space and k is the polarization factor of the seed. While the source field strength of the generator G is the following

$$u(t) = \frac{\varepsilon_r - 1}{\varepsilon_r + 2} E \quad , \qquad (4)$$

where E is the electrical field strength of the external field trough the seed and ε_r is the relative permittivity of the seed.

Let us apply the second Kirhhoff's equation for the circuit we get the differential equation

$$r \frac{dQ}{dt} + c^{-1} Q = u(t) \qquad (5)$$

for the charge of the seed.

If the space charge density is not too high, then u(t) has same mathematical form as U (see Fig. 2.).

Let the time of the first half period τ be small, then from (5) we get

$$Q(t) = E_o(1- e^{- t/T}) \; [\frac{\varepsilon_{r\infty} - 1}{\varepsilon_{r\infty} + 2} \tau + $$

$$+ \frac{T_1 (\varepsilon_{r\infty} + 2)^2 - 3(\varepsilon_{r\infty} - 2)T_1 - 3T_1}{T \, T_1(\varepsilon_{r\infty} + 2)} \tau^2] \; ; \; 0 \le t \le \tau, \qquad (6)$$

where E_o is the field strength of external field at the seed during the first half period and T_1 is the time constant of field charging

$$T_1 = r\,c\,. \qquad (7)$$

In the following we shall turn our attention to the discharge process of a seed.
The discharging process can be investigated by the equivalent circuit shown in Figure 4., where r_r is the reduced electric resistance formed from the seed, junction and the carrier layer.
It is easy to see from the Fig. 4. that the charge of the seed can be described by the function

$$Q_d(t) = Q_0\, e^{-t/T_d} \quad ; \tau \le t \le \Theta \,, \qquad (8)$$

where Q_0 is evaluated by (6) with inserting $t = \tau$ and the time constant of discharge process T_d is

$$T_d = r_r\, c\,. \qquad (9)$$

It is well known that the instantaneous force F acts on a charged particle in an electric field may be computed by the equation

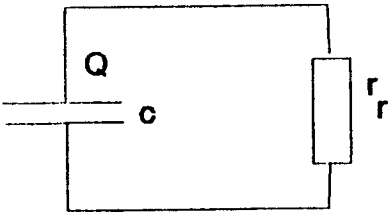

Figure 4.

$$F = Q\,E\,. \qquad (10)$$

Let us apply this equation to a seed and evaluate the average force on a period of the supply voltage. With the symbols of Fig. 2. we can write

$$\hat{F} = \frac{1}{\Theta} \int_0^{\Theta} Q(t)\, E(t)\, dt = \frac{1}{\Theta} \Big[\int_0^{\tau} Q(t)\, E(t)\, dt \; +$$

$$+ \int_{\tau}^{\Theta} Q(t)\, E(t)\, dt \Big]\,. \qquad (11)$$

After some algebra we get

$$\hat{F} = \frac{1}{\Theta}\, \hat{Q}_{ch} \int_0^{\tau} E(t)\, dt + \frac{1}{\Theta}\, \hat{Q}_d \int_{\tau}^{\Theta} E(t)\, dt\,, \qquad (12)$$

where $\hat{Q}_{ch}$, $\hat{Q}_d$ are the average charges in charging and discharging sequence. Since we use alternating current to supply the charge electrode, thus

$$\int_0^{\tau} E(t)\,dt = -\int_{\tau}^{\Theta} E(t)\,dt \quad . \tag{13}$$

From above equations we get

$$\hat{F} = \frac{1}{\Theta}(\hat{Q}_{ch} - \hat{Q}_d)\int_0^{\tau} E(t)\,dt \quad . \tag{14}$$

From this result follows:

(i) in a field of AC corona discharge an average attractive ($\hat{Q}_{ch} < \hat{Q}_d$) or repulsive ($\hat{Q}_{ch} > \hat{Q}_d$) force acts on a particle of some mixture;

(ii) the electric force is resulted by the transient dielectric behavior of the particle.

3. EXPERIMENTAL APPARATUS

The main parts of the experimental apparatus are as follows:

(i) mechanical part with carrier rotor, vibratory feeder, splitter and collecting bin;

(ii) electrical part with corona electrode, high voltage AC power supply, discharging brush and DC driving motor with PWM controller.

The simplified scheme of the mechanical part is shown in Figure 5. The vibratory feeder (a) is positioned to feed the mixture to the top off carrier rotor (b). The grounded rotor is coated by a thin isolating layer. The splitter (c) serves to deflect the particle into a cell of the collecting bin (d).

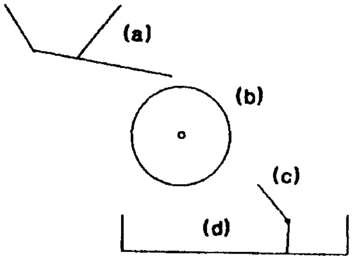

Figure 5.

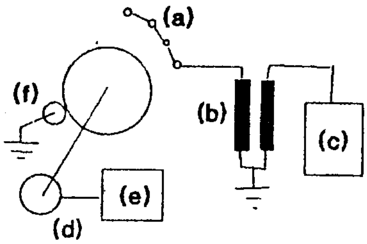

Figure 6.

The schematic diagram of the electrical part of the experimental apparatus is shown in Figure 6.

The corona discharge electrode (a) connected to the secondary coil of a transformer (b). The primary coil of transformer is supplied

by an AC power supply (c). The rotor is driven by an DC motor (d). The speed of rotation is varied by a PWM controller (e). The grounded discharge brush (g) neutralizes the surface of the rotor.
The rotor has a diameter of 160 mm. The speed of rotation is altered in the range from 10 to 60 revolutions per minute. The corona electrode connected to a 15 to 40 kV source of alternating current potential. The frequency of the high voltage power supply is varied in the range from 100 Hz to 1 kHz.

4. RESULTS

We have favorable results in the case of many agricultural materials.
Some results of several tests for seed separation using the electrodynamic separator are shown in Table 1. The fraction of a mixture Q is denoted by A, B, C (see Fig. 7.). The symbol S in Table 1. denotes the mixture of sunflower seed and sclerotium. This are the x and y components of the input material S.
The second investigated material is denoted by the symbol K. The x and y components of K are carthamus tinctorius (L) seed and sclerotium.

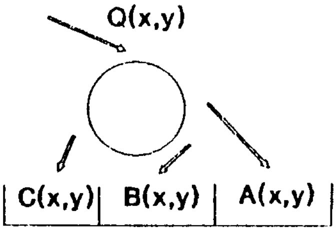

Figure 7.

Table 1.

Characteristics		Input materials and it's fractions							
		S				K			
		Q	A	B	C	Q	A	B	C
Mass distribution of components (%)	x	92,33	85,06	98,90	99,67	73,57	49,46	94,55	99,40
	y	7,67	14,94	1,10	0,33	26,43	50,54	5,45	0,60
Output mass of components (%)	x	100	45,61	14,03	40,37	100,0	34,22	10,70	55,08
	y	100,0	96,53	1,87	1,06	100,0	97,36	1,72	0,92

In the experiments the carrier rotor had a wide of 110 mm. The average input mass current was 500 g per minute and the electric power demand was about 60 W.

5. ACKNOWLEDGMENT

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