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Modelling and Analysis of the Electric Field in a Chamber for Pre-Sowing Electrical Treatment of Seeds of Field Crops

Kiril Sirakov

Department of Electrical Power Engineering, University of Rousse “Angel Kanchev”, 7017 Rousse, Bulgaria,
e-mail: csirakov@uni-ruse.bg

GOAL OF THE STUDY

For the purpose of improving the yields of agricultural crops, various traditional practices, such as for triticale [1,2], cotton [3,4] and non-traditional practices are used [5,6,7]. A comparatively new trend in this respect is the pre-sowing treatment of seeds in different kinds of physical fields.

The analysis of the unconventional ways for increasing the yields of agricultural crops reveals the use of magnetic [8,9], electrical and electromagnetic fields [10,11].

The space between the electrodes of the device is non-uniform since the inter-electrode space of the pre-sowing electromagnetic treatment device is occupied by grain piles. They consist of seeds and air in between, as well as air in the free space, unoccupied by the grain piles.

The purpose of the study is to create and study a computer model of the electric field arising in the device for pre-sowing electrical treatment of field seeds.

METHODOLOGY OF THE INVESTIGATION

The device [13] for pre-sowing electromagnetic treatment of seeds of cereal grains (Fig.1) consists of a metal screw and shaft representing the active electrode, and a metal casing shaft – the inactive electrode (with internal dielectric coating of Hostaphan) insulated from the screw.

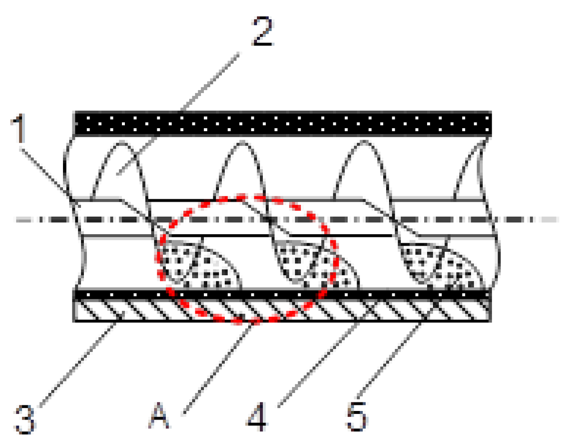

Fig.1. Device for pre-sowing electromagnetic treatment of seed material: 1 – shaft; 2 – metal screw; 3 – metal casing; 4 – dielectric coating; 5 – seed material

From Fig.1 it can be concluded that the medium between the electrodes mentioned above is non-uniform. The inter-electrode space of the device for pre-sowing electromagnetic treatment is filled with grain piles consisting of seeds with air in between, as well as air in the unoccupied, free from grain piles, space.

The above described, complex in design, electrodes, and the non-uniformity of the dielectric space between them make the task of analytical calculation of the electric field of the device extremely difficult and involving many assumptions. All this leads to inaccuracies that affect the quality of calculations of the field.

The software product Finite Element Method Magnetics (FEMM) [14,15] was selected to create a computer model of the electric field arising in the device. As the name of the product suggests, first a network of finite elements is built, and then the space occupied by the field is broken down, with the help of straight and curved lines, to separate parts that have sufficiently small yet finite dimensions. These parts are known as finite elements [15].

The analysis reveals that the main advantage of the software product FEMM [16,17] is that with its help it is possible to build computer models of devices with actual dimensions, which fully resolves the issue of development of expensive and complex models.

To achieve the purpose, the device [13] "is filled" with grain piles located in front of each thread in the direction of movement of seeds. Once the actual geometrical dimensions of the device are drawn, for each element of the model (steel, air, seeds and Hostaphan) its absolute permittivity ε_{rc} is determined. Steel and air are included in the product library with their permittivity values. Since seeds and Hostaphan are not present in the library, their dielectric permittivity values are input manually, considering that according to [15] for maize seed it is ε_{rc} = (6,4...6,9), and according to [18] for Hostaphan it is ε_{rc} = 2.

The analysis of the obtained models revealed that the nature of the field remained unchanged. Therefore, only one model of each the voltage and the field strength between the two electrodes is discussed below. According to [13], the voltage supplied to the active electrode of the device is 1,6 kV, while the voltage supplied to the inactive electrode (the screw device metal casing) is set to 0 kV. The specified voltage value of 1,6 kV is adopted based on the fact that after many years of research it is proven to have contributed to the greatest extent for the efficiency of the pre-sowing electromagnetic treatment of maize and wheat seeds.

As specified in [19], the productivity of the electromagnetic treatment of seeds is determined not only by the applied voltage and the resting time of the seeds into the active zone of the chamber but also by the level of occupancy of the treatment device. In [19,20] it is reported that in order to allow seed sprouts to change their position relative to the equipotential lines and lines of force of the field it is necessary that the so-called “grain pile” is formed in the inter-electrode space and that it occupies about 30% of that space. The analysis of the location of an individual seed seen in X-ray images [20] shows that during the pre-sowing treatment it changes its position, and thus the position of the shoot, relative to the electric field. In this way an effective impact of the field is ensured upon the individual seed and its living part – the sprout.

MAIN RESULTS FROM THE STUDY

Fig.2 represent the images obtained from the computer modelling of the electric field of the device when empty of seeds. Image analysis shows that in the airspace, in the middle of the distance between two adjacent screw tips, the equipotential lines are almost parallel to the shaft and the surrounding metal body. As you approach the surface of the screw, the equipotential lines are distorted and tend to copy its shape.

After the model of the field is built and the scale is repeatedly increased, in the programming environment FEMM are successfully obtained the equipotential lines of the filed particularly in the area below the vertex of the screw. They are represented in Fig.3.

From Fig.3 it can be found that in the area around the tip of the screw the unevenness of the electric field is greatest. This gives reason to assume that in this area the field intensity is greatest. In the areas near the surface of the screw, the equipotential lines are distorted and tend to copy its shape. The distortion of the electric field when filling the device with seeds, in the form of grain pile, must be investigated.

Fig.4 shows the resulting image of the performed computer modelling of the electric field of the device when full of seeds forming a grain pile.

In the left part of Fig.4 the colour backgrounds show the values of electric field strength for the different areas of the inter-electrode space. For instance, for the area surrounding the shaft (shown in blue) the field strength value is about 0 V/m, and for the area around the vertex of the screw (shown in pink) it reaches up to 50 000 V/m.

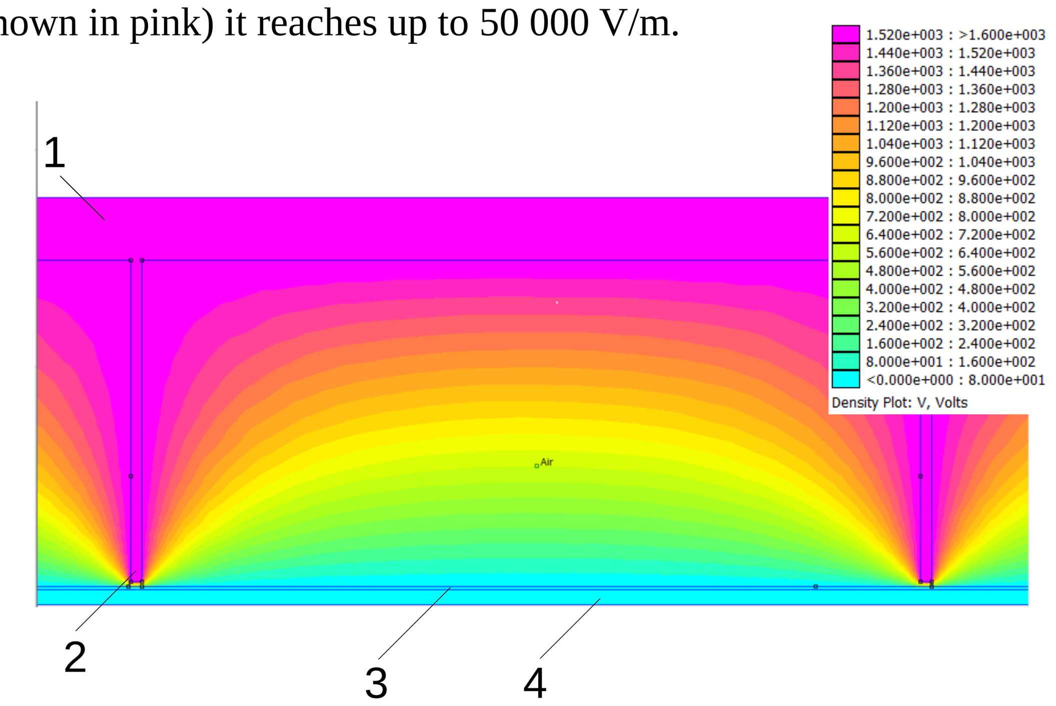

Fig.2. Computer model of the equipotential lines of the electric field of the treatment device with no seeds in it: 1 – shaft; 2 – vertex of screw; 3 – Hostaphan; 4 – metal casing; 5 – equipotential lines

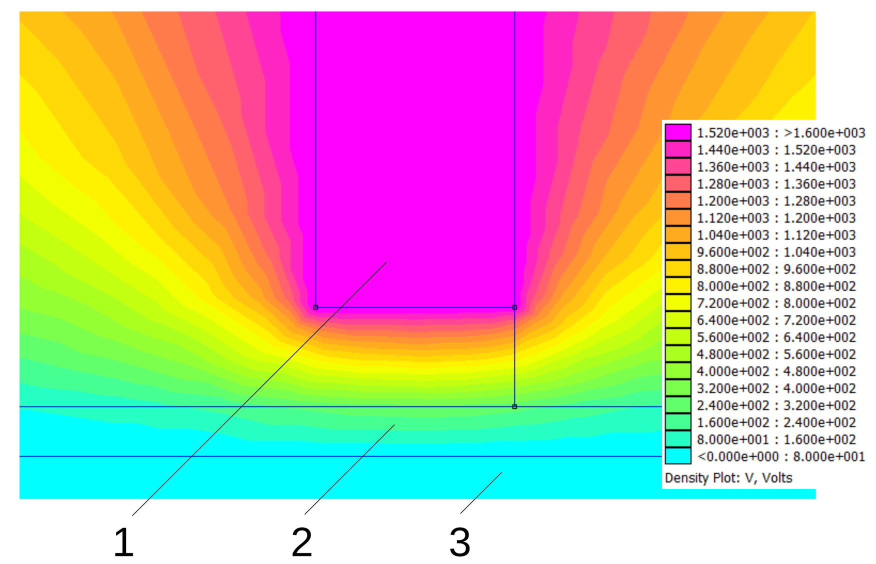

Fig.3. Model of the equipotential lines of the electric field of the treatment device in the area below the vertex of the screw: 1 – vertex of the screw; 2 – Hostaphan; 3 – metal casing

The analysis reveals that the presence of seeds “distorts” the electric field, and its equipotential lines in the air space between two adjacent vertices of the screw are no longer parallel to the shaft of the device.

Interesting is also the area around the surface of the grain pile, seen in a position - 6 in Fig.4, which represents a computer model of the field of the treatment device with seeds present in the inter-electrode space.

The obtained computer model (Fig.4) confirms the authors’ assertions [19,20] that the concentration of lines of force in the grain pile is higher than in the remaining part of the inter-electrode space.

From Fig.4. it can be concluded that in the area around the surface of the grain pile the equipotential lines are refracted. The latter could be explained with the boundary between the two dielectric media – seeds having air space in between, and the air. The refraction of the equipotential lines is observed also in the area below the screw (Fig.5).

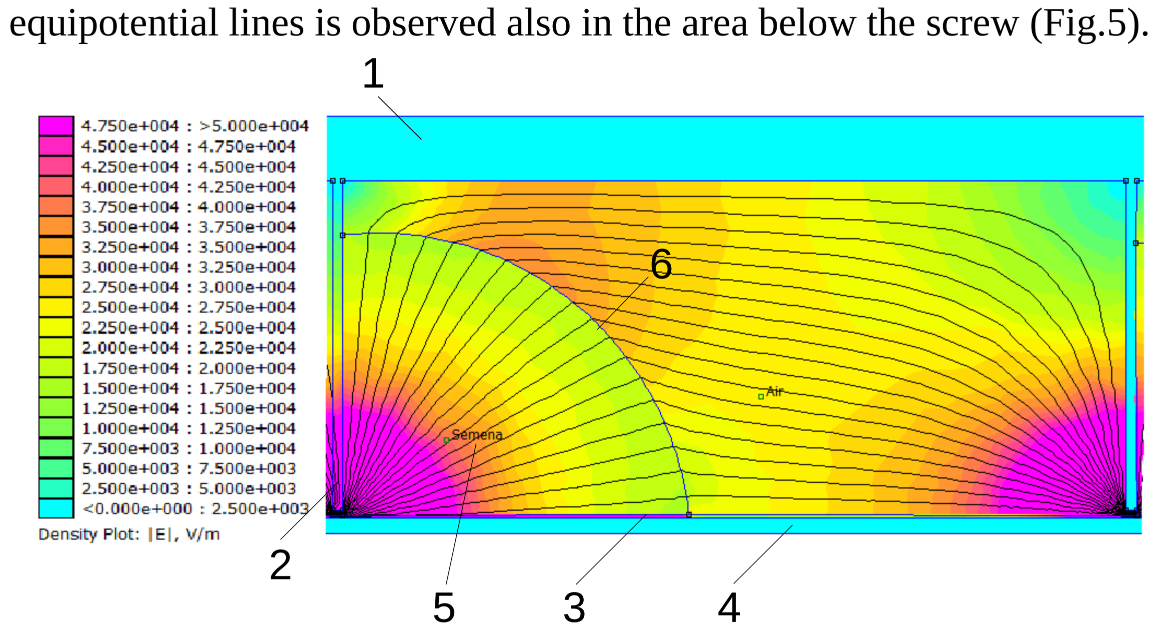

Fig.4. Computer model of the image of the field of the treatment device with seeds present (in the form of grain piles) in the inter-electrode space: 1 – shaft; 2 – screw; 3 – dielectric coating of the casing; 4 – metal casing; 5 – area with seeds; 6 – grain pile surface

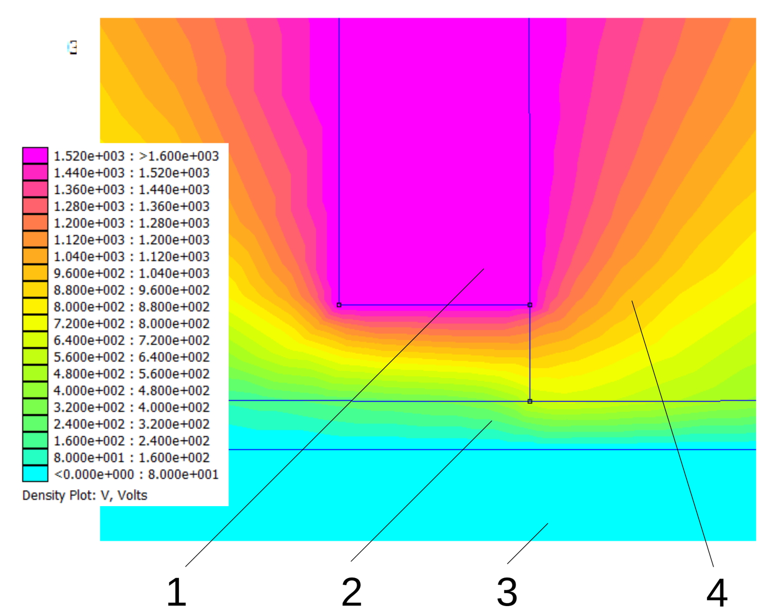

Fig.5. Image of the electric field of the treatment device in the area below the thread, with seeds present in the device: 2 – Hostaphan; 1 – vertex of the screw; 3 – metal casing; 4 – area with seeds

The analysis of the results in Fig.5 reveals that the equipotential lines pass under the vertex of the screw, i.e. this is where they are concentrated. From [19,20] it is known that in this exact area the grain pile is located. The latter is a prerequisite for a non-uniform treatment of the seeds. This observation suggests that ways should be sought to limit the size of this area and to optimize the screw.

CONCLUSIONS

1. A laboratory chamber with plane-to-plane electrodes and increased alternating voltage were used for the pre-sowing electromagnetic treatment of seeds rich in fat.
2. Models of the electric field of the plane-to-plane electrode system of a chamber with parallel plane electrodes were created in the Finite Element Method Magnetics (FEMM) software environment.
3. It was established that the adopted shape of the working chamber created a non-uniform electric field in the area of the treated seeds and therefore unequal pre-sowing effect of the electric field upon the seeds.
4. In order to achieve uniform pre-sowing treatment of seeds rich in fat, optimization of the design of the working chamber is required.