STUDY OF ELECTRIC CAPACITORS USING FINITE ELEMENT METHOD

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Abstract: *A capacitor is made of two armatures and a dielectric between the two armatures. In this paper, we are going to study the plane capacitor , which is made of two equal metal armatures, plane and parallel, having the S surface, situated at a distance d much shorter than the armatures dimensions, between which there is a liniar, homogenous and isotropic dielectric having a constant electrical permittivity.The purpose of studying the plane capacitor, through MEF, presented in this paper,is to establish the stress to which the dielectrics may be subject to, in daily practice, and the influence that their superposition in an electric field has, on each of them. The study of the plane capacitor , finalised with observations on the raise of the dependence of the electric field intensity in air on the size of the air layer and having as parameter the type of dielectric material introduced between the armatures, is an example of confirmation or invalidation of the possibility and utility of using layers of dielectrics between the armatures of the capacitors.*

1. THE PLANE CAPACITOR

1.1 General concepts

It is taken into consideration a system made of two conductors *1, 2* loaded with equal, real electrical charges which are opposite and situated into a dielectric medium that can be either isotropical or unisotropical, liniar or unaligned, homogenous or inhomogenous, but electrically uncharged and without permanent polarisation. The capacitor is such a device (*see fig.1*). The two metallical conductors of the system are called the armatures of the capacitor. The form and the layout of these may vary.

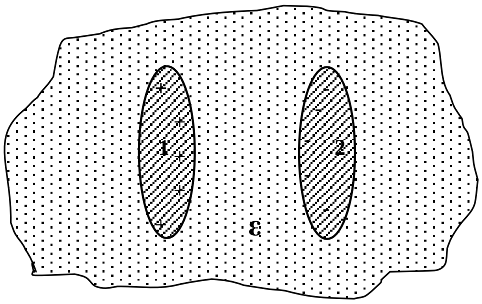

Figure 1. Capacitor

The imposed condition that the electrical charges of the armatures should be equal and of opposite value shows the fact that we are dealing with a complete electrical field, which means that all the field lines starting on one armature end on the other one. The proportion between the electrical charge of one of the conductors and the difference of potential, respectively the voltage between one conductor and the other is a positive value *C*, called *electrical capacitance of the capacitor*:

$$C = \frac{Q_1}{V_1 - V_2} = \frac{Q_1}{U_{12}} > 0 \quad (1)$$

or

$$C = \frac{Q_2}{V_2 - V_1} = \frac{Q_2}{U_{21}} > 0 \quad (2)$$

Since $Q_2 = -Q_1$, and $V_1 - V_2 = -(V_2 - V_1)$. The reciprocal value $S = 1/C$ is also called elastic capacitance of the capacitor.

If the dielectrical value between the armatures is liniar, according to the theory of the superposition, the charge on the armature varies directly proportionally with the potentials, that is with the difference of potential between the armatures.Therefore, the electrical capacitance in this situation is independent from the electrical charge, that is from the difference of potential, being a characteristic value of the respective capacitor.

In the case of the unaligned dielectricals, the electrical charge not being proportional with the difference of potential, the capacitance is not a constant one. In this case, the capacitance defined by the relation (*1*) is also called static capacitance.

Related to the above mentioned concepts, there are some specifications to be made:

- Electrical capacitance is a global parameter of a capacitor, based on a defining ratio. Nevertheless, the term „capacitance" should not be used, as it often happens, to define the technical device itself; for this, one should use the term „capacitor".

- The capacitance of a condenser depends on the geometry and the dimensions of the armatures system and also on the nature of the dielectric between the armatures.

- The defining equation of capacitance may also be applied, by principle, in a varied system.In general, up until high voltages, we may consider the values of capacitance established in an electrostatic system.These values must be changed, though, if in the dielectric between the armatures appears, for example, the post effect. It may also be mentioned the fact that capacitance is not the only parameter of a capacitor, in general. Thus, due to the finite conductivity of the real dielectrics and in the case of high voltages due to the supplementary losses , the capacitor is also defined by a certain resistance.

- To the capacitors used for practical training, one must also indicate the working tension, besides the capacitance; this should be stated because if the tension in the capacitor outgrades a certain value, the dielectric between the armatures will pe pierced.

- The term of capacitance is inherent not only to capacitors , but also in the case of other technical systems. In this case we may spekak of, for example, the capacitance between turns, the capacitance of an electrical line, the capacitance between the electrolytes of an electronic tube etc.; in all of these situations, we may speak of an electric field occurring, having a certain configuration and having a correspondent capacitance.

Classification of capacitors:

- *According to their type of dielectrics*, there are: the gasous dielectric capacitors(vacuum, air, gas); liquid (oil); solid anorganic (glass, enamel, ceramics); solid organic (paper, polish, synthetical enamel); metal oxydes (electrolitical).
- *According to their construction design*, we have: still, variable, semi-adjustable (adjustable).
- *According to their working system*, there are capacitors for: continuous current, alternative current, high voltages.
- *According to their working tension*, capacitors may be: low tension, high tension.
- *According to their material* we may distinguish: capacitors in plastic shell; in metal shell, in ceramics shell.

1.2. Elements of technology

Still capacitors with air are made of several metal plates, which are parallel and distanced. The plates form two groups, insulated by ceramical supports. These are made of silvered brass or aluminium and they form the armatures of the capacitor.

Variable capacitors with air are generally made of mobile plaquettes of aluminiun thin sheets obtained through punching, called the rotor, which are introduced by rotating movements between the still thin sheets, called the stator.

Capacitors made of mica are formed of thin metal sheets applied by pressure on the surface of the insulating material or by spraying a thin layer on the surface of the mica plate. The impregnation of the capacitor is made in mineral wax, epoxy resin, etc.

Ceramics capacitors shaped as a disk, a plaquette, a pan or tubular ones, have the dielectric made of ceramics plaquettes obtained from steatite or magnesium titanate. The electrodes are made by silvering the two facettes of the dielectric; the protection of the capacitor is made of wax, epoxy resin, plastic, etc.

Paper capacitors are made of aluminium thin sheets in which are introduced layers of special paper, that is impregnated with wax or mineral oil. The technical procedures are: the positionning of the aluminium and paper layers; the rolling of the layers as a cylindrical roll or as a flat cylinder; impregnating the paper with oil, resin or mineral wax.

Electrolyte capacitors are based on the chemical reaction between an electrolyte and a metal, which forms a layer of insulating oxide that makes the dielectric.

Electrolyte capacitors with electrolyte liquid are made of an aliminium tube in which are put the anode from oxidised aluminium and the liquid electrolyte obtained from a boracic acid solution .

Semidry electrolyte capacitors are obtained from the simultaneous rolling of the following elements: oxidised aluminium foil, forming the anode , paper band, a second aluminium foil , forming the cathode.

The resulting roll is impregnated in boracic acid solution, ethylene glycol and ammonium hydroxide. The procedure is to be made under vacuum conditions.Because the oxide film gets deteriorated during the rolling and impregnation technologies, it has to be restored by applying a tension which is raised , gradually, above 0 , for a few hours; the same procedure is to be made if the capacitor has not been used for about one year.

The most often used capacitors are the ones with sintered anodes.The anode is made of a body of synthesised tantalum powder.

Sintered anodes are oxidised and then impregnated with an electrolyte formed of phosphoric and sulphuric acid combined with lithium chloride , while the cathode is a silver capsule.

Capacitors are used in: radiotechnics, television, radiolocation, telephony and telegraphy , for improving the functioning parameters in networks, fluorescent lamps, transformers and to start monophasic engines.

Industrial capacitors have the dielectric under relatively heavy loads, because of its functioning at high voltage and industrial frequency. The dielectric losses also stress the insulation, causing the heating of the capacitor.

In the dielectric, it is generally used paper made of different fabrics.As impregnating liquid, mineral oil or chlorinated oil are used. There is also the option of using alternative paper and plastic film layers in the dielectric, in which case we are talking about the mixed dielectric.

The„all film"capacitors have as solid insulation material several layers of plastic film and are contructed similarly to the paper/oil capacitors..

The MP capacitors have their armature metalised by evaporation, in vacuum, directly on the paper support.

The MKV capacitors also have their armature metalised by evaporation, in vacuum, but on both sides of the paper, which only has the role of impregnation wick. The dielectric is made of a layer of polypropylene film.

The MKP capacitors have the armature metalised by evaporation, in vacuum, directly on a plastic support. They are built dry or are filled with an electronegative gas.

1.3. The plane capacitor

The plane capacitor is made of two equal metal armatures, plane and parallel, having the S surface, situated at a distance *d* much shorter than the armatures dimensions, between which there is a liniar, homogenous and isotropic dielectric having a constant electrical permittivity *fig.2*. The thickness of the armatures is considered to be negligible.

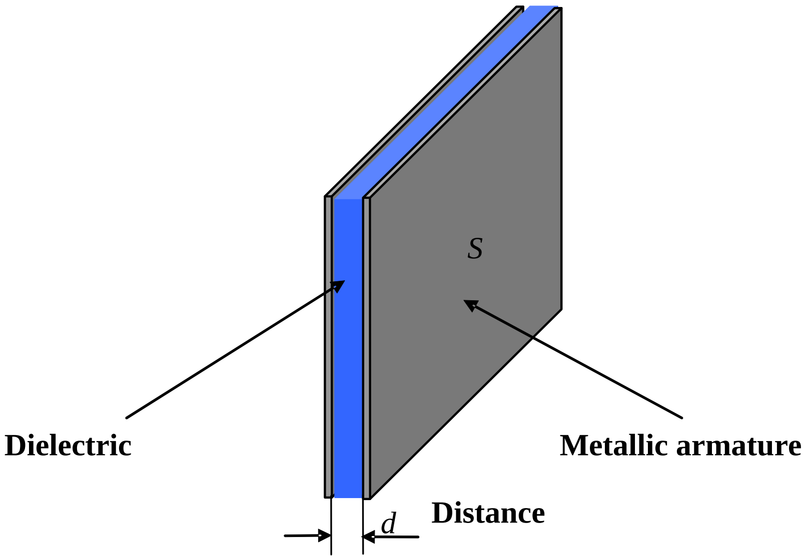

Figure 2. The plane capacitor

Obviously, the configurations obtained by replacing the homogenous, liniar isotropic dielectric by another one (nin liniar, non homogenous ,etc.) are also called plane capacitors. Such cases will be analysed and interpreted in the present paper by taking into account the electrical stress on the dielectric.

1.4. How to calculate the electrical charge, the intensity of the electric field and the capacitance of the plane capacitor

Faraday's law, particularised for the electrostatic condition and Gauss's law, together with the constitutive equation lead to the Laplace equation, which represents the starting point in the MEF analysis of the plane capacitor –type configurations.

Gauss's law allows, in its integral form, the identification of the electric charge of an armature:

$$\int_{\Sigma} \overline{D} \cdot \overline{ds} = Q \qquad (3)$$

The closed surface *Σ* surrounds one of the capacitor's armatures, the surface $\overline{ds}$ being considered based on the exterior normal.

The MEF post processing of the meshed potential values set, generated by a first order triangle elements meshing, leads to a single value of the electric field intensity, that is a single value for the electrical induction in each element. This aspect implies an attentive meshing of the domein to analyse , to offer all along the Σ surface sufficient values for these measurements , on one hand, and a correlation of the number of elements with the variations of the field in certain areas, on the other hand.

Calculating the capacitance becomes an easy task, using the (1) equation, after calculating the electric charge.

The analytical way of calculating , while taking into consideration the uniform field between the armatures and by neglecting the edge effect, becomes, obviously, very simple:

$$V_1 - V_2 = U_{12} = \int_1^2 \overline{E} \cdot \overline{dl} = \frac{\rho_S \cdot d}{\varepsilon} = \frac{Q \cdot d}{\varepsilon \cdot S} \tag{4}$$

in which the line integral is calculated between the armatures *1* and *2* , resulting:

$$E = \frac{V_1 - V_2}{d} \tag{5}$$

By using (1) and (4) one may determine the capacitance of the plain capacitor with a uniform field:

$$C = \frac{\varepsilon \cdot S}{d} \tag{6}$$

Making these measurements is equally easy in the case of liniar, isotropical and homogenous dielectrics, placed in parallel layers between the armatures, but still considering a uniform electrical field.Thus, we consider a dielectric formed of two layers, parallel to the armatures, which have d_1 and d_2 thickness values, and ε_1 and ε_2 permittivity values *:*

By expressing the difference of potential between the armatures, we get:

$$V_1 - V_2 = U_{12} = \int_1^2 \overline{E} \cdot \overline{dl} = E_1 \cdot d_1 + E_2 \cdot d_2 = \frac{Q}{S} \cdot \left(\frac{d_1}{\varepsilon_1} + \frac{d_2}{\varepsilon_2} \right) \tag{7}$$

resulting the capacitance of the plain capacitor with a non-homogenous, two-layered dielectric:

$$C = \frac{S}{\frac{d_1}{\varepsilon_1} + \frac{d_2}{\varepsilon_2}} \tag{8}$$

Taking into consideration the interface condition between two dielectrics on which the charge density is zero and the constitutive equation, we may conclude:

$$\frac{E_{1n}}{E_{2n}} = \frac{\varepsilon_2}{\varepsilon_1} \tag{9}$$

In the analysed configuration, there are only normal components of the intensity of the electrical field and from (7) and (8), the expressions of this item in the two dielectric

$$E_1 = \frac{V_1 - V_2}{d_1 + \frac{\varepsilon_1}{\varepsilon_2} \cdot d_2} \tag{10}$$

and

$$E_2 = \frac{V_1 - V_2}{d_2 + \frac{\varepsilon_2}{\varepsilon_1} \cdot d_1} \tag{11}$$

The calculus of these items , should we consider the edge effect, is a problem without an analytical solution, the calculation methods involved being numerical ones. In all the configurations analysed through MEF , analytical solutions will be given in this paper, in order to estimate the influence of not taking into consideration the edge effect.

1.5. The study, through MEF, of the plane capacitor with a liniar, isotropic and homogenous dielectric

The configurations to be studied include the plane capacitor with a liniar, isotropic and homogenous dielectric, having a relative permittivity ε_r ,with the armatures in a square shape with *16 mm* long side, the distance between the armatures being *4 mm*, connected to *8 KV* difference of potential and a parallelepiped cutting through the domain situated at *16 mm* distance all around the capacitor , on the surface of which are defined homogenous Neuman-type bordering conditions. The size of the parallelepiped has been chosen, after numerous trials, in such a way that the infinite border condition should not be affected by significant errors and the study field should not be too vast – a thing that would require a very large amount of elements.

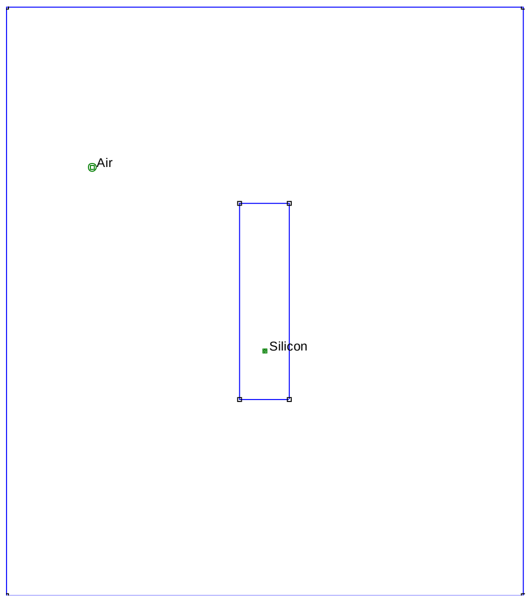

Figure 3.The plane-parallel analysed configuration, having silicone as dielectric

The MEF analyses have been made using the same device as in the case of the FEMM 4.0 electromagnet, a fact which imposed the 2D analysis. This led to transferring the tridimensional problem to a plane parallel one.

We have put under study the capacitors having the following dielectric: air, $\varepsilon_r = 1;$ rubber, $\varepsilon_r = 3;$ mica, $\varepsilon_r = 6$ and silicone $\varepsilon_r = 12$. The four configurations are geometrically identical, only the dielectric type being different, *Fig.3 for the silicone dielectric*.

The meshing of the field, offered automatically by the programme, is not satisfactory not even for showing the equipotential lines, much less for the calculation and the phenomenological interpretation of certain values. Bearing in mind the things revealed by the calculus of the electric charge (paragraph III 2.4), the meshing network will be refined like this: the accentuated thickening in the capacitor dielectric, setting a smaller size for the sides of the elements forming the armatures and for the dielectric-air separation area, in order to create an area with a greater number of elements on the line of the integration curve of the normal component belonging to the electric induction.

The accordingly refined meshing , *Fig. 4*, includes 15507 nodes and 30646 elements.

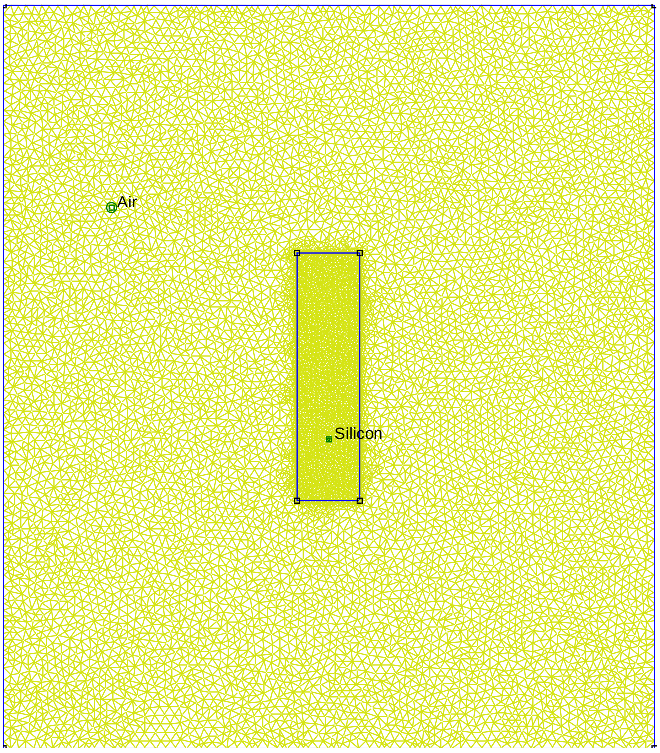

Figure 4. Refined meshing

Starting with this network, the MEF analysis offers the values of the electrical potential in any point of the field. Based on these facts, it is easy to figure out the aspect of the equipotential lines, *fig. 5,* an example for the silicone dielectric.

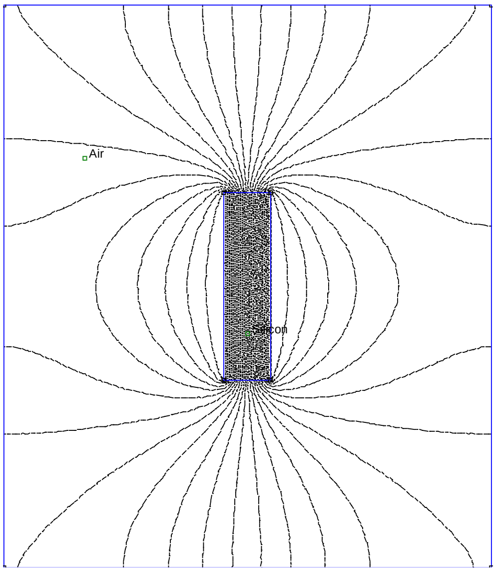

Figure 5. The equipotential lines for the dielectric, silicone

It is also the solutions found for potential that allow us to calculate the intensity of the electric field and the electrical induction. The device used for doing this, FEMM 4.0, allows the mapping out the distribution of the electric field intensity, *Fig. 6*, for silicone.

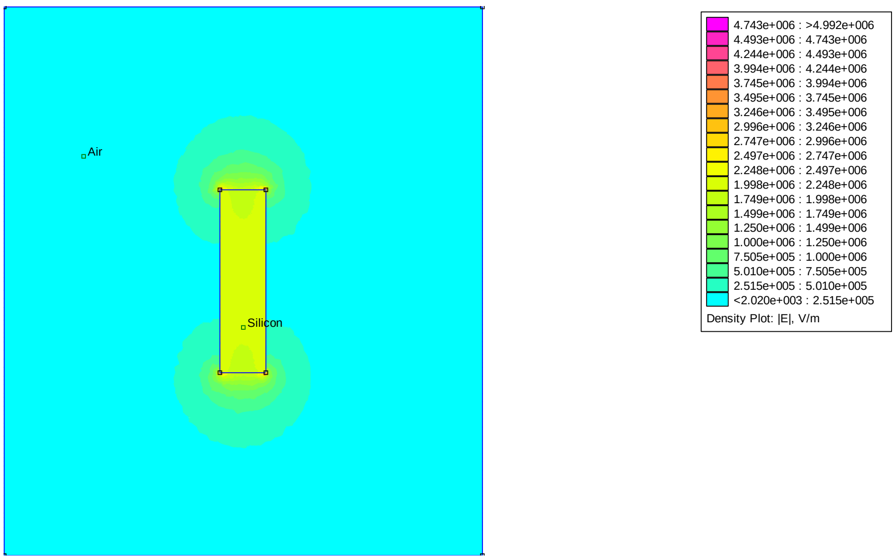

Figure 6. The distribution of the electric field intensity in the case of silicone as dielectric material, between the armatures

Very useful and explicit, besides the equipotential lines map, in visualising the influence of the edge effect on the plane capacitor, is also the distribution of the electrical intensity within a central section, between the armatures , which is parallel to these, *figure 7*. One may notice the decreasing of this value near the edges of the capacitor, a decreasing which becomes more accentuated with the decreasing of the relative permittivity of the dielectric. Thus, the values on the dielectric-air separation surface decrease from *19,4 KV/cm*, in the case of the silicone, to *17,9 KV/cm*, when using the rubber as dielectric and reaching

15,8 KV/cm in the case of the air-air separation.

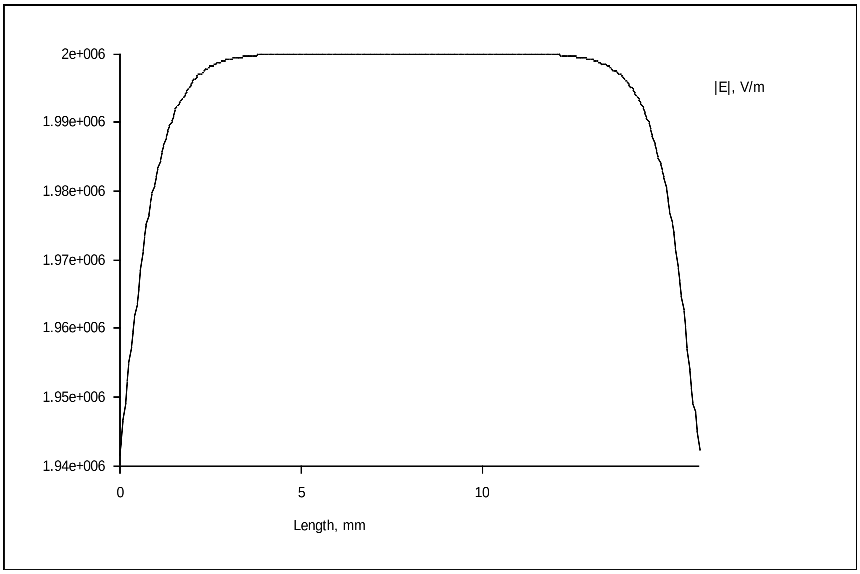

Figure 7 The distribution of the electrical intensity within a central section between the armatures, which is parallel to these

It is to be noticed that the values of the electric field intensity between the armatures, in their central area, where the uniform field appreciation is real, are of *20 KV/cm*, the same as they are when using the analytical formula.

The problem with the difference between the analytical solution and the numerical one becomes more obvious when evaluating the electrical charge.

The marking of the integration outline , in the FEM post processing page, is to be seen in *fig. 8*, whereas the results to the electrical charge calculations, made both ways, are presented (including the error percentage between the two) in *table 1*.

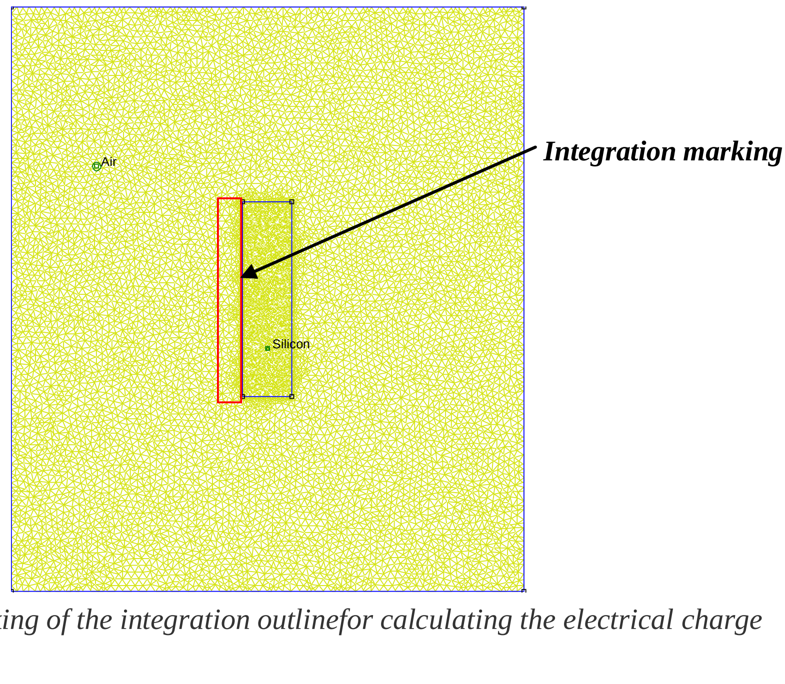

Figure 8. The marking of the integration outlinefor calculating the electrical charge

The FEMM 4.2 software, though two-dimensional, makes the transposition of line or surface integrals, into surface or volume integrals by setting a field at the same time with defining the problem referring to the depth of the plane parallel model, according to the *oz* axis.

Table 1. The values of the electrical charge, through FEM and analytical calculations

Relative permittivity	Q calculated through FEM	Q calculated analytically	Error percentage
-	[C]	[C]	[%]
1	6.06074E-09	4.52707E-09	25.30
3	1.51567E-08	1.35812E-08	10.39
6	2.87685E-08	2.71624E-08	5.58
12	5.59755E-08	5.43249E-08	2.95

The evolution of the error percentage from 25% to 3%, as the electric permittivity increases is normal, it is generated by the accentuated presence of the edge effect, if the dielectric and the environment are comparable.

The FEM analyses of the plane capacitors with liniar, isotropic and homogenous dielectric have been required, firstly, by the necessity to establish optimal values for the quantities influencing the FEM analysis (number and density of the elements on certain subfields, materials setting, bordering conditions, etc) and, secondly, by the necessity to offer value to some quantities which should allow their report in the studies to be made on non-homogenous dielectrics.

1.6. The study, through FEM, of the plane capacitor with liniar, isotropic and non-homogenous dielectric, in layers

The purpose of studying the plane capacitor, through FEM, presented in this paper,is to establish the stress to which the dielectrics may be subject to, in daily practice, and the influence that their superposition in an electric field has, on each of them.

As it is already known, the dielectrics used in daily practice are not ideal ones.They have a certain electrical conductivity, due mainly to their own ions or to the impurities they may contain. If the applied or the intensity of the electric field exceed certain values, it may appear in the dielectric a disruptive electrical discharge called breakdown. The maximal value of the intensity of the electric field which may be found inside a dielectric before its breakdown is called dielectrical rigidity (E_{str}). This item, specific to every dielectric, is determined experimentally, within the specified conditions that make it valid. The dielectrical rigidity relies on a series of factors , such as pressure, form and distance between the electrodes producing the breakdown (for the gasous ones), impurities, etc.

In *table 2.* , we are given the values of the dielectrical rigidity for some materials (Mocanu, 1981):

Table 2. The values of the dielectrical rigidity for some materials:

Dielectric	*Dielectrical rigidity [KV/cm]*	*Dielectric*	*Dielectrical rigidity [KV/cm]*
Air	*32*	*Rubber*	*400*
Mineral oil	*120 – 150*	*Cellulose*	*300 – 400*
Paraffin	*200 – 300*	*Mica*	*850 – 1200*
Polyethylene	*400*	*Porcelain*	*300 – 350*
Polystyrene	*200 - 300*	*Bakelite*	*300 -400*

The exposure of some dielectrics to certain amounts of stress may be done only after a careful study, which today is made mainly by numerical methods, the most commonly used being *The Finite Element Method*.

A research will be conducted, to establish the influence of introducing, between the armatures of a plane capacitor in air of a dielectric having the electrical permittivity $\varepsilon_r>1$, being parallel to the armatures and glued to one of them, leaving, however, some empty space between the armatures . The geometry of the capacitor is the one stated in the previous paragraph, the extra notes being : *1* – the air dielectric and *2*- a different dielectric, *fig. 9*.

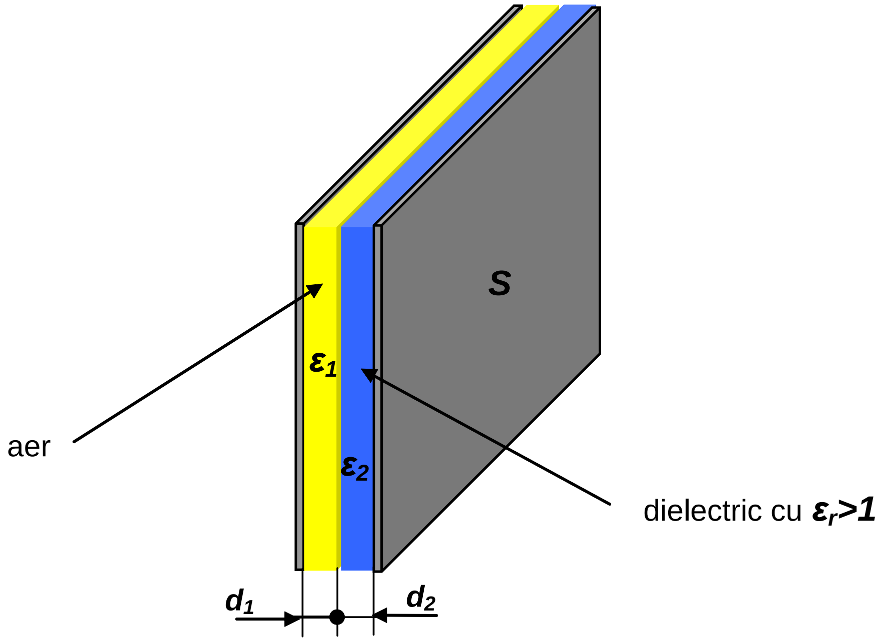

Figure 9. The plane capacitor with two parallel dielectrical layers

The study is based on the results found after FEM post processing of the configurations resulted from the following combinations:

1. air and rubber,
2. air and mica,
3. air and silicone.

For each of the three dielectric distributions , we will analyse the models to which the thickness of the air between the left armature and the dielectric, d_1, varies between half the distance between the armatures, that is *2mm* and *0,5mm* , with a *0,5mm* pace.

In order to avoid the abundance of data and figures, it will only be recorded the map of the equipotential lines and the distribution of values for the electric field intensity on the symmetry axis of the capacitor, data which are necessary for the quantitative and qualitative illustration of the reciprocal influence that the dielectrics have, when introduced in the electrical field.

The principles of the initial meshing network refinement, offered by the device, are identical with those mentioned in the previous paragraph, the settings of the air-dielectric separation surface, parallel with the armatures, being also done for very small element dimensions, as shown in *fig. 10,* in the case of of the air-rubber dielectric, with $d_1 = 1mm$.

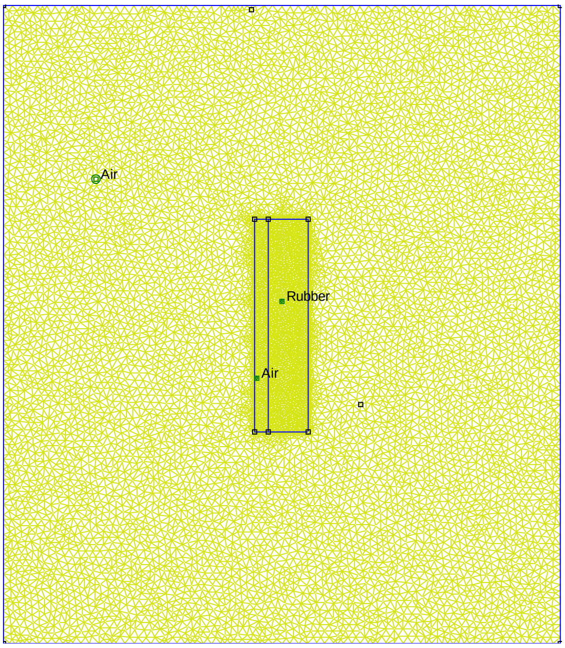

Figure 10. Refined meshing for the capacitor with air-rubber dielectric and thickness of the air layer of 1mm.

For this same model, the mapping of the equipotential lines reveals a concentration of the electric field in the air dielectric area, to the disadvantage of the rubber dielectric, *figure 11*. Obviously, this phenomenon comes with an increase of the electrical sollicitation on the air layer.

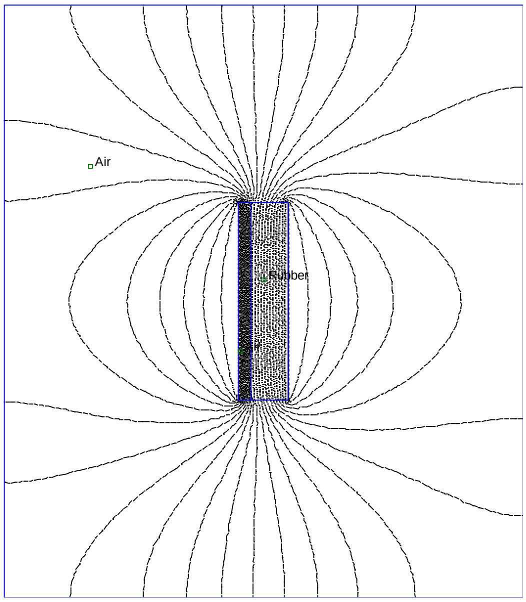

Figure 11. The equipotential lines for the capacitor with air-rubber dielectric and thickness of the air layer of 1mm.

By showing the distribution of the values attributed to the intensity of the electric field on the symmetry axis of the capacitor, *figure III.32*, one may easily notice the spectacular leap made by the intensity of the field when passing from one dielectric to the other.Thus, the values we refer to are *40 KV/cm* in air and *13,35 KV/cm*, in rubber. The constant aspect on the two levels is obviously justified by the position of the line on which the distribution was shown , that is an area with practically uniform electric field. Except for some corner areas, these values are the maximum values of the electric field intensity and they represent the basis of the dielectric sollicitation appreciation.

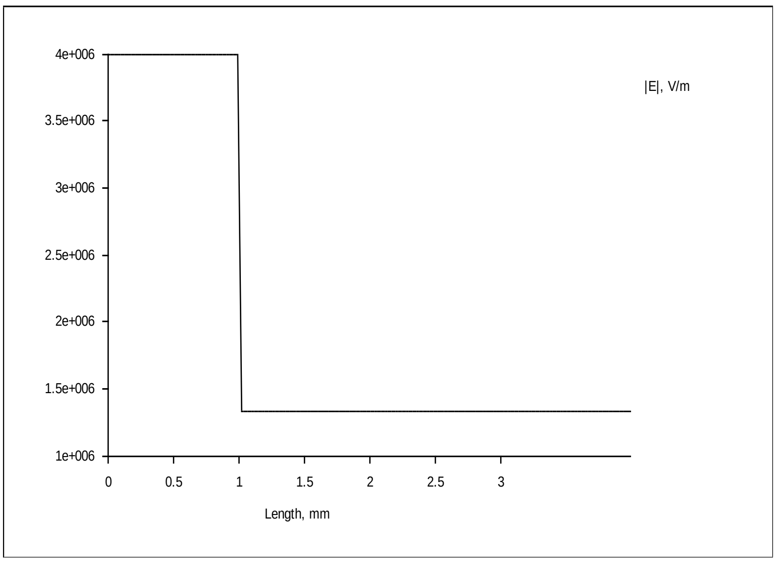

Figure 12. The distribution of the electric field intensity valueson the symmetry axis of the capacitor with air-rubber dielectric and the thickness of the air layer of 1mm.

The same figures are presented in Annex 3 for all the analysed configurations, but, in order to conclude the research in the present paper, we will put in a table only the values of the electric field intensity to be found in the air and in the dielectric, for all the combinations and all sizes of the air layer and type of dielectric analysed, *table 3*.

In all the possible combination of a dielectric with an air layer, we may notice the substantial modification of the electric field from the capacitor –meaning a raise of the stress level on the one with lower electrical permittivity. Taking into account the initial aspect of the field, before introducing the dielectric(see the previous paragraph), one may notice , in all the cases, an increase of the electrical field intensity in the air and a decrease in the dielectric we have introduced.

Table 3. The intensity of the electric field for the analysed configurations

d_1 [mm]	E_1 [KV/cm]			E_2 [KV/cm]		
	$\varepsilon_r = 3$	$\varepsilon_r = 6$	$\varepsilon_r = 12$	$\varepsilon_r = 3$	$\varepsilon_r = 6$	$\varepsilon_r = 12$
4	20	20	20	-	-	-
2	30	34.29	36.92	10	5.72	3.08
1.5	34.27	41.81	46.68	11.44	6.97	3.92
1	40	53.32	63.94	13.33	8.91	5.35
0.5	47.92	73.87	100.1	16.01	12.35	8.44

The lowest dielectrical rigidity may be found in the air, of all the dielectric layers that exist between the armatures of the analysed plane capacitors (*table 3),* therefore none of the non-air dielectrics is going to stand solicitations which are close to this value, especially since the values of the electrical intensity lowers in these dielectrics compared to the capacitor that has an air layer between the armatures, that is compared to the value of *20 KV/cm, figure 13.*

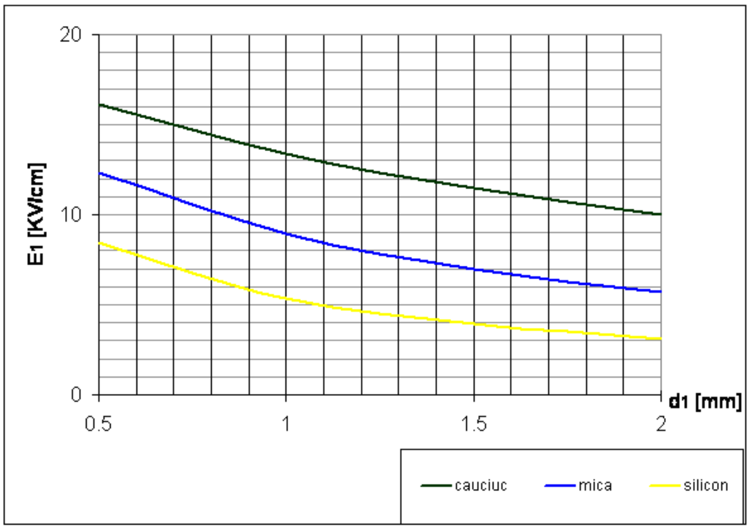

Figure 13. The dependence of the electric field intensityin the dielectric in relation with the size of the air layer, having as parameter the type of dielectric material introduced between the armatures

We may notice, however, the higher values of the electric field intensity in the dielectrics with lower permittivity, such as rubber and mica, opposed to the silicone.

By interpreting the data resulted from the FEM analyses, it has been noticed the strong solicitation to which is subdued an air layer, if we introduce between the armatures of a capacitor a dielectric having $\varepsilon_r > 1$, so that it does not completely fill the space between the armatures. The graphic representation of the data in the *table 3* ,referring to the air area on which we superpose the value of of the dielectrical rigidity of the air, under atmospheric pressure, offers a very clear figure of this problem, *figure 14*.

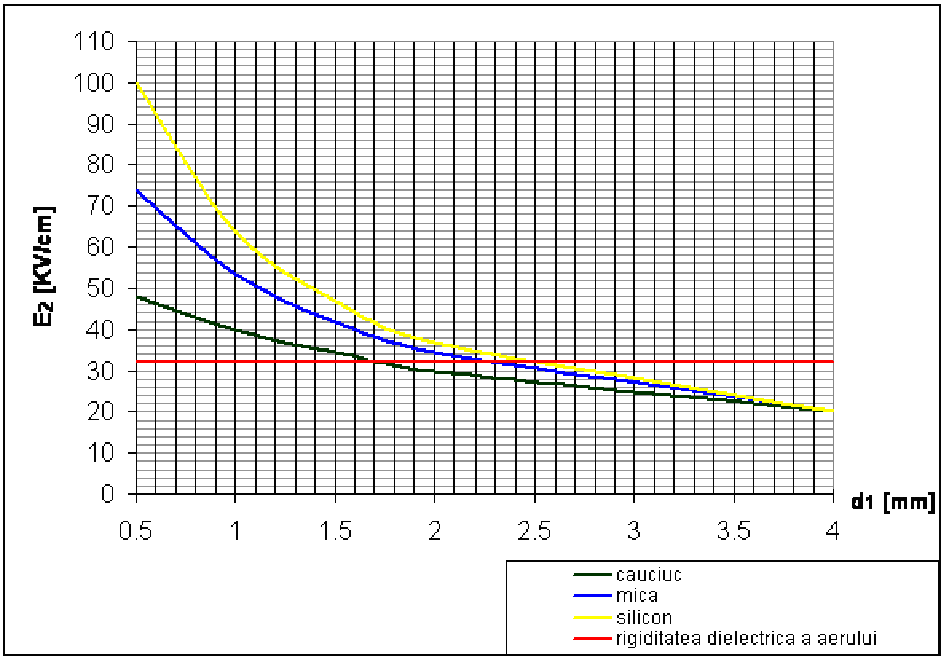

Figure 14. The dependence of the electric field intensity from the air to the size of the layer, having as parameter the type of dielectric material introduced between the armatures

Thus, by introducing a dielectric material, rubber, between the armatures of the plane capacitor, the breakdown of the air interstice between the left armature and the rubber will occur if the interstice size drops is under *1,7mm*. The value reached by the electric field intensity in an air layer of *0,5mm* is *47,92 KV/cm*, much higher than the breakdown value.

The situation gets worse if the dielectric materials used are mica and the silicone. The minimum layer of air that does not breakdown is *2,25mm*, respectively *2,5mm*, and the values reached by the electric field intensity inside the air layer of *0,5mm* are *73,87 KV/cm,* respectively *100,1 KV/cm.*

The study of the plane capacitor , with liniar, istrope and homogenous/non homogenous dielectric ,finalised with the raise of the dependence of the electric field intensity in air on the size of the air layer and having as parameter the type of dielectric material introduced between the armatures, is an example of confirmation or invalidation of the possibility and utility of using layers of dielectrics between the armatures of the capacitors.

By making a report of all the values of the elements inherent to the capacitor with a homogenous dielectric, having an electrical permittivity ε_2 and defining the equationt k:

$$k = \frac{\varepsilon_2}{\varepsilon_1} \quad \text{(III.20)}$$

the results may be extended for any dielectric material combinations, *figure 15.*

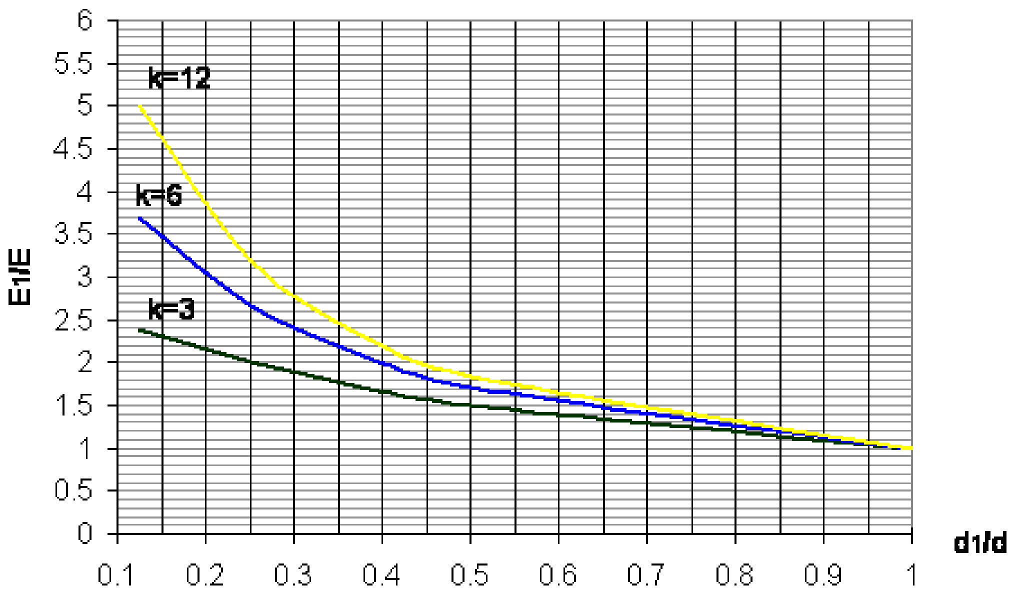

Figure 15. The dependence of the relative electric field intensity in the dielectric layer on the lowest permittivity, in relation with the size of the layer and having as parameter the K equation

2. CONCLUSIONS

It was illustrated the necessarily steps in Finite Element Method analysis of an electrostatic problem. Setting the geometry, choosing the materials, the meshing refinement, proper choosing of boundary conditions are some of them.

Also it was outlined the Finite Element Method educational potential due to the illustrative results.

Finaly, the general form of the the dependence of the relative electric field intensity in the dielectric layer on the lowest permittivity, in relation with the size of the layer and having as parameter the K equation it was produced.

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