COMPUTER SIMULATION OF ESD FROM CONE

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Abstract - The paper is devoted to computer simulation of Electrostatic Discharge (ESD) from cone. Numerical model is based on the electrodynamical consideration of the problem. The Method of Moments in time domain, coupled with non-linear model of arc, is used to develop the efficient algorithm of ESD simulation. Transient currents and fields are analysed from EMC point of view. Results of numerical simulation are shown to be in a good agreement with experimental data.

I. INTRODUCTION

Numerical calculations together with experimental studies can be considered as powerful tool for investigation of ESD. The objective of this paper is to investigate ESD process from the cone. A complete solution of the problem would combine the breakdown physics with an electrodynamics of transient, lossy three-dimensional (3D) non-linear problem. This problem has numerically hard to handle dimensions, i.e., arc lengths < 2 mm and body sizes up to 1 m. Due to the non-linearity of the arc, the time-domain methods are preferable.

In this work the algorithm cone discharge is considered by the time domain Method of Moments (MoM). The non-linear arc model is added to the MoM scheme. Algorithm based on such approach was developed in [1-4] for prolonged rotational bodies. Algorithm was checked against measured data and showed high accuracy. The main physical ideas of computer simulation of ESD of cone and the comparison of experimental and theoretical results are presented.

II. PHYSICAL CONSIDERATION OF THE PROBLEM

Let us consider rotational perfectly conducting body, charged up to some fixed voltage and moving slowly to the grounded plane (Fig. 1.).

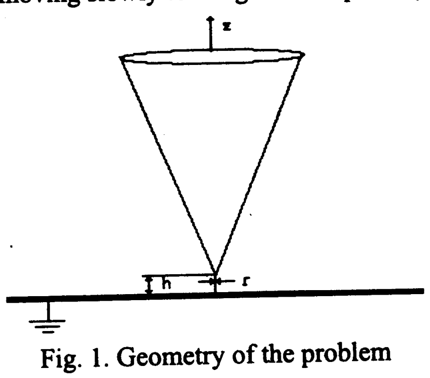

Fig. 1. Geometry of the problem

On some distance h from the plane the breakdown begins. Lets assume that chosen metallic body is approaching to the plane with such a small speed that its movement does not affect the initial electrodynamical state of the system. This initial state in this case is determined by electrostatic distribution of charges on the body, that is located on fixed distance h above the plane. The physical process in the discharge channel (in the arc) depends on geometry of the body, on length of the channel, initial voltage and parameters of air in the channel (humidity, presence of ionisation factors and so on). In general all these factors determine non-linear behaviour of the arc-resistance and it's dependence on the strength of electric field in the channel. There are some phenomenological models that describe time dependence of arc-resistance as a function of main parameters of problem, for example, models of Braginski [5], Rompe and Weizel [6], Toepler [7], Mesiats [8] and others. It was found [1], that for extremely short arcs and high voltages the models of Rompe and Weizel [6] and Mesiats [8] are more preferable. If compared with other models, they describe with more accuracy the time-dependence of arc resistance and they can predict more precisely time-derivatives of arc currents. This is very important in EMC practice. In this work we are using the model of Rompe and Weizel.

The moment a discharge current starts to flow, an electrostatic description can not be used anymore. As long as the discharging structure supports a TEM-wave (for example, a coax cable, a conical line), the discharge current can be calculated by transmission lines and reflection coefficients. But most real structures do not support TEM-mode and the full-wave electrodynamical analysis should be used. In this paper the following approach is stated: the object must be seen as an antenna which is excited by the discharge current. As the excitation is non-linear, the numerical analysis of the transient fields should be done in the time domain. This allows the combination of the antenna algorithm with a physical description of the ionisation process in the arc [1-4].

III. NUMERICAL RESULTS

To validate the algorithm for perfectly conducting objects, we first compared IEMF algorithm to literature data (linear scattering problems) and to analytical results for a spheroid. Then we included the arc model and compared the calculated currents and fields with measured data of discharges from a spheroid with semi-axis 31 cm and 5 cm [2-4]. In this work we present results for a cone.

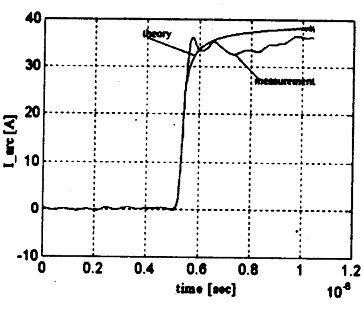

Fig.2a. Cone currents. V_0=3 kV, h=0.199 mm

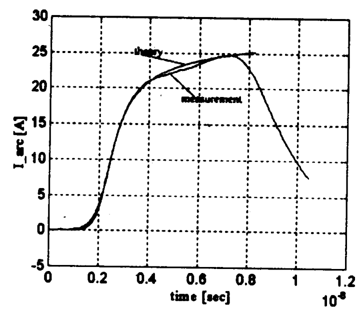

Fig.2b. Cone currents. V_0=3 kV, h=0.572 mm

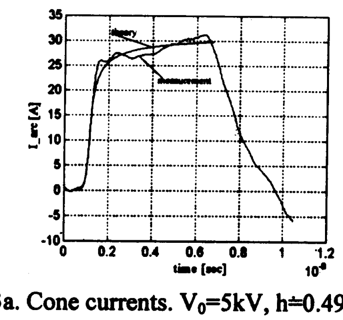

Fig.3a. Cone currents. V_0=5kV, h=0.496 mm

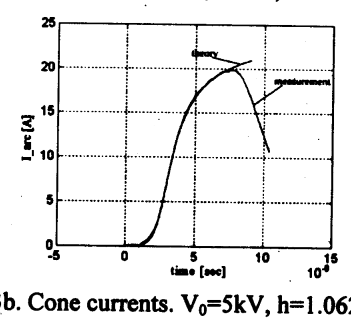

Fig.3b. Cone currents. V_0=5kV, h=1.062 mm

Comparison of experimental and calculated arc currents for the cone of length 770 mm and diameter of big end 150 mm, are shown in the Figs.2 and 3. Computer simulation is made for semi-infinite cone. From these results it can be seen quite a good agreement between measurement and theory. In computational model currents on the surface of cone were not calculated by integral equation. These currents can be found considering the cone as a structure, supporting TEM fields.

SUMMARY

The computer simulation of the process of Electrostatic Discharge of cone is presented. The algorithm is based on electrodynamical full-wave analysis. Numerical solution is obtained by the time
domain Method of Moments coupled with phenomenological model of arc. Computational results are found to be in a good agreement with measurements.

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