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FINITE ELEMENT METHOD ANALYSIS OF AN ELECTROMAGNETIC FIELD INSIDE PULSED POWER GENERATOR

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Abstract: The paper describes a numerical solution of a transient analysis process, inside a helical microwave pulsed generator. The generator function runs for approximately 10μs. The separated components were verified by mathematical model, which was formulated in integral form. The results of a solution and values were verified by measurement. The supposed peak power of the generator is P_n=10MW.

Keywords: Finite element method, model, integral equations, partial differential equations, power, pulsed microwave power generator, mathematical model, physical model, electric intensity *E*, magnetic flux density *B*, current density *J*, transient analysis, Poynting´s vector, Faraday's law.

1 Introduction

The pulsed power microwave generator function is based on two principals. The first of them is the classical Faraday's induction law and the second is its modification. The second variation is using of construction autotransformer in the apparatus technology. Basic stages of pulsed power generator function are showed in Fig. 1. The voltage U_0 is got to generator winding at the t_0 time. The electric field with intensity $E(t)$ and with current density $J(t)$ is created inside the electric conductor in given configuration. Together magnetic flux density $B(t)$ is created inside the generator in given configuration. The inner cylindrical contact is deformed in the second step at the time $t_0+\Delta t$ and the voltage $U(t)$ is increased on a turns of coil and the voltage is dependent on Faraday's law. The winding is connected to high frequency part of microwave power generator at the third time step $t_0+2\Delta t$. The obtained energy is

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radiated in a high frequency part; it can be describe by Poynting's vector as it is showed in Fig. 1.

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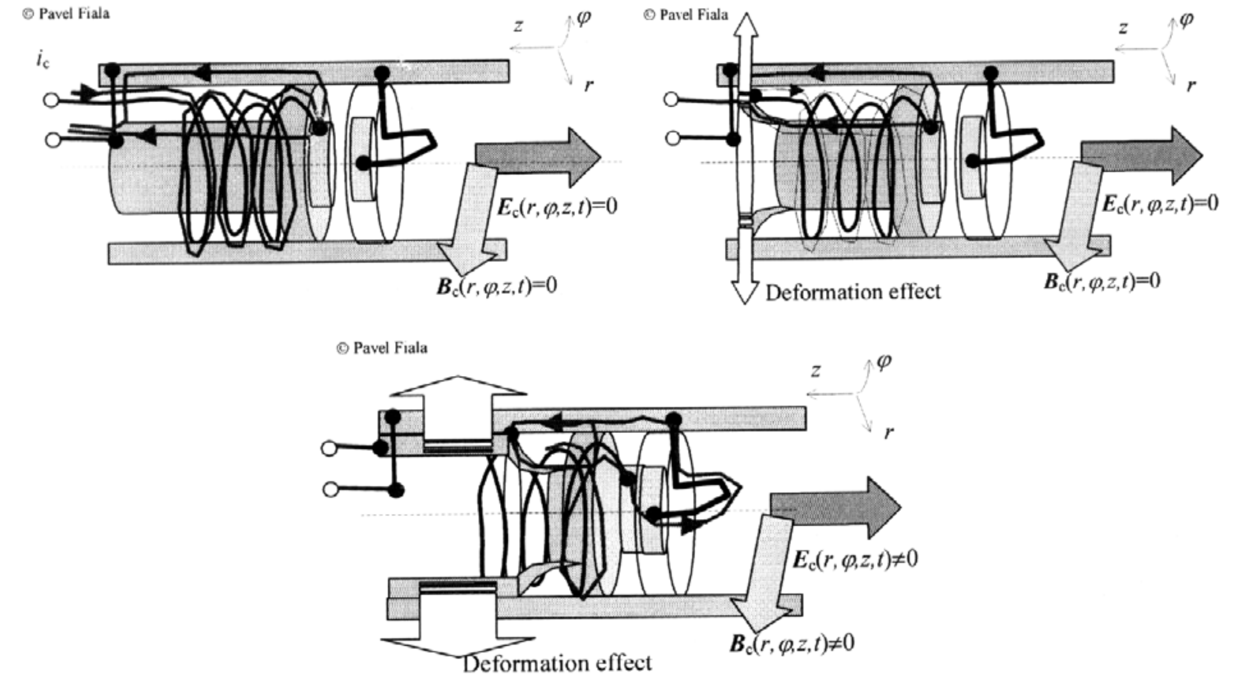

Fig. 1 The principal function of power pulsed generator

2 Basic physical model

In the case, when the magnetic flux density vector $\boldsymbol{B}$(t) is non-stationary and the area S(t) created by one turn is non-stationary too, thereafter Faraday's law formulation is written

$$\oint_{\ell} \boldsymbol{E}(t) \cdot d\,\boldsymbol{l} = -\int_{S} \frac{\partial\,\boldsymbol{B}(t+dt)}{\partial t} \cdot d\,\boldsymbol{S} + \oint_{\ell} (\boldsymbol{v} \times \boldsymbol{B}) \cdot d\,\boldsymbol{l}\,, \qquad (1)$$

where $\boldsymbol{v}$ is a change velocity of coil position or coil geometry, ℓ is length of turn array boundary S, $\boldsymbol{E}$ is electric intensity vector, respectively. The relations are described in some detail in research report [3]. One of high effective configuration variant of pulsed power generator is cylindrical configuration and it is showed in Fig.2. An induced electric voltage on coil turns is specified as

$$u_2(t)=u_1(t)-\frac{\partial}{\partial t}\iint_S B_0 dS-\frac{\partial}{\partial t}\iint_{S_L} B_{c1} dS-\frac{\partial}{\partial t}\iint_{S_K} B_{c2} dS-\oint_{\ell_T}(v_1\, B_{c1})dl-\oint_{\ell_T}(v_2\, B_{c2})dl\,, \qquad (2)$$

and total surface power density is

$$\boldsymbol{\Pi}\ (t)=\boldsymbol{u}_r\ E_\varphi H_{0z}+\boldsymbol{u}_\varphi\ E_z H_{0r}+\boldsymbol{u}_r\ E_\varphi H_{cz1}+\boldsymbol{u}_r\ E_\varphi H_{cz2}\,, \qquad (3)$$

where $\boldsymbol{u}_{r,\varphi,z}$ is an unit vector of used coordinate system, H is a magnetic field intensity, respectively.

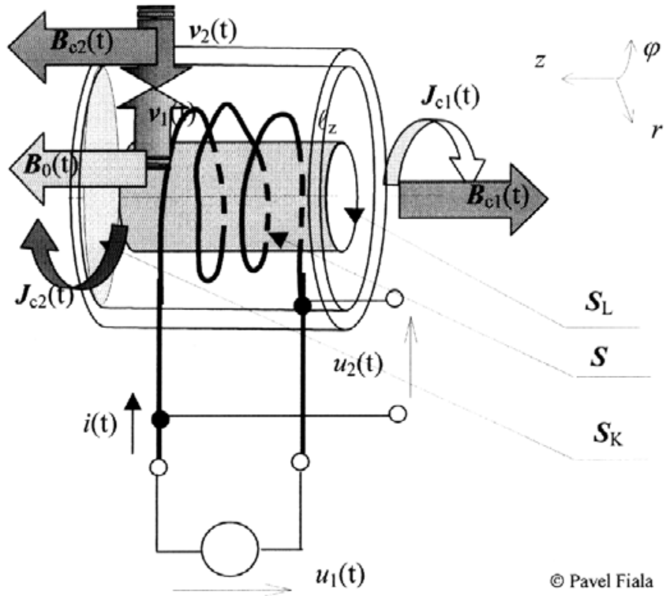

Fig.2 Configuration of a pulsed power generator

3 Mathematics-physical model

The model is set up on Maxwell reduced equations solving. After derivation and representation by finite element method [3] the model is written in the form

$$\begin{bmatrix} \boldsymbol{L}_A+\boldsymbol{L}_{A\varphi} & 0 & \boldsymbol{0} \\ \boldsymbol{0} & 0 & \boldsymbol{0} \\ \boldsymbol{0} & 0 & -\Theta \boldsymbol{L}_S \end{bmatrix} \begin{Bmatrix} \dot{\boldsymbol{a}} \\ \dot{\phi} \\ \dot{\boldsymbol{S}} \end{Bmatrix} + \begin{bmatrix} \boldsymbol{K}_{A1}+\boldsymbol{K}_{A2}-(1-\Theta)\boldsymbol{K}_{A3} & 0 & \boldsymbol{0} \\ \boldsymbol{0} & K_\varphi+K_{\varphi\varphi} & \boldsymbol{0} \\ \boldsymbol{0} & 0 & \boldsymbol{0} \end{bmatrix} \begin{Bmatrix} \boldsymbol{a} \\ \phi \\ \boldsymbol{S} \end{Bmatrix} = \begin{bmatrix} \boldsymbol{z}_J & z_{\varphi\varphi} & \boldsymbol{0} \\ \boldsymbol{0} & 0 & \boldsymbol{0} \\ \boldsymbol{0} & 0 & \boldsymbol{0} \end{bmatrix} \begin{Bmatrix} \boldsymbol{j}_s \\ \rho \\ \boldsymbol{0} \end{Bmatrix} . \qquad (4)$$

We can use the own formulation [6] and solvers. For pre-processor and post-processor was used the ANSYS program. The other way is determined a chance of modification the element SOLID97 in the system ANSYS. There are respected boundary and initial conditions for transient analysis with some known accuracy.

4 Geometrical model

The geometrical model of turns is showed in Fig.3. The model was built by APDL language in the ANSYS program. It has 48260 nodes, 54885 elements and 189858 degrees of freedom. Transient analysis for time t∈<0.1,300>μs was solved about from 15 to 300 hours in the computer PC compatible, CPU 1.6GHz ATHLON, 1.5GB RAM, 30+60GB HD, OS WIN2000.

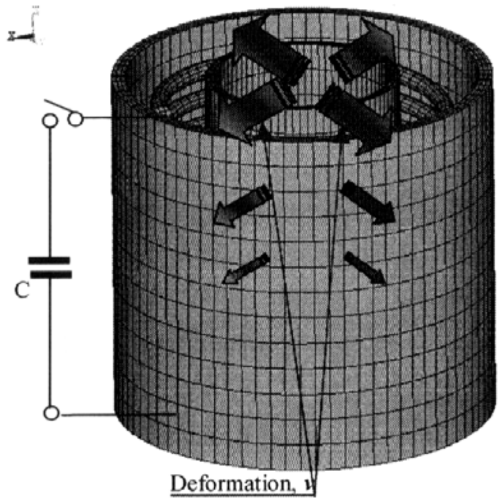

Fig. 3 Geometrical model of power pulsed generator

5 Conclusion

The contribution describes theoretical basement of microwave power generator model. The mathematical and physical model is formulated by partial differential equations by finite element method. The University of Technology Brno FECT co-operated with firm PROTOTYPA a.s. Brno on measuring and verification this models.

References

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