

EVOLUTION OF 3D SIMULATION MULTIPACTORING CODE MultP

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Calculation results of multipactoring possibilities in various parts of microwave structures are presented. 3D multipactoring simulation code MultP was used. Source code was improved and now it allows making the calculations for standing and traveling waves. Improved code possibilities are tested for coax and different types of input couplers. Obtained results are compared with known experimental data.

PACS: 29.27.-a

1. INTRODUCTION

The program "MultP" has been developed at Institute for Nuclear Research to investigate possible electron multipacting in RF cavities using preliminary numerically calculated field components. The main challenge was development of multipacting simulation procedure for realistic 3D shape of RF cavity. Also an easy and convenient interface along with a broad range of possibilities was considered as an important goal.

The "MultP" provides different options of numerical study of electron multipacting. Particularly it is possible:

- to track separate electrons;
- to track a group of electrons;
- to scan electric field levels and initial phases of electrons and to determine a possibility of resonance electron multipacting;
- to simulate multiplication of a number of randomly distributed electrons. [1].

The simulation of multipactor discharge ignition in device under investigation starts with direct modeling statistical computation. This computation of multipactor discharge for given RF power level (for waveguides) or accelerating field strength (for accelerating cells) is carried out for detecting of dangerous areas subject to multipactor. After statistical simulation and dangerous areas scouting the electron trajectories are investigated. The variations in electron parameters are implied including initial velocity and field phase at the emission moment. Electron trajectories analysis yields the additional data for possible multipactor discharge whether it is one or two point one and the multipactor order.

However, till nowadays there was not possibility to calculate structures at TW-regime. It is necessary for research of such structures as waveguides and TW accelerating structures. Moreover it is necessary to research multipactor possibility at TW structures. From 2006 RF laboratory at MEPHI in cooperation with Institute for Nuclear Research improve account possibilities of the program. Main goal of this work is program creation giving possibility to research multipactor rise at any element or construction of accelerating structure. Nowadays program can including earlier created possibilities ca solve following problems:

- to carry out calculations at SW-regime (accelerating cavities) and at SW-regime (waveguides);

- to set values of second emission coefficients for various materials, that is important for calculations of ceramic windows at power couplers;
- to draft relatively complicated geometrical constructions, because program includes additional geometry primitives such as toroid, cone.

Because of these upgrades existing and enlarge program MultiP gives possibility to calculate most elements of accelerating structures including power couplers. At this report program new possibilities are shown on waveguide different elements account. Results were compared with known calculation and experiment data.

The statistical simulations were made using 1000 initial particles of 1eV energy. Secondary electron emission yield for metal was 3, i.e. electron of energy 50...1500 keV hitting the surface gives spawn three secondary electrons. This assumption well suites for such evaluative simulation with relatively small number of particles. For the more precise study of multipactor properties for different secondary emission yield the simulations with more than 100.000 particles should be done.

2. MULTIPACTOR ANALYSIS FOR COAXIAL WAVEGUIDES OF INPUT COUPLERS

In order to test the upgraded MultiP code several different geometries were simulated and the results compared to the ones obtained with Multipac code 2.1.

2.1. The coaxial waveguide for TESLA Test facility power coupler model TTF3 was investigated [4]. External conductor diameter D is equal 42 mm, internal one d is 17 mm. Electromagnetic fields were computed by Microwave Studio code with mesh consisted of about 30.000 nodes. Multipactor simulation showed the discharge could occur for the RF power in range from 60 kW to about 1100 kW. Most severe discharge up to 4th order is observed for power exceeding 260 kW. Figs.1,2 present the examples of statistical simulations for waveguide operated at 200 kW RF power with electron trajectories shown. It is seen that the particle number grows exponentially with field period's number increase thus indicating the multipactor discharge is very probable to occur. The electrons trajectories allow one to figure out that this discharge is one-point multipactor of 5th order, i.e. electron hits back the surface it was emitted from after five full RF field periods.

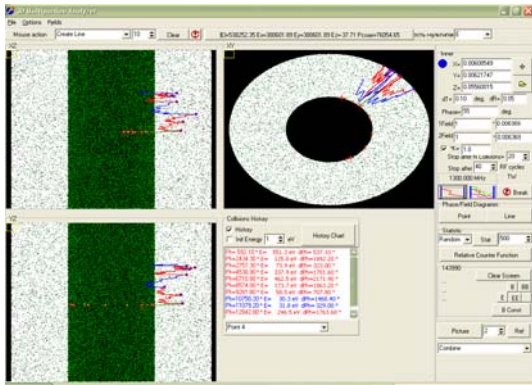


Fig.1. Electrons trajectories. RF power $P = 200$ kW

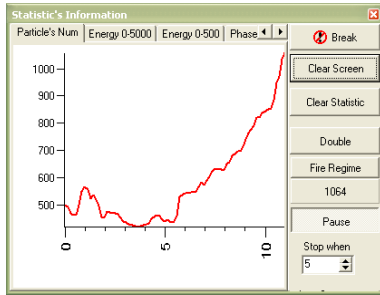


Fig.2. Particle number on RF periods dependence. RF power $P = 200$ kW

The multipactor simulation results for one-point discharge ignition possibility at different power levels are present at Table. The comparison with results obtained using Multipac code is also presented.

Multipactor discharge order found in coax lines. MultiP and Multipac codes results

D = 42 mm, d = 17 mm							
P, kW	105	165	200	260	350	601	890
MultP	7	6	5	4	3	2	2
Multipac	7	6	5	4	3	2	1
D = 62 mm, d = 28.8 mm							
P, kW	200	270	365	518	898	1556	
MultP	8	7	6	5	4	3	
Multipac	8	7	6	5	4	3	
D = 62 mm, d = 22.8 mm							
P, kW	233	314	424	545	1043	1808	
MultP	8	7	6	5	4	3	
Multipac	8	7	6	5	4	3	

2.2. The second model analyzed was the coaxial line like the one used in warm part of Energy Recovery Linac power coupler [5]. External conductor diameter D is equal 62 mm, internal d is 28.8 mm. The Microwave Studio code was used to get the electromagnetic fields with mesh consisted of about 30.000 nodes. The research results showed the multipactor discharge could arise for power range from 65 to 1600 kW. Most dangerous multipactor discharge of 4th (and less) orders was found at 800 kW and higher power levels.

2.3. The same simulations were done for coaxial line used in ERL power coupler cold part. Outer conductor diameter is equal to $D = 62$ mm, inner is $d=22.8$ mm. The RF power range from 75 to 2100 kW is found to be dangerous. Multipactor less than 4th order was found for powers exceeding 1000 kW.

It is seen that the results obtained with MultiP code are in good accordance to the Multipac ones. Research data were shown as program test results.

3. RECTANGULAR WAVEGUIDE SIMULATIONS

For the geometries having no axial symmetry such as rectangular waveguide the full 3D multipactor modeling is essential with electromagnetic fields non-symmetric pattern taken into account.

At Elementary Particle Physics Lab at Cornell University the experimental researches of multipactor in rectangular waveguides were carried out [6] and its suppression ways were proposed. It was observed that for RF power more than 180 kW at 1.3 GHz in WR650 rectangular waveguide (165 x 82.5 mm) the low-order multipactor arises. Introducing the slot made along the waveguide broad wall introducing the negligible disturbance in electromagnetic fields pattern could do discharge depression. The researches confirmed that this change in design lead to the multipactor lowered 2 to 7 orders.

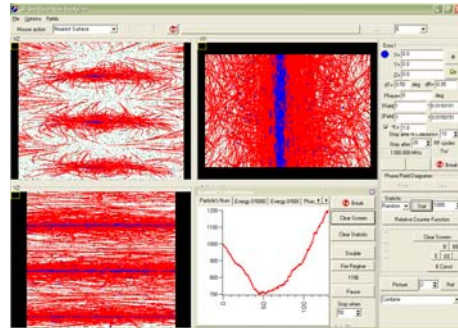


Fig.3. Statistical simulation of WR650 rectangular waveguide operated on 200kW power

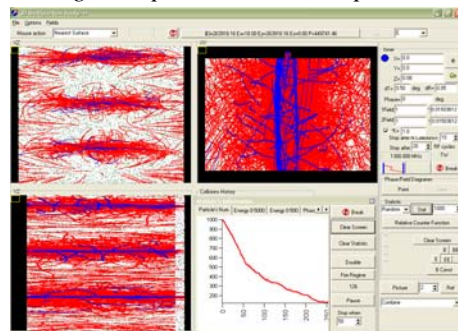


Fig.4. Statistical simulation of rectangular waveguide with groove operated on 200kW power

The upgraded MultiP code was used for simulation of multipactor both for regular waveguide and for the one having 5x5 mm groove on the inner surface just like in the Cornell proposal. Electromagnetic fields were obtained using Microwave Studio code for model consisted of mesh with about 100.000 nodes.

The simulations were done using MultiP code for both waveguides transmitting power in range from 100 to 450 kW. It was found that the multipactor in regular waveguide occurs at power exceeding 180 kW that agrees with experiment results [6]. Statistical simulations confirm that the groove depresses or eliminates the multipactor in this power range. The examples of statistical simulation for both structures at 200 kW power are presented on Figs.3,4.

The statistical simulation results obtained using MultP code in 3D mode for both designs agree with the experimentally observed multipactor depression in rectangular waveguide by minor design modifications [6].

4. MULTIPACTOR IN CERAMIC RF WINDOWS RESEARCH

The MultP code after the upgrade is suitable for doing the multipactor simulations in power coupler ceramic RF windows. The ceramics has high secondary electron emission yield and is usually limiting the entire device performance due to multipactor. Moreover it could be permanently damaged by discharge due to electron bombardment and surface heating. The ceramic window design used for ERL power coupler simulation results are presented below.

The cold window model used for simulations included the ceramics, upstream coaxial line from warm window ($D=62$ mm, $d=28.8$ mm) and the downstream one to cavity ($D=62$ mm, $d=22.8$ mm).

The statistical simulations were made using 1000 initial particles of 1eV energy. Secondary electron emission yield for metal was equal to 3 and for the ceramics was 6. Electromagnetic fields were obtained using Microwave studio run for model with 30.000 nodes.

The simulation results showed that the multipactor could occur for power range from 50 up to 4000 kW. For low power less than 200 kW the dangerous areas located close to coaxial waveguides whereas the discharge in the ceramics vicinity could occur for higher power. Fig.5,a,b presents the areas marked blue with electron number rapid growth.

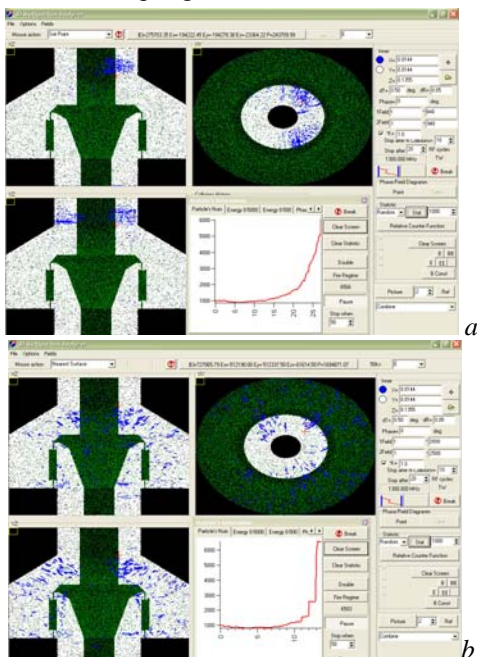


Fig.5: (a) – Statistical simulation results for ceramic window operated at 100kW; (b) – Statistical simulation results for ceramic window operated at 700 kW

For power 1500 kW and more main area subjected to multipactor discharge moves to the wall of transition from cold coax to ceramic window as shown on Fig.6,a,b.

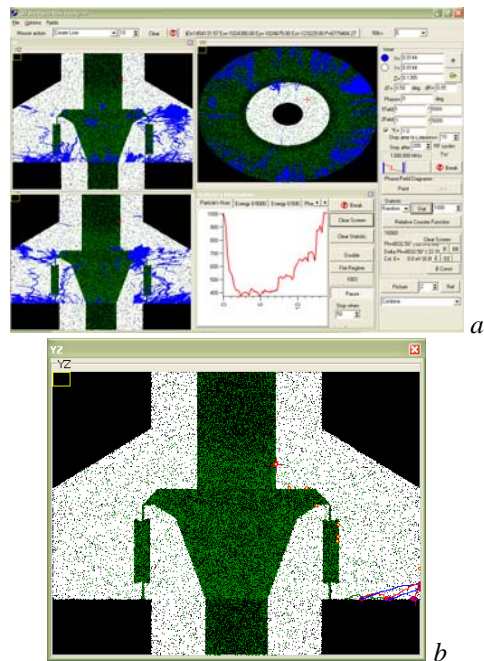


Fig.6: (a) – Statistical simulation results for 2800 kW power; (b) – Sample electrons trajectories for 2800 kW power

Figs.7,8 present the sample simulation results and electrons trajectories in the areas where the multipactor discharge is most probable to occur for 250 kW power.

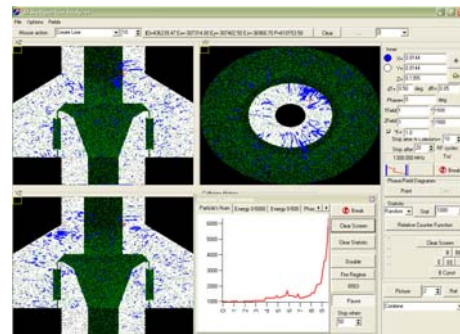


Fig.7. Statistical simulation results for 250 kW power

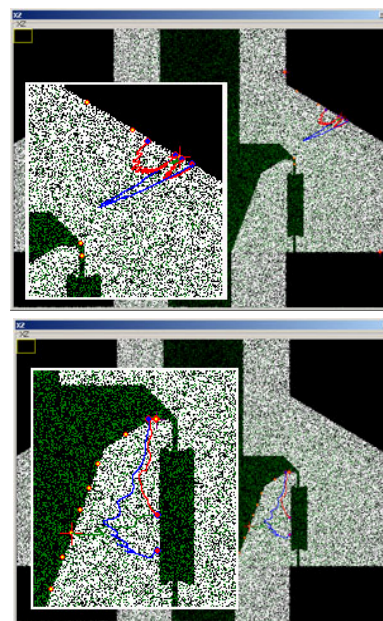


Fig.8. Sample electron trajectories for 250 kW power

According to the electrons behavior it was found that the multipactor order will be 6 or higher for RF power not exceeding 500 kW. However the simulations done were evaluative ones and more detailed study should be done.

CONCLUSIONS

New version of MultP code could be used as a tool for multipactor simulations. This code is suitable for multipactor analysis in wide range of particle accelerators RF components. Provided with 2D or 3D electroagentic fields obtained by any electromagnetic simulation code available MultP is able to simulate multipactor discharge in either traveling or standing wave mode depending on the device under study.

REFERENCES

1. L.V. Kravchuk, G.V. Romanov, S.G. Tarasov. Multipacting Code for 3D Accelerating Structures //

XX International Linac Conference. Monterey, California. 2000.

2. CST Microwave Studio, CST GmbH, Buedinger Str.2a, D-64289, Darmstadt, Germany.

3. E. Simersalo, P. Ylä-Oijala, and D. Proch. Analysis of Multipacting in Coaxial Lines // *Proceedings of the IEEE Particle Accelerator Conference*. 1995, v.3, p.1500-1502.

4. H. Jenhani. Developments in Conditioning Procedures for the TTF-III Power Couplers // *EPAC'06*. Edinburgh, UK, June 2006.

5. B. Barstow, I.V. Bazarov, S. Belomestnykh, et al. The Cornell ERL Prototype Project // *Proceedings of the 2003 Particle Accelerator Conference*.

6. R.L. Geng, S. Belomestnykh, H. Padamsee, et al. Experimental Studies of Electron Multipacting in CESR Type Rectangular Waveguide Couplers // *EPAC'2002*. Paris, June 2002, p.2238.

НОВЫЕ ВОЗМОЖНОСТИ ПРОГРАММЫ MultP

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Представлены результаты расчета различных элементов СВЧ-устройств с точки зрения возможности возникновения в них мультипакторного разряда. Для расчета использовалась программа трехмерного моделирования MultP. Программа усовершенствована и позволяет проводить расчеты как в режиме стоячей волны, так и в режиме бегущей волны. На примерах коаксиальных и прямоугольных устройств ввода мощности в сверхпроводящие резонаторы продемонстрированы возможности программы, результаты сопоставлены с известными экспериментальными данными.

НОВІ МОЖЛИВОСТІ ПРОГРАМИ MultP

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Представлено результати розрахунку різних елементів НВЧ-пристроїв із погляду можливості виникнення в них мультипакторного розряду. Для розрахунку використалася програма тривимірного моделювання MultP. Програма вдосконалена і дозволяє проводити розрахунки як у режимі стоячої хвилі, так і у режимі хвилі, що біжить. На прикладах коаксіальних і прямокутних пристроїв введення потужності в надпровідні резонатори продемонстровані можливості програми, результати зіставлені з відомими експериментальними даними.