MULTIPACTOR SIMULATION IN SC ELLIPTICAL SHAPE CAVITIES*

S. Kazakov, I. Gonin, V. P. Yakovlev, FNAL, Batavia, IL 60510, USA

Abstract

A technique of multipactor (MP) simulation by CST studio is discussed. Results of MP simulations for several shapes of elliptical cavities are presented. New simple cavity shape, which significantly suppress MP is found.

INTRODUCTION

MP - frequent phenomenon in vacuum microwave systems. There is the class of devices, superconductive cavities (SC), where MP is not particularly desirable. SC usually has very high quality factor ~ 10^{10}. Losses caused by MP can greatly reduce the quality factor and increase a cryogenic losses or may completely destroy a superconductivity. Therefore it is important to be able to predict the presents or absence of MP in SC cavities and find cavity with optimal shapes, which decrease of probability or eliminate MP.

There are several computers codes, which simulate MP in RF structures. For example, in our laboratory (Technical Division, FNAL) we use following codes for MP simulations: Fishpac, MultiPac [1], Analyst [2] and CST studio.[3] First two codes are 2-D codes with simplified models of secondary emission. Analyst is 3-D code with also simplified description of secondary emission (at the time of described simulations). CST studio is 3-D program with more sophisticated model of secondary emission (it uses Furman model) [3]. These programs give different results of MP simulations in SC cavities. First three codes do not find MP in the 1.3GHz ILC cavity.

For example Figures 1 and 2 present the Multipac code results of MP simulations in the middle cell of ILC cavity. Figure 1 shows the middle cell shape and zoomed plot of the 2-point first order electron trajectory in the equator area during a few RF periods.

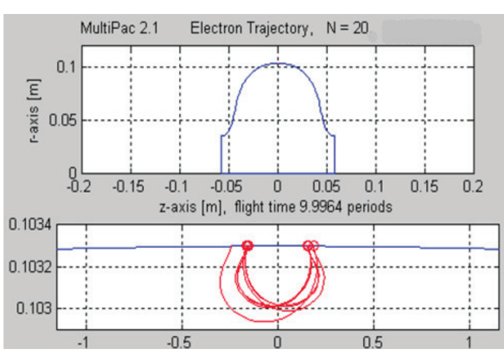

Figure 1: TESLA cell shape and zoomed plot of trajectories. The circles indicate impact on the wall.

Upper plot of Fig. 2 shows the average impact energy of the last impact in eV and the lower shows the Enhanced Counter Function (ECF) after 20 impacts. One can conclude that at the level of peak electric field 47 MV/m the ECF has maximal value that indicates the presence of resonance trajectories. The impact energy is less than 40 eV and for those the secondary yield function is <1 - no MP, Figure 7.

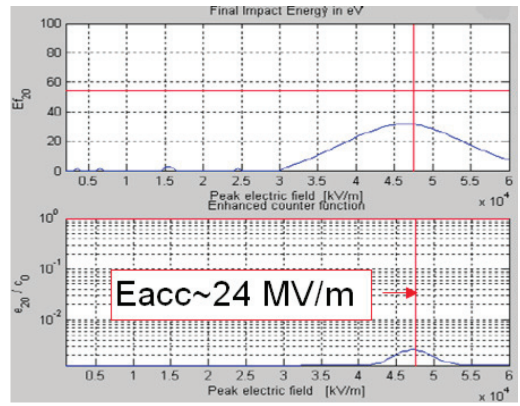

Figure 2: Final impact energy (upper plot) and ECF after 20 impacts (lower plot).

Contrary, CST studio predict MP with maximum growth rate around 20-25 MV/m accelerating gradient and it is consistent with experimental observations. We have tried to understand the reason for the differences of results of modeling by 2-D codes and CST studio. First we will describe the technique of simulation using CST studio.

MP SIMULATIONS BY CST STUDIO

Fine mesh is necessary

In SC cavities a multipactor usually exist in area near equator and sizes of this area are noticeable smaller then basic dimensions of cavity, see Fig.3. Multypactor occurs in weak electric field (weak relatively to accelerating electric field) and typical energy of electrons involved in MP is less then 1 keV. Energy of maximum of secondary emission yield for niobium is about 300 eV. It means that for accurate modeling the energy error of moving particles has to not exceed several eV. It requires accurate calculations of electromagnetic fields and small sizes of mesh cells for particles motion simulations. Therefore the calculations of fields and simulations of motion in the whole cavity are difficult because of large size of mesh.

To solve this problem we used following methods. The cavity fields do not have angle variation (do not depend on angle in cylindrical coordinates) and particles motion practically is 2-D in RZ plane. Thus, it is enough to simulate only angular sector of cavity, not whole cavity. As we said before, MP area is located near cavity equator and has sizes much smaller then cavity sizes. Thus, only small volume of sector near equator, which is several times lager then MP area, was used for particles motion

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simulations. Electromagnetic field was calculated by HFSS code on 1^{O} sector. The mesh in the equatorial region has been condensed. The second-order fields approximation was chosen - the highest for HFSS. Then the fields was read on the plane and these 2-D fields was transformed into 3-D ones on the rectangular mesh of MP simulation aria. Then the field was entered into the CST studio and MP was simulated, see Figures 3 and 4.

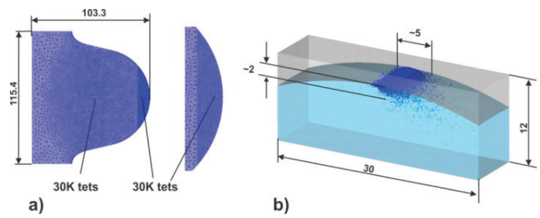

Figure 3: a) Typical sizes of L-band superconducting cavity and mesh quality for field calculation.
b) Typical sizes of multipacting zone. All sizes are in mm.

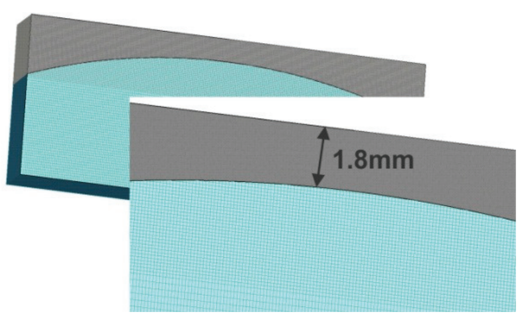

Figure 4: Volume and typical mesh sizes for particles moving simulation in CST studio. Cell sizes ~0.1mm x 0.2mm.

Results of simulation of 1.3GHz cavity is presented in Figure 5. We had to reduce mesh cell sizes to ~0.1mm~0.2mm to get a good convergence. Total number of cell was > 2 million. Found MP zone of accelerating gradient coincides well with the experimentally observed.

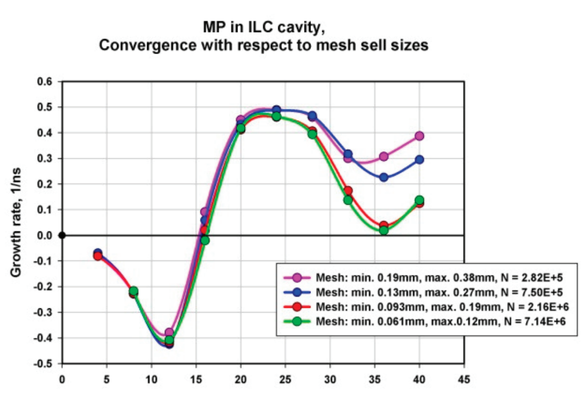

Figure 5: Results of simulations of multipactor in ILC cavity with different sizes of mesh cells. Cells dimensions min 0.093mm, max 0.19mm or smaller provide a good convergence. Experimentally this type of cavity shoes MP at accelerating gradient around 20-25 MV/m.

Importance of secondary emission model

As it was mentioned, other codes did not find MP in ILC cavity. Possible reason can be a simplified model of secondary emission. To test this assumption the secondary emission property of material was changed in CST studio: 'Redeffused' and 'Elastic' secondary particles were excluded from model. Only 'True secondary' electrons were used. Total secondary particles yield was kept the same, see Figures 6 and 7.

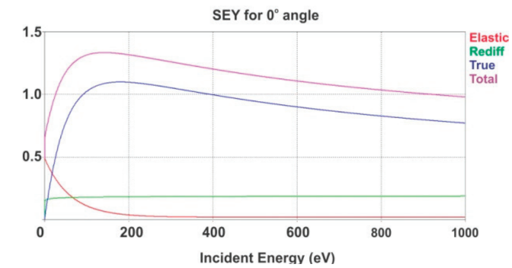

Figure 6: 'Elastic' and 'Rediffused' electrons are included in the model of secondary emission.

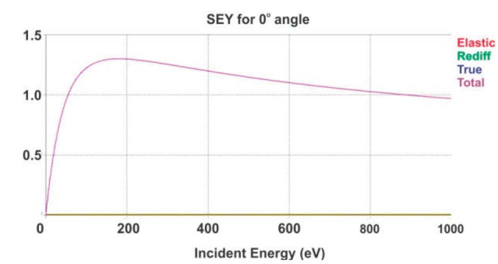

Figure 7: 'Elastic' and 'Rediffused' electrons are excluded from model of secondary. 'True secondary' curve is coincide with 'Total' curve.

Calculation with modified materials showed practically an absence of MP in ILC cavity, see Figure 8. So, we came to obvious conclusion: not only total yield of secondary particles is important, but details of energy distribution play essential role.

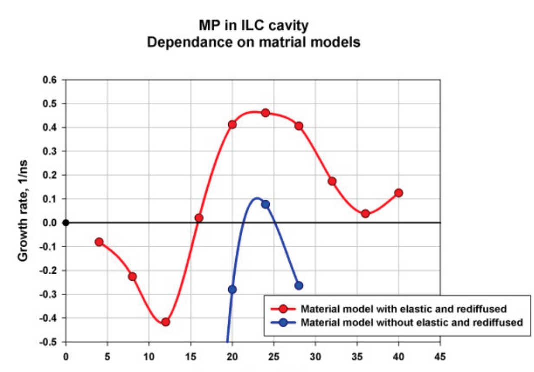

Figure 8: Dependence of simulation results on secondary emission model of material. Red - full 'Furman' model of CST studio. Blue - "Rediffused" and "Elastic" secondary electrons are excluded from model. Totals yields of secondary electrons are the same.

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NEW SHAPE

We simulated 650 MHz elliptical cavities designed by FNAL and JLAB. JLAB cavity has ~9.8 mm flat area near equator, FNAL cavity has a curvature R = 58 mm. According to simulations, both cavity have MP around 10 MV/m accelerating gradient. JLAB cavity shows slightly better features: it has a lower growth rate and narrower MP zone. After that FNAL geometry was modified adding flat areas near equator. It improve the properties of cavity but not too much. Situation changes drastically if convexity added to equator, see Figure 9 and 10.

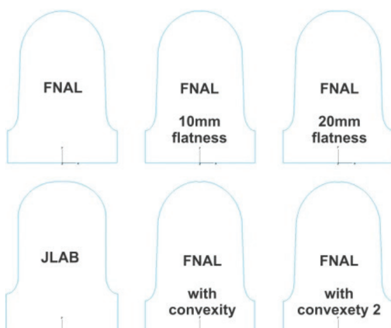

Figure 9: Deferent shape 650MHz cavities which was simulated for multipactor properties.

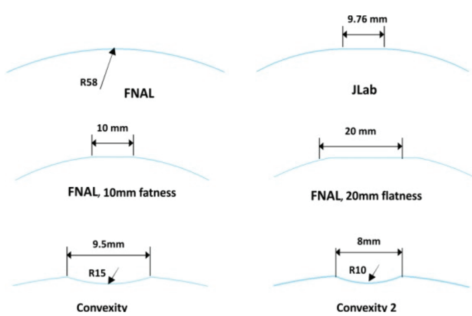

Figure 10: Cavities' shapes near equator, multipactor areas.

Convexity 2 is completely suppress MP. We have to note that convexity does not change other important parameters of cavity such as electric and magnetic fields enhancement, quality factor. Results of all described simulations are presented in Figure 11.

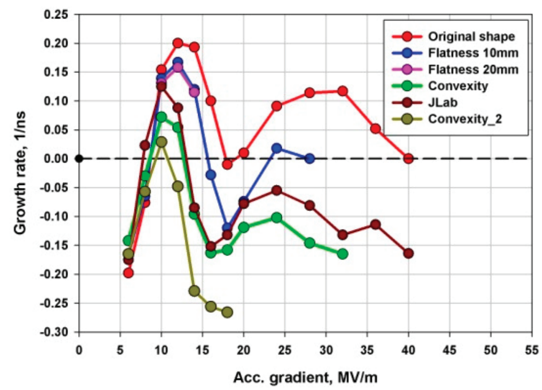

Figure 11: Growth rates of cavities with different shapes. One can see that convexity 2 suppress MP.

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[2] J. DeFord et al., Proc. of PAC 2003, Portland, OR, pp. 3554-3556.

[3] www.cst.com

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